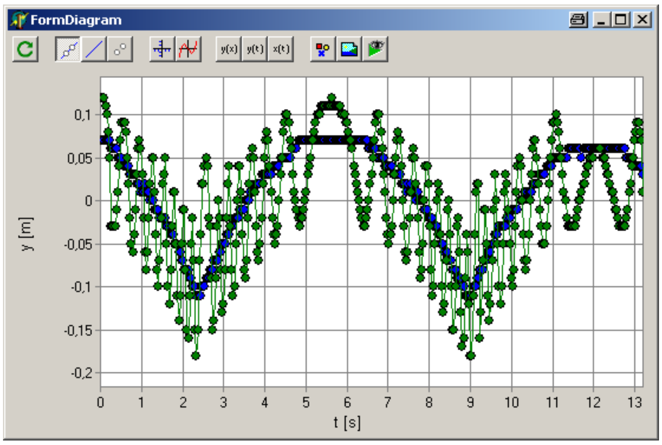
measure Dynamics

Version 1.222f

Manual



Contents

1 *measure Dynamics* in short form

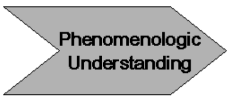
1.1 Description of the contents

The newly developed *measure Dynamics* software package of PHYWE Systeme GmbH & Co. KG is used to analyse movements, which have been documented in the form of a video and matches precisely to kinematics and dynamics teaching in physics classes at lower and upper secondary education level.

measure Dynamics assists the teacher through the whole video analysis process, after the video has been produced (Fig. 1):

Fig. 1: The video analysis of *movements* in physics classes can be broken down into several blocks. After the video has been captured, phenomenological access to the movement is provided, especially at lower secondary education level. More in-depth analysis of the movement and modelling is based on this.

measure Dynamics picks up from a previously captured video – the following process is then completely implemented in the program package. Alternatively, numerous saved movement examples (projects) can be used, which have already been analysed.



Video analysis with *measure Dynamics* enables very precise observation, even of complex movements. Here the movement is initially captured phenomenologically, according to a tried and tested didactic approach, which is particularly important at lower secondary education level.

measure Dynamics provides function for the phenomenological access, which support observation: the superimposing of locus diagrams (Fig. 2–A) or vector arrows (Fig. 2–B), the stroboscope display of the whole movement in one figure (Fig. 2–C) or the freezing of the movement *via* image series (Fig. 2–D).

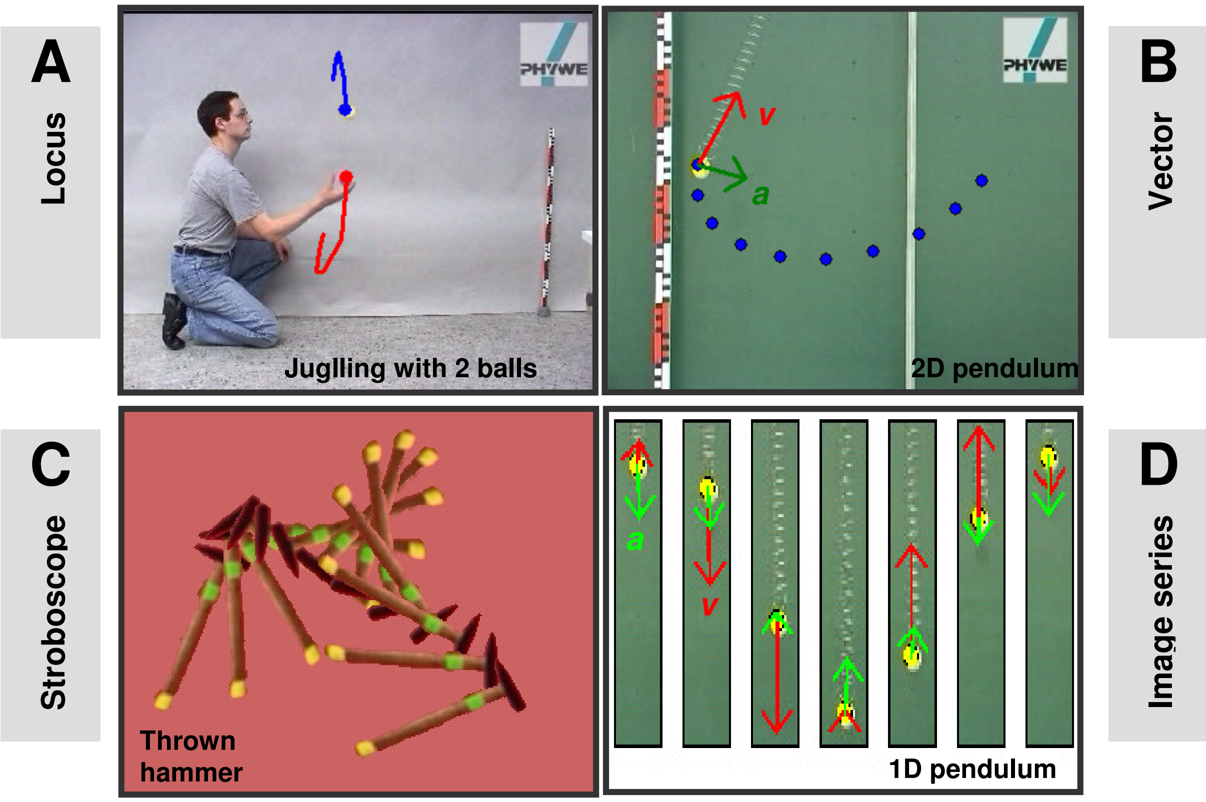


Fig. 2: Possibilities in *measure Dynamics* for supporting the phenomenological recording of movements.

Analyse

If movements are to be analysed further, the locus diagrams (polar plots) $s(t)$, velocity curves $v(t)$ or acceleration curves $a(t)$ can be assigned via difference quotients. For example, for falling or throwing experiments, from this the acceleration of gravity g can be determined. The close link between the video, which directly shows the original movement and the deduced variable, acceleration $a(t)$ forms an intuitive bridge to the term force and thus to the Newton's second axiom $F = m \cdot a$.
The example (Fig. 3) shows the movement analysis of a vertical throw upwards. In the vertical projection of the movement $y(t)$ the 2^{nd} order parabola can be recognised as that which describes the movement. Second-order differentiation of time $a_y(t)$ results in a constant, which very precisely gives the actual value for acceleration of gravity g.

