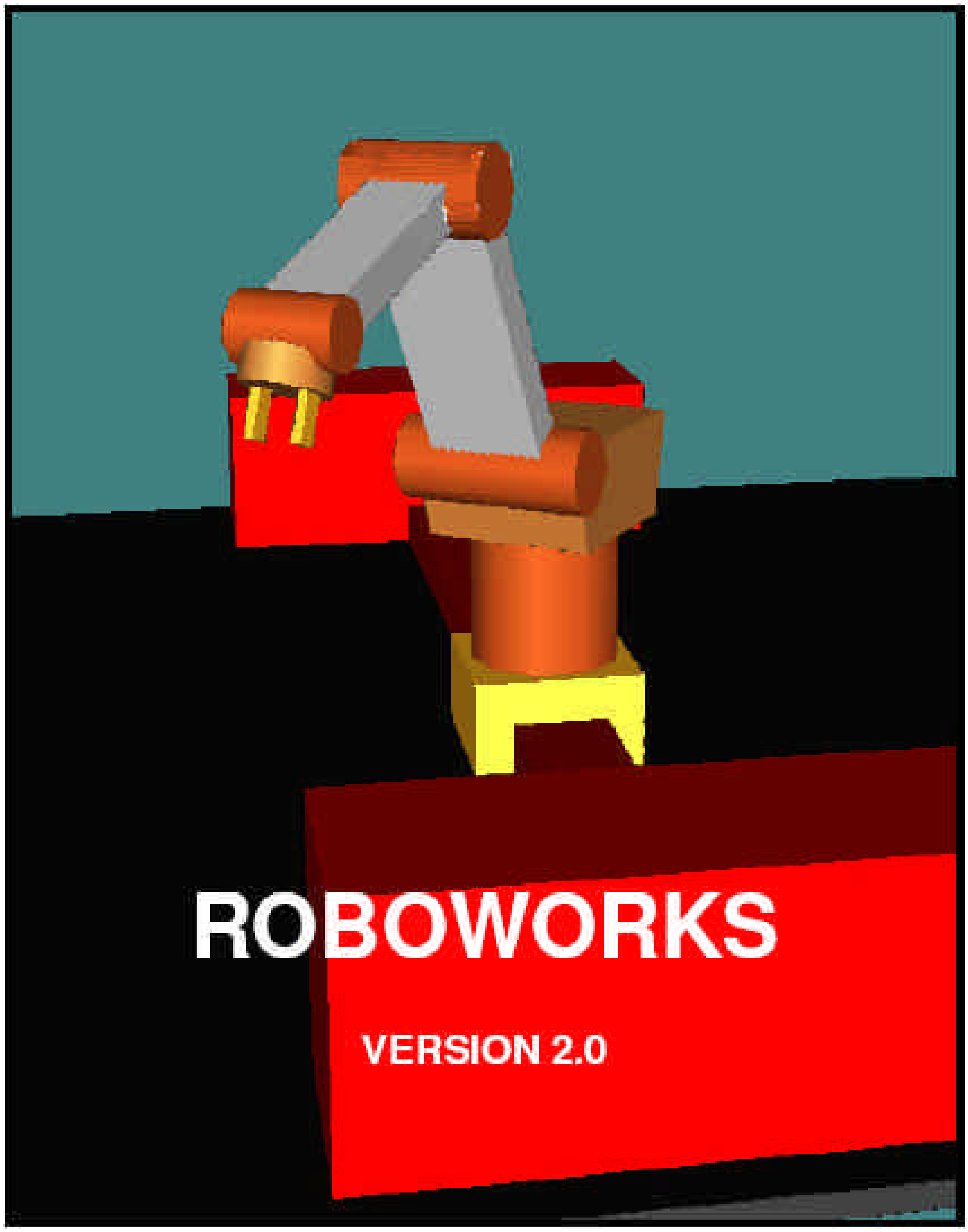

ROBOWORKS
VERSION 2.0

INTRODUCTION

What Is RoboWorks?

RoboWorks is a software package used to model and simulate three-dimensional mechanical elements. This program allows the user to create 3D models and animate them via the keyboard, a .dat file created by the user or an executable file created in MatLab, C++, LabView, etc.

In this guide we will learn how to model in the RoboWorks environment and how to use programming software to animate our models.

Who Should Use RoboWorks?

RoboWorks is useful for people in the Robotics field who have a need to simulate movement from a control program, whether you wish to analyze the results from a stimulus to a robot or have an idea of the real-time movement of the components of a mechanical system.

Who Created RoboWorks And How Can I Obtain It?

RoboWorks software was created by Chetan Kapoor under Newtonium. To obtain the software or to resolve common questions regarding the software or the company, visit the following web pages:

www.newtonium.com
www.newtonium.com/public_html/Products/RoboWorks/RoboWorks.htm
www.newtonium.com/public_html/Products/RoboWorks/RoboWorks_faq.htm

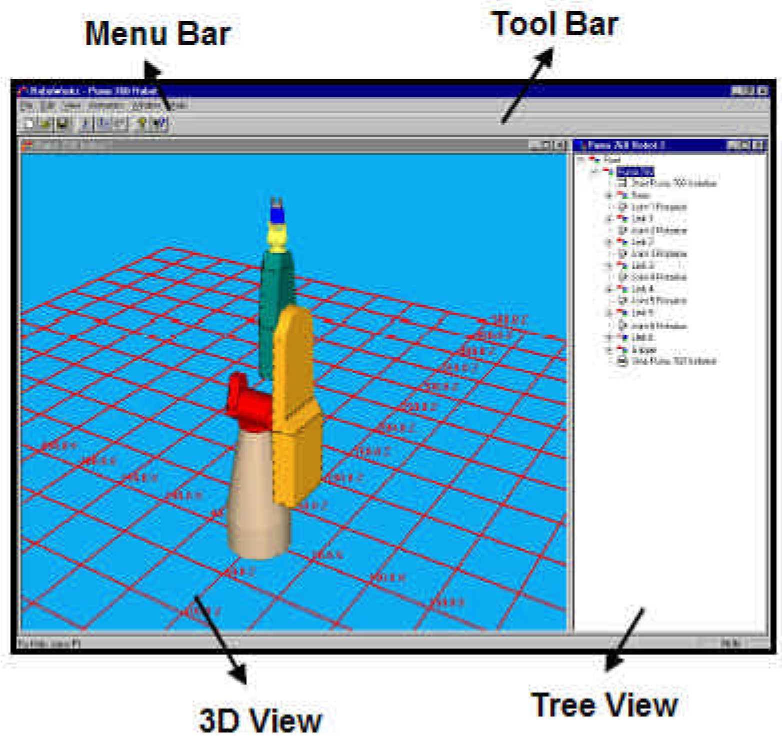
Send e-mail to support@newtonium.com.

