

Coach 7

User's Guide



cma-science.nl

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CHAPTER 1

Getting Started

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Welcome

Coach 7 is a versatile Learning and Authoring Environment for Science, Technology, Engineering and Mathematics (STEM) Education.

Coach integrates ICT tools such as Data-logging, Control, Video and Image analysis, Modeling and Animations and Data Processing. These tools are similar to the tools, which are used by professional scientists and which facilitate inquiry-based approach to education.

As Authoring software Coach offers possibilities to create teaching and learning student activities filled with texts, images, videos, and web-pages. These Activities can be customized to be used by students starting at primary up to undergraduate level (age 8 to 21).

Following modern and innovative educational ideas, CMA develops, which illustrate the use of tools offered by Coach at different school levels. The materials consist of Teacher Guides, Student Worksheets and Coach Activities. Coach 7 Licensees (owners of the Single User License and teachers of school, which have purchased the Site License) have free access to the materials but need to first. For registration a valid Coach 7 license code is required!

On the CMA you can find short video tutorials, which help to getting started and to get familiar with options and features of Coach 7.

First Steps

The topics in this chapter will help you to get started and get familiar with the layout and options of the Coach Main Screen.

Starting Coach 7 (Windows)

After installation the group **CMA Coach 7** will be created in the Windows Start menu and the **Coach 7** icon will be placed on the desktop. The CMA Coach 7 group has the following shortcuts:

Author: This icon starts Coach 7 in the Author mode. This mode is protected by the Author key. To enter Author mode, log in with the default Author key '0000'. This Author key can be changed for your school via the main menu option **Options > Author Key Settings**.

Student: This icon starts Coach and opens Activities/Results in the user level specified in the Activity/Result.

Utilities:

Mount VinciLab: This shortcut starts the program, which mounts VinciLab as network location and creates the access to the VinciLab's user folder 'My Files' in Windows Explorer under Network Location.

Unmount VinciLab: This shortcut starts the program, which removes the access to the VinciLab's user folder 'My Files' in Windows Explorer.

To start Coach 7

- » Click the **Coach 7** icon on the desktop. Coach starts and will open Activities in the user level specified in the Activity.

Or

- » Double-click a Coach Activity file (*.cma7) or a Coach Result file (*.cmr7). Coach directly opens the selected Activity or Result in the user level specified in the Activity.

Or

- » Click on the **Start** button (Windows Start menu). Select **All Programs** and hence **CMA Coach 7**. Next click on one of icons as described above.

When Coach 7 is started the first time it asks to specify:

- » the **preferred language** of the Coach interface - select the language from the list.
The Coach interface language can also be set in Coach via the Dashboard button **Switch language** or Main menu option **Options > Switch Language** (present only in Senior student and Author modes).
- » the **license information** - type in your **License Name** and **License Code** exactly as they appear in your License document. Confirm with OK. Notice that this is done per user; if another user will start Coach again he/she will be asked to enter the license information again.

Starting Coach 7 (MAC)

To start Coach 7

- » Click the **Coach 7** App located in Applications.

When Coach 7 is started the first time it asks to specify:

- » the **preferred language** of the Coach interface - select the language from the list.
The Coach interface language can also be set in Coach via the Dashboard button **Switch language** or Main menu option **Coach 7 > Switch Language** (present only in Senior student and Author modes).

- » the **license information** - type in your **License Name** and **License Code** exactly as they appear in your License document. Confirm with **OK**. Notice that this is done per user; if another user will start Coach again he/she will be asked to enter the license information again.

Coach opens Activities and Results according to the user level specified in the Activity.

To set Coach 7 in the Author mode

- » Start **Coach 7** App.
- » Press the Dashboard button **Login**.
- » Select **Author** in the user level drop-down list.
- » Type in the **Author key**. The default Author key is '0000'. This Author key can be changed for your school via the main menu option **Coach 7 > Author Key Settings**.
- » Confirm with **OK**. From now on all Activities and Results will be opened in the Author mode.

To set Coach 7 in the Senior student mode

- » Start **Coach 7** App.
- » Press the Dashboard button **Login**.
- » Select **Senior student** in the user level drop-down list.
- » Confirm with **OK**. From now on all Activities and Results will be opened in the Senior student mode.

Main Screen

After opening Coach its Main Screen appears. It has three parts:

MENU BAR

Contains menu which is displayed when Coach works in the Author or Senior student mode.

Menu options in **Coach for Windows** are organized slightly different than in **Coach for Mac**. Options: **Author Key Settings**, **Preferences** and **Switch Language** are located on Windows under the menu option **Options** and on Mac under the menu option **Coach 7**. The **Quit Coach 7** option is on Windows under the menu option **File** and on Mac under **Coach 7**.

Some options are present only in the Author mode, these are indicated with *.

File

- » **New Activity*** – to create a new Activity
- » **Open** – to open an Activity/Result
- » **Open CMA Coach Projects** – to open a CMA Activity or Result. Starting from Version 7.7 CMA Projects are not delivered in Coach anymore and have to be downloaded from the CMA website.
- » **Login** – to log in as the Senior student user or the Author user.
By default Coach opens an Activity/Result in the user level specified in the Activity. When logged in as Senior student or Author, Coach opens an Activity/Result in the Senior student or Author mode respectively .
- » **Quit Coach 7** – to close Coach

Options

- » **Preferences*** – to set user locations for Coach projects and files
- » **Author Key Settings*** – to disable or change an Author key
- » **Switch Language** – to switch a Coach interface language

Tools

- » **Hardware Settings** – to specify settings for some interfaces
- » **Activate Hardware** – to deactivate or activate communication with interfaces

Help








- » **Help** – to start Coach 7 Help (Internet access required)
- » **About Coach 7** – to display the Coach version and the License information
In the Author mode it is possible to change the current License Name and Code.
- » **CMA Website** – to go to the CMA website (Internet access required)

Author specific options are described in the part 'For Authors'.

DASHBOARD

Dashboard is a collection of buttons that give you quick access to Activities and let you quickly do some tasks.

Get Started






- »  **Measurement** with options **Time-based, Event-based, Manual**
– to open an empty Activity (Type: Measurement) offering measurement environment with predefined measurement settings.
- »  **Control** with options **Programming with CoachLab II+, Programming with WiLab**
– to open an empty Activity (type: Measurement with Program) offering control instructions for creating measurement and control programs for the selected interface.
- »  **Data Video** with options **Video Analysis, Video Capture**
– to open an empty Activity (type: Data Video) offering environment for video analysis and video capture.
- »  **Data Image**
– to open an empty Activity (type: Data Image) offering environment for image analysis.
- »  **Spectrometer** with options **Recording Emission Spectrum, Recording Absorption Spectrum**
– to open an empty Activity (type: Spectrometer) offering environment for recording and analyzing Emission and Absorption spectra respectively.
- »  **Modeling** with options **Modeling in Graphical mode, Modeling in Text mode**
– to open an empty Activity (type: Modeling) offering environment for creating graphical or textual models respectively.
- »  **Spreadsheet**
– to open an empty Activity (type Spreadsheet) offering environment for working with data in the Data Table.

Note that Activities opened via Dashboard will not be listed in the Recent Activity or Result list.



Quit

- »  **Quit Coach 7** - to close Coach 7.

Open




- »  **Activity or Result** – to open an Activity or Result.
- »  **CMA Tutorials** – to open a CMA Tutorial provided in Coach 7.
- »  **CMA Projects** – to open a CMA Activity or Result.
Starting from Version 7.7 CMA Projects are not delivered in Coach anymore and have to be downloaded from the CMA website.
- »  **Recent Activity or Result** – to open a recently opened Activity or Result.
- »  **Download CMA Projects** – to download CMA Projects from the CMA website (Internet connection required).

Author





- »  **Login** - to log in as Senior student or Author.
By default Coach opens an Activity/Result in the user level specified in the Activity. When logged in as Senior student or Author, Coach opens an Activity/Result in the Senior student or Author mode respectively .
- » When logged in as Author the  **New Activity** button appears. This button can be used to create a new Activity.

Author specific options are described in the part 'For Authors'.

Tools

- »  **Switch Language** – to switch a Coach interface language.
- »  **Hardware Settings** – to specify settings for some interfaces.
- »  **Firmware Update** – to check and update the firmware of interfaces.

Support

- »  **User's Guide** – to open Coach 7 User Guide.
- »  **Help** with options:
Coach Help – to start Coach 7 Help.
About Coach 7 – to display the Coach version and the License information. In the Author mode it is possible to change the current used License Name and Code.
CMA website – to open the CMA website.
- »  **Video Tutorials** – to open the CMA channel on YouTube.
- »  **Check for Updates** – to check if there is a newer version of Coach 7 available to download.

Note that for all options under Support an Internet access is required.


STATUS BAR

Shows the Coach version number, owner's name and the current selected user level (left corner).

Login

Login allows forcing Coach to ignore the student-user level defined in the Activity/Result and open Activities and Results always as Senior-student or Author.


To login:

- » Click the Dashboard button  **Login**.
- » In the User level drop-down list as default is shown **Default Activity user level**.
- » Select **Senior student** – to open Activities/Results from now on in the Senior student mode.
- » Select **Author** – to open Activities/Results from now on in the Author mode. The Author mode is by default protected with a password (by default 0000). Type in the Author key and accept with **OK**.
- » You can always return to the default settings by selecting **Default Activity user level**.

Switch Language

It is possible to change the default language of the Coach user interface.


To switch the user-interface language:

- » 1. Select the Dashboard button  **Switch Language**, or
2. Select the Main menu option **Options > Switch Language**.
- » A list with all installed languages appears. The current used language is marked.
- » Check the desired language.
- » 1. On **Windows** computers Coach automatically restarts and opens in the selected language.
2. On **Mac** computers you have to manually restart Coach.

Hardware Settings

The **Hardware Settings** option allows to configure the settings of some interfaces, e.g. the serial port number that an interface is connected to (older models of the CoachLab II+ interface), or an IP-address for wireless communication (the VinciLab interface).


To configure hardware settings:

- » Click the Dashboard button  **Hardware Settings**.
- » Under the header **Interfaces**, select the interface.
- » Adapt the interface settings where needed.
- » **Activate Hardware** – uncheck this option to deactivate communication with interfaces. Coach will not try to set up communication with an interface upon opening an Activity. The hardware is deactivated for the whole Coach session, or until this option is switched on again.
- » Accept with **OK**.




Firmware Update

The **Firmware Update** option allows updating the firmware of CMA interfaces.

To update a CMA interface:


- » Connect an interface you want to update to your computer.
- » Click the Dashboard button  **Firmware Update**.
- » Select your interface from the list.
- » Press **Update** to renew the firmware of your interface.
- » If desired select the firmware file (*.hex) and accept with **OK**.
- » If you want to check the version of the current firmware installed in your interface press **Check**.

Help

- » Click the Dashboard button  **Help** and select **Coach Help**.
Specific help can be found by selecting the **Help** option available in the Tool menus or clicking the **Help** button available in some Coach dialogs
- » Click the Dashboard button  **User's Guide** to open on-line Coach 7 User's Guide (pdf document which can be downloaded).
- » Click the Dashboard button  **Video Tutorials** to go to the CMA You Tube channel. On-line CMA Video Tutorials offered additional support on using Coach.

Coach 7 License

Use **About Coach 7** to get information about the Coach program and your License.

- » Click the Dashboard button  **Help** and select **About Coach 7**.
- » Information about the Coach 7 version and its License type will be given.

In the Author mode it is possible to change the License Name and Code.

To change the Coach License:

- » Log in as Author.
- » Press the **Change** button.
- » Enter the new **License Name** and **Code** again.
- » Accept with **OK**.

Working with hardware

When using Coach for data collection and control you work with hardware: interfaces, sensors and actuators.

Supported Interfaces

To collect data via sensors or to control devices via actuators you work with interfaces. Coach supports the following CMA interfaces:

- » €Sense (Windows, Mac, Android Tablet with USB)
- » €Lab (Windows, Mac, Android Tablet with USB)
- » WiLab (Windows/Mac via USB, Android Tablet/iPad via Bluetooth)
- » €Motion (**only** Windows)
- » CLAB (Windows, Mac, Android Tablet with USB, CASIO Graphical Calculators)
- » CoachLab II+ (Windows, Mac, Android Tablet with USB)
- » MoLab (**only** Windows)
- » VinciLab (Windows/Mac via USB and WiFi, Android Tablet/iPad via WiFi)

Starting from version Coach 7.3 Coach supports an internal microphone of your computer. On tablets the internal accelerometer is also supported.

Supported Sensors

Coach supports the following types of sensors:

BT TYPES OF SENSORS

These sensors are equipped with British Telecom-style plug (a right-hand connector for analog sensors, and a left-hand connector for digital sensors) and work with €Lab, WiLab, CLAB, CoachLab II+ and VinciLab. Coach supports all CMA sensors, but also many Vernier, 3B, Texas Instruments and CASIO BT sensors. Modern BT sensors are equipped with a sensor memory (EEPROM) and are automatically recognized when connected to an interface. The sensor information stored in EEPROM is by default used in Coach for these sensors. For BT sensors, which are not automatically recognized e.g. older sensors, the sensor has to be manually selected from the Coach Sensor Library.



4-mm TYPES OF SENSORS

These sensors are equipped with 4-mm style banana plugs, they are older CMA sensors and can be connected directly to CoachLab II+ or via '4-mm to BT adapter' to analog BT inputs of €Lab, WiLab, CLAB, CoachLab II+ and VinciLab. These sensors are never automatically recognized and have to be manually

selected from the Coach Sensor Library.

ML TYPES OF SENSORS

These sensors are equipped with 5-pin mini jack and work **only** with MoLab. These sensors are always automatically detected and the sensor information stored in the sensor memory is used in Coach.



Sensor Input Ranges

For many of the sensors defined in the Coach Sensor Library additional calibrations are present, these calibrations are called **Sensor Input Ranges** and can be selected if needed.

To select other than default sensor range:

- » Right-click the sensor icon, select Set Input Range and select a range from the list.

Supported Actuators

Coach supports a number of actuators (1-bit actuators, 2-bits actuators and stepper motors), which can be connected via 4-mm wires to control outputs of CoachLab II+. These actuators have to be manually selected from the Coach Actuator Library. Make sure that the selected actuator is correctly selected for the real connected actuator, e.g. when you connect 3V-bulb then select 3V-lamp from the Actuator Library, selecting 12V-lamp will cause burning of the connected 3V-bulb.

Connecting an Interface

Before you start to use your interface with a computer we strongly recommend to first install the Coach program on your computer.

For older models of CoachLab II+ (2008 and 2009) and €Motion additional low-level drivers are needed, these drivers can be downloaded from the [CMA website](#).


Most interfaces use a USB connection; some of them can also communicate wirelessly e.g. VinciLab via WiFi or WiLab via Bluetooth.

To connect an interface via a USB port

- » If needed, connect power to your interface using its power supply.
- » If needed, turn on the interface.
- » Connect the interface to your computer using the supplied USB cable.

To connect VinciLab for wireless communication via WiFi

- » Turn the VinciLab on.

- » Click the Dashboard button  **Hardware Settings** to open the **Hardware Settings** dialog.
- » Select **VinciLab**.
- » Select as Connection Wi-Fi.
- » Provide the IP address (for Wi-Fi) of the device you want to connect to.
- » Click **OK**.

To connect WiLab for wireless communication via Bluetooth

- » If needed disconnect WiLab from a USB port. When WiLab is connected to a USB port then it is not possible to turn Bluetooth on.
- » After the starting procedure is finished or the Power button is pressed, WiLab "advertises" itself as a Bluetooth device to host devices nearby. This lasts 5 minutes and during this period the Status LED is blinking blue.
- » If during this "advertising" period a connection is made by Coach 7 running on a host device with this WiLab, the wireless communication will be established and the Status LED will stop blinking and turn blue.
- » Briefly press the Power button to turn Bluetooth advertising on again for 5 minutes.

You can connect more interfaces at the same time to your computer (it is not recommended) but you can use only one interface at the time for measuring in Coach (with exception for €Lab and €Motion which can be used together).

Do you experience problems with communication with VinciLab?

Check the FAQs on the CMA website.

Activities and Results

Activities (*.cma7 files) are teaching and learning materials created by Author users for Student users. Student users work with Activities and perform experiments, make calculations, execute and create models, use simulations and make reports.

Student users cannot overwrite the Activities made by Author, they save the results of their work in Results (*.cmr7 files).

The topics in this chapter will help you to get familiar with the layout and options of the Activity/Result screen.

Opening an Activity or Result



To open an Activity via the Dashboard 'Get Started' buttons

- » Press the button of the Activity type you want to open e.g. **Measurement**.
- » If more Activities are present then select the desired type from the list e.g. **Time-based Measurement**.
- » The predefined (empty) Activity opens.

To open an Activity/Result via the Dashboard 'Open' buttons

- » Press **Activity or Result** to open a Activity/Result. Browse in the dialog to the desired Activity or Result, select and confirm with **Open**.
- » Press **CMA Tutorials** to open a CMA Tutorial. Browse in the dialog to the desired Tutorial and confirm with **Open**.
CMA Tutorials are Activities meant for learning basics of Coach.
- » Press **CMA Projects** to open a CMA example of Activity/Result. Note that before you can use this functionality you have to download the CMA Projects.
Use **Download CMA Projects** to download the projects from the CMA website.
- » Press **Recent Activity or Result** to open a recent opened Activity or Result file. Select an Activity/Result from the list.

To open an Activity/Result in a Activity/Result

1. Click to Toolbar icon **Open**  to open a Activity/Result. Browse in the dialog to the desired Activity or Result, select and confirm with **Open**.
or
2. Click the arrow next to the **Open**  button and select one of the options:
 - » **Activity or Result** to open a Activity/Result. Browse in the dialog to the desired Activity or Result, select and confirm with **Open**
 - » **CMA Projects** to open a CMA example of Activity/Result. Note that before you can use this functionality you have to download the CMA Projects.
 - » **CMA Tutorials** to open a CMA Tutorial. Browse in the dialog to the desired Tutorial and confirm with **Open**. CMA Tutorials are Activities meant for learning basics of Coach.
 - » **Recent Activity or Result** to open a recent opened Activity or Result file.

Activity Screen

After opening an Activity/Result the Activity Screen appears. This screen is divided into several parts:

TITLE BAR

Shows the name of the current opened Activity/Result.

MENU BAR

Contains bar with menu options. Not all options are available for all user levels.

MAIN TOOLBAR

Appears directly under the menu bar and contains buttons for quick access.

PANES

Windows fixed in the area between the Toolbar and the status bar. Different Coach objects, such as Graph, Meter, Value, Text, Animation, Image, Video, Web-page and Student text, can be placed in these panes.

APPLICATION WINDOWS

Windows, which display special Coach objects, such as Data Table, Interface, Program, Model and Data Video, with tools for doing science. These windows can be placed on the top of panes or can be docked into panes.

STATUS BAR

Shows Coach 7 version and owner's name and the actual selected user level (left corner).

Activity Menu

Some menu options are only available in the Author mode. These are indicated with an *.

File

- » **New** – to create a new Activity*
- » **Open** – to open an Activity/Result
- » **Close** – to close an opened Activity/Result and return to the Dashboard
- » **Save** – to save an opened Activity/Result
- » **Save as** – to save an opened Activity/Result to a specific location on your computer with a specific name
- » **Save for MoLab/VinciLab** – to save an opened Activity/Result in format suitable for MoLab/VinciLab. Then you can open such Activity in Coach running on MoLab/VinciLab.
- » **Print** – to print the Activity/Result screen
- » **Printer Setup** – to set up a printer
- » **Quit Coach 7** – to exit Coach

Display

- » **Screen Layout** – to change the panes layout
- » **Graph, Meter, Value, Text, Image, Video, Web Pages, Student Text** – to display a respective object in a pane

Tools

- » **Settings** – to open the Setting dialog
- » **Activity Options** – to open Activity Options dialog
- » **View As** – to view an Activity as a student user defined in the Activity options *
- » **Activate Hardware** – to activate/deactivate communication to an interface *

Help

- » **Help** – to start Coach Help (online)
- » **About Coach 7** – to show information about the Coach 7 program and your License.

» **CMA Website** – to go to the CMA website

Author specific options are described in 'For Authors'.

Activity Toolbar

The Toolbar provides quick access to main tools of Coach. Some of the buttons will appear and disappear in the Toolbar depending on the User mode or Activity type. Below an overview of all buttons, which can appear in the Activity Toolbar.



Close – to close the Activity and return to Main screen



Open – to open an Activity or Result file

Save as – to save an Activity (Author mode, *.cma7 file) or Result (Students modes, *.cmr7). You will be prompted to enter a file name and location



New Activity – to create a new Activity (Author mode)



Print – to print the whole Coach screen



Interface – to Show/Hide the Interface window with a screen image of the used interface. Here sensor/actuator icons of sensors/actuators connected to the interface are displayed



Program – to Show/Hide the Program window, in this window programs are edited or created



Model – to Show/Hide the Model window, in this window models are edited or created



Data Video – to Show/Hide the Data-Video window, in this window video measurements are made



Data Image – to Show/Hide the Data-Image window, in this window image measurements are made



Spectrometer – to Show/Hide the Spectrometer window, in this window light spectra measurements are made



Data Table – to Show/Hide the Data Table window, in this table all available variables and their data are displayed



Settings – to open Measurement, Control or Model Settings dialog



Send Settings – to send experiment settings to a data-logger



Start – to start a measurement, video or image measurement, program and model execution. Each time the button is pressed a new run is added to the Data Table



Stop – to stop a measurement, video or image measurement, program and model execution



Start a manual measurement – to start a manual event



Stop a manual measurement – to stop a manual event



Replay – to replay the latest run at a selected rate



Get Data – to upload the measurement data from a data-logger to Coach



Graph – to select a Graph for display, or to add a new empty graph



Meter – to select a Meter for display



Value – to select a Value for display



Text – to select a Text for display, or to add a new empty text (only Author mode)



Image – to select an Image for display or to add a new Image



Video – to select a Video for display, or to add a new video



Web page – to select a Web page for display or to add a new web page



Student Text – to select a Student Text for display, or to add a new empty student text






Help – to open a help item



Activity Panes



Panes take up most of the Activity screen. They are located between the Toolbar and status bar. A Pane can be empty or it can display a Coach object. It has a Toolbar and Tool menu available via the Tool menu button or by right-clicking the pane.

To resize a pane

- » Place the cursor over a vertical pane divider, the shape of the cursor changes into . Drag the vertical line left or right, the pane will adjust accordingly.
- » Place the cursor over a horizontal pane divider, the shape of the cursor changes into . Drag the horizontal line up or down, the pane will adjust accordingly.
- » Each pane can be maximized to fill the whole screen by using its Maximize  button.

To create a new pane or to remove a pane

- » Place the cursor over the upper horizontal line (the line between the Toolbar and panes), the shape of the cursor changes into . Drag the horizontal line downwards to create a new pane.
- » Place the cursor over the bottom horizontal line (the line between the panes and the status bar), the shape of the cursor changes into . Drag the horizontal line upwards to create a new pane.

- » Place the cursor over the left vertical border line, the shape of the cursor changes into . Drag the vertical line rightwards to create a new pane.
- » Place the cursor over the right vertical border line, the shape of the cursor changes into . Drag the vertical line leftwards to create a new pane.
- » If a pane divider is dragged back towards the borders of the Coach screen, the pane disappears.

To change panes layout

- » You can change your panes layout manually on the screen by resizing panes, creating new or removing not needed panes.
- » Coach offers a selection of predefined layouts: click the menu option **Display > Screen Layout** and select a desired layout.

To move a pane content into another pane

- » Click a caption of the pane, which content you want to move.
- » Start to drag the caption, the cursor changes into an object icon, drag the icon further into a pane, in which you want to display the content, until the pane is selected. Release the icon.

To fill an empty pane

- » Right-click an empty pane and select an object you want to display.
or
- » Click an object Toolbar button (Graph, Meter, Value, Animation, Text, Image, Video, Web-page, Student text). All predefined items of the selected object will be listed.
- » Select the desired item.
- » The cursor changes into the object icon, drag the icon into a pane, in which you want to display it and click this pane.

To replace the content of a pane

- » Click an object Toolbar button (Graph, Meter, Value, Animation, Text, Image, Video, Web-page, Student text). All predefined items of the selected object will be listed.
- » Select the desired item.
- » The cursor changes into the object icon, drag the icon into a pane, in which you want to display it and click this pane.
or
- » Move an object from another pane into the pane.

To copy a pane content into the clipboard

- » Right-click a pane which content you want to copy or click its **Tool** menu button and select Clipboard Copy.
- » When copying a graph to the clipboard its zoom information, scan information and comments are copied along. A graph is always exported as a picture.
 - » When copying the data table to the clipboard the selected part of the table will be copied including 2 header rows with the quantity and unit of the data ranges. When no selection is made, only the visible part of the table is copied.

- » When copying a table with the **Copy** option (<Ctrl>+<C>), the header rows are not included.
- » Models can be copied into the clipboard as texts or pictures.
- » Paste the item in another Windows program (Word processor, text editor, drawing program, spreadsheet, etc.), by using **Paste** there.
- » Texts can also be copied to the clipboard using text edit options or keys (**Cut** (<Ctrl>+<X>), **Copy** (<Ctrl>+<C>) and **Paste** (<Ctrl>+<V>).

To print a pane

- » Right-click a pane to be printed or click its **Tool** menu button and select **Print**.
- » When printing a video, only the current, visible, frame is printed.
- » You can also print the whole Coach screen by using the **Print** button or <Ctrl>+<P>.

To empty a pane

- » Click the **Close** button (cross in right corner of the pane caption).

Application Windows

Application windows are windows, which offer special tools:

Data Table – this window is present in all types of activities and displays activity variables and their data.

Interface – this window is present in the Measurement and Control types of Activities and displays the interface image to which sensors and actuator icons are connected.

Program – this window is present in the Control and Measurement (with Program) types of Activities and offers a programming environment for working with programs.

Spectrometer – this window is present in the Spectrometer type of Activities and offers the tools to record emission and absorption spectra.

Data Video – this window is present in the Data-Video type of activities and offers the tools to make video measurements.

Data Image – this window is present in the Data-Image type of activities and offers the tools to make image measurements.

Model – this window is present in the Modeling type of Activities and offers a modeling environment for working with models.

The application windows can be toggled on/off by using their respective Activity Toolbar buttons. By default the application windows are undocked and are displayed on the top of panes. However these windows can be docked into panes.

To dock/undock an application window:

- » Right-click an undock application window (Data-Table, Interface, Program, Model or Data-Video) and select **Dock**. Undock windows do not have the Tool button, you have to right-click an undock window to open its Tool menu.
- » The cursor changes into the icon of the selected object. Move the icon above a pane in which you want to place it and click it.
- » To undock the window select its Tool menu option **Undock**.

Activity Objects

Coach offers the following objects, which can be divided into three groups.

I. Objects, which offer tools:

- » **Interface** – to measure with sensors via a connected interface
- » **Program** – to create and use programs, including programs which control actuators via connected interfaces
- » **Data Video** – to measure on videos and images
- » **Model** – to create and use dynamical models
- » **Animations** – to create and use animations.

II. Objects, which allow to work with data:

- » **Data Table** – to display and process data in the table (only one global table per Activity)
- » **Graphs** – to display and process data in graphs
- » **Meters** – to display data on meters
- » **Values** – to display data as large digits.

III. Objects, which help to create multimedia learning content:

- » **Texts** – to display texts prepared by Authors for Students
- » **Images** – to display images
- » **Videos** – to display videos
- » **Web-pages** – to display Web-pages or other documents like pdf or word
- » **Student texts** – to write notes and reports by students.


Managing Results

A Coach Result (*.cmr7 file) is the result of student's work in an Activity. It consists of all elements of the Activity (like texts, pictures, videos, etc.) together with student changes and resulting data like student notes, measurement data, calibrations, models, control programs etc.

To open a Result

- » Results can be opened in the similar way as Activities, see Opening Activities.


To save a Result

- » Press the **Save as**  button.
- » Enter the name of your Result file.
- » Click **Save**.
- » Author and Senior-student users can also open or save a Result via the **File** menu option.

To delete a Result file

- » Delete the file in your computer.


or

- » Click the **Open**  button.
- » Browse in the dialog to the desired Result (*.cmr7) file.
- » Delete the file.

CMA Projects and Activities


CMA Tutorials

The CMA Tutorials are Activities to learn certain options and features of Coach.

Tutorials in English and Dutch are included in Coach and can be accessed via the Dashboard  **CMA Tutorials** button directly after installation.

Tutorials in other language are not included and can be downloaded together with the CMA Projects from the CMA website.

CMA Projects

The CMA Projects are examples of Activities for different subjects and school levels. They are not included in the installation and can be downloaded via the Dashboard button  **Download CMA Projects** from the CMA website.

After downloading the following projects are present under CMA Projects:

- » **Measurement** - examples of Measurement Activities for Primary, Middle and High school level.
- » **Control** - examples of Control for €Sense, WiLab and CoachLab II+.
- » **Data Video** - examples of Data Video Activities
- » **Data Image** - examples of Data Image Activities
- » **Modeling** - examples of Modeling Activities for Biology, Chemistry and Physics.
- » **Animations** - examples of Activities with Animations.
- » **Spreadsheet** - examples of Spreadsheet Activities .

CMA Learning and Teaching Resources

Additionally CMA offers extended Teaching and Learning Resources (in English and Dutch) consisting of Teacher Guides, Student Worksheets and Coach Activities. Coach 7 Licensees (teachers of school, which have purchased the Coach 7 Site License) have free access to the materials but need to register first. For registration a valid Coach 7 License Code is required!


CHAPTER 2

Measurement

Measurement activities are used to collect data from sensors e.g. for temperature, light intensity, sound level, pH, etc. and to display, analyze and process the measurement results.

A sensor, connected to an interface, measures a physical quantity and transforms it into an output voltage, which is read by an interface. The interface, connected to the computer, converts an analog voltage signal into a digital signal that is transferred and interpreted by the computer.

Coach collects measurement data according to the measurement settings after

pressing the green **Start**  button. Although Coach supports many ways of measuring, the most often used are time-based measurements, in which data are collected at regular time intervals defined by the sampling frequency. Other methods of measuring are event-based measurement, in which data are collected each time a pulse (event) is received on a sensor input, and manual measurement, in which a single data point is collected every time the user presses a button. This method also allows to type in data via the keyboard.

Coach is also able to do measurements of time intervals, counting and frequency. This is accomplished by means of a special mode in which analog sensors are 'converted' into digital sensors to measure pulses or time-intervals.

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The Basics

The topics in this chapter will help you to get familiar with the Interface window.

Interface Window

The Interface window displays the screen image of the used interface and offers options to work with sensors and actuators. There is only one such window in a Coach Activity/Result and it is available not only in Measurement but also in Control Activity.

To display/hide the Interface window

- » Click the Activity Toolbar button **Interface**  to show the Interface window.
- » Click the Activity Toolbar button **Interface**  to hide the Interface window.
- » By default the Interface window is placed on top of the Coach panes.

Interface Screen Image

The screen image of the interface is a clickable image of the used interface. It shows inputs for sensors, and for some interfaces, like CoachLab II+, outputs for actuators, just like the connectors on the real interface. These areas are sensitive (called hot spots) and can be clicked to open a specific Tool menu.





Interface Tool Menu

The Interface Tool menu is available after clicking the Tool menu button in the Interface window (only when the Interface window is docked). Also some areas of the Interface are sensitive (hotspots) and show a different tool menu.

To use the Actuator Outputs and their menus, see the section on Control.

Tool menu or any other area of the Interface window but not a hotspot

Sensor Settings – to open Sensor Settings which gives an overview of all sensor connections

Change Interface – to change an interface used for measurement, here only detected interfaces are displayed

Reset Interface – to renew the communication to the interface

Dock/Undock – to dock and undock the Interface window

Print – to print the Interface window

Clipboard Copy – to copy the interface (image) to the clipboard

Help – to consult a help system

Hotspot: an empty sensor input

Display as > Graph, Meter, Value – to display measured sensor values on a standard Graph, Meter or Value

Sensor Settings – to open the Sensor Settings dialog, which gives an overview of all sensor connections

Choose a Sensor – to manually select a sensor from the Sensor Library

Create a New Sensor > 0 .. 5 V, -10 .. 10 V (present only for analog sensor inputs) – to create a new sensor, the correct sensor voltage range should be selected

Enable (present only for internal sensors) – to enable an internal sensor

Hotspot: a sensor icon connected to an input

Display as > Graph, Meter, Value – to display measured sensor values on a standard Graph, Meter or Value

Sensor Settings – to open the Sensor Settings dialog which gives an overview of all sensor connections

Set Input Range – to set a sensor input range (calibration)

Set to > Zero or Value) – to set an actual measured value to zero or to another value

Calibrate – to calibrate a sensor and store the new calibration in the Sensor Library

Calibrate (EEPROM) – to calibrate a sensor and store the new calibration in the sensor's EEPROM memory

Remove – to remove a sensor

Exchange (present only when another than predefined sensor is detected) – to change a predefined sensor to a detected sensor

Replace (present only when sensor is detected or if is a sensor defined) – opens the Coach Sensor Library to allows selecting a sensor from the library


Help – to consult a help system

Data Collection

The topics in this chapter will help you to learn how to connect interface and sensors, how to modify measurement settings, and how to perform different types of measurements.

How to open a Measurement Activity

You can open a Measurement Activity in Coach in the following ways:

- » **Quick Start:** click the  **Measurement** button in Dashboard and select an Activity in the given measurement mode: Time-based, Event-based or Manual Measurement.
- » Open an example of a Measurement Activity located in the **CMA Projects** in the **Measurement** folder.
- » Open a Measurement Activity prepared by your Teacher.

How to establish connection to an interface

Before you start the data collection connect your interface via the USB port or set-up a wireless connection.

Measurement and Control Activities/Results store information about the interface with which the Activity/Result is made. When Coach opens such Activity it automatically detects hardware: initializes this "default" interface and establishes the connection. Note that there is a slightly different procedure for Activities without data and Activities/Results with data.

Interface initialization for Activity without the data

When Coach is not able to establish connection with this default interface then it automatically checks if any other interfaces are connected to the computer. When:

- » **another interface is detected:** then the Activity/Result opens and converts the default interface to the detected interface and tries to match the sensor connections.
- » **more than one interface is detected:** then the last, used in Coach, interface will be chosen automatically. In case, the connection to the "last used interface" cannot be established; a list with all detected interfaces is shown. After selecting the desired interface the Activity/Result opens and converts the default interface to the selected interface and tries to match the sensor connections.
Note: You can also change an interface directly in an Activity/Result. Right-click the interface image in the Interface window and select the option **Change Interface**. Select the desired interface from the list of detected interfaces.

In case the sensor connections cannot be matched, e.g. the default interface uses 3 sensor inputs but the detected interface has only 2 inputs, or the detected interface offers less measurement possibilities, then Coach will warn about possible problems and you may have to make some adaptations.

In case Coach **cannot establish connection** to any interface the following options are offered:

Retry – Coach will try to initialize the interface again.

Keep interface inactive for this Activity – Coach will open the selected Activity/Result with the interface inactive which means that real-time measurement and control is **not** possible, no values and states are shown on sensor and actuator icons, but it is possible to work with data.

Keep interface inactive for all Activities – Coach will open all Activities/Results with the interface inactive each time the connection with an interface cannot be established. This behavior will be kept as long as you work in Coach. Quitting Coach will reset this.

Use another interface – Coach will open this Activity/Result for another interface selected from the list given after confirming this option. If the selected interface will be detected then Coach tries to match the sensor connections.

- » Select the desired option and confirm with **OK** button.

Note: To deactivate hardware initialization for all interfaces, uncheck the **Activate hardware** option in the **Hardware Settings** dialog.

Interface initialization for Activity with the data

In case an Activity/Result consists of data the automatic interface adjustment is not executed. Coach tries to establish communication only to the default interface stored in the Activity/Result and does not look for any other interfaces. If the connection to this default interface is not established then the following options are offered:

Retry – Coach will try to initialize the default interface again.

Keep interface inactive for this Activity – Coach will open the selected Activity/Result with the interface inactive which means that real-time measurement and control is **not** possible, no values and states are shown on sensor and actuator icons, but it is possible to work with data.

Keep interface inactive for all Activities – Coach will open all Activities/Results with the interface inactive each time the connection with an interface cannot be established. This behavior will be kept as long as you work in Coach. Quitting Coach will reset this.

Use another interface – Coach will open this Activity/Result with data for another interface selected from the list given after confirming this option. If the selected interface will be detected then Coach tries to match the sensor connections but some data information may be lost.

- » Select the desired option and confirm with **OK** button.

Note: To deactivate hardware initialization for all interfaces, uncheck the **Activate hardware** option in the **Hardware Settings** dialog.

Lost communication with Interface

The communication between Coach and the connected interface may be lost while working in an Activity e.g. the sensor values do not change at all for a longer period of time (normally, the sensor values fluctuate a little bit because of noise, unless the number of decimals is set to low values) or if nothing happens when you press the green Start button. In such situation the interface panel has to be reset.

To reset the interface

- » Right-click the interface image (but not on its inputs and outputs) and select **Reset Interface**.
- » If this does not help, first hard reset the interface (e.g. for CoachLab II+, disconnect and reconnect the power supply, for VinciLab restart it) and try **Reset Interface** again.
- » If this does not help, close and open the Activity again.

How to manage sensors

In Coach sensors are represented by the sensor icons. In some Measurement Activities/Results sensors are already set-up for measurement, their sensor icons are placed on the sensor inputs. After opening and successfully establishing communication with an interface, Coach checks if the sensors, which icons are set on the interface image are physically connected to the interface. If this is not the case Coach tries to match the sensors as good as possible.

Selecting Sensors from the Sensor Library

Sensors which are not automatically detected e.g. older type of sensors, can be selected from the Sensor Library.

To select a sensor icon manually

- » Click an empty sensor input on the screen interface and select **Choose a Sensor**.
- » Select the desired sensor from the sensor list and click **OK** to accept it. Since the list consists of many sensors you can sort them on their name or article code and/or show only a selected brand (CMA, CMA Archive, 3B, Vernier or created by User).
- » The sensor icon will be placed on the input and the data measured by the sensor will be displayed on the icon (on active interface).
- » Additionally in the Sensor Library there are two sensor icons which do not correspond to real sensors: Voltmeter (0 .. 5 V), and Voltmeter (-10 .. 10 V). These Voltmeter icons are kind of "generic" sensors, which measure a (un-calibrated) voltage signal. Please note that when using CMA Adapter 0519, only voltages between 0 .. 5 V can be measured.

Connecting Sensors

After a sensor is physically connected to the "active" interface then the following can happen:

1. When a sensor input of the interface image in Coach is **empty**, then:
 - » A sensor icon automatically appears on the sensor input whenre Coach identifies the connected sensor.
 - » Nothing changes because Coach is not able to identify the connected sensor e.g. it is an older CMA sensor not equipped with Auto-ID resistor or EEPROM memory. Such sensor has to be selected manually from the Sensor Library.
2. When a sensor input of an interface image in Coach is **not empty** because a predefined sensor is already set up, then:
 - » When the physically connected sensor is the same as the predefined sensor icon then live readings appear on the sensor icon.
Note: It may happen that a sensor which should be detected (has built-in EEPROM memory) is not automatically identified. This can happen for example for CMA Force sensor BT42i connected to €Lab when €Lab is connected to a USB port, which does not provide enough power. In such case:
 - » if there is no sensor icon on a sensor input in Coach, right-click the empty input and select the sensor manually from the Sensor Library.
 - » if there is a sensor icon on a sensor input in Coach and it remains grey, right-click the sensor icon and select **Confirm**.
 - » When the physically connected sensor belongs to the same family of sensors as the predefined sensor then Coach automatically adapts the sensor icon to the icon of the physically connected sensor. For example if the predefined sensor is CMA Temperature sensor 0511 but the real connected sensor is CMA Temperature sensor BT84i then the icon of 0511 will be automatically replaced by the icon of BT84i. This is because both sensors belong to the same family of temperature sensors; they both measure temperature.
 - » When the physically connected sensor is different then the predefined sensor icon and Coach is able to identify the connected sensor, then the sensor icon does not show any live readings. The yellow tip shows information that the identified sensor is different than the predefined sensor. In such case connect the defined sensor or change the predefined sensor into the detected sensor by selecting **Exchange**.
 - » When the physically connected sensor is different then the predefined sensor, and Coach is not able to identify it, then the sensor icon does not show any live readings. The yellow tip shows information that there is no sensor connected. In such case connect the defined sensor or remove the predefined sensor by selecting **Remove** or **Replace**.

When a sensor icon is present on an input the sensor the sensor info is displayed in the yellow tool tip when the mouse cursor is placed over the sensor icon. This tool tip displays the sensor's name, article number, brand, and the measurement range e.g. *Temperature sensor (BT84i) (CMA) (-18 .. 110°C)*.

When a sensor is successfully connected its sensor icon shows live data measured by the sensor. These live readings are not stored in the Coach.

For setting up an internal (built-in) sensor read Setting Up Internal sensor.

Disconnecting Sensors

After a sensor is physically disconnected from the "active" interface the following can happen:

- » The detected sensor automatically disappears.
- » The manually selected sensor icon remains on the input and stops to display live readings. The sensor icon has to be manually removed. To remove the sensor icon click the icon and select **Remove**.

When a disconnected sensor has data then on the moment of disconnecting the sensor (detected sensor) or removing its icon (sensor selected from the Sensor Library) its data are "disconnected" from the sensor. The variable associated with the sensor data becomes Manual Input type

However, in case you reconnect the same, or a compatible sensor, to the same input, Coach will try to "reconnect" the variable with the sensor again and new-collected data will be added to the same variable (column) in the Data Table. If this is not possible a new variable (column) is created for a new sensor.

This behavior is introduced in Coach version 7.7.

Notes:

- » In case there are no data associated with the disconnected sensor its variable (column) will not be set to Manual Input but it will be deleted.
- » When the sensor gets another range via the Set Input Range option as long as Coach is able to recalculate the units (e.g. °C to °K) the variable (column) remains connected to the sensor and the data are recalculated. If Coach is not able to do it then a new variable (column) is added.
- » When the sensor is set to a digital mode (counter, digital sensor, frequency or time interval Meter set via the Sensor settings > Use as option) then a new variable (column) is created for the selected new range.

Setting up Internal Sensors

This is only available for interfaces that have internal, built-in sensors.

- » To enable an internal sensor click its empty sensor input on the screen interface and select **Enable** [*name of the sensor*].
- » To disable an internal (built-in) sensor click its sensor icon and select **Disable**.

Sensor Settings

The screen image of the interface uses icons to visually show the sensor connection. Another way to get a complete overview of sensor connections is the option **Sensor Settings**. This option gives an overview of sensor inputs, displays the sensor settings and allows sensor setup of connected sensors. The dialog has tabs for each sensor input, and if an interface has built-in sensors, also for its internal sensors.

When a sensor is automatically detected or selected from the Sensor Library then all its settings are automatically loaded and displayed on the respective sensor input tab.

To edit sensor settings

- » Click a sensor tab, e.g. A1 for VinciLab, to display the current settings of the sensor connected to the sensor input A1.

Sensor: displays the name of the connected sensor or **None** if there is no sensor connected or identified. To manually set up the sensor click **Choose** and select a sensor from the Sensor Library.

Enabled (appears only for internal sensor):

- » Select **Enabled** when you want to activate the sensor.
- » Deselect **Enabled** when you do not want to measure with the sensor.

Range: displays the default input range (calibration) of the sensor. Many sensors have multiple ranges.

- » Click the drop down list to choose another range. The calibration stored in the sensor's memory is indicated by 'EEPROM'.

Use as: displays the mode in which the sensor works. The following modes available: Analog sensor, **Counter**, **Digital sensor (1-bit)**, **Frequency meter** and **Time-interval meter**. Most sensors are used by default in Analog mode.

- » To change the sensor mode click the drop down list and select the desired mode.
- » Specify the conversion settings where needed.

Use **Set to Zero** or **Set to Value** to shift the provided sensor calibration.

Use **Calibrate** to calibrate the sensor.

Via **Reset** the user calibration will be reset to the original calibration.

Current value: displays the actual value measured by the sensor.

Note: Some options might be not available for certain interfaces, e.g. €Lab does not support Frequency meter and Time-interval meter. See Users' Manuals of respective interfaces.

How to modify measurement settings

The Measurement Activities started via Dashboard or Measurement Activities provided in the CMA Projects have the predefined measurement settings. However these settings can be modified.

To modify measurement settings

- » Click the Activity Toolbar button **Measurement Settings** .

For the **Time-based** measurement:

- » Enter the Measuring time, type in the duration of the measurement and select the unit from the drop-down list (default 10 s).
- » Enter the frequency of the measurement. Type in the sampling rate and select the unit from the drop-down list (default 50 per s).
- » The Number of samples is automatically calculated from the settings of the fields above. The actual measured number of samples is usually the shown number plus 1, because the measurement starts at time $t=0$. It is also possible to enter the desired number of measurements. In this case the measuring time will be adapted. The maximum number of points in Coach is 500,000.

For the **Event-based** measurement:









- » Enter the **Number of samples**.
- » If needed re-define the **threshold** and the **direction** of the signal.

For the **Manual** measurement:

- » Enter the **Number of samples**.



How to do a measurement


After a Measurement Activity/Result has been opened, the interface is active and the sensors are properly connected/identified/manually selected - their live readings are shown on the sensor icons, you are ready to start a measurement. The measurement will be executed according to the measurement settings.


- » Click the Activity Toolbar button **Measurement Settings**  to check the measurement settings. They will depend upon the type of measurement selected for the Activity. If desired change the default settings.
- » To start collecting data click the button **Start** .
 - » In most cases, Coach directly starts the measurement and data are displayed in the Data Table and on predefined Graphs, Meters and Values.
 - » If triggering is enabled then the measurement is started automatically when the trigger conditions are met. To manually start the measurement when **Waiting for trigger conditions** click **Trigger**.
 - » When the type of measurement is set to Manual then the **Manual Start** button  appears in the Activity Toolbar. Press this button to collect a single measurement. When a keyboard input is specified then the value of one or more quantities has to be typed in. When a counter is used, pulses can be counted during a certain time interval after a button press.
- » The measurement stops when the specified measurement time or specified number of samples has been reached. If you want to interrupt the measurement process click the button **Stop** .
- » To replay measurement click the button **Replay** , set the replay speed (default real-time) or specify the time interval in which the measurement should be replayed and click **Start** .
- » Each time you click , the data collection starts again and a new measurement run is added to the Data Table.
- » Once you have collected your data you can analyze and process the data.
- » Save your results via the Toolbar button **Save As** .

How to do off-line measurement

Off-line measurement mode allows you to set up a data-logger such as CLAB for collecting data away from the computer. After performing the data collection you have to reconnect the data-logger to your computer to retrieve the data.

In the Activities for off-line measurement the Activity Toolbar shows two extra buttons: **Send Settings**  and **Get Data** .

- » Open an Activity/Result for off-line measurement e.g. when working with the CLAB data-logger.
- » Click **Send Settings**  to send the experiment settings to the data-logger.
- » Now you can disconnect the data-logger from the computer and perform your measurement. The collected data are stored in the data-logger.
- » When the measurement is finished reconnect the data-logger to the computer.

- » Open the Coach Activity from which the experiment settings were sent.
- » Click **Get Data**  to transfer the collected experiment data into Coach.





How to do a measurement together with video capturing

In Measurement Activities it is possible to capture video during the course of a measurement. In this way the measurement results of an experiment can be illustrated by video images in real-time.

Before you start capture in Coach your camera should be plugged in and turned on. If Coach does not detect the connected camera then the option Capture is disabled.

The video capture can be synchronized with the measurement i.e., it starts automatically when the **Start** button is pressed, and stops when the measurement is finished or the Stop button is pressed. When the **Synchronized Capture** option is not marked then the measurement and capture process have to be started separately.