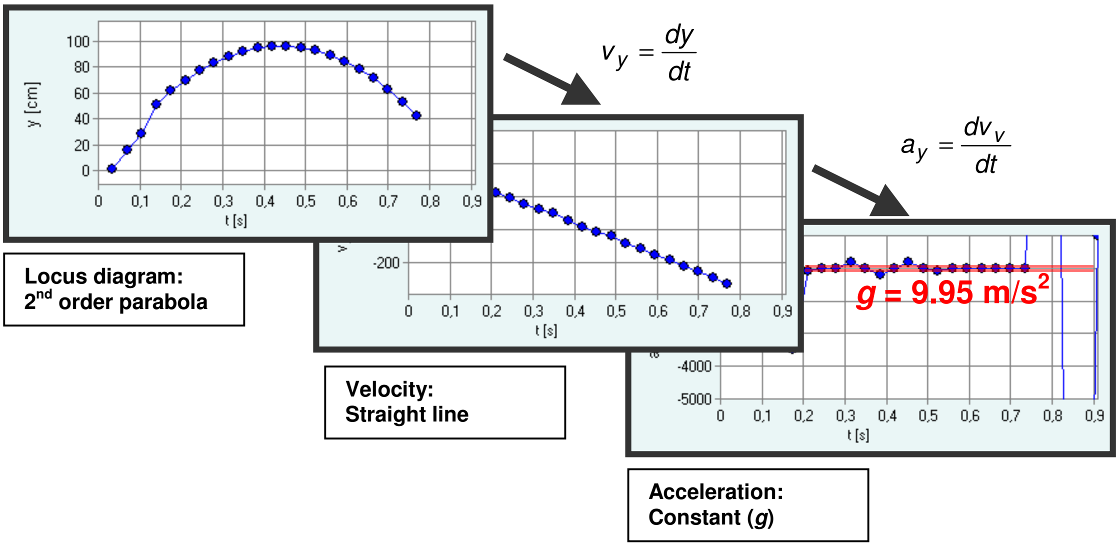


Fig. 3: Analysis of a vertical throw upwards (uniformly accelerated movement)

The final step of modelling or the didactic transfer is simply enabled by copying the determined values as a table (csv format) or as a direct copy in the intermediate memory of the computer. This enables the mathematical analysis to then be continued in other mathematical programs. Alternatively, the determined curves can be approximated to a mathematical model in *measure Dynamics* .

1.2 Possibilities with *measure Dynamics*

Movement analysis using videos has become increasingly attractive in recent years and is the subject of the work of various scientists, boards and commercial suppliers.

The video analysis of movements offers various advantages compared to conventional models – photogates or contact free (optical) ranging sensors:

- Students are familiar with the measuring tool itself, the inhibition level preventing independent experimenting is thus correspondingly lower
- The degree of abstraction can be kept very low, whereby fundamental terms such as velocity and acceleration can nevertheless be didactically and clearly covered
- The analysis of two-dimensional movements is easy with videos, due to the system

- Complex two-dimensional movements can also be easily and quickly reduced to what is physically important (see Fig. 2–C centre of gravity movement / relative movement)

measure Dynamics assists the teacher or student with movement analysis using videos in various ways:

- Completely analysed and evaluated videos of numerous movement examples (projects) already exist
- Previously very time-consuming processes of actual movement analysis are completely automated (the object no longer has to be clicked in each image)
- Stroboscope display: intuitive understanding of complex movements (*e.g.* trampolining)
- Insertion / overlaying of velocity and acceleration vectors or movement traces
- Interpolation of locus diagrams, velocity and acceleration curves
- Various possibilities for didactic transfer and modelling are integrated

1.3 Content of *measure Dynamics*

Essentially, ***measure Dynamics*** includes the following components:

- Main program with setup routine
- Example videos with evaluation (projects)
- Tools (freeware, release for passing on)
    - Virtual Dub (video software)

2 Installation

The software is equipped with its own installation program. To install, insert the original CD in the relevant drive. The installation program automatically starts.

If not, open Windows Explorer, now select the CD-ROM drive and double-click the program

start.exe.

Now follow the instructions on the screen.

3 Using *measure Dynamics*

3.1 User interface

After starting *measure Dynamics* the main interface appears, which can be divided into 4 fields (Fig. 4).

1. Main menu – for opening the functions assigned to the respective process step
2. Video (raw data) – displays the video with the assigned functions (for example, cutting, 3.2.1)
3. graphic evaluation – after the analysis has been carried out the calculated loci or time derivations are displayed graphically
4. Tabular evaluation – after the analysis have been carried out, all relevant information is filed in the form of a table

