

Introduction

Short Description

The programme *Analytic Geometry, Version 7.1*, is a flexible system for presenting geometrical objects with hidden surfaces (on an OpenGL-Basis) in a rotatable 3D-coordinate system. This new version introduces the concepts of *interactive Geometry* in the 3rd dimension. So most of the objects are easily rotated or translated with the mouse in combination with certain keys on your keyboard.

You may select parallel or central projection.

Beside the known objects of the 2d-world like point, vector, line segment, straight line, circle, circular disk, ellipse the programme also supports solids like rectangular solid, regular tetrahedron, pyramid, prism, sphere, cone, cylinder and torus.

You can calculate distances and intersections of the most often occurring object combinations. Here too, you can find the concept of *Interactive Geometry*. All objects that are the result of distance or intersection calculations are automatically recalculated during translation or rotation of participating objects.

You can find special options with spheres: You can define points on the surface, translate them on the surface and connect them by great circles. Additionally you can switch on or off a grid of longitudes and latitudes. Every sphere can be endowed with an own rotation. Also distances between points (as segments of a great circle) on the sphere can be calculated.

We have also implemented chapters from elementary courses in geometry. So it is possible to test 2 vectors on collinearity or 3 vectors on linear dependency. Also linear combinations of vectors can be drawn.

As a very powerful improvement we mention *animations* of points and spheres. The flexibility comes through general functions in parametric form, that can be assigned to these objects. These functions can be defined relative to a reference object (point or sphere). So you can easily define the movement of planets including satellites.

If necessary all data of a point, sphere or line segment can be watched in an inspection window - even while they move e.g. during an animation.

This new version of the programme includes affine transformations. This - together with animations - offers a great bandwidth of effects.

Also the graphs of functions of 2 variables $f(x,y)$ and those of functions in parametric form can be drawn in the scene (including families of functions).

The palette of programme features is completed by the presentation of Bézier curves, defined by a set of control points, where weights are accepted.

It is possible to show the object data in an always visible and sizable text

window.

You can certainly save, load or print the scene or export it as graphic to be included in word processing projects.

This programme can be used in various ways in the mathematical education in secondary or higher schools of all types and even in colleges of higher education.

Also individuals interested in mathematics outside of educational institutions may enjoy this programme and benefit from it.

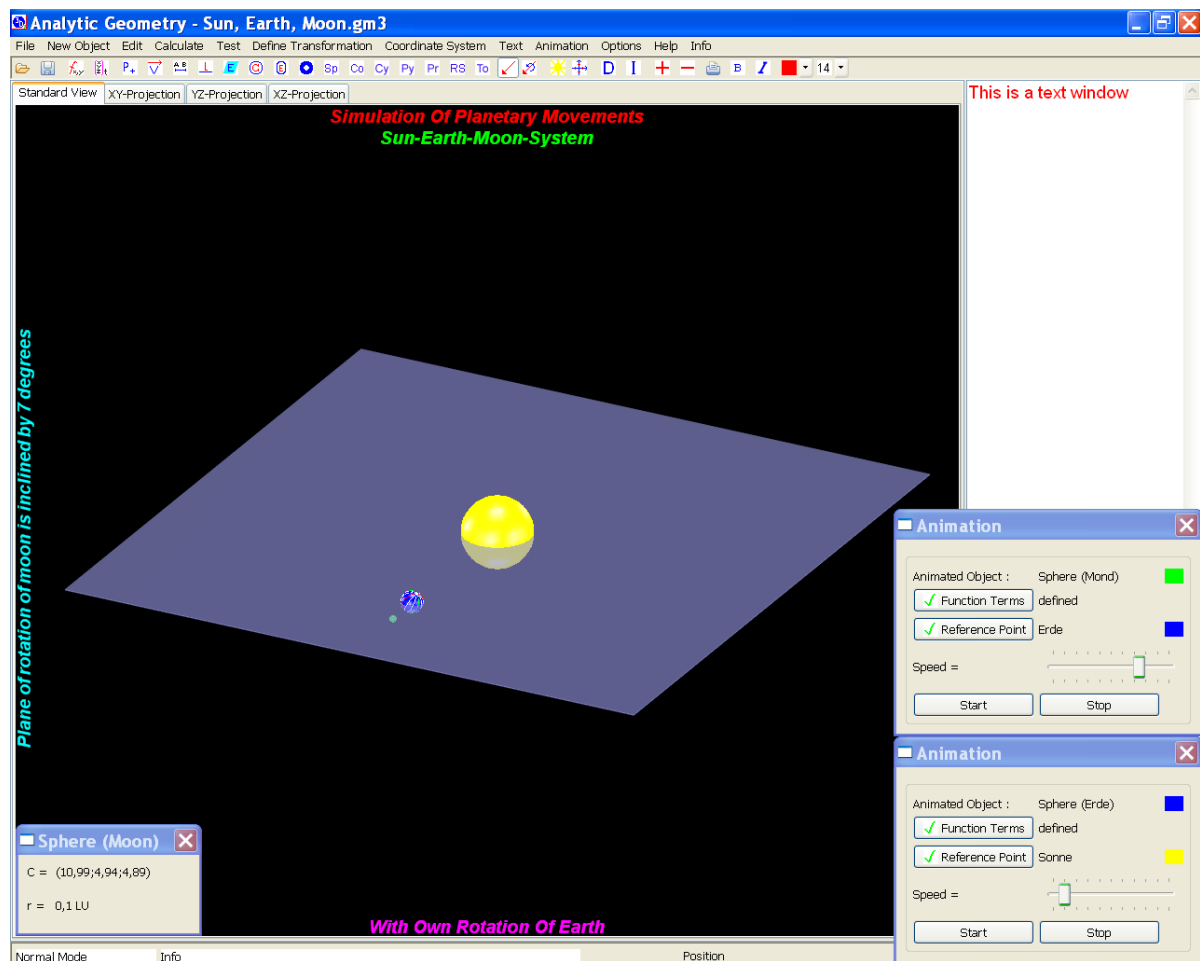
The emphases of this programme with interactive geometry are high quality graphical representation of the constructed scene, calculations of distances and intersections as well as animations.

The Programme's Appearance

The Screen

Beside the usual user interface elements like main menu and toolbar the screen shows a text window in the right quarter. This window (data window) is resizable and the place where all text output of the programme goes.

The remaining portion of the screen is used to display the objects of the scene. There are two title areas above, one on the left and one below.



In the bottom right corner you can place a control window, which influences animations. In the bottom left corner so called inspection windows can be placed. These show the data of certain objects (even during movement).

The text window is visible all the time. On default, previous outputs will be cleared when new output is generated, so that only the necessary actual information is shown. Nevertheless this setting can be changed by right clicking on the window and selecting insert mode. This will add the output at the cursor position. Using this setting you are able to generate a kind of protocol, which can be saved and reloaded.

You may add notices by typing information.

Caution: The text window is not a control window of the objects. Changing the output (e.g. point coordinates) has no effect on the objects in the scene!

The Main Menu

Overview

The main menu shows the following items:

- File
- New Object
- Edit
- Test
- Calculate
- Define Transformation
- Coordinate System
- Text
- Animation
- Options
- Help
- Info

Menu File

These are the file menu items:

- New
- Open
- Save
- Save As
- Export Graphic
- Print Page Settings
- Print

File - New

This item closes the active scene and presents an empty coordinate system.

Internally all graphical objects are initialized, so that all lists are empty.

File - Open

Files saved with the programme **Analytic Geometry** can be reopened by selecting this item. The programme uses a special file format with the file extension *.gm3.

File - Save

You can save the actual graphic with all objects and labels. The used format is a vector format, which means that you are able to open the saved file on a computer with a graphic-card with higher resolution so that the better capabilities will take effect. The file extension is *.gm3.

File - Save As

This item saves the file with a new name.

File - Export Graphic

Most of the word processing programmes allow the import of an image in the format „Portable Network Graphics“ (*.png).

When you select this item, the actual scene will be saved in this format. It is also possible to write the file as a **jpg**-image.

You may choose to include or exclude the titles in the image.

File - Print Page Settings

Print Page Settings

Format

Portrait
 Landscape

Size of Graphic

Automatically
 Manually

Frame

With Frame
 Without Frame

Width in cm
15.00

Height in cm
14.00

Position On Page

Top Left
 Top Center
 Top Right
 Mid Left
 Mid Center
 Mid Right
 Bottom Left
 Bottom Center
 Bottom Right
 Special

Page Margins

Left
2.00

Right
2.00

Top
2.00

Bottom
2.00

OK Cancel

This dialogue lets you determine the size of the graphic and set the position on the print page.

File Print

This item sends the graphical output directly to the selected printer.

Menu - New Object

The following objects can be placed in the scene:

- Function $f(x,y)$
- Function in Parametric Form $(x(t),y(t),z(t))$
- Point
- Vector
- Line Segment
- Straight Line
- Planel
- Circle
- Circular Disk
- Ellipse
- Rectangular Solid
- Prism
- Pyramid
- Sphere
- Cylinder
- Cone
- Torus
- Bézier Curve

Moving Objects With The Mouse

Nearly all of the objects can be translated or rotated with the mouse.

Whether translation or rotation takes place depends on two buttons in the toolbar:



is the symbol for translation



is the symbol for rotation

One of these buttons is always pressed. The default button is translation.

As the camera position changes by default, when you drag the mouse horizontally or vertically, a different way of moving objects had to be implemented. The movement of objects only takes place, when certain keys on the keyboard are pressed while you drag with the mouse.

Translation selected:

Ctrl-Key is pressed: Translation parallel to the x-axis

Shift-Key is pressed: Translation parallel to the y-axis

Ctrl+Shift-Keys are pressed: Translation parallel to z-axis

Rotation selected:

Ctrl-Key is pressed: Rotation about an axis parallel to the x-axis

Shift-Key is pressed: Rotation about an axis parallel to the y-axis

Ctrl+Shift-Keys are pressed: Rotation about an axis parallel to the z-axis

Imagine a vertical slider during mouse dragging:

Upward mouse movement increases the value, downward mouse movement decreases the value.