To execute a measurement with synchronized video capture






- » Click the Activity Toolbar button  **Video** and select the camera or click the **Capture**  button in the Toolbar of the Video pane.
- » Right-click the Video-Capturing window and mark **Synchronized Capture** (by default off). The Record button becomes disabled.
- » Click  **Capture Settings** and specify the capture settings.
 - » The maximal capturing time is disabled. This time depends on the selected type of measurement and is set automatically.
 - » For slow measurements (measurement frequency of 1 per second or lower) it is possible to select the Frame rate follow measurement option. Then the frame rate of the captured video will be the same as the measurement frequency.
- » Click the **Start** button  to start the measurement/capture process. Coach measures and captures according to the specified measurement settings and capture settings (but the capture time is neglected). If triggering is enabled then the capture starts at the moment of clicking the Start button and the measurement starts when the trigger conditions are met.
- » To interrupt the measurement/capture process, click the **Stop** button or press **<Esc>**. The measurement/capture stops when the measurement process is finished. Then the Video-Capturing window is automatically closed and the recorded file with the name REC# is placed in the Video pane. Depends on the video size this process may take a few moments.

For recorded video the green Begin and the red End markers indicate the moments when the video starts and ends. The green line indicator indicates the frame at which the first measurement sample is taken. Coach sets the position of the green indicator automatically but it can happen (especially for slower computers) that this indicator is not positioned correctly; there is a time difference between its position and the moment of collecting the first measurement sample. In such situation the position of the green indicator can be corrected manually by moving the green line to another location or by defining a time interval between the beginning of the video and the moment of collecting the first measurement sample via the Tool menu option **Adjust Synchronization** option.

The Measurement Activity can consist of more videos but only one video can be synchronized with the latest measurement run.

When a new measurement run with synchronized capture is performed (the **Capture** option has to be selected again) then a new video together with a new measurement run are registered. The previously recorded video is added to the list of videos available in the Activity.



To execute a measurement with non-synchronized video capture

- » Click the Activity Toolbar button  **Video** and select the camera or click the **Capture**  button in the Toolbar of the Video pane.
- » Right-click the Video-Capturing window and of selected deselect **Synchronized Capture** (by default off).
- » Click  **Capture Settings** and specify the capture settings.
- » Click the **Record** button to start the capture and click the **Start** button  to start the measurement. Coach measures according to the specified measurement settings and records according to the specified capture settings.
- » After video recording has been finished use the  **Use Recorded Video** button to transfer the captured video to the Video pane.
- » The green Begin and the red End markers are placed in the frame controller of the Video pane at the frames where the measurement was started and stopped. If these moments fall out side the frame controller range then the markers are placed at their outmost positions.

How to replay a measurement synchronized with a video

After a measurement is completed, it is possible to replay it. The replay of the measurement can be synchronized with a video located in a Video pane.

To replay a measurement synchronized with video

- » Click the Activity Toolbar button  **Video** and select the desired video or use a captured video.
- » Place the video in one of the panes.
- » Right-click the Video pane and mark the **Synchronized Replay** option. By default this option is marked for measurements with synchronized video capture.
- » To synchronize the measurement with the selected video click the **Adjust Synchronization** option and specify the time interval between the beginning of the video and the moment when the first measurement sample is collected. Mark **after video starts** if your video starts the given time interval after the measurement is started or mark **before the video starts** if the video starts the given time interval before the measurement.
- » When the after the video starts option is marked the green marker appears in the frame controller and can be used for adjusting manually the moment of collecting the first measurement sample.
- » To replay measurement click the Activity Toolbar button **Replay** , set the replay speed (default real-time). During the replay the video starts at the position of the blue Begin marker.
- » **Note:** When the **Synchronized Replay** option is marked then during scanning in the graph (via the **Scan** option) Coach shows the corresponding video frames of the connected video.

Setting Up an Own Experiment

Before you can set up your own experiment you need to take the following steps:

1. Setup your measurement:
 1. Open a Measurement Activity
 2. Connect an interface,
 3. Connect sensors,
 4. Select an appropriate measurement mode,
 5. Setup your measurement settings.

In this chapter all these steps are described in details.

Selecting Appropriate Measurement Mode

Coach offers three methods of measurement: time-based, event-based, and manual. Select an appropriate method for your experiment.

TIME-BASED MEASUREMENT

During the time-based measurement, measurements are taken at regular time intervals according to the defined sampling frequency rate. A measurement is started with the Activity Toolbar button Start. A measurement is finished when its measurement time interval has elapsed. Most measurements are of this type.

Examples of time-based measurements are:

- » measurement with a temperature sensor of 100 values during 10 seconds (i.e. a sampling frequency of 10 Hz, or
- » measurement with a sound sensor 0.2 s long with a sampling frequency of 40,000Hz.

This measurement type can also be used with sensors converted into counters or time-interval meters.

For very short measurements or when you want to start a measurement under specific conditions (e.g. when it becomes dark), you can start the measurement automatically by using the **triggering option**. The trigger conditions (the trigger level and direction) determine the state of the signal on the trigger channel to automatically start the measurement. Sometimes the signal just before the moment of triggering is also relevant. Registration of this part is possible when a pretrigger time is used.

The trigger conditions are indicated by an arrow on all graphs axes to which a trigger channel has been attributed. The data obtained during the pretrigger time is also displayed.

Additionally a time-based measurement may be executed **off-line**. This means that during the data collection the interface may be disconnected from the computer.

EVENT-BASED MEASUREMENT

During an event-based measurement, data are taken each time a pulse (event) is received on a sensor input. A measurement is started with the Activity Toolbar button Start. A measurement is finished when the given number of samples has been reached.

Examples of event-based measurements:





- » Titrations: the droplets falling through a light gate generate pulses, the pH is measured;
- » Measuring distance with a smart pulley: the spokes of the smart pulley generate pulses, the distance and/or time is measured;
- » Measuring time intervals of a falling ladder with equidistant holes.
Use a light sensor converted to time-interval meter. Adjust the threshold to a suitable value and set the

interval type to T up or T down (depending on the threshold settings of the sensor). Set the number of points to the number of holes in the ladder;

- » Measuring the speed of a cart on a track (or a rebounding cart).
Mount a rectangular piece of cardboard on the cart. Use a light sensor converted to time-interval meter to measure the passage time of the cardboard. Select the desired Interval type (e.g. Low). Set the number of points, or stop the measurement by pressing the red stop button.

MANUAL MEASUREMENT


During manual measurement a single measurement is taken every time the button is pressed. This includes the following type of measurements:

- » **Measurement with sensors** – the sensor readings are taken when the **Manual Start** button  is pressed.
- » **Measurement with keyboard input** - the values of one or more quantities have to be entered when the **Manual Start** button  is pressed.
- » **Measurements with sensors and keyboard input** (combination of 1 and 2) – the sensor readings are taken and the values of one or more quantities have to be entered when the **Manual Start** button  is pressed.
- » **Measurement with a counter** - pulses can be counted during a certain time interval after **Manual Start** button  is pressed.

Examples of manually triggered measurements:

- » Boyle's law – measuring the pressure value with a pressure sensor and typing in the respective volume value
- » Investigating the relation between radiation level and distance from the radiation source - measuring the number of counts with a GM-sensor during a fixed time interval for different distances to the radiation source.
- » Measuring the mean background radiation by measuring several series of counts during a fixed time interval.


Setting up a Time-Based Measurement


1. Click the Activity Toolbar button  **Settings** and select the **Time-based** type of measurement.
2. In the tab sheet **Method**:
 - » Enter the Measuring time, type in the duration of the measurement and select the unit from the drop-down list (default 10 s).
 - » Enter the frequency of the measurement. Type in the sampling rate and select the unit from the drop-down list (default 50 per s).
 - » The Number of samples is automatically calculated from the settings of the fields above. The actual measured number of samples is usually the shown number plus 1, because of the measurement at time $t=0$. It is also possible to enter the desired number of measurements. In this case the measuring time will be adapted. The maximum number of points in Coach is 500,000.
 - » A message **Triggering is enabled** shows up if triggering is enabled.
 - » If a counter is connected to the panel, the **More** button reveals a pane with the **Reset counter to zero each sample interval** option. If this option is checked, the counter will be reset each

sample time interval (specified by the frequency). This option (default off) is not available for off-line measurements.






3. If you want to trigger the measurement click the **Triggering** tab and mark the **Enable triggering** option. The trigger settings options become active. With these settings you can specify a signal condition at which the computer automatically starts a measurement.
 - » Select the **Trigger channel**. This channel will be checked for the trigger conditions. Coach automatically selects the lowest channel to which a sensor icon is connected.
 - » Enter the **Trigger level**. When the signal passes this level the measurement is triggered. The sensor range is displayed behind the field.
 - » Select the **Direction** in which the signal should pass the trigger level to trigger the measurement. Choices are **Up** (passing the level from smaller values to larger values); **Down** (passing the level from larger values to smaller values) or **Both** (both directions will trigger the measurement). The trigger conditions are indicated by a solid up or down arrow displayed on the diagram axis of the trigger channel. In case the direction is both, a double-pointed arrow will be displayed at the trigger level with the middle of the arrow at the indicated level.
 - » Specify **Pre-trigger time**. This is the time interval for which data is shown prior to the trigger moment. The range is displayed behind the field.
4. If you want to repeat your measurement automatically click the **Advanced tab** and mark the **Repeat** option. This tab is not available for off-line measurements.
 - » Select **Total number of runs** and enter how many times the measurement should be repeated or select **Continuously** if the measurement will be continued until the red Stop button will be used.
 - » Select the **Delay** option if you want to specify a delay time between the repeat cycles. After each measurement run, Coach waits the delay time before starting a new measurement run. With this setting it is possible to measure 10 minutes each hour (delay = 50 minutes). Notice that when "repeat" is used, the resulting data set is not entirely equidistant in time as it is computer dependent how long it takes to process the resending of the measurement settings to the interface.

Setting up an Event-Based Measurement

1. Click the Activity Toolbar button  **Settings** and select the **Event-based type** of measurement.
2. In the tab **Method**:
 - » Enter the **Number of samples**, which will be measured. This number also determines when an event-based measurement will stop.
 - » Select the **Event source** - the sensor input, which delivers the pulses. By default the lowest numbered input is chosen which has a counter connected to it. If no counter is connected then the lowest numbered input, which has an analog sensor connected to it, is chosen.
 - » The **Threshold** option is active if the event source is an analog sensor; the default threshold is 50% of the calibrated scale. If the source is already an analog sensor used as counter or as a digital sensor then the threshold and direction will be displayed in these (inactive) fields. The sensor's unit and range is displayed behind this field.
 - » **If Direction=Both**, then up and down flanks are taken alternatively, which, in case of a falling drop through a light gate, would lead to two pulses per drop instead of one. The default values depend on the type of event source. In case of:
 - » an analog sensor: a default threshold is taken at half of the full scale and direction is up.
 - » an analog sensor defined as a counter: the threshold and direction fields will display the values from the use-as-a-counter sub-menu. It is no longer possible to restore the sensor as it is the event-source channel.

- » a digital sensor, the default threshold is set at the state which approximates 50% of the state values and direction is up.
3. The **More** button reveals a pane with the following advanced options:
 - » When **t=0 at first event** is checked then $t = 0$ is assigned to the first pulse. Otherwise, time starts running when the Start button is pressed, regardless of the detection of a pulse.
 - » When **Stop measurement after** is checked then not only the number of events, but also the duration of the measurement serves as a stop condition. Besides, this value is also taken as the length of the time axis. If the option is off, a default time-axis of 10 s is used.
 - » The **Use every** option is designed for the case too many pulses are generated. E.g. if the user selects **Measure only every 5th event**, then only one out of every five events results in a measurement.
 4. If you want to repeat your measurement automatically click the **Advanced** tab and mark the **Repeat** option. This tab is not available for off-line measurements.
 - » Select **Total number of runs** and enter how many times the measurement should be repeated or select **Continuously** if the measurement will be continued until the  **Stop** button will be used.
 - » Select the **Delay** option if you want to specify a delay time between the repeat cycles. After each measurement run, Coach waits the delay time before starting a new measurement run. Notice that when a repeat is used, the resulting data set is not entirely equidistant in time as it is computer dependent how long it takes to process the resending of the measurement settings to the interface.

Setting up a Manual Measurement

1. Click the Activity Toolbar button  **Settings** and select **Manual** type of measurement.
2. In the tab **Method**:
 - » Enter the **Number of samples** that will be measured. This number also determines when a manual measurement stops.
 - » When the **First point at start button** is checked then the press on the Activity Toolbar button Start will become the first measured point (default=on). If unchecked, no measurement will be taken upon pressing this button, but only on pressing the  **Manual Start** button .
3. The **More** button reveals a pane with the following advanced options:
 - » When a counter is used then the **With counters** option should be checked. Two more options become available.
 - » **Manual start and stop** - both the start and stop of the counting interval is determined by a press on a button. Start by the  **Manual Start** button and stop by the  **Manual Stop** button.
 - » **Manual start, stop after a certain time interval** - each time the  **Manual Start** button is pressed, counting is done during the indicated time interval. Enter the time interval and select the time unit.
 - » When **t=0 at first event** is checked then $t = 0$ is assigned to the first pulse. Otherwise, time starts running when the green button is pressed, regardless of the detection of a pulse.
4. If you want to use the keyboard input during the measurement click the Input tab and define the keyboard inputs.
 - » Select the number of variables for the keyboard input(s) (maximum 4).
 - » Specify **Quantity**, **Unit** and number of **Decimals** for each variable.

- » Click **OK**. The variables defined for the keyboard inputs will be automatically added to the Data Table.

Setting Appropriate Measurement Settings

Sampling frequency

Several factors usually compete for selecting an appropriate sampling rate. Your aim is to sample fast enough to capture important changes in the measured signal. Few examples:

1. The temperature signal changes rather slowly, a sampling frequency of 4 Hz or 2 Hz (4 or 2 times per second) is sufficient for temperature measurements.
2. Such low sampling frequency will be absolutely not sufficient for a rapidly changing sound signal. Here the sampling frequency of 20,000 or 40,000 measurements per second is needed otherwise important signal information may be lost.

Another limitation for the sampling frequency is the used interface. Each interface has its own maximum sampling frequency, which also might depend on the number of channels used during the data collection. For example for the CLAB interface, for measurement via one channel the maximum sampling frequency is 100,000 Hz (samples/second), for measurement via two channels simultaneously 60,000 Hz, and via three channels 40,000 Hz. For detailed information about maximum sampling frequency consult User's Manuals of respective interfaces.

Number of points/measurement time

You want to sample fast enough but you do not want to generate an excessive number of measured points because it slows down the performance of your computer especially if your data have to be processed.

The maximum number of points in Coach itself is 500,000 points. High sampling frequency produces a large number of measured points – shorter measuring time should be selected.

But also an interface might limit the maximum number of data points. For detailed information consult User's Manuals of respective interfaces.

Notice that when "repeat" is used, the resulting data set is not entirely equidistant in time as it is computer dependent how long it takes to process the resending of the measurement settings to the interface.

Working with Sensors

The topics in this chapter will help you to work with sensors and sensor icons.

Sensor Input Ranges

Modern sensors are equipped with EEPROM memory, which stores the factory calibration of the sensor. For these sensors Coach uses as default this EEPROM calibration. For other sensors the calibration stored in the Coach Sensor Library is used as the default calibration.

For many sensors not only the default but also a few more calibrations, so called sensor input ranges, are offered, e.g. a temperature sensor by default uses the °C range but it can also be set to measure in °F.

To change the input range of the sensor

- » Click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears. The abbreviation 'EEPROM' indicates the calibration stored in the sensor memory.
- » Select the desired range.
- » The readings of the sensor will be adjusted accordingly.

Set to Zero

For some experiments it can be useful to quickly reset the sensor value to zero. For example:

- » When you reset the equilibrium force of a mass on a spring connected to a force sensor to zero, then forces with respect to the equilibrium position can be measured.
- » When you reset the reading of a temperature sensor to zero at room temperature, then temperature differences with respect to room temperature can be measured.

To reset the sensor value to zero

- » Click a sensor icon and select **Set To > Zero**.
- » The readings of the sensor will be adjusted.
- » Click a sensor icon and select **Set To > Reset** when you want to remove the new calibration.

Set to Value

If the value measured by the sensor is too high or too low, you can shift the sensor calibration through a third point defined by its a value. This feature can be used for example to improve the sensor's accuracy when the sensor's factory calibration measures a different value than expected.

To set the sensor value to another value

- » Click a sensor icon and select **Set To > Value**
- » Type in a value and confirm with **OK**.
- » The readings of the sensor will be adjusted accordingly.
- » Click a sensor icon and select **Set To > Reset** when you want to remove the new calibration.

Calibrating a Sensor

Most sensors do not need to be calibrated. Their calibrations are provided by the sensors themselves (stored in the sensors' EEPROM memory) and by the Coach software (included in the CMA Sensor Library). For better accuracy these calibrations can be improved.

New calibration can be stored in the sensor's EEPROM memory (calibration via the option **Calibrate (EEPROM)**) or added as new sensor input range (calibration via the option **Calibrate**).

The sensor calibration in Coach provides the sensor name, its measurement range and the mathematical relation between the voltage values produced by the sensor (in most cases) and the values of the physical quantity measured. There are two ways to perform a calibration:

- » By providing a calibration function: method **Function**.
For this method the type of calibration function has to be selected (Linear, Quadratic or Logarithmic function), and the required calibration's function coefficients are typed in. The resulting calibration is drawn in the calibration graph. Most sensors in Coach are calibrated via a function.
- » By providing calibration points: method **Points** (not possible for the EEPROM memory)
For this method calibration points are added to a calibration table. These points can be:
 - » measured, the actual sensor voltage value is measured and the value of the corresponding quantity is typed. In this case the sensor has to be connected to the active interface. Such a calibration is the most accurate calibration.
 - » typed, both the actual sensor voltage value and the value of the corresponding quantity are typed.

To connect the calibration points in a curve, approximating function (Linear, Quadratic or Logarithmic) should be used. The best function fit, through the calibration points, is calculated according to the least-squares method. The calibration function will be then extrapolated to cover the whole range.

To replace the calibration stored in the sensor's EEPROM memory

Detailed description is given in [Storing a New Calibration in the sensor memory \(EEPROM\)](#).

To perform a new calibration

- » Click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears.
- » Select a range from the CMA Library (no EEPROM and no User range below the vertical line).
- » Click the sensor icon again and select **Calibrate**.
- » The Calibration dialog opens and shows the sensor name, calibration settings and a calibration graph. In most cases on the calibration graph the sensor voltage value V is displayed along the x-axis and the measured by the sensor quantity is displayed along the y-axis (with the exception of temperature sensors using an NTC thermistor and Steinhart calibration function).
- » The sensor info, its name, number, brand and measurement range is displayed in the non-editable fields. This info cannot be changed.
- » In the Range ID enter the new calibration name. This name will be added, as a new user input range, to the list of sensor input ranges.
- » Select the calibration method: **Function** or **Points**. When the method Points is selected the tab **Points** with a respective calibration table is added.
- » If desired change the scaling information: **Quantity**, **Unit**, **Minimum** and **Maximum** of the new sensor range.
- » Select the desired function-fit type.
- » Perform the calibration:

for the Function method

- » Type the function coefficients in the **Coefficients** fields.
- » The calibration graph is drawn.

for the Points method

- » Click the **Points** tab.
- » Make sure an experimental setup is available to do measurements. And have instruments available to determine a reference value of the quantity (e.g. a thermometer, melting ice and boiling water, etc.).
- » The small digital display below the calibration graph/table continuously displays the actual measured sensor voltage. If necessary wait for the voltage to stabilize.
- » As soon as you press the **Add Row** button the measured voltage value appears in the **Voltage** field. If Coach is running without an active panel then the voltage value will not appear. In this case this value has to be typed in.
- » Click the **Quantity** field and type the corresponding value of the quantity. Click **OK** to accept.
- » Repeat the above steps until a sufficient number of calibration points have been obtained.
- » To delete a calibration point click **Delete Row**. Click **Yes** to confirm that you want to delete the calibration point.
- » To delete all calibration points click **Delete All**. Click **Yes** to confirm that you want to delete all calibration points.
- » Click the **Test** button to perform a calibration test. During the test Coach shows the actual voltage and the calibrated quantity value. Click **Stop** to hide the Calibration Test dialog.
- » Click **Save** to finish calibration process.
To store your new calibration in the User Library select **Yes**. In this case your calibration will be available globally and you can use it in any Coach Activity.
To store your new calibration in the current Activity select **No**. In this case the new calibration will be available locally only in this Activity.

To perform an update of a user calibration

- » Click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears.
- » Select a user range you want to modify. The user input ranges are listed below the vertical line .
- » Click a sensor icon and select **Calibrate**.
- » The Calibration dialog opens and shows the sensor name, calibration settings and a calibration graph.
- » Perform a new calibration as described above.
- » Click **Save** to finish calibration process.
To update the calibration in the User Sensor Library select **Yes**. In this case your calibration will be available globally and you can use it in any Coach Activity.
To update the new calibration in the current opened Activity select **No**. In this case the new calibration will be available locally only in this Activity.

To remove a user made calibration (a user input range)

- » Click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears.
- » Only calibrations – input ranges added by users can be deleted. These input ranges are listed below the vertical line.
- » Select the desired user input range.
- » Then click the sensor icon again, select **Set Input Range** and **Delete from User Library**.

Storing a New Calibration in the sensor memory (EEPROM)

For sensors equipped with EEPROM memory it is also possible to modify the factory calibration and replace the factory calibration by a new calibration made in Coach. This allows making an accurate calibration per

physical sensor. Next time such a sensor will be connected and detected its new calibration will be used. This is a very useful feature for example for pH sensors.

The new calibration does not really overwrite the factory calibration of the sensor and if needed its factory calibration can be restored.

Note: not all interfaces and sensors support this feature; consult User's Manuals of respective interfaces and sensors.

To change existing EEPROM calibration and store it in the sensor memory

This is possible only when a sensor equipped with the EEPROM memory is physically connected and identified in Coach. In such case the EEPROM range is set as the default range, which means that the calibration stored in the sensor memory is used.

- » Click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears.
- » Make sure that the EEPROM range is selected (the word EEPROM is displayed between brackets).
- » Click the sensor icon again and select **Calibrate EEPROM**.
- » The EEPROM Calibration dialog looks similar to a standard Calibration dialog however some of the options are disabled. It is not possible to edit quantity, minimum and maximum of the sensor range and function type. This is because the EEPROM calibration has a specific format.
- » Type new coefficients and if needed a new unit. The calibration graph will be adjusted accordingly.
- » You may use the **Get from Library** button to load an existing calibration from library.
- » Click the **Test** button to perform a calibration test. During the test Coach shows the actual voltage and the calibrated quantity value. Click **Stop** to hide the Calibration Test dialog.
- » Click **Save** to store the new calibration in the sensor memory (there is no way to save it to the User Library).
- » The question 'Do you want to replace the calibration in the sensor memory (EEPROM)?' appears. Click **OK** to accept.
- » The new EEPROM calibration replaces the old EEPROM calibration in the sensor memory.

To restore the factory calibration

- » Right-click a sensor icon and select **Set Input Range**.
- » A list of all available sensor ranges appears. Select the EEPROM range.
- » Right-click the sensor icon again and select **Calibrate**.
- » In the Calibration dialog click **Reset calibration to factory settings**. Click **OK** to confirm that you want to reset the calibration.
- » After the reset is performed successfully the message 'The calibration has been reset' appears.

Creating a New Sensor

Users can create their own sensors and add them for use in Coach. Since analog inputs of CMA interfaces measure voltage signal in two ranges, between 0 .. 5 V or -10 .. 10 V, it is important to indicate which voltage range is used by a new sensor.

To create a new sensor

- » Click an empty sensor input on the screen interface, select Create a New Sensor and select the voltage range used by your new sensor.
- » By default the sensor settings are filled like for a Voltage sensor. Enter the sensor information adequate to your sensor.

- » Perform the sensor calibration by providing a function by typing/measuring the calibration points in the same way as described for the standard calibration.
- » Click **Save** to finish creating a new sensor. A question where to store your new sensor appears. To store your new sensor in the Sensor Library select **Yes**. In this case the sensor is stored in the Sensor Library as Self-made and will be available globally to use in any Coach Activity (on this computer). To store your new sensor in the Activity select **No**. In this case the new sensor will be available only in this Activity.

Sensor Library

The Sensor Library consists of sensors predefined by CMA and sensors created by users. It can be used to select:

- » a predefined sensor for not auto-detected sensor
- » a sensor created by users.

The sensor list can be sorted according to a sensor name or a sensor code.

The sensor list can be filtered to show only a selected sensor brand. Mark the brand and sensors of this brand will only be shown in the list. The CMA Archive brand is used to indicate older CMA sensors which are not sold anymore.

Users own sensors and sensor calibrations are in the file `usercal.dat`. To share these you may copy the file into a different computer (or a different user). Be aware that in case of overwriting the original file you lose all the definitions from the original `usercal` file, `usercal` files cannot be merged.

The `usercal` is located by default in:

Windows: `C:\ProgramData\CMA\Coach7\usercal.dat`.

Mac: `/Users/USERNAME/Documents/CMA/Coach7/usercal.dat` where `USERNAME` is the user's name.

Converting Analog Sensors to Digital Sensors

Analog sensors generate a voltage signal and use a provided calibration to convert the measured voltage values into a measured quantity.

Any analog sensor can be turned into a digital sensor by defining its digital threshold. When a sensor measures above the defined threshold value then the value is treated as digital 1 (true or on), when a sensor measures below the defined threshold value then the value is treated as digital 0 (false or off).

Based upon such assumptions any analog sensor can be converted in Coach into a:

- » Digital (1-bit) sensor
- » Counter
- » Frequency meter
- » Time-interval meter

Some options might not be available for certain interfaces, e.g. €Lab does not support Frequency meter and Time-interval meter. See User's Manuals of respective interfaces.

Converted sensor icons can be recognized by their color, they are lilac. Moreover, the counter, frequency meter and time-interval meter have a set-to-zero button, while the 1-bit digital sensor displays a state name for each of its two states. Also the tooltip description of the sensor icon has a suffix 'as counter', 'as frequency meter' etc. The input is internally monitored at 10 kHz, which puts a limit on the maximum frequency (5 kHz) or count rate (5000 counts/s).

Such converted sensors can be very useful as pulse source for event-based measurements.

Use as a Digital (1-bit) Sensor

A 1-bit digital sensor only assumes two values: 0 and 1. If the analog values are above the threshold, the 1-bit digital sensor has the value 1 (state 'On'), if the values are below the threshold, the 1-bit digital sensor will have the value 0 (state 'Off'). The names of the states are also displayed, and the names can be edited. This can be useful for measurements with a photogate. The sensor simply displays when an object is between the photogate and when it is not. It is also useful in combination with control programs.

To use an analog sensor as a digital sensor (1-bit)

- » Click a sensor icon and select **Sensor Properties**.
- » Select Use as: **Digital sensor (1)**.
- » Enter the **Conversion settings**. Enter the **Threshold value** in calibrated units. This is the value the signal has to pass to flip into its other state. The total range of the sensor is displayed.
- » In the **Sensor definition** section, enter the properties for the 1-bit digital sensor: the **Quantity** and the strings for the state names.
- » Click **OK** to confirm.

Converted sensor icons can be recognized by their color, they are lilac. Moreover the 1-bit digital sensor displays a state name for each of its two states. Also the tooltip description of the sensor icon has a suffix 'as digital (1)'. The input is internally monitored at 10 kHz, which puts a limit on the maximum frequency (5 kHz) or count rate (5000 counts/s).

To stop using an analog sensor as a digital (1-bit) sensor:

- » Right-click the converted sensor icon and select **Sensor Properties**.
- » Select Use as: **Analog**.

Use as a Counter

A counter counts the number of pulses. In order to count, the sensor should generate pulses (an oscillating signal). Each time the signal passes the threshold value in the indicated direction, the counter value is increased by 1.

Some sensors in Coach are already set by default in the counter mode; these are for example Photogate or Radiation sensor.

To convert an analog sensor into a counter

- » Click a sensor icon and select **Sensor Properties**.
- » Select Use as: **Counter**.
- » Enter the **Conversion settings**. Enter the **Threshold value** in calibrated units. This is the value the signal has to pass to be counted. The total range of the sensor is displayed.
- » Select the direction **Up**, **Down** or **Both**. This is the direction, which the signal should pass to be counted as a pulse. When **Both** is selected, a pulse is detected when the signal passes the threshold upwards and when it passes the threshold downwards.
- » In the **Counter setup** section enter the properties for this counter: the **Maximum** number of expected pulses (defines the vertical axis in a diagram), the **Quantity**, the **Unit** and the number of **Decimals**. In this section also the signal of the counter can be calibrated quickly. To shift the zero point of the counter mark the Shift option and specify the shift value. To make this calibration cyclic mark the Periodic option (e.g. when rotation is measured) and specify the period value
- » Click **OK** to confirm.

Converted sensor icons can be recognized by their color, they are lilac. Moreover, the counter, has a set-to-zero button. Also the tooltip description of the sensor icon has a suffix 'as counter'. The input is internally monitored at 10 kHz, which puts a limit on the maximum frequency (5 kHz) or count rate (5000 counts/s).

Such converted sensors can be very useful as pulse source for event-based measurements.

To stop using an analog sensor as a counter:

- » Right-click the converted sensor icon and select **Sensor Properties**.
- » Select Use as: **Analog**.

Use as a Frequency Meter

A frequency meter displays the number of pulses per time unit. In order to measure the frequency of a signal, the sensor should generate pulses (an oscillating signal). It is theoretically not possible to measure frequencies higher than 5000 Hz, but in practice this value may be as low as 3000 Hz.

To use an analog sensor as a Frequency meter

- » Click a sensor icon and select **Sensor Properties**.
- » Select Use as: **Frequency meter**.
- » Enter the **Conversion settings**. Enter the Threshold value in calibrated units. This is the value the signal has to pass to flip into its other state. The total range of the sensor is displayed.
- » In the **Sensor definition** section, enter the properties for the frequency sensor: the **Minimum**, **Maximum**, **Quantity** and **Unit** and the number of **Decimals**.
- » Click **OK** to confirm.

Converted sensor icons can be recognized by their color, they are lilac. Moreover, the frequency meter has a set-to-zero button. Also the tooltip description of the sensor icon has a suffix 'as frequency meter'. The input is internally monitored at 10 kHz, which puts a limit on the maximum frequency (5 kHz) or count rate (5000 counts/s).

To stop using an analog sensor as a frequency meter:

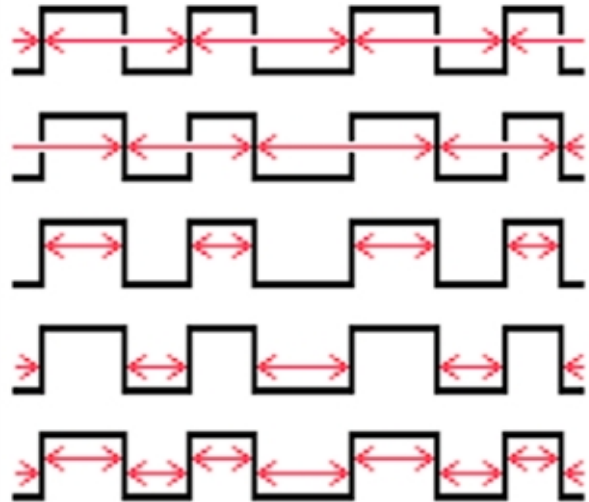
- » Right-click the converted sensor icon and select **Sensor Properties**.
- » Select Use as: **Analog**.

Use as a Time-interval Meter

A time interval meter in general measures length of a pulse.

There are a few types of measurement possible.

1. **Time Interval Up-Up** (default): time intervals between successive signal up flanks.
2. **Time interval Down- Down**: time intervals between successive signal down flanks.
3. **Time interval Up – Down (High)**: time intervals between successive signal up and down flanks.
4. **Time interval Down – Up (Low)**: time intervals between successive signal down and up flanks.
5. **Time interval Up – Down & Down- Up, (High & Low)**: time intervals between both signal up and down and signal down and up flanks.



There are five different interval types in the drop-down list, but not all types are available for all interfaces e.g. CoachLab II+ supports all five types. If fewer types are supported, then only these are shown in the list.

To use an analog sensor as a Time-interval meter

- » Right-click a sensor icon and select **Sensor Properties**.
- » Select **Use as: Time-interval meter**.
- » Enter the **Conversion settings**. Enter the **Threshold value** in calibrated units. This is the value the signal has to pass to flip into its other state. The total range of the sensor is displayed.
- » Select the **Interval** type.
- » In the Sensor definition section, enter the properties for the Time-interval meter: the Minimum, Maximum, Quantity, Unit and Number of Decimals.
- » Click **OK** to confirm.

Converted sensor icons can be recognized by their color, they are lilac. Moreover, the time-interval meter has a set-to-zero button. Also the tooltip description of the sensor icon has a suffix 'as time-interval meter' etc. The input is internally monitored at 10 kHz, which puts a limit on the maximum frequency (5 kHz) or count rate (5000 counts/s).

To stop using an analog sensor as a time-interval meter :

- » Right-click the converted sensor icon and select **Sensor Properties**.
- » Select Use as: **Analog**.

CHAPTER 3

Control

The Programming window offers the environment for creating and executing programs in the programming language called Coach Language.

For controlling the following interfaces can be used :

- » CoachLab II+, that have outputs to which actuators can be connected, and
- » €Sense and WiLab that have built-in actuators.

Examples of control programs are: an automated temperature control system used in a greenhouse or a controllable robot-arm. Through an interface, Coach collects data via sensors built in the system. These sensors provide feedback on the state of the system, and perform actions by controlling outputs to which the actuators (such as buzzers, lights, motors, pumps, or relays) are connected.

Coach offers two type of activities in which the Programming window is present:

Measurement with Program

In this type of Activity a program determines the duration of the control process and the sensor/actuator signals are evaluated according to the sampling frequency.

Data from sensors and actuators are stored and available in the Data Table.

Program variables cannot be selected for display in the Data Table.

The advantage of this setting is that the signals are evaluated independent of the program speed. For an example see CMA Projects > Control > Control examples with CoachLab II+ > Make a thermostat.cma

Control with Program

In this type of Activity a program determines the way measurements are being taken or is used to do calculations on measured signals.

Data from sensors and actuators are stored **ONLY** when the standard procedure

SaveData is used in the program.

Program variables can be selected and defined for display in the Data Table.

Disadvantage of this setting is that the sensitivity to signal changes depends strongly on the execution speed of the program (and hence on the processor speed of the computer). For an example see CMA Projects > Control > Control examples with CoachLab II+ > Proportional frequency controller.cma.

Note: The Control Activity without Program allows you **only** to control actuators in the Interface Window manually .

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The Basics

The topics in this chapter will help you to get familiar with the layout of the Program window and the Interface window for use in Control.

Programming Window

The Programming window is the place for creating, editing and displaying programs.

A program in Coach is a sequence of commands in Coach Language. There is only one control program. With such a program:



- » control tasks are executed automatically. A control program is often based on sensor values: e.g. if the temperature is too high, switch on the fan; if the temperature is too low, switch off the fan and switch on the heating element, etc.
- » measurements can be controlled: e.g. create beeps at random to which the user must react as quickly as possible by pressing a button.

The Program window can consist of up to three areas:


- » the **Buttons** area, where programming buttons are located,
- » the **Editor** area, where the lines of the program appear,
- » the **Commands** area, with the list of programming commands.

In most cases only one or two areas of the Program window are available, depending upon the choices of the Author.

To display/hide the Program window

- » Click the Activity Toolbar button **Program**  to open the Program window.
- » Click the Activity Toolbar button **Program**  to hide it.

Programming Tool Menu

The Tool menu is available after clicking the **Tool** menu button  in the Programming window (only when the Program window is docked). Also some areas of the Programming window are sensitive (hotspots) and show a different tool menu (here only Student not Author options are present).

Tool menu or editor area of the Program Window

Monitor – to execute a program in the Monitor mode

Own Commands (only if own commands are present) – to list and manage own commands

Text Zoom – to zoom text in the program window

Text Edit – to edit the program text

Erase Program – to remove the program (only if program present)

Import Program – to import a program from another Coach Activity/Result

Select Variables... - to select variables used in the program, which will be added to the Data Table and available for Graphs, Meters, Values and Animations

Dock/Undock – to undock/dock the Program window

Print Program – to print a program

Clipboard Copy – to copy a program into the clipboard

Help – to consult a help system

Hotspot: a command in the command list

Insert (before or after) – to insert an own command

Delete – to delete an own command (only when an own command present)

Cut – to cut an own command (only when an own command present)

Copy – to copy an own command (only when an own command present)

Edit Own Command – to edit an own command (only when an own command present)

Rename Own Command – to rename an own command (only when an own command present)

Delete Own Command – to delete an own command (only when an own command present)

Help – to consult a help system

Hotspot: an own command editor

Back to Program – to return to a program

Own Commands – to list and manage own commands

Erase Own Command – to delete an own command (only when an own command present)

Print Own Command – to print an own command (only when an own command present)

Text Edit – to edit the command text

Import Program – to import a program from another Coach Activity/Result

Interface Window

In Control Activities/Results the Interface window is exactly the same as in Measurement Activities/Results. Interfaces, which are suitable for connecting actuators, have outputs to which actuator icons can be connected e.g. CoachLab II+. Interfaces, which have built-in actuators, have the actuator icons already placed on the interface image e.g. WiLab.

Some areas of the interface image are sensitive (hot spots) and show a different tool menu. Some of these menus are specific for Control and Actuators.

» Click or right-click a hot spot to evoke the respective menu.

Hot spot: an empty actuator output

Display as > Graph, Meter, Value – to display actuator values on a standard Graph, Meter or Value.

Choose an Actuator – to select an actuator from the Actuator Library. Note the actuators are not detected automatically.

Hot spot: an actuator icon on an actuator output

Display as > Graph, Meter, Value – to display actuator values on a standard Graph, Meter or Value.

Remove – to remove an actuator selected from the Actuator Library.

Hot spot: an actuator icon of built-in actuator

Display as > Graph, Meter, Value – to display actuator values on a standard Graph, Meter or Value.

The icon of a built-in actuator displays the status of the actuator (Off or On).

- » Click the icon to change the status. When the actuator is On then you can use the icon slider e.g. to change the tone of the built-in buzzer.

Interface Screen Image

The screen image of the interface is a clickable image of the used interface. It shows inputs for sensors, and for some interfaces, like CoachLab II+, outputs for actuators, just like the connectors on the real interface. These areas are sensitive (called hot spots) and can be clicked to open a specific Tool menu.




Program Execution

The topics in this chapter will help you to work with actuators and to run a program.

How to open an Activity with Program

You can open an Activity with program (this can be Control Activity or Measurement Activity with Program) in Coach in the following ways:

- » **Quick Start:** click the Dashboard  **Control** button and select Programming with CoachLab II+ or Programming with WiLab .
- » Open an example of a Control Activity located in the **CMA Projects** in the **Control** folder.
- » Open a Control Activity prepared by your Teacher.

How to manage actuators

In Coach actuators are represented via actuator icons. In some Control Activities/Results actuators are already set-up, their actuator icons are placed on actuator outputs. After opening and successfully communicating to an interface actuator icons show the state of the physically connected actuators and interface's outputs can be manually controlled.

Connecting Actuators

After an actuator is physically connected to the "active" interface:

- » Click an empty actuator output on the screen interface and select **Choose Actuator**.
- » Select the desired actuator from the list and confirm with **OK**.
- » The actuator icon will be placed on the output and the actual state of the actuator will be displayed on the icon.

If an actuator icon is present on an output its info is displayed in the yellow tool tip when the mouse cursor is placed over the actuator icon. The tool tip displays the actuator's name, brand and the number of bits (i.e. a measure for the number of different states the actuator can have), e.g. Lamp (12V) (062) (CMA) (1).

Actuator Library

The Actuator Library consists of actuators predefined by CMA.

The number of actuator's bits defines a number of the actuator's states. When number of bits is 1 then the actuator has 2 states, when number of bits is 2, the actuator has 4 states.

A step motor rotates a given number of steps in a given direction. It can be set to a certain position very accurately (as the number of steps corresponding to one turn is very high). Select the type that corresponds to your step motor.

- » **2 bits** - The outputs control the step motor in the following order: 01 11 10
- » **4 bits** - The outputs control the step motor in the following order: 0011 0010 0110 0100 1100 1000 1001

The number of bits of the actuator and the number of bits of the output determine how many interface outputs the actuator icon occupies. However, you do not have to worry about this as Coach does not allow connecting more actuator icons than possible.

Disconnecting Actuators

After an actuator is physically disconnected from the "active" interface:

- » Click the icon of this actuator and select **Remove**.
- » The actuator icon will be removed from the output.

Manual Control of Actuators

With manual control you can turn outputs, to which actuators are connected, on and off. This mode offers a convenient way to check the effects of certain connections and actions and can be useful while designing a control program.

To manually control an actuator connected to CoachLab II+

- » Click the LED next to an actuator icon to turn it on or off. It works only when an actuator icon is placed on the output.
- » A 1-bit actuator can be set into two states e.g. a lamp can be set on or off. Here only one LED is clickable.
- » A 2-bit actuator can be set into four states e.g. a motor can be set on-left, on-right, stop or off. Here two LED's are clickable, the left (green when on) and the right (red when on). The actuator states are indicated on the real interface by different colors, e.g. the LED of the CoachLab II+ interface can be off, green, orange and red.
- » A 4-bit actuator, used for step-motors only, can be set in more positions. Such actuator makes use of two actuator outputs. LEDs of both outputs (in total 4) are clickable.
- » For some actuators it is also possible to set the output power of the connected actuator e.g. to adjust the speed of a motor or the brightness of a lamp. Click arrows at the right side of the actuator icon to increase or decrease the power. The height of the red bar indicates the level of the output.



To manually control built-in actuator e.g. WiLab

- » Click an actuator icon to turn it on or off.
- » Click arrows at the right side of the actuator icon to change its tone (buzzer) or brightness (LED).


How to run a program

Once your program has been written it can be executed. During program execution the computer carries out all instructions of the program. This can be done slowly line-by-line in the Monitor mode or fast.

To execute a program in the Monitor mode

- » Check the **Monitor** option in the Tool menu of the Programming window (default this option is on).
- » Click the Activity Toolbar button **Start**  to start program execution. The Monitor window opens.
- » To carefully monitor what the commands of the program are doing you can use the button **1**, each time you click this button a single line of the program is executed.
- » Click the Monitor button **Start** to run a program line-by-line.
- » Adjust the execution speed with the slider (this also can be done during program execution).
- » Click the Activity Toolbar button **Stop**  or keep **<Esc>** pressed to interrupt program execution.

To execute a program fast

- » Uncheck the **Monitor** option in the Tool menu of the Programming window (default this option is on).
- » Click the Activity Toolbar button **Start**  to start program execution.
- » The program is executed in the background and the Programming window is not visible. This is a lot faster than execution in the Monitor mode.

» Click the button **Stop**  or keep **<Esc>** pressed to interrupt program execution.

Creating Programs

A program in Coach can be created in various ways. In general three ways are possible:

- » with programming buttons;
- » by selecting commands from the command list. This can be a pre-defined command list (made specifically for a certain control model), called a Micro-world, or via the full Coach Language command list with all possible commands for the used interface. In more advanced user modes, the command list can be extended with own commands made by the user.
- » by freely typing Coach Language commands in the Editor area.


The topics in this chapter will help you to create and work with programs.

Creating a Program via Programming Buttons

Programming buttons are buttons with pre-defined actions. The button's action is explained in a yellow tool tip, which appears when pointing the mouse cursor over the button. Often also the picture on the button gives an idea about its action.

With the programming buttons a model connected to an interface can be manually controlled. By clicking the buttons, certain actions are performed (e.g. a motor turns the given number of steps to the right) and Coach writes a program in the background. This program can be visible in the Program Editor area but it does not have to. After pressing the Start button the recorded program is executed, Coach repeats the recorded actions.

To create a program using the programming buttons

- » Use the programming buttons in the Program window to perform control actions.
 - » Some buttons require only a simple mouse-click, like **Stop** or **Lamp_On**.
 - » Other buttons, like **Wait** or **Turn-left**, must be pressed for a while, because the computer needs to measure also how long the button was pressed.
- » When you are ready, click the Activity Toolbar button **Start**  and the computer will repeat your recorded actions (will execute your recorded program).
- » If you are not satisfied with the result, you can erase it (even when the program itself is not visible) by right-clicking the Program window and selecting **Erase Program** from the menu.

Creating a Program via Commands

The command list contains a series of programming commands. It can contain only a few pre-defined commands (micro-world) tuned to a particular control model or a complete list with Coach Language commands. Programming via commands helps to write correct programs (according to the syntax of Coach-Language).

To create a program using the commands

- » Click a command in the list to place it in your program.
- » If a new list appears the command is not yet completed:
 - » Select a following command e.g. an output name.
 - » Repeat this step until the command is completed.
 - » Click **-BACK-**, or press **<Esc>** in the command list if you want to return to the previous step (without making a selection).
 - » Some lists may be used to enter several items (e.g. several outputs). These lists have a command **Ready**. Click **Ready** when you are finished selecting from this list.

- » If a number entry box appears the command needs a value:
 - » Type the value (e.g. a number of seconds) and press **<Enter>**.
 - » If you want to return to the previous step, first press **<Esc>**, and then click **-BACK**, or press **<Esc>** once more.
- » The command is placed in the program. Coach indents the commands automatically according to general program conventions. If the indentation is lost due to program editing, click a program line, and press **<Tab>** or **<Shift>+<Tab>** to restore the right indentation yourself.

Managing Own Commands

Users can create their own commands and add them to the command list. These commands are created from the commands available in the command list (including other own commands) and are indicated with a blue color.

To create an own command

1. To insert your own command at a specific position in the command list:
 - » Right-click the command in the command list and select **Insert (before)** or **Insert (after)**.
 - » In the **Add New Command to the Command List** dialog, select **New Command**.
 - » Type the name of the new command, follow the rules of Coach Language and do not use spaces or reserved characters and words.
2. To create your own command and insert it at the end of the command list:
 - » Right-click the Program window and select **Own Commands**.
 - » In the Own Commands window click the **New Command** button.
 - » Enter a name of the new command and click **OK**. Follow the rules of Coach Language and do not use spaces or reserved characters and words.

The own-command editor opens. It has a grey background to indicate that you are creating/editing an own command. The commands appear in red.

- » Create your own command by selecting commands from the list.
- » When you are ready, right click in the program area.
- » Select **Back to Program** to return to your program. The created own command appears in blue in the command list.

To edit an own command

- » Right-click the own command in the command list and select **Edit Own Command**.

Or:

- » Right-click the Program window and select **Own Commands**.
- » Select a command from the list and click **Edit**.
- » Modify the commands. Use the same procedure as editing a program.
- » When you are ready, right-click the program area and select **Back to Program**.

To delete an own command

- » Right-click the own command in the command list and select **Delete Own Command**.

Or:

- » Right-click the Program window and select **Own Commands**.
- » Select a command from the list and click **Delete**.

It is not possible to delete an own command while it is used in the main program. First clear the lines in where the own command appears (by selecting the line and pressing ****) or erase the main program.

To rename an own command

- » Right-click the own command in the command list and select **Rename Own Command**.
- » Type the new name and press **OK**. Follow the rules of Coach Language and do not use spaces or reserved characters and words.

Or:

- » Right-click the Program window and select **Own Commands**.
- » Select a command from the list and click **Rename**.

To print an own command

- » Right-click the Program window and select **Own Commands**.
- » Select the command and click **Edit**.
- » Again right-click the Program window and select **Print Own Command**.

To insert an own command in the command list

An own command can appear more than once in the command list.

1. In case of an existing command:
 - » Right-click the command list and select **Insert (before)** or **Insert (after)**.
 - » Check **Command Exists Already** and select an own command from the drop-down list.
2. In case of a new own command:
 - » Right-click the command list and select **Insert (before)** or **Insert (after)**.
 - » Check **New Command** and enter the name.
 - » Create your own command by selecting commands from the list.
 - » When you are ready, right-click in the editor and select **Back to Program**.

Advanced Programming

Experienced users can program freely by choosing commands from the complete command list of Coach Language or by typing commands directly in the program editor (Senior-students only). In the last case, Coach does not guide you any longer in writing commands correctly (according to the syntax of Coach-Language), until the program is executed. When failing to compile the program Coach will show an error message and place the cursor at the point where the error is.

Working with Programs

In Junior student user modes, editing a program can be done only by whole lines at once. In Senior student mode, it is also possible to type commands directly in the program editor. The user level set for the Activity is displayed at the left side of the status bar.

To insert an empty line

- » Click the line above which you need an empty line and press **<Ins>**. An empty line will be inserted. You can select a new command.