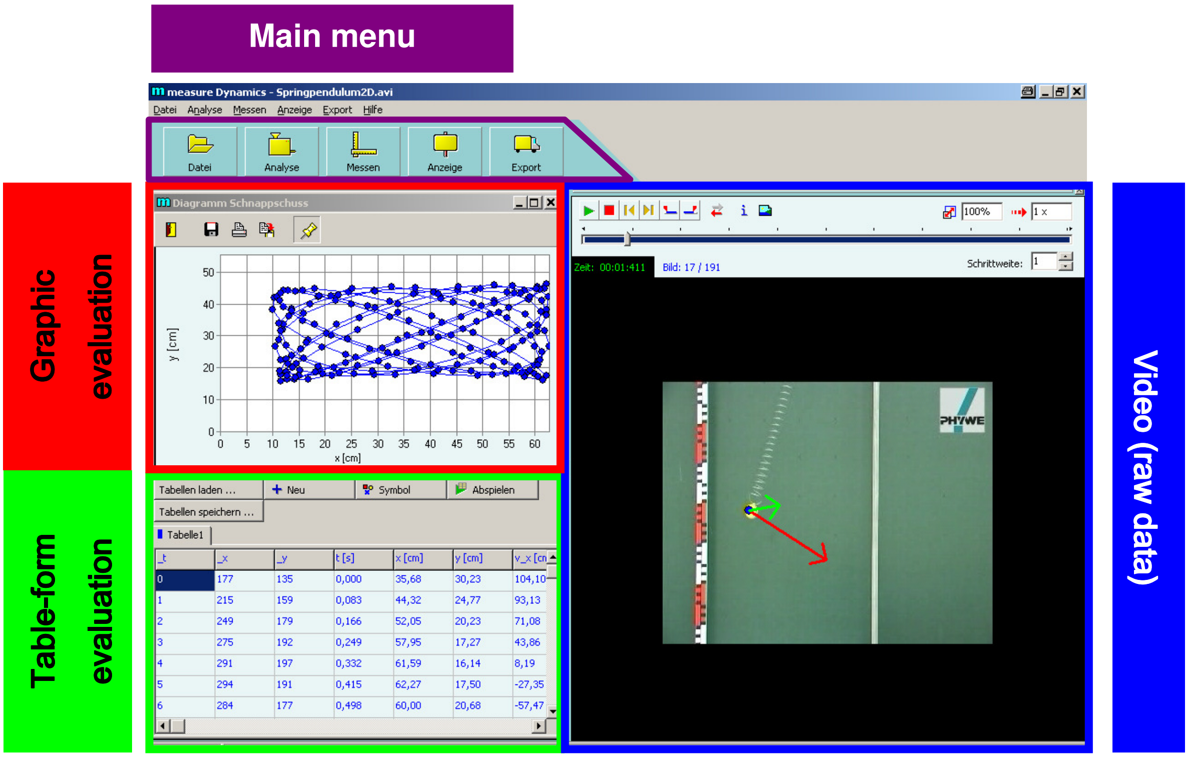


Fig. 4: User interface of measure *Dynamics* (after starting the 2D spring pendulum project).

3.2 Creating and preparing videos

The following rules must be observed when capturing a video:

- Highest possible contrast between the moved object and background
- Still background
- Film from a tripod
- Brightness rather too high than too low
- Moved objects rather small
- As far as possible, objects move over the whole video

There are no limits for the recording equipment (digital camera / camcorder / webcam / camera mobile phone). Nevertheless, the following tips are given:

- The camera should be adaptable to tripod (threaded bushing). It is advisable to fix a mobile phone into position with a universal clamp
- 30 images per second recommended as frame rate for fast movements (especially for free fall experiments)
- Interlacing leads to artefacts, especially with fast movements, which can be reduced afterwards using Virtual Dub (1.3)

After the video recording, the video should be prepared before the actual analysis in order to ensure manageability

- Videos should be cut to the necessary length
- Compress videos (3.2.2)
- Convert videos into Windows-compatible avi (avi is an established format standard among a large number of video formats)

3.2.1 Cutting videos

Start *measure Dynamics* and open the videos with **Open Video**. The following status line with functions appears above the video (in the right-hand half of the window) (Fig. 5):

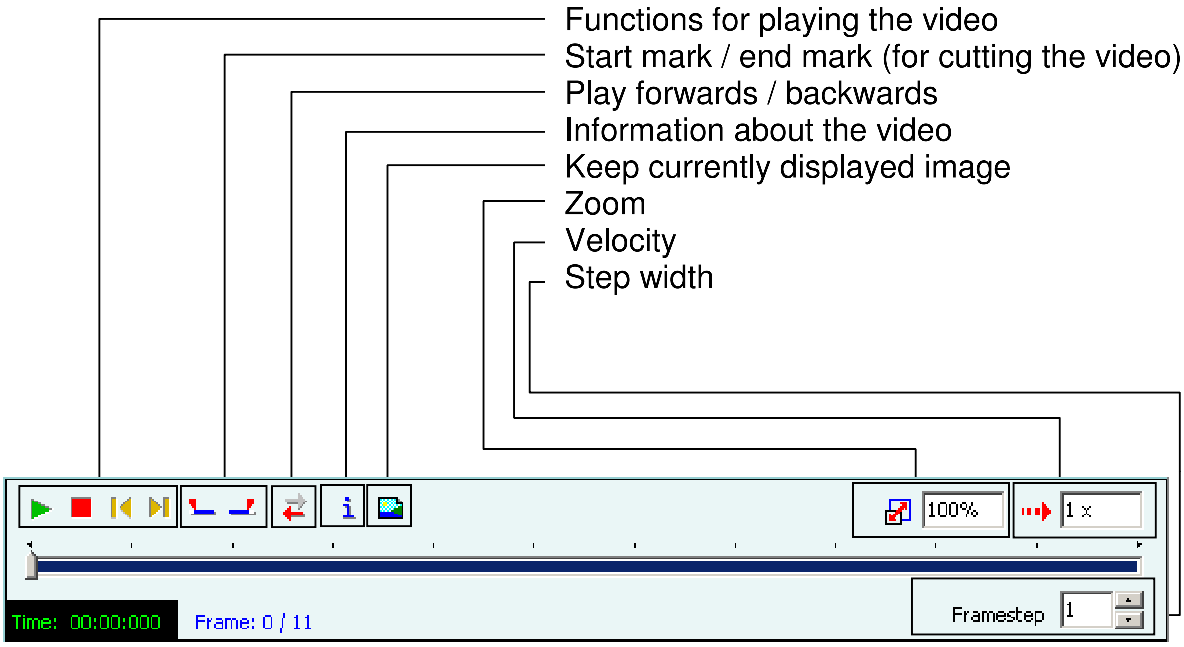


Fig. 5: Status line for playing back and cutting video.

If you play the video, you quickly find the relevant sequence to which the video is to be cut.

Select the required **first** frame, then  click.

Select the required **last** frame, then  click.

In the following steps (analysis, save,...) only the limited image sequence is used!

3.2.2 Compressing videos and saving in avi format

If you have modified a video in *measure Dynamics* (for example, by cutting or superimposing vector arrows), these changes can be saved in a (new) video.

Preferably save videos as Windows compatible avi, to enable use of as many video players as possible.

- Compressing videos is definitely recommended to

maintain manageability of the files and to keep the memory requirements within limits.
- With correctly set compression algorithms, there is no identifiable quality loss in the video.

Open **Export**, then **Export Video,** then **Compression** (Fig. 6).

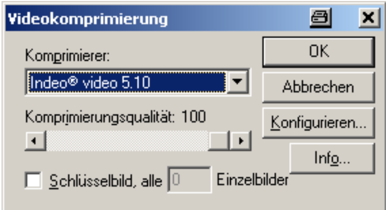


Fig. 6: Selection window for compression algorithms. The quality loss of the video if compressed with the algorithm **Indeo Video 5.10** and a compression quality of 100 is not recognisable.