The Graphical Interface Of RoboWorks

The graphical interface of RoboWorks consists of the following parts:

3D View: In this view you can see in three dimensions the state of the model. This window cannot be used to modify the model; it is only used to view the position of all of the objects.

Tree View: The models are created in this view. Every object visible in the 3D screen will be referenced in this window and only in this window can modifications of the parameters be made.



Menu Bar: Allows the classic tools of every Windows-based program: File, Edit, View, Window and Help as well as a new option for RoboWorks, Animate. The function of every option under the menu will be explained later.

Tool Bar: The tool bar contains only the icons pertaining to general Windows applications. They are: New, Open, Save, Cut, Paste, About and Help. The function of every icon will be explained later.

HOW TO CREATE A MODEL IN ROBOWORKS

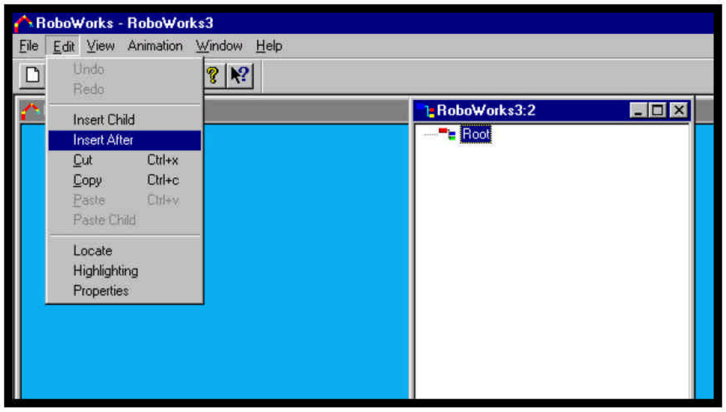
To start, it is necessary to familiarize yourself with the Tree View Window, since all of the models are created in this window.

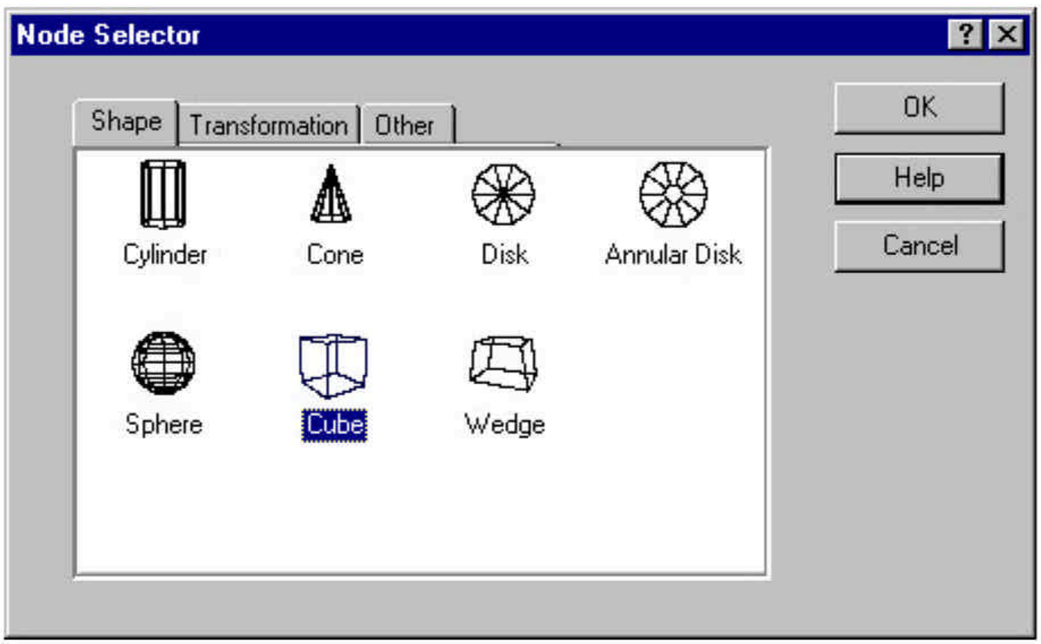
Tree View Window

All of the modeling elements appear in the order they are created in the tree view window. Three types of elements can be created in this window: Shape, Transformation and Other.