An Example: Pressing the Ctrl-Key while dragging the mouse upward (starting with the mouse pointer over an object's location) leads to an increasing x-value and dragging the mouse downward leads to a decreasing x-value.

New Object – Function

You can choose between a function of two variables with symbol $f(x,y)$ and a function in parametric form symbolized by $(x(t);y(t);z(t))$.

a) $f(x,y)$

New Function $f(x,y)$

$f(x,y) =$

Dx = [;]

Dy = [;]

Line Width = Line Colour

Globally defined

Typing the function term you have to follow some rules. The following table shows the available functions and their notations:

Abbrev.	Function
arcsin	Arc Sine
arccos	Arc Cosine
arctan	Arc Tangent
sin	Sine Function
cos	Cosine Function
tan	Tangent Function
sinh	Hyperbolic Sine
cosh	Hyperbolic Cosine
ln	Natural Logarithm
log	Decimal Logarithm
int	Integer Part
frac	Dezimal Part
exp	Exponential Function
sqrt	Root Function
sqr	Square Function

The functional argument always has to be surrounded with round brackets.

An example:

$$f(x) = 2 \cdot e^{-\frac{1}{2} \cdot x^2}$$

You type the following:

2*exp(-1/2*x^2)

Right clicking on the graph brings up the function's local menu.

b) (x(t);y(t);z(t))

There are three input fields for x(t), y(t) and z(t). The input rules are the same as cited above.

This option should be of interest to physicists, because it allows the drawing of paths (e.g. satellite paths).

A parameter s for a family of functions can be specified.

New Function in Parametric Form

D = [0.00 ; 6.28] Family

x(t) = 5

y(t) = 5+3*cos(t)

z(t) = 5+3*sin(t)

Line Width = 1

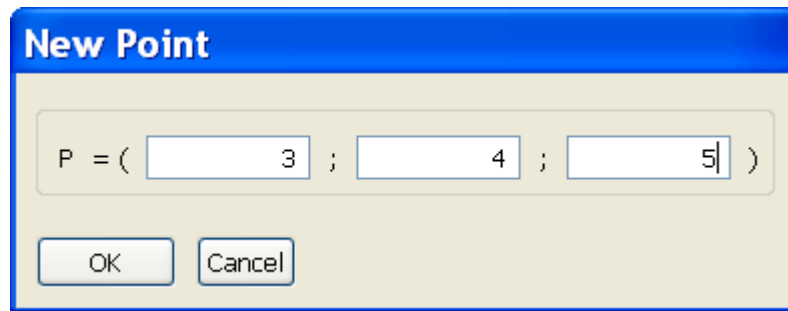
Line Colour

OK Cancel

New Object – Common Items

You will find that the input dialogues are self-explanatory. Some of the objects allow a variety of input methods. Planes, for example, offer the following items: Parametric form, normal form, coordinate form or point and normal. Additionally it is possible to define a plane by selecting three existing points. Right clicking on an object brings up the object's local menu.

New Object - Point

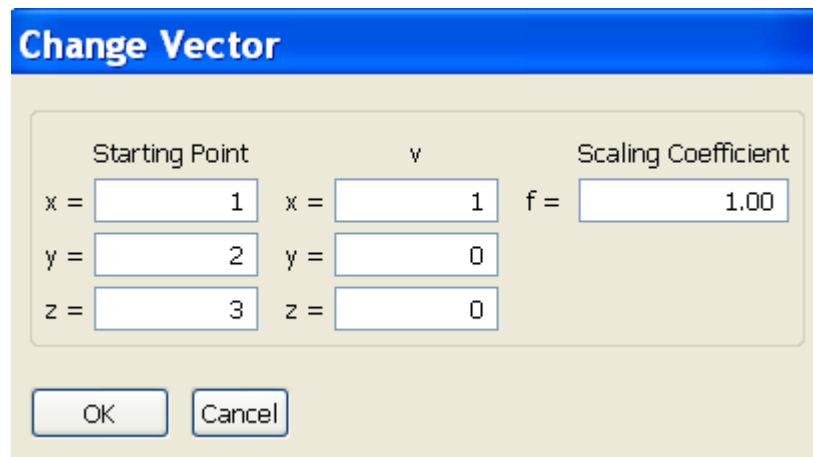


The 'New Point' dialog box has a blue title bar. Below the title bar, there is a text input field for the point coordinates, showing $P = (3 ; 4 ; 5)$. The numbers 3, 4, and 5 are each in its own input box. Below the input field are two buttons: 'OK' and 'Cancel'.

This dialogue asks for the three point coordinates.

New Object - Vector

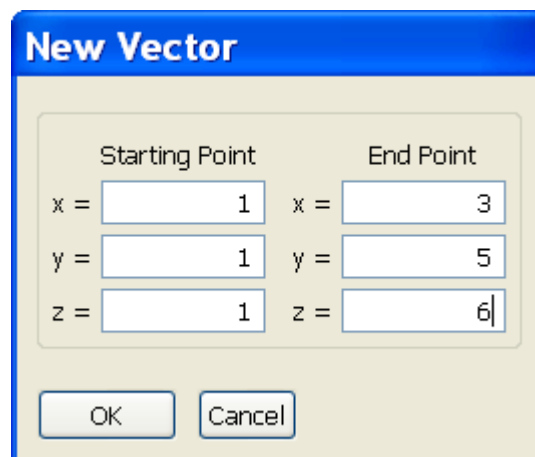
1. Option: Starting point, v, scaling coefficient



The 'Change Vector' dialog box has a blue title bar. Below the title bar, there are three columns of input fields: 'Starting Point', 'v', and 'Scaling Coefficient'.
Starting Point: x = 1, y = 2, z = 3
v: x = 1, y = 0, z = 0
Scaling Coefficient: f = 1.00
At the bottom are 'OK' and 'Cancel' buttons.

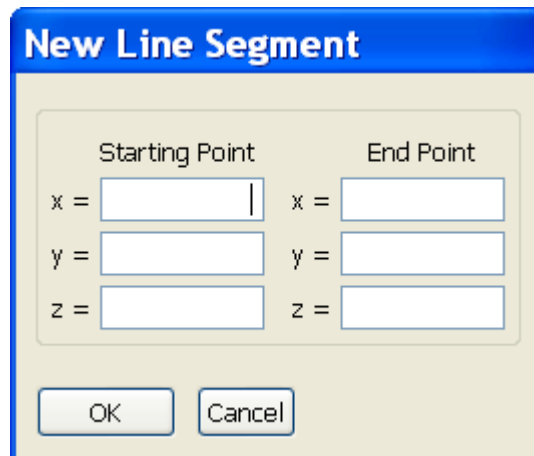
The scaling coefficient is meant to allow for the construction of linear combinations. If the coefficient differs from 1, the basic vector v will be drawn as well as the scaled vector.

2. Option: Initial point, end point



The 'New Vector' dialog box has a blue title bar. Below the title bar, there are two columns of input fields: 'Starting Point' and 'End Point'.
Starting Point: x = 1, y = 1, z = 1
End Point: x = 3, y = 5, z = 6
At the bottom are 'OK' and 'Cancel' buttons.

New Object - Line Segment



The dialog box titled "New Line Segment" has a blue header. It contains two columns of input fields. The first column is labeled "Starting Point" and the second is labeled "End Point". Each column has three rows for x, y, and z coordinates. At the bottom, there are "OK" and "Cancel" buttons.

Starting Point		End Point	
x =	<input type="text"/>	x =	<input type="text"/>
y =	<input type="text"/>	y =	<input type="text"/>
z =	<input type="text"/>	z =	<input type="text"/>

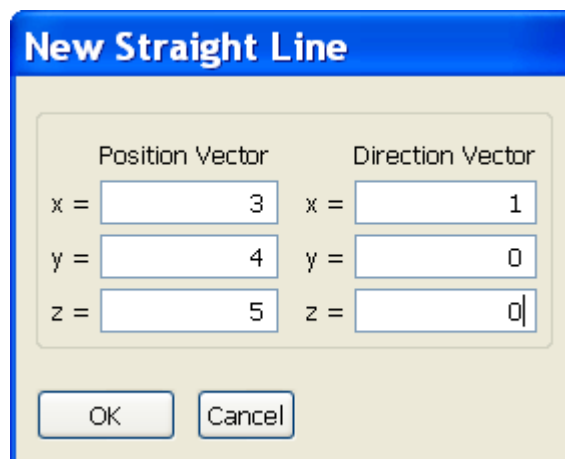
OK Cancel

You have to specify the initial point and the end point.

New Object - Straight Line

You choose the parametric form or you select two existing points from the scene. In the latter case the line is tied to the points, which means that translating the points will also change the line.

A sample dialogue of a straight line:



The dialog box titled "New Straight Line" has a blue header. It contains two columns of input fields. The first column is labeled "Position Vector" and the second is labeled "Direction Vector". Each column has three rows for x, y, and z coordinates. At the bottom, there are "OK" and "Cancel" buttons.

Position Vector		Direction Vector	
x =	<input type="text" value="3"/>	x =	<input type="text" value="1"/>
y =	<input type="text" value="4"/>	y =	<input type="text" value="0"/>
z =	<input type="text" value="5"/>	z =	<input type="text" value="0"/>

OK Cancel

New Object - Plane

a) Input in parametric form

You have to specify the coordinates of a point and the two direction vectors, which have to be linearly independent.

New Plane

Position Vector	Direction Vector 1	Direction Vector 2
x = <input type="text"/>	x = <input type="text"/>	x = <input type="text"/>
y = <input type="text"/>	y = <input type="text"/>	y = <input type="text"/>
z = <input type="text"/>	z = <input type="text"/>	z = <input type="text"/>

OK Cancel

b) Input in normal form

The equation $(\vec{x} - \vec{a}) \cdot \vec{n} = 0$, describing a plane, where \vec{a} is a position vector of a point of the plane and \vec{n} is a normal vector, can be written as: $\vec{x} \cdot \vec{n} - \vec{a} \cdot \vec{n} = 0$.