To replace a line

- » Click the line and press **<Enter>**. The command on the line is removed.
- » Select a new command.

To delete a selection

- » Make a selection (in some user modes whole lines only) and press ****.

To move a selection of program lines

- » Make a selection (in some user modes whole lines only).
- » Right-click the selection and select **Text Edit > Cut** (or press **<Ctrl>+<X>**).
- » Right-click the line above which you want to paste the cut lines and select **Text Edit > Paste** (or press **<Ctrl>+<V>**).

To copy a selection of program lines

- » Make a selection (in some user modes whole lines only).
- » Right-click the selection and select **Text Edit > Copy** (or press **<Ctrl>+<C>**).
- » Right-click the line above which you want to paste the copied lines and select **Text Edit > Paste** (or press **<Ctrl>+<V>**).

To copy the whole program to the clipboard

- » Right-click the program and select **Clipboard Copy**.
- » Use the **Paste** command in another Windows application to paste the text of the program.

To insert an empty line

- » Click the line above which you need an empty line and press **<Ins>**. An empty line will be inserted. You can select a new command.

To erase the whole program

- » Right-click the program and select **Erase Program**.

To import a program from another Coach Activity/Result

- » Right-click in the editor area of the Program window and select **Import program**.
- » The new program and its command list overwrite the current program and its command list. Save your work before importing a program in this way, or your work will be lost.

To print a program

- » Right-click the editor area of the Program window.
- » Select **Print Program**.

CHAPTER 4

Data Video

Data-Video Activities are used to collect data from digital videos and can be used for analyzing motion of real objects. Such activities bring real-life events into the classroom.

During measurements on a video the position and time data are collected in the selected video frames manually by clicking or automatically by tracking a moving object, e.g. a ball or a head. The video points measured this way can serve to calculate the locations of other points on the video screen e.g. the center of mass of a body.

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The Basics

The topics in this chapter will help you to get familiar with the Data-Video window.

Data-Video Window

The Data-Video window is the place for video measurements and is present in the Data-Video type of Activities. The Data-Video window has its own Toolbar and Tool Menu. The video is displayed in the middle and the video control bar at the bottom of the Data-Video window.

To display/hide the Data-Video window

- » Click the Activity Toolbar button **Data Video**  to display the Data-Video window.
- » Click the button **Data Video**  to hide the Data-Video window.

The Data-Video window remains empty until a Video is opened.

- » To open a video click the Toolbar button **Open Video** . Select a Video from the list of Videos present in the Activity or add a new Video.

Data-Video Toolbar

The Toolbar of the Data-Video window has the following buttons when there is no video opened:



Open Video – to open a Video



Capture - to open Capturing Video window to capture a video.

After opening a video additional buttons appear:



Zoom - to zoom in and out a video, the **Auto Fit** option fits the video to the Data-Video Window window size (default setting).



Scaling – to show and hide scale and coordinate system and to specify the real world scale and the coordinate system position.



Magnifier – to activate and deactivate a magnifier which magnifies a space around a cursor for more accurate point selection during manual measurements. This button becomes active after the measurement has been started. A magnification factor can be selected after clicking the arrow next to the button.



Point tracking – to turn on and off the point tracking. The tracking settings can be defined directly on video (limited) or via the menu of the button.



Perspective correction – to display and hide the perspective correction rectangle and apply perspective correction.



Co-ordinate system – to display and hide the coordinate system.



Trace – to display or hide markers of collected video points.



Measure – to measure distances by using the ruler or angles by using the protractor.



Annotation – to add an annotation on video frame(s).

Data-Video Control Bar

The Data-Video Control Bar is located at the bottom of the Data-Video window and offers Playback controls and Frames controls.

Playback controls

Playback controls allow you to control a video file



From left to right:

00.00.00.00 – time information

1 - a number of the current selected frame



Go to the **first frame** of a video



Go to the **previous frame** of a video



Play a video - on slower computers "large" videos may play slower than in real time. On faster computers videos should play correctly provided no perspective correction is used.



Pause a video



Go to the **next frame** of a video.



Go to the **last frame** of a video.



Playing speed – to adjust the speed of playing video. 1000% means that the video will be played 10 times faster than the default (100%) setting.

Frame controller

Frame controller allows you to see singles frames and to select and deselect frames for measurement.



From left to right:



Zoom – allows zooming the frame display to distinguish individual frame bars for easier selection. This could be useful for long videos. By default the zoom is set to 100%, which fits all frame indicators in the given space.

Frames display - frames are indicated as small vertical bars. Selected for measurement frames have black bars and non-selected grey bars. Use the green **Start** marker and the red **End** marker to set the start and end of the video. The orange marker indicates the currently displayed video frame.

< 1 > to select equidistant frames, for 1 all frames are selected, for 2 every 2nd frame is selected, etc. The display becomes red when this equidistant selection is not valid anymore for example by selecting additional frame with **Select/Unselect** button.



Select/Unselect - to select and unselect individual frames . This could be useful if you want collect some additional points in a part of the video.

Data-Video Tool Menu

The Data-Video Tool menu is available after clicking the Tool menu button in the Data-Video window (only when the Data-Video window is docked) or by right clicking the Data-Video window.

Edit Title – to rename the video

Adjust – to adjust the brightness, the contrast and to rotate the video

Export Video – to export the video

Dock/Undock – to dock/undock the Data-Video window

Print – to print the content of the Data-Video window

Clipboard Copy – to copy the content of the Data-Video window into the Clipboard

Copy a Frame – to copy the current video frame

Help – to consult the Help system

When Point Tracking active:

Go to Tracking Frame – to jump to the frame where the tracking marker is displayed

Point Tracking Settings – to specify tracking settings

Perspective correction - to apply perspective correction.

When Perspective correction is active:

Reset Perspective – to reset perspective correction.

Video Resources

Many videos can be found on Internet, students and teachers can capture their own videos


Data-Video Measurement

In video measurements position and time data are collected in the selected video frames manually, by clicking on an object, or automatically, by tracking a moving object.

After the video measurement is finished, there are a number of possibilities to modify the video points.





How to open a Data-Video Activity


You can open a Data Video Activity in Coach in the following ways:

- » **Quick Start:** click the  **Data Video** button in Dashboard and select **Video Analysis**.
- » Open an example of a Data-Video Activity located in the **CMA Projects** in the **Data Video** folder.
- » Open a Data-Video Activity prepared by your Teacher. How to open a Data-Video Activity
- » You can open a Data Video Activity in Coach in the following ways:

How to do manual video-measurement (by clicking)

To perform video-measurement manually





- » Open a Data-Video Activity.
- » Prepare the video for measurement.
- » Start the measurement by clicking the Activity Toolbar button **Start** .
- » Coach will automatically bring the first selected video frame on the screen.
- » Press **Magnifier**  if you want to magnify area around the cursor. Select the magnification factor (by default x2).
- » Move the cursor over the video screen (the cursor changes its shape to a cross or magnifies a small area when the Magnifier is selected) to locate the video point, for example a ball or the head of a runner.
- » Click to store the first video point. Depending on the settings, three things can happen:
 1. If the video advances to the next frame, click the next point of the object. (In this case you only measure the position of one object per frame).
 2. If the first video point was set up to be the origin of the measurements for this frame, then a coordinate system appears with its origin at the clicked point. Next click the video point(s) to determine the position(s) of another object(s).
 3. If nothing happens you have to click another video point. Repeat this step until the video advances to the next frame. In this case you measure more than one video point per frame.
- » The data will be added in the Data Table and, if predefined, in graphs.
- » Repeat the procedure for each frame until you reach the last selected frame of the video or press the Activity Toolbar button Stop to interrupt the measurement.
- » Press the Toolbar button **Trace**  to display markers of measured points
- » Press the Toolbar button **Measure**  to measure distances or angles on the video.
- » Once you have collected data from the video you can still add, move or delete points to the measurement run you have made.
- » The collected data can be used for further analysis and processing.



- » When scanning the last measurement run in the graph, Coach shows the corresponding frames with video point(s) (also calculated point(s)) on the video screen. Such synchronization works only for the last run and not for previously made measurement runs. Such run is indicated in the Data Table by the small video icon.
- » You can replay the last video measurement run; video measurement will be shown in the Data-Video window while the graphs with data evolve. Click the Activity Toolbar button **Replay**  to replay the video measurement.
- » Notice that when you start the measurement again the following can happen:
 - » **if your previous video measurement was not completed**, e.g. you interrupted your measurement and did not collect all video points, or after the measurement was finished you have selected additional frames for measurement, then Coach continues the previous measurement and adds additional data to the existing run;
 - » **if your previous video measurement was completed**, then Coach asks to add a new run, and after confirming a new measurement run will be started.

How to do automatic video-measurement (by Point Tracking)

To avoid time-consuming, monotonous manual clicking the possibility to automatically track a moving object is given. By checking the option **Point Tracking** the measurement is automatically performed by Coach based on the given tracking settings.

To perform video-measurement automatically

- » Open a Data-Video Activity.
- » Prepare the video for measurement.
- » Press the Data-Video Toolbar button **Point Tracking** .
- » Start the measurement by clicking the Activity Toolbar button **Start** .
- » Coach automatically brings the first selected video frame on the screen. This frame is called the tracking frame because it is the only frame on which the tracking area (a viewfinder) and the search area (a rectangle of user-specified dimensions) are displayed.
The option **Go to Tracking Frame** in the Tool menu can also be used to jump directly to the tracking frame.
- » If needed adapt the tracking area and the search area. You can do it directly on the video screen by resizing a rectangle (search area) and a circle (tracking area) or via the option .Point Tracking Settings.
- » Move the tracking area – viewfinder over the object you want to follow, e.g. a marker or an eye-catching point such as a white ball. If there are more points to be measured per frame (or there is a moving coordinate system) then there are separate tracking and search areas for each of these points.
For Coach to be able to follow a video point – object it is important that this object stands out against the background of the video for all frames on which you want to measure.
- » Start the measurement by clicking the Activity Toolbar button **Start** .
- » The measurement is performed automatically through the selected frames according to the given settings. When using point tracking it is the best to select all frames for measurement.
- » The data will be added automatically into the Data Table and, if predefined, in graphs.
- » After the measurement is finished the tracking areas are displayed on all measured frames. Turn point tracking off by deselecting the option **Point Tracking**.
- » Press the Toolbar button **Trace**  to display markers of measured points.

- » Press the Toolbar button **Measure**  to measure distances or angles on the video.
- » When point tracking fails, you can repeat your measurement only in a selection of frames where tracking was not correct. First select the frames on which the tracking failed and remove data associated with these frames by using the **<Backspace>**-key (Windows) or **<Delete>**-key (Mac). Now the first selected frame without data is chosen as the new tracking frame. Relocate the tracking area or even change its settings and/or the dimensions of the search area. Start the measurement again to continue point tracking from this frame on using the new settings and measure all selected frames without data. It is also possible to measure the remaining frames manually.
- » Once you have collected data from the video you can still add, move or delete points to the measurement run you have made.
- » The collected data can be used for further analysis and processing.
- » When scanning the last measurement run in the graph, Coach shows the corresponding frames with video point(s) (also calculated point(s)) on the video screen. Note that this link works only for the last run and not for previous made measurement runs.
- » You can replay the last video measurement run; video measurement will be shown in the Data-Video window while the graphs with data evolve. Click the Activity Toolbar button **Replay**  to replay the video measurement.
- » Notice that when you start the measurement again the following can happen:
 - » **if your previous video measurement was not completed**, e.g. you interrupted your measurement and did not collect all video points, or after the measurement was finished you have selected additional frames for measurement, then Coach continues the previous measurement and adds additional data to the existing run;
 - » **if your previous video measurement was completed**, then Coach asks to add a new run, and after confirming a new measurement run will be started.


Tracking Settings

The tracking settings define the search area and the tracking area for each video point. When point tracking is turned on, the search and tracking areas are displayed by default on the first selected frame (called Tracking frame) and are not displayed on other frames.

To define tracking settings

- » On the Tracking frame drag the handles of the circle (Tracking area) and the rectangle (Search area) directly on video screen.

or

- » Press the Data-Video Toolbar button **Point Tracking** . Click the arrow next to the Point Tracking button and select the option **Point Tracking Settings**. Define the Search area by specifying its **Height, Width** and **Color**. You should limit the Search area in order to reduce computing time or to avoid ambiguity. The color is used for the search area rectangle.
- » Define the Tracking area for each video point by specifying its **Name, Radius** and **Color**. The tracking area is bounded by a circle with a given radius. The color is used for the track area circle.

Note: The Tracking area cannot be larger than Search area.

Advantages and Disadvantages of Point Tracking

Point tracking has a lot of advantages compared to manual video measurement. The main advantages of point tracking are:

- » When a manual video measurement takes more than 100 mouse-clicks it becomes too much work of monotonous and RSI-risky nature.
- » Collection of data is done in a much shorter time than ever could be achieved by manual recording of data.
- » Point tracking is an objective way of data collection. The accuracy of measurements is the same for each frame of the video

But it does not mean point tracking is not free of problems. Videos must match the following requirements for successful point tracking:

- » Tracked objects may not change much in size, shape, and color.
- » Markers are preferably of circular shape (so rotating objects can be tracked) and they should have a color distinct from the background scene in the search area, in order to minimize errors in tracking.

Tracked points must stay within the search area as much as possible. If a tracked point temporarily disappears within the search area and later reappears again, there is no guarantee that the point is always automatically found again. In this case the user must reinitialize the point tracking and continue from the frame where the point reappears in the video or start over again with a larger search area.

How to modify the collected video points

After the video is finished, there is a number of possibilities to modify the video points.


» **Moving Video Points**

If you are not satisfied with your marked point you can come back to a frame and move the point to another location. After each adjustment, the data in the Data Table or in Graphs are automatically updated.

» **To move a measured point**

- » Select the point via the **Scan** option in the graph or click the frame on the frame controller in which the measured point must be corrected.
- » Drag the point to the desired location.

» **To move the co-ordinate system**


- » Click the button **Scaling** .
- » **If Origin = Same at all frames**
 - » Drag the origin to the desired new position.
- » **If Origin = First point clicked at each frame**
 - » Select the frame where you want to update the chosen origin.
 - » Drag the origin to the desired new position.
 - » If necessary, repeat the procedure for the origin of other frames.
- » Click **OK**.

» **Deleting Video Points**

If you are not satisfied with your marked point you can come back to a frame and delete the point.

» **To delete a measured point**


- » Select the point via the **Scan** option in the graph or click a frame on the frame controller in which the measured point must be deleted.

- » Use  to deselect a frame and delete a point. The deselected frame becomes grey in the frame controller.
- » When the Tracking frame is deselected then the tracking areas will be moved to the new tracking frame (next first selected frame without data).


» **Adding Video Points**

You can also add extra points after your measurement is finished.


» **To add extra video point(s)**

- » Click an additional frame on the frame controller and manually select this frame by using the button . The selected frame becomes black.

For manual measurement:

- » Click the Activity Toolbar button **Start** .
- » The first selected extra frame automatically appears on the screen.
- » Locate a new video point.
- » Repeat this for all extra selected frames.

For point tracking:

- » The first selected extra frame becomes the Tracking frame.
- » Relocate the tracking area, which appears again on this frame.
- » Click the Activity Toolbar button **Start** .
- » The measurement is automatically performed for all added frames only.

Preparing a Video for Measurement

Before you can analyze your own video or image, you must open it and prepare it for measurements. The steps are as follows:


- » opening a video
- » capturing your own video
- » editing a video [optional]
- » scaling a video
- » adapting video measurement settings
- » selecting standard video graphs.

After you have made these steps you are ready to start your measurement. In this chapter all the steps are described in details.

Opening Video

Suitable videos for measurement can be found on the Internet or can be recorded by students and authors.

To open a video

- » Press the Data-Video Toolbar button **Open Video**  .
- » Select a video from the list.
If the list is empty or if the desired video is not in the list, add a video to the list by clicking **Add video**.
The selected video will be added to the list of videos available in the Activity.
- » Click **OK**.
- » The first video frame appears in the Data-Video window. Notice that all frames in the frame controller are selected by default (i.e. all frames are black).

Video formats accepted by Coach

Coach accepts the following video formats:

- » *.AVI – Audio Video Interleaved, the most common digital format for Windows.
- » *.MOV – QuickTime format, standard for Macintosh computers .
- » *.MPEG
- » *.MP4
- » *.WMV
- » *.3GP
- » *.ASF
- » *.M4V

Videos in other formats should first be converted to formats accepted by Coach.







Capturing Video

Good to know before you start video capture

- » Video capture is one of the most system-intensive tasks you can demand of a personal computer. Good results depend on the performance and capacity of all components of your system that have to transport frames from a video-capture device to the processor and hard disk. Frames will be dropped from the captured clip if one of these components cannot handle the workload.

- » Make sure your system is optimized by reviewing and following the guidelines set by the manufacturers of your video-capture device and hard drive.
- » To capture your own video materials you need a digital camera (a digital video camera, a digital photo camera or a web cam). Before you start to use the camera in Coach test it first with the software and the instructions that came with the camera to make sure the connection is working and you can pre-view/capture video using the provided with your camera software. If that software does not work, capturing in Coach will not work, either.


To capture a video

- » Video capture is possible both in the Data-Video window and in the Video pane but not in both windows at the same time.
- » Before you start capture in Coach your camera should be plugged in and turned on. When Coach does not “see” the connected camera then the Capture option is not available (remains gray).
- » To open the Capturing-Video window press the Toolbar button Capture  or select **Open Video**  and select a video capture device from the list.
- » The Capturing-Video window includes: Toolbar, the live camera image or the playback video, video controls, time and frame rate info.
- » To configure the way Coach will capture, use the Toolbar button **Capture Settings** .
- » Use the **Record**  button to start recording a video. The capture will stop automatically when the maximal time has elapsed. Alternatively, you can click the **Stop**  button or press the **<Esc>** - key to terminate capturing before the time expires.
- » After a video has been recorded it can be viewed directly in the Playback mode.
- » The recorded video file is a temporary file (with default name REC#) and is replaced by a new file each time a new recording is started. To use the recorded video in Coach select use the Toolbar **Use Recorded Video**  button.
- » The recorded video will be transferred to the Data-Video window/Video pane and will be added to the list of videos available in the Activity/Result.
- » The recorded video(s) will be embedded in the Activity/Result file after it will be saved.

Capture Settings

The way Coach will capture is done via capture settings.

To define capture settings

- » Click the Data-Video Toolbar button **Capture Settings** .
- » Define the following settings in the Capture Settings dialog:

Video source

This option specify the video source used for capturing.

Video codec

This option specifies the video codec (**C**ompressor/**D**ecompressor) used for a recorded video. Coach displays the list of Video codecs installed on your computer.

Resolution

This option specifies the height and width of the video, in pixels. A larger frame size lets you see more detail but requires (far) more processing. The lowest frame size that is acceptable in most situations is 240x180 pixels (for Coach the best size is 320x240 pixels).

Frame rate

This option allows setting the frame rate of the captured video. Coach will try to record with the given frame rate but at the moment your computer and/or your capture device will not be able to deliver the set frame rate, the rate will be lowered to avoid dropping frames. The time of recorded frames will be adjusted respectively.

Frame rate follows measurement

This option is present for video capture synchronized with measurement when the measurement frequency is 1 per second or lower. Then the frame rate of the captured video is the same as the measurement frequency.

Max. time

This option specifies the maximal time of capturing. The capture will stop when the time has elapsed. Alternatively, you can click the **Stop** button or use **<Esc>** - key to terminate capture before that time expires.


Preview during capture

By checking this option you can turn on/off the preview area, which shows the live camera image.

Scaling Video

Scaling is used to specify which distance on the video corresponds to a known real-world distance. This allows you to convert the coordinates of collected video points from screen pixels into real distance values e.g. in meters. It is also used to set the origin of the co-ordinate system.

To scale a video

- » Click the Data-Video Toolbar button **Scaling** .
- » The **Scaling Settings** dialog appears on the screen and the scale-ruler and the coordinate system appear on the video. If different scales in the horizontal and vertical direction are chosen then two scale-rulers, a horizontal ruler and a vertical ruler, appear.
- » Drag the end points of each scale-ruler to match a known distance on the video screen. Often in videos created for measurement purposes a known length can be found in one of the first video frames.
- » In the dialog box, type in the corresponding "real" length(s) of the ruler(s) (default 1 m).
- » In the majority of videos you can use the default setting **Same scale in all directions** which assumes the same scale is applicable in x and y directions. Select **Different scale in horizontal and vertical direction** if the scale is different in x and y directions.
- » If desired, move the co-ordinate system by dragging its origin (circle). You can also rotate the co-ordinate system by dragging the yellow dot next to the origin.
- » Define the origin of the co-ordinate system:
 - » Select **Same at all frames** if the camera did not move during the recording of the video (i.e. a fixed co-ordinate system is assumed),
or
 - » Select **First point clicked at each frame** if the camera moved during the recording of a video or if you want to measure according to a moving center of mass (moving co-ordinate system). In this case, the first point clicked on each frame defines the origin of the co-ordinate system. This option is not available for a single image

- » Define x-axis direction. Select **From left to right** if the horizontal axis direction is from left to right, or select **From right to left** if the horizontal axis direction is from right to left.
- » Define y-axis direction. Select **From bottom to top** if the vertical axis direction is from bottom to top, or select **From top to bottom** if the vertical axis direction is from top to bottom.
- » Specify the colors of the co-ordinate system, the ruler(s) and the protractor.
- » Click **OK** to close the Scaling mode.

You can change the scaling settings at any time, even after the measurement is finished.

Video Measurement Settings

The **Settings** dialog in the Data-Video Activity consists of all settings needed to set up the video measurement.

- » Click the Activity Toolbar button **Settings** .

The dialog has three tabs:

Tab Points

Here you can define video points collected on each selected video frame during video measurement.

- » Enter the **Number of measured points per frame** (max. 8 points per frame).
- » From a set of measured video points another point can be calculated, for example the center-of-mass location. Such a calculated point can be displayed directly in the video screen during a measurement.
 - » If needed enter the **Number of calculated points per frame**.
 - » When the chosen number is higher than 0 the **Calculated points** section appears in the dialog.
 - » Select formulas to calculate X and Y co-ordinates of calculated point(s). By default the Data range connections are **Empty**.
 - » Formulas appear in the drop-down lists only if these formulas have been defined as variables in the data table.
 - » If there are no formulas available in the drop-down lists of the X and Y co-ordinates of calculated points, you first have to define these in the data-table, then select the option **Video Points** once more and select the formulas from the drop-down lists.
- » Specify **Names**, **Markers** and **Colors** of measured and calculated video points. Every point has its own name, marker and color. If you do not want to display a video point in the video screen, hide it by checking its Hidden option

Tab Time

Here you can specify how fast the video was taken.

- » Specify video timing, there are three ways to do this:
 1. By specifying the frame rate – number of frames per time unit. Usually the video frame rate (the number of frames per second) is included in the video and you can rely on the default value specified in the box. If this information is lacking or appears to be incorrect, specify the video-recording speed.
 2. By specifying the time between frames.
 3. By specifying the absolute time – the time associated with every frame (for example 0.03; 0.06; 0.09; 0.15; 0.20; 0.22; 0.24, 0.28, 0.31; 0.35 or when the time intervals between frames are equal 01-10\$0.0333).

- » Specify a zero point setting for time. Select one of the methods:
 - » use time from video,
 - » $t = 0$ at frame # - enter a valid frame number,
 - » $t = 0$ at first selected frame,
 - » $t = \#$ at first frame - enter time associated with the first frame; select a time unit from the drop-down list.

Tab Frames

Here you can make a selection of frames on which you want to perform the measurement. By default all frames are selected. This is a convenient setting for a measurement via point tracking.

- » The total number of frames available in the video is displayed in the upper part of the dialog.
- » Make a frame selection. Use one of the methods:

From

Type in the first and the last frame number of the frame range; type in the step size. For example **From 10 to 30 step size 3** - selects every 3rd frame in the frame range between 10 and 30.

Individual frames

Type in the list of frames you want to select, for example:

- 10-20: selects frames from 10 to 20
- 1,5,10: selects frames 1, 5 and 10
- 10-20\$2: selects every 2nd frame between 10 and 20.


You can also select frames via button in the frame controller .

Video Variables in the Data-Table and Graphs

Each video point is described by four variables: its horizontal P_x and vertical P_y Cartesian co-ordinates, and its angle P_{angle} and distance P_{dist} polar co-ordinates and rotation angle P_{rot} (for rotating movements via continue angle measurements for angles larger then 360 degrees).

Note that the unit with which angles are measured can be radians or degrees, depending on the pre-defined settings in the Activity Options. All four variables are added to the Data Table when a point is selected for measurement (one point is always selected). By default variables P_x and P_y are visible, and P_{angle} , P_{dist} and P_{rot} are hidden in the Data Table. The standard graphs of these variables are created automatically by Coach. For video measurement this is the P_x and P_y (per the selected video point) versus time plots.

To select a standard Video Graph:

- » Click the Activity Toolbar button **Graph** . The list of graphs appears under the button.
- » Select a standard graph, the icon changes into the Graph icon. Move the Graph icon above a desired pane and click the pane.
- » If you want to display data differently then you can edit the video graph or create new graphs. The graphs can be setup prior to starting a video measurement or after it. The advantage of preparing the graphs before is that the data are displayed during measurement.

Scanning

In Data Video Activities graphs are synchronized with the video points. When scanning in the graph, Coach shows the corresponding video points (also calculated points) on the video screen. This allows to connect the real situation with its abstract graphical representations. Note that if there are more measurements runs this is valid only for one for the latest run.

When the Origin is chosen as the **First point clicked at each frame** (in the Co-ordinate settings dialog), then the first point clicked in each selected frame defines the origin of the co-ordinate system and is not displayed.

Editing Video


Coach provides limited possibilities for editing videos. Editing options include:

- » removing the begin/end part of the video
- » adjusting brightness, contrast, rotating and flipping
- » placing annotations
- » correcting perspective distortion

In case you save the Activity after editing then the options are saved in the Activity. It is also possible to export video or image included in the Coach Activity. All these topics are described in this chapter.

Removing The Begin/End Part of a Video

To remove several frames from the beginning and/or end of a movie the green and red markers must be used.

- » Slide the left green Begin and the right red End markers, located on the frame display, to the desired begin and end of the video. All frames outside the blue triangles will be automatically deselected.
- » The edited video can be previewed by clicking the **Play** button .

Adjusting Video/Image

To adjust a video/image use the Tool menu option **Adjust**. In the Adjust dialog:


- » Use the **Brightness** slider change the brightness of a video/image.
- » Use the **Contrast** change the contrast of a video/image.
- » Use the **Rotate** slider to rotate a video/image. This slider has three kinds of adjustments:
 1. Raw - drag the thumb of the slider to rotate the image as needed. This can be done quickly but not very precisely.
 2. Fine - click on the arrows at the ends of the slider. This will advance the slider by 5 degrees.
 3. Very fine - click on the slider outside the thumb but not on the arrow buttons. This will advance the slider by 5 degrees. Hold down the mouse to achieve continuous rotation by 0.5 degree.
- » Mark the **Flip horizontally** option to flip a video/image horizontally.
- » Mark the **Flip vertically** option to flip a video/image vertically.
- » Use the **Reset** button to reset all settings to original settings.

All the video adjustments are applied in real-time on the video file, without writing a new file. These adjustments are stored in the Coach Activity.

Annotating Video/Image

To place text labels on frame(s) of a video or on an image use the option **Annotation**.

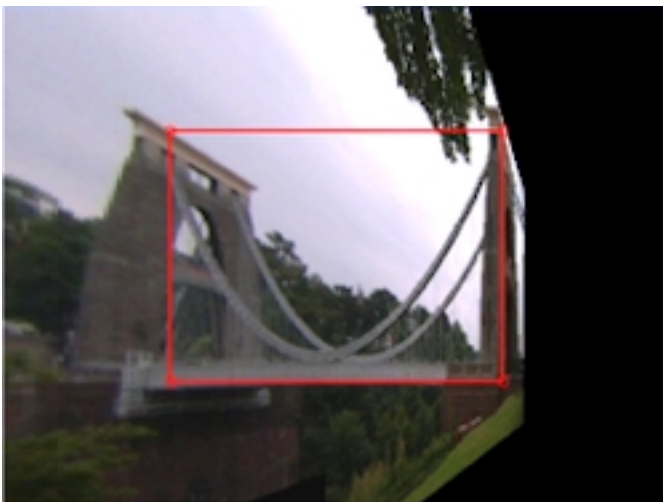
To add an annotation

- » Click the Toolbar button **Annotation** .
- » Type in the text.
- » If desired change the font and its color.
- » Check **Framed** to place the annotation in a frame.


- » [only for videos] Check **Show on all frames** to place the annotation in all video frames. When this option is not checked the annotation appears only in the current frame.
- » Click **OK**.
- » Drag the annotation to the desired position. You can also change its size.
- » If needed, repeat this procedure to create more annotations.
- » To edit or delete an annotation right-click an annotation and select **Edit** or **Delete**.

Correcting Perspective Distortion

The perspective distortion of a plane can be corrected in Coach by using the option **Perspective Correction**. As an example the shape of the Golden Suspension Bridge is used. In reality, the piers of the bridge are parallel to each other; but this is not the case in the photograph of the bridge. The image transformation that restores this property is determined by mapping 4 points – in this case the 2 bottom and 2 top points of the piers with a projective transformation to the corners of a rectangle in a new image. The plane formed by the piers and the left side of the road is rectified to a fronto-parallel view. Then the bridge cable is almost in this plane and a more realistic measurement can be done.



To perform a perspective correction

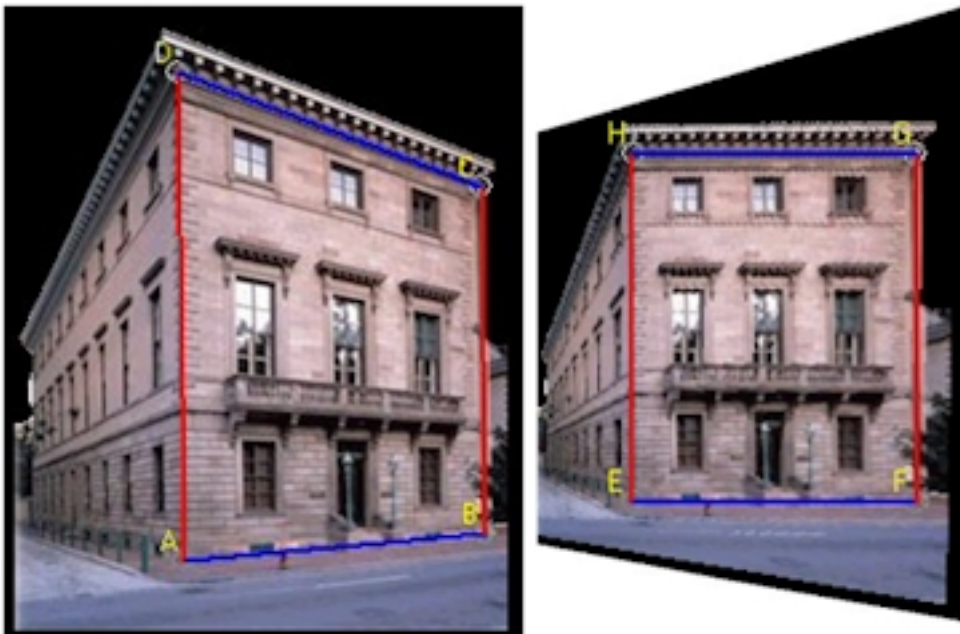
- » Click the Toolbar button **Perspective Correction** .
- » A red perspective rectangle appears on the video/image.

- » Map the four corners of the red perspective rectangle. Every time a corner of the perspective rectangle is moved the video screen/image is distorted. After mapping all four points the distorted figure is transformed into the corrected rectangle.
 - » To move perspective points: place the cursor over a point (the cursor changes into a closed hand) and drag the point to a desired location.
 - » To move the perspective rectangle (translate the "view"): place the cursor inside the perspective rectangle (the cursor changes into an open hand) and drag the rectangle to a desired location.
 - » Turn the option **Perspectieve correction** off - click . The red rectangle disappears but the video/image remains transformed.
 - » Use **<Ctrl>+<Z>** (Windows) or **<Cmd> + <Z>** (Mac) to undo your last step.
 - » Use the **Reset** option, to reset all changes and set the video/image to its original format.

Note: Applying perspective correction may slow down the video playing speed because the calculations are done in real-time.

What is perspective correction?

The left image shows a photograph of a building. The rectangular features of the building, such as the windows, do not appear as rectangles in the photograph, the photograph shows perspective distortion. The plane geometry has undergone a transformation that distorts Euclidean properties such as length, angles and parallelism. The right image shows the perspective corrected front of the building, where the plane geometry is that as it would be seen if the original photograph had been taken with the camera fronto-parallel to the wall.



Rectification of planes in digital images is part of the discipline that is known as computer vision. Projective geometry lays the mathematical foundation under this discipline. For example, the map between the world plane and the perspective image is a plane projective transformation (2D homography). Correcting perspective distortion is a matter of determining the eight degrees of freedom of the homography. The rectifying homography is computed from scene geometric information, specifically parallelism, angles between lines, and ratios of length along lines in different direction. A full description of the mathematics of image rectification of planes can be found in many textbooks on computer vision.

Exporting Video/Image

Videos and images are embedded and stored in the Coach Activity/Result. To be able to save a video/image file as a separate file on a disk the Export Video option should be used.

To export a video/image file

- » Right-click the Data-Video/Image window and select **Export video/image**.
- » The **Save as** dialog opens.
- » Type in a file name.

CHAPTER 5

Data Image

Data-Image Activities are used to collect data from digital images and can be used to analyze shapes of real objects. During measurements on an image the position data, or position and time data for a stroboscopic image, are collected.

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The Basics

The topics in this chapter will help you to get familiar with the Data-Image window.

Data Image

Data-Image Activities are used to collect data from digital images and can be used to analyze shapes of real objects. During measurements on an image the position data, or position and time data for a stroboscopic image, are collected.

Data-Image Toolbar

The Toolbar of the Data-Image window has the following buttons when there is no image opened:



Open Image – to open an Image

After opening an image additional buttons appear:



Zoom - to zoom in and out an image, the Auto Fit option fits the image to the Data-Image window size (default setting).



Scaling – to show and hide scale and coordinate system and to specify the real world scale and the coordinate system position.



Magnifier – to activate and deactivate a magnifier which magnifies a space around a cursor for more accurate point selection during measurements. This button becomes active after the measurement has been started. A magnification factor can be selected after clicking the arrow next to the button.



Perspective correction – to display and hide the perspective correction rectangle and apply perspective correction.



Co-ordinate system – to display and hide the coordinate system.



Measure – to measure distances by using the ruler or angles by using the protractor.



Annotation – to add an annotation on the image.

Data-Image Tool Menu

The Data-Image Tool menu is available after clicking the Tool menu button in the Data-Image window (only when the Data-Image is docked) or by right clicking the Data-Image window.

Edit Title – to rename the image

Adjust – to adjust the brightness, the contrast and to rotate the image

Export Video – to export the image

Dock/Undock – to dock/undock the Data-Image window

Print – to print the content of the Data-Image window

Clipboard Copy – to copy the content of the Data-Image window into the Clipboard

Help – to consult the Help system.


Data-Image Measurement

During measurements on an image, position data, or position and time data for stroboscopic images, are collected by clicking points of interest in an image.

After the image measurement is finished, there are a number of possibilities to modify the image points.

How to open a Data-Image Activity



You can open a Data-Image Activity in Coach in the following ways:

- » **Quick Start:** click the  **Data Image** button in Dashboard.
- » Open an example of a Data-Image Activity located in the **CMA Projects** in the **Data Image** folder.
- » Open a Data-Image Activity prepared by your Teacher.

How to do image measurement

During measurements on an image, position data, or position and time data for stroboscopic images, are collected by clicking points of interest in an image.

To perform image-measurement

- » Open a Data-Image Activity.
- » Prepare the image for measurement Prepare the image for measurement.
- » Start the measurement by clicking the Activity Toolbar button **Start** .
- » Press **Magnifier**  if you want to magnify area around the cursor. Select the magnification factor (by default x 2).
- » Move the cursor (it changes its shape to a cross) to locate the image point. Click to store the first image point.
- » Repeat for other image points.
- » The data will be displayed automatically in the Data Table and, if predefined in, graphs.
- » Once you have collected data from the image you can still add, move or delete points to the measurement run you have made.
- » The collected data can be used for further analysis and processing.
- » When scanning the last measurement run in the graph, Coach shows the corresponding point on the image screen. Note that this synchronization works only for the last measurement run and not for previously made runs.
- » Notice that when you start the measurement again the following can happen:
 - » **if your previous image measurement was not completed**, e.g. you interrupted your measurement and did not collect all image points, or after the measurement was finished you have selected additional points for measurement, then Coach continues the previous measurement and adds additional data to the existing run.
 - » **if your previous image measurement was completed**, then Coach asks to add a new run, when confirming with yes a new measurement run will be started.

How to modify the collected image points

After the image measurement is finished, there is a number of possibilities to modify the image points. After each adjustment, the data in the Data Table or in Graphs are automatically updated.


» Moving Image Points

If you are not satisfied with your marked point you can come back to an image point and move the point to another location.

» To move a measured point

- » Click the point which must be corrected. This point becomes the active point and changes its color.
- » Drag the point to the desired location.

» To move the co-ordinate system

- » Click the button **Scaling** .
- » Drag the origin to the desired new position.
- » Click **OK**.

» Deleting Image Points

If you are not satisfied with your marked point you can come back to an image point and delete the point.


» To delete a measured point

- » Click the point which must be deleted. This point becomes the active point and changes its color.
- » Use the **<Delete>**-key to remove the point.

» Adding Image Points

You can also add extra points after your measurement is finished.

» To add extra image point(s)

- » Insert an empty data row in the data table in the following way:
 - » Select the row, which you would like to add.
 - » Right-click in the Data Table window and select **Rows > Insert**.
 - » Fill the number of the first row and the last row to add. If the first and last row have the same number only one row with this number will be added. The other cells shift down.
 - » Click **OK**.
- » Click **Start** .
- » Locate a new image point.
- » Repeat this for all points you want to add. Rows will be filled in downward direction.

Preparing an Image for Measurement


Before you can analyze your own video or image, you must open it and prepare it for measurements. The steps are as follows:

- » opening an image
- » scaling an image
- » adapting the image measurement settings
- » selecting standard video graphs.

After you have made these steps you are ready to start your measurement. In this chapter all the steps are described in details.

Opening Image


To open an image

- » Click the Data-Image Toolbar button **Open Image** .
- » Select an image from the list.
- » If the list is empty or if the desired image is not in the list, add an image to the list by clicking the **Add** button.
- » The selected image will be added to the list of videos available in the Activity.
- » Click **OK**.
- » The image appears in the Data-Image window.

Scaling Image

Scaling is used to specify which distance on the image corresponds to a known real-world distance. This allows you to convert the coordinates of collected image points from screen pixels into real distance values e.g. in meters. It is also used to set the origin of the co-ordinate system.

To scale an image

- » Click the Data-Image Toolbar button **Scaling** .
- » The **Scaling Settings** dialog appears on the screen and the scale-ruler and the coordinate system appear on the image. If different scales in the horizontal and vertical direction are chosen then two scale-rulers, a horizontal ruler and a vertical ruler, appear.
- » In the majority of images you can use the default setting **Same scale in all directions** which assumes the same scale is applicable in x and y directions. Select **Different scale in horizontal and vertical direction** if the scale is different in x and y directions.
- » Drag the end points of each scale-ruler to match a known distance on the image.
- » In the dialog, type in the corresponding "real" length(s) of the ruler(s) (default 1 m).
- » If desired, move the co-ordinate system by dragging its origin. You can also rotate the co-ordinate system by dragging the yellow dot on the x-axis.
- » Define the co-ordinate x-axis direction. Select **From left to right** if the horizontal axis direction is from left to right, or select **From right to left** if the horizontal axis direction is from right to left.
- » Define the co-ordinate y-axis direction. Select **From bottom to top** if the vertical axis direction is from bottom to top, or select **From top to bottom** if the vertical axis direction is from top to bottom.
- » Specify the color of the co-ordinate system.

- » Check the **Show coordinate system** option to display the co-ordinate on the image during the measurement. When this option is marked you can also check **Show grid**.
- » Click **OK** to confirm.

You can change the co-ordinate settings and scale settings at any time, even after the measurement is finished.

Image Measurement Settings

The **Settings** dialog in the Data-Video Activity consists of all settings needed to set up the video measurement.

- » Click the Activity Toolbar button **Settings** .

The dialog has two tabs:

Tab Points

Here you can define image points collected on each selected video frame during video measurement.

- » Enter the **Number of measured points**.
- » Specify **Name**, **Marker** and **Color** of the active (selected) point and the **Color** of inactive points.

Tab Time

This tab is used only for a stroboscopic image.

- » Select the option **Stroboscopic image**.
- » Type in a stroboscopic frequency or stroboscopic time interval.


Image Variables in the Data-Table and Graphs

Each image point is described by five variables: its horizontal P_x and vertical P_y Cartesian co-ordinates, and its angle P_{angle} and distance P_{dist} polar co-ordinates and rotation angle P_{rot} (for rotating movements via continue angle measurements for angles larger than 360 degrees).

Note that the unit with which angles are measured can be radians or degrees, depending on the pre-defined settings in the Activity Options. All four variables are added to the Data Table when a point is selected for measurement (one point is always selected). By default variables P_x and P_y are visible, and P_{angle} , P_{dist} and P_{rot} are hidden in the Data Table. The standard graphs of these variables are created automatically by Coach.

- » For image measurement this is a plot of the P_y versus P_x .
- » For a stroboscopic image it is the P_x and P_y variables versus time.

To select a standard Video/Image Graph:

- » Click the Activity Toolbar button **Graph** . The list of graphs appears under the button.
- » Select a standard graph, the icon changes into the Graph icon. Move the Graph icon above a desired pane and click the pane.
- » If you want to display data differently then you can edit the video graph or create new graphs. The graphs can be setup prior to starting a video measurement or after it. The advantage of preparing the graphs before is that the data are displayed during measurement.

Scanning

In Data Video Activities graphs are synchronized with the image points. When scanning in the graph, Coach shows the corresponding image points (also calculated points) on the image.

Editing Image

Coach provides limited possibilities for editing images. Editing options are similar to video editing options and include:

- » adjusting brightness, contrast, rotating and flipping,
- » placing annotations,
- » correcting perspective distortion.

It is also possible to export image included in the Coach Activity.

All these topics are described in the part **Data Video**.

CHAPTER 6

Modeling

Modeling activities are used to create and analyze computational models.

Modeling in Coach is basically similar to the System Dynamics Modeling, which use a stock-flow metaphor for dynamically changing systems (approach developed by Prof. J.W. Forrester in the early 1960s). Additionally Coach modeling is enriched with elements such as the Event element that allows introducing a discrete change in continuously varying systems, and the Process element that allows to model situations in which the principle of flow balance does not hold.

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The Basics

The topics in this chapter will help you to get familiar with the Model window.

Why to use Modeling?

For creating models there are three types of modes (editors) available: graphical, equations-based and text-based. Research indicated that graphical modeling offers an easier to use and richer framework for understanding the structure of a dynamic system in comparison with text-based modeling, and that it allows to build more complex models, because you can first concentrate on qualitative specifications during initial stages of the modeling process and do quantitative, formula-based specifications at later stages.

The use of various modeling modes is flexible in the sense that you can start the creation of a model in graphical mode and then you can switch to the equation or text model and add or change the model.

Once the model is created, it is easy to investigate it by changing values of parameters. Students can use this to test a hypothesis and to compare empirical data with results obtained from a theoretical model.

Ways of using Modeling

Generally there are three possible ways of using Modeling:

1. Open an earlier prepared model, run it and discuss with the students how it works. Here modeling is used as a simulation, with this difference that the model is visible and can be changed. The Simulate option is very helpful in this case.
2. Start with a prepared model or with parts of a model and build up a new model, after discussion, by revising or adding to what is already there. This way is useful in helping students to see how different problems relate to each other.
3. Start with nothing, and build up the desired model from scratch. This way is useful for example in modeling a phenomenon being studied in a student investigation.

Model Window



The Model window is the place for displaying, editing and creating models. It consists of a modeling area, whose design depends on the selected modeling mode.

In the graphical mode it is a canvas in which the graphical structure of the model is drawn. The variables of a model are represented by graphical symbols; connectors drawn between the symbols indicate the relations between the variables.

In the equation-based and text-based mode the window is divided into two parts showing the mathematical equations in the left part and initial values of state variables and constants in the right part.

The Model window also has its own Toolbar and Tool menu that offer options specific to modeling.

To display/hide the Model window

- » Click the Activity Toolbar button **Model**  to open the Model window,
- » Click the Activity Toolbar button **Model**  to close it.

Model Toolbar

The Toolbar of the Model window may have the following buttons (not all buttons are always present):



Zoom in and out a model



Create a State variable (graphical and equations modes)



Create a Process variable (graphical and equations modes)



Create a Flow variable (graphical mode)



Create an Auxiliary variable (graphical and equations modes)



Create a Constant (graphical and equations modes)



Create an Event (graphical and equations modes)



Draw a connector (graphical mode)



Delete an element (graphical mode)



Show the Independent Variable (graphical and equations modes)



Add an annotation (graphical and equations modes)



Zoom model structure to fit the Model window (graphical mode)



Show model equations – to display model equations, model equations are shown but are not editable).

Click



to hide model equations.



Open the Graphical mode (equations and text modes)



Open the Equations mode (graphical and text modes)



Open the Text mode (graphical and equations modes)



Store and open favorite models. The models listed under favorites show a mode in which they were created, graphical or text. Text models are visible only in text mode. The favorite models can be replaced or can be added to the existing model.



Insert a delta symbol, Coach Language Command or open the Formula Editor (text mode)




Select Variables button (text mode) - to select variables used in the text model, which will be added to the Data Table and available for Graphs, Meters, Values and Animations.

Model Tool Menus

The Model Tool menu is available after clicking the Tool menu button in the Model window (only when the Model window is docked) or by right clicking the Model window. The menus differ in graphical, equations and text mode. Also some areas of the Model window are sensitive (hotspots) and show a different tool menu.

GRAPHICAL MODE

Tool menu or empty space

» Click the Tool menu button  or an empty space in the Model window

Run Controller – to display the Run controller

Simulate – to display the Simulate dialog

Zoom – to zoom the model

Edit – to edit a selected part of the model

Erase Model – to erase a model

Import Model – to import a model from another Coach Activity/Result

Dock/Undock – to dock/undock the Model window

Print Model – to print a model

Clipboard Copy - to copy a model to the clipboard (as an image)

Help – to consult the help system

Hotspot: a variable symbol in the Model window

» Right-click a hot spot to evoke its menu.

Edit – to edit a selected part of the model, the following options are present: Undo, Cut, Copy, Paste, Font, Select All

Display as a Graph – to display a variable in a standard graph

Display as a Meter – to display a variable in a standard meter

Display as a Value – to display a variable in a standard value

Properties – to open the Variable Properties dialog

Convert to Constant (only for an auxiliary variable) - to change a type of variable to a constant

Convert To Aux (only for a constant) - to change a type of variable to an auxiliary variable.

Hotspot: the submenu symbol in the Model window

» Right-click a hot spot to evoke its menu.

Edit – to edit a model, the following options are present: Undo, Cut, Copy, Paste, Font, Select All

Properties – to open the Variable Properties dialog

Remove Subsystem – to delete a subsystem

EQUATIONS MODE

Tool menu or empty space

» Click the Tool menu button  or an empty space in the Model window

Run Controller – to display the Run controller

Simulate – to display the Simulate dialog

Zoom – to zoom the model

Edit – to edit a selected part of the model, the following options are present: Undo, Cut, Copy, Paste, Font, Select All

Import Model – to import a model from another Coach Activity/Result

Erase Model – to erase a model

Dock/Undock – to dock/undock the Model window

Print Model – to print a model

Clipboard Copy - to copy a model to the clipboard (as an image or as text)

Help – to consult the help system.

Hotspot: a variable equation in the Model window

» Right-click a hot spot to evoke its menu.