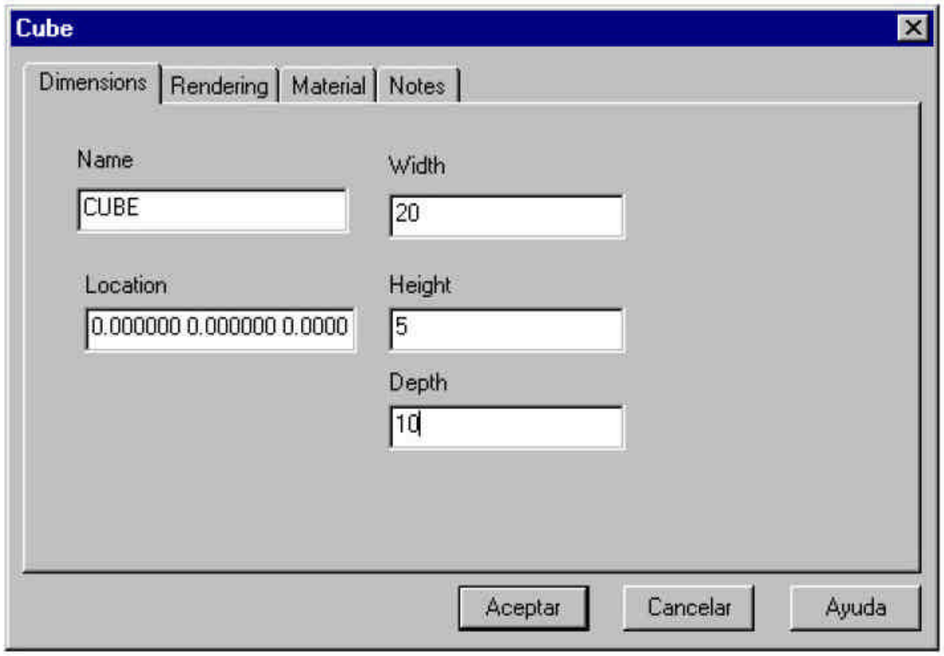
Shape contains the basic figures used to create any 3D object. You can create cylinders, cones, discs, spheres and cubes. Transformation contains all the possible movements an object can undergo such as a rotation or translation. Other contains the option of creating groups and selecting materials for the objects.

To insert an element in this view, go to "Edit" (tree view window must be activated) and select "Insert Child." In the next window, select the element that you want to insert from the Shape, Transformation or Other categories.



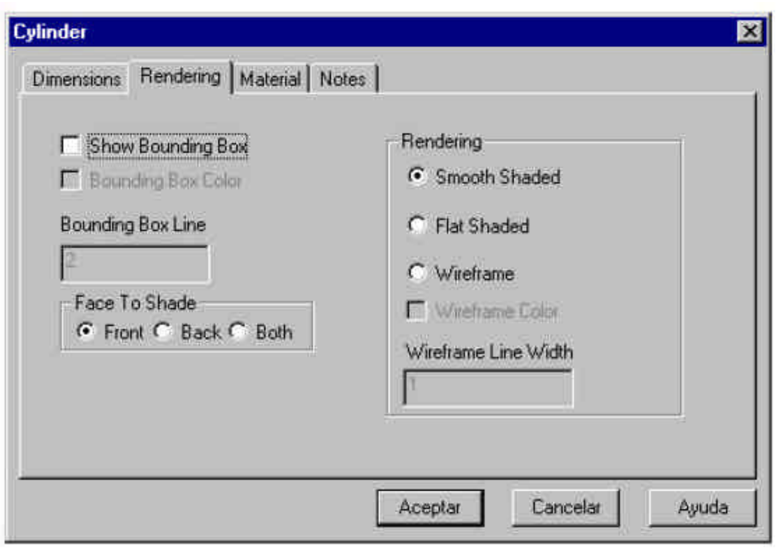


To insert a cube for example, select cube from the Shape tab and press OK (or double click cube). In the next window you can specify the dimensions and location of the cube. For example, place the center of the cube in the origin (point 0,0,0) and give the dimensions 20x5x10.

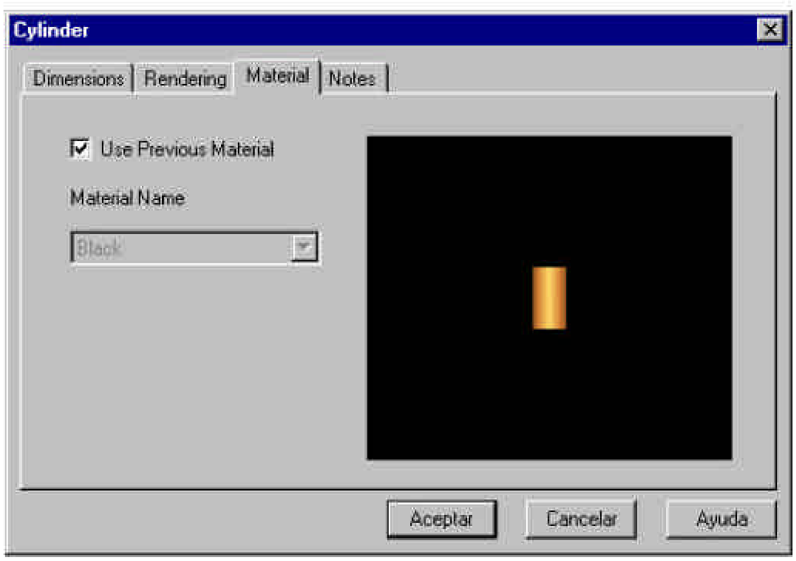


Besides the option of dimensioning, two other options exist, Rendering and Material. Both of these options have default values but we will change these values to understand the effects of each.