The expression $\vec{a} \cdot \vec{n}$ is usually denoted as d , so that the equation has the following form: $\vec{x} \cdot \vec{n} - d = 0$.

Specifying \vec{n} and d defines the plane.

n*x-d=0

Normal

x = <input type="text"/>	d = <input type="text"/>
y = <input type="text"/>	
z = <input type="text"/>	

OK Cancel

c) Input of point and normal

The former equations show, that the plane can be defined by specifying a point and a normal.

Plane By N And P

Normal	Point
x = <input type="text"/>	x = <input type="text"/>
y = <input type="text"/>	y = <input type="text"/>
z = <input type="text"/>	z = <input type="text"/>

OK Cancel

d) Input in coordinate form

Writing the scalar product $\vec{x} \cdot \vec{n}$ in detail you get the coordinate form of the plane $a \cdot x + b \cdot y + c \cdot z - d = 0$.

The coefficients a, b and c are the components of the normal vector.

a*x+b*y+c*z=d

a :

b :

c :

d :

OK Cancel

e) Selecting 3 points

If at least 3 points exist in the scene, this option is applicable. After selecting this item, the cursor changes the shape to an up-arrow. Now you have the opportunity to select three points. These define the plane. If later one of the defining points is moved, the plane will change accordingly.

New Object - Circle

1. Option:Centre, normal and radius have to be specified.

New Circle

Center	Normal	Radius
x = 5	x = 0	r = 2
y = 5	y = 0	
z = 5	z = 1	

OK Cancel

2. Option: Click on three existing points

When you use the second option, the programme changes to selection mode (the cursor's shape changes to up-arrow). You are expected to select three existing points of the scene. The circle will be tied to these points. Moving one point will change the circle too. The circle cannot be moved independently.

New Object - Circular Disk

New Circular Disk

Center	Normal	Radii
x = 5	x = 0	rIn = 2
y = 5	y = 0	rOut = 3
z = 5	z = 1	

OK Cancel

The input dialogue looks very similar to that of the circle. Additionally you have to specify a second radius.

New Object - Ellipse

You have to enter centre, normal, direction vector of a and the two semi-axes a and b.

New Ellipse

Center		Normal		Direction of a		Semi-Axes	
x =	<input type="text"/>	x =	<input type="text"/>	x =	<input type="text"/>	a =	<input type="text"/>
y =	<input type="text"/>	y =	<input type="text"/>	y =	<input type="text"/>	b =	<input type="text"/>
z =	<input type="text"/>	z =	<input type="text"/>	z =	<input type="text"/>		

OK Cancel

New Object - Rectangular Solid

New Rectangular Solid

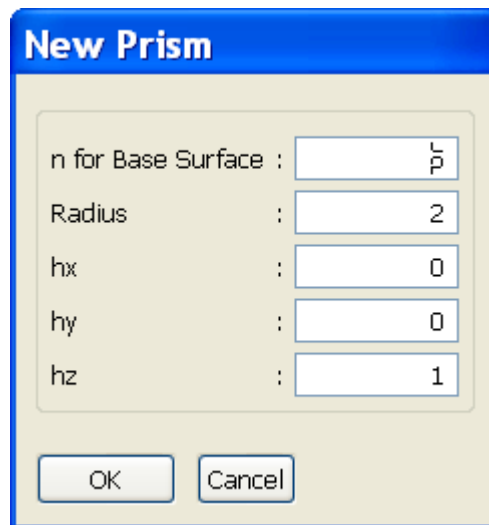
Vertex		Direction 1		Direction 2		l, w, h	
x =	<input type="text" value="7"/>	x =	<input type="text" value="0"/>	x =	<input type="text" value="-1"/>	l =	<input type="text" value="2"/>
y =	<input type="text" value="3"/>	y =	<input type="text" value="1"/>	y =	<input type="text" value="0"/>	w =	<input type="text" value="3"/>
z =	<input type="text" value="3"/>	z =	<input type="text" value="0"/>	z =	<input type="text" value="0"/>	h =	<input type="text" value="4"/>

OK Cancel

Vertex, direction 1 and direction 2 define the base plane. The first edge points in direction 1. It is not necessary that direction 1 and direction 2 be rectangular. The programme calculates the proper direction.

New Object - Prism

- Option: Regular Prism



New Prism

n for Base Surface : $\begin{matrix} L \\ p \end{matrix}$

Radius :

hx :

hy :

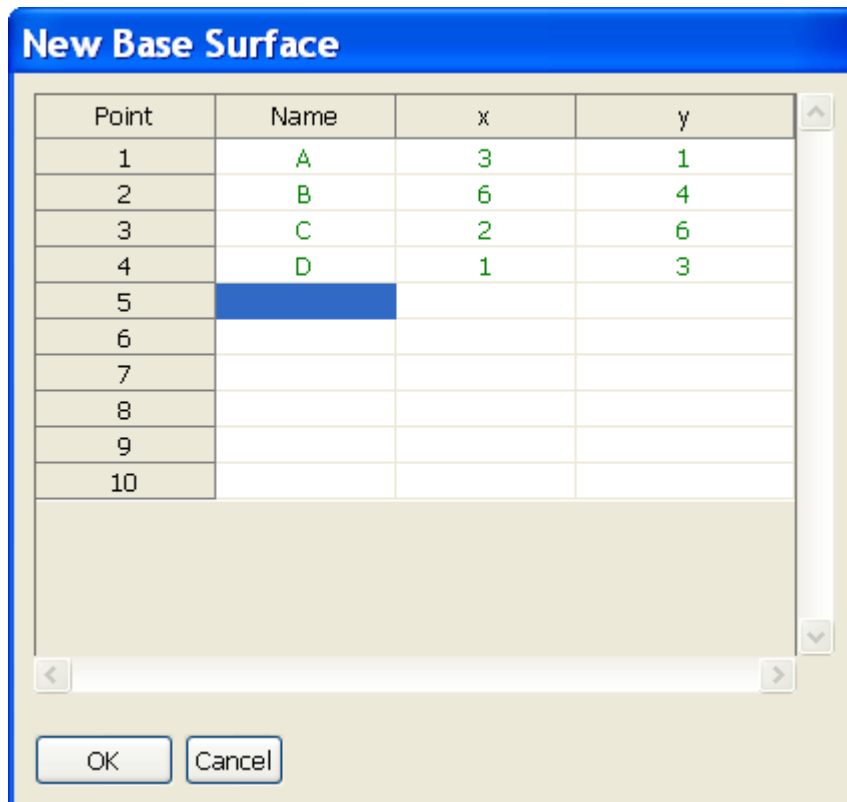
hz :

OK Cancel

N defines the number of vertices in the base plane. Hx, hy, and hz are the components of the vector from one vertex in the base plane to the corresponding one in the upper plane of the prism.

2. Option: General Prism

The first dialogue queries the 2-dimensional coordinates of all vertices in the base plane..



New Base Surface

Point	Name	x	y
1	A	3	1
2	B	6	4
3	C	2	6
4	D	1	3
5			
6			
7			
8			
9			
10			

OK Cancel

After that you have to specify the vector to the upper surface:

Vector to Up...

x = :

y = :

z = :

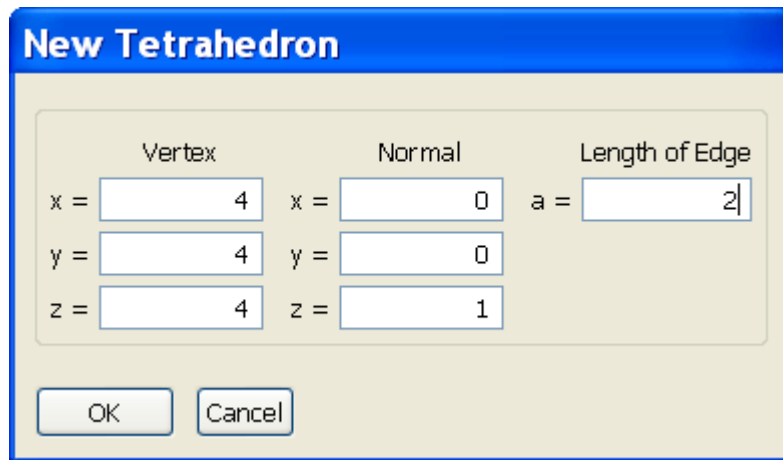
New Object - Pyramid

New Pyramid

Vertex	Direction 1	Direction 2	l,w,h
x = <input type="text" value="1"/>	x = <input type="text" value="1"/>	x = <input type="text" value="0"/>	l = <input type="text" value="3"/>
y = <input type="text" value="1"/>	y = <input type="text" value="0"/>	y = <input type="text" value="1"/>	w = <input type="text" value="4"/>
z = <input type="text" value="1"/>	z = <input type="text" value="0"/>	z = <input type="text" value="0"/>	h = <input type="text" value="6"/>

Similar to the rectangular solid you specify a vertex and 2 direction vectors. Length, width and height complete the necessary data.

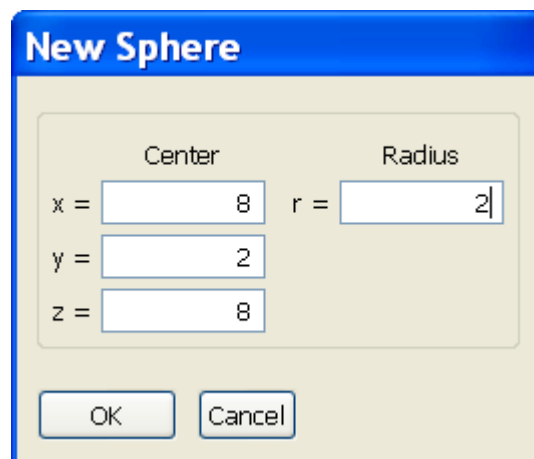
New Object – Regular Tetrahedron



The dialog box titled "New Tetrahedron" contains three columns of input fields. The first column, labeled "Vertex", has three rows: "x = [4]", "y = [4]", and "z = [4]". The second column, labeled "Normal", has three rows: "x = [0]", "y = [0]", and "z = [1]". The third column, labeled "Length of Edge", has one row: "a = [2]". At the bottom are "OK" and "Cancel" buttons.