Edit – to edit a model, the following options are present: Undo, Cut, Copy, Paste, Font, Select All

Display as a Graph – to display a variable in a standard graph

Display as a Meter – to display a variable in a standard meter

Display as a Value – to display a variable in a standard value

Properties – to open the Variable Properties dialog

Dock/Undock – to dock/undock the Model window

TEXT MODE

Tool menu or the left side of the Model window

» Click the Tool menu button  or the left side of the Model window

Monitor – to execute a model in the Monitor mode

Simulate – to display the Simulate dialog

Zoom – to zoom the model

Edit – to edit a selected part of the model, the following options are present: Undo, Cut, Copy, Paste, Constants, Select All

Import Model – to import a model from another Coach Activity/Result

Erase Model – to erase a model

Select Variables – to select variables used in the text model, which will be added to the Data Table and available for Graphs, Meters, Values and Animations

Dock/Undock – to dock/undock the Model window

Variables – to open the List of Variables dialog to select variables for display in the data table

Print Model – to print a model


Clipboard Copy - to copy a model to the clipboard (as an image and as text)

Help – to consult the help system.

Model Settings

The Model Settings dialog consists of all settings needed to run a model. For a new model Coach uses default settings. The Model Settings dialog in text mode is simpler than in graphical and equation mode and offers only a few options.

To change the model settings

- » In the Activity Toolbar click the **Settings**  button.
- » **Adjust where needed.**

In graphical and equations mode:

Start: defines the begin value of the independent variable. By default the independent variable is time t .

Stop: defines the value of the independent variable or the condition at which model execution stops.

Step interval: defines the step of the independent variable.

Save data every # steps: in case of large data sets it can be useful to save only part of the calculated data. By default data are saved every step.

Display run controller: check if you want to display the Run controller. By default this option is off.

Draw connectors automatically – check if you want to automatically draw connectors of variables used in a variable definition (formulas). By default this option is off.

Integration method: specifies the integration method used for solving differential equations in graphical and equations modes. Coach provides three iteration methods: Euler (default), Runge-Kutta 2 and Runge-Kutta 4.

Notation: specifies the way the differential equations are presented in the equations mode. Two ways are available: difference e.g. $x = x + \Delta x$ (default) and differential e.g. dx/dt .

In text mode:

Number of Cycles: define number of time the model has to be calculated until it stops.

Save data every # cycles: in case of large data sets it can be useful to save only part of the calculated data. By default data are saved every cycle.

Managing Models

In general, models are saved together with all other Activity settings in the Coach Activity/Result file.

Importing models

In general, models are saved together with all other Activity settings in the Coach Activity/Result file.


To import a model

- » Right-click the Model window and select the option **Import model**.
- » Select a desired Coach Activity/Result and open it.
- » Loading a new model will erase your current model.

Favorite models

Favorite models (or part of a model) can be added and store in Coach so they can be available during creation of new models.

To store a favorite model

- » Create a model you want to store.
- » Click the Favorites Toolbar button  and select **Add current**.
- » Name your favorite model.
- » Click **OK** to confirm.


To add a favorite model to existing model

- » Click the Favorites Toolbar button

 and select **My Models**.

- » A list of favorite models will be given.
- » Select a model you want to add.
- » The cursor displays the Model icon.
- » Click the location where you want to place your model.

To remove a model from the list of favorite models

- » Click the Favorites Toolbar button  and select **Remove**.
- » A list of favorite models will be given.
- » Select a model you want to remove.

Model Execution


During model execution calculations of the model variables are done based on the model, initial values and model settings.

Via the Simulate option, the effect of a single parameter on the model can be studied.

To verify whether the theory matches the reality the model results can be compared with experimental data.



How to open a Modeling Activity

You can open a Modeling Activity in Coach in the following ways:

- » **Quick Start:** click the  **Modeling** button in Dashboard and select the option **Modeling in Graphical Mode** or **Modeling in Text Mode**.
- » Open an example of a Modeling Activity located in the **CMA Projects** in the **Modeling** folder.
- » Open a Modeling Activity prepared by your Teacher.

How to execute a model

In this basic procedure it is assumed that you work with a Coach Modeling Activity with a ready-to go model.

- » Start the model execution by clicking the Activity Toolbar **Start** button .
- » Model execution starts and the data appear in the data table and graph(s).
- » Model execution stops when the stop value or the stop condition (in the graphical and equations modes) or the number of given cycles (in the Text mode) is reached.
- » To interrupt model execution use the Activity Toolbar button **Stop**  or keep **<Esc>** pressed.

How to control the speed of model execution

Often when executing the model via the Start button the model calculations are performed quite fast. To slow down the speed of execution of graphical or equations models the Run Controller can be used, for text models the Monitor option can be used. During slower model execution the calculated values of all model variables are shown in the Model window.

RUN CONTROLLER


The Run controller is available in **graphical and equations** mode. It can be placed on the screen by checking the option **Display Run controller** in the Model Settings dialog or the **Run Controller** option in the Tool menu of the Model window. The Run controller allows you to:



- » execute the model,
- » stop the model execution,
- » pause the model execution, and
- » adjust the execution speed by using the **Speed** slider bar (also during a run),

During model execution the progress of the independent variable and its current value is displayed next to the independent variable slider. The calculated values of all model variables are shown in yellow digital displays in the Model window. After model execution is finished, one can scroll through the independent variable values.

MONITOR WINDOW

The Monitor window is available in text mode when the **Monitor** option, in the Tool menu of the Model window, is checked.

After starting the model execution (clicking the Activity Toolbar Start button ) , the Monitor window opens and the execution of the model can be followed line-by-line.

- » Adjust the speed of the monitoring with the slider (this can also be done during execution).
- » Execute a single line of the model by pressing the 1-button in the Monitor bar.
- » Click the Start button in the Monitor bar  to start line-by-line model execution. During monitoring the line being calculated is indicated and all values of the variables are displayed at the right side.
- » Click the Activity Toolbar button Stop  or keep <Esc> pressed to interrupt model execution.

How to execute the model via the Simulate option

Another way of executing the model and at the same time investigating the effect of a single model parameter on the model is via the **Simulate** option.

- » Right-click the Model window and select the **Simulate** option.
- » Select the parameter from the drop-down-list of model variables.
- » Specify a parameter value by typing a value in the **Value** field or setting a value with the **Range** slider.
- » Click the **Execute** button. Model execution starts and the data appear in the data table and graph(s).
- » Repeat for other values of the parameter. Each time the model is executed a new run is added to the data table and graph(s). This allows easy comparison of graphs created for different parameter values.

How to compare model data to experimental data

One of the most valuable features of Modeling is hypothesis testing during which model data can be compared to experimental data from measurement or video measurement. By modifying the model or by changing the value of a parameter students can test their hypothesis and construct links between the real experiment and the theoretical model.


To verify whether the theory (calculated data) matches the reality (measured data) the option **Simulate** may be used with the presence of a .Background Graph. Each diagram allows for one (measurement) graph to be placed as a background graph. Graphs resulting from model calculations can be compared against the background graph. A hypothesis can be tested by varying a parameter, to investigate which value leads to the best fit of the experimental graph.

If the calculated graph partially overlaps the background graph, the option **Shift Background Graph** enables you to shift the background graph horizontally. This option becomes available in the graph Tool menu after the background graph is placed in the diagram.

Elements Used in Graphical and Equations Modes

The following variables are available for creating models in graphical and equations modes:

- » State variable
- » Process
- » Flow
- » Auxiliary variable
- » Constant
- » Event
- » Independent variable.

To draw and show relations between variables in a graphical model Connectors  are used. The variable at the end of a connector, to which a connector's arrow is attached, depends on the variable at the start of the connector.

Each model variable has its own properties, which are defined in the Variable Properties dialog.


To open Variable Properties

- » In graphical mode – double-click a variable symbol in the Model window.
- » In equations mode - double-click a variable symbol placed before an Equation.

Formulas, used to define variables or conditions, can be simply typed in directly in the definition fields of model variables or the Formula Editor can be used. The formulas should obey the .rules of Coach Language.

In formulas new variables (not yet used in the model) can be introduced. When Coach detects such a new variable then a new graphical symbol/equation for this "unknown" variable, indicated with a question mark, is automatically created and added to the model. After that the new variable should be identified in the Select Type dialog, which opens after double-clicking of the unknown variable equation. After selecting the variable type the corresponding Variable Properties dialog opens and its definition can be made.


State Variable

State variables  are used to represent variables that change in time. State variables can represent countable, physical accumulations like the amount of water in a bathtub, the number of trees in a forest, a country population, or can represent the degree of non-physical accumulations such as knowledge or fear. State variables can also be used for more abstract variables changing in time e.g. the position or velocity of a moving object (kinematics problems).

A State variable is determined by its initial value and by the ingoing and outgoing flows. The total sum of all inflows and outflows defines the total rate of change of the state variable. The initial value is almost always specified by a value, but it may be specified by a formula.

The State variable has a default label State_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name in order to interpret it correctly.

Process Variable


A Process  is used to describe changes in variables that are interrelated in one process. A typical application is chemical kinetics of a reaction where the stoichiometry is such that the number of reacting species

differs from the number of products, for example the reaction $A + B \rightarrow C$. The graphical model of such a reaction resembles the chemical notation of a reaction (mechanism), including the stoichiometry. In this application, and in particular in a single reaction step, the process icon (the Erlenmeyer flask) represents a reaction, flows going towards the process originate from reactants and flows going away from the process point at products of the chemical reaction. Process variables make it easy to extend investigations of chemical kinetics beyond the level of studying very simple, monomolecular reactions or simple reaction mechanisms.

A process variable is defined by a formula. In the example of chemical kinetics, it stands for the reaction rate of a chemical reaction step, which depends on the reaction rate coefficient, the concentrations of reactants involved in the reaction step and their stoichiometric coefficients. The listed In and Out Coefficients are added automatically to the process variable properties window based on the flows going in and out of the process variable. The stoichiometric coefficients In and Out determine the exact relationship between the ingoing and outgoing flows connected to the process variable and the formula represented by the process variable. Therefore there is no need to use connectors from the process towards these flows.

The Process variable has a default label Process_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name in order to interpret it correctly.

Flow Variable

Flow variables  are used to represent actions that lead to a change of state and process variables.

Flows can represent water coming through a tap into a bathtub, births and deaths in a population, concentration changes of reactants, velocity (rate of change) of object position, etc.


For state variables: if the arrow of the flow has a direction into the state variable then the flow contributes positively to the change of this variable. If the arrow is out-going then the flow contributes negatively to the change of this variable.

For process variables: the In and Out stoichiometric coefficients defined for a process variable determine the formulas for flows connected to this process variable.

The Flow variable has a default label Flow_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name in order to interpret it correctly.

By default a flow label is not displayed in the Model window. Check the Show label option to display the name. By checking the option Use condition, the additional fields for constructing a condition are displayed.

Auxiliary Variable

Auxiliary variables  take in information (data) and transform it for use by another variable in the model. For example, for the population model an auxiliary variable can be used for calculating the growth rate; for motion an auxiliary variable can be used for calculating forces acting on a body or body acceleration. An auxiliary variable is determined by a formula or by data, which originates from the data table. The auxiliary variable has a default label Aux_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of not allowed to use by characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name in order to interpret it correctly.

An auxiliary variable can be defined via formula or via data.

To define an auxiliary variable by formula

- » In the Auxiliary Variable Properties dialog select the **Formula** option.

- » Type in the formula in the field behind Aux_# =. The formula should be written according to the rules of Coach Language to avoid mistakes you can use the .formula editor.
- » By checking the option **Use condition** the additional fields for constructing a condition are added.


To define an auxiliary variable by data

Before this definition can take place, a variable with desired data should be present in the data table of the Activity/Result. Such a variable can be constructed in Coach by:

- » using the Sketch option and drawing a graph, the Sketch variable is then added to the data table.
- » adding a manual variable to the data series of the data table and typing the respective data manually.
- » importing data from an external .csv file.
 - » In the Auxiliary Variable Properties dialog select the **Data** option and click the **Define** button.
 - » Specify the Run in the data table from which the data will be used.
 - » Specify the variable whose data will be used for the dependent variable. The quantity and unit of the linked column are automatically displayed.
 - » Specify the variable whose data will be used for the independent variable. The quantity and unit of the linked column are automatically displayed.
 - » Click **OK**. Notice that the chosen data will be stored along with the variable.


The graphical symbol of an auxiliary variable defined by a data column is enriched with an extra symbol \square . During the model run, values of the variable from the column are interpolated.

Constant

Constants  are variables, which are defined by constant values. The value for a constant can be typed in or selected from a database with predefined physical constants. A constant selected from the database is fully defined; its Name, Unit, Description (Quantity) and Value are copied. It is not possible to link any variable to a constant.

The Constant has a default label Const_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of / not allowed to use by characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name to in order to interpret it correctly.

Event


For processes with abrupt changes, the Coach modeling environment is enriched with the Event element . The event allows changing the value of a state variable once, based on a condition; this causes a discrete change in a continuously varying system. An event can be used to describe the bounce of a falling ball: when a ball reaches the ground (in Coach Language condition 'height <=') then the ball velocity changes its direction and because of energy dissemination also its value.

An event definition is built from two parts: a trigger condition and actions. A trigger condition is defined by entering a conditional equation. Similar to formula it should be written according to the rules of Coach Language. A list of actions is created by using the buttons Add and Remove. The actions can only be applied to state variables.


The Event has a default label name Event_# (where # denotes a number). The variable name used by Coach is displayed below the label and is not editable. If a variable label consists of not allowed to use by characters/words not allowed to use by Coach Language then Coach automatically adds square brackets around the variable name in order to interpret it correctly.

By default an event label is not displayed in the Model window. Check the **Show label** option to display the name.

Independent Variable

The Independent variable  is the variable that determines the steps for the change of the state variables. By default it is time t with unit s .

The Independent variable properties dialog opens by:

- » clicking the **Independent variable** button in the Model window Toolbar  when the Independent variable symbol is not visible in the Model window, or
- » double-clicking the Independent variable symbol in the Model window.

By default the independent variable graphical symbol is not shown in the Model window. Check the option **Symbol visible** in the Model window if you want to display it.

Modeling in Graphical Mode

In graphical mode models are built with graphical elements, which represent model variables: state, process, flow, auxiliary, constant variables. Discrete changes of state variables can be constructed with events. Relationships between the model variables are given by connectors.


The state and process variables together with the flows connected to it define the differential equations of the model. These mathematical equations describe the way the state and process variables change in time. Together with other variables, a graphical model represents a computer model, which provides an iterative numerical solution of the model's differential equations.

The topics in this chapter will help you to learn how to work in graphical mode.


Creating a Graphical Model

1. By default variable t (time) is used as the independent variable in a new model. If you want to change it click the Independent variable symbol and specify a new independent variable.
2. Create the graphical structure of your model.
 - » Place variable symbols in the modeling area:
State, Process, Auxiliary and **Constant** variables: click their respective symbol buttons on the Toolbar, the cursor displays a small icon of this symbol, move the cursor onto the modeling area, position it and click.
Flows (in): click the **Flow** button on the Toolbar, the shape of the cursor changes into a small flow icon, click a state or process variable (or a suitable empty beginning point in the window), hold and drag the cursor to the state variable or process until it is selected, then release the mouse.
Flows (out): click the **Flow** button on the Toolbar, the cursor displays a small flow icon. Click a state or process variable, hold and drag the cursor out of the state or process variable. Or if you want to connect it as an in-flow to another state or process variable, hold and drag the cursor out until it reaches and selects this new state or process variable, then release the mouse.
Use **<Shift> + <click>** to make corners (only in Windows).
 - » Rename your variables. All symbols get default names, which are located under the symbol (not displayed for flow and event symbols). To change a default name, select a name and overwrite it. You can also change the name anytime in the variable properties dialog.
 - » Draw connectors between the model variables: click the Connector button on the Toolbar, the cursor displays a small connector icon, click a symbol from which the connector has to start, hold and drag the cursor to the symbol where it has to end.
 - » By default the relation arrows are drawn in red and model objects in blue. These colors can be adapted for a whole or a part of the model. To change a color select (a part of) a model and use the Tool menu option **Edit > Colors > Relations** or **Objects**.
 - » You can also change the default font used to describe the model variables. To change the font select (a part of) a model and use the Tool menu option **Edit > Fonts** .
3. Define the variables. The symbols which miss definition will show a question mark '?'.
 - » Double-click a variable symbol; its variable properties dialog opens.
 - » Enter mathematical formulas for flows, events and auxiliary variables. The formulas can be typed in or created with the formula editor. The formulas should obey the rules of Coach Language.
 - » Enter initial values for state variables. Initial values can be typed in (value) or created with the formula editor (formula).
 - » Enter values for the constants. A constant value can be typed in or selected from the database with predefined constants.

4. Define your model settings.

- » Click the Activity Toolbar button **Settings** .
- » Define start and stop conditions.
- » Choose the integration method. By default the **Euler** method is selected.

5. Select the way of presenting your model data. Right-click a variable symbol and select a graph, Meter or a value or .create new graphs.

6. Execute your model by clicking the Activity Toolbar button **Start**  or by using .Run controller.

7. ,Errors of various kinds, 'bugs', can be made during a modeling process. Some errors can be simple mistakes, like misspelling a variable name (leading to confusion with a different variable) or creating a wrong formula (not according to the rules of Coach Language). In such cases Coach gives an error message and suggests where a problem was found.

8. Some errors can be more fundamental, for example the choice of sign. 'Friction force' with the wrong sign will produce spontaneous acceleration and absurd results.

Editing a Graphical Model

To edit a variable

- » Double-click a symbol in the model structure. Edit the variable properties..

To make a selection

- » Click a variable symbol in the model symbol to select it. Use **<Ctrl>+<click>** (Windows) or **<Cmd>+<click>** (Mac) to select more symbols.

or

- » Drag an area in the Model window to select the symbols inside.


To move a variable symbol

- » Click a variable symbol in the model to select it or make a selection of several symbols.
- » Use the cursor keys to move the selection to another location in the Model window.

To copy a selection of variable symbols

- » Make a selection of variable symbols.
- » Right-click outside of the selection and select **Edit > Copy** (or **<Ctrl>+<C>**).
- » Right-click the Model window and select **Edit > Paste** (or **<Ctrl>+<V>**).
- » Copied symbols will be placed in the Model window. Notice that the new variables automatically get new names.

To delete a variable symbol

- » Click the **Delete** button in the Toolbar  (the cursor changes into a pair of scissors), place the cursor on a variable symbol and click it, or
- » Select a variable symbol or make a selection of more symbols and press **** (only in Windows).

To change a color of relation arrows or model objects

- » Drag to select (a part of) a model in the model window or use the Tool menu option **Edit > Select all** to select the whole model.
- » Go to the Tool menu option **Edit > Color > Relation** to change the color of the selected relation arrows.

- » Go to the Tool menu option **Edit > Color > Objects** to change the color of the selected model objects.
- » Select the desired color.

To change a font of model labels

- » Drag to select (a part of) a model in the model window or use the Tool menu option **Edit > Select all** to select the whole model.
- » Go to the Tool menu option **Edit > Font** and select the desired font.

To erase a model

- » Right-click in the Model window and select the option **Erase model**.
- » Click **Yes** when the question **Do you want to erase model?** appears. The whole model will be deleted.

Useful shortcuts

- » With the menu option **Undo** or **<Ctrl>+<Z>** the last performed action is cancelled.
- » With **<Ctrl>+<A>** the whole model is selected.
- » By using the menu option **Edit > Font**, the fonts of all selected variables can be changed at once.
- » **<Shift> + <cursor>**-keys moves the whole model in the Model window.

Creating Subsystems

Graphical subsystems allow closing a selected part of the model and showing it as one single graphical element. Using subsystems simplifies the structure of complex models.

To create a subsystem

- » Drag an area in the Model window to make a selection of the variables for your subsystem.
- » Right-click the selected area and select the option **Create Subsystem**.
- » The subsystem **Subsystem_#** (where # denotes a number) is created and its symbol, a closed box, appears in the Model window.
- » To make the subsystem visible, click the **+** sign in the upper right corner of the closed subsystem symbol. To close it again click the **-** sign.
- » By double-clicking a subsystem element, its properties window opens. It allows specifying the subsystem's name, description and display.
- » A subsystem can be locked for users by using the lock symbol placed in the upper left corner of the subsystem symbol. This can be done only in the Author mode of Coach. In the Senior or Junior modes locked subsystems cannot be opened or closed.


To remove a subsystem

- » Right-click the closed or opened subsystem and select **Remove Subsystem**.
- » The variables of the subsystem will remain in the model.

Displaying a Graphical Model in Equations or Text Mode

A graphical model can be viewed and modified in equations or text mode. Changes made in equations mode will be transferred back to graphical mode.

To display a Graphical model in the Equations-based Editor:

- » Click the Toolbar button **Equations mode** .
- » The graphical model is automatically converted into an equations-based model based on the model definitions.

- » Now the model can be modified. Changes made in equations mode will be transferred back to graphical mode.

To display a Graphical model in the Text-based Editor:

- » Click the Toolbar button **Text mode** . The icon is a small square with a blue border containing the letters 'ABC' in blue.
- » The graphical model is automatically converted into a text-based model based on the model definitions and selected integration method e.g. selecting Euler iteration method will create a much simpler program than selecting the Runge-Kutta method.
- » After a text model is modified a warning message appears after trying to change the mode. Forcing to change the mode **removes** all modifications made in text.

Modeling in Equations Mode

In Graphical mode the model is defined with mathematical equations "hidden" behind the graphical symbols. In equations mode these mathematical equations can be made visible.

It is also possible to create models directly in equations mode; instead of graphical symbols variable equations are constructed. Equations are created automatically after defining variables. Variables are defined in a similar way as in graphical mode by clicking a variable icon on the Modeling Toolbar and entering its properties.

The topics in this chapter will help you to learn how to work in equations mode.

Formats of Variable Equations

A **state variable** is determined by its initial value and its rate of change, which equals to the sum of flows going in and out of the variable. This results in a model differential equation. The form of this equation depends on the notation selected in the model settings.

The **Independent variable** equation is not shown in the model. However, the independent variable is shown (indirect) in the state variable equations. The independent variable cannot be typed over in equations; it can be changed only in the Independent variable properties window, which opens after clicking the Independent variable icon in the Toolbar.

Difference equation notation

$$\square \text{State}_1(t) = \text{State}_1(t-\Delta t) + (\text{Flow}_1 - \text{Flow}_2) * \Delta t$$

$$\clubsuit \text{Flow}_1 = ?$$

$$\clubsuit \text{Flow}_2 = ?$$

Differential equation notation

$$\square d\text{State}_1 = (\text{Flow}_1 - \text{Flow}_2) * dt$$

$$\clubsuit \text{Flow}_1 = ?$$

$$\clubsuit \text{Flow}_2 = ?$$

A **process** variable is determined by a formula and creates a fixed relationship between the connected inflows through the corresponding coefficients (by default equal to 1).

$$\triangle \text{process} = k * \text{state}_1 * \text{state}_2 ()$$

$$\square \text{state}_1(t) = \text{state}_1(t-\Delta t) + (- \text{Flow}_1) * \Delta t$$

$$\square \text{state}_2(t) = \text{state}_2(t-\Delta t) + (- \text{Flow}_2) * \Delta t$$

$$\clubsuit \text{Flow}_1 = (1) * (\text{process})$$

$$\clubsuit \text{Flow}_2 = (1) * (\text{process})$$

$$\square \text{state}_3(t) = \text{state}_3(t-\Delta t) + (\text{Flow}_3) * \Delta t$$

$$\clubsuit \text{Flow}_3 = (1) * (\text{process})$$

Flow variable equations are added automatically to the model equations. Undefined flows display a question mark '?'.
Auxiliary variable equation

$$\circ \text{Aux}_1 = ?$$

Constant equation



$$\circ \text{Const}_1 = ?$$

Event equations are actually conditions.

 Once $y \leq 0$ Do

$$v = -0.9 * v$$

Creating an Equations Model

1. By default variable t (time) is used as the independent variable in a new model. If you want to change it click the Independent variable symbol and specify a new independent variable.
2. Create model equations by defining variables with the variable icons available in the Toolbar.
 - » Click a variable symbol icon.
 - » Fill in the name and display properties. In the state variable dialog use the buttons **Add inflow** and **Add outflow** to create flows.
 - » You do not need to fill in definitions directly; you can first create all variable equations. The equations with no defined values and formulas display a question mark '?'.
 - » The variable equations are displayed in the left part of the Model window.
 - » Enter initial values, formulas and constants. These values are displayed in the right part of the Model window.
3. Define your model settings.
 - » Click the **Settings** button in the Activity Toolbar .
 - » Define start and stop conditions.
 - » Define the iteration method. By default the **Euler** method is selected.
4. Select the way of presenting your model data. Right-click a variable symbol and select a graph, Meter or a value or .create new graphs.
5. Execute your model by clicking the Activity Toolbar button **Start**  or by using .Run controller.
6. Errors of various kinds, 'bugs', can be made during a modeling process. Some errors can be simple mistakes, like misspelling a variable name (leading to confusion with a different variable) or creating a wrong formula (not according to the rules of Coach Language). In such cases Coach gives an error message and suggest where a problem was found.
7. Some errors can be more fundamental for example the choice of sign. 'Friction force' with the wrong sign will produce spontaneous acceleration and absurd results.

Editing an Equations Model

To edit an equation

- » Double-click an equation to open its variable properties dialog or click an equation symbol and move the cursor to the field you want to edit. You can only edit variable names, formulas and values of constants and initial values.

To make a selection of equations

- » Click on the small graphical symbol to select an equation.
- » Use **<Ctrl>+<click>** (Windows) or **<Cmd>+<click>** (Mac) to select more equations.

To move an equation

- » Select an equation.

- » Move the equation to another location by using the keys **<PgUp>** and **<PgDown>** (Windows) and **<Fn> + <arrow up and down>** (Mac).

To copy equation(s)

- » Make a selection of equations.
- » Right-click outside of the selection and select **Edit > Copy** (or press **<Ctrl>+<C>**).
- » Right-click and select **Edit > Paste** (or press **<Ctrl>+<V>**). The equation lines are copied at the end of the model equations.

To delete equation(s)

- » Make a selection of equations.
- » Delete equations by pressing **** (Windows) or **<fn> + <backspace>** or **<fn> + <Delete>** (Mac).

To erase a model

- » Right-click in the Model window and select the option **Erase model**.
- » Click **Yes** when the question **Do you want to erase model?** appears. The whole model will be deleted.

To move an annotation up and down

- » Mac - use the arrow up and down key together with **<Cmd>**-key.
- » Windows - use the arrow up and down key together with **<Alt>**-key.

Useful shortcuts

- » With the menu option **Undo** or **<Ctrl>+<Z>** the last performed action is canceled.
- » With **<Ctrl>+<A>** the whole model is selected.
- » By using the menu option **Edit > Font**, the fonts of all selected variables can be changed at once.

Displaying an Equations Model in Graphical or Text Mode

An equations-based model can be viewed and modified in graphical or text mode.

To display an equations model in graphical mode:

- » Click the Toolbar button **Graphical mode** .
- » The equations-based model is automatically converted into a graphical model based on model definitions.
- » Now the model can be modified. Changes made in graphical mode will be transferred back to equations mode.

To display an equations model in text mode:

- » Click the Toolbar button **Text mode** .
- » The equations-based model is automatically converted into a text-based model, based on model definitions and a selected integration method e.g. selecting Euler iteration method will create a much simpler program than selecting the Runge-Kutta method.
- » After a Text model is modified a warning message appears after trying to change the mode. Forcing to change the mode **removes** all modifications made in text.

Modeling in Text Mode

A text model is a model constructed according to the Coach Language rules; it is actually a program that consists of equations for calculations of the model variables. A text mode does not recognize differential equations automatically, these equations have to be written by the users. The number of iterations for the model calculations is defined in the model settings.

The topics in this chapter will help you to learn how to work in text mode.

Creating a Text Model

1. After opening an empty Model window in text mode, the independent variable is already defined. The default independent variable is t (model equation $t := t + dt$), with the initial value $t = 0$ and step size $dt = 0.1$.
2. In the left part of the Model window type in the model equations. Coach does not guide you to write equations correctly, these equations have to be built according to the rules of Coach Language. However, on executing a model with syntax errors, Coach will indicate which equations are not correct and place the cursor at the error position. A few general rules are:
 - » Constants may be defined either in the model or in the list of initial values.
 - » Variables defined by an expression containing the variable itself, e.g. $variable := variable + dvariable$ must be defined in the model. To be able to calculate this variable at the first iteration, the initial value of this variable is needed.
 - » Variables obtain a new value in each iteration and so they must be defined in the model.
3. There is a little help you to create conditional and loop statements.

» Click the **Coach Language Command** button .

» The list of Coach Language commands, which can be used in text mode opens. You can use the following conditional and loop statements:

If *Conditional expression* **Then** *Statements* **EndIf**

If *Conditional expression* **Then** *Statements* **Else** *Statements* **EndIf**

Repeat *Statements* **Until** *Conditional expression*

Redo *Number Statement* **EndRedo**

While *Conditional expression* **Do** *Statements* **EndDo**

Once *Conditional expression* **Do** *Statements* **EndDo**.

» Click a command to select it; the command will be placed at the cursor position in the model.

» Additionally, the **Formula Editor** option is added to the list of commands. In this way the formula editor can be started at any place in the model.

4. In the right part of the Model window type in initial values. In Text mode, initial values may also be given as an expression (provided that this expression results in a number).

5. Click the **Settings** button  and specify the number of iterations. Default is 101.

6. To be able to display your data variables in the data table and on graphs you have to select and define these variables:

- » Right-click the Model tool menu and select **Variables**.
 - » Click **Add**, select a variable from the drop-down list.
 - » Type in its unit, decimals, minimum and maximum.
 - » Click **OK** to confirm.
7. Select the way of presenting your model data. Right-click a variable symbol and select a graph, Meter or a value or . create new graphs.
 8. Errors of various kinds, 'bugs', can be made during a modeling process. Some errors can be simple mistakes, like misspelling a variable name (leading to confusion with a different variable) or creating a wrong formula (not according to the rules of Coach Language). In such cases Coach gives an error message and suggest where a problem was found.
 9. Some errors can be more fundamental for example the choice of sign. 'Friction force' with the wrong sign will produce spontaneous acceleration and absurd results.

Editing a Text Model

To edit a text model

The model equations and initial values can be edited directly in the Model window. The equations have to be built according to the Coach Language rules.

In the Text mode you can now mix all three ways of writing: dt, deltat and Δt .

To move a selection

- » Make a text selection.
- » Right-click the selection and select **Edit > Cut** (or press **<Ctrl>+<X>**).
- » Right-click the line above which you want to paste the cut lines. Select **Edit > Paste** (or press **<Ctrl>+<V>**).

To copy a selection

- » Make a text selection.
- » Right-click the selection and select **Edit > Copy** (or press **<Ctrl>+<C>**).
- » Right-click the line above which you want to paste the copied lines. Select **Edit > Paste** (or press **<Ctrl>+<V>**).

To delete a selection

- » Make a text selection.
- » Press **** (Windows) or **<fn> + <backspace>** or **<fn> + <Delete>** (Mac).

To erase a model

- » Right-click in the Model window and select the option **Erase model**.
- » Click **Yes** when the question **Do you want to erase model?** appears. The whole model will be deleted.

Useful shortcuts

- » With the menu option **Undo** or **<Ctrl>+<Z>** the last performed action is canceled.
- » With **<Ctrl>+<A>** the whole model is selected.

Displaying a Text Model in Graphical or Equations Mode

A model build in text mode cannot be viewed in graphical and equations mode.

A graphical model and equation model can be viewed and modified in text mode. As long as the text model is not changed, it is possible to switch back to graphical or equation mode via Graphical mode and Equations mode Toolbar buttons. After a Text model is modified a warning message appears after trying to change the mode. Changing the mode anyway **removes** all modifications made in Text mode.

Executing models in Coach

This advance topic will help you to better understand how models are executed in Coach.

Numerical Methods for solving differential equations

There are three numerical methods for solving differential equations offered by Coach:

Euler Method	Coach uses the forward Euler method: $y_{n+1} = y_n + h * f(x_n, y_n)$
Second order Runge-Kutta method	Coach uses the MidPoint method: $k1 = h * f(x_n, y_n)$ $y_{n+1} = y_n + h * f(x_n + 0.5*h, y_n + 0.5*k1)$
Fourth order Runge-Kutta method	Coach uses the classical fourth order Runge-Kutta method: $k1 = h * f(x_n, y_n)$ $k2 = h * f(x_n + 0.5*h, y_n + 0.5*k1)$ $k3 = h * f(x_n + 0.5*h, y_n + 0.5*k2)$ $k4 = h * f(x_n + h, y_n + k3)$ $y_{n+1} = y_n + (k1 + 2*k2 + 2*k3 + k4)/6$

Model is a Coach Language Program

A model created in graphical and equations mode is converted into a text model by Coach according to the rules of Coach Language and the selected in the model settings integration method. Such a resulting model is not visible in these modes for users but can be seen when opening the model in text mode.

A text model in Coach should be written according to Coach Language rules. Coach does not give any guidance during the creation of text models.

The text model is actually a Coach program and after starting its execution it is interpreted by the Coach Language interpreter.

Executing Text Model by Coach

A text model is executed in the following way:

The **initial value section** is executed one time at the beginning of the model execution to set the initial values and to calculate the first point. The first point is defined completely by the model and initial values and is the same for all three iteration methods.

The independent variable is defined by its initial value and step interval, state variables have initial values defined by constant values or expressions, constants are defined with constant values or expressions. Auxiliary variables and flows are calculated from these values. This leads to the following for the initial section of the model program:

1. <independent variable>:= <start value>
2. d<independent variable>:= <step value for independent variable>
3. All constants and state variables with their initial expressions are added in their order of dependency. Only the independent variable is known here so that is the only object skipped in the dependency check.
<constant>:= <constant expression>
<state variable>:= <state variable initial expression>
4. All auxiliary variables and flows are added in order of their dependency. All other variable types are already known and dependency checking is done only for auxiliary variables and flows.

<aux> := <expression>

<flow>:= <expression>

5. All variables have values and the first point is saved: SaveData.

The **model section** is repeated in a loop. An integration step for state variables is calculated based on their rates of change (sum of all in and out flows), auxiliary variables and flows are recalculated based on their expressions, the independent variable is increased with its step value and events are added. The basic structure for the program is the same for all three integration methods. Assuming that we go from a moment t_n and to a moment t_{n+1} then state variables are integrated from t_n to t_{n+1} . All three methods are forward integration methods starting in t_n and using values of the flows in t_n for the start of the integration step. In the Runge-Kutta methods intermediate points are used to calculate the integration step and the original values are stored.

1. For the Runge-Kutta methods the values of the independent variable, state variables, auxiliary variables and flows are stored:
old_<state>:= <state>
old_<independent variable>:= <independent variable>
old_<aux>:= <aux>
old_<flow>:= <flow>
2. The calculation of the integration step is different for all three methods, e.g. for Euler:
<state> := <state> + d<independent variable>* (<inflow1> + <inflow2> - <outflow1> - <outflow2> etc.)
3. The state variables are in t_{n+1} and the independent variable is increased:
<independent variable> := old_<independent variable> + d<independent variable>
4. For the Runge-Kutta methods the auxiliary variables and flows are restored to their previous values:
<aux>:= old_<aux>
<flow>:= old_<flow>
5. The program part for events is added:
Once (condition) Do
<state>:= <expression in case of event>
EndDo
6. The auxiliary variables and flows are calculated in point t_{n+1} . They are added in order of their dependency. All other variables are known so we only look at dependencies on other auxiliary variables and flows when determining the order.
<aux>:= <expression>
<flow>:= <expression>
7. SaveData is automatically added at the end of the loop (not visible for users).

CHAPTER 7

Animations

Presenting data in graphs or in Data Table may not be enough for students to fully understand the underlying principles of a phenomenon. Coach 7 is enriched with another way of representing the data – Animations. Animations allow to visually represent models, to interact with models and control programs, they give visual feedback to measurements.

Coach animations consist of animated graphics objects, like ellipses, rectangles, vectors and images, which can be linked to model variables, program variables or sensor values to control their positions or sizes. The heart of an animation is a model, program or sensor data. This is the ‘engine’, which contains all the rules and formulas governing the variables involved and which leads to data as input for the animation. Parameters can be linked to control elements, like, buttons and sliders, which can be used for interactive change of conditions before or during the simulation.

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The Basics

The topics in this chapter will help you to get started with Animations.

Animation Toolbar

Animations have two modes of working:

- » **Play** mode, in which animations are executed, and
- » **Edit** mode (only possible in Author and Senior Student mode), in which animations are created and edited.

Each of the modes has its own Toolbar.

Play mode Toolbar



Hide/Show Properties to switch between Play mode (the Properties dialog is hidden) and Edit mode (the Properties dialog is shown)



Fit to Stage to fit the animation to the size defined by the pane or by the fit markers.

Edit mode Toolbar



Hide/Show Properties to switch between Edit (the Properties dialog is shown) and Play mode (the Properties dialog is hidden)



Insert Ellipse object - to create an animated ellipse (also: circle)



Insert Rectangle object - to create an animated rectangle (also: square)



Insert Vector object - to create an animated vector or line



Insert an Image - to create an animated image



Insert a Control Button - to add a control button



Insert a Control Slider - to add a control slider



Select Mode - to reposition objects on the Animation stage (either this mode or Rotate mode is operational)



Rotate Mode to rotate objects on the Animation stage (either this mode or Select mode is operational)



Insert an Annotation - to insert an annotation



Fit to Stage - to fit the animation to the size defined by the pane or by the fit markers



Interpret - to interpret a model and assign (initial) values variables controlling animation objects.

Animation Tool Menus

The Animation Tool menu is available after clicking the **Tool** menu button in the Animation pane or by right-clicking the Animation pane. The menus differ in Play and Edit mode. Also some areas of the Animation pane are sensitive (hotspots) and show a different tool menu.

PLAY MODE

Tool menu or right-click the Animation pane

» Click the **Tool** menu button  or right-click in the Animation pane.

Edit Title – to edit a title of the displayed animation

Run Controller – to display the Run controller

Reset Animation – to reset animation to its starting position

Zoom (50%, 75%, 100% 125% 150% 200%) – to zoom the animation stage

Zoom to fit – to fit the animation stage to the pane size or fit markers


Print – to print an animation canvas

Clipboard Copy - to copy the animation canvas as an image to the clipboard

Help – to consult the help system.

EDIT MODE

Tool menu or right-click in the Animation pane

» Click the **Tool** menu button  or an empty space in the Animation pane.

Edit Title – to edit a title of the displayed animation

Run Controller – to display the Run controller

Edit – to Undo and Redo the last user action

Center Coordinate System – to place the animation coordinate system in the center of the animation canvas

Hide Stage Rules – to hide or display the stage rules

Use Fit Markers – to use fit markers of the animation for the zoom to fit

Zoom (50%, 75%, 100% 125% 150% 200%) – to zoom the animation stage

Zoom to fit – to fit the animation stage to the pane size or fit markers

Animation Z-order - to display and modify the Z-order of animation objects

Print – to print an animation canvas

Clipboard Copy - to copy the animation canvas as an image to the clipboard

Help – to consult the help system.

Hotspot: an animation object

» Right-click a hot spot to evoke its menu.

Digital Display – to show a digital display next to a variable during the animation

Object Z-order – to modify the object's Z-order



Edit – to cut, copy or copy to Clipboard, delete and paste the object and undo and redo the last user action

Copy Position from – to copy the position used by another animation object.


Executing animation

Animations are executed in Play mode.

To execute animation(s)

- » Click the Activity Toolbar **Start** button  to run a model, control program or a measurement.
- » The animation(s) will be executed as long as the model or program is executed or as long as the measurement lasts.
- » If desired use the **Zoom to fit** button to fit the animation to the size of the Animation pane.
- » To interrupt execution use the Activity Toolbar button **Stop**  or keep **<Esc>** pressed.
- » Alternatively, the animation can also be controlled by using the **Run Controller** in a similar way as in Modeling. It can be placed in the screen by checking the option **Run Controller** in the Tool menu of the Animation pane or the Model window.
- » After the animation is finished you can reset it by right-clicking the Animation pane and selecting **Reset Animation**.


Managing Animations

An Activity may consist of several Animations. By clicking the Activity Toolbar button **Animation**  or the arrow next to it, you can see if there are more Animations present. An Animation can appear only once; it can be displayed in a pane or listed in the Animations list.


To move an Animation to another pane

- » Click the caption of the Animation pane you want to move.
- » Start to drag the caption; the cursor displays the Animation icon.
- » Move the Animation icon over a pane in which you want to place the Animation and click the pane.

To select another than the displayed Animation

- » Click the Activity Toolbar button **Animation** . Select an animation from the list and click **OK** to confirm.


or

- » Click the arrow at the right side of the button **Animation**  and select an animation.
- » The cursor displays the Animation icon.
- » Move the Animation icon over a pane in which you want to place the animation and click the pane.

To edit an Animation title

- » Click the Activity Toolbar button **Animation** . Select the desired animation and click **Edit**.


or

- » Click the Tool button of the Animation pane  and select **Edit Title**.
- » Enter a title. This title will be displayed in the Animation pane caption.


- » Click **OK** to confirm.

Author and Senior-student users may select but also create, delete and copy animations.


To add a new (empty) Animation

- » Click the Activity Toolbar button **Animation**  and select **New Animation**.
- » Type in an animation title and click **OK**.
- » A new animation is added to the list. Click **Edit** if you want to change the animation title.
- » Click **OK** to select the animation. The cursor displays the Animation icon.
- » Move the Animation icon over a pane in which you want to place it and click the pane.
- » A new (empty) animation is displayed in the pane.


or

- » Click the arrow next to the Activity Toolbar button **Animation**  and click **Add new**.
- » Type in an animation title and click **OK**.
- » The cursor displays the Animation icon.
- » Move the Animation icon over a pane in which you want to place it and click the pane.
- » A new (empty) animation is displayed in the pane.
- » Right-click an animation pane and select **Edit title** if you want to change its title.

To delete an Animation

- » Click the Activity Toolbar button **Animation**  and select an animation you want to delete and click **Delete**.
- » Confirm that you really want to delete the animation.

To copy an Animation

- » Click the Activity Toolbar button **Animation**  and select an animation you want to copy and click **Copy Animation**.
- » A duplicate animation appears in the list.

Elements of Animations

Coach animations are created on the . Animation Stage.

Each animation has its Background.

Animations consist of:

- » Animated Graphics Objects, like ellipses, rectangles, vectors and images, which can be linked to model variables, program variables or sensor values to control their positions or sizes.

Animation Stage

The Coach pane where the animation is placed is called the animation stage or simply the 'stage'. The stage consists of the Background and animation objects. All objects used in the animation are displayed under the drop-down list of the Properties sheet.

Stage Coordinate System

Each animation has one **stage coordinate system** which is defined in its Background properties (in pixels or other units).

Local (object) Coordinate System

Each animation object has its **own local coordinate system** defined in terms of the stage coordinate system. The position of this local coordinate system is defined by the location where the object is placed on the stage or, when controlled by variables, by the initial values of the connected variables. The object's coordinates are displayed then with respect to its local object's coordinate system.

It is also possible to use the stage coordinate system globally for all animation objects. Then all objects just share the stage coordinate system and do not have local coordinates systems.

Stage Rules

The stage rulers follow the coordinate system settings and display the size of the stage in the stage coordinate system units.

To hide/show the stage rulers:

- » The stage rules are displayed by default in Edit mode.
- » To hide the stage rules, right-click the Animation pane and select the option **Hide Stage Rulers**.
- » To show the stage rules again, right-click the Animation pane and select **Show Stage Rulers**.

Fit Markers

With the fit markers, the creator of an animation can specify a stage area which remains visible when zoom-to-fit is used. This is useful when the animation is run on a computer with a different screen resolution, or if an object is moving during the animation, to reserve some extra space in direction(s) of its motion.

To set the fit markers

To be able to set the fit markers the stage rules should be visible.

- » Right-click the Animation pane and select the option **Use Fit Markers**.
- » Specify a 'zoom-to-fit' stage area by moving dark gray bars on the stage rulers. The light gray bars define the area.

Note: After resizing the Animation pane you can have a problem to "find" the dark gray bars. To solve it first uncheck the option **Use Fit Markers** and then check it on again. After this action the markers adjust to the new Animation pane size and are easy to get.

Background

An animation always has a Background. All options regarding the properties of the background can be found in Edit mode after selecting Background from the drop-down list of the **Edit Properties** dialog.

Background: Coordinate System

Each animation has one **stage coordinate system**. The location of the origin (0, 0) of this stage coordinate system is given by the X and Y coordinates with respect to the lower left corner of the Animation stage. By default in a new animation the origin of the stage coordinate system is placed in the middle of the stage and the unit is 1 pixel. The stage rulers follow this system and display their values in the stage coordinate unit.

Change the location of the coordinate system

- » Drag the origin or one of the axes of the coordinate system displayed in the Animation stage (the cursor above the coordinate system changes into a hand).

Note: Be careful with dragging too much in the neighborhood of objects. Dragging objects has prevalence above dragging the coordinate system.

Or

- » Select **Background** from the drop-list of the Properties sheet.
- » Type the coordinates X, Y of the new origin in the respective **X** and **Y** fields of the **Coordinate System** tab.
- » The coordinate system origin can simply be re-centered by right-clicking the Animation stage and selecting **Center Coordinate System**.

Show - check if you want to display the stage coordinate system in Play mode.

Same system for all objects - check to use the stage coordinate system as the global system for all objects. It will then be not possible to define the objects' local coordinate systems. The options regarding local coordinate systems will disappear from the objects' properties.

Scale coordinate system - check to re-scale the stage coordinate system into other units than pixels.

Change the scale of the stage coordinate system

- » Check the **Scale coordinate system** option.
- » The scaling fields, from pixels into other units, appear. By default 100 px to +100 u.
- » A ruler displaying a distance of 100 px appears on the stage.
- » Type in a new scale and its unit (+ means that the direction is positive (from left to right), - means that the direction is negative (from right to left). You can drag the ruler on the stage to define the new distance in pixels.
- » After this is done all information in the objects' properties will be displayed in the new units. Also the stage rulers use the new scale.

Background: Display

Background Color

By default the color of the background is white.

- » To change the **Background color** click the color box and select a color from the Pick a Color dialog.

Background Grid

A grid can be displayed on the background.

- » To show a grid check the option **Grid** and type in the number of pixels/units between the grid lines.
- » Also the color of the grid can be changed.

Image

The Background can contain an image.

- » Check the option **Image**. Now several related options appear.
- » Click the **Browse** button and browse your computer to find a background image.
- » Click **OK**.
- » If needed specify other related options:

Has transparent color – check to indicate which color in the image becomes transparent.

Position on stage – displays the actual position of the image on the stage, the X and Y coordinates of its lower left corner in units of the stage coordinate system.

- » To place a image in another location on the stage type the new X and Y coordinates of the lower left corner of the image or move the cursor over the image on the stage, until it changes into a cross, and drag the picture to its new location.

Size – displays the size of the image (in stage units).

- » To change the size type new values for **Width** and **Height**.

Keep aspect ratio - check (on by default) to keep the ratio between width and height of the image constant during resizing of the image.

Reset - use to reset the image to its original dimensions.

Tile (Horizontally, Vertically, All directions) - check to place copies of the original background image to fill the stage (respectively in horizontal, vertical or both directions). The original image is indicated by a black frame around it.

Auto-fit - when selected then Coach resizes the image to fill the Animation stage. However, if also the option **Keep aspect ratio** is on, then Coach fills the smallest of either width or height, such that the aspect ratio stays the same.

Background type - a background image can be displayed stationary or can move during the animation, the following is possible:

- » stationary - the background image does not move,
- » looping- the background image moves in a horizontal or vertical loop,
- » zooming - the background image is zoomed in or out.

Moving the background image in a loop

If the option **Looping** is selected as the Background type then the background image can move in horizontal or and/or vertical direction in a loop. This motion can be controlled by a constant-rate factor, or by a variable. This is specified in the tab **Looping**, which appears after the background type is set to Looping. If the background image is tiled in the chosen direction(s) then a continuously unwinding background image can be created. To make this look realistic, the image should have suitable end points. So motion can be simulated, e.g. by creating a street with houses which moves with a constant rate (while the object itself can stay at the same place).

To control the motion of the background image

- » Select the reference point of the background image from where the motion takes place. By default the center of the image is taken.

- » Make a connection by selecting a **constant rate** or a **variable** from the list of available variables for the zoom.
- » Check **Local scale** to change the scaling of the motion by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).
- » **Note:** When **Constant rate** is chosen, local scaling can be used to fine-tune the speed of movement.