After activating compression, the video can be saved with **Export**, then **Export Video,** then **Save Video.**

3.3 Analysis of movements

There are 2 ways available for the movement analysis:
- **Open Video** – independent analysis of a video (3.3.1)
- **Open Project** – Showing or further examination of a video which has already been analysed (3.3.5)

3.3.1 Open Video

Load a video with menu item **File**, then **Open Video**

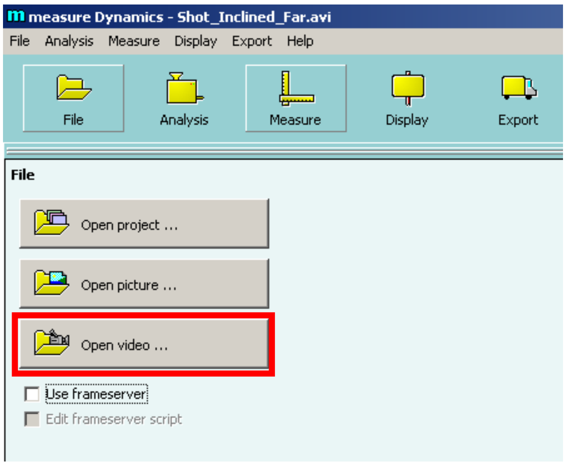


Fig. 7: Selection window: Load a project or image or video. A project (*.prj) is an already analysed video.

3.3.2 Analyse Videos

There are 2 ways of analysing videos:

- Stroboscope display (3.3.6)
- Movement analysis

Movement analysis only is described in this section.

The video should be scaled (3.3.2.1) before the actual analysis to simplify the following evaluation!

3.3.2.1 Set origin, scale video

The following functions are available under **Scaling**:

- Set origin, here it is useful to use the start point, end point or zero crossing of a movement
- Calibrate (length)

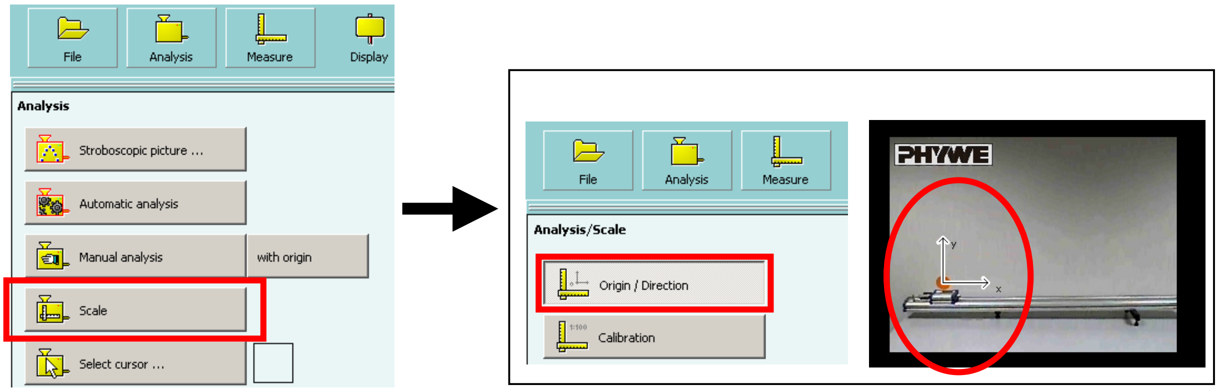


Fig. 8: Procedure for specifying the origin and direction

Rotate coordinate system : Right-click and rotate axes

Next, calibrate the video:

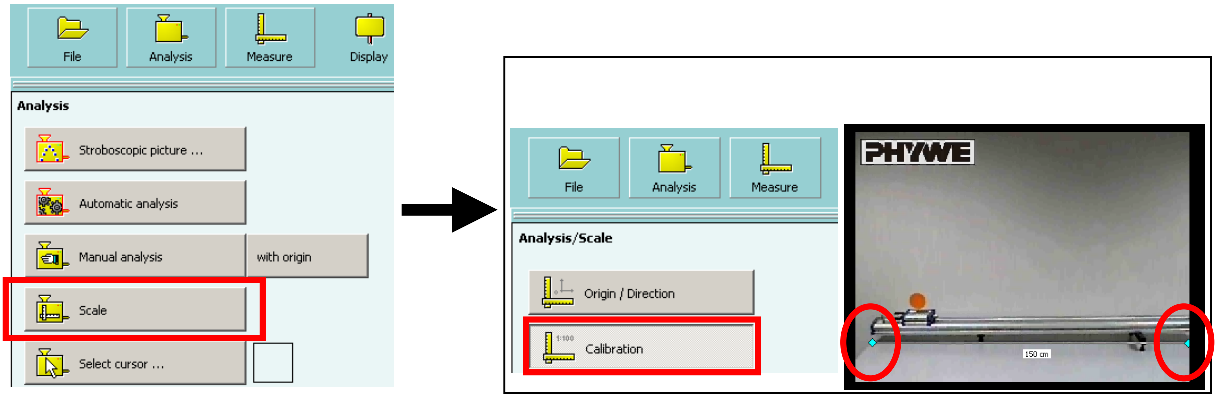
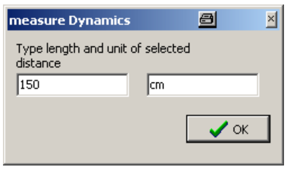


Fig. 9: Procedure for specifying the scale.

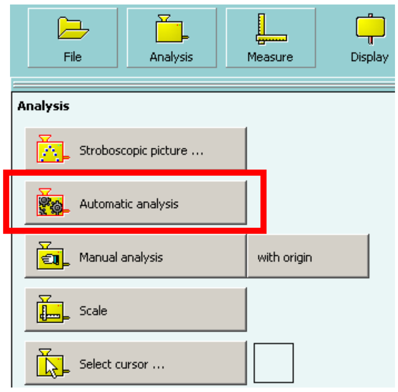
Drag the two ends of the measuring bar to an object with a known size.



Both the amount of the specific length and the size (m, cm) can be changed.

For precise evaluations, it is advisable to always have an object with a known size in the image when creating the video, ideally a large scale, in order to be able to take in camera recording errors.

3.3.2.2 Automatic analysis



Normally, select **Automatic Analysis** !
Manual Analysis means: clicking the moved object in each picture frame.

After starting the automatic analysis, a preliminary examination begins, which ends with the prompt to **Select Object**.

One or several objects can be traced through the image sequence in each video. However, each object must be assigned to its own worksheet.

If you move the cursor in the video a collimator appears. Use it to click the centre of the object.

Successful object recognition is displayed *via* a window, a green square appears in the object.

Fig. 10: Automatic analysis: the preliminary examination algorithm has recognised a moved object at this point.