You specify a vertex, normal and the length of an edge.

New Object - Sphere



The dialog box titled "New Sphere" contains two columns of input fields. The first column, labeled "Center", has three rows: "x = [8]", "y = [2]", and "z = [8]". The second column, labeled "Radius", has one row: "r = [2]". At the bottom are "OK" and "Cancel" buttons.

The dialogue queries centre and radius.

New Object - Cone

New Cone

Center		Normal		Radius and Height	
x =	<input type="text" value="5"/>	x =	<input type="text" value="0"/>	r =	<input type="text" value="4"/>
y =	<input type="text" value="5"/>	y =	<input type="text" value="0"/>	h =	<input type="text" value="8"/>
z =	<input type="text" value="0"/>	z =	<input type="text" value="1"/>		

New Object - Cylinder

New Cylinder

Center		Normal		Radius and Height	
x =	<input type="text" value="5"/>	x =	<input type="text" value="0"/>	r =	<input type="text" value="2"/>
y =	<input type="text" value="5"/>	y =	<input type="text" value="0"/>	h =	<input type="text" value="7"/>
z =	<input type="text" value="0"/>	z =	<input type="text" value="1"/>		

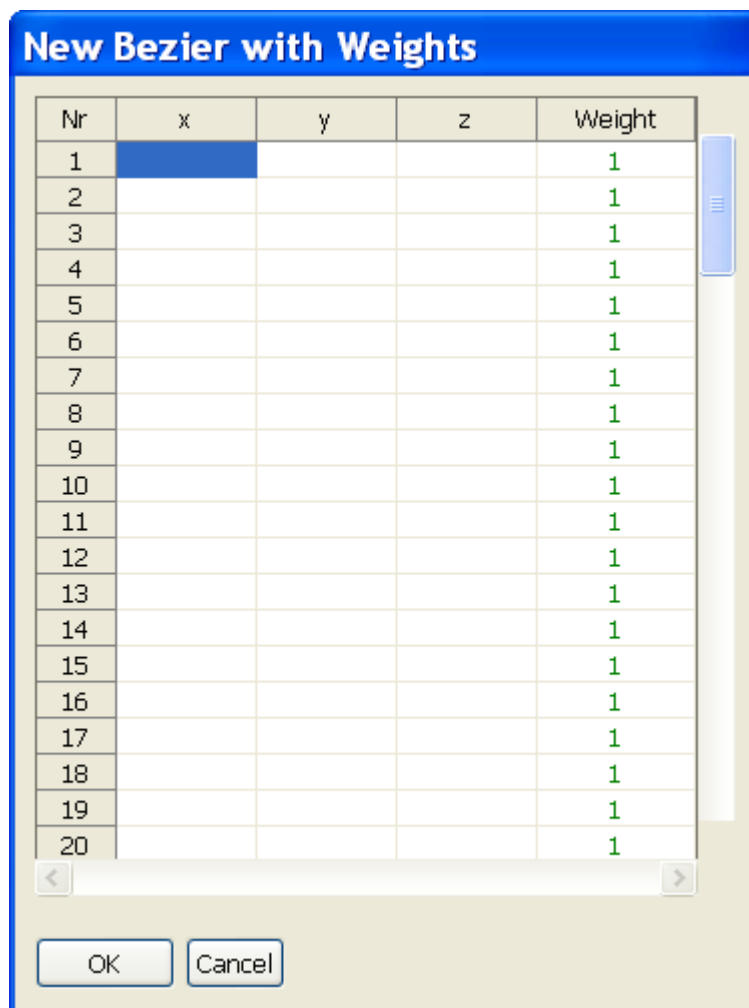
New Object - Torus

Center		Normal		Radii	
x =	5	x =	0	r_big =	3
y =	5	y =	0	r_small =	0.5
z =	5	z =	1		

OK Cancel

New Object - Bézier Curve

The corresponding dialogue asks for a series of points, that shall be approximated by a continuous Bézier curve. You may specify a weight for each point.



Menu Edit

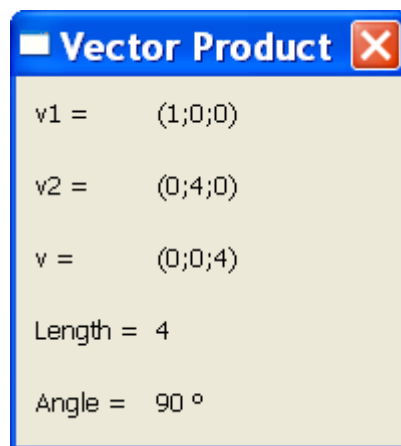
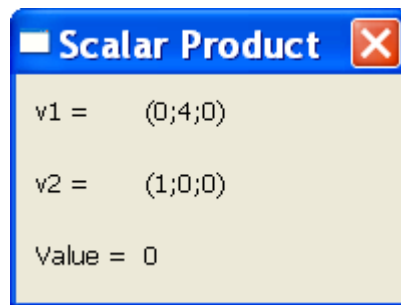
- Back to state before deletion
- Vector Product
- Scalar Product

The first item restores the state before the last delete-operation.

Vector Product or **Scalar Product** lead to a drop-down menu showing the items Window and Delete.

If you choose Window, a list of all calculated scalar and vector products appears. Selecting one opens an inspection window showing the appropriate data. If that window is already open, nothing happens.

In the following you find an example of an inspection window for both cases:



Menu Calculate

- Distance
- Intersection
- Angle
- Vector Product
- Scalar Product

Calculate – Distance or Intersection

If you select this item, the programme turns to the so called **selection mode**. The cursor's shape changes to an up-arrow. You then select the two objects with the mouse. When finished, the programme calculates the distance or the intersection of the selected objects. This works for the most common combinations of objects. The intersection object will be added to the actual list of all objects. This way it is possible to assign certain attributes to the intersection object by right clicking it.

Calculate - Angle

There are three options:

- select 3 points

- select straight line and plane
- select two straight lines

„Select 3 points“ initiates selection mode and expects you to click on 3 points. The first point must be the vertex the second is assumed to be situated on leg 1 and the third on leg 2. The result of measurement will be shown in the text window on the right. The measured angle will be added to the list of angles. No additional lines will be drawn. If necessary, calculate the distances between the points in question and you have lines symbolizing the legs of the angle.

If „Select straight line and plane“ is chosen, selection mode starts. At first select a straight line in the scene and then a plane. The result of measurement will be shown in the text window and an angle object will be created.

If „Select two straight lines“ ist chosen, selection mode starts and you you are expected to select two existing lines in the scene. In this case only the text output is generated, but no angle object is created because in general the two lines do not intersect.

Calculate - Vector Product

This item again leads to selection mode. You have to select two existing vectors. Their vector product will be calculated and a corresponding vector will be drawn in the scene.

At the same time an inspection window is created, showing the actual data of the vector product. If one of the vectors building the vector product is rotated, the resulting vector is recalculated and redrawn. If one vector is translated, the other two vectors are also translated.

Closing the inspection window will not delete the vector product. If this is your intention, you have to go to the menu **Edit - Vector Product**. There you can delete the desired product. Only the product vector is deleted and the two base vectors are uncoupled.

Calculate - Scalar Product

Similar to the vector product the programme expects the selection of two vectors from the scene. An inspection window is generated showing the resulting data dynamically. As the scalar product is a number, no object is generated. The scalar product can be deleted by choosing **Edit - Scalar Product**. The associated vectors will be uncoupled.

Menu Test

Two tests are offered:

- Are 2 vectors collinear?
- Are 3 vectors linearly independent?

In the first case you have to select 2 existing vectors from the scene, in the second case 3 vectors. The result is shown in the text window.

Menu Transformations

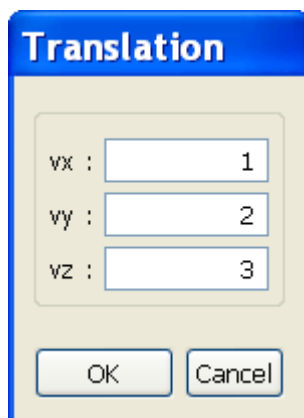
The programme lets you transform the objects by affine transformations. You choose between:

- Rotation
- Translation
- Reflection with respect to a plane
- Reflection with respect to a point
- Shear
- Scaling relative to a point
- General affine transformation

It is possible to define the transformation via the main menu or via the local menu of an object. The plane of reflection, for example, can be defined through the local menu of the plane by choosing **Select As - Plane of Reflection**.

Translation

The vector of translation has to be defined:



A dialog box titled "Translation" with a blue header. It contains three input fields for the translation vector components: vx, vy, and vz. The values entered are 1, 2, and 3 respectively. At the bottom, there are two buttons: "OK" and "Cancel".

Component	Value
vx :	1
vy :	2
vz :	3

Rotation About A Straight Line

You have to specify a point on the straight line, the direction of the line and the rotation angle in degrees:

Rotation

P On Line		Direction of Line		Rotation Angle (degrees)
x =	<input type="text" value="5"/>	x =	<input type="text" value="0"/>	w = <input type="text" value="45"/>
y =	<input type="text" value="5"/>	y =	<input type="text" value="1"/>	
z =	<input type="text" value="5"/>	z =	<input type="text" value="0"/>	

OK Cancel

The straight line will not be generated as an object and hence will not be shown in the scene. If you want the line to be drawn, create the line separately, call the line's local menu and select the item **Select As - Axis of Rotation**.