Zooming the background image

If the option **Zooming** is selected as the background type, then the size of the background image is either enlarged or diminished during the animation. This zooming motion can be controlled by a constant-rate factor, or by a variable. This is specified in the tab **Zooming**, which appears after the background type is set to Zooming.

To control the zooming of the background image

- » Select the reference point of the background image from where the zooming takes place. By default the center of the image is taken.
- » Make a connection by selecting a **constant rate** or a **variable** from the list of available variables for the zoom.
- » Check **Local scale** to change the scaling of the motion by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).
- » **Note:** When **Constant rate** is chosen, local scaling can be used to fine-tune the speed of zooming.

Animated Objects

There are four types of objects which can be animated on the animation stage:

- » Ellipse,
- » Rectangle,
- » Vector, and
- » Image.

Each Animated object has its own properties sheet which is displayed in Edit mode when the object is selected. Animation is achieved by letting the objects move across the screen, by changing their dimensions or by rotation.

Ellipse

This graphic object allows you to create an animated object, which has the shape of an ellipse or a circle.

POSITION TAB

With the options on this tab it is possible to control the position of the reference point of the ellipse during animation, or to rotate it.

Reference point (Center, Left center, Top center, Right center, Bottom center) - use to set the reference point of the ellipse. By default **Center** is used.

Origin of local coordinate system - the X and Y coordinates of the origin of the local coordinate system are specified in terms of the stage coordinates.

- » To relocate the Local Coordinate System type in the new **X** and **Y** coordinates of the origin in terms of the stage coordinates, or drag the local coordinate system to a new position on the stage (the cursor

above the coordinate system changes into a hand).

- » Check **Show** if you want to show the local coordinate system of the object in Play mode.
- » Click **Color** to change the color of the displayed object's coordinate system.

Note: When the stage coordinate system is used as the global coordinate system for all objects, the section **Origin of local coordinate system** is not shown.

Connections - the options in this section allow to define the object movement on the stage during the animation.

- » To define a screen movement in the horizontal direction select the connection (stationary or a connection to a variable) from the drop-down list under **Horizontal direction**.
 - » To define a screen movement in the vertical direction select the connection (stationary or a connection to a variable) from the drop-down list under **Vertical direction**.
 - » To define a rotary movement of an object around its center (**only**) as the reference point, select the connection (stationary or a connection to a variable) from the drop-down list under **Angular direction**. It is not possible to scale this connection locally; for rotation always real angles are used. : The animation uses the settings for degrees/radians as specified in the **Activity Options**.
1. When **Stationary** is selected, then the object does not move/rotate. The respective position - coordinate of the reference point, given in terms of the local coordinate system, is specified in the field next to the drop-down list. By default it is 0. An object can be relocated in its own coordinate system by typing a new value or dragging an object to a new location on the stage.
 2. When a connection to a **variable** is made then the selected variable controls the movement of the reference point of the object. The initial value of this variable determines the initial location of the object in its local coordinate system. This value is automatically received from the model, program or sensor.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DIMENSION TAB

With the options on this tab it is possible to control the size of an object during the animation.

Circle - select when you want use a circle instead of an ellipse. When selected some options disappear, definitions have to be done only for the circle radius.

Semimajor axis/Semiminor axis - allow controlling the dimensions of the object during the animation.

- » To define resizing in along the semimajor axis select the connection (stationary or a connection to a variable) from the drop-down list under **Semimajor axis**.
 - » To define resizing in along the semiminor axis select the connection (stationary or a connection to a variable) from the drop-down list under **Semiminor axis**.
1. When **Stationary** is selected, then the object does not change its size . The respective fixed dimension, given in terms of the local coordinate system, is specified in the field next to the drop-down list. The size can be changed by typing a new value or by resizing an object on the stage.
 2. When a connection to a **variable** is made, the selected variable controls the length along the respective axis. The initial value of this variable determines the initial dimension. This value is automatically received from the model, program or sensor.
Note: Mind that if the variable has a small value (or is equal to zero), the object will disappear from the screen. It can be reselected via the drop-down list in the Properties sheet.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging

the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DISPLAY TAB

This tab contains options connected to the way the object is displayed on the stage.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show digital display - check to display digital values of the connected variable(s) next to the object on the stage. The digital display can be dragged to any desired position with the mouse. The **Edit** button opens the dialog in which the digital displays can be specified per selected variable (e.g. if an object has several connections, you can specify which values to show).

Fill color - to select the inside color of the object. Check **Semi-transparent** to make an object semi-transparent. When **Gradient** is checked, the fill style of the object can be selected via the **Style** button. In this way a suggestion of 3D can be obtained.

Border color - defines the color for the object's border.

Border width - to set the width of the object's border or to hide the border (none).

Z-Order - to set the stacking order of objects in the animation. The Z-order can be changed by typing a new order value or by using the dialog which opens after pressing the **Change** button.

Show trajectory of - by checking this option the path of the selected point (default the reference point) is displayed on the stage during the animation. This option is only active if the object has a connection. When this option is marked then the Edit Style button appears. Clicking this button opens the dialog **Edit Trajectory Style** and allows specifying a **Color, Marker, Type** and **Line width** of the trajectory.

Trace every # steps - when checked then the object leaves a picture ('shadow') on the stage during the animation each given interval. The interval is defined by the number of time steps.

Only first frame - when checked only the start and end position of the object are marked.

Rectangle

This graphic object allows you to create an animated object, which has the shape of a rectangle or a square.

POSITION TAB

With the options on this tab it is possible to control the position of the reference point of the rectangle during animation, or to rotate it.

Reference point (Center, Left center, Top center, Right center, Bottom center) - use to set the reference point of the ellipse. By default **Center** is used.

Origin of local coordinate system - the X and Y coordinates of the origin of the local coordinate system are specified in terms of the stage coordinates.

- » To relocate the Local Coordinate System type in the new **X** and **Y** coordinates of the origin in terms of the stage coordinates, or drag the local coordinate system to a new position on the stage (the cursor above the coordinate system changes into a hand).
- » Check **Show** if you want to show the local coordinate system of the object in Play mode.
- » Click **Color** to change the color of the displayed object's coordinate system.

Note: When the stage coordinate system is used as the global coordinate system for all objects, the section **Origin of local coordinate system** is not shown.

Connections - the options in this section allow to define the object movement on the stage during the animation.

- » To define a screen movement in the horizontal direction select the connection (stationary or a connection to a variable) from the drop-down list under **Horizontal direction**.
 - » To define a screen movement in the vertical direction select the connection (stationary or a connection to a variable) from the drop-down list under **Vertical direction**.
 - » To define a rotary movement of an object around its center (**only**) as the reference point, select the connection (stationary or a connection to a variable) from the drop-down list under **Angular direction**. It is not possible to scale this connection locally; for rotation always real angles are used.: The animation uses the settings for degrees/radians as specified in the **Activity Options**.
1. When **Stationary** is selected, then the object does not move/rotate. The respective position - coordinate of the reference point, given in terms of the local coordinate system, is specified in the field next to the drop-down list. By default it is 0. An object can be relocated in its own coordinate system by typing a new value or dragging an object to a new location on the stage.
 2. When a connection to a **variable** is made then the selected variable controls the movement of the reference point of the object. The initial value of this variable determines the initial location of the object in its local coordinate system. This value is automatically received from the model, program or sensor.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DIMENSION TAB

With the options on this tab it is possible to control the size of an object during the animation.

Square - select when you want use a square instead of a rectangle. When selected some options disappear, definitions have to be done only for the square height.

Width/Height - allow controlling the dimensions of the object on the stage during the animation.

- » To define resizing horizontally select the connection (stationary or a connection to a variable) from the drop-down list under **Width**.
 - » To define resizing vertically select the connection (stationary or a connection to a variable) from the drop-down list under **Height**.
1. When **Stationary** is selected, then the object does not change its size . The respective fixed dimension, given in terms of the local coordinate system, is specified in the field next to the drop-down list. The size can be changed by typing a new value or by resizing an object on the stage.
 2. When a connection to a **variable** is made, the selected variable controls the length along the respective axis. The initial value of this variable determines the initial dimension. This value is automatically received from the model, program or sensor.
Note: Mind that if the variable has a small value (or is equal to zero), the object will disappear from the screen. It can be reselected via the drop-down list in the Properties sheet.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DISPLAY TAB

This tab contains options connected to the way the object is displayed on the stage.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show digital display - check to display digital values of the connected variable(s) next to the object on the stage. The digital display can be dragged to any desired position with the mouse. The **Edit** button opens the dialog in which the digital displays can be specified per selected variable (e.g. if an object has several connections, you can specify which values to show).

Fill color - to select the inside color of the object. Check **Semi-transparent** to make an object semi-transparent. When **Gradient** is checked, the fill style of the object can be selected via the **Style** button. In this way a suggestion of 3D can be obtained.

Border color - defines the color for the object's border.

Border width - to set the width of the object's border or to hide the border (none).

Z-Order - to set the stacking order of objects in the animation. The Z-order can be changed by typing a new order value or by using the dialog which opens after pressing the **Change** button.

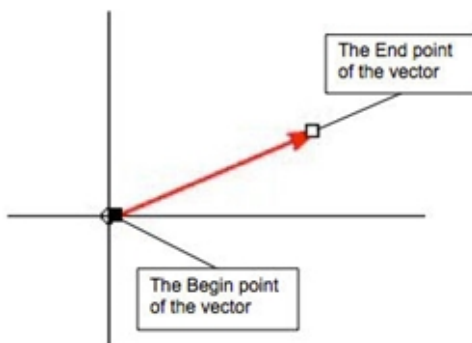
Show trajectory of - by checking this option the path of the selected point (default the reference point) is displayed on the stage during the animation. This option is only active if the object has a connection. When this option is marked then the Edit Style button appears. Clicking this button opens the dialog **Edit Trajectory Style** and allows specifying a **Color, Marker, Type** and **Line width** of the trajectory.

Trace every # steps - when checked then the object leaves a picture ('shadow') on the stage during the animation each given interval. The interval is defined by the number of time steps.

Only first frame - when checked only the start and end position of the object are marked.

Vector

This graphic object allows you to create an animated line or vector. The image below indicates the Begin and End points of the vector.



POSITION TAB

With the options on this tab it is possible to control the movement of the begin point of a vector.

Reference point - as the reference point the Begin point is used.

Origin of local coordinate system - the X and Y coordinates of the origin of the local coordinate system are specified in terms of the stage coordinates.

- » To relocate the Local Coordinate System type in the new **X** and **Y** coordinates of the origin in terms of the stage coordinates, or drag the local coordinate system to a new position on the stage (the cursor

above the coordinate system changes into a hand).

- » Check **Show** if you want to show the local coordinate system of the object in Play mode.
- » Click **Color** to change the color of the displayed object's coordinate system.

Note: When the stage coordinate system is used as the global coordinate system for all objects, the section **Origin of local coordinate system** is not shown.

Connections - the options in this section allow to define the movement of the vector begin point on the stage during the animation.

- » To define a movement in the horizontal direction select the connection (stationary or a connection to a variable) from the drop-down list under **Horizontal direction**.
 - » To define a movement in the vertical direction select the connection (stationary or a connection to a variable) from the drop-down list under **Vertical direction**.
1. When **Stationary** is selected, then the begin point does not move. Its position - coordinate of this point, given in terms of the local coordinate system, is specified in the field next to the drop-down list. By default it is 0. A vector's begin point can be relocated in its own coordinate system by typing a new value or dragging a vector to a new location on the stage.
 2. When a connection to a **variable** is made then the selected variable controls the movement of the vector's begin point. The initial value of this variable determines the initial location of the begin point in its local coordinate system. This value is automatically received from the model, program or sensor.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DIMENSION TAB

With the options on this tab it is possible to control the vector size during animation. The vector's dimensions can be displayed in Cartesian or Polar coordinates. In Cartesian coordinates the vector is described in terms of its X and Y components. In Polar coordinates the vector is described in terms of its length and angle.

X-component/Y-component - allow controlling the position of the end point of the vector during animation in Cartesian coordinate system.

- » To control the length of the vector horizontal component select the connection (stationary or a connection to a variable) from the drop-down list under **X-component**.
 - » To control the length of the vector vertical component select the connection (stationary or a connection to a variable) from the drop-down list under **Y-component**.
1. When **Stationary** is selected, then the selected vector component does not change its size. Its length, given in terms of the local coordinate system, is specified in the field next to the drop-down list. The length can be changed by typing a new value or by dragging the vector's end point on the stage.
 2. When a connection to a **variable** is made, the selected variable controls the selected vector component. The initial value of this variable determines the initial component length. This value is automatically received from the model, program or sensor.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

Length/Angle - allow controlling the position of the end point of the vector in Polar coordinate system .

- » To control the length of the vector select the connection (stationary or a connection to a variable) from the drop-down list under **Length**.

- » To control the angle of the vector select the connection (stationary or a connection to a variable) from the drop-down list under **Angle**. The animation uses the settings for degrees/radians as specified in the **Activity Options**.
1. When **Stationary** is selected, then the length/angle does not change. Their respective values, given in terms of the local coordinate system, are specified in the field next to the drop-down list. The vector's end point can be relocated in its local coordinate system by typing a new value or dragging the vector's end point to a new location.
 2. When a connection to a **variable** is made then the selected variable controls the selected the vector's length and/or angle. The initial value of this variable determines the initial length/angle. This value is automatically received from the model, program or sensor.
Mind that if the initial length is **zero**, the vector seems to disappear from the screen (its length is zero)!
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DISPLAY TAB

This tab contains options connected to the way the object is displayed on stage.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show digital display - check to display digital values of the connected variable(s) next to the object on the stage. The digital display can be dragged to any desired position with the mouse. The **Edit** button opens the dialog in which the digital displays can be specified per selected variable (e.g. if an object has several connections, you can specify which values to show).

Show arrow - check to display (by default on) an arrow head at the end of the line.

Show components - check to display horizontal and vertical vector components. The components will be drawn in the selected color.

Line color - defines the color of the line.

Line width - defines the width of the line.

Z-Order - to set the stacking order of objects in the animation. The Z-order can be changed by typing a new order value or by using the dialog which opens after pressing the **Change** button.

Show trajectory of - by checking this option the path of the **Begin point** or **End point** is displayed on the stage during the animation. When this option is marked then the Edit Style button appears. Clicking this button opens the dialog **Edit Trajectory Style** and allows specifying a **Color**, **Marker**, **Type** and **Line width** of the trajectory.

Trace every # steps - when checked then the object leaves a picture ('shadow') on the stage during the animation each given interval. The interval is defined by the number of time steps.

Only first frame - when checked only the start and end position of the object are marked.

Image

This graphic object allows to create an animated image. A desired image is selected via the **Open file** dialog.

POSITION TAB

With the options on this tab it is possible to control the position of the reference point of the ellipse during

animation, or to rotate it.

Reference point (Center, Left center, Top center, Right center, Bottom center) - use to set the reference point of the ellipse. By default **Center** is used.

Origin of local coordinate system - the X and Y coordinates of the origin of the local coordinate system are specified in terms of the stage coordinates.

- » To relocate the Local Coordinate System type in the new **X** and **Y** coordinates of the origin in terms of the stage coordinates or drag the local coordinate system to a new position on the stage (the cursor above the coordinate system changes into hand).
- » Check **Show** if you want to show the local coordinate system of the object in Play mode.
- » Click **Color** to change the color of the displayed object's coordinate system.

Note: When the stage coordinate system is used as the global coordinate system for all objects, the section **Origin of local coordinate system** is not shown.

Connections - the options in this section allow to define the image movement on the stage during the animation.

- » To define a movement in the horizontal direction select the connection (stationary or a connection to a variable) from the drop-down list under **Horizontal direction**.
 - » To define a movement in the vertical direction select the connection (stationary or a connection to a variable) from the drop-down list under **Vertical direction**.
 - » To define a rotary movement of an object around its center (**only**) as the reference point select the connection (stationary or a connection to a variable) from the drop-down list under **Angular direction**. It is not possible to scale this connection locally, for rotation always real angles are used. The animation makes use of settings of degrees/radians specified in the Activity Options.
1. When **Stationary** is selected, then the image does not move/rotate. The respective position - coordinate of the reference point, given in terms of the local coordinate system, is specified in the field next to the drop-down list. By default it is 0. An object can be relocated in its own coordinate system by typing a new value or dragging an object to a new location on the stage.
 2. When a connection to a **variable** is made then the selected variable controls the movement of the reference point of the object. The initial value of this variable determines the initial location of the object in its local coordinate system. This value is automatically received from the model, program or sensor.
 3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

DIMENSION TAB

With the options on this tab it is possible to control the size of an object during the animation.

Width/Length - allows controlling the dimensions of the image on the stage during the animation.

- » To control the width of the image select the connection (stationary or a connection to a variable) from the drop-down list under **Width**.
 - » To control the length of the object select the connection (stationary or a connection to a variable) from the drop-down list under **Length**.
1. When **Stationary** is selected, then the image does not change its size. The respective fixed dimension, given in terms of the local coordinate system, is specified in the field next to the drop-down list. The size can be changed by typing a new value or by resizing an object on the stage.
 2. When a connection to a **variable** is made then the selected variable controls the length along the respective axis. The initial value of this variable determines the initial dimension. This value is automatically

received from the model, program or sensor.

Note: Mind that if the variable has a small value (or is equal to zero), the object will disappear from the screen. It can be reselected via the drop-down list in the Properties sheet.

3. Check the **Local scale** option to change the scaling of the selected connection from the stage coordinate units to the local coordinate units. This can be done by typing values in the scale boxes, or by dragging the ruler displayed on the animation stage. Default 100 stage units means 100 new (variable) units (+ means the positive direction is to the right or up, - means the positive direction is to the left or down).

Lock aspect ratio – check to keep the ratio between the width and height of the image constant when resizing the image (default on). Use the **Reset** button to reset the image to its original dimensions.

DISPLAY TAB

This tab contains options connected to the way the object is displayed on stage.

Image file name - displays the name of the picture file. If the name is too long, a tooltip displays the full name (and path). Use the **Browse** button to replace the existing image by another image.

Has transparent color - check to define a transparent color in the image.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show digital display - check to display digital values of the connected variable(s) next to the object on the stage. The digital display can be dragged to any desired position with the mouse. The **Edit** button opens the dialog in which the digital displays can be specified per selected variable (e.g. if an object has several connections, you can specify which values to show).

Z-Order - to set the stacking order of objects in the animation. The Z-order can be changed by typing a new order value or by using the dialog which opens after pressing the **Change** button.

Show trajectory of - by checking this option the path of the selected point (default the reference point) is displayed on the stage during the animation. This option is only active if the object has a connection. When this option is marked then the Edit Style button appears. Clicking this button opens the dialog **Edit Trajectory Style** and allows specifying a **Color, Marker, Type** and **Line width** of the trajectory.

Trace every # steps - when checked then the object leaves a picture ('shadow') on the stage during the animation each given interval. The interval is defined by the number of time steps.

Only first frame - when checked only the start and end position of the object are marked.

Control Objects

Parameters e.g. a constant or a model initial value, can be assigned to Control objects. These Control objects are active during the animation; they allow the user to change parameter values during the animation and to observe the effects of these changes. There are two types of Control objects:

- » Button, and
- » Slider.









Each Control object has its own properties sheet which is displayed in Edit mode when the object is selected.

Button

This graphic object allows you to create a Control button, which has the shape of a button, a checkbox, a switch or a radio button. Such Control button can have two value states e.g. On and Off. Specific values are assigned to these two states.

DEFINITION TAB

Shape - use to select the shape of the control button. There are four shapes available:

- » **Button** - not pressed  /pressed 
- » **Checkbox** - not checked  State 0 / checked  State 1
- » **Switch** - Off  State 0 / On  State 1
- » **Radio Buttons** -  State 0
 State 1

Position on stage - the X and Y coordinates of the left bottom corner point of the button are specified in terms of the stage coordinates.

- » To relocate the control button type in the new **X** and **Y** coordinates of the left bottom corner point in terms of the stage coordinates or select the button on the stage, press and hold **<Ctrl>** and drag it to another location.

Dimensions - the width and height of the control button are specified in terms of the stage coordinates.

- » To change the control button size type in new values of **Width** and **Height** in the indicated unit or select the control button on the stage and drag to re-size it.
- » Check **Keep aspect ratio** to keep the ratio between the width and height of button constant during resizing.

Control parameter - use the option Variable to assign a parameter to the control object. As soon as a variable is selected from the drop-down list, the Range properties, State 0 (Off) and State 1 (On) appear.

- » Select a state value field and type in the value which should be used for the selected state.

DISPLAY TAB

This tab contains options connected to the way the object is displayed on stage.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show state names - check to display (by default on) the names of the states on the control object on stage. The **Font** button allows changing the font of the displayed states. If needed drag to a desired position.

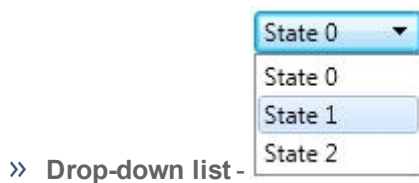
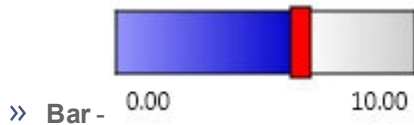
Show value - check to display the current state value next to the control object on the stage. The **Font** button allows changing a font of the displayed value. If needed drag to a desired position.

Slider

This graphic object allows you to create a Control slider, which has the shape of a slider, a bar, a spinner, radio buttons or a drop-down list. Such Control slider can have 'multiple states' to which values are assigned in a continues or a discrete way (only up to 25 values).

DEFINITION TAB

Shape - use to select the shape of the control slider. There are five shapes available:



Position on stage - the X and Y coordinates of the left bottom corner point of the slider are specified in terms of the stage coordinates.

- » To relocate the control slider type in the new **X** and **Y** coordinates of the left bottom corner point in terms of the stage coordinates or select the slider on the stage, press and hold **<Ctrl>** and drag it to another location.

Dimensions - the width and height of the control slider are specified in terms of the stage coordinates.

- » To change the control slider size type in new values of **Width** and **Height** in the indicated unit or select the control slider on the stage and drag to re-size it.
- » Check **Keep aspect ratio** to keep the ratio between the width and height of button constant during resizing.

Control parameter - use the option Variable to assign a parameter to the control object. As soon as a variable is selected from the drop-down list, the **Type** and **Range** properties appear. Use **Continues** if your slider needs to have many steps e.g. 100 steps and **Discrete** if only few states are needed e.g. 5 steps. For Radio buttons and Drop-down list shapes only Discrete type is possible.

- » For **Continues** specify the slider minimum value, maximum value, number of steps or step size used in the slider, and the number of decimals which will be used on its display.
- » For **Discrete** specify the number of steps (max. 25) and a value for each step.

DISPLAY TAB

This tab contains options connected to the way the object is displayed on stage.

Name - displays the object's name. To change type in a new name.

Show name - check to display the object's name next to the object on the stage. The **Font** button allows changing a font of the displayed name.

Show state names/Show range - check to display (by default on) the names of the states/ on the control object on stage. The **Font** button allows changing the font of the displayed states. If needed drag to a desired position.

Show value - check to display the current state value next to the control object on the stage. The **Font** button allows changing a font of the displayed value. If needed drag to a desired position.

Orientation - to select **Horizontal** or **Vertical** orientation of the control slider (not available for Radio buttons and Drop-down list shapes).

Empty color, **Full color** and **Pointer color** - can be defined for the Bar shape.

Color can be defined for the Drop-down list shape.

Animation Z-order

Each of the animation objects has its own Z-order which determines the arrangement of the objects on the stage. The object's Z-order is set automatically during the creation of the animation (and follows the order the objects are inserted); the background always gets Z-order 0, the first created object gets Z-order 1, the secondly created object gets Z-order 2, etc. The object with the highest Z-order is in front of all other objects, the object with the lowest Z-order is behind all objects (usually the Background), i.e. the arrangement of the objects determines which object covers which when they are moving over each other.

To change the Z-order of an object


- » In Edit mode, right-click the Background and select the Animation Z-order or right click an object and select **Object Z-order**.
- » The **Z-order** dialog appears which displays the list of the animation objects in the given Z-order.
- » Select an object.
- » Click **Backward** or **Forward** to move the object backward or forward in the arrangement.
- » Click **Delete** to delete the selected object.

Note: Placing objects behind the background assigns them a negative Z-order value. This can be useful if the background image covers only part of the stage.

Creating Animations

Creating an Animation



Animations are created in **Edit** mode. To open an animation in **Edit** mode :



- » In Play mode click the **Hide/Show Properties**  button .
- » The animation pane displays extended Toolbar and the **Edit properties** dialog.


Note: A newly created animation is opened in **Edit** mode.

Constructing an animation is an easy process: in general, define the animation background, choose the desired graphical objects, place them on the animation stage and assign their properties to define the way they are displayed and animated. Add additional interactive control objects and assign their properties. These control objects will allow altering parameter variables during the execution of the animation to interact with the system and to see the effect of those changes.


The steps below describe this process in detail:

1. Click the arrow next to the Animation button  and select **Add new** or click the **Animation** button  and click **New Animation** (present only for Author and Student user modes).
2. Enter a title of your new Animation and click **OK**. The shape of the mouse cursor changes into the animation symbol.
3. Click in a pane to place the animation, or click **<Esc>** to cancel.
4. The new animation opens in **Edit** mode. Only in this mode it is possible to construct and modify an animation. The Properties dialog for the **Background** is displayed directly on the screen.
5. Define the Animation stage.
6. Define the **Background**: the location of the stage coordinate system (default the center of the pane), color, grid, movement etc.
7. Place animated objects on the stage and connect them to a variable(s) to animate it:

- » **Ellipse and Rectangle:** Click the **Ellipse** button  or the **Rectangle** button  , the cursor shape changes into the small ellipse or rectangle symbol. Move the cursor into the stage to the roughly desired position and click. The ellipse/rectangle gets the default name *Ellipse 1/Rectangle 1*.

- » **Vector:** Click the **Vector** button  , the cursor shape changes into a small vector symbol, move the cursor into the stage to the roughly desired position, click and drag to form a vector. The begin point of the vector is displayed as a small black rectangle; the end point of the vector is displayed as a small white rectangle. The vector gets the default name *Vector 1*.




Note: If you just click and do not drag, a standard vector will be drawn with two components of 50 pixels each. You can change the size later by dragging its end point.

- » **Image:** Click the **Image** button  , in the **Open file** dialog select the desired image file and click **Open**, the cursor shape changes into a small image symbol, move the cursor into the Animation pane, position it and click. The picture gets the default name *Image 1*.

- » Notice that on the moment of placing a new object on the stage the origin of the object's local coordinate system goes through its reference point.

8. Define the properties of all .animated objects.

Note: If your new object makes use of the same Position properties (connections and scaling) as an already defined animated object, you can copy these properties by right-clicking the new object, choosing **Copy position from**, and selecting an already defined object from the list.

9. Place or , Place control objects, (Button or Slider), on the stage. Click a control button  or control slider , the cursor shape changes into a small object symbol, move the cursor into the stage to the roughly desired position and click. The control object gets the default name *Control 1*.

10. Define the properties of all control objects.

Editing an Animation

To open an Animation in Edit mode

» Click the **Hide/Show Properties** button  in the Animation Toolbar.

To select an object and display its properties

» Click an object on the animation stage or select the object's name from the drop-down list in the **Properties** dialog.

To edit an object properties

- » Select the object on the animation stage.
- » Edit its properties in the **Properties** dialog.

To move an animated object (Ellipse, Rectangle, Vector or Image) on the stage

- » Select the animated object on the stage.
- » Drag the object to its new position or type its new coordinates in the **Properties** dialog.

To move a control object (Button and Slider) on the stage

- » Select the control object on the stage.
- » Hold the **<Ctrl>** _ key and simultaneously drag the control object to its new position or type its new coordinates in the **Properties** sheet.

To delete an object on the stage

- » Select an object on the stage.
- » Press **** - key to delete it.

Useful shortcuts

- » With the menu option **Undo** or **<Ctrl>+<Z>** the last performed action is canceled.

CHAPTER 8

Spectrometer

Spectrometer activities are used to collect data from CMA Spectrometer and allow to record Emission and Absorption spectra over a range of 360 - 940 nm.


The topics in this chapter will help you to work with the Spectrometer.

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The Basics

How to open a Spectrometer Activity



You can open a Spectrometer Activity in Coach in the following ways:

- » **Quick Start:** click the  **Spectrometer** button in Dashboard and select the option **Recording Emission Spectrum** or **Recording Absorption Spectrum**.
- » Open an example of a Modeling Activity located in the **CMA Projects** in the **Spectrometer** folder.
- » Open a Spectrometer Activity prepared by your Teacher.

Spectrometer Window

The Spectrometer window displays a live image of the connected Spectrometer. After a spectrum has been collected the window can also display a recorded spectrum image. The tool menu offers specific tools and depends on the selected type of spectrum. When the Absorption spectrum is selected then the window also offers a simple Toolbar.

To display/hide the Spectrometer window

- » Click the Activity Toolbar button **Spectrometer**  to display the Spectrometer window.
- » Click the Activity Toolbar button **Spectrometer**  to hide the Spectrometer window.

When the live image of the spectrometer is selected it is possible to set:


- » **Measurement Slit** - a strip on the video image, in which the measurement is taken. It is visualized by a semi-transparent rectangle painted on top of the video screen. The strip can be set visually or via the **Settings** button or option.

» *To define the Measurement Slit on the video screen*

The default slit is 20 pixels wide.

You can move the whole slit to another place without changing its width. Note that this is possible only if the slit is wide enough. You can make the slit wider or narrower by dragging the slit's lower and upper lines. The slit cannot be made narrower than 5 pixels.

» *To define the Measurement Slit via the Settings option*

Click the Activity Toolbar button **Settings**  or select the option **Settings** from the Spectrometer window tool menu. Define the position of the split **Y** and its height **H**.

- » **Exposure** - to modify the brightness of a Spectrometer live image. On some computers (often Mac computers) this option is not available. In such cases you may influence the brightness of the live image by changing the distance between a Spectrometer and a light source.

Spectrometer Toolbar and Tool Menus

The Spectrometer Tool menu is available after clicking the Tool menu button in the Spectrometer window.

Toolbar of Absorption Spectrum



Record Dark Spectrum - press to record the dark spectrum



Record Dark Spectrum - indicates that the dark spectrum is already recorded, press to record a new dark spectrum (the previous spectrum will be overwritten)



Record Reference Spectrum - press to record the reference spectrum



Record Reference Spectrum - indicates that the dark spectrum is already recorded, press to record a new reference spectrum (the previous spectrum will be overwritten)

Tool menu of Emission Spectrum

Spectrometer – to select a connected Spectrometer and display its live image

Set Calibration– to display and modify the spectrometer calibration

Settings – to set the measurement slit position and height

Live Spectrum – to display the live image of the Spectrometer

Spectrum Image – to select and display a recorded spectrometer image. When such image is shown you cannot collect data, the Start button remains grey. The measurement can only be performed when a live image is being displayed.

Dock/Undock – to dock and undock the Spectrometer window

Print – to print the Spectrometer window

Clipboard Copy – to copy the Spectrometer window image to the clipboard

Help – to consult the Coach 7 Help System

Tool menu of Absorption Spectrum

Spectrometer – to select a connected Spectrometer

Set Calibration– to display and modify the spectrometer calibration

Settings – to set the measurement slit position and height

Live Spectrum – to display the live image of the Spectrometer

Spectrum Image – to select a recorded for each run a spectrum image. When a spectrum image is shown you cannot record a spectrum, the Start button remains gray. It is because the measurement can only be performed when live image is being displayed in the Spectrometer window.

Record Dark Spectrum – to record the dark spectrum. When this option is checked, it indicates that the dark spectrum is already recorded. When selecting this option again a new dark spectrum, which overwrites the previous spectrum, can be recorded.

Record Reference Spectrum - to record the reference spectrum. When this option is checked, it indicates that the reference spectrum is already recorded. When selecting this option again a new reference spectrum, which overwrites the previous spectrum, can be recorded.

Dock/Undock – to dock and undock the Spectrometer window

Print – to print the Spectrometer window

Clipboard Copy – to copy the Spectrometer window image to the clipboard

Help – to consult the Coach 7 Help System

The principle of the Spectrometer measurement

The Spectrometer acts as a camera and delivers a video image. The device's default video size is 1280 by 1024 pixels.

The principle of the measurement is to read rows of pixels from the video image and for each pixel compute the corresponding wavelength and light intensity. The place in the image to read the rows of pixels is defined by the **Measurement slit** which is displayed as a transparent rectangle on the video image. By default this slit is 20 pixels high and positioned in the middle of the video image but both its position and height can be changed via the option **Settings**.

Calibration of the Spectrometer defines the relationship between the wavelength in nanometers that corresponds to each pixel number of the video image (which is actually the x-coordinate of the pixel in the video image). Each Spectrometer device has its own specific 3-points calibration (pixel number and respective wavelength per calibration point) that are written at the bottom of the device. The default calibration is always asked at the first start of Spectrometer Activity and is done by typing the 6 numbers.

Light intensity values in % are determined based on the R, G, B values of pixels.

To avoid noise a several consecutive video frames (up to 20) can be used for averaging. This is done via the **Settings** option.

For Absorption spectra Transmittance and Absorbance are automatically calculated in Coach by using the following formulas:

Transmittance $T = I / (I_0 - I_d)$

Absorbance as $A = \log (1/T)$, where:

I_d - are light intensity values recorded for the dark spectrum (no source light present). These values are also stored as variable **I_d** in the data table (by default the variable is hidden).

I₀ are light intensity values recorded for the reference (for a cuvette filled with the solvent). These values are also stored as the variable **I₀** in the data table (by default the variable is hidden).

How to calibrate Spectrometer

Each Spectrometer device has its own specific 3-points calibration (pixel number and respective wavelength per calibration point) - 6 numbers are written at the bottom of the device. The default calibration is always asked at the first start of a Spectrometer Activity and is done by typing these 6 numbers.

To check or modify the spectrometer calibration





- » Select the tool menu option **Set Calibration**.
- » Check the numbers displayed in the dialog **Set the spectrometer calibration** with the numbers displayed at the bottom of your Spectrometer. If the numbers are different type in new numbers. Note that the new calibration will be in effect only for next measurements.



Recording Spectra

Recording Emission Spectrum

Activity of the type **Spectrometer > Emission Spectrum** allows to record and analyze Emission spectra from f.i. light bulbs or gas discharged tubes. In this type of Activity the graph of light Intensity I in % versus wavelength λ in nm is already predefined as graph I.

To record an Emission Spectrum

- » Connect a Spectrometer to a USB port of your computer.
- » Start Coach 7.
- » Create a new (only in the Author mode) or open an existing Activity of the type **Spectrometer > Emission Spectrum**.
- » If there is no live image shown in the Spectrometer window, click the tool menu option **Spectrometer >** and select the connected Spectrometer. When the Spectrometer is connected properly it should show a live image of Spectrometer. If this is not a case check your connection or start Coach again.
- » Select the tool menu option **Set Calibration**. Check if the numbers displayed in the calibration dialog are the same as the numbers written at the bottom of your instrument. If they are different overwrite the numbers present in the dialog by new numbers written an the bottom. Accept with **OK**.
- » Click the **Graph** icon  and select the **I** graph. Display the graph in one of the panes. Below the graph a strip with colors is displayed.
- » Direct your Spectrometer to a light source to get the image of a light source. If needed:
 - » Modify the **Measurement Slit** visually on the live video image or click the **Settings**  button. By default the slit is 20 pixels high and located in the middle of the image.
 - » In the **Settings** dialog modify the number of **Frames to average**. By default 1 is selected.
 - » Use the slider below the video image to set the **Exposure**. On some computers (often Mac computers) this option is not available. In such cases you may influence the brightness of the live image by changing the distance between a Spectrometer and a light source.
- » When you are satisfied with your image click the Activity Toolbar button **Start**  and record a spectrum. The first run appears in the graph and in the data table.
- » At the same moment a spectrum image is taken. To see the image click the tool menu option **Spectrum Image > Run 1**. Then the image is displayed in the Spectrometer window. The same image with the name **Spectrometer image for Run 1** is available after clicking the Activity Toolbar button **Image** . This image can be placed in any of the Coach panes.
- » If you want to record another Emission spectrum check if the live image is selected, if not then select it via the tool menu option **Spectrum Image > Live Image**.
- » Each time you click the **Start** button the data are collected again and a new run is added to the graph and data table, and a new spectrometer image is added to the list of images. Note that when a Run is removed then its respective image will be removed also.
- » Once you have collected your data you can analyze and process the data.
- » A very useful option for spectral analysis is the option **Show peaks value**. It finds peaks in the spectrum and label it with the respective values of wavelength. This option is not set by default on. To turn this option on:

- » click the Graph Toolbar **Graph Properties**  button or select the graph tool menu option **Graph Properties**,
 - » click tab **I**,
 - » check the option **Show peak values**, and
 - » click **OK** to accept. The peaks in the graph will be now labeled with the values of wavelength λ .
- » Save your results via the Activity Toolbar button **Save As** .

Recording Absorption Spectrum

Activity of the type **Spectrometer > Absorption Spectrum** allows to record and analyze Absorption spectra. In this type of Activity three graphs are already predefined: Light Intensity I in % versus wavelength λ , Transmittance T versus wavelength λ and Absorbance A versus wavelength λ .






In Coach Transmittance is calculated as $T = I / (I_0 - I_d)$ and Absorbance as $A = \log (1/T)$, where:






I_d - are light intensity values recorded for the dark spectrum (no source light present). These values are also stored as variable **I_d** in the data table (by default the variable is hidden).

I_0 are light intensity values recorded for the reference (for a cuvette filled with the solvent). These values are also stored as the variable **I_0** in the data table (by default the variable is hidden).

The CMA Spectrometer can also make absorbance measurements when used together with the CMA Light source with the built-in cuvette holder.

To record an Absorption Spectrum

- » Connect a Spectrometer to a USB port of your computer. Connect a Light source with cuvette holder to the Spectrometer.
- » Start Coach 7.
- » Create a new (only in the Author mode) or open an existing Activity of the type **Spectrometer > Absorption**.
- » If there is no live image shown in the |Spectrometer window click the tool menu option **Spectrometer >** and select the connected Spectrometer. When the Spectrometer is connected properly it should show a live image of Spectrometer. If this is not a case check your connection or start Coach again.
- » Select the tool menu option **Set Calibration**. Check if the numbers displayed in the calibration dialog are the same as the numbers written at the bottom of your instrument. If they are different overwrite the numbers present in the dialog by new numbers written an the bottom. Accept with **OK**.
- » Turn off the light source. Click the Toolbar button **Record Dark Spectrum**  or select the tool menu option **Record Dark Spectrum**. The icon displayed on the button changes into  and the option is checked - the dark spectrum has been recorded.
- » Insert a cuvette filled with the solvent (water). Click the Toolbar button **Record Reference Spectrum**  or select the tool menu option **Record Reference Spectrum**. The icon displayed on the button changes into  and the option is checked - the reference spectrum has been recorded.
- » You are now ready to record absorption spectra. Rinse the cuvette with the solution to be tested and fill it with the same solution. Insert the cuvette into the cuvette holder.
- » Click the **Graph** icon  and select the **A** graph. Display the graph in one of the panes. Below the graph a strip with colors is displayed.

- » In similar way you can also select the **T** and **I** graphs.
- » If needed:
 - » Modify the **Measurement Slit** visually on the live video image or click the **Settings**  button. By default the slit is 20 pixels wide and located in the middle of the image.
 - » In the **Settings** dialog set the number of **Frames to average** (by default 1 is selected).
 - » Use the slider below the video image to set the **Exposure**. On some computers (often Mac computers) this option is not available. In such cases you may influence the brightness of the live image by changing the distance between a Spectrometer and a light source.
- » When you are satisfied with your image click the Activity Toolbar button **Start**  and record a spectrum. The first run appears in the graphs of $A(\lambda)$, $T(\lambda)$ and $I(\lambda)$ and in the data table.
- » At the same moment a spectrum image is taken. To see the image click the tool menu option **Spectrum Image > Run 1**. Then the image is displayed in the Spectrometer window. The same image with the name **Spectrometer image for Run 1** is available after clicking the Activity Toolbar button **Image** . This image can be placed in any of the Coach panes.
- » If you want to record another Absorption spectrum check if the live image is selected, if not then select it via the tool menu option **Spectrum Image > Live Image**.
- » Each time you click the **Start** button the data are collected again and a new run is added to the graph and data table, and a new spectrometer image is added to the list of images. Note that when a Run is removed then its respective image will be removed also.
- » Once you have collected your data you can analyze and process the data.
- » A very useful option for spectral analysis is the option **Show peaks value**. It finds peaks in the spectrum and label it with the respective values of wavelength. This option is not set by default on. This option is not set by default on. To turn this option on:
 - » click the Graph Toolbar **Graph Properties**  button or select the graph tool menu option **Graph Properties**,
 - » click tab **I**,
 - » check the option **Show peak values** and
 - » click **OK** to accept. The peaks in the graph will be now labeled with the values of wavelength λ .
- » Save your results via the Activity Toolbar button **Save As** .

CHAPTER 9


Spreadsheet

Spreadsheet Activities are used to manually create a data set or to import data into the data table for example from a csv file. These kinds of activities make use of the Data Table, which consists of rows and columns that help sort and arrange data, and make calculations using mathematical functions available in Coach language.

Data from the Data Table can be then displayed in Graphs and analyzed by using the Analyze & Process tools. For details look into the chapter 'Working with Data' .

How to open a Spreadsheet Activity

You can open a Spreadsheet Activity in Coach in the following ways:

- » **Quick Start:** click the  **Spreadsheet** button in Dashboard.
- » Open an example of a Data-Video Activity located in the **CMA Projects** in the **Spreadsheet** folder.
- » Open a Spreadsheet Activity prepared by your Teacher.

CHAPTER 10

Working with Data

Data collected from measurements with sensors, video or image measurements, models and programs can be displayed in:

Data collected from measurements with sensors, video or image measurements, models and programs can be displayed in: Data Table, Graph(s), Meter(s) and Value(s) and processed with the help of advanced analysis and processing tools.

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Data Table

Coach automatically creates variables for the data collected via sensors, actuators, video measurements, generated by models, mathematical functions or entered manually. The data of these variables are stored and can be found as columns of the Data Table.

There is only **one** Data Table in an Activity/Result.



On starting a data collection, video measurement or a model the Data Table is filled with data.

The number of variables (data columns) is not limited in the Data Table.

A Run can maximally contain 500,000 rows of data.

A new Run is added in the Data Table after each new measurement run.

To display the Data Table

- » Click the Activity Toolbar button **Data Table**  to show or  to hide the Data-Table window.
- » By default the Data-Table window is placed on the top of Coach panes. To dock the window right-click the Data Table and select **Dock**. To undock right-click the Data Table or click its Tool menu and select **Undock**.
- » If the Data-Table window is too small to display all the columns, use the horizontal scroll bar at the bottom of the window to see each column or zoom the text in the table by using the Tool menu option **Text Zoom**.
- » To move through the rows of data, use the vertical scroll bar on the right side of the table.

The Basics

The topics in this chapter will help you to get familiar with the Data Table window.

Data Table organization

A Data Table is organized in the following way:

LEFT PART - displays Run Series, by default the run number and its name. Also Run Variables interpreted as run parameters (having one value per run), are displayed at this side of the table. Such variables are for example constant variables from a model or variables whose values are manually typed in. By default these parameter variables are hidden in the Data Table.

RIGHT PART - displays Data Series, often Time Series.

MIDDLE PART – links the left and right parts of the table and visualizes the connection between the Run and its Data Rows.

- » Click the '+' button to expand the selected Run to show all its Data Rows.
- » Click the '-' button to close it and to display the total number of Data Rows.
- » Move the horizontal divider to make the left side of the table wider.
- » Click the '+' button on the top to expand all runs, and the '-' button on the top to close all Runs.

Data-Table Toolbar

The Toolbar of the Data-Table window has the following buttons:



Zoom - to zoom text and digits displayed in the Data Table



Run Variables - to display properties of variables used in Run Series (the left side of the table)

 **Data Variables** - to display properties of variables used in Data Series (the right side of the table)


 **Insert** – to insert empty Runs in Run Series or empty Data Rows in Data Series

 **Delete** – to delete Runs in Run Series or Data Rows in Data Series

 **Add Variable** – to add Variables into Run Series or into Data Series

 **Delete Variable** – to delete Variables in the Data Table

 **Scan** – to scan data in the Data Table

 **Statistics** – to show statistics of all Variables in the Data Table

Tool Menu

The Data-Table Tool menu is available after clicking the Tool menu button in the Data-Table window (only when the Data-Table window is docked). Also some areas of the Data Table are sensitive (hotspots) and show a different tool menu.

Tool menu

Show Variable - to show/hide a Variable in Run or Data Series.

Add a New Variable - to add a new Variable into Run or Data Series.

Delete Variable – to delete a Variable (only possible for variables added by users)

Data Rows - to sort, delete and insert empty Data Rows into a Data Series.

Runs - to delete, import, export and insert new Runs.

Text Zoom - to zoom the fonts used in the Data Table.

Dock/Undock - to dock/undock the Data-Table window.

Print – to print the visible part of the table.

Clipboard copy - to copy the image of the visible part of the Data Table.

Help – to consult Help.

Hotspot: Variable header

Properties – to open the Variable Properties dialog.

Delete – to delete the Variable (only possible for variables added by users).

Hide – to hide the Variable.

Add a New - to add a new Variable into Run Series or Data Series, depending on which side of the table the option is selected.

Hotspot: Run number

Properties – to open the Run Properties dialog

Delete – to delete a Run.

Insert – to insert an empty Run.

Move Up - to move the selected Run up.

Move Down - to move the selected Run down.

Editing Data Table

To select a run

- » Click a Run number on the left side of the Data Table.

To open/close a Data Series

- » Click the '+' button to expand the selected Run to show all its Data Rows.
- » Click the '-' button to close it and to display the total number of Data Rows.

To select a Data Series

- » If a Data Series is closed click a row with information about the number of Data Rows on the right side of the Data Table.
- » If a Data Series is opened click a cell.

To make a selection

- » Click and drag the mouse pointer across ranges of cells in a table.

To select a Data Row in a Data Series

- » Click the '+' button to expand a Run in which you want to select Data Row.
- » Click the Data Row you want to select.

To select and edit a cell

- » To select a single cell click in the cell.
- » When possible, e.g. for manual variables, you can edit the cell.

To move a Variable column

- » Click the variable header of the column you would like to move.
- » Drag the variable icon to the border between the two variables columns. The area where to drop it is highlighted by the blue rectangle.
- » Drop the icon. The Variable will be placed between the two columns.

To move a Run

- » Click the number of the Run you would like to move and select **Move Up** or **Move Down**.
- » You can also move a Run by dragging its number up or down.

Working with Variables

Variables in Data and Run Series

Variables in Data Series

Variables displayed at the right side of the Data Table are Data-Series variables.

Such variables are for example time and temperature measured in an experiment with a temperature sensor, time and position measured in a video measurement or time and voltage used in a model.

The number of Data Rows per Run depends on sampling frequency in your measurement or time settings of

your video measurement or model.

For these Data-Series Variables additional calculation can be made.

Variables in Run Series

Variables displayed under Run Series, at the left side of the Data Table, are interpreted as run parameters (having a one value per run). Such variables are for example model constants or variables, which values are manually typed in. (Often these parameters e.g. model constants, are by default, hidden in the Data Table.)

For example in your experiment you measure voltage during the process of discharging a capacitor. In each measurement run you change the capacitor (capacitance value). Then you can add a manual variable 'Capacitance' to your Data Table and manually enter the capacitance value for each of your measurement runs.

Or you model the motion of a parachute jump and you simulate the motion depending on the parachute diameter. If the parachute diameter is defined in the model as a constant variable then it is interpreted as run parameter (by default not shown in the table). You can use **Simulate** option, available via the Tool menu of the Model window, and execute your model for different values of the parachute diameter. For each value of the parameter a new run is added to the table with the respective diameter value inserted into the table.

Displaying and Hiding Variables

Variables automatically generated by Coach cannot be deleted from the Data Table. For better visibility you can hide variables in the table. For this reason, by default some variables (such as Flow and Constant model variables), are hidden in the table.



To hide a Variable

- » Click the variable name (header) in the Data Table and select the **Hide** option. The variable will be removed from the table.