If the object recognition fails:

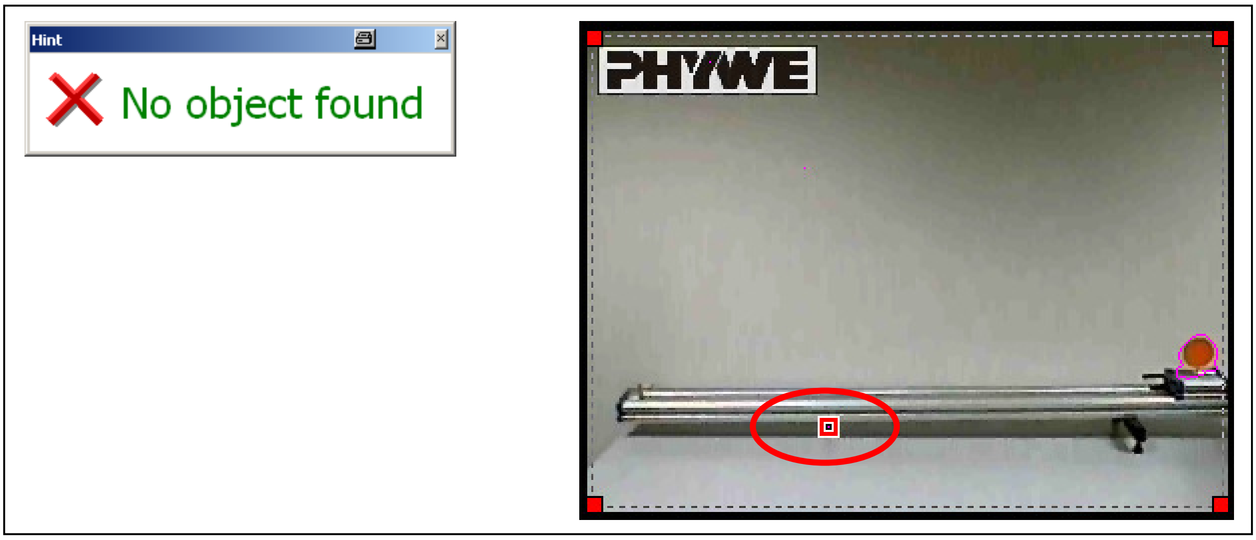


Fig. 11: Automatic analysis: the preliminary examination algorithm has not recognised a moved object at this point (!)

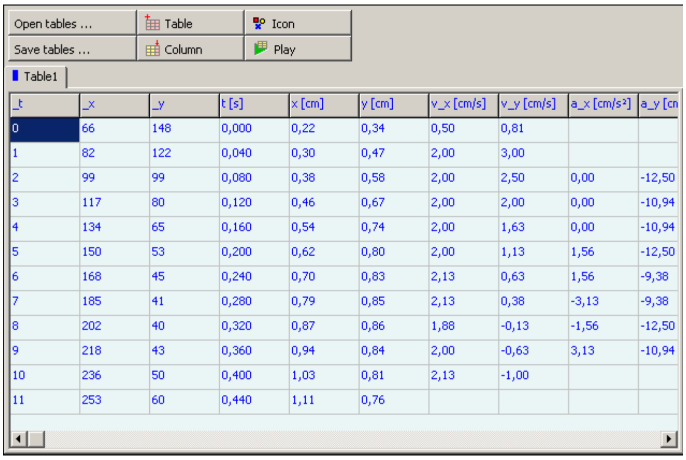
What to do if object recognition fails?

- Optimise the automatic analysis options
- Switch to manual analysis
- Create a new video

After successful object recognition: Click **Start**:

The actual calculation of the object point per image frame then begins; the result is filed in the table.

The table for the individual object includes all values determined during the analysis – spread over the worksheets for the object. In addition, the table can be used to change the marking of the loci in the video.



_t	_x	_y	t [s]	x [cm]	y [cm]	v_x [cm/s]	v_y [cm/s]	a_x [cm/s²]	a_y [cn
0	66	148	0,000	0,22	0,34	0,50	0,81		
1	82	122	0,040	0,30	0,47	2,00	3,00		
2	99	99	0,080	0,38	0,58	2,00	2,50	0,00	-12,50
3	117	80	0,120	0,46	0,67	2,00	2,00	0,00	-10,94
4	134	65	0,160	0,54	0,74	2,00	1,63	0,00	-10,94
5	150	53	0,200	0,62	0,80	2,00	1,13	1,56	-12,50
6	168	45	0,240	0,70	0,83	2,13	0,63	1,56	-9,38
7	185	41	0,280	0,79	0,85	2,13	0,38	-3,13	-9,38
8	202	40	0,320	0,87	0,86	1,88	-0,13	-1,56	-12,50
9	218	43	0,360	0,94	0,84	2,00	-0,63	3,13	-10,94
10	236	50	0,400	1,03	0,81	2,13	-1,00		
11	253	60	0,440	1,11	0,76				

Table 1: Information on an object point per picture frame

_t	Counter
_x	x coordinate of the object point in pixel values
_y	y coordinate of the object point in pixel values
t[s]	Time stamp of the picture frame
x[m]	x coordinate of the object point, calibrated
y[m]	y coordinate of the object point, calibrated
v_x [m/s]	x component of the velocity, difference quotient, averaged
v_y [m/s]	y component of the velocity difference quotient, averaged
a_x [m/s]	y component of the acceleration difference quotient, averaged
a_y [m/s]	y component of the acceleration difference quotient, averaged

Velocity and acceleration are calculated values (difference quotient).
If trajectories (loci curves) are not smooth or the plotted points are scattered, smooth them first and then differentiate (for example, in measure).

3.3.2.3 Transfer table values

The generated table values include the results of the movement analysis. They can be edited and transferred in various ways.

The following **Functions** are available (right-click table):

- Edit cell
- Clear cell
- Clear row
- Clear column
- Open table
- Save table
- Copy table to clipboard
- Refresh automatic entries
- Fetch values

- Changing and deleting cell values also have an effect on the object markings in the video!
- Most important function: Copy table to clipboard

3.3.3 Diagram evaluation

It is advisable to illustrate the completed analysis with a diagram; whereby there are 2 possibilities. Display *via*

- diagram: the diagram is fixed
- Extra diagram: the diagram can be moved.

Extra Diagram offers the following advantages:

- Diagram is movable
- Several diagrams can be opened (is interesting if several objects are involved or if the movement of an object is analysed using a locus diagram and a velocity curve.)

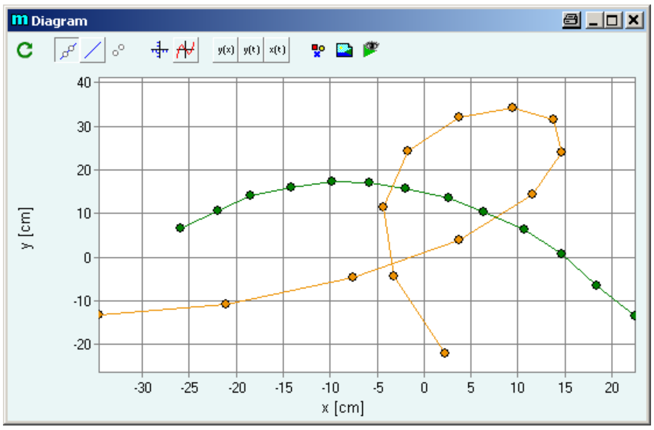


Fig. 12: Display of the movement of a triple pendulum in the form of a diagram.