Reflection With Respect To A Plane

Input consists of an initial vector, which points to a point of the plane, and a normal vector:

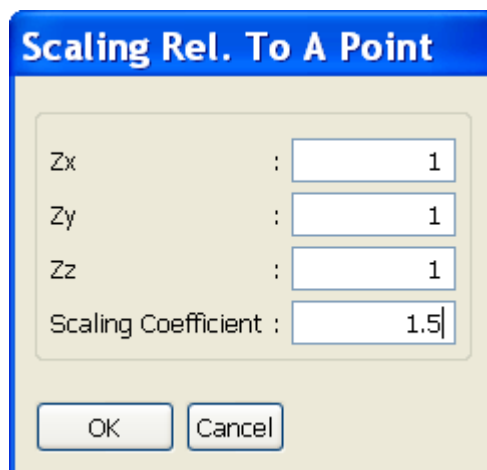
Reflection Rel. To Plane

Start Vector of e		Normal Vector of e	
ax	<input type="text" value="5"/>	nx	<input type="text" value="0"/>
ay	<input type="text" value="5"/>	ny	<input type="text" value="0"/>
az	<input type="text" value="5"/>	nz	<input type="text" value="1"/>

OK Cancel

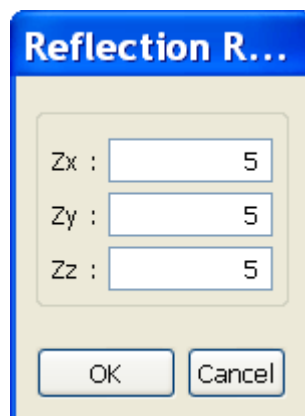
Scaling With Respect To A Point

Necessary data are the center of scaling and the scaling coefficient:



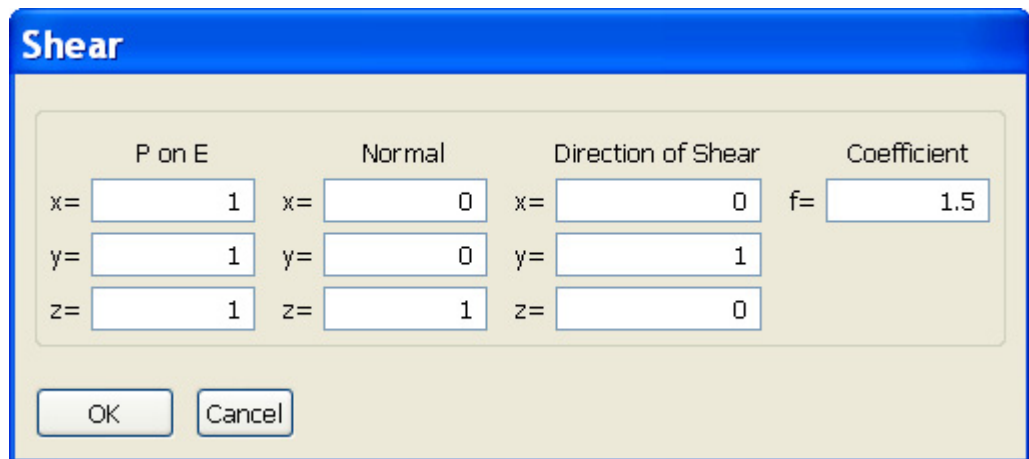
Reflection With Respect To A Point

The point coordinates have to be specified:



Shear

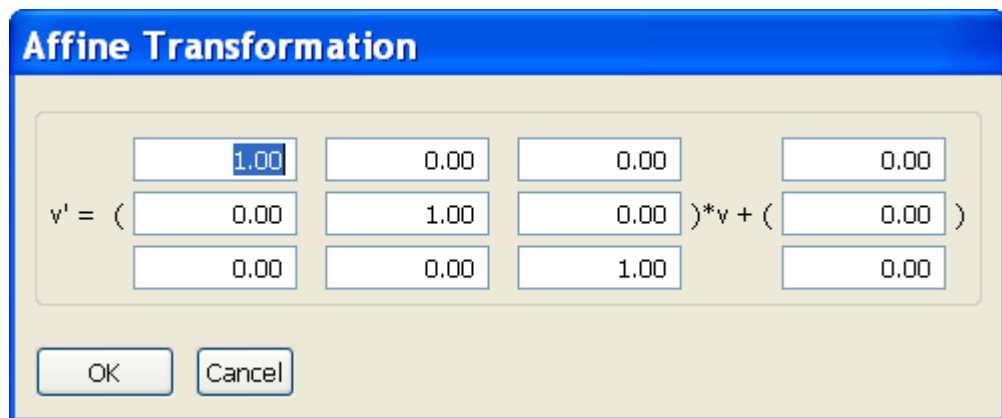
The dialogue expects the position vector of the plane, a normal vector, the direction vector of the shear and the shear coefficient:



The direction vector will be projected on the plane if it is not parallel to it. Torus, sphere, cone and cylinder objects cannot be transformed by shear in this programme.

General Affine Transformation

Required data are the matrix 9 elements and the components of the translational vector.:



At this place we speak out a warning: Be cautious in deleting objects, that are originals of transformations, because all following images will be deleted too!

Menu Coordinate System

Several settings can be edited when selecting this item:

- Intervals
- Switches
- Scaling
- Colours

Coordinate System – Intervals

The screenshot shows the '3D-Coordinate-System' dialog box with the 'Intervals' tab selected. The dialog has four sub-tabs: 'Intervals', 'Switches', 'Scaling', and 'Colours'. The 'Intervals' tab contains the following settings:

- x-Interval = [0.00 ; 10.00] x-Symbol [x]
- y-Interval = [0.00 ; 10.00] y-Symbol [y]
- z-Interval = [0.00 ; 10.00] z-Symbol [z]
- Standard Borders []
- Line Width = [1]

At the bottom of the dialog are 'OK' and 'Cancel' buttons.

On this tab you determine the x-, y- and z-intervals that are shown in the scene. Additionally a symbol of each axis can be specified.

Coordinate System – Switches

The screenshot shows the '3D-Coordinate-System' dialog box with the 'Switches' tab selected. The dialog has four sub-tabs: 'Intervals', 'Switches', 'Scaling', and 'Colours'. The 'Switches' tab contains the following settings:

- Wired Rectangular Solid: Off, Half, Full
- CS-Text: Back, Front, At Axes
- Axes Visible
- Axes Labeling And Scaling
- x-Axis: x-Axis With Labeling, x-Axis With Ticks, Draw yz-Grid
- y-Axis: y-Axis With Labeling, y-Axis With Ticks, Draw xz-Grid
- z-Axis: z-Axis With Labeling, z-Axis With Ticks, Draw xy-Grid

At the bottom of the dialog are 'OK' and 'Cancel' buttons.

Coordinate System – Scaling

The first option is automatic scaling. The second is to specify the step size of the labels and the number of ticks between the labels.

Coordinate System – Colours

- You can choose colours of
 - Axes
 - Grid
 - Numbers

Hint for ***moving the coordinate system***:

You can rotate the coordinate system including all objects in the following way:

Start dragging the mouse vertically and the camera position changes up or down. Horizontally dragging the mouse rotates the scene about an axis through the centre of the scene parallel to the z-axis.

Menu Text

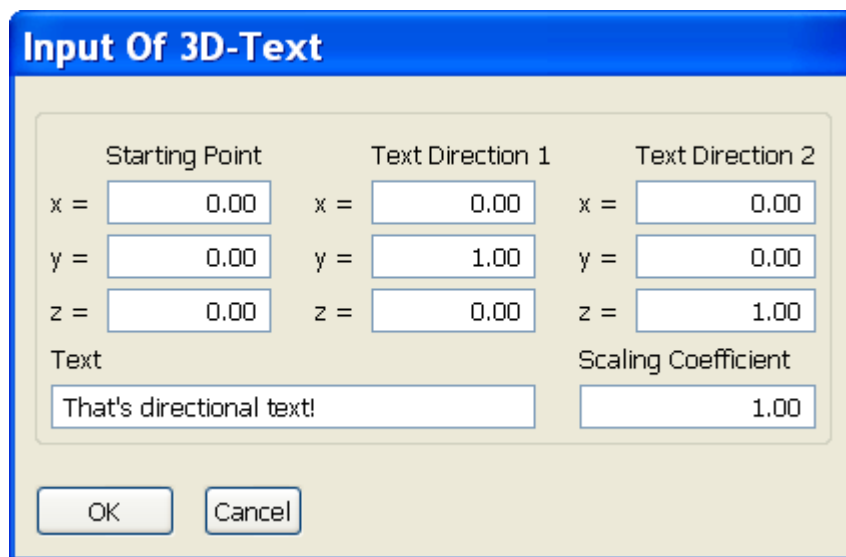
The following options for labels are available:

- Title
- Subtitle
- X-Title
- Y-Title
- Directional Text

The text of the first four items appears in fixed positions:

Title and subtitle on top of the graphic, x-title below the graphic and y-title on the left of the graphic. Double-clicking on the desired area brings up the input-dialogue for that region.

Directional text offers a scalable text including vector arrow and index.



The scaling coefficient sizes the stroke text. The programme calculates a default value which is a certain percentage of the coordinate section.

Three special symbols can be used within the text:

Typing | has the effect, that the following letter will have a vector arrow on top of it.

Typing _ has the effect, that the following letter will appear as index and the symbol ^ writes the following letter as superscript.

An example:

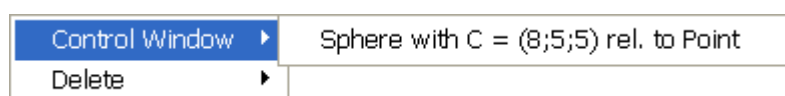
Input |v_1

the result will be: \vec{v}_1

The directional text in the scene can be resized with the mouse. Start dragging vertically, starting with the mouse pointer at the text position, while the **Alt-key** is held pressed. Dragging upwards sizes the text up, dragging downwards sizes the text down. This is also applicable to text, that belongs to objects.

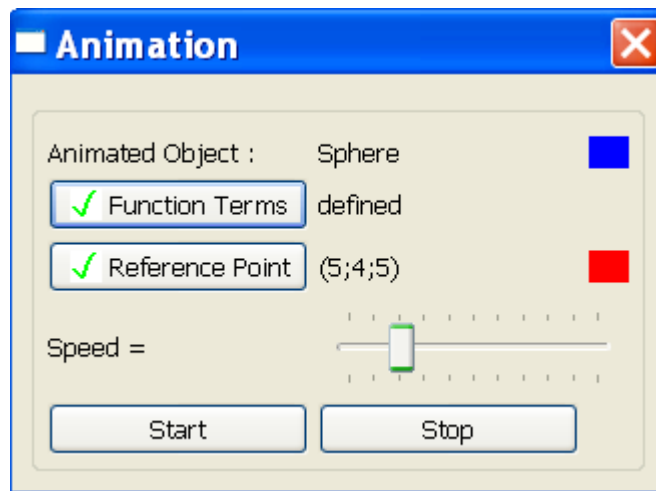
Menu Animation

From the local menu of points or spheres animations can be initiated. After the definition of the animation you can access the animation via the main menu selecting **Control Window** and the desired entry.