To show a Variable

- » Right-click the Data-Table window or click its Tool menu. Select **Show Variable** and depending on the position of the variable in the table select in **Run Series** or in **Data Series**. A list of all variables is displayed; the visible variables are indicated by the check symbol. Check a Variable which you want to show, and/or uncheck a Variable, which you want to hide.

or

- » Click the Toolbar button **Run Variable**  or **Data Variable**  and select a tab with the desired variable. Uncheck the **Hide** option.
- » The Data Table will be adjusted accordingly.

Adding and Deleting Variables

Adding a Variable into Data Series

Via the Hotspot menu

- » Click a variable name (header) at the right side of the Data Table and select **Add new**.
- » Select the connection: **Manual**, **Formula** or **AutoFill**.
- » The **Variable Properties** dialog appears. Fill in the properties of the new variable.
- » Confirm with **OK**.
- » A new variable will be added to the table and depends on the selected connection filled in the following way:
Manual: empty cells in which data can be directly typed in.

Formula: cells filled with data calculated based on the given formula.

AutoFill: cells filled with equidistant points in the given range and the number of rows present

Via the Tool menu

- » Right-click the Data-Table window or click its **Tool** menu.
- » Select **Add a new Variable** and select **into Data Series**.
- » Select the connection: **Manual, Formula** or **AutoFill**.
- » The **Variable Properties** dialog appears. Fill in the properties of the new variable.
- » Confirm with **OK**.
- » A new variable will be added to the table and depends on the selected connection filled in the following way:
 - Manual:** empty cells in which data can be directly typed in.
 - Formula:** cells filled with data calculated based on the given formula.
 - AutoFill:** cells filled with equidistant points in the given range and the number of rows present

Adding a Variable into Run Series

Via the Hotspot menu

Not possible when there is no variables under Run Series.

- » Click a variable name (header) at the left side of the Data Table and select **Add new**.
- » The **Variable Properties** dialog appears. Fill in the properties of the new variable.
- » Confirm with **OK**.
- » A new **Manual** type variable will be added to the left side of table and filled with empty cells, one cell per Run.

Via the Tool menu

- » Right-click the Data-Table window or click its **Tool** menu.
- » Select **Add a new Variable** into **Run Series**.
- » Select: **Manual**.
- » The **Variable Properties** dialog appears. Fill in the properties of the new variable.
- » Confirm with **OK**, a new **Manual** variable will be added to the left side of the Data Table. This variable has only one cell per Run.

Deleting a Variable

Variables automatically generated by Coach cannot be deleted from the Data Table. Only variables created by users can be deleted.

Via the Hotspot menu

- » Click a (user) variable name (header) in the Data-Table and select **Delete**.
- » Click **Yes** to confirm deleting the selected variable.
- » The variable will be removed from the table.

Via the Tool menu

- » Right-click the Data-Table window or click its **Tool** menu.
- » Select **Delete Variable**.
- » Click **Yes** to confirm deleting the selected variable.

- » The variable will be removed from the table.

Variables Properties

Each variable has its default properties: its connection, label, unit, number of decimals and color.

To change Variable Properties

- » Click a Variable name (column header) in the Data Table and select **Properties**. The **Variable Properties** dialog opens.
- » Specify the variable properties:
 - Connection:** The Connection shows to which data source the variable is coupled.
 - Label:** The unique variable name used in the column headers, graph axis labels and dialogs.
 - Unit:** The Unit follows the Label in the column headers and in graph labels. For some variables their units are defined via connected data and cannot be edited here e.g. the clock, sensor values or model variables.
 - Decimals:** The number of decimals used to display data in the table.
 - Scientific notation:** If checked then data in the table are displayed in scientific notation.
 - Color:** The Color applies to the column header, variable data in the table, graph labels/units and markers/line style used in graphs. Runs of the same variable are indicated by different shades of the selected color.
- » **Hidden:** the check box to hide or the variable in the Data Table.
- » Click **OK** to confirm or **Cancel** to cancel the changes.

Data Sources used in Connections

The Coach program automatically creates new variables for storing data and adds them to the Data Table. Depending on the type of Activity there can be different types of data connected.

Clock: The clock is the connection type, which represents time data in Measurement, Control and Data-Video Activities.

Time interval: The time interval gives the difference in clock values of two successive data points. This works in backwards form: the time interval value is assigned to the last point of the two, so its first point remains undefined.

Index : This connection represents the Data Row index and is used for example in Manual measurements.

Interface inputs and outputs: These connections depend on the used panel inputs/sensors and panel outputs/actuators. For example connection *A1: Light sensor* represents the data measured through the light sensor connected to input 1 of the interface.

P*: These connections are linked to video or image points. For example connection **P1X** represents the x coordinate of the video point P1.

Variables: These connections are linked to variables from a model or a program. For the text model and the control program only variables defined in the List of Variables are displayed.

Manual input: This connection type is used for:

1. manual type of measurements, Coach prompts to type the variable values each time the Manual Measurement button is pressed.
2. direct typing of the values in the cells of a column.
3. for data of not connected sensors (after a sensor with data was disconnected or removed)
4. furthermore, variables with imported data or variables, generated via some processing tools like Signal Analysis or Histogram, are automatically set to manual input.

Formula: This connection type is used to assign a formula to a variable and to perform calculations on data. To create a formula you can:

- » type a formula directly, the formula has to obey the Coach Language rules (recommended only for experienced users),
- » use the Formula Editor (available for Senior student and Author users),
- » use the Formula Wizard (available for Junior student users).

AutoFill data: This connection type automatically creates equidistant set of data. There two ways of defining the data fill:

- » via specifying the **Start** and the **Stop** values.
- » via specifying the **Start** and the **Step** value.

Coach will automatically generate equidistant points in the given range and fills the values into the number of rows present in a run.

Formula Editor

To create a formula you can use the Formula Editor (Senior student and Author users).

To create a formula with the Formula Editor

- » When applicable click the **Formula** or **Define** button to open the **Formula Editor** dialog.
- » Create the formula by selecting variables, operations, functions, and typing numbers.
- » For mathematical operations which use more than one parameter, e.g. Filter(X;n) or DerivativeSmooth(X;Y;n,), parameters are specified between brackets and are separated with semi-colon ';' (special mathematical functions). By default the cursor is placed in the position to type the first parameter. It is necessary to move the cursor to the next position for entering the next parameter.

In formulas values of constants can be entered directly from Coach. The program offers a database with pre-defined constants, which consists of the following fields: Symbol, Value, Unit and Quantity.

- » Click the **Constants** button.
- » Select a symbol, value, unit or quantity of a constant and click the **Select** button.
- » The value of the constant is placed in the formula at the cursor position.

Variables defined by formulas are automatically evaluated and if possible calculated. Such variables can also be defined before a run is executed, then they are calculated in real-time during measurements. For example: position is measured against time and velocity is prepared to be calculated with Derivative(t;x) formula. During the measurement, both the position and the velocity are displayed in real-time.

Notes:

- » Formulas should obey the rules of Coach Language.
- » For inexperienced users, it is recommended to use the formula editor rather than free typing.
- » Some of the mathematical formulas are placed automatically in the Data Table as a result of using processing tools in graph e.g. Derivative, Integral, Smoothing, etc.

Formula Wizard

To create a formula you can use the Formula Wizard (Junior student users).

To create a formula with the Wizard

- » Click the **Edit** button to open the **Formula Wizard** dialog.
- » Create the formula by selecting quantities from the list.

- » Select **Number** when you need to enter a number in your formula.
- » Select **OK** to close the Formula Wizard.

Copying Variable data from one Run to another Run

Different Runs of the same Variable can be nicely compared in the graph, but it is a rather qualitative comparison. To be able to make comparative quantitative calculations of the variable data for different runs it is possible to copy the data of a variable from a certain Run into another Run.

To copy a Variable data from one Run to another Run

- » Select a Data Series (at the right side of the table) or select a cell in a column of the Data Series from which you want to copy the data.
- » When you start to drag a variable header you want to copy e.g. **T(C)** the cursor changes into an icon representing the variable.
- » Continue dragging until you place the cursor over a run number e.g. 2 (to which you want to copy the data (at the left side of the table).
- » When the run number is selected release the icon. A new variable column with the heading **Copied T (C)** will be added to run 2. If desired you can edit the variable and change its name.

Working with Data Rows

Data Series in the Data Table consist of data rows. The topics in this chapter will help you to learn how to work with data rows.

Sorting Data Rows

This option rearranges the Data Rows in the Run according for the selected variable in ascending or descending order. Sorting is useful when the quantity along the x-axis of a graph does not consists increasing or decreasing series of values.

To sort data rows

- » Click the Data Row or make a selection of Data Rows in a run you want to sort.
- » Select the Tool menu option **Data Rows > Sort**.
- » Select a Run for which the data rows should be sorted. The Run, in which the cursor was located is pre-selected.
- » Select a Variable to be sorted. The variable, in which the cursor was located is pre-selected.
- » Accept **All Rows** or select the Data Rows to be sorted. If a selection of Data Rows was made these rows are pre-selected under the **Rows**.
- » Select the sort order: **Ascending or Descending**. The sorting process of a variable defined by a formula can take some time to complete.
- » Other variables values will be rearranged accordingly, so the data in the same row stays together.
- » Graphs, which use the variable(s) being sorted, are rearranged accordingly.

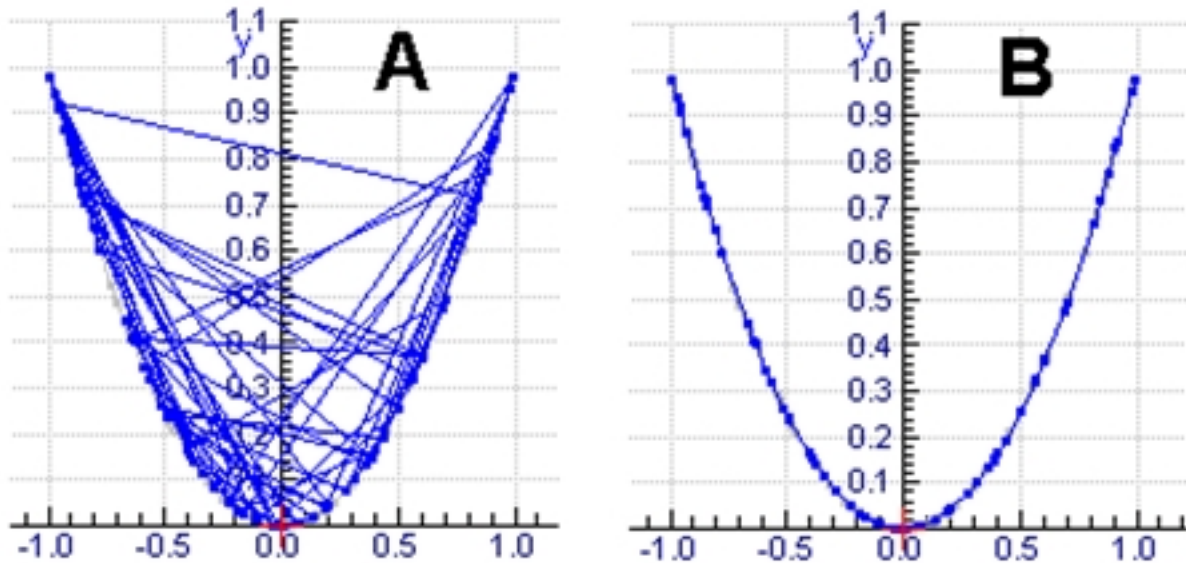
Note: Sorting is not possible for data collected via video measurement or measurement on stroboscopic images.

EXAMPLE

If the type of graph is set to Line, the points in the graph are connected point-to-point. When the values along the horizontal axis are not in increasing order, this setting will result in a messy diagram. Use the Sort option to remedy this problem.

As an example take the function $y = x^2$. In diagram A, this function has been drawn with its x-co-ordinates in

random order. In diagram B, this function has been drawn after sorting its x co-ordinates in ascending order.



Deleting Data Rows

This option deletes a number of Data Rows.

To delete Data Rows:

- » Click the Data Row or make a selection of rows.
- » Select the Tool menu option **Rows > Delete > Odd Rows of Run #** or **Even Rows of Run #** to directly remove odd or even data rows from the selected run.
- » Select the Tool menu option **Rows > Delete > User-defined rows of Run#** to specify the rows you would like to delete.
- » Select the Run for which the data rows will be deleted. The Run, in which the cursor was located is pre-selected.
- » Specify the first and the last row indexes. By default the indexes are taken from the selection. When desired, change the first and/or last row index.
- » If desired, specify the **Step** value for the rows to delete. The step value indicates the number of rows, which will be skipped during removal.
- » Mark either **Delete rows** (the selected rows will be deleted), or **Keep rows** (the non-selected rows will be deleted).
- » Click **OK** to confirm. The specified rows will be deleted from the table.

Inserting Data Rows

This option inserts a number of empty Data Rows.

To insert empty Data Rows

- » Click a cell of the row from where you want to insert empty rows or make a selection of rows at the point to insert empty rows.
- » Select the Tool menu option **Data Rows > Insert**.
- » Select a Run, for which the data rows will be added. The run, in which the cursor was located is pre-selected.

- » Specify the first and the last row indexes. By default the indexes are taken from the selection. When desired, change the first or last row index. These will be the row numbers of the inserted rows.
- » Click **OK** to confirm. The specified data rows are inserted and the existing data rows are shifted down.

Working with Runs

The topics in this chapter will help you to learn how to work with runs in the Data Table.

Run Properties

The **Run Properties** dialog display information about Run, its number and name and the number of Data Rows. It also allows to overrule the default color of a Run.

To change Run Properties

- » Right-click the Run number and select **Properties**.
- » Type in a name of the Run.
- » Select **Use special color** and select the color. This color will be used for graphs for all Variables in this run.

Renaming a Run

To change the run name

- » Click the **Name** field next to the run number and enter a name.

Or

- » Click the Run number, select **Properties** and enter a name in the **Name** field.

Deleting a Run

Each time a new measurement, video or image measurement or a model is executed via the Start button a new run is added to Run Series. Runs can be deleted via the Data-Table Tool menu or via the Graph Tool menu.

To delete a run:

- » Right-click the Data Table window or click its Tool menu and select **Runs > Delete**.

Or

- » Right-click the Run number and select **Delete**.

Or

- » Right-click the **Graph** pane or click its Tool menu and select **Delete Run**.
- » Select the Run you would like to delete. Options **All** and **All Except Newest** allow to delete all Runs or all Runs with exception of the latest Run.
- » The selected Run is removed from the table and the remaining Runs are renumbered. This action cannot be undone and the data of the deleted Run are lost.

Changing a sequence of Runs

The sequence of Runs in the table can be change, for example you can move Run 4 to position 1 to make it Run 1.

To move a run to another position

- » Click the Run number, select **Move Up** or **Move Down**. The run numbers will be adjusted.

Or

- » Select the Run number and drag it, when you start to drag the cursor changes into the run icon. Drag the icon above another Run, until the blue frame appears and drop it. The selected Run will be moved above that run. The run numbers will be adjusted.

Inserting an Empty Run

It is possible to manually add a new, empty run to the Run Series. This is useful when working with data manually.

To insert a run

- » Select the Tool menu option **Runs > Insert**.
- » Type in a number of rows for data in the new Run. Confirm with **OK**.
- » The new Run with the required number of rows will be created in the Data Table.

Importing Run

With the **Import Run** option data from another Coach 7 Activity or Result file can be imported. The dialog shows information about Runs and Variables present in the imported Coach file, and uses an “intelligent” way of matching variables from the imported file with variables in the Data Table of the current opened Activity.

To import Run

- » Select the Tool menu option **Runs > Import Run**.
- » Open the Coach file with data you want to import.
- » Specify the **Run** you want to import. Information about the Run name and number of Data Rows are given.
- » The detailed information about each variable is shown via tabs. Specify how to add the variables, you may:
 - » add as New **Manual** or **Formula** Variable depending on its original type,
 - » associate with existing in the Data Table variable, select a **Variable** to connect to from the list of variables present in the current Data Table,
 - » not import it.
- » In the **Import range** section specify the row indexes (one setting for all columns) to be imported. If desired, specify the **Step value** for the rows to be imported.
- » Mark either **Import selected** (the selected rows are imported), or **Import inverse** (the not-selected rows are imported).
- » Click **OK**. The specified data are imported as a new Run.

Importing CSV file

With the **Import CSV file** option data from CSV file can be imported into a new run. A CSV file (Comma-Separated Values) is a text file.

To import a CSV file into a run

- » Select the Tool menu option **Runs > Import CSV file**.
- » Open the file you want to import.

- » Specify the file structure and then proceed with the Define CSV file dialog.
- » Define the Text File structure:
 - » In the **File settings** section, specify the decimal separator, text qualifier and thousands separator.
 - » The **Row range and meaning** section gives the possibility to specify which rows to import (e.g. you can omit the rows which do not contain numbers) and how the first row(s) will be interpreted. It is possible that the original file uses the first one or two rows as a header, containing the quantity and unit of the column. Check the options as desired.
 - » In the **Column delimiters** section specify the column delimiter, i.e. the symbol, which separates the values of the various data in the file.
 - » Press **OK** to confirm your settings.
- » The **Import Data** dialog opens. In this dialog information about the imported file, such as the file name, the number of rows and the number of data columns, are given.
- » Click the column tab e.g. C1 to display quantity, unit, minimum and maximum. In the **Import as** section select the variable column to which the data from this column should be imported. If you do not want to import a column, select Do not import. If you want to import to a new Variable column select **New manual column**. If needed edit the suggested quantity, unit and number of decimals.
- » Repeat these steps for all columns of the imported file.
- » In the **Import range** section specify the row indices (one setting for all columns) to be imported. If desired, specify the **Step** value for the rows to be imported. The Step value indicates the number of rows, which will be skipped during import.
- » Mark either **Import selected** (the selected rows are imported), or **Import inverse** (the not-selected rows are imported).
- » Click **OK**. The specified data are imported as a new run.

Exporting into CSV file

With the option **Export CSV file** data from the Data Table can be exported into a CSV file.

To export a CSV file

- » Select the Tool menu option **Runs > Export CSV file**.
- » Specify the parameters in the **Define CSV File** dialog. This dialog is very similar to the dialog used for importing CSV file:
 - » In the **File settings** section, specify the decimal separator.
 - » In the **Header Rows** section you can specify how the first row(s) will be interpreted. The first one or two rows can be used as headers containing the quantity and unit of the column. Check the options as desired.
 - » In the **Column delimiters** section specify the column delimiter, i.e. the symbol, which separates the values of the various data in the file. Do not select a comma as separator when the comma is also used as decimal separator. The Result is a file, which will not be interpreted correctly by the other program. (If necessary, check your decimal separator in the Regional settings in Windows' Control Panel).
 - » Under **Run to export** select a run, whose data have to be exported.
 - » Press **OK** to confirm your settings.
 - » Save the file.

Often it is much simpler to export data via **Copy** and **Paste**. First make a selection, copy it and paste it into another program e.g. Excel or Notepad.

Graph

A graph is used to graphically display variables data to show the relation between them. Variables can be displayed along horizontal and left/right vertical axes. Graphs are automatically updated during data collection and for each new data collection a new data set - run is added to the graph(s).

Graph objects can be placed in panes. There can be many graphs in an Activity/Result.

The topics in this chapter will help you to learn how to work with graphs.

The Basics

The topics in this chapter will help you to get familiar with the Graph pane.


Displaying a Graph

Graph objects can be placed in panes. There can be many graphs in an Activity/Result.

To display a standard graph in a Measurement/Control Activity:

Sensor/Actuator not connected to an interface yet	Sensor/Actuator connected to an interface
<ul style="list-style-type: none">» Right-click an empty input/output position on the interface and select Display as a Graph.» Drag the Graph icon over a pane in which you want to place the graph, click this pane.» The resulting graph is a graph with the time (clock) along the horizontal axis and an "unknown input/output quantity" along the vertical axis. As soon as a sensor/actuator is connected to the respective input/output the graph is adjusted and shows the quantity measured by the connected sensor/actuator.» For Manual type of measurements, the row index replaces time along the horizontal axis.	<ul style="list-style-type: none">» Right-click a sensor/actuator icon located on the interface and select Display as a Graph.» Drag the Graph icon over a pane in which you want to place the graph, click this pane.» The resulting graph is a graph with the time (clock) along the horizontal axis and the quantity of the sensor/actuator along the vertical axis.» For Manual type of measurements, the row index replaces time along the horizontal axis.

To display a standard graph in a Data-Video Activity:


- » Click the **Graph** button  in the Activity Toolbar.
- » Video graphs, graphs with Cartesian coordinates of video point(s) e.g. Px and Py against time, are listed.
- » Select the desired graph .
- » Drag the Graph icon over a pane in which you want to place the graph, click this pane.

To display a standard graph in the a Modeling Activity:

- » Right-click on a variable symbol in the Model window and select **Display as a Graph**.
- » Drag the Graph icon over a pane in which you want to place the graph, click this pane.

- » The resulting graph is a graph with the independent variable along the horizontal axis and the selected variable along the vertical axis.

To display a ready-to-go (pre-defined) graph:

- » Click the Activity Toolbar button **Graph**  and select the graph from the list of all available graphs.
- » Drag the Graph icon over a pane in which you want to place the graph and click this pane.

Graph Toolbar

When a graph is placed in a pane, the pane offers a Graph Toolbar. This Toolbar provides quick access to some useful tools.



Text zoom - to set the fonts size of a graph label and scale used along graph axes.



Zoom to fit – to auto-scale the graph



Zoom out – to return to the previous graph state



Grid – to place or remove a grid on the graph



Graph Properties – to open the Graph Properties dialog



Sketch (on/off) – to turn on/off the sketching tool to draw a graph manually



Scan (on/off) – to turn on/off the scanning mode in which coordinates of the clicked points are displayed



Analyze/Process – to open Analyze/Process menu



Run# – to display/hide a run#

Graph Tool Menu

The graph tool menu offers options for editing graphs and tools for data analysis and processing.

Zoom to fit – to auto-scale the graph

Zoom out – to return to the previous graph state

Grid – to place or remove a grid on the graph

Graph Properties – to open the Graph Properties dialog

Show Run – to display and hide a selected run on a graph

Delete Run – to delete a selected run

Scan – to turn on the scanning mode in which coordinates of the clicked points are displayed

Stop Scanning – to turn off the scanning mode

Sketch – to turn on the sketching tool to draw a graph manually

Stop Sketching – to turn off the sketching tool

Add an Annotation – to add graph annotation(s)

Import Background Graph – to import a Coach Activity/Result file and place it in a graph as a background graph. When a graph is inserted as a background graph then the options to **Shift Background Graph** and **Delete Background Graph** are added

Analyze/Process – to select Analyze/Process options

Print – to print the Graph pane


Copy to Clipboard – to copy the Graph pane

Help – to consult Help

Displaying Runs

A graph can contain several measurement runs. Runs are distinguished by means of a shade of the variable color (specified in the Variable or Graph Properties dialogs). The latest Run gets the darkest shade. The Run buttons, displayed at the right side of the Graph Toolbar, indicate the number of available Runs.

To hide/show a run

- » Click on the active Run# button  to hide the run#.
- » Click on the inactive Run# button to show the run#.


Working with Graphs

The topics in this chapter will help you to learn how to work with graphs.

Creating a New Graph

A new graph can be easily created via dragging variable headings from the Data Table.

To add a new graph

- » Click the Graph button  in the Activity Toolbar and select Add new.
- » Drag the Graph icon over a pane in which you want to place the graph. Click this pane.
- » A "graph" with no variables assigned to its axes is created.
- » To assign its horizontal axis, drag a variable heading from Data Table (the cursor changes into the variable icon) to the bottom of the pane until a blue rectangle appears. Release the icon.
- » To assign its left vertical axis, drag a variable heading from Data Table (the cursor changes into the variable icon) to the left side of the pane until a blue rectangle appears. Release the icon.
- » To assign its right vertical axis, drag a variable heading from Data Table (the cursor changes into the variable icon) to the right side of the pane until a blue rectangle appears. Release the icon.
- » You can drag and place more variables along the left and right vertical axes, but only one variable can be used along the horizontal axis.
- » A created graph gets a default name Graph#. You can change the name via the **Graph Properties** option.

Modifying Graph Axis

To modify what is plotted on a graph move the cursor over a graph axis label, until a small rectangle appears around the label, and click the label.

- » To remove a variable displayed along the axis select **Remove**.
- » To replace a variable by another variable select **Replace by** and select a new variable from the list.

- » To add another variable displayed along the axis select **Add** and select a new variable from the list. Notice that this option is not present for the horizontal axis, along this axis only one variable can be selected.
- » Another way of adding another variable is dragging a new variable directly from Data Table.

Additional variables can also be added by dragging them from the Data table.


- » Drag the header of a column (with the variable name) to one of the axes in the chart. When a blue box appears, release the mouse and place the variable on the axis.
- » Multiple variables can be placed on the y-axis (left and right). Only one variable can be placed on the x axis.

You can drag a variable from axis of a graph and drop it to another axis of the same graph or drop it to an axis of another graph. Extra settings of that variable such as min and max, marker type or show peaks will be copied too.

Editing Graph Style

Each graph has its own style; you can change it via the Graph Properties option.

To edit graph properties:

- » Open the Graph Properties dialog:
 - click the Graph Properties  button in the graph Toolbar, or
 - right-click the graph or click its Tool menu and select **Graph Properties**, or
 - click a graph axis label and select **Graph Properties**.
- » Adapt the graph properties.
 - Name:** The graph name used in the caption of the Graph pane.
 - Show grid:** When marked, the grid is displayed in the graph.
 - Identical axes ratio:** When marked, the units along the horizontal and vertical axis in the graph use the same number of screen pixels. For example with the Identical axes ratio marked, a circle will be displayed as a real circular shape on the screen (rather than an ellipse).
- » Variables used along the graph axis are displayed via tabs. Click a tab to edit the variable properties and their style in the graph:
 - Label:** A unique variable name. This name is shared in graphs and Data Table (linked to each other).
 - Min/Max:** The minimum and maximum values limit the scale of the graph. Notice that the duration of a measurement is only determined by the measurement settings, not by the maximum of the time axis in the graph.
 - Color:** The color applies to the markers and line style used in the graph. The same color is also used for the name of the variable label and unit along the axes and for the Data Table.
 - Marker:** A marker used to mark the individual data points.
 - Notice if Marker = Small dot and Connection type=Line, the small dot is not visible (the dots are overlapped by the line). The same may apply to other markers when the line width is set to a thicker line.
 - Type:** A type (none, line, bar, block, histogram) specifies if and how individual data points are connected.
 - When Connection type = none, data points are not connected.
 - When Connection type = line, data points are connected by straight lines.
 - When Connection type = bar, data points are not connected to each other but via vertical lines to the horizontal axis.
 - When Connection type = block, data points are connected by the first horizontal line up to x position of the next point and then a vertical line.
 - When Connection type = histogram, data points are connected to the horizontal axis by a vertical bar. The bar is positioned in the middle the data point.
 - Line width:** A thickness of the graph line.
 - The setting of line width does not apply when Connection type = None.

Show peaks values: When checked the peaks of the variable showed in the graph are labeled with their respective values. This option is very useful when displaying spectra.

Notes:

- » If no graphs appear in the diagram, check whether both Marker and Type are set to None. With this setting, the particular graph will be invisible.
- » The defaults are Marker = Square 3x3, Type = Line and Line width = 1.

Background graph

A background graph is used to visually compare data in one graph. It is useful for instance for hypothesis testing in Modeling. A background graph can be created from the data stored in another Coach Activity/Result file. Contrary to regular graphs, the data of a background graph is not available in the Data Table: this graph is displayed as a picture only. It can be shifted horizontally, however.

To import a background graph

- » Right-click a graph to which you would like to add a background graph or select the Tool menu option **Import Background Graph**.
- » Open a Coach Activity/Result file in which the data are stored that you want to be displayed on a background graph.
- » Import Background Graph dialog opens. The Data source section displays the file name, the selected run and the number of data rows present.
- » Select the **Run** you want to use it.
- » Specify the variables which will be used along the horizontal and vertical axes of the background graph. If desired type in the respective variable labels. Select whether the data should be displayed along the **Left** or **Right vertical axis**.
- » In a similar way as for a normal graph specify the background graph style settings: its color, marker, type and line width.
- » Click **OK**. The background graph appears in the graph.
- » To delete the background graph select the Tool option **Delete Background Graph**.

To facilitate the comparison to a calculated or measured graph you can shift the background graph.

- » Select the Tool menu option **Shift Background Graph**.
- » Drag the graph to the left or the right with the mouse or with the arrow keys for pixel steps. Use **<Shift>-<arrow-keys>** for larger steps.
- » It is possible to zoom the graph during the shifting process, by pressing the **<Shift>** key.
- » Select **Stop Shifting Background Graph**.


Simple Analysis Tools

The Graph pane has a range of tools for adjusting its display and analyzing the data. These tools are available via buttons in the Toolbar of the Graph pane or via the Graph Tool menu. Some tools and options can be used only when there are data available.

The simple tools are: Grid, Zoom, Scan, Sketch, Annotating graph. Go to the 'Analyze/Process Tools' chapter to learn about advanced tools available in Coach.

Grid

The option Grid is used to place a grid on the graph.

- » Click the **Grid On**  button to show it and click it again to hide it.



or

- » Check/Uncheck the Tool menu option **Grid** to show/hide the grid on the graph.


Zoom

By zooming in an area of the diagram will be enlarged, e.g. for closer inspection. There are a couple ways of zooming.

Zoom to fit

- » Click the **Zoom-to-fit**  button , or select the Tool menu option **Zoom to Fit** to re-scale the horizontal and vertical axes to optimally display all graphs.
- » Click the **Zoom-out**  button , select the Tool menu option **Zoom Out** to return to the previous zoom state.

Zoom in/out a part of the graph

- » Move the cursor over the graph.
- » Click and drag a rectangle area to zoom in. The area will be enlarged to fill the whole diagram.
- » Click the **Zoom-out**  button to return to the previous zoom state.


Stretch or squeeze axes scales

- » Point to the scale markings just below the horizontal axis. When the pointer symbol changes to a horizontal double arrow  click and drag to stretch or squeeze the scale. You can repeat this as many times as you like.

- » In a similar way you can stretch or squeeze the vertical scale by pointing to the scale markings beside the vertical axes and dragging them up or down.

- » Click the **Zoom-out**  button to return to the previous zoom state.



Scroll axes

- » Point in the middle just below the horizontal axis. The pointer symbol should change to crossed arrows  . You can then use the mouse to drag the whole axis. A similar effect can be achieved for the vertical axis.
- » When the graph is zoomed in then scroll arrows appear along the diagram axes. By pressing an arrow button, the diagram scrolls in the direction of the arrow.

Scan

The option **Scan** is used to read co-ordinates of data points in graphs. A crosshairs in the graph marks the scanned point. The co-ordinates of all the points of active runs are displayed in a box in the upper right corner of the graph. This box can be dragged to another location.



To scan data points

- » Click the **Scan On**  button in the Toolbar or select the Tool menu option **Scan**.
- » Click a point of the graph and its co-ordinates are displayed. When there are more Runs or more variables displayed along the vertical axes the co-ordinates of all Runs/Variables are displayed. Move through the data points in the graph with the mouse or with the right and left arrow keys. The following is possible:
 - » Click/Drag - goes to the closest measured point in x direction.
 - » <Alt> + click/drag goes to the closest measured point in Euclidean metrics.
 - » <Ctrl> (on Mac <Cmd>) + click/drag allows to freely scan regardless of measured points and shows the coordinates of the cross using the first y-axis only.
 - » Holding <Shift> key allows zooming in Scan mode.
- » The co-ordinates can be moved to another position by dragging.
- » If you want to store co-ordinates, you have to write them down, or type them in a Student text pane. It is not possible in Coach to store the scanned co-ordinates automatically.
- » Stop scanning by clicking the **Scan Off**  button or by selecting **Stop Scanning** from the Tool menu.

Sketch

The option Sketch can be used to manually draw a graph. The drawing tool allows you to create your own graphs independently of sensors or keyboard data. It can also be used to draw prediction of a measurement graph; after the measurement run is executed, the shape of the predicted graph can be compared with the measured graph. Or such graph can be used as input data for an auxiliary variable in Modeling.

To sketch a graph

- » Make sure only one variable is displayed along the vertical axis.
- » Click the **Sketch On**  button in the Toolbar or select the Tool menu option **Sketch**.
- » Draw a smooth curve by dragging to the right (erase by dragging to the left) or click several points to draw a point-to-point graph. Double-click at a point in the sketched graph to erase the part of the graph beyond this point.
- » Stop sketching by pressing <Esc>, by clicking the **Sketch Off**  button or by selecting the Tool menu option **Stop Sketching**.
- » A new set of data, a new run named Sketch of variable with a variable Sketch var and a new run named Sketch, are added to the table. The Sketch variable is a manual type of variable and its data may be edited directly in the Data Table. By default the sketch graph is drawn in black color.

Annotating a Graph

It is possible to place descriptive labels - annotations in a graph. They can be used to label individual graphs or to point out interesting features. Annotations are displayed in the graph, but also appear when the graph is printed or copied to the clipboard.

To add an annotation

- » Select the Tool menu option **Add an Annotation**.
- » Type in text.

- » If desired click the **Font** button to change the text font and its color.
- » Select **Framed** to place your annotation in a frame.
- » Click **OK** to confirm or **Cancel** to return to the original graph.
- » Drag the annotation to the desired position of the graph.
- » When desired, repeat this procedure to create more annotations.

To edit/delete an annotation

- » Right click an annotation.
- » Select **Edit** or **Delete Annotation**.

Meter

A Meter is a scaled analog display; its pointer indicates the values generated by a variable. Each variable has its own default Meter display. Author and Senior student users can modify this display and store it in a Coach Activity/Result.

The topics in this chapter will help you to learn how to work with Meters.

Displaying a Meter

There are more methods of selecting a variable Meter:

Method 1.


In a Measurement/Control Activity:

- » Right-click a sensor/actuator icon located on the screen interface and select **Display as Meter**.
- » Drag the Meter icon over a pane in which you want to place the Meter and click the pane.

In a Modeling Activity:

- » Right-click of a variable symbol in the Model window and select **Display as Meter**.
- » Drag the Meter icon over a pane in which you want to place the Meter and click the pane.

Method 2

- » Click the Activity Toolbar button **Meter**  in the Activity Toolbar, a list of all available variable meters appears below the button.
- » Select a variable Meter from the list, the cursor changes into the Meter icon.
- » Drag the icon over a pane in which you want to place the Meter and click the pane.

Editing a Meter

(only possible in Author and Senior student mode)

The Meter pane offers a simple editor to modify the standard Meter.

- » Right-click the Meter pane or click its Tool menu and select Edit.
 - » Modify a default Meter to create your own Meter.
 - Name:** the name used in the Meter pane caption.
 - Display type:** the way the scale of a Meter is displayed. The following display types are available: Horizontal bar, Vertical bar, Quarter circle (90°), Half circle (180°), Full circle (360°).
 - Quantity:** the variable label of the Meter shown below its analog display (by default on).
 - Unit:** the unit label of the Meter shown between brackets next to the Quantity label.
 - Display:** the display shown in the upper part of the Meter pane, this part is always present.
 - Scale:** the scale of the Meter, by default shown on the Meter.
- For Quantity, Unit and Display colors can be set. When the lock is closed (default) then the same color is used for all.
- Min., Max.:** allow to define the range of the Meter's scale. For standard meters these values are read from the variable properties.
- The options **Background color**, **Body color** and **Pointer** define the Meter's colors.
- » Use the **Reset Name** button to reset the Meter name to its default name.
 - » Use the **Reset** button to reset your new Meter into a standard Meter.

Value

Value is a digital display, which displays values generated by a variable in large-sized numbers. Each variable has its own default Value display. Author and Senior student users can modify this display and store it in a Coach Activity/Result.

The following topics will help you to learn how to work with Values:

Displaying a Value

There are more methods of selecting a variable value:

Method 1.


In a Measurement/Control Activity:

- » Right-click a sensor/actuator icon located on the screen interface and select **Display as a Value**.
- » Drag the Value icon over a pane in which you want to place the value and click the pane.

In a Modeling Activity:

- » Right-click of a variable symbol in the Model window and select **Display as a Value**.
- » Drag the Value icon over a pane in which you want to place the value and click the pane.

Method 2

- » Click the Activity Toolbar button **Value**  a list of all available variable values appears below the button.
- » Select a variable value from the list, the cursor change into Value icon.
- » Drag the icon over a pane in which you want to place the Value and click the pane.

Editing a Value

(only possible in Author and Senior student mode)

The Value pane offers a simple editor to modify the standard value display.

- » Right-click the Value pane or click its Tool menu and select **Edit**.
 - » Modify a default value display to create your own display.
 - Name:** the name used in the Value pane caption.
 - Quantity:** the variable label shown above its digital display (by default on).
 - Unit:** the unit label shown between brackets next to its digital display (by default on).For **Quantity** and **Unit** labels colors can be set. When the lock is closed (default) then the same color is used for both.
 - Decimals:** the number of decimals used in the display. For very large or very small values the Scientific notation can be turned on.
 - Background color:** defines the background color used in the Value pane.
- » Use the **Reset Name** button to reset the value name to its default name.
 - » Use the **Reset** button to reset your new value into a standard value.

Analyze and Process Tools

The collected data can be processed with the help of advanced tools, which are available via the Tool menu of the Graph pane.

The Analyze/Process options work in a similar way. After selecting an option an extensive dialog that includes the graph and specific parameters is shown. The tools can be executed on one selected measurement run, and if more variables are displayed along the vertical axis, on one selected variable. At the bottom of the dialog box an explanation is given about what action is possible. The **Copy Window to Clipboard** button allows copying the displayed Processing dialog as an image for use in other programs.



The tools are divided into 5 groups depending on the results of these operations:

Slope Area Change Statistics	Original variable data will not be changed. The results of the calculations are temporarily shown in the Processing dialog. These results can be copied into text or other applications (e.g. MS-Word) via Copy to Clipboard.
Select/Remove Data Smooth	Original run data will not be changed. As the result of Select/Remove Data and Smooth > New Run a new run with new data is added to the Data Table and in the graph(s). As the result of Smooth > New Formula a new variable (based on the used smooth formula) is added to the Data Table for the selected run. When Apply to all runs is checked, the new variable is calculated for all runs. Also a new graph is created.
Function Fit	Original variable data will not be changed. As the result of this option: <ul style="list-style-type: none"> » a new variable, based on the resulting fit formula is added to the Data Table for the selected run, » a fit-function graph is added to the existing graph. The formula of the fit-function can be copied into text via Copy to Clipboard.
Derivative Integral	Original variable data will not be changed. As the result of these options: <ul style="list-style-type: none"> » a new variable, based on the resulting formula is added to the Data Table for the selected run, and when Apply to all runs is checked, the new variable is calculated for all runs, » a new graph is created.
Signal Analysis Histogram	Original variable data will not be changed. As the result of these options: <ul style="list-style-type: none"> » two new variables used along the axis of the new graph are added to the Data Table, » a new run is added and the new variables for selected run are added to this run, and - a new graph is created.

Slope

Use the **Slope** option to determine the slope of the tangent at any point of the displayed graph. This can be done manually (default setting) or automatically.


To determine a slope

- » Select **Analyze/Process> Slope**.
- » If your graph has more runs, select a run number under **Run**.
- » The red crosshairs indicate the selected point and the coordinates of this point are displayed below the graph.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**.
- » Select the point in which you want to determine the slope. For small steps use the right and left cursor keys. A black line is drawn through the selected point.
- » To find the slope **manually** rotate the line with the mouse or the up and down cursor keys to approximate the tangent. When you determine the slope manually then the only way is to do it by your own judgment; Coach does not indicate which slope is 'correct'.
- » To find a slope **automatically** click the **Slope**  button. The Coach program determines and displays the correct slope.
- » The slope value is displayed in the **Slope** field.
- » Click the **Copy to Clipboard**  button to copy the coordinates of the selected point and its Slope value to the clipboard, for use in text or another application.
- » Click **Close** to close the Slope dialog.

Change

Use the **Change** option to determine changes in data values in horizontal and vertical directions (implemented in version 7.7).


To determine an area

- » Select **Analyze/Process> Change**.
- » The diagram shows the green (start) and the red (end) boundary lines between which the change is calculated.
- » If your graph has more runs select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is blue and zoomed-to-fit. The other variable graphs (if any) remain gray.
- » Drag the boundary lines to the required position, or type the values for the boundary lines in the **Begin** and **End** fields. The black vectors show the horizontal and vertical changes in the selected light gray area.
- » The value changes in both directions are displayed in the **Change** fields.
- » The rate of change value is calculated and displayed in the **Rate** field.
- » Click the **Copy to Clipboard**  button to copy the **Begin**, **End** and **Change** values for horizontal and vertical directions and the **Rate** value to the clipboard for use in a text or another application.
- » Click **Close** to return to the regular Coach screen.

Area

Use the **Area** option to determine an area between the graph, the horizontal axis and the two boundary lines.

To determine an area

- » Select **Analyze/Process > Area**.
- » The diagram shows two red boundary lines between which the area is calculated.
- » If your graph has more runs select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is blue and zoomed-to-fit. The other variable graphs (if any) remain gray.
- » Drag the boundary lines to the required position, or type the values for the boundary lines in the **Begin** and **End** fields. The selected area is dark red.
- » The area value is displayed in the **Area** field.
- » Click the **Copy to Clipboard**  button to copy the **Begin**, **End** and **Area** values to the clipboard for use in a text or another application.
- » Click **Close** to return to the regular Coach screen.

Statistics

Use the **Statistics** option to display statistical information about the variable values of a selected run.

To display statistics

- » Select **Analyze/Process > Statistics**.
- » If your graph has more runs, first select a run number in the **Select Run** dialog.
- » The statistical information is displayed in the Statistic dialog. For each variable:
 - Number**: number of values
 - Max**: maximum value
 - Min**: minimum value
 - Average**: average value
 - Sum**: sum of all values
 - Sum sqr**: sum of the squared values
 - s(n)**: standard deviation based on n values
 - s(n-1)**: standard deviation based on n-1 values
- » Click the **Copy** button to copy the statistical information to the clipboard for use in text or another application.
- » Click **Close** to return to the regular Coach screen.

Select and Remove Data

Use the **Select/Remove Data** option to create a new run with the reduced number of points (version 7.3 or higher). A range of data or single points can be selected for removal or retention.

To select/remove data

- » Select **Analyze/Process > Select/Remove Data**.
- » If your graph has more runs select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is blue and zoomed-to-fit. The other variable graphs (if any) remain gray.
- » Select the selection method. Depending on the selected method red boundary lines (Range) or red crosshairs appear (Point-to point).
- » For the **Range** method: select the range by dragging the red boundary lines, or type the boundary values in the **Begin and End** fields.

- » For the **Point-by-point** method: select points on the graph by clicking. Use the cursor keys to walk from point to point. Click a selected point to deselect it. For the selection you can also use buttons: **All**, **None**, **Even** and **Odd**.
- » Select between **Keep selected** - all non-selected points will be removed or **Delete selected** - all selected points will be removed.
- » Click **OK** to confirm or **Cancel** to close the Select/Remove Data dialog without changes.
- » After confirmation a new run with the selected data rows will be added to the graph and data table.

Smooth

Use the **Smooth** option to create a smooth curve that fits (interpolates) a rough or limited number of points. This option offers three techniques of approximations: Moving average, Spline or Bezier.

Starting from Coach 7.4 the **Smooth** option has two possibilities:

- » **New Formula** - as the result a new Formula variable is added to the existing run. The new variable is calculated based on the formula used for smoothing:
 - » the Filter formula for the Moving average method,
 - » the Spline formula for the Spline method, and
 - » the Bezier formula for the Bezier method.

As the result a graph displaying a new "smoothed" variable is created. Coach draws a smoothed line, for which points are computed for each pixel and not only for the values on the horizontal axis. The line is not extrapolated outside the measurement points.

- » **New Run** - as the result a new Run with a modified set of data is added. The new data set may consist of more points than the original data set (only Spline and Bezier methods) and can successively be processed.

The Smooth option cannot be used on variables defined by formulas.

To smooth and create a new variable in the existing run

- » Select **Analyze/Process > Smooth > New Formula**.
- » If your graph has more runs, select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired variable under **Variable**.
- » Select the smooth method: **Moving average**, **Spline** or **Bezier**.
- » Specify the smoothing parameters:
 - For Moving average enter the desired **Filter width**.
 - For Spline leave the **Smoothing factor** to **Automatic** or enter the factor manually by selecting **Factor** and typing the desired value in the field.
- » Click **Plot** to calculate and display the smoothed graph. The resulting graph is displayed in red. If you are not satisfied with the result, change parameter settings and press **Plot** again.
- » **Apply to all runs** - when checked the same formula will be applied to all runs. Note that when you use Spline with the manually set factor then the same factor will be used in the formula for all runs, while the factor may "not work well" for other runs. If you leave the factor on **Automatic** then it will be automatically chosen for each run based on the data of that run.
- » Click **OK** to confirm or **Cancel** to close without any changes.
- » After confirmation a new variable defined by the used smoothing formula will be added as a new graph and in the data table.

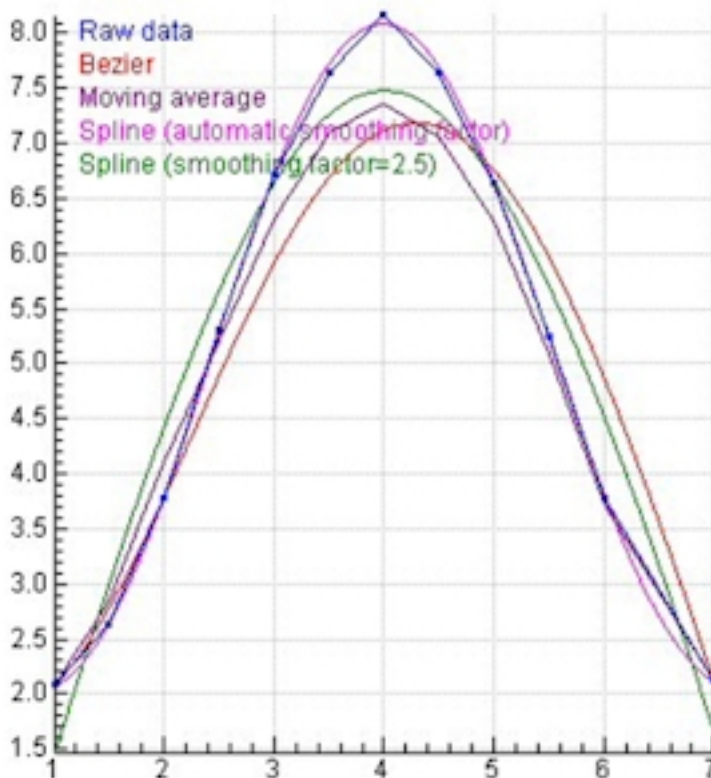
To smooth and create a new run

- » Select **Analyze/Process > Smooth > New Run**.

- » If your graph has more runs, select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired variable under **Variable**.
- » Select the smooth method: **Moving average**, **Spline** or **Bezier**.
- » Specify the smoothing parameters:
 - For Moving average enter the desired **Filter width**.
 - For Spline leave the **Smoothing factor** to **Automatic** or enter the factor manually by selecting **Factor** and typing the desired value in the field.
- » Click **Plot** to calculate and display the smoothed graph. The resulting smoothed graph is dark red. If you are not satisfied with the result, change parameter settings and press **Plot** again.
- » After confirmation, for the Spline and Bezier methods, the **Compute Data Points** dialog appears. Specify the number of points to compute. By default the number in the original run is given. The number of points can be increased up to 500 000 points.
- » Click **OK** to confirm or **Cancel** to close without any changes.
- » After confirmation a new run will be added to the graph and data table.

EXAMPLE

An example of several types of data smoothing. The graphs in the graph below show the effect of some smoothing techniques when applied to a small data set.



Moving Average

The **Moving average** method is used to reduce random noise in the graph. The result is a smoother graph that consists of the same number of points. Each point of the graph is replaced by the average value of a range of neighboring points. The filter width parameter determines how many points will be used to calculate the smoothed value. When filter width is set to n , each point is replaced by the average of itself, its n

predecessors, and its n successors (i.e., in Coach a central moving average filter is used whose filter range is $2n+1$ points). Moving averages are often used in time series analysis to eliminate short-term fluctuations in time series and highlight long-term trends and cycles.