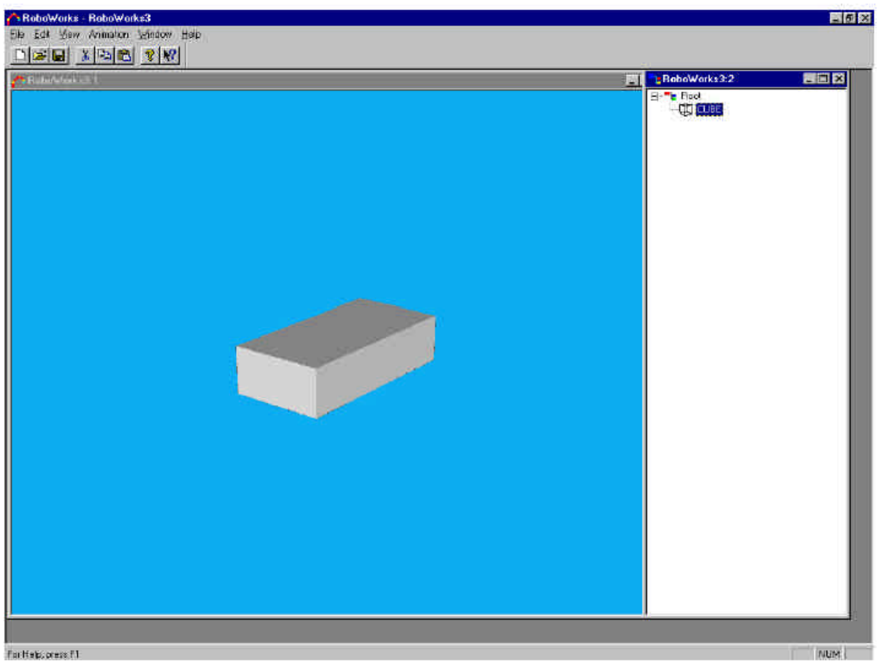
The Rendering tab allows you to change the shading of the object. You can select your shape to be Smooth Shaded, Flat Shaded and Wireframe. You also select what side to shade: Front, Back or Both.



The Material tab allows you to define a new material for the shape or to use the previously defined material. When defining a new material, a window allows you to see the color you wish to apply to the shape before you accept any changes.



Going back to the example, define a material for the cube and select Smooth Shaded from the Rendering tab. Immediately after OK is selected, the cube is created in the 3D View Window. The properties can be modified in the Tree View Window by double clicking the element.



In RoboWorks, every object is referenced to the origin so you should specify the distance from the center of the object to the origin as well as the dimensions. Since the cube's center is located at the point (0,0,0), the upper face is 2.5 units from the origin and so on.

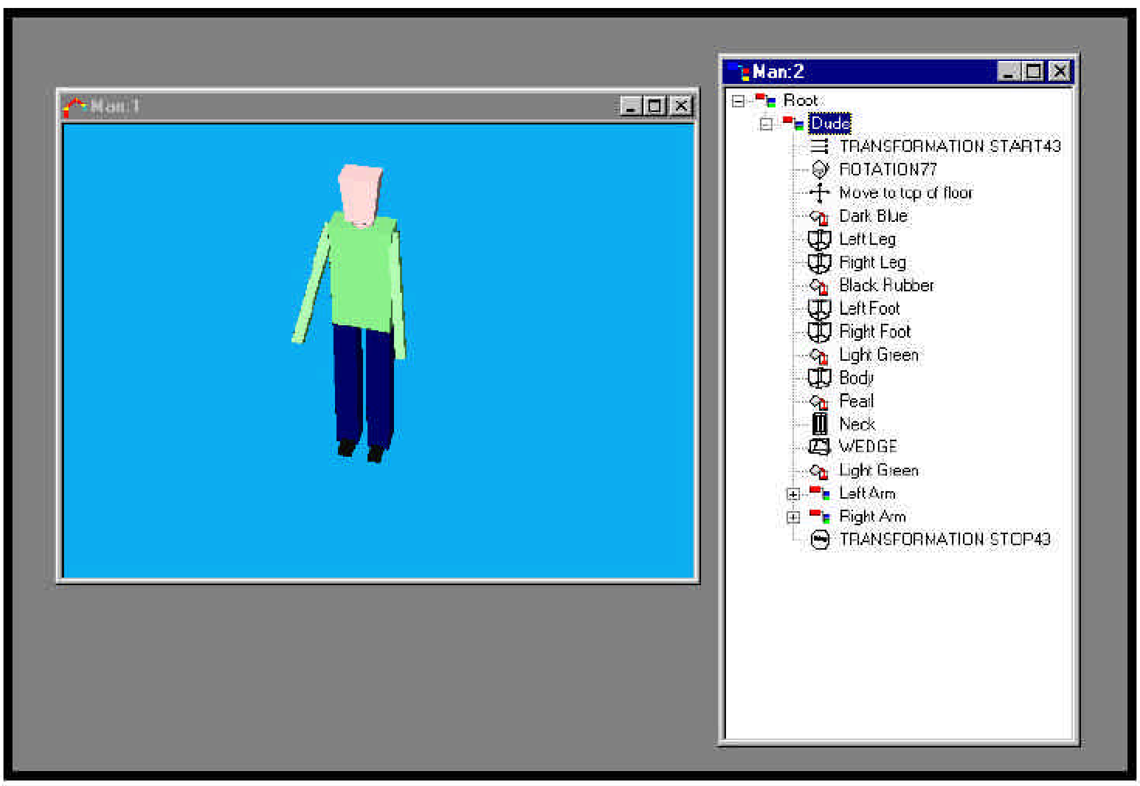
The steps to create any shape are the same. RoboWorks will ask what type of shape and its dimensions. For practice, try to create a sphere above the cube. Remember, that the cube in this moment is found in the origin.

From the Edit menu with the Tree View window activated, there are two ways to insert an object. With “Insert Child” you will be able to insert an element within a group and with “Insert After” you will be able to insert an element after a group. With the other options you can locate an element in the 3D view (“Locate”), highlight an element (“Highlight”), and modify the properties of the elements. You also have the other classic functions: Copy, Cut and Paste.