This is the corresponding drop-down menu in case of an animation assigned to a sphere.

Selecting an entry opens the control window in the bottom right position. It is structured as follows:

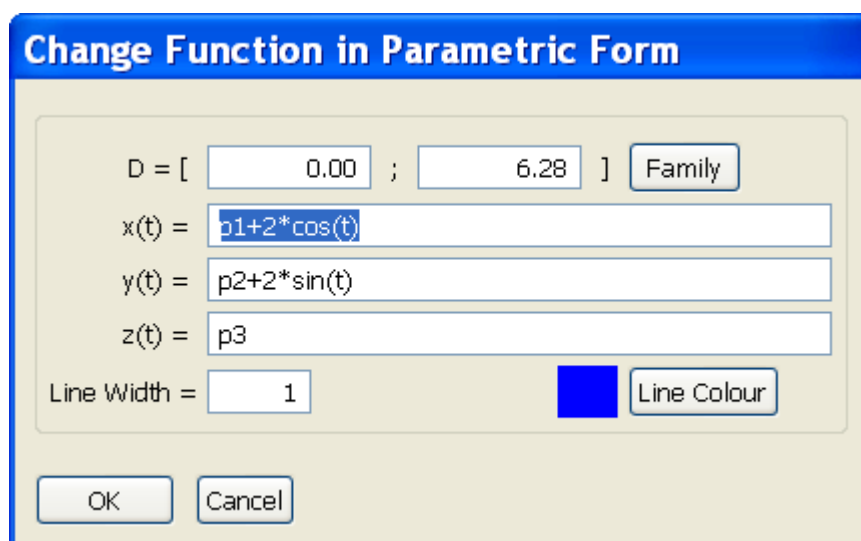


In the first row the animated object and its colour are shown. As showing coordinates is not very meaningful, the programme offers the item Alias in the local menu of an object as a means of an additional description. This Alias name is shown in row one if it exists.

The second row shows the button „Function Terms“. On the right of it you find whether a parametric function has been defined or not. If there is a valid function term the button appears with a green check. If the function definition is not valid, the button shows a red question mark.

If you push the button „Function Terms“, the corresponding dialogue appears and you are prompted to specify the three terms of a function in parametric form.

There is a special option: You can use the parameters p1, p2, p3 which are meant to represent the components of the reference point, defined by the dialogue in row three. An example:



p1 stands for the x-component of the reference point, p2 for the y- and p3 for the z-component.

This way it is achieved that the movement along the path, defined by the function terms, takes place relative to the reference point.

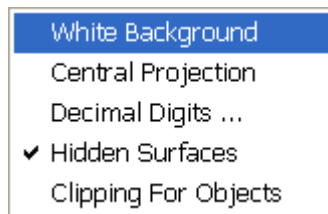
In row 3 there is a button to initiate the input of the reference point. This time there is no dialogue but the programme expects you to select an existing point or a sphere from the scene. If the selection was successful the button shows a green check.

In row four you can vary the speed of the animation.

The two buttons in row five let you start and stop the animation.

In the Examples folder you find a file „Sun, earth, moon.gm3“, which could be a basis for experimenting.

Menu Options



Options – White Background

The default setting is a black background in order to achieve a good spatial impression. Selecting this item changes the background to black.

The setting of this option will be saved too, when you save the whole scene in a file. Therefore loading a file restores the saved state.

Options - Central Projection

The default value is parallel projection. Choosing this item changes to central projection.

Options – Decimal Digits

This option defines the precision, with which data appear in the output window.

Options - Hidden Surfaces

The default setting is „hidden surfaces“. Unchecking this item leads to a wireframe model of all objects in the scene.

Options - Clipping For Objects

If „clipping for objects“ is checked, only the intersections of the objects with the rectangular solid defined by the intervals of the coordinate system are shown. The standard coordinate system is defined as $[0;10]^3$.

The Toolbar



This part of the toolbar contains buttons to load or save the scene and to create new objects. If the mouse pointer is over a symbol a short description appears.



Starting from left, this part contains the two buttons to specify translation or rotation.

The third button brings up a window, where you can switch on and off the six light sources:



The light sources are situated in a certain distance from the surfaces of the rectangular solid defined by the intervals of the coordinate system.

„Upon XY“ means: The light source is located above the xy-plane.

„Against XY“ means: The light source is located below the xy-plane.

The fourth symbol is a switch to show or hide the coordinate axes.

Pressing the button „D“ expects you to select two objects, for which you want to calculate the distance. If you decide to cancel this process before it is completed, press the esc-key.

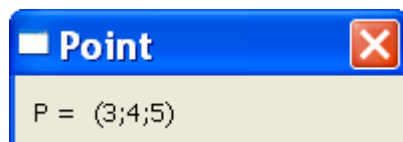
Pressing the button „I“ expects you to select two objects, for which you want to calculate the intersection. The esc-key lets you cancel the procedure.

All other buttons are self-explanatory.

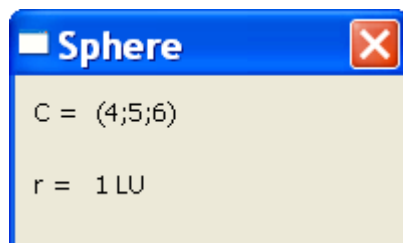
Inspection Window

From the local menu of the objects **point**, **line segment** and **sphere** you can access an inspection window, that will be opened in the bottom left part of the screen. These windows are meant to dynamically „inspect“ the actual object data.

Points show an inspection window like this one:



For spheres it looks this way:

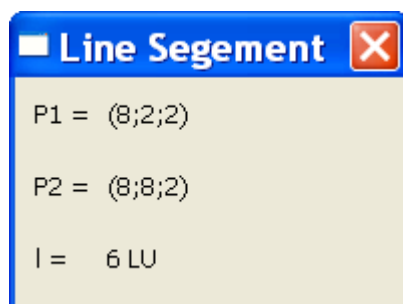


The centre and the radius are displayed (LU means length unit).

If the sphere is translated or it is subject to an animation, the data will be actualized permanently.

This option is also of interest in the case of distance calculations. The object of distance is a line segment. Thus it is possible to open an inspection window through the local menu of this line segment.

Here is an example:



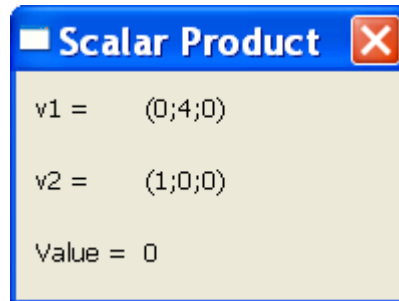
Initial and end-point as well as the length are displayed.

If an object is moved, that participates in a distance calculation, the data in the inspection window are continuously recalculated.

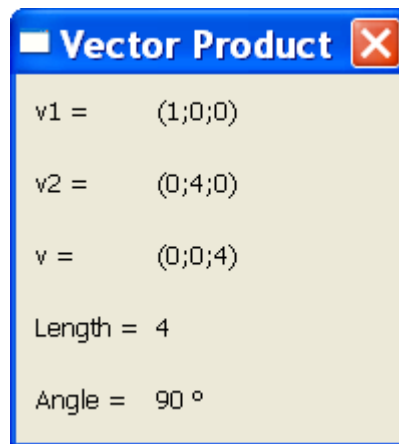
If a calculation of a scalar or vector product takes place, this will also open an inspection window. If one of the vectors is scaled up or down (holding

Ctrl-key+dragging the mouse vertically, starting at the arrow head of the vector) the values in the inspection window change accordingly.

This is a sample inspection window of a scalar product:



This is an example for the inspection window of a vector product:



Local Menu

Invocation

The local menu of an object is accessed by right clicking on the object.

Common Options

The following menu entries are common to all objects:

- Change Object ...
- Text
- Colour
- Style
- Projection
- Transformation by ...
- Show Data
- Delete

Local Menu – Change Object

This item calls the standard input dialogue belonging to the selected object using the actual values as default.

Local Menu - Text

This option opens an input window, where the name of the object can be specified.

You can use indices using the underscore character in front of the number.

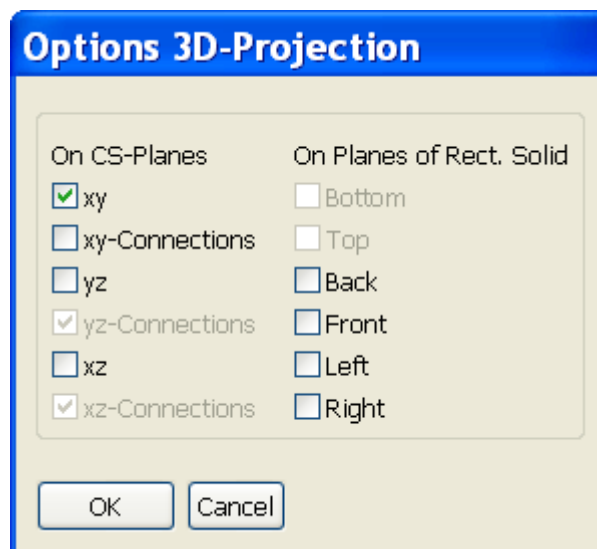
g_1 as an input text leads to the following representation g_1 .