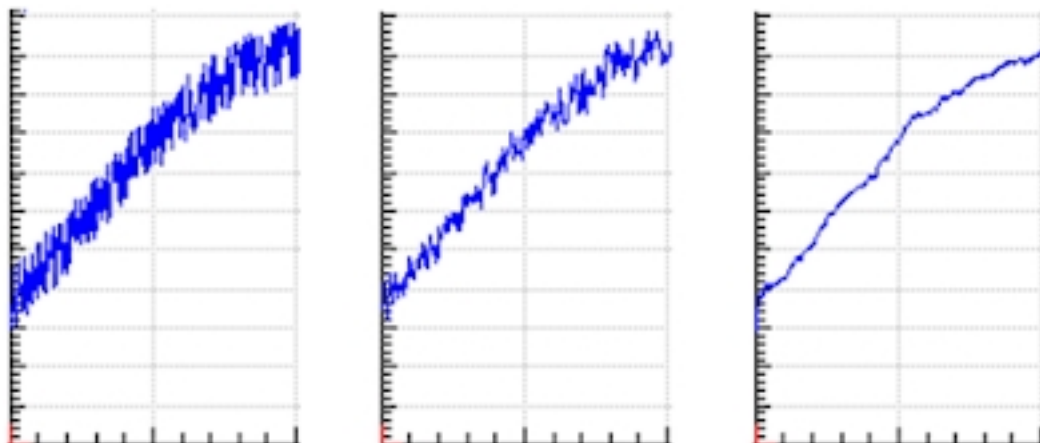
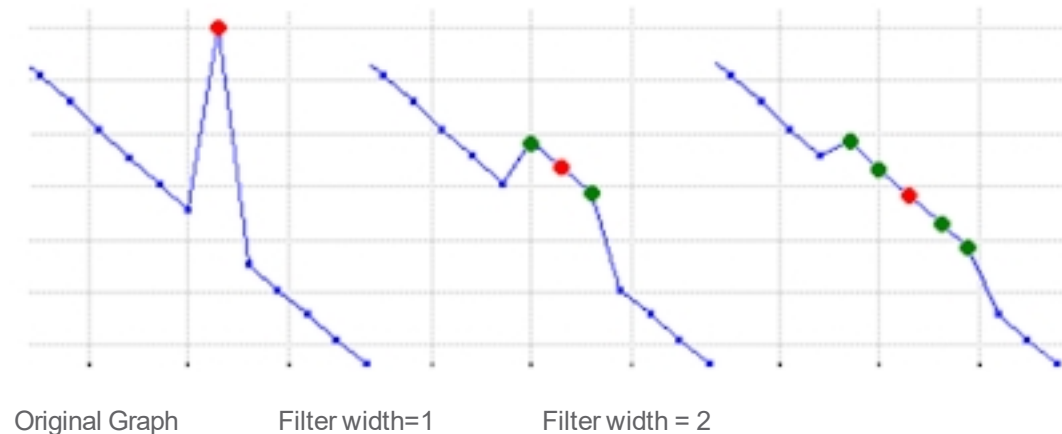
Filtering applied prior to taking the derivative leads to a far less noisy graph of the derivative. But beware, this method does not always provide enough smoothing to enable velocities and accelerations to be calculated and it has a broadening effect on sharp features, especially if the number of points in the moving average is large and the smoothing method is applied more than once.

Although moving average filtering is adequate for many purposes despite its simplicity, other data smoothing tools are needed in many cases.

- » If filter width is set low, the filtered graph may be hardly visible (as it falls together with the original graph), or not enough noise may be filtered out. If filter width is set too high, there is a risk that significant details of the original data are filtered out (especially near maxima or minima).
- » A better result may be obtained by filtering two (or three) times with Filter width = 2 than one time with Filter width = 5. When filtering several times, do not forget to select the last filtered graph under column.
- » Spikes (single points lying clearly outside the curve determined by the other points) can be removed by changing/deleting the value in the table cell. It works best in combination with Scan to pinpoint the spike in the diagram.
- » A variable calculated based on the formulae $Filter(VariableX;Interval)$ can also be added to the Data Table. In that case, the smoothed graph consists of the same number of data points as the source graph.

» **EXAMPLE**

The Filter width size determines the degree of filtering.



Bezier

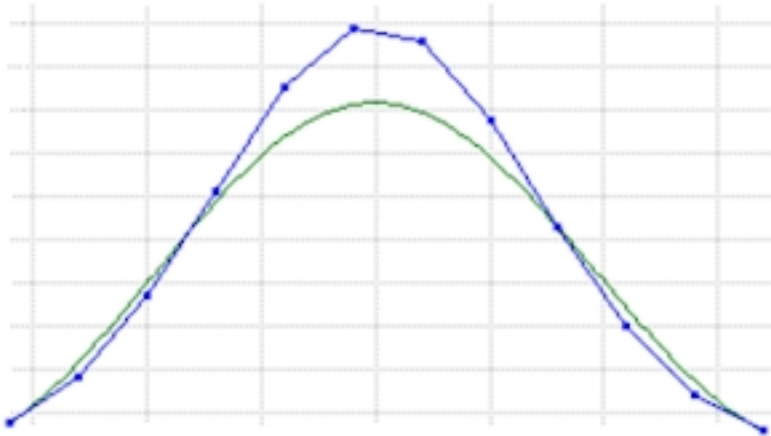
With a **Bezier** approximation, a curve is created that at least contains the first and the last of the original points. The shape of the calculated graph depends on the position of all the intermediate points. It tends to the original graph, but it will generally not contain the original points. For a Bézier approximation, the number of points in the graph must be less than 100 and greater than 2, and all values of the quantity along the horizontal axis must be in ascending order. You can reduce the number of points in a graph by using the **Select/Remove Data** option or by deleting rows from the Data Series.

The number of resulting points after the Bezier approximation can be as high as 500000.

- » A variable calculated based on the formulae $Bezier(VariableX; VariableY)$ can also be manually added to the Data Table. In that case, the smoothed graph consists of the same number of data points as the source graph.

EXAMPLE

The Bézier smoothing is forced through the first and the last original point. The intermediate points determine the degree of curvature of the graph.



Spline

The option **Spline** approximates a curve by means of a natural quintic spline, i.e., by a piecewise polynomial approximation of degree 5 that satisfies certain conditions of continuity, smoothness, and boundary. There is a smoothing factor that controls the trade off between fitting the raw data and minimizing the roughness of the approximation. A large value of the smoothing factor (infinity in theory) will result in the best parabolic fit of the data. If you decrease the smoothing factor, data smoothing becomes less important and the spline curve gets closer to the raw data. If the smoothing factor is set to zero, the natural quintic spline interpolation through the data points is obtained.

When **Automatic** is checked then the smoothing factor that determines the best compromise between data fitting and data smoothing is automatically calculated via a built-in method (generalized cross-validation criterion). The automatically chosen value is displayed (in gray) in the disabled text field **Factor**. If you want to set the smoothing factor yourself, check the radio button **Factor** and specify a smoothing factor.

The resulting number of points after the Spline approximation can be as high as 500000 (minimal number of points is equal to 8).

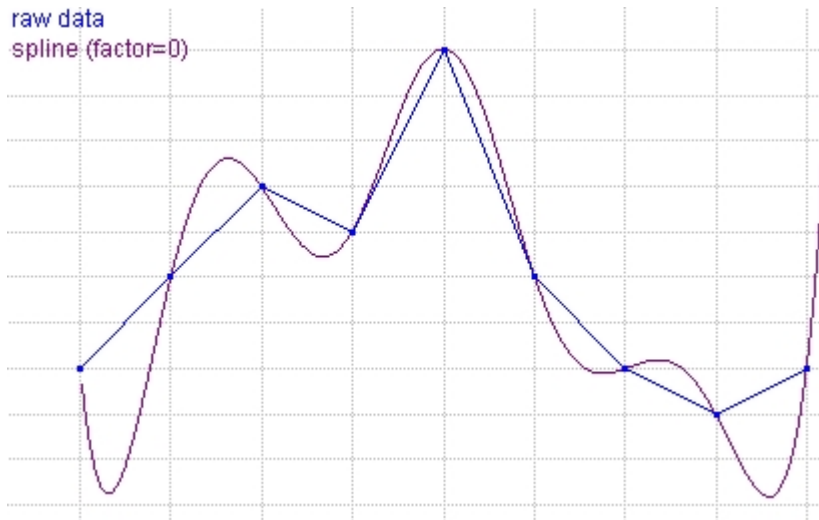
The Spline approximation is a powerful tool to deal with noisy data and to enable good derivative estimation. An important application of spline smoothing is the computation of derivatives that still have smooth graphs.

- » A variable, calculated based on the formulae *Spline (VariableX;VariableY;Factor)* can also be manually added to the Data Table. In that case, the smoothed graph consists of the same number of data points as the source graph. A negative value indicates the automatic choice of the smoothing factor.

EXAMPLE

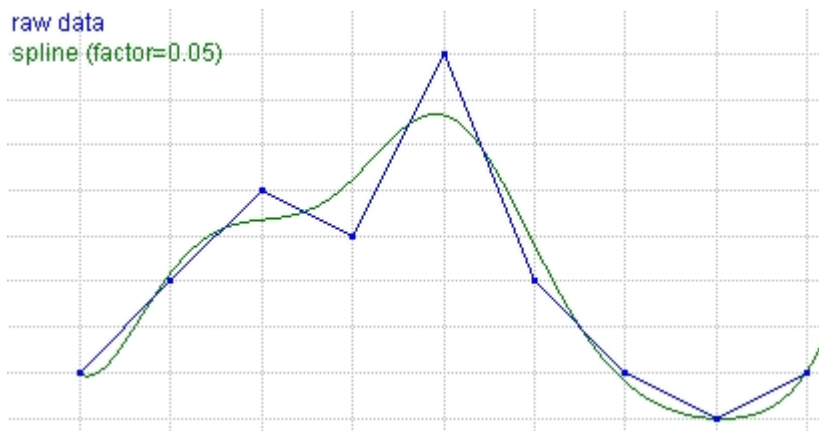
Smoothing factor = 0

the curve is a natural quintic spline curve through all original points.



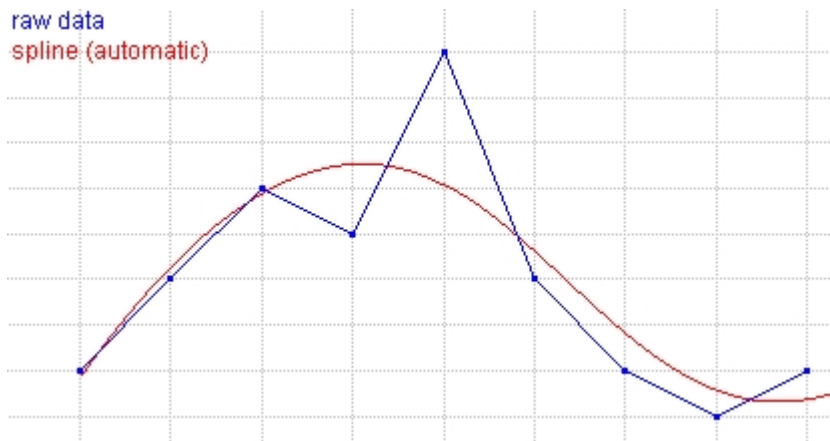
Smoothing factor = 0.05

the curve will not be forced through all original points and a compromise between data fitting and data smoothing is made.



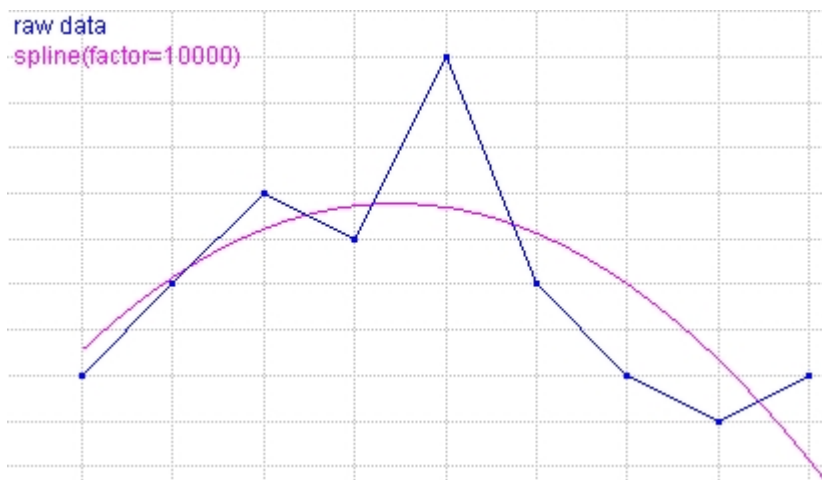
Smoothing factor = Automatic

the best compromise between data fitting and data smoothing via a built-in method (in this example, smoothing factor = 5.154).



Smoothing factor = 10000

very large values of the smoothing factor will lead to a parabola that fits the raw data best.



Function Fit


The **Function-fit** option is used to approximate the data in the graph with a standard mathematical function. You can choose from a large number of function types. The coefficients of the fit function are determined using a least-squares method.

Fitting can be done automatically or manually.

To determine a function fit automatically

- » Select **Analyze/Process> Function Fit**.
- » When starting function fit from a zoomed diagram, Coach will only use the visible part of the data for its fit.
- » If your graph has more runs, select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under Variable. The fit function is dark red.
- » Select the **Function type** that will be used.
- » Click the **Estimate** button, Coach automatically estimates the best initial parameter values of the function fit. In some cases this is already an optimal fit e.g., in case of linear regression.
- » Click the **Refine** button, Coach automatically refines the suggested fit (via the Levenberg-Marquardt method) to find the best function fit based on the initial parameter values. The quality of the fit, the

standard deviation of the fitted function from the original data, is indicated behind **Fit quality**. The lower the deviation, the better the quality.

- » You can interrupt the automatic fit process with **<Esc>**. Keep it pressed until the fit process stops. This may take a short while.
- » The coefficients of the function fit function are displayed in the **Coefficients** fields. By checking the **Fix** check box next to a coefficient, the coefficient will be "locked" and will not be changed during calculations. When a function coefficient(s) is fixed then only the Refine button can be used, the Estimate button is disabled (grey).
- » When you check the **Add annotation to graph** box the annotation with function fit information will be added to the original graph.
- » Click the **Copy to Clipboard** button  to copy the function fit information to the clipboard for use in text or an other application.
- » Click OK to **confirm**, or **Cancel** to close the Function-Fit dialog without changes.
- » After confirmation a new variable '*Fit of variable*run#' is added to the Data Table. The variable is calculated based on the formula of the fit function and is calculated only for the selected run.

Manual Function Fit

The manual function fit allows finding the coefficients of a fit function by translating and stretching it. This can be started any time during the fit process. It is used for example when the graph consists of a repeating pattern of exponential functions (you can try to fit the exponential fit function to one of the exponential parts of the graph), or to help an automatic fit get initialized. To obtain a reasonable result with manual function fit, it is often necessary to go a few times through a cycle of steps.

On the fit function, one point is marked with a pin, which can be moved along the fit function by dragging it. The pin can be opened or closed (by clicking on it). When the pin is opened, the fit function can be shifted; when the pin is closed the fit function can be shaped.

To determine a function fit manually

- » Select a point on the original graph by shifting the opened pin along the fit-function. If you cannot find a suitable point continue with the next step.
- » Shift the fit function itself by dragging with the mouse somewhere on the line (mouse cursor is a hand). Using the fit-function type $f(x)=a*x$, the pin stays fixed in the origin. In fact, this function can only be rotated.
- » Click the pin to 'close' it, i.e. to fix the fit curve at the pinpoint.
- » Shape the fit-function by dragging a point of the curve towards the pin or away from the pin. Dragging past the pin reverses some parameter values of the fit-function.
- » Repeat the above steps until a satisfying result is obtained.
- » When desired, press the **Refine** button to finalize the fit process.

Derivative

Derivatives are a measure of the rate of change of a quantity. They are often used in science to calculate among others the speed of processes. Use the **Derivative** option to plot the graph of the first derivative or the second derivative.

To calculate a derivative

- » Select **Analyze/Process> Derivative**.
- » If your graph has more runs, select a run number under **Run**.

- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is zoomed-to-fit.
- » Select a derivative order.
- » Select a method of calculating the graph of the derivative.
 - Differences method** – this method uses a difference of successive values from the variable displayed along the vertical axis, divided by the difference of the corresponding values in variable displayed along the horizontal axis (differential quotient). For data sets with a few points (up to 20), a boundary effect may become noticeable.
 - Smooth method** - first a smoothing spline for the raw data is computed, followed by an exact differentiation of the spline function. In most cases this method gives the best results, but is not set as default for two reasons: (i) it needs at least 7 data points and (ii) in case the automatically chosen smoothing factor is not useful enough, a user has to fine-tune the smoothing manually.
- » When desired change the **Label** and/or **Unit**.
- » Click **Plot** to calculate the Derivative graph. The red derivative graph is added; its variable is displayed along the right vertical axis. Both, the original graph and its derivative, are displayed optimally because of the independent scales.
- » Select **Apply to all runs** if you would like to calculate a derivative of the selected variable for all runs.
- » Click **OK** to confirm or **Cancel** to close the Derivative dialog without changes.
- » After confirmation a new variable with the name specified under Label is added to the Data Table. When **Apply to all runs** is checked (default settings), the new variable is calculated for all runs, otherwise the variable is calculated only for the selected run. The new derivative graph is created and the graph icon is shown after the dialog is closed. Move the graph icon above the pane in which you want to place the graph and click the pane to place the derivative graph there.

The new variable will then be evaluated in real time! So on a next measurement run the original data will be measured and its derivative will be calculated and displayed in real time. This is useful for measuring position-time, velocity-time (first derivative) and acceleration-time (second derivative) graphs, while actually only the position is measured.

Notes:

- » A variable, calculated based on the formulae $Derivative(VariableX;VariableY)$ or $DerivativeSmooth(VariableX;VariableY;Factor)$ can also be manually added to the Data Table. A difference quotient, which is an approximation of the derivative, can be added manually as $Deltafil(VariableY)/Delta(VariableX)$.
- » A variable, calculated based on the formulae $DerivativeSecond(VariableX;VariableY)$ or $DerivativeSecondSmooth(VariableX;VariableY;Factor)$ can also be manually added to the Data Table.

Integral

The **Integral** option is used to calculate the function (the primitive function) whose derivative is equal to the displayed graph. Such an integral function can be determined but for a constant - the constant of integration.

To calculate an integral graph

- » Select **Analyze/Process> Integral**.
- » If your graph has more runs, select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is zoomed-to-fit. The other variable graphs (if any) remain gray.
- » In the **Initial value** field enter the constant of integration. This is the value assigned to the quantity along the vertical axis for $x=0$.
- » When desired, change the **Label** and/or **Unit**.

- » Click **Plot** to calculate the integral graph. The red integral graph is added; its variable is displayed along the right vertical axis. Both, the original graph and its integral, are displayed optimally because of the independent scales.
- » Select **Apply to all runs** if you would like to calculate the integral of the selected variable for all runs.
- » Click **OK** to confirm or **Cancel** to close the Integral dialog without changes.
- » After confirmation a new variable with the name specified under Label is added to the Data Table. When **Apply to all runs** is checked (default settings) the new variable is calculated for all runs, otherwise the variable is calculated only for the selected run. The new integral graph is created and the graph icon is shown after the dialog is closed. Move the graph icon above the pane in which you want to place the graph and click the graph to place the integral graph.

The new variable will be then evaluated in real time! So on a next measurement run the original data will be measured and its integral will be calculated and displayed in real time.

Note:

- » A variable, calculated based on the formulae $Integral(VariableX; VariableY; Constant)$ can also be manually added to the Data Table.

Signal Analysis

The **Signal Analysis** option is used to find the frequency spectrum of a time-based periodical signal. The resulting values are presented as amplitudes of spectral components plotted against the frequency.

To determine a frequency spectrum

- » Select **Analyze/Process> Signal Analysis**.
- » If your graph has more runs, select a run number under **Run**.
- » If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**. The selected graph is blue and zoomed-to-fit. The other variable graphs (if any) remain gray.
- » In the Function type field select the method of signal analysis: **Fourier transform, Linear prediction, R-ESPRIT or Prony**.
- » Select **Linear** or **Logarithmic** for the intensity scale along the y-axis. A linear scale gives a good overview of the size of different signals compared to each other (not available for the R-ESPRIT and Prony methods). For a linear scale, the highest intensity has the value 1. A logarithmic scale, however, gives more information about how the sound signal will be perceived by the human ear, as the human sense of hearing has a logarithmic character. For a logarithmic scale, 0 dB corresponds to 1 mV.
- » Specify signal parameters:
 - **Linear Prediction (LP)**: enter the number of coefficients. This number determines the maximum number of peaks (formants), which will be found in the spectrum.
 - **R-ESPRIT**: enter the number of frequencies and the snapshot dimension. The number is determined by the ARMA model used in the spectral analysis and the maximum number of peaks in the spectrum. The snapshot dimension determines the autocorrelation matrix that is used in the R-ESPRIT method to estimate frequencies. The snapshot dimension can be determined automatically when the Automatic option is checked, or entered manually when the option Value is checked.
 - **Prony**: only enter the number of frequencies.
- » The value entered behind **Decimals** defines the number of decimals used for the frequency variable.
- » Click **Spectrum** to calculate the frequency spectrum for the specified settings. You can limit your time range dragging the red boundary lines or by typing the **Begin** and **End** values. The spectrum is drawn in dark red in a new graph. Coach automatically couples time and frequency units; if the time unit is seconds, minutes or hours, then the frequency unit will be Hz, if millisecond then the frequency unit will be kHz.
- » Click the **Data** button to return to the original graph.

- » Click **OK** to confirm or click **Cancel** to close the Signal Analysis dialog without changes.
- » After confirmation:
 1. The two new variables, Frequency f and Intensity I are added into the Data Table. The calculated values of frequency and intensity are entered and the variable is treated as the manual type. The data of these variables are present only in a new run described in the next point.
 2. The new run, named 'Analysis method of variable_{run#}', e.g. 'FT of x1 (can be read as Fourier Transform of run 1 of variable x), is added to the Run series.
 3. The new frequency spectrum graph is created and the graph icon is shown after the dialog is closed. Move the graph icon above the pane in which you want to place the graph and click the pane. A new graph displaying 'Intensity' along the vertical and 'Frequency' along the horizontal axis is added.

Some tips on Signal Analysis

- » If the signal contains frequency components, which are higher than half the sample frequency, then these samples can affect the displayed spectrum considerably.
- » For a successful use of Fourier Transform (FT) or Linear Prediction (LP) e.g. human voice studies, we recommend to choose a measuring time of less than 200 ms.
- » When applying LP to human voice signals it is not recommended to set the number of coefficients higher than 14, because the expected number of characteristic formants is at most 6.
- » The spectrums of FT and LP are normalized, i.e. the area below the graph is always set to a fixed number (presumably 1). If the original signal data does not have an average value of 0, then there is a so-called d.c. (direct current) frequency component. This component may take so much of the fixed area of the total spectrum that a lot of detail in the remainder of the spectrum may be lost. First create a shifted set of original data (by subtracting/adding a suitable number via a formula). Shift until the average value of the data is zero (the average value of a data set can be calculated via the option Statistics in a Table). Then the d.c. component will be zero as well, and all the 'energy' in the spectrum will be available for the frequency components. This process of shifting the data set to one that has zero mean value is called 'zero mean correction'. In R-ESPRIT this is automatically applied.
- » When analyzing musical tones (from instruments, or sung), the first frequency component in the spectrum is called the 'fundamental'. The higher frequency components (which are exact multiples of the fundamental frequency in pure tones), are called the 'harmonics'. Amongst others, the mixture and intensity ratio of the harmonics determine the timbre of the tone.
- » When the sample size is small only use R-ESPRIT or Prony and add the approximation to the original diagram from which the signal analysis was invoked to check the quality of the spectral estimation.
- » Experiment with the snapshot dimension in the R-ESPRIT method to see if you can improve the quality of the spectral estimation in case you are not quite pleased or want to obtain a better result. Try to minimize the sum of squared errors before you add the graph. Note that if the frequency estimates do not change much, the approximation will not change much either.
- » If you need more data for improvement of spectral analysis, you are advised not to sample at a higher frequency, but to measure for a longer time interval (if you can, of course). This reduces the variance of the frequency estimates.
- » If a signal is composed of more than 8 frequency components, you can subtract the computed approximation of the signal in the R-ESPRIT and Prony method from the original signal and continue the spectral analysis with this difference.
- » It is possible that very sharp peaks in the source function are not displayed on the screen.
- » When the number of coefficients in LP is set very high, the spectrum approaches the Fourier spectrum.
- » It is possible that the R-ESPRIT method leads to a numerical error message (connected with the definition of the artificial spectrum). Ignore such a message and choose another snapshot dimension to work with.

Histogram

The **Histogram** option is used to create a statistical histogram – a graph representing the distribution of the data. The range of the variable is divided into equal size bin, for which the frequency of occurrence is counted. The height of the graph bar is equal to the frequency of occurrence within the bin.

To determine a histogram

- » Select **Analyze/Process> Histogram**.
 - If your graph has more runs, select a run number under **Run**.
 - If your graph uses more variables along the vertical graph axis, select the desired graph under **Variable**.
- » Enter the **Lower** and **Upper** boundary values. The initially displayed boundaries are computed from the data. It is possible to type values here
- » Type the number of bins (default 5).
- » Click **Plot** to show the histogram graph, the red bar graph appears. If you are not satisfied with the result, change the parameters and press **Plot** again.
- » Click **OK** to confirm or click **Cancel** to close the Signal Analysis dialog without changes.
- » After confirmation:
 1. The two new variables, labeled 'Variable bins' and 'Number', are added into the Data Table. The calculated values are entered and the variables are treated as of the manual type. The data of these variables are present only in a new run, see below.
 2. A new run, named 'Histogram of variablerun#' e.g. 'Histogram of x1' (which can be read as histogram of run 1 of variable x), is added to the Run series. This Run has the number of rows equal to the number of bins.
 3. The new histogram graph is created and the graph icon is shown after the dialog is closed. Move the graph icon above the pane in which you want to place the graph and click the pane. The new histogram graph displaying 'Number' along the vertical and 'Variable bins' along the horizontal axis is added.

CHAPTER 11

Learning Content

Coach Activities can be enriched with multimedia learning content. Such learning content can be presented via the following objects: Text, Image, Video, Web page.

Additionally students can write their observations, answers and conclusions in Student Texts. These objects can be displayed in Coach panes.


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Texts

Texts are made by Author users for Student users and can consist of Activity descriptions, instructions for students or explanations.

Author users can create and edit these Texts only in Author mode. In this mode Author users can use the same text editor as for writing Student texts.

Student users cannot edit these Texts. To write their notes student users should use Student texts.

An Activity may consist of more Texts than the Text(s) shown on the Activity screen. By clicking the Activity Toolbar button Text  or the arrow next to it, you can see if there are more Texts present.

A Text can appear only once, can be displayed in a pane or listed in the Texts list.

The following topics will help you to work with texts:

Managing Texts

To browse through Texts

When there are more Texts you can browse through these in the Text pane. Coach follows the numbering or alphabetical order.

- » Click the forward  and the backward  arrow buttons in the Text pane caption.

Or

- » Right-click the Text pane or click the Tool button and select **Next** or **Previous** Text.


To move a Text to another pane

- » Click the caption of the Text pane you want to move.
- » Start to drag the caption; the cursor displays the Text icon.
- » Move the Text icon over a pane in which you want to place the Text and click the pane.

To select another than displayed Text

- » Click the Activity Toolbar button Text . Select a Text from the list and click **OK** to confirm.

or

- » Click the arrow at the right side of the button Text  and select a Text.
- » The cursor displays the Text icon.
- » Move the Text icon over a pane in which you want to place the Text and click the pane.

Text Tool Menu

The tool menu of the Text pane consists of the following options:

Next Text – to display the next Text

Previous Text – to display the previous Text

Copy – to copy the selected text

Select all – to select all text

Print – to print the Text pane (only the visible part of the text will be printed)

Clipboard Copy – to copy the Text pane to the clipboard


Help – to consult the Help system.

This menu is shown for Student Users.

For Author Users the tool menu is extended and is the same as the Tool menu of the Student text pane.

Images

Images are useful to illustrate phenomena, experiments or equipment.

An Activity may consist of more Images than the Image(s) shown on the Activity screen. By clicking the Activity Toolbar button **Image**  or the arrow next to it you can see if there are more Images present in the Activity.

The same Image can be displayed in more panes.

The topics in this chapter will help you to work with Images.

Managing Images

Senior-student users may select but also add and delete added images. These images will be saved in the Result file.


To move an Image to another pane

- » Click the caption of the Image pane you want to move.
- » Start to drag the caption; the cursor displays the Image icon.
- » Move the Image icon over a pane in which you want to place the Image and click the pane.


To select another than displayed Image

- » Click the Toolbar button **Image**  (in the Video-pane Toolbar or Activity Toolbar). Select an image from the list and click **OK** to confirm.

or

- » Click the arrow next to  and select an image from the list.
- » The cursor displays the Image icon.
- » Move the Image icon over a pane in which you want to place the image and click the pane.


To edit an Image title

- » Click the Toolbar button **Image**  (in the Video-pane Toolbar or Activity Toolbar). Select the desired image and click **Edit**.


or

- » Click the Tool menu option **Edit Title**.
- » Enter a title. This title will be displayed in the Image pane caption.
- » Click **OK** to confirm.


To add a new Image

- » Click the Toolbar button **Image**  (in the Video-pane Toolbar or Activity Toolbar) and select **Add**.
- » Browse to the desired image file and click **Open**.
- » A new image is added to the list. The file name is used as the title of the image. Click **Edit** if you want to change this title.

or

- » Click the arrow next to  and click **Add new**.
- » Browse to the desired image file and click **Open**.
- » The cursor displays the Image icon.
- » Move the Image icon over a pane in which you want to place the Image and click the pane.
- » A new image is displayed in the pane. The file name is used as the title of the image.
- » Right-click an image and select **Edit title** if you want to change this title.

To delete an Image

- » Click the Toolbar button **Image**  (in the Video-pane Toolbar or Activity Toolbar).
- » Select an image you want to delete and click **Delete**.
- » Confirm that you really want to delete the image.

To export an Image


- » Right-click or click the tool menu button  of the Image pane.
- » Select **Export Image**.
- » Browse to the location you want to store the image.
- » If desired enter the file name and click **Save**.

Image Toolbar

The Toolbar of the Image pane has the following buttons:



Zoom to fit - to zoom image to fit the Image pane



Open Image – to open an Image.

Image Tool Menu

The tool menu of the Image pane consists of the following options:

Edit Title – to edit the image title

Export Image – to export the image

Print – to print the Image pane

Clipboard Copy – to copy the Image pane to the clipboard


Copy Image – to copy the image

Help – to consult the Help system.

Videos

Videos are useful to illustrate phenomena, experiments or equipment, or to include different author's or students' podcasts.

An Activity may consist of more Videos than the Video(s) shown on the Activity screen. By clicking the Activ-

ity Toolbar button **Video**  or the arrow next to it, you can see if there are more videos present. The same video can be displayed in more panes.

The topics in this chapter will help you to work with videos.


Managing Videos

Senior-student users may select but also add and delete added videos. The videos will be saved in the Result file.


To move a Video to another pane

- » Click the caption of the Video pane you want to move.
- » Start to drag the caption; the cursor displays the Video icon.
- » Move the Video icon over a pane in which you want to place the Video and click the pane.


To select another than the displayed Video

- » Click the Toolbar button **Video**  (in the Video-pane Toolbar or Activity Toolbar). Select a video from the list and click **OK** to confirm.


or

- » Click the arrow next to Activity Toolbar button **Video**  and select a video.
- » The cursor displays the Video icon.
- » Move the Video icon over a pane in which you want to place the video and click the pane.


To edit a Video title

- » Click the Toolbar button **Video**  (in the Video-pane Toolbar or Activity Toolbar). Select the desired video and click **Edit**.


or

- » Click the **Tool** button of the Video pane  and select **Edit Title**.
- » Enter a title. This title will be displayed in the Video pane caption.
- » Click **OK** to confirm.


To add a new Video

- » Click the Toolbar button **Video**  (in the Video-pane Toolbar or Activity Toolbar). and click **Add**.
- » Browse to the desired video file and click **Open**.
- » A new video is added to the list. The file name is used as the title of the video. Click **Edit** if you want to change this title.


or

- » Click the arrow next the Activity Toolbar button **Video**  and click **Add new**.
- » Browse to the desired video file and click **Open**.
- » The cursor displays the Video icon.
- » Move the Video icon over a pane in which you want to place the video and click the pane.
- » A new video is displayed in the pane. The file name is used as the title of the video.
- » Right-click a video and select **Edit title** if you want to change this title.

To delete a Video


- » Click the Toolbar button **Video**  (in the Video-pane Toolbar or Activity Toolbar).
- » Select an video you want to delete and click **Delete**.
- » Confirm that you really want to delete the video.

To export a Video

- » Right-click or click the **Tool** menu button  of the Video pane.
- » Select **Export Video**.
- » Browse to the location you want to store the video.
- » If desired enter the file name and click **Save**.


Data-Video Toolbar

The Toolbar of the Video pane has the following buttons:

 **Zoom** - to zoom in and out a video, the **Auto Fit** option fits the video to the Image Panel window size (default setting).

 **Open Video** – to open a Video

 **Capture** - to open Capturing Video window to capture a video.

 **Annotation** – to add an annotation on video frame(s).

Video Control Bar

The Video Control Bar is located at the bottom of the Video pane and offers Playback controls to control a video file.

From left to right:

00.00.00.00 – time information

1 - a number of the current selected frame

 Go to the **first frame** of a video

 Go to the **previous frame** of a video



Play a video - on slower computers "large" videos may play slower than in real time. On faster computers videos should play correctly provided no perspective correction is used.



Pause a video



Go to the **next frame** of a video



Go to the **last frame** of a video



Playing speed – to adjust the speed of playing video. 1000% means that the video will be played 10 times faster than the default (100%) setting.

Use the green **Start** marker and the red **End** marker to set the start and end of the video. The orange marker indicates the currently displayed video frame.

Video Tool Menu

The tool menu of the Video pane consists of the following options:

Edit Title – to edit the video title

Adjust – to adjust the video

Export Video – to export the video file

Print – to print the Video pane

Clipboard Copy – to copy the Video pane to the clipboard

Copy Frame – to copy the image of the selected frame

Help – to consult the Help system.


Only for Measurement and Control types of Activities when the video was recorded synchronized with measurement:

Synchronized Replay- when selected then after clicking the Replay button the video will be replayed synchronized with the measurement.

Adjust synchronization - allows to adjust the synchronization between the start of the measurement and the start of the synchronized video.

Web Pages

Web pages can offer extra teaching and learning (on-line) resources for students. The Web Page pane has a built-in simple browser.

An Activity may consist of more Web pages than the Web page(s) shown on the Activity screen. By clicking the Activity Toolbar button **Web Page**  or the arrow next to it you can see if there are more web pages present.

The same web page can be displayed in more panes.

The topics in this chapter will help you to work with web pages.


Managing Web Pages

Senior-student users may select but also add and delete added Web pages. The Web pages will be saved in the Result file.


To move a Web page to another pane

- » Click the caption of the Web page pane you want to move.
- » Start to drag the caption; the cursor displays the Web page icon.
- » Move the Web page icon over a pane in which you want to place the Web page and click the pane.

To edit a Web page title

- » Click the Activity Toolbar button **Web page** . Select a Web page.
- » Click **Edit** and enter a title. This title will be displayed in the Web page pane caption.
- » Click **OK** to confirm.

To add a new Web page

- » Click the Activity Toolbar button **Web page**  and click **Add** or click the arrow next the Activity Toolbar button **Image** and click **Add new**

There are three options present:

Internet link: select if you want to make a link to an on-line website.

- » Enter the webpage title.
- » Enter its URL web-address.

Link to a local file: select if you want to make a link to a local file (e.g. a html file or a pdf file) or a local (off-line) web-site structure. Notice that if you want to share the Activity, which link to a local file(s) you have to copy all linked files together with your Activity.


- » Enter the file title.
- » Type in a file name including path to the file or use the **Browse** button to find and open the desired file. After selecting a file its name including path to the file will be placed in the File field.
- » The option **Store file path relative to the Activity location** is by default checked.

Embed local file: select if you want to embed a local file (e.g. html file or a pdf file) in your Activity. If you want to share your Activity the file(s) will be included in the Activity.


- » Enter the file title.
- » Use the **Browse** button to find and open the desired file.

- » Check **Include files from the file's folder and its subfolders** when you want to embed not only the linked file but also other files connected to it, e.g. all files which belong to an off-line web structure.

To delete a Web page

- » Click the Activity Toolbar button **Web page** .
- » Select a Web page you want to delete and click **Delete**.
- » Confirm that you really want to delete the Web page.

To set a Web page as Home page

- » Click the Activity Toolbar button **Web page** .
- » Select the Web page.
- » Click **Set as Home**.

Web Page Toolbar

The Web page pane has its own Toolbar, which consists of the following buttons:



to return to the last viewed page



to view one of the last nine pages visited in this session



to return to the Home page



to stop loading the current Web page



to refresh a Web page

Web Page Tool Menu

The Tool menu of the Web page pane consists of the following options:

Back – to return to the last viewed page

Forward – view one of the last nine pages visited in this session

Home – to return to the Home page

Refresh – to refresh a Web-page

Copy URL – to copy a URL address of the displayed page

Add to Selected Pages – to add the selected page to the list web-pages present in the Activity

Print – to print the Web page pane (only its visible part will be printed)

Clipboard Copy – to copy the Web page pane to the clipboard

Help – to consult help system

Note when you right-click the web page pane then instead of standard Coach Tool menu the Browser menu is shown.

Student Texts

Student texts are meant for student notes, answers and reports, etc. Students can create and edit new texts.

An Activity may consist of more Student texts than the Student text(s) shown on the Activity screen. By clicking the Activity Toolbar button Student text or the arrow next to it you can see if there are more Student texts present. A Student text can appear only once; it can be displayed in a pane or listed in the Student texts list.

The topics in this chapter will help you to work with student texts.


Managing Student Texts

When there are more Student texts you can browse through these in the Student texts pane. Coach follows the numbering or alphabetical order.

To browse through Student texts

- » Click the forward  and the backward  arrow buttons in the Student text pane caption.

Or

- » Right-click the Student text pane or click its Tool button  and select **Next** or **Previous Student text**.


To move a Student text to another pane

- » Click the caption of the Student text pane you want to move.
- » Start to drag the caption; the cursor displays the Student text icon.
- » Move the Student text icon over a pane in which you want to place the Student text and click the pane


To select another than the displayed Student text

- » Click the Activity Toolbar button **Student text** . Select a Student text from the list and click **OK** to confirm.


or

- » Click the arrow placed at the right-hand side of the button **Student text** .
- » The cursor displays the Student text icon.
- » Move the Student text icon over a pane in which you want to place the Student text and click the pane.

To add a new Student text


- » Click the Activity Toolbar button **Student text** .
- » Click **New Student text** and type in its title.
- » Click **OK** to select the new text.

or

- » Click the arrow placed at the right-hand side of the button **Student text**  and click **Add new**.
- » Type in its title and click **OK**.

- » The cursor displays the Student text icon.
- » Move the Student text icon over a pane in which you want to place the Student text and click the pane.


To delete a Student text

- » Click the Activity Toolbar button **Student text** .
- » Select a Student text you want to delete and click **Delete**.
- » Confirm that you want really delete the selected Student text.

To edit a Student text title

- » Click the Activity Toolbar button **Student text** . Select a Student text and click **Edit**.


or

- » Click the Tool button of the Student text pane  and select **Edit Title**.
- » Enter a title. This title will be displayed in the Student text pane caption.
- » Click **OK** to confirm.

Student Text Toolbar


For writing the text Student text pane is equipped with a simple text editor. The editing options are available via the Toolbar or via the Tool menu.


The Toolbar consists of the following buttons:

 to zoom in and out text


 to change the font style and text size


 to change the font color

 to apply respectively a bold, italic and underline font style

 to put text in subscript or superscript

 to format text (align left, center, align right)

 to make a bullet list

 to make a numbered list

 to indent text respectively to the left and to the right

 to insert a symbol

 to insert an image

 to insert a link to other Coach Text or Student text.

Student Text Tool Menu

The tool menu of the Student text pane consists of the following options:

Edit title – to edit the title used in the pane caption

Next Student Text – to display the next Student text

Previous Student Text – to display the previous Student text

Cut - to cut the selected text

Copy – to copy the selected text

Paste – to paste the selected text

Font – to set a font and font size for the selected text

Select all – to select all text

Undo – undo last action

Redo – redo last action

Save to File – to save text as RTF file

Print – to print the Student text pane (only its visible part will be printed)

Clipboard Copy – to copy the Student text pane to the clipboard

Help – to consult The Help system.

CHAPTER 12

Coach Language

Coach Language is a programming language, which is used in formulas, text models and programs.

A formula consists of a variable, to which a single expression is assigned. A model or a program consists of one or more statements, which are composed of words, numbers and symbols. The statements must meet certain criteria to be understood by Coach. The Coach Language interpreter checks whether expressions and statements are correct. If not, an error message appears on the screen. The formula or model must always be corrected before it can be executed.

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Comparison with other programming languages

Coach Language is a relatively simple programming language derived from Pascal. If you have some experience in languages like BASIC or Pascal, you may recognize most of the expressions and statements.

Programs and Text models written in Coach Language can only be executed within Coach. To write a such a program or model in Coach Language you need to know about the order in which the words in expressions and statements should appear (**syntax**) and about their meaning (**semantics**).

Unlike more complex programming languages, it is not possible to define arrays and character variables ('chars') in Coach Language, to enter values by means of the keyboard (input/output), or handle files while running a program. On the other hand, when using Expressions, and Standard Procedures and Functions offered by Coach Language you have direct control over the 'in', 'out' ports of the interfaces.

Variable Names

Variable names used in formulas, text models or programs should be written according to Coach Language rules. In Graphical and Equation modeling modes labels are used to describe the variables. The labels are interpreted by Coach language and if they consist of characters or words that are not allowed to be used by Coach Language than Coach automatically adds square brackets around the label. The variable name used by Coach is displayed below the label name in the Variable Properties dialog.

The topics in this chapter will help you to learn rules which need to be followed by variable names.

Names

When composing names it is **allowed** to use characters from the following sets:

- { **A B C .. Z** } capital letters;
- { **a b c .. z** } lower case letters;
- { **1 2 3 .. 0** } numbers;
- { **£ _ & ~ ! | { } []** } symbols;

The Coach interpreter is case-sensitive and distinguishes between capital letters and lower case letters. For example PopulationGROWTH and populationgrowth are recognized as different words. When composing names, certain characters and words are reserved to Coach and may not be used. For these words Coach is not case-sensitive.

Numbers

When composing numbers you can use characters from the set:

{ **0 1 2 3 4 5 6 7 8 9 + - . e E** }

Notice that a number may not begin with a decimal separator.

The maximum number of significant figures is eleven. Coach uses an internal representation of numbers that can store numbers whose absolute value is either zero or lies between $3.4E-4932$ and $1.1E4932$.

Reserved Characters

Some characters have a special meaning in Coach. It is not allowed to use them in names of constants, variables, procedures and functions. These characters are listed below.

- » Characters with ASCII codes: **0 .. 31**
- » Symbols for arithmetic operators: **() - + * / + ^ = < >**
- » **Spaces** and the symbols: **' . , % " " : ; \$ # @**

Furthermore it is not allowed to use a number as the first character of a name.

Notes:

- » By placing a name between square brackets the above restrictions do not apply. The first character of the name will be "[" and the last character "]", e.g. $[2\pi r]$ is allowed as a variable name.
- » The following character pairs have a special meaning (and may be used in the right place): **<= >= := <>**

Reserved Words

Some words have a special meaning in Coach. It is not allowed to use them as names of constants, variables, procedures and functions. These words are listed in the table below.

Abs	Domain	Min	Set
And	Else	Not	SetAbsolute
ArcCos	EndDo	Off	SetLevel
ArcSin	EndFunction	On	Sign
ArcTan	EndIf	Once	Sin
Becomes	EndProcedure	Or	Sound
Bezier	EndRedo	Pi	Spline
Bit	Entier	Print	Sqr
ClearData	Exp	Procedure	Sqrt
Column	Fac	Pulse	Stop
Cos	Filter	Rand	Stopwatch
Count	Function	Redo	Sum
Counter	If	Repeat	Tan
Delta	Integral	RepeatedPulse	Then
DeltaFil	Interval	Reset	UnitStep
Derivative	Latched	ResetAbsolute	Unlatched
DerivativeSmooth	Level	ResetCounters	Until
DerivativeSecond	Ln	Round	Wait
DerivativeSecondSmooth	Log	RunningTime	While
Do	Max	SaveData	

The reserved words **On**, **Off** and **Pi** [π] are the names of constants. The value of these constants is 255, 0 and 3.141592654... respectively. They can not be changed.

True and False

A condition is either **True** or **False** (logical **1** respectively Logical **0**).

For **True**, Coach Language uses the term **On**.

On corresponds to terical value **255**.

For **False**, Coach Language uses the term **Off**.

Off corresponds to the numerical value **0**.

Expressions

An expression is any combination of variables, operators, constants and functions **resulting in a single value**. There are two groups of expressions, simple expressions and expression with operators.

Simple Expressions

A simple expression is

- » a single number like **6.13** or **105**
- » a single constant like **Pi**, **On**, **Off**
- » a variable like **x**, **time**
- » a call to a standard mathematical function, a special mathematical function or a standard Coach Language function. The result of a function is **always** a value.

Variables

A variable can be considered a label for a changing numerical value. Assigning the value of an arithmetical expression to a variable means that the value is stored in a memory position of the computer under that label, e.g. "Total := 5 + 6" means that the value "11" is stored under the label "Total". The name of the variable can be chosen freely, but must meet the rules for naming in Coach Language.

The result of a logical expression is also a value and stored in memory. The label is called a logical variable (or Boolean variable).

If the result of a logical expression is **On** (True/High), the memory position is filled with the value 255. If the result is **Off** (False/Low), it is filled with the value 0. The preference of the names **On** and **Off** in Coach Language has to do with the control facilities available in the program.

Expressions with Operators

An expression with operators consists of values and operators. An operator acts on one or more values. An operator is a prescription by which values are converted into other values. There three different types of operators: Arithmetical operators, Logical operators and Relational operators.

In expressions with more than one operator, the priority of each operator determines the order of execution. For example: in the expression $3*(V+1)$, the operator "*" works on the values "3" and "(V+1)".

Expressions with logical and/or relational operators are also used to define **conditions** in statements. An expression can be used as a condition when the result is one of the Boolean values True (**On**) or False (**Off**).

For example:

- » Temperature > 15
- » Brightness <> (I+1)/I
- » (Brightness > 20) AND (Colour <> Red)
- » More examples

Arithmetic Operators

Operator	Description	Priority
-	Reverse sign	1
^	Raise to the power	1

Operator	Description	Priority
*	Multiply	2
/	Divide	2
+	Add	3
-	Subtract	3

When operators in an expression have equal priority, the expression is evaluated from left to right. The priority of an operation in a expression can always be overruled by using parentheses.

Logical Operators

Logical operators (or Boolean operators) act on logical values, for example on the result of relational operators. In Coach Language, there are three logical operators:

Operator	Description	Priority
NOT	negation of logical value	1
AND	logical AND	2
OR	logical OR	3

Truth tables for the Logical operators

Note: S1 and S2 in these tables stand for statements like for instance "A>B" or "Number<1".

NOT		
S1		NOT S1
On		Off
Off		On

AND		
S1	S2	S1 AND S2
On	On	On
On	Off	Off
Off	On	Off
Off	Off	Off

OR		
S1	S2	S1 OR S2
On	On	On
On	Off	On
Off	On	On
Off	Off	Off

Relational Operators

Relational operators always act on two values. These values are compared with each other. The result is a Boolean, one of the logical constants On (True) or Off (False). All relational operators have equal priority. Complex relational expressions can be composed using Logical operators. In such cases the relational expressions must always be placed between parentheses.