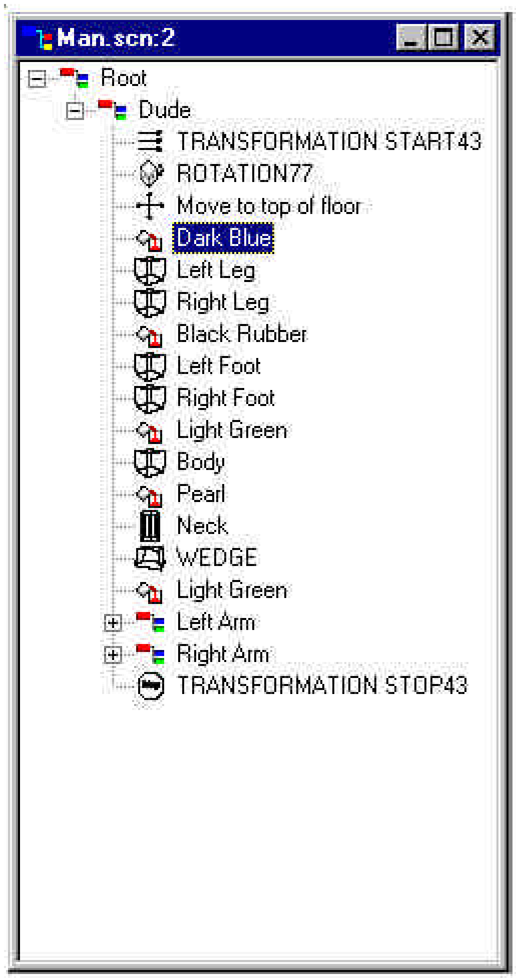
Other than shapes, you can insert groups within which you can insert elements of the same part of the assembly and materials that define the color of the shapes.

Now that you know how to insert elements, lets study the following example.

Example: Human Figure



Observe the configuration of the figure. For now ignore the transformations since they have not been studied. To start, when you define a material, all of the elements to follow will have the same material unless a new material is defined.



First a dark blue material was inserted. The two legs, made of rectangles, where then inserted (the legs have a dark blue color). Next, a new material was defined (Black Rubber) for the feet. The body was given a Light Green material. To finish, the color Pearl was used for a "Cylinder" neck and a "Wedge" head. The wedge is a six-faced polygon in which two opposing faces are not parallel. The two arms are part od an animation and for this reason each is a group comprised of various transformations and an inclined rectangle.

THE 3D WINDOW

With the 3D window activated, other options are found in the edit menu. This window serves exclusively to view the model or simulation that has been planned in the tree view window.

The options in the edit menu are:

1. Background. This option allows you to change the background color.
2. Auto Rotation. Rotates your model continuously.

3. Grid. Lets you view the coordinate axis that is the initial reference.
4. Coordinate Frames. Allows you to view all of the origins created through transformations.
5. Antillas. This option is useful to visualize the solids in high quality rendering. Do not use this option if your PC does not have a good graphics card.
6. Interactive Mode. This option is divided into various options that allow you to view the model in various points of view. These options are: Rotation, Translation, Zoom and Picking which allows you to modify the properties of the model's elements through a double click of the element.
7. Rendering. Allows you to modify the way you want to render your model. The three options are: Wire Frame, Smooth Shaded and Flat Shated.
8. Projection. This option is useful to visualize the model in perspective or orthographic view. In perspective view you can see how the lines move away from the horizon and in orthographic view the lines are always parallel.
9. View. Allows you view the model from the Top, Bottom, Front, Back, etc. You can also view the model in the original position.
10. No Clear. When this option is selected and the point of view is changed, the previous point of view remains allowing you to see both positions simultaneously.

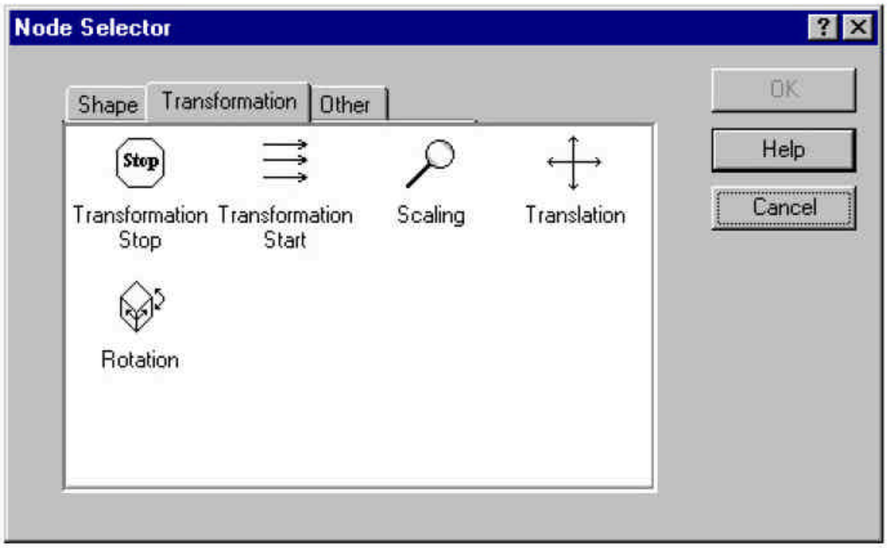
TRANSFORMATIONS

Two types of transformations exist in RoboWorks: Static Transformations and Dynamic Transformations. These transformations are what allow for animation and movement of the model.