Local Menu – Colour



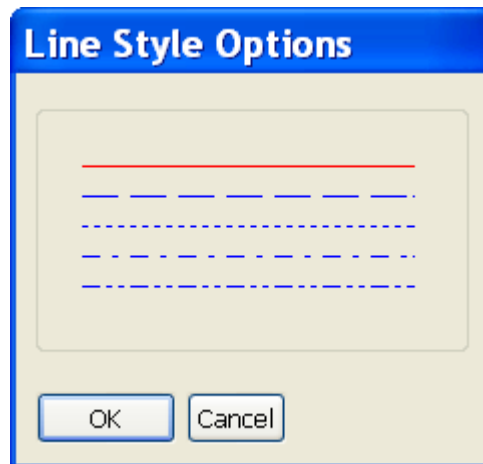
This dialogue lets you choose the object colour (in German as a variety).

Local Menu - Projection



Some of the objects can be projected on the coordinate planes or on the planes of the rectangular solid defined by the intervals of the coordinate system. You can check the desired projections.

Local Menu - Style



Simply click on the desired pattern to choose a line style.

Local Menu - Transformation by

This option offers the chance to transform the selected object by choosing one of the already defined affine transformations. The image of the transformation will be calculated, added to the internal list of objects and displayed.

Local Menu – Show Data

This menu item shows the actual location data of the object in the text window on the right.

Local Menu – Delete

This item deletes the selected object. For safety a window asks if you are sure. **Caution:** If the object is coupled with others side effects will appear. For example, if the object is the original of a transformation, the image of the original will be deleted too. Anyway, there is an undo function which restores the state before the deletion. This can be achieved through the **Edit** menu.

The Local Menu $f(x,y)$

The following options are available:

Change Function Term
Colour
x-Steps (50)
y-Steps (50)
transparent
Show Data
Delete

x-Steps, y-Steps

These numbers specify, how many steps will be taken walking through the x- and y-intervals. A bigger number rises the number of calculations on one hand, but leads to a more detailed representation on the other. With modern hardware this is not an issue.

Transparent

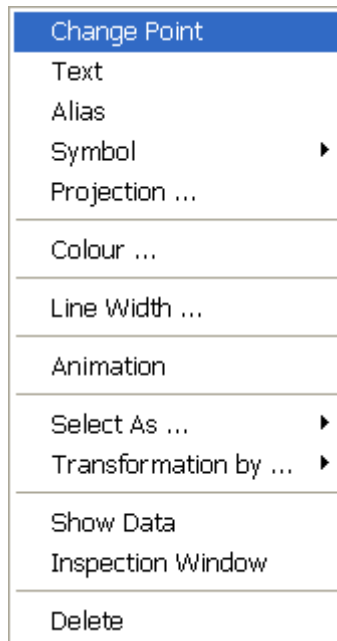
This option allows to make the generated surface transparent.

The Local Menu ($x(t);y(t);z(t)$)

Change Function Term
Colour
Line Width
Projection ...
Steps To Projection ...
Dotted Projection
Table of Values
Show Data
Delete

The entries are self-explanatory.

The Local Menu **Point**



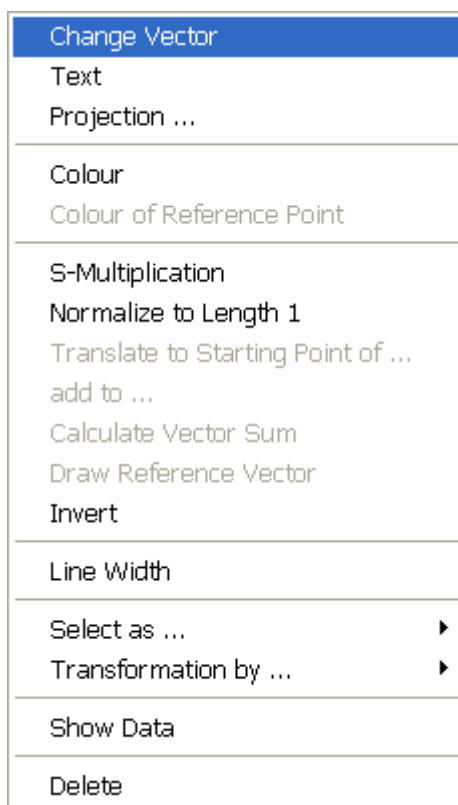
Alias represents the option of assigning an additional name to the point. This name will be shown in the animation window, if the point is subject to an animation.

The item **Animation** opens a window, which is described in detail in the Animation chapter.

Select As... offers the opportunity of making the point a centre of certain transformations:

- Centre of reflection
- Centre of scaling

The Local Menu Vector



Remark: We always speak of a **vector**, while the mathematically exact formulation would be **representative of the vector**, since it is a matter of an equivalence class.

If you specify a scaling coefficient which is not 1 during input, it may be reasonable to assign different colours to the base vector and the scaled one. This is done by choosing **Colour of Reference Vector**.

S-Multiplication (*scalar* multiplication) allows to directly specify the scaling coefficient.

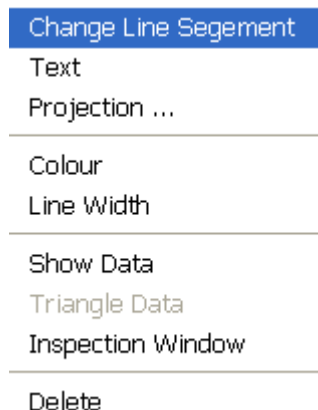
Translate to Starting Point of ... initiates selection mode. You are expected to select an existing vector.

Add to starts selection mode. It is expected that you select an existing vector. The initial point of the actual vector will be translated to the end point of the selected one.

Calculate Vector Sum looks, whether the actual vector belongs to a chain of vectors. If so, the sum of all vectors in the chain will be calculated and the resulting vector will be added as an object and will be drawn.

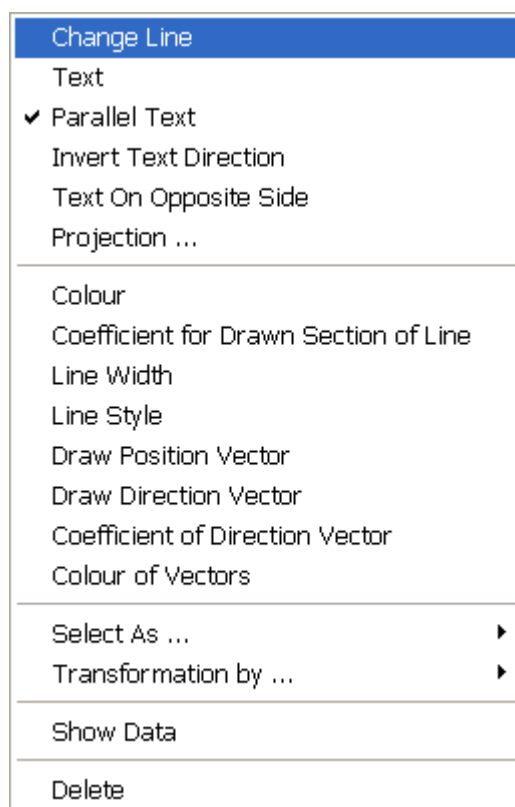
Invert swaps the initial and the end point.

The Local Menu **Line Segment**



Note that there is a special chapter about the inspection window.

The Local Menu **Straight Line**



Most of the items are self-explanatory.

Coefficient of Drawn Section of Line is explained here:

When clipping of objects in the Options menu is switched off, the straight lines in the scene are quite long to some extent. This coefficient influences the length of the line. The reference length is always the length of the diagonal in the rectangular solid defined by the coordinate systems intervals.

The Local Menu **Angle**

Name
Smaller Arc
Bigger Arc
<input checked="" type="checkbox"/> Text in Plane of Angle
Rotate Text about 180 Degrees
Colour of Arc
Show Data
Delete

Name entitles the angle. Not the whole greek font has been implemented but some common letters like α , β , γ , δ , λ , μ . In the input window always the latin equivalents appear, e.g. a instead of α .

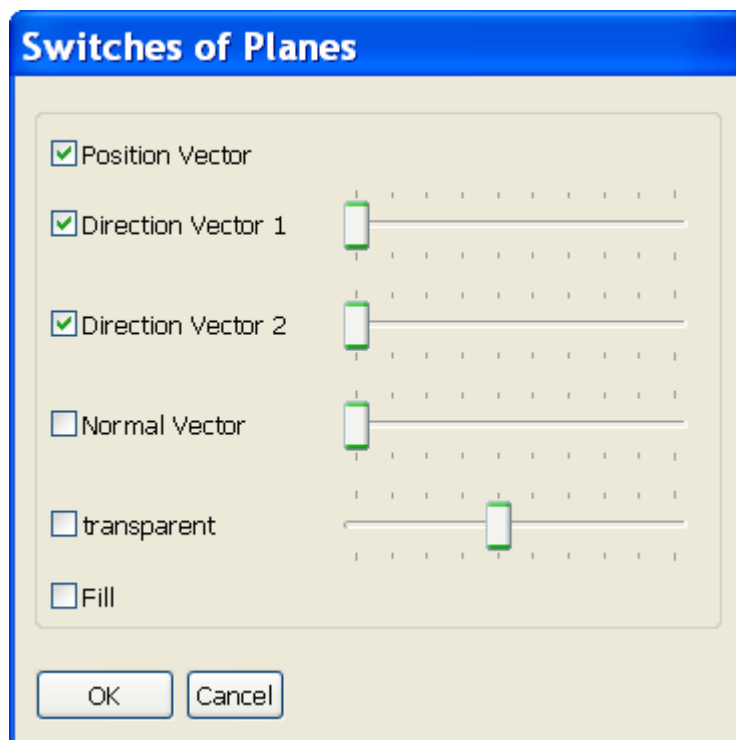
The other items are self-explanatory.

The Local Menu **Plane**

Change Plane
Text
<input checked="" type="checkbox"/> Text Parallel To Plane
Text in Opposite Half-Space
Colour
Coefficient for Section of Plane
Switches ...
<input checked="" type="checkbox"/> Draw Trace Points
<input checked="" type="checkbox"/> Connect Trace Points
Show Trace Points in Text Window
Direction of Shear ▶
Select As ... ▶
Transformation by ... ▶
Show Data ▶
Delete

Similar to the local menu of lines you find the item **Coefficient for Section of Plane**. This number influences the size of the area symbolizing the plane.