If there are several analysed objects the loci paths can be displayed separately in different diagrams!
→ Diagram options → Table:

3.3.4 Superimpose functions (modelling)

Further analysis of movements is also possible in *measure Dynamics* . To this end, manually created function curves can be added to the movement curves to be determined.

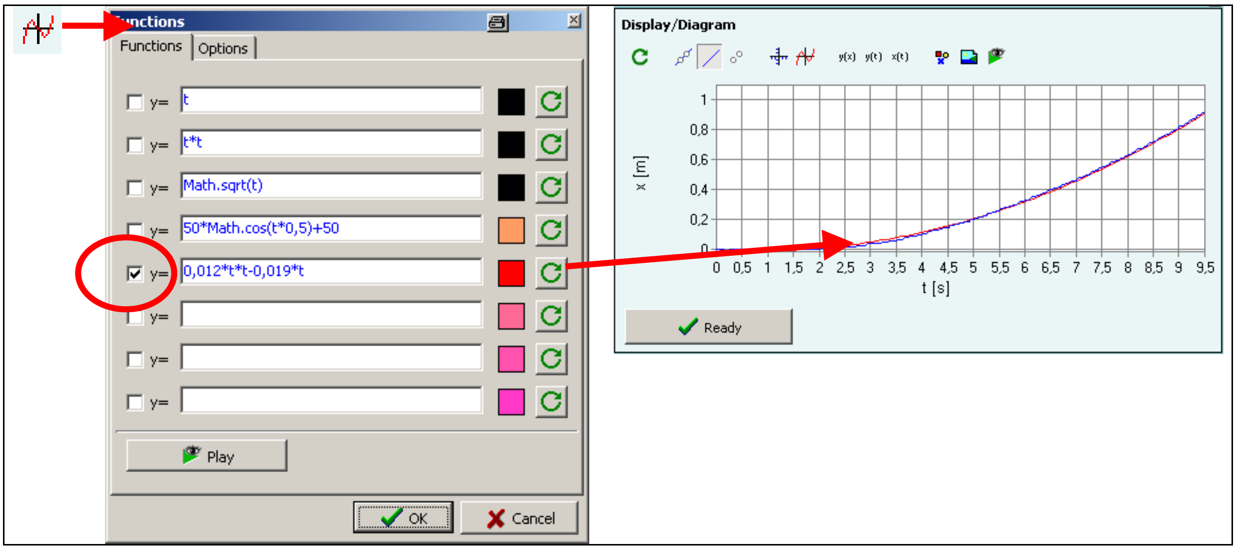


Fig. 13: Modelling with *measure Dynamics* using the example of a uniformly accelerated movement.

Functions are stored in fct file format and if necessary are linked with projects (3.3.5).

3.3.5 Load project

A project (*.prj) links the created analysis (.csv), functions as overlays (.fct) and created filter sets (.pfs) to a video (.avi).

This enables the results of a teaching unit to be easily and elegantly saved.

3.3.6 Stroboscope

The moving object is analysed in all images, is extracted from the background and is displayed superimposed relative to a background image.

Open the Stroboscope dialog box with the menu item **Analysis**, then **Stroboscope Picture**.

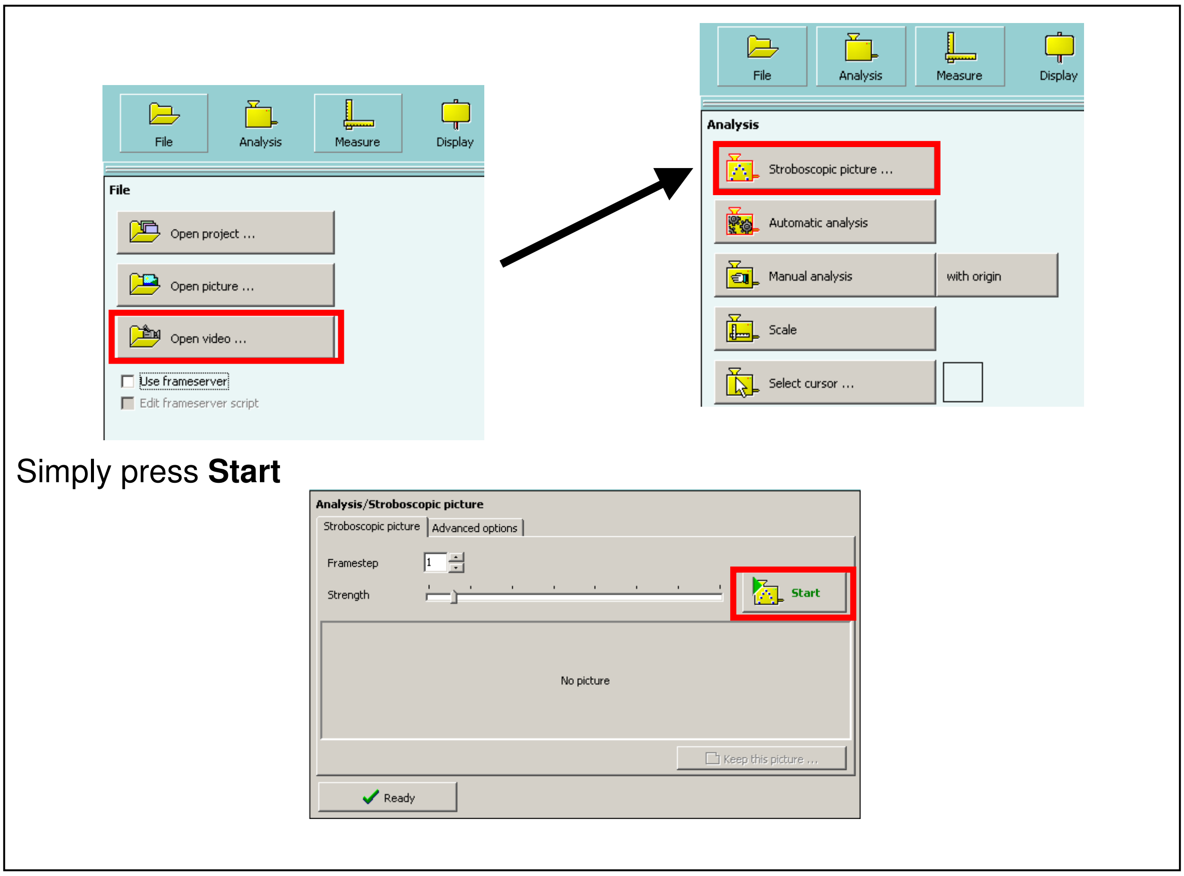


Fig. 14: Stroboscope display: Menu assistance.