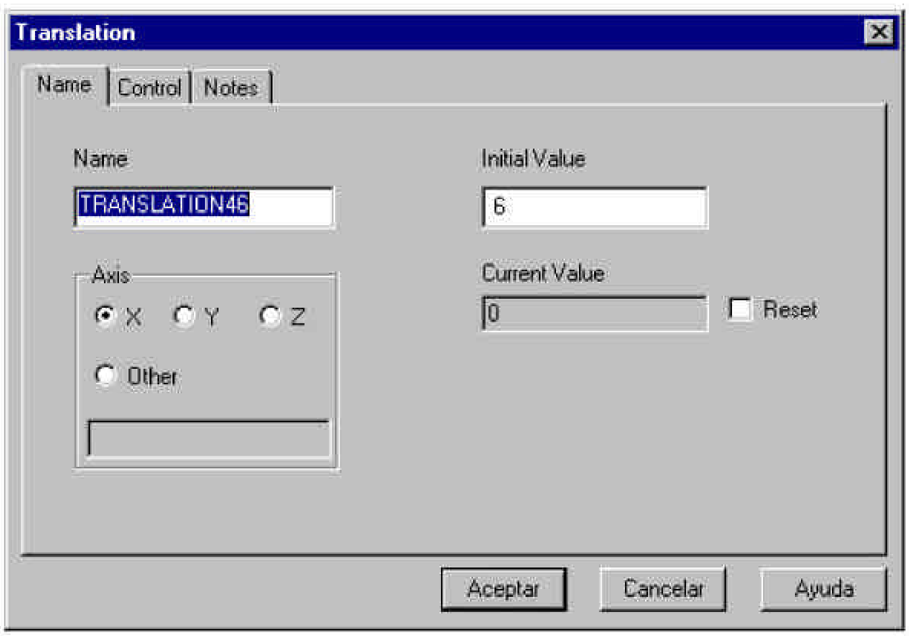
Static Transformations

The transformations modify the model by changing the point of reference of the elements of the model. In other words, they allow you to move the origin to facilitate the modeling process and animation.

To insert a static transformation, select (with the tree view window activated) "edit," followed by "insert after" and then click on the "Transformation" tab.

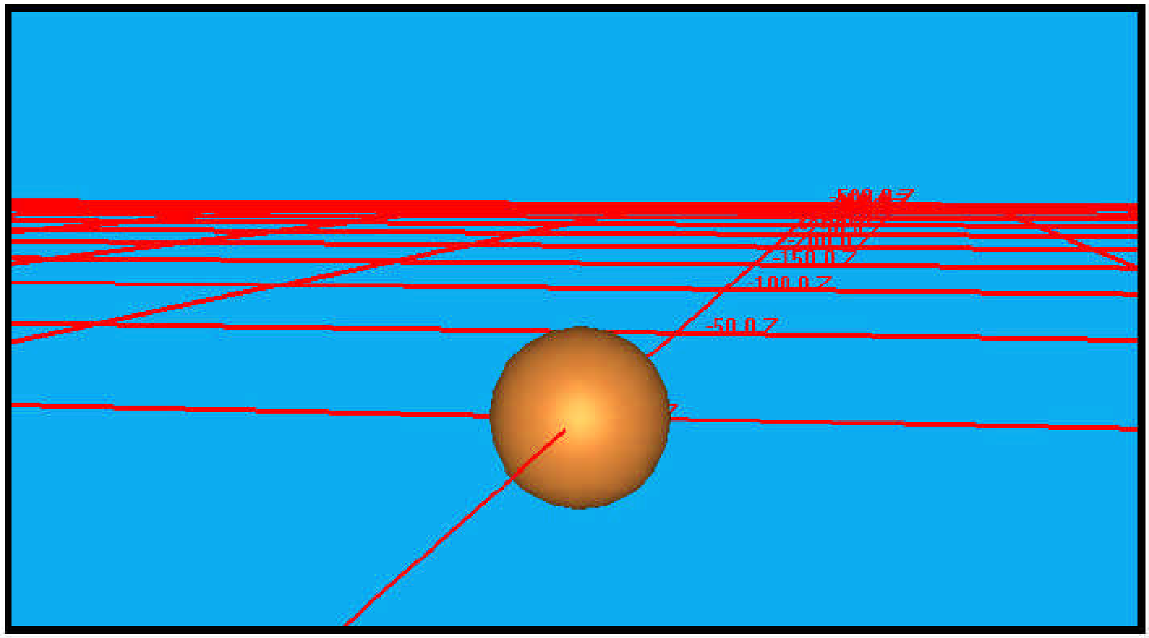


To start, begin with the classic Translation and Rotation. Translation displaces the origin in the x-, y- or z-directions. To displace the origin in more than one direction, you will have to translate the origin in one direction at a time. To perform a translation, select Translation from the Transformation tab. The following window will appear:

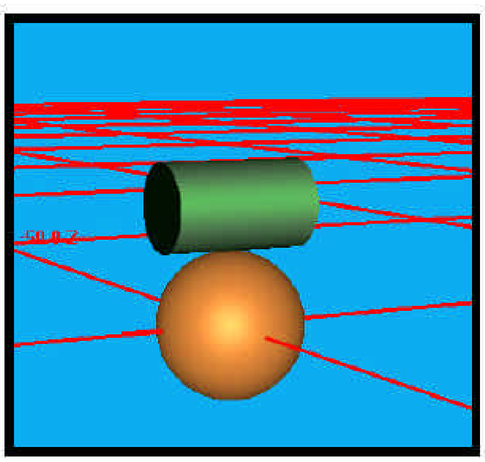


In this window, select in what axis the displacement will occur and by how much. Displace the origin 6 units in the x-direction. The control window will be used later. Now every object that is created after this transformation will be displaced 6 units in the x-direction.

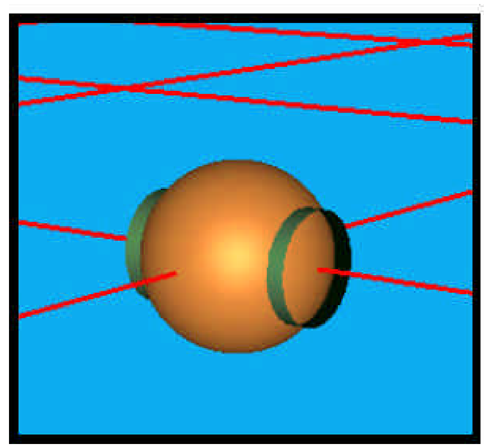
Example: To start, create a sphere with a radius of 5 units located at the origin (0,0,0) with a bronze material. Once the grid is activated the figure should look like this:



After the sphere, insert a new material (green color) and a translation in the y-direction of 8 units. Then, insert a cylinder aligned with the x-axis that has a constant radius of 3 units and a length of 10 units and place the cylinder at the origin (0,0,0). The result is a cylinder displaced 8 units above.



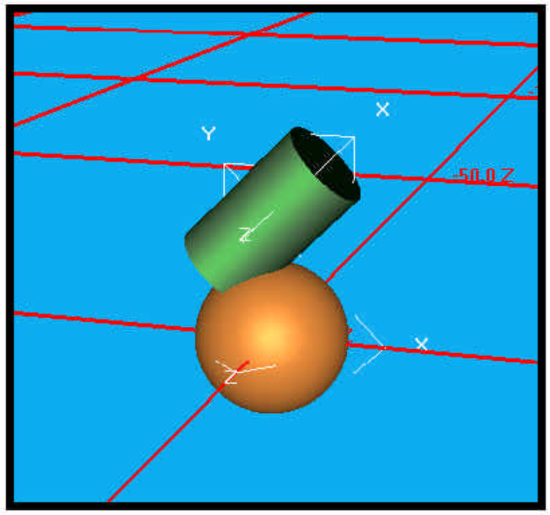
Model with transformation.



Model without transformation.

If the transformation had not been placed, a cylinder in the middle of the sphere would have resulted. This simplifies the modeling process greatly since you do not need to remember the position of every object with respect to the origin.

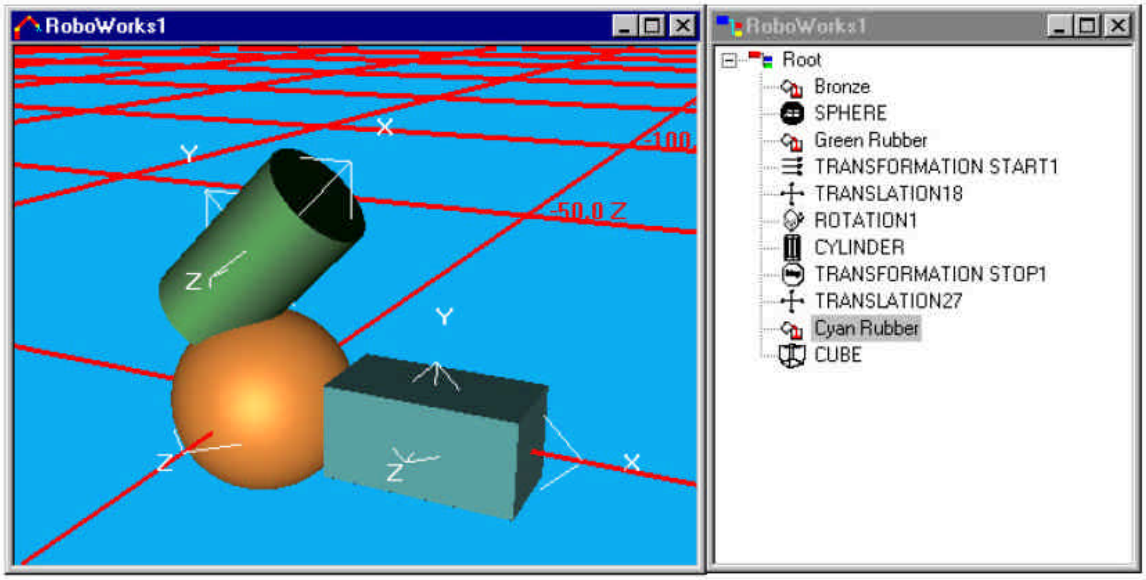
Another option is Rotation. With this option you can create inclined objects, something that without this transformation would not be possible. Practice by placing the model in the following position:



To help with the model you can use the tool “Coordinate Frames” to visualize the positions of the coordinate systems.

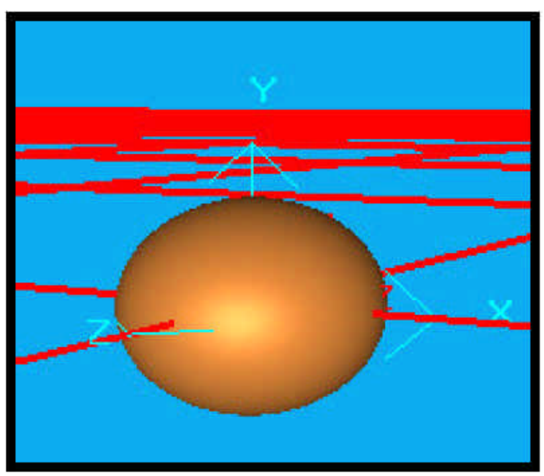
The options “Transformation Start” and “Transformation Stop” allow you to insert various transformations from the same point. That is, if, for example, you needed to first place an inclined cylinder above then a cube to the side it is not necessary to move the origin up then bring it down and then to the side. Simply begin a transformation to move the origin up (by placing a Start before the transformation) and then stop the transformation after it has created the inclined cylinder. With this the origin goes back to its original location before the transformations with in the Start-Stop sequence were created and afterwards you can create new transformations to move the origin to the desired location.

The following is an example of the this situation:



Place a "Transformation Start" before you move the cylinder up and it is rotated about the z-axis. After the inclined cylinder is created, insert a "Transformation Stop" and the coordinate system returns to the original location. Now create a new transformation that will displace a blue cube 10 units in the x-direction.