Complex relational expressions can be composed using logical operators. In such cases the relational expressions must always be placed between parentheses.

Operator	Equation	Priority
=	equals	4
<>	not equal	4
<	less than	4
>	greater than	4
<=	less or equal	4
>=	greater or equal	4

Note: When operators in an expression have equal priority, the expression is evaluated from left to right. The priority of an operation in an expression can always be overruled by using parentheses.

EXAMPLES

(x>1) AND (x<2)

For example if $x=1.3$ then the condition has the value **True (On)**.

If $x=4$ then the condition has the value **False (Off)**.

NOT (Temperature >100)

The condition has the value **True (On)** if the temperature is smaller or equal to 100, and **False (Off)** in all other cases.

(y<-1) OR (y>1)

The condition has the value **True (On)** if e.g. $y = 2$, and **False (Off)** if e.g. $y = 0.2$.

(z>1) AND (z<2) OR (z>5) AND (z<6)

The condition has the value **True (On)** if z has a value between 1 and 2 or between 5 and 6, and **False (Off)** in all other cases.

Syntax of Expressions

Use of spaces and <Enter> (line breaks)

- » In a **logical expression** spaces must be placed to separate the logical operator from the value(s).
- » In an **arithmetical expression** or a **relational expression** the use of spaces is optional.
- » It is not necessary to write an expression on a single line. It may, for reasons of clarity, be desirable to spread an expression with more than one function over a few lines.
- » Expressions have to be separated from each other by spaces or by **<Enter>** (hard line break). When separated by spaces, it is possible to place two or more expressions on one line. When using **<Enter>** to separate expressions, each expression is placed on a new line.

Use of brackets

- » Brackets in an expression are required if you wish to alter the priority of an operation.
- » Brackets may be used to increase the clarity of expressions.

Expressions with operators

If an operator acts on a single value, then the value must be placed behind the operator. If an operator acts on two values, then the operator must be placed between the values. Operators with priority one are performed first, then operators with priority two, etc.

Example: Interpretation of Expressions

Expressions with arithmetic operators	Interpretation
A*B^C	A*(B^C)
A^B*C	(A^(-B))*C
A^B-C	(A^(-B))-C
A/B-C	(A/B)-C
A+B*C	A+(B*C)
A-B*-C	A-(B* (-C))
a3*x^3 + a2*x^2 + a1*x + a0	(a3*x^3)+(a2*x^2)+(a1*x)+a0
Expressions with logical operators	Interpretation
NOT Dry+1	(NOT(Dry))+1
On OR NOT (Available)	On OR (NOT(Available))
Dry AND Wind OR Sun	(Dry AND Wind) OR Sun
Sun OR Dry AND Wind	Sun OR (Dry AND Wind)
Expressions with logical operators	Interpretation
X<Z/(Z-1)	X<(Z/(Z-1))
X>=1+Y	X>=(1+Y)
X*2<=Y+5	(X*2)<=(Y+5)
(A<=B) AND NOT (C>B)	(A<=B) AND (NOT(C>B))

Notes:

- » When comparing a logical variable with a numerical variable, keep in mind that **On** and **Off** correspond with the numerical values 255 and 0. However, a Boolean variable automatically has the logical value **On** if its numerical value is not equal to 0.
- » You may prefer to work with the names True and False instead of the names **On** and **Off**. This is only allowed if you define the following assignments:
True := On
False := Off

Statements

A statement is a program element which can be executed independently. Here, we distinguish between simple statements and structured statements.

Simple statements

Assignment

With an assignment the value of a variable is replaced by the result of an expression. The symbol for the assignment operator is ':=' (colon equal sign). In Coach Language you can also just use the symbol '=', or the word **becomes**. It is not necessary to separate the operator with spaces.

Syntax: variable := expression

Examples:

X := Y + Z

Wet **becomes** (rain) **AND** (**NOT**(umbrella))

Procedure call

Procedures are used to organize a program. A procedure consists of one or more statements and carries a name. The result of a procedure is the execution of the defined statements. The statements are executed at the position where the call to the procedure name is placed in the program. In Coach there are several types of procedures possible:

- » Standard Coach-Language procedures
- » Own Commands, i.e. procedures created by the end-user.
- » Pre-defined procedures by the author of the Activity ('Micro-world').

Structured statements

A structured statement is a statement which has a prescribed structure. There are two types of such statements in Coach Language: Conditional statements and Loop statements.

Conditional statements

This statement conditionally executes a group of statements, depending on the value of a conditional expression. The conditional expression must generate a Boolean value: **True** (On) or **False** (Off).

If .. Then

If the condition is **True** (On), then statements between **Then** and **EndIf** are executed. If the condition is False (Off) no statements are executed.

Syntax:

If Conditional expression **Then** Statements **EndIf**

Example:

If x>0 **Then**

 y:= sqrt(x)

EndIf

If .. Then .. Else

If the condition is **True** (On), then the statements between **Then** and **Else** are executed. If the condition is

False (Off), then the statements between **Else** and **EndIf** are executed.

Syntax:

If Conditional expression **Then** Statements **Else** Statements **EndIf**

Example:

If (a<2) AND (b>5) **Then**

a:=a + 1

b:=b – 5

Else

a:=a –1

b:=b + 3

EndIf

Once .. Do .. EndDo

If the condition is **True** (On), then the statements between **Do** and **EndDo** are executed.

Syntax:

Once Conditional expression **Do** Statements **EndDo**

Example:

Once x>0 **Do**

v:= -0.9*v

EndDo

Loop Statements

In a loop statement, a number of statements are executed a certain number of times.

There are three different types of loop statement, two of which are controlled by a conditional expression. The third is an unconditional loop statement.

In a loop statement, a number of statements are executed a certain number of times.

Repeat .. Until

Repeats the statements between **Repeat** and **Until** as long the condition is **False** (Off). The statements will at least be executed once.

Syntax:

Repeat Statements **Until** Conditional expression

Example:

Repeat

Set(1)

Reset(1)

Until RunningTime > 125

While .. Do .. EndDo

Repeats the statements between **Do** and **EndDo** as long as the condition behind **While** is **True** (On). If the condition is **False** (Off) at the start, no execution will follow.

Syntax:

While Conditional expression **Do** Statements **EndDo**.

Example:

While r<> 3 **Do**

 If x>1 Then

 Set(2)

 Else

 Reset(2)

 EndIf

EndDo

Redo .. EndRedo

Repeats the statements between **Redo** and **EndRedo** a fixed number of times (determined by the parameter 'Number'). The statements will be executed at least once.

Syntax:

Redo Number Statements **EndRedo**

Example:

Redo 10

 Wait(0.5)

 Set(1)

 Wait(0.5)

 Reset(1)

EndRedo

Functions and Procedures

Coach Language consists of functions and procedures:

- » standard mathematical functions,
- » special mathematical functions,
- » standard functions, and
- » standard procedures.

Standard Mathematical Functions

The functions listed below can be used in formulas (where they use columns of one row and the result is one number that will be put in the same row as well), control programs and text models.

Note: Coach uses an internal representation of numbers that can store numbers whose absolute value is either zero or lies between 3.4E-4932 and 1.1E4932.

Function	Description	Remarks
Sin(x)	Sine of x	x in deg/rad*
Cos(x)	Cosine of x	x in deg/rad*
Tan(x)	Tangent of x	x in deg/rad*
Arcsin(x)	Inverse sine function (radians)	x in [-1;1]
Arccos(x)	Inverse cosine function (radians)	x in [-1;1]
Arctan(x)	Inverse tangent function (radians)	
Exp(x)	e-power of x (e^x)	
Ln(x)	Natural logarithm (base e)	
Log(x)	Briggs logarithm (base 10)	
Sqr(x)	Square of x	
Sqrt(x)	Square root of x	
Abs(x)	The absolute value of x	
Entier(x)	Rounds a number down	
Round(x)	Rounds off a number	
Fac(x)	Generates (round(x))! (factorial)	
Max($x_1;x_2;\dots;x_i$)	Selects the largest of i parameters	
Min($x_1;x_2;\dots;x_i$)	Selects the smallest of i parameters	
Rand	Generates a random number in the interval [0, 1]	
Sign(x)	Generates: -1 for $x < 0$; 0 for $x = 0$; 1 for $x > 0$	

* The angle unit, radians or degrees, depends on settings in the Activity Options.

Special Mathematical Functions

The functions listed below can be used only in formulas inside the Data Table and they typically use several rows of the columns and sometimes they also generate more than one result (fill several cells of the target column or all cells of the target column). These functions cannot be used in Control programs.

Function	Description
Bezier(X;Y)	Calculates a polynomial approximation according to the Bezier method, based on the values of variable in the column X (x-axis) and column Y .
Column(K;N)	Fills a new column with the values equal to the value from a column K and a row N e.g. Column (2;100) gives the 100 th value of column 2.
Delta(X)	Calculates the difference between two successive values in the variable X . Cell(n) is filled with the value of the expression Cell(n+1) - Cell(n) from the source column. The last cell in the target column remains undefined.
Deltafil(X)	Combines Delta(X) and Filter(X;n). This function is only useful if the data points in variable column X are equidistant. For the filter interval n the fixed value of 2 is taken.
Derivative(X;Y)	Calculates the numerical differentiation of the values in column Y with respect to column X .
DerivativeSmooth(X;Y;n)	Calculates a smooth derivative Y with respect to X , first a spline with the smoothing factor n is computed, then numerical differentiation of the spline function.
DerivativeSecond(X;Y)	Calculates the numerical second order differentiation of the values in column Y with respect to column X .
DerivativeSecondSmooth(X;Y;n)	Calculates a smooth second derivative Y with respect to X , first a spline with the smoothing factor n is computed, then the second numerical differentiation of the spline function.
Domain(b;e)	Fills all cells of a new column with equally distributed values over the interval [b,e] (b : begin value; e : end value) according to the formula: cell(index) = $b + [(e - b) * (index - 1)] / (n - 1)$, where n denotes the number of rows.
Filter(X;n)	Performs filtering of the values in column X with filter interval n . The value in each cell is replaced by the average value of the cell itself, its n predecessors and n successors (i.e. the average over $2n+1$ points). At the boundaries, mirroring is used to obtain sufficient values.
Histogram(X;n;l,u)	Divides the value from column X in n different classes (bins) and for each class gives the frequency of occurrence. The i -th class runs from $l+(i-1)*(u-l)/n$ to $l+i*(u-l)/n$ where l is lower and u is upper boundary.
Integral(X;Y;r)	Calculates the numerical integration of values in column Y with respect to X . r is the constant of Integration (initial value).
Pulse(X;b;l;h)	Generates a pulse of variable X which starts at a begin value b , has duration l and height h .
RepeatedPulse(X;b;l;i;h)	Generates pulses of variable X with repeated interval i . The first pulse starts at a begin value b , has a duration l and a height h .

Function	Description
Sum(X)	Adds the values of cells of variable X . The value in cell(n) contains the sum of all values in column X which have an index smaller or equal to n .
Spline(X;Y;f)	Calculates a smooth Spline approximation of the data set, based on the values in the column X and Y , and the smoothing parameter f . If the smoothing factor f is set to zero, the natural quintic spline interpolation through the data points is obtained.
UnitStep (X,b)	Generates 0 for $X < b$ and 1 for $X \geq b$

Standard Functions

The following standard functions can be used in programs.

Bit

The function Bit(n) returns On (True) if the digital input (n) is "High", and Off (False) if it is "Low". The numerical values On and Off correspond with 255 respectively 0.

Example:

- » In an assignment: State = Bit(1)
- » In a conditional statement: If Bit(2) = On Then ...
- » or shorter: If Bit(2) Then ...

Counter and Reset Counters

The standard function **Counter**(n) returns the number of pulses that has been detected on Counter input (n). All counters are reset to 0 with the standard procedure **ResetCounters**. Counters cannot be set individually to 0, so ResetCounters has no parameters.

Example:

- » In an assignment: State = Counter(1)
- » In a conditional statement: If Counter(2) < 100 Then ...

Interval

The standard function **Interval** returns the time (in seconds), which has lapsed after the execution of the standard procedure **Stopwatch(On)**, and returns 0 after the execution of **Stopwatch(Off)**.

Example:

```
Stopwatch(On)
Repeat
...
Until Interval > 10
```

Level

The standard function **Level**(n) returns the value of the sensor which has been connected to analog input (n). If the sensor is calibrated, the value will be expressed in the calibrated unit.

Example:

- » In an assignment: Brightness = Level(1)
- » In a conditional statement: If Level(2) < 0,5 Then ...

Latched

The standard function **Latched(n)** returns **On** (True), if the digital input (n) has been "High" after the last call of Latched(n), otherwise it returns **Off** (False). The numerical values of On and Off correspond with 255 respectively 0. Latched is the complement of the standard function **Unlatched**.

Example:

- » In an assignment: State = Latched(1)
- » In a conditional statement: If Latched(2) = On Then ...
- » or shorter: If Latched(2) Then ...RunningTime

Unlatched

The standard function **Unlatched(n)** returns **On** (True) if the digital input (n) has been "Low" after the last call of Unlatched(n), otherwise it returns **Off** (False). The numerical values of On and Off correspond with 255 respectively 0. Unlatched is the complement of the standard function **Latched**.

Example:

- » In an assignment: State = Unlatched(1)
- » In a conditional statement: If Unlatched(2) = On Then ...
- » or shorter: ... If Unlatched(2) Then

RunningTime

The standard function **RunningTime** returns the time (in seconds) which has lapsed since the start of the program.

Example:

Repeat

...

Until RunningTime > 100

or

While RunningTime < 100 Do

...

EndDo

Standard Procedures

The following standard procedures can be used in programs.

Count

The standard procedure **Count(n;p)** counts pulses via the counter input n. The program waits until the number of pulses (p) is reached. The maximal value of (p) is 65535. By pressing any key (except <Esc>), the program is forced to continue with the next statement even though the specified number of pulses has not yet been reached (this prevents the program from halting). <Esc> is reserved to interrupt program execution.

The use of the standard procedure Count is analogous to the use of the standard procedure **Wait**. Count counts pulses, **Wait** 'counts' time.

Clear Data

The procedure ClearData erases all data (in all diagrams and tables) in the current Coach Activity. ClearData is the complement of the standard procedure SaveData.

Set

The standard procedure **Set(i, j,..)** sets the digital outputs i, j, .. to 'High'. The list of parameters can be as long as the number of outputs of the interface. Set is the complement of the standard procedure **Reset**.

Example:

- » For an interface with four digital outputs is allowed Set(1;2;3;4) .
- » If no parameters are mentioned, Set sets all digital outputs to 'High'. So, with four outputs the command Set does the same as Set (1;2;3;4).

SetLevel

This procedure only works with the CoachLab II/II+ interface. The standard procedure **SetLevel(i,p)** sets the power level of the digital output i to p. It should be a number between 1 and 4, where 1 corresponds to output A, 2 to output B etc, and p should be a number between 1 and 16, where 1 corresponds to the lowest power and 16 to the highest power level. The highest power obtained with the SetLevel command is limited automatically by the setting of the power slider range. Higher values for p than the maximum value specified above do not lead to an error message, they also invoke the maximum allowed power for the actuator.

Reset

The standard procedure **Reset(i, j, ..)** sets the digital outputs i, j, .. to **Low** and leaves the state of the other outputs as they are. The list of parameters can be as long as the number of outputs of the interface. **Reset** is the complement of the Standard Procedure **Set**.

Example:

For an interface with for example four digital outputs Reset(1;2;3;4) is allowed. If no parameters are mentioned, Reset sets all digital outputs to 'Low'. So, with four outputs the command Reset does the same as Reset(1;2;3;4).

SetAbsolute

The standard procedure SetAbsolute(i, j, ..) sets the digital outputs i, j, .. to 'High' and all others to 'Low'. The list of parameters can be as long as the number of outputs of the interface. SetAbsolute is the complement of the Standard Procedure ResetAbsolute.

Example:

For an interface with for example four digital outputs SetAbsolute(1;2;3;4) is allowed. If no parameters are mentioned, SetAbsolute sets all digital outputs to 'High'. So, with four outputs the command SetAbsolute does the same as SetAbsolute(1;2;3;4).

ResetAbsolute

The standard procedure ResetAbsolute(i, j, ..) sets the digital outputs i, j, .. to 'Low' and all others to 'High'. The list of parameters can be as long as the number of outputs of the interface. ResetAbsolute is the complement of the standard procedure SetAbsolute

Example:

For an interface with for example four digital outputs ResetAbsolute(1;2;3;4) is allowed.

If no parameters are mentioned, ResetAbsolute sets all digital outputs to 'Low'. So, with four outputs the command ResetAbsolute does the same as ResetAbsolute(1;2;3;4).

Sound

The standard procedure Sound(f;t) produces a sound with a frequency of f Hertz during t seconds. The

standard procedure Stop halts the execution of the program at the position of this procedure.

Stop

Standard procedure Stop halts the execution of the program at the position of this procedure.

StopWatch

The standard procedure StopWatch(B) starts a time measurement (in seconds) if the Boolean variable B has the value On (True). The elapsed time after the start of the time measurement is recorded by the Standard Function Interval. Interval returns the value 0 immediately after the execution of StopWatch(On). The function Interval remains 0 after the execution of Stopwatch(Off).

Example:

Stopwatch(On)

Repeat

...

Until Interval > 10

SaveData

The standard procedure SaveData stores the values of variables which are present in diagrams or tables. On each pass, the values of the variables will be written once. If SaveData is not used or erroneously used, empty or wrong diagrams and tables will result. SaveData is the complement of the standard procedure ClearData.

Example:

Measure during half an hour and only store the values if the temperature is higher than 20° C:

Correct solution:

As long as the temperature is below 20 °C, no values are written to the Diagram. (SaveData is located inside the If statement which tests the temperature).

Repeat

If Temperature > 20 Then

Wait(1)

SaveData

EndIf

Until RunningTime>1800

Incorrect solution:

Values are also written in the Diagram when the temperature is below 20 °C. (SaveData is located outside the If statement which tests the temperature).

Repeat

If Temperature > 20 Then

Wait(1)

EndIf

SaveData

Until RunningTime>1800

Wait

The standard procedure **Wait(t)** pauses program execution for t seconds. **<Esc>** interrupts Program execution. By pressing any key (except **<Esc>**), the program is forced to continue with the next statement even though the specified time has not yet been lapsed. **<Esc>** is reserved to interrupt program execution.

The use of the standard procedure Wait is analogous to the use of the standard procedure Count. Wait pauses a time interval, while Count pauses until a specified number of pulses has been detected.

Error Messages

Two kinds of errors may occur:

- » syntax errors which are detected during the interpretation of the program or the text model preceding the execution or preceding the selection of variables along diagram axes.
- » execution errors which are only detected while programs and text models are executed.

Error messages during interpretation

If an error is detected during interpretation of the program or the text model, an error message pops up. The cursor flashes behind the position in the program or the text model where the error has been detected. The error can be corrected immediately.

Error message	Cause
"Character not expected"	A character is placed where it is not expected to be.
"Number not correct"	The interpreter fails to read a number.
"This name is already in use"	Appears when two variables, functions or procedures have identical names.
"Type conflict"	Occurs when a value has been assigned to the name of a Procedure, or when the Function result has been assigned outside the Function definition.
"... expected"	The interpreter expects a name or a symbol.
"... NOT expected"	The interpreter does not expect the symbol entered. Often the cause is not immediately clear.
"Too many variables"	The available memory for names of variables has been used. Solution: choose shorter names.
"Function result not assigned"	The function definition does not contain the final assignment: function_name := function_result

Examples of syntax error messages

Examples of syntax errors and corresponding error messages:

Program	Error message
a : 1	Character not expected
a 1	"Assignment" expected
a := / 1	"/" not expected
a := 1e=12	Number is not correct
If a>0 Then a:=1e12	"EndIf" expected
Repeat a:=1e12	"Until" expected
Redo a := 1e12	"Assignment" not expected
Redo a 1e12	Number not expected

Program	Error message
Function a(x;y) EndFunction	"EndFunction not expected"
Function a(x;y) z=x*y EndFunction	"Function result not assigned"
Function a(x;y) a=x*y EndFunction Procedure a(e) w = sqrt(e) EndProcedure	"This name is already in use"
Function a(x;y) a=x*y EndFunction a = 12	"Type conflict"
Procedure a(x;y) z = x+y EndProcedure s = a(1;2) a(1;2;3) a(1)	"Type conflict" "" expected" ";" expected"
Procedure b b = 12 EndProcedure	"=" not expected"

Error messages during execution

When a Program or Model has been developed, there is no guarantee that errors will not occur during the execution. If such an error occurs, the program or the text model is halted and a message appears on the screen. Possible execution errors and corresponding causes:

Error message	Cause
Division by zero"	A variable in the denominator of a fraction has become 0. A number becomes too large or too small.
"Number out of range" or "Value not in the domain"	The argument of a standard function receives a value which is not allowed.

EXAMPLE

A program, which returns error messages when executed.

Program	Error message
a := 100 w := 100	
Redo 100	
a := a - 1	
y := 12/a	"Division by 0 (in the last loop (when a=0))"
y := ln(a)	"Value not in the domain (in the last loop (when a=0))"
w := w*w EndRedo	"Number out of range (in the 6th loop)"

CHAPTER 13

For Authors

Coach is an authoring environment and allows teachers or other curriculum developers (called Authors in Coach), develop and manage Coach Activities for student users.

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User Levels

Coach distinguishes the following user levels: Author, Senior student and Junior student .

The user level is set by the Author and is stored in the Activity.

By default Coach starts and opens Activities in the user level stored in the Activity, however Coach can be forced to open Activities in Senior-student mode or Author mode.


Author

Author users may create, edit and manage Coach Activities. This includes the possibility to:

- » specify the type of used tools,
- » set the student-user level,
- » decide on Activity design e.g. more open student investigation, ready-to go experiments, etc.,
- » decide how data are presented,
- » provide learning content.

To make impossible for Student users to login in and work as Authors, Author mode is protected with an Author key. The default Author key is '0000' (four times digit 0). This key can be changed via the main menu option **Options > Author Key Settings**.

To set Coach into Author mode


- » Click the  **Login** button in Dashboard.
- » Select **Author** in the user level drop-down list.
- » Type in the correct Author key to enter Author mode.
- » The default Author key is '**0000**'.
- » Confirm with **OK**.
- » From now on now all Activities will be opened in Author mode.

Senior Student

Senior-student users are the most powerful student users, they can use almost all functions of Coach **excluding**:

- » creating and saving Activity files (cma7 files), they can save only result files (cmr7),
- » editing Texts made by Authors,
- » removing objects created by Authors.

To set Coach into Senior-student mode

- » Click the  **Login** button in Dashboard.
- » Select **Senior student** in the user level drop-down list.
- » All Activities will open in Senior-student mode, regardless of the Activity user level stored in the Activity.

Junior Student

The Junior student level distinguishes between three sub-levels: Fixed, Flexible and Own Lab.

- » In **Fixed** mode: students cannot change the Activity screen layout; only objects displayed on the Activity screen are visible to students. Not all Activity buttons are present, nor a Settings button. This means that Authors should provide all required objects on the Activity screen.
- » In **Flexible** mode: students have a little more freedom, they can change the duration of measurements and they can change objects displayed in panes via the Activity Toolbar buttons. However, only those Toolbar buttons are present, which have defined at least one object. For example if there are no images included then the Activity Toolbar button Image will be not displayed. Additionally students can also handle sensors and actuators on the interface image.
- » In **Own-Lab** mode: students can do simple calibrations and all Activity Toolbar buttons are present.

Creating Activity


Follow the steps described in this chapter to create an Activity for your students.

Step 1: Starting a New Activity

An Activity can be created and modified only by Authors, not by student users.

After login as an Author, the button **New**  is added to the Dashboard.

To start a new Activity

- » Click the Dashboard button **New**  or select **File > New** from the menu.
- » An empty Activity is started and the **Activity Options** automatically appear on the screen.
- » Go to Step 2.

Step 2: Selecting an Activity Type

The Activity Options dialog displays the Activity type tab. Here you have to decide with which of the tools students will work in this Activity.

Measurement

This type is used for Activities, in which data are collected via interface and sensors or are manually typed in.

- » Select **Measurement**.
- » Select the interface from the drop-down list. Notice that when Coach has detected a connected interface then this interface is displayed as default on top of the list.
- » In case you want to only manually type in data you can select the **No Interface** option.
- » The **Off-line** option will be automatically selected when an interface, which is able to work off-line, is selected e.g. CLAB. In this case two additional buttons **Send Settings** and **Get Results**, will be added to the Activity Toolbar.
- » If desired check the option **With a program**. This option should **only** be checked for Activities, in which data from sensors and/or actuators have to be stored in the data table, while a program is used to control. Program variables cannot be displayed in diagrams/tables. The duration of the control process is determined by the program, while the sensor/actuator signals are evaluated according to the measurement settings. The advantage of this setting is that the signals are evaluated independent of the program speed. The Activity Toolbar button Start is available to start a measurement run and program execution.
- » When the option **With a program** is checked, then the **More button** becomes active, click this button to see additional options. To hide these options again, press **Less**.
- » If the Program button should be hidden, for example for Junior-student users, deselect the **Show Program button**. Only the button will be hidden. It is still possible to display a program on the Activity screen if the Program window is visible at the moment of saving the Activity.
- » Select **Stop on digital input** to determine which of the panel inputs is used to unconditionally end program execution. The program stops as soon as the value on the selected Input becomes High (only when With a program is On).

Note: When creating Coach Measurement Activities for interfaces, which are not connected to the computer, it is possible to deactivate the hardware. This means that Coach does not try to communicate with the selected interface. As soon as the Activity is run on a computer where the hardware is available, it works properly.

Control

This type is used for Activities, in which control programs can be designed, created and executed. Such control programs can determine the way measurements are being taken, or are used to do calculations on measured signals. Program variables can be displayed in the data table. However, the values are stored in memory (and appear in the data table) **only** when the standard procedure **SaveData** is used in the program. Disadvantage of this setting is that the sensitivity to signal changes depends strongly on the execution speed of the program (hence on the processor speed of the computer).

- » Select **Control**.
- » Select the interface from the drop-down list. Notice that when Coach has detected a connected interface, then this interface is displayed as default on the top of the list.
- » By default, the option **With a program** is checked. When this option is unmarked then the resulting Activity can be used for manual control of actuators connected to an interface.
- » If sensor signals change rapidly, it is better to use the setting **Measurement with a Program**. In that case, however, program variables cannot be displayed in the data table and graphs.
- » When the option **With a program** is checked, then the **More** button becomes active. Click this button to reveal additional options. To hide these options again, press **Less**.
- » If the Program button should be hidden, for example for Junior-student users, deselect the **Show Program Window button**. Only the button will be hidden. It is still possible to display a program on the Activity screen if the Program window is visible at the moment of saving the Activity.
- » Select **Stop on digital input** to determine which of the panel inputs is used to unconditionally end program execution. The program stops as soon as the value on the selected Input becomes High (only when With a program is On).

Note: When creating Coach Control Activities for interfaces, which are not connected to the computer, it is possible to deactivate the hardware. This means that Coach does not try to communicate with the selected interface. As soon as the Activity is run on a computer where the hardware is available, it works properly.

Modeling

This type is used for Activities, in which dynamical models can be designed, created and executed.

- » Select **Modeling**. The option **No Interface** becomes selected.
- » Click the **More** button to reveal additional options. To hide these options again, press **Less**.
- » If the Model button should be hidden for Junior student-users, deselect **Show Model Window button**. Only the button will be hidden. It is still possible to display a model on the Activity screen if the Model window is visible at the moment of saving the Activity.
- » Deselect **Allow switching between different modes** to hide the Modeling buttons to change the modeling modes.

Data Video

This type is used for Activities, in which video measurements are performed.

- » Select **Data Video**. The option **No Interface** is automatically selected.

Data Image

This type is used for activities, in which image measurements are performed.

- » Select **Data Image**. The option **No Interface** is automatically selected.

Spectrometer

This type is used for Activities, in which measurements with a spectrometer are performed.

- » Select **Spectrometer**.
- » Select the type of spectra you want to record Emission or Absorption spectra.
- » Select the connected spectrometer under **Spectrometer**.

Spreadsheet

This type is used for Activities to work with data in the Data Table.

- » Select **Spreadsheet**. Behind **Data Table Rows** type in the number of rows in the Data Table (default 101). The given number of empty rows will be created in the table.

Go to Step 3.

Step 3: Selecting a User Level

The next step is to set the default user level of the Activity. In general, this is the user level in which Coach runs this Activity, unless explicitly overruled by the user level login.

- » Click the tab **User Level**.
- » Select the user level for the Activity.
- » By default Senior student is selected.
- » The Junior level is split up into three levels: Fixed, Flexible and Own Lab. First click the Junior student and then select the sub-level from the drop-down list.
- » Go to Step 4.

Step 4: Setting Advanced Activity Options

The next step is to set the advanced Activity options. Most of the options are used only in rare cases.

- » Click the tab **Advanced**.
- » Mark the option **Always run in Quick mode** only when fast program execution is required. This mode is needed when your program is not reacting quickly enough for the real events because it is painting something on the screen e.g. graphs, meters, etc. Check if this option is unmarked when no data appear in diagrams or tables during a measurement.
- » Specify the unit for angles used in the Activity (e.g. in formulas), or measured in the Data-Video window. Changing the angle unit when data or formulas are present in the Activity may lead to faulty results, as Coach does **not convert** angles to the new unit.
- » Select a language for **Coach Language** commands, the drop-down list shows all installed languages. By default the Coach user interface language is selected. This option makes possible to use for example English Coach Language in Coach which runs in "another language", for example in Dutch language. The selected language is stored in the Activity.
- » Click **OK** to close the Activity Options dialog.
- » Go to Step 5.

Step 5: Filling an Activity

After the Activity options are set an empty Activity is opened. The Activity screen displays four panes and the Activity Toolbar is adjusted depending on the selected Activity type. Now you are ready to design your Activity. Depending on the user level and the aim of your Activity, the Activity can be ready-to-go: many things are ready for use by students. Or can be more open: students decide how they want to measure, display and process their data.

To fill an Activity



Depending on the type of Activity and the selected user level:

- » Prepare the measurement, for example: select sensors, select the type of measurement, specify the measurement setting, open and calibrate a video for measurement, create a model or command list in the program window, etc.
- » Decide how the data will be displayed in the data table, graphs, meters, etc.
- » Fill panes with additional learning content by writing texts, adding images and videos, linking to web-pages. If needed you can add new panes to the Activity screen.
- » During the development process, Authors can immediately view and evaluate the Activity in the selected student-user mode by using the Activity menu option **Tools > View as**. Except for the Activity Toolbar, the Activity will behave exactly as a student user would experience it. The **View as** menu option stays available to change back to Author mode again.
- » Note that it is possible to prepare an Activity for an interface, which is currently not connected to the computer (inactive). To avoid getting messages that the interface could not be initialized, deactivate the interface by deselecting the option **Activate Hardware** in the Tools menu. As soon as the Activity is opened on a computer which has the interface connected (and provided the option **Activate Hardware** is marked) it will work normally.
- » Finally decide on the Activity screen layout. Via the menu option **Display > Screen Layouts** you can find a few pre-defined layouts.
- » Go to Step 6.

Step 6: Saving the final Activity

When you are ready with your Activity you can save it. All objects used in an Activity like texts, images, videos, data and modified or newly created sensors/actuators, are stored in the Activity (*.cma7) file, similar to pictures in a Word document. The current Activity screen layout is also stored and this will be the layout used when student users open the Activity. Student users can work without overwriting the Activity. When they work with the Activity, they can save it only as a Result (*.cmr7) file.

To save an Activity

- » Select the Activity Toolbar button **Save as**  or select **File > Save** from the menu or press **<Ctrl>+<S>**. If an Activity is saved for the first time, all these commands invoke the Save as dialog.
- » Browse to the desired location.
- » Type in a descriptive Activity file name.
- » Once an Activity is saved, the **Save as** button  always invokes the Save as dialog. Using **Save** from the Activity File menu or **<Ctrl>+<S>** immediately updates (overwrites) the current Activity.

Because all necessary files are embedded in the Activity/Result file, it is very easy to exchange activities with other users, simply by giving/sending someone a *.cma7 or *.cmr7 file. In one double-click the complete Activity will start on the other computer (provided Coach 7 is installed). In a similar way, hyperlinks to CMA files can be put on a website to be downloaded and started in Coach.


Author Tools

Author tools are available through the Main menu

- » via the **Options** and **Tools** menu for Windows, and
- » Via the **Coach 7** and **Tools** menu options for Mac.

These are the available tools: Preferences and Author Key Settings.

Preferences

The option **Preferences** allows selecting a location for user Coach files upon starting Coach. This location will be opened when the **Open**  button is used. The selection can be made between:

- » **User Projects** by default this is ../User/Documents/Coach 7 folder. If you want to change the default folder click **Browse** and select the desired location.
- » **School Projects** - this location is defined during network installation .
- » **Last open location** - the last folder used during the previous session.

When you check **Automatically open 'File open'** then the **Open** dialog, displaying content of the User Projects folder, is automatically open upon starting Coach.

Author Key Settings

The option Author Key Settings allows changing the Author key. The Author key can also be disabled, i.e. upon logging in as an Author there will be no request for the Author key.

» **To change an Author key**

- » Windows: In the Main menu, select **Options > Author Key Settings**.
- » Mac: In the Main menu, select **Coach 7 > Author Key Settings**. The Author Key Settings dialog appears.
- » First, type in the current Author key.
- » Check the option **Change Author key**.
- » Type in the new Author key, and type it once more in the **Confirm new Author key** field.
- » Click **OK**.

» **To disable an Author key**

- » Windows: In the Main menu, select **Options > Author Key Settings**.
- » Mac: In the Main menu, select **Coach 7 > Author Key Settings**. The Author Key Settings dialog appears.
- » Enter the current Author key.
- » Unmark the **Option Enable Author key** and click **OK**.
- » Be aware that without an Author key, the Author mode is no longer protected, and any user of Coach can switch to Author mode and make changes to the Coach settings.

» **Lost Author key**

If the Author key is lost, copying the authorkey.bak file to authorkey.ckf restores the Author key to its default ('0000'). This file resides in the Coach 7 folder. In case of a network installation the location of the file is specified during the installation.

Starting Coach via Command Line

In Windows it is possible to force Coach to start in a certain mode by extending the command line to Coach7.exe program with an extra option. The following options are possible:

/A – start in Author mode

/X – start with "activate hardware" switched off

/S – start without splash screen

With the option pair **/W:number** and **/H:number** one can specify the dimensions of the Coach window upon startup, i.e. when putting /w:800 /h:600 behind the reference to Coach32.exe, it will make Coach run in an 800x600 window.

Creating a customized programming environment

When creating a Control or a Measurement Activity with a Program, the Program window offers standard Coach Language programming instructions. Authors can customize this standard list and adapt it for a specific application, also called Micro-world. Such a Micro-world consists of a set of commands - functions or procedures, tuned to a particular control application. This can simplify the programming environment/language for f.i. younger students.

The topics in this chapter will help you to learn how to create a customized programming environment (micro-world) for your students:


Creating Procedures and Functions

The following topics will help you to learn how to create new functions and procedures for use in your programming environment (micro-world).

Opening Procedure Window

Authors can create specific (micro-world) programming commands in the Procedure window. The Procedure window is placed in the Program window and is hidden behind the program editor.

To open the Procedure window

- » Place the mouse cursor on the bottom line of the title bar of the Program window, until it changes its shape to  .
- » Drag the top edge down. The Procedure window opens. In this window new procedures and functions can be entered.

Creating New Functions

To define a new function

- » Open the **Procedure window**.
- » Type the function.
- » In a function a number of statements are defined under the name of the function. The result of a function is a calculated value.

The syntax of function is:

Function Function_name(p1; p2)

Statements

Function_name:= expression (assign a value to the function's name)

EndFunction

Keep the following in mind:

- » The function name may not be identical to the name of a reserved word, a variable, a procedure or an already defined function.
- » The statements should be separated from each other by spaces or <Enter>.
- » The parameters, as defined in the function name, act as local variables. The names of each parameter must be unique. It is not allowed to use the same names at other positions in the Micro-world.
- » The parameters have to be separated from each other by a semicolon (;).
- » Only functions with 0, 1 or 2 parameters can be used in the command list.

- » In a function it is allowed to call an already defined function.
- » Uppercase and lowercase names are different in Coach.

EXAMPLES

Function Mean(A; B)

C = A+B

Mean = C/2

EndFunction

Function Light

If LightIntensity > 50 Then

Light = 1

Else

Light = 0

EndIf

EndFunction

Creating New Procedures

To define a new procedure

- » Open the **Procedure window**.
- » Type the procedure. In a procedure, a number of statements are defined under the name of the procedure. The result of a procedure is the execution of the defined statements. The definition of a procedure is very similar to the definition of a function. The difference is that the definition of a function ends with an assignment (i.e. the function results in a value) and the definition of a procedure does not.

The syntax of the procedure is:

Procedure Procedure_name(p1; p2; ...)

Statements

EndProcedure

Keep the following in mind:

- » The procedure name may not be identical to the name of a reserved word, a variable, a function or of an already defined procedure.
- » The statements should be separated from each other by spaces or <Enter>.
- » The parameters, as defined in the procedure name, act as local variables. The names of each parameter must be unique. It is not allowed to use the same names at other positions in the Micro world.
- » The parameters have to be separated from each other by a semicolon (;).
- » Only procedures with 0, 1 or 2 parameters can be used in the command list.
- » In a procedure it is allowed to call an already defined procedure.
- » Uppercase and lowercase names are different in Coach.

EXAMPLES

Procedure Lamp

Set(1)

EndProcedure

Procedure Lamp(n)

Set(n)

EndProcedure

Procedure Lamp(n; State)

If State = 1 Then

 Set(n)

Else

 Reset(n)

EndIf

EndProcedure

Creating programming buttons

Students can make programs by manually controlling a system via so-called programming buttons.

By clicking the programming buttons, Coach executes procedures that are associated with these buttons and translates them into the program lines. The automatically created program can be visible in the program editor area (but it does not have to). By executing the program, Coach carries out the recorded program instructions.

When the mouse cursor is placed above a button, a tool-tip with the procedure name (indicating its action) will appear.

Note: The button area is displayed when the Program-window Tool menu option **Show Programming buttons** is marked.

Programming Button Types

The following button types are available:

ONE SHOT

A one-shot button executes a procedure once when it is pressed. Only procedures without parameters (standard and created in a micro world) can be selected.

Pushing the button executes the procedure once and places the procedure name in the program line.

Example:

Procedure Main_road_Red

Set(4)

Reset(5;6)

EndProcedure

PUSH/RELEASE

A push/release button executes two procedures: one when the button is pushed and one when the button is

released. There is a wait between the two operations.

Only procedures without parameters (standard and created in a micro world) can be selected.

Pushing the button executes the first procedure only once and places the procedure name in the program line. As long as the button is pressed a Wait command counts the time in the next line in the program. When the button is released, the time counting is finished, the second procedure is executed and its name is placed in the next program line.

Example:

These buttons can be used for example to turn a lamp or a motor on for a certain time interval.

STEPPING

A stepping button causes a procedure to be executed a number of times while the button is pressed. A parameter 'steps' is added to the procedure name.

Only procedures with one parameter can be selected. This parameter must determine the number of repetitions in the procedure.

Example:

```
Procedure Go_Down(Number)
Repeat
Do_a_Step
....
Until Number
EndProcedure
```

Managing Buttons

To add a new button

- » Right-click the Program window and mark the **Show Programming Buttons option**.
- » Right-click an empty place in the button area of the Program window and select **New Button**.
- » Select a button type.
- » Select the procedure(s) associated with this button. In the list only procedures appear, which can be used for the selected button type. These can be standard Coach Language procedures or procedures created in the Procedure window.
- » Select a button icon from the list of icons.
- » Click **OK**. The new button is placed in the Program window.

To edit a button

- » Right-click a button and select **Edit**.
- » Edit properties of the button and click **OK**.

To move a button

- » Right-click a button and select **Move**.
- » Move the button to another location and click it.

To delete a button

- » Right-click a button and select **Delete**.

- » The button is removed from the Program window.

Modifying Command List

The command list in the Program window consists of references to either standard Coach Language commands or to commands (functions and procedures) created by an Author.

The command list can be adapted by deleting references to existing commands from the command list and by adding references to new procedures and functions. Such an adapted command list forms an easy programming environment for student users. They create programs by selecting commands from the list. In many cases, to obtain a complete command they select items from several submenus e.g. to select parameters for the command, to enter a value or to put together a conditional expression. Through this system, Coach ensures that constructed commands always have a correct syntax.

The command list is displayed when the Show Command List option is marked.

Managing Command List

To edit the command list title

The command list by default has the title **Command**. To change this title:

- » Right-click the Command List and select **Edit Command List Title**.
- » Edit the title and confirm with OK.

To delete a command from the list

- » Right-click the command you would like to remove and select **Delete**.
- » The name will be removed from the command list, together with the submenu for the item. When you want to restore the name, you have to create the submenu again.

To cut a command from the list

- » Right-click the command you would like to cut and select **Cut**.
- » The name and corresponding submenu(s) are moved to the clipboard and can be placed elsewhere in the list with Paste.

To copy a command from the list

- » Right-click the command you would like to copy and select **Copy**.
- » The name and corresponding submenu(s) are copied to the clipboard and can be placed elsewhere in the list with Paste.

To paste a command into the list

- » Make sure you have copied or cut an item from the command list.
- » Right-click the position after which the command should be placed and select **Paste (after)**. The option **Paste (before)** is available only for the first position of the command list.

Creating a New Command

1. Before you add the new self-made command to the list, you have to create a new function or procedure in the Procedure window. This is not necessary if you want to add a standard Coach Language command.
2. Right-click a command or an empty place in the command list and select **Insert**.
3. In the **Add New Command to the List** dialog type in the **Name** of the new procedure. Here you can also type a name of the standard Coach procedure or function.

- Coach automatically recognizes the name (as a name of procedure defined in the Procedure window or the standard Coach Language command) and adds its description to the **Description** field. Coach can display the following descriptions:

Operator or unknown command - The name is not recognized to be a standard command or a micro-world procedure or function. A procedure or function with this name still has to be made, or the name is wrong.

Procedure with a variable number of parameters - These are standard Coach Language procedures (e.g. Set, Reset, Sound, etc.). The corresponding submenus cannot be edited.

Function with a variable number of parameters - These are standard Coach Language functions. The corresponding submenus cannot be edited.

Procedure with (n) parameters / Function with (n) parameters - Only submenus of commands with 0, 1 or 2 parameter(s) can be edited.

Statement with an expression - These are **If**, **Until**, **While** and **Redo**. Conditions for these commands can be edited.

Other Coach Language word - Like **Repeat**, **Else**, **EndIf**, **EndRedo**, etc. These commands do not need a submenu.

- The description given by Coach determines whether menus (e.g. for parameters) are available. The type of command menu can be chosen in the **When the user selects this command** part of the dialog box. The following options are available:

Default command menu - select this option only for standard commands (loop commands or conditional statements).

Adapted command menu (Use the Edit Menu button) - with help from the wizard, an Author puts together a command menu.

No command menu - select this option for commands without parameters.

Comment - by selecting this option, the item in the list is regarded as a comment only. This is useful e.g. to create subtitles in the list. Also blank lines have this setting. Clicking a comment in the list during programming does not lead to any action.

- After selecting **Adapted command menu**, click the **Edit Menu** button. This will start the wizard that helps to create a command menu (selection list and/or fields for typing values) and command conditions.

Submenus for procedures and functions with 1 or 2 parameters

For procedures and functions with 1 or 2 parameters Coach opens the Menu Wizard which allows creating the selections list or typing fields per parameter. For each parameter:

- » Type the title of the submenu.
- » Mark one of the options:
 - » **Type a value** - user has to type a value; or
 - » **Selection list** - user has to select an item from the list.
- » After the **Selection list** option is marked, type in the items of the list.
- » Click **OK** when the submenus for all parameters are ready.

Conditions for Conditional and Loop statements

For conditional statements (If...Then... EndIf) and loop statements (Repeat... Until, While... Do... EndDo) users create conditional expressions via submenus. For these commands wizard allows creating a conditional expression by defining separate submenus on the right side of the operators for each item on the left side (Submenu per item marked), or to make one submenu which appears for all items on the left side (Submenu per item not marked). Only expressions with relational operators can be created.

Left side of the conditional expression

- » Type a title for the first selection list.
- » If you mark the **Submenu per item** check-box, then each item on the left has its own list on the right. If you do not mark this check box then all items on the left will have the same submenu.

- » Type the names of the functions and variables. When a function has parameters, a **Menu** button appears.
- » Click the **Menu** button to enter submenus for the parameters.

Relational operators of the expression

- » Mark relational operators that will appear in the selection list.

Right side of the conditional expression

- » Select a function or variable at the left side by marking a radio button at the left side of the name. Enter the item(s) to which it has to be compared at the right side. Again you have possibility to select between the **Type value** or **Selection list** option.
- » Click **OK** when the submenus for all items at the left are defined. Remember if you do not mark the **Submenu per item** check-box, at the left side then you have to create only one submenu at the right side.

Editing an Existing Command

- » Right-click a command in the command list and select **Properties**.
- » In the **Edit Menu Item** dialog edit the properties of the command in the similar way as creating a new command

Tutorial: Adding a New Command

Imagine a system consisting of 4 small lamps (3V-bulbs) which can be connected to the outputs of the CoachLab II+ interface to be turned on and off. To control lamps a procedure Lamp must be defined.

Procedure **Lamp(n;m)**

If m=On Then

Set(n)

Else

Reset(n)

EndIf

EndProcedure

This procedure uses 2 parameters; the first parameter gives information about which output should be activated; the second parameter informs if the selected output should be turned on or off.

1. Type the above listed procedure **Lamp** in the Procedure window.
2. Right-click a command or empty space in the command list and select **Insert**.
3. Type in the name **Lamp**. Coach recognizes that this is a procedure with 2 parameters.
4. Mark **Adapted submenu**.
5. Click the **Edit Menu**.
6. For this command two menus are required, the first to select the lamp output, and the second to select the state of the lamp. The submenu for the first parameter (selection of the output) is done in the left part of the Submenu wizard. Give a title to the first submenu: Select output.
7. Mark the option **Selection list**. The user will select the output from the command list.
8. Type list items: A, B, C, D. When you use variables A, B, C, D instead of the default output numbers, then you have to declare them explicitly in the Procedure window. For CoachLab I these declarations are: A=1 B=2 C=3 D=4, for CoachLab II these declarations are: A=1 B=3 C=5 D=7.

9. Define the submenu for the second parameter.
10. Mark the option **Selection list**.
11. Type the list items: **On, Off**.
On, Off are standard Coach Language commands, you do not have to define them in the Procedure window.

Tutorial: Redefining a of Structural Statement

A structural statement, like a conditional statement **If... Then... Endif**, always needs a logical expression to be evaluated. By default you build a structural statement from lists that pop-up as soon as you select the opening word, e.g. **If**. This structure can not be modified. A micro-world must use either the standard structural command or a replacement submenu, designed by the author of the micro-world. Below you find an example of creating a replacement submenu of a conditional statement.

Imagine a system that reacts on the light intensity, measured by a light sensor connected to one of the inputs of CoachLab II/II+ (an automatic shop window illumination). To read a value measured by the light sensor a function `Light_Intensity` must be defined:

Function **Light_Intensity(p)**

`Light_Intensity = Level(p)`

EndFunction

1. Type in the Procedure window the function **Light_Intensity**.
2. Right-click the **If** command in the command list and select **Properties**.
3. Mark **Adapted submenu**.
4. Click the **Edit Menu** button.
5. In this window you have to create a condition.
6. Remove all settings that are placed in the fields at the left side of the window.
7. Type in a new title for the first selection list.
8. Type in the function name `Light_Intensity` in the first field.
9. The function `Light_Intensity` has one parameter that allows selecting the input of the light sensor. For this parameter the submenu can be created. To create a list of inputs that can be selected click the **Menu** button.
10. Select the **Selection list** option.
11. Type in the inputs: 1, 2, 3, 4 and click **OK**.
12. Mark the operators used in the condition '<' and '>'. (If necessary remove all default settings).
13. Finally define the right side of the condition. Users will have to type a value of the light intensity. (If necessary remove all default settings).
14. Type in a title for this part, for example **Type value**.
15. Select the **Type value** option.
16. Click **OK**. Your new condition is ready.

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