Frame Step specifies the increments between the images, from which the moved object is summarised using the Strobo function.

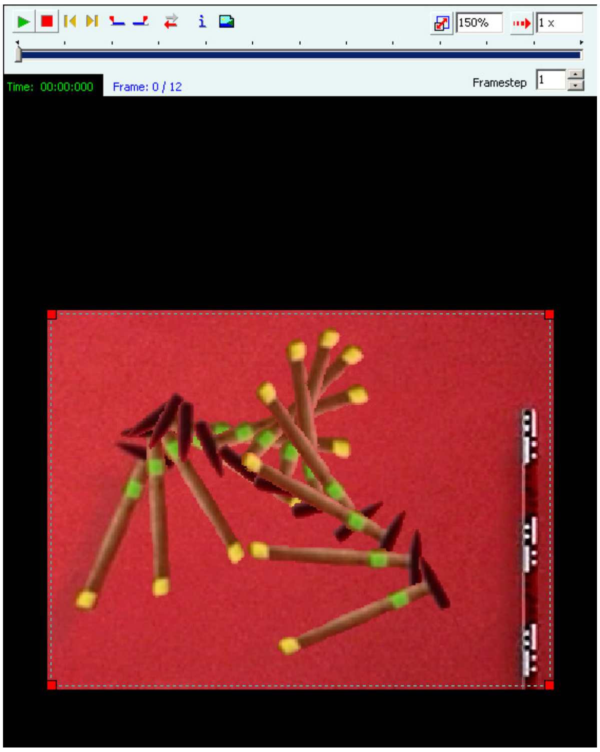


Fig. 15: Stroboscope display of the movement of a thrown hammer.

Stroboscope settings:

- Framestep: Specifies the distance between the images, from which the respective objects are extracted (increase is useful for slow movements)
- Strength (Sensitivity)
- Monochrome background: useful if background is busy, note the colour selection for the monochrome background
- Coloured flashlights: more gadgetry than useful, not absolutely necessary
- Transparent frames: increases the dynamic impression.

3.4 Counting objects in individual images

Open the function with the menu item **File**, then **Measure**, then **Count**

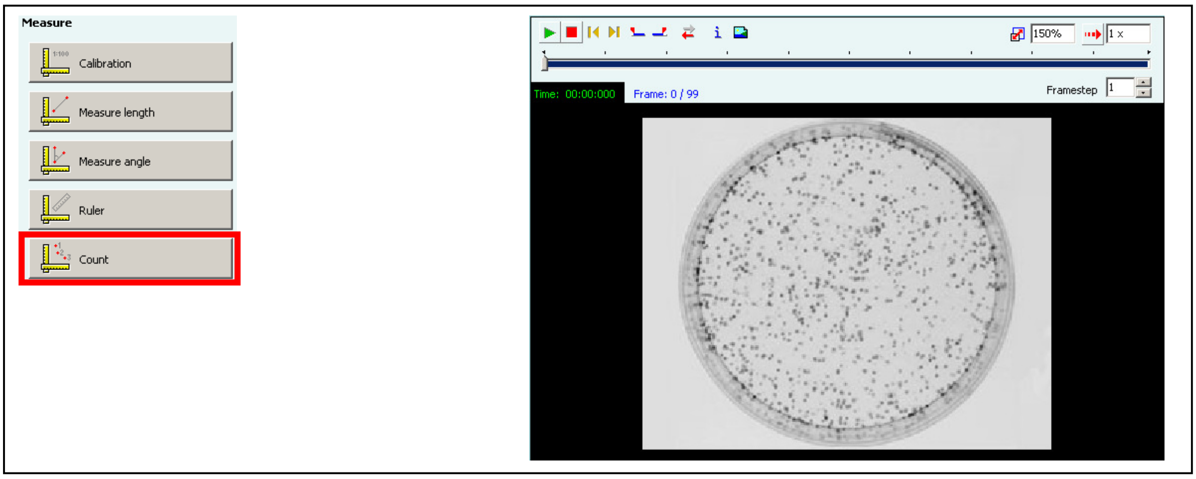
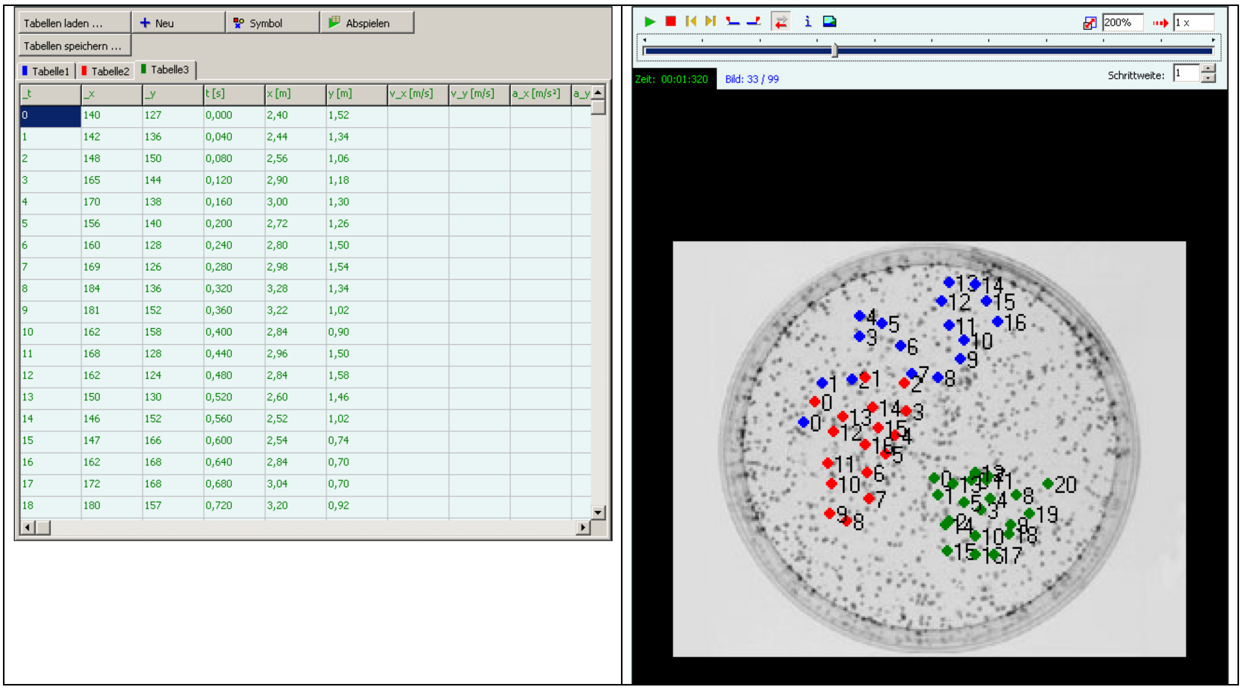