Switches ... leads to the following dialogue:



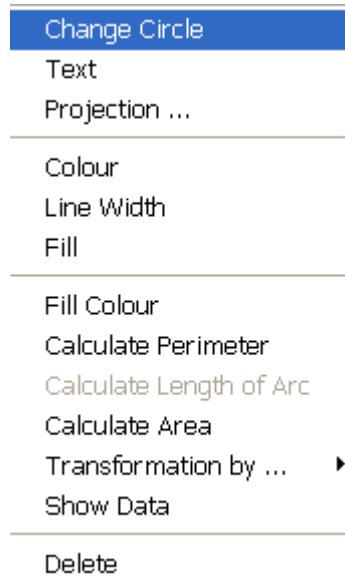
All sliders influence the length of the vectors.

A check box switches the particular option on or off.

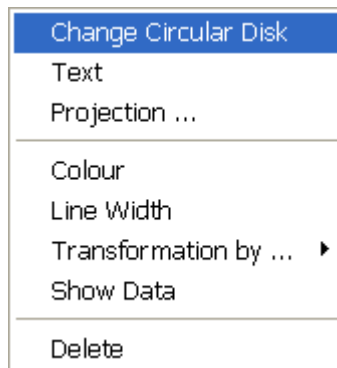
If for example Direction Vector 1 is checked, it will be drawn.

If Clipping is switched off in the Options menu, the trace points (points of intersection between plane and the coordinate axes) mark an orientation. The menu items **Connect Trace Points** and **Draw Trace Points** are switches for the drawing.

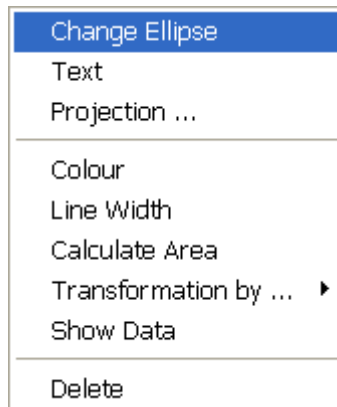
The Local Menu Circle



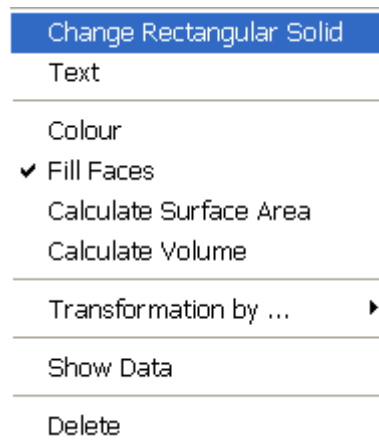
The Local Menu Circular Disk



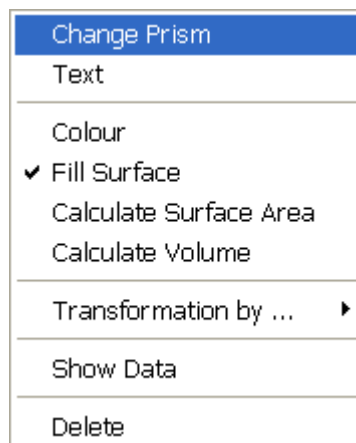
The Local Menu Ellipse



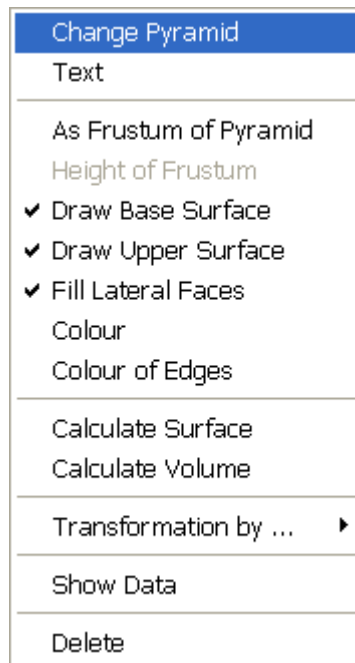
The Local Menu Rectangular Solid



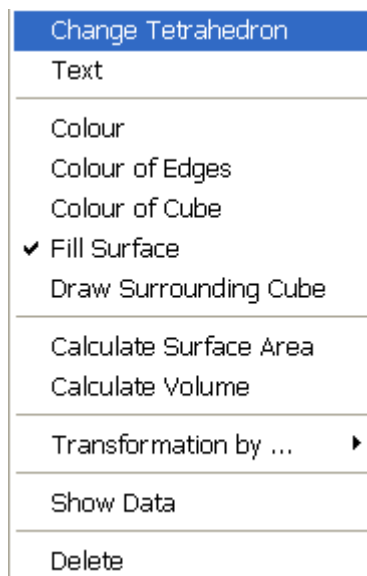
The Local Menu Prism



The Local Menu Pyramid



The Local Menu Regular Tetrahedron



A speciality is the item **Draw Surrounding Cube**. Because of the tetrahedron's high symmetry it is possible to fit it into a cube in a way that two edges of the tetrahedron build the diagonal of two opposite squares of the cube.

This option draws this cube together with the tetrahedron.

The Local Menu Sphere

Change Sphere
Text
Alias
Projektion ...
Colour
Line Width
Draw Axis of Sphere
Own Rotation
Longitudes
Latitudes
Delta for Own Rotation
Partition of Longitude
Partition of Latitude
New Point on Sphere
Great Circle
Select Reference Point for Polar Plane ...
Tangential Plane
Animation
Angle of Plane rel. to Axis
Calculate Area
Calculate Volume
Transformation by ... ▶
Show Data
Inspector Window
Delete

Spheres have a comprehensive local menu.

Draw Axis of Sphere shows a vector symbolizing a fixed axis of the sphere.

Own Rotation makes the sphere spin around the fixed axis.

Delta for Own Rotation influences the speed of rotation.

Longitudes and **Latitudes** are switches.

New Point on Sphere creates a point on the surface.

Great Circle acts depending on the number of points drawn on the surface of the sphere.

If there are 2 points present, the programme calculates the great circle (a circle with the radius of the sphere and the same centre as the sphere) through these points.

If more than two points are present, you have to select two of them with the mouse.

Select Reference Point for Polar Plane initiates selection mode. You are expected to select an existing point outside of the sphere.

Tangential Plane creates a tangential plane (with small symbolic extent). This plane can be moved along the surface of the sphere with the mouse:

Pressing the **Ctrl**-key or the **Shift**-key while dragging the mouse (starting at the boundary) the tangential plane moves along the latitudes.

Pressing **Ctrl + Shift** together while dragging, the tangential plane moves along the longitudes.

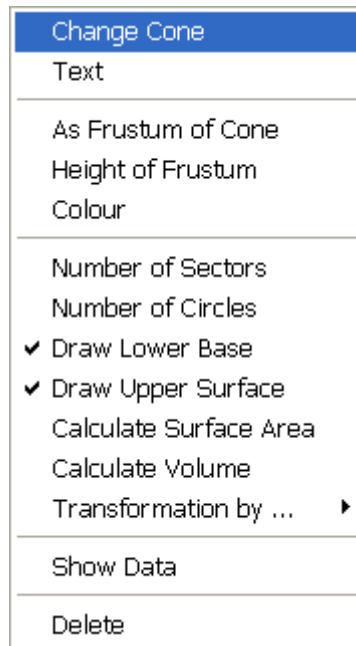
Animation brings up the animation window. Look in the corresponding chapter for details.

Angle of Plane relative to Axis is a very special feature. If the actual sphere is the reference object of an animation, which means that a point or a different sphere moves relative to this sphere, this value defines the inclination of the plane, relative to which the function terms of the animation are defined.

An example: Assume the actual sphere be the earth. It be defined as the reference object of another sphere, the moon. The movement of the moon can be imagined as a path relative to a local coordinate system which is anchored at the centre of the earth. By default this coordinate system has axes parallel to the global system. If an angle is specified, the xy-plane of the local coordinate system will be rotated by this value. This is an easy method to change the reference plane of the movement of the moon without having to define complicated function terms (which would also be possible).

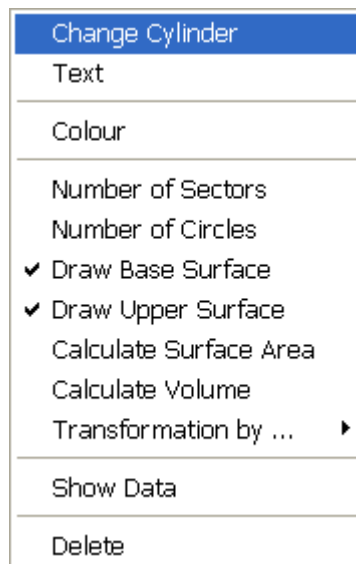
Inspection Window opens a window for viewing the sphere's data.

The Local Menu Cone

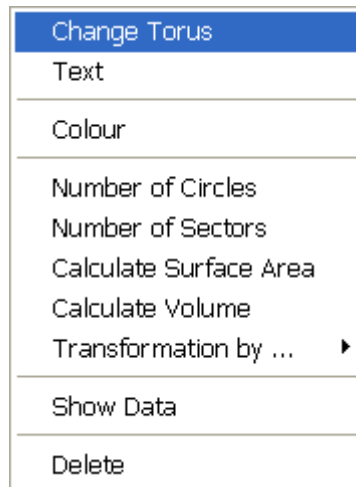


Of special interest is the option of drawing a frustum instead of the whole cone. For this you have to specify the desired height.

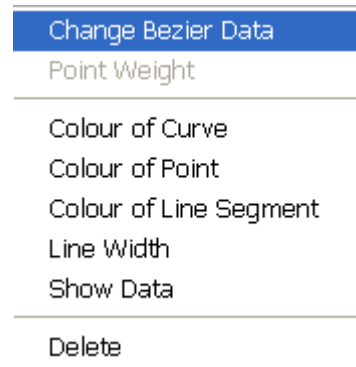
The Local Menu Cylinder



The Local Menu Torus



The Local Menu Bézier Curve



Right clicking on a data point lets you change the point weight.

Licence Information

The Copyright is by:

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