To finish, the last transformation that can be created in RoboWorks is "Scaling," which serves to scale figures. This is useful to deform the objects in a given direction. If you wish to create a sphere in which the y-direction is shorter, simply scale the object down in this direction leaving the other directions unchanged yielding a figure like this:



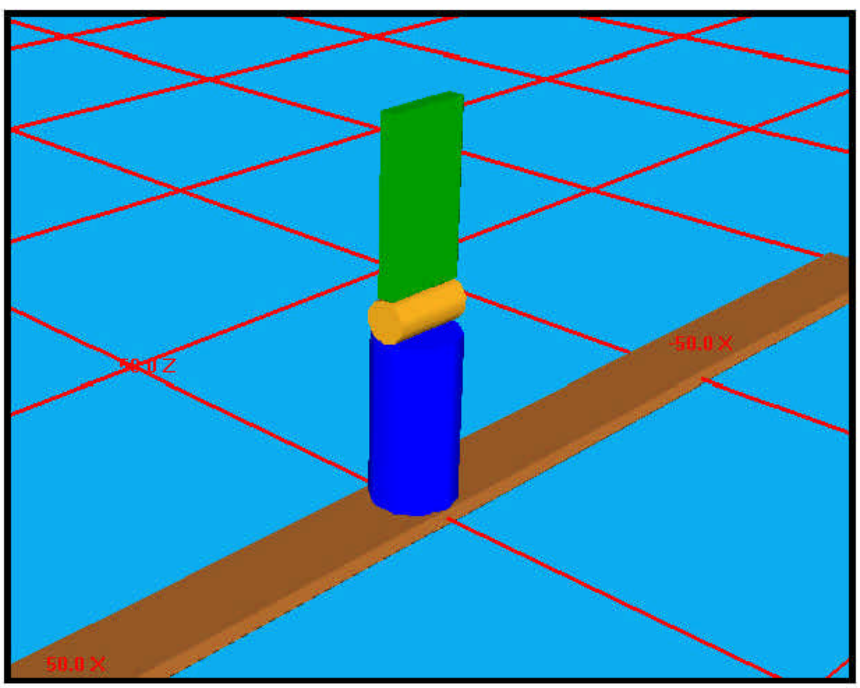
Now that the static transformations are understood, the dynamic transformations will now be discussed.

Dynamic Transformations

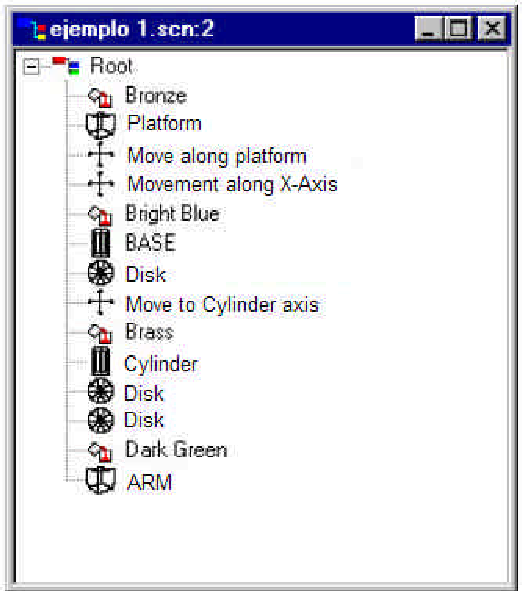
Dynamic transformations do not have a specific value associated with them like static transformations. For dynamic transformations the magnitude of the transformation is a variable whose value is input by the user. This allows us to animate the objects by means of another program, the keyboard or a file generated by the user. As with static transformations, a dynamic transformation can translate, rotate and scale the model. The options “Transformation Start” and “Transformation Stop” again allow us to return to a point of reference given before the transformation and they allow us to animate several objects in the model independently.

Example:

In this example you will create a mechanic arm that is capable rotating about itself, translating along the X-axis and rotating about its elbow. Create a model of the arm with your preference of dimensions. Remember to draw a platform so the arm can move and an axis for elbow rotation. Your model should look similar to the one shown below:

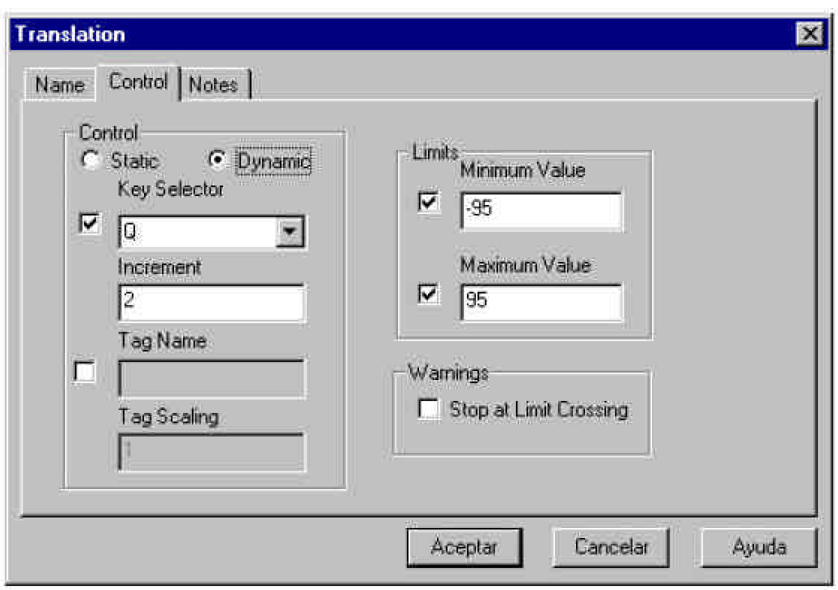


Remember that all of the transformations depend on the previous transformations; hence, if you want to rotate the arm of the robot about the axis of the cylinder you first have to move the coordinate axis to coincide with the axis of the cylinder. Create the dynamic transformations before the object you wish to move. If you wish to translate the arm without moving the platform you must place the transformation between the platform object and the cylinder object as follows:



In the tree view window above, notice transformation that allows movement along the x-axis between the platform and the base. This a translation about the x-axis with it's control set to dynamic and limits specified so the arm will not go beyond the platform.

To change the properties of the transformation, select the Control tab and modify the properties. The window looks like this:



In this window you can select the type of transformation (static transformation is the default). For this example select dynamic. You can also select what type of control (Key Selector or Tag Name) will be used depending on the type of animation you want. The explanations for these options will be given later. You can also select the limits of the transformation and, if you wish, a warning given when limits are crossed.