Fig. 16: Counting using the example of colony counting, *i.e.* counting cell colonies in a Petri dish.

- If you want to count different species, a worksheet should be created for each species.
- All information (as recorded in the videos) for each point is filed in the table

Each point is stored as a separate frame



_t	_x	_y	t [s]	x [m]	y [m]	v_x [m/s]	v_y [m/s]	a_x [m/s²]	a_y
0	140	127	0,000	2,40	1,52				
1	142	136	0,040	2,44	1,34				
2	148	150	0,080	2,56	1,06				
3	165	144	0,120	2,90	1,18				
4	170	138	0,160	3,00	1,30				
5	156	140	0,200	2,72	1,26				
6	160	128	0,240	2,80	1,50				
7	169	126	0,280	2,98	1,54				
8	184	136	0,320	3,28	1,34				
9	181	152	0,360	3,22	1,02				
10	162	158	0,400	2,84	0,90				
11	168	128	0,440	2,96	1,50				
12	162	124	0,480	2,84	1,58				
13	150	130	0,520	2,60	1,46				
14	146	152	0,560	2,52	1,02				
15	147	166	0,600	2,54	0,74				
16	162	168	0,640	2,84	0,70				
17	172	168	0,680	3,04	0,70				
18	180	157	0,720	3,20	0,92				

Fig. 17: Count the objects of the different species in a Petri dish.

3.5 Angle measurement in individual images

Open with menu item **Measure**, then **Angle Measurement**.

The angle measuring instrument appears in the selected picture frame (individual image or image of a video sequence), which can be adjusted to the relevant object by dragging and moving.
If the result of the angle measurement is to be adopted, the measured value is copied into the current worksheet with CTRL + W.

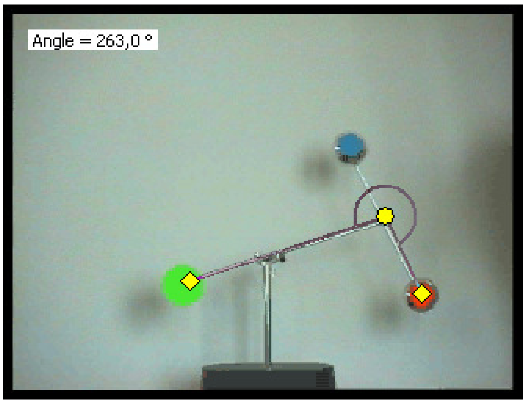


Fig. 18: Angle measurement in the image.

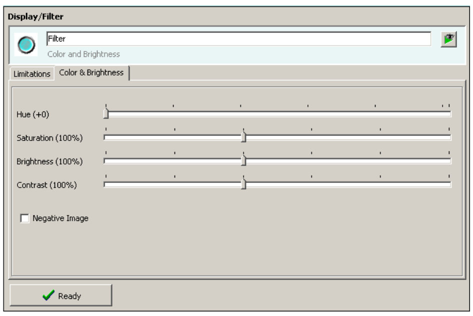
3.6 Changing the brightness, contrast,... of images / videos

Open with menu item **Display**, then **Filter**, then  then the **Colour** icon, then **Colour and Brightness**.

The following filters appear in the filter selection list

which with the  icon leads to the actual user interface for setting and adjusting

- Colour value
- Saturation
- Contrast

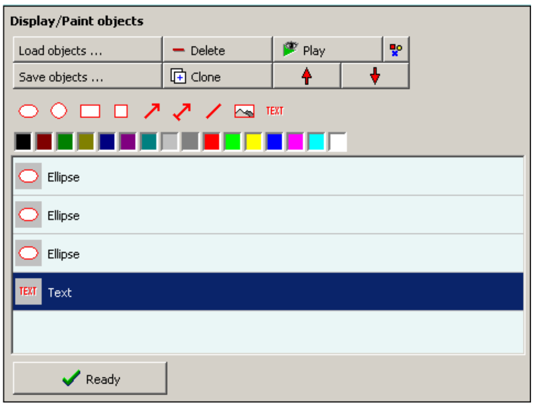


The brightness, contrast,..., etc. settings affect all images of a video!

3.7 Insert texts, images,... in individual images and videos

Open with menu item **Display**, then **Paint**:
The following dialog box appears, with which the objects can be superimposed in the image:

- Ellipse
- Circle
- Rectangle
- Square
- Arrow
- Line
- Image
- Text element



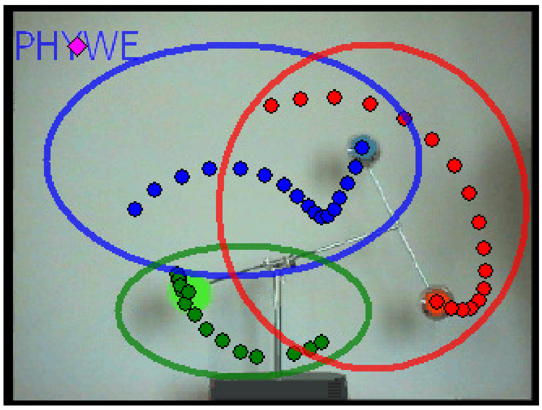


Fig. 19: Superimposing elements in an image. Left: Dialog box for selecting the elements. Right: Example of a superimposed image with an image, 2 text elements and an arrow.

3.8 Languages

The language setting of *measure Dynamics* can be changed with the menu item **File**, then **Options**, **General**. A change in language does not become effective until the program is restarted!

PHYWE Systeme GmbH & Co. KG
Robert-Bosch-Breite 10
D - 37079 Göttingen

Phone: +49/551/604-0
Fax: +49/551/604-107
E-mail: info@phywe.de
Internet: www.phywe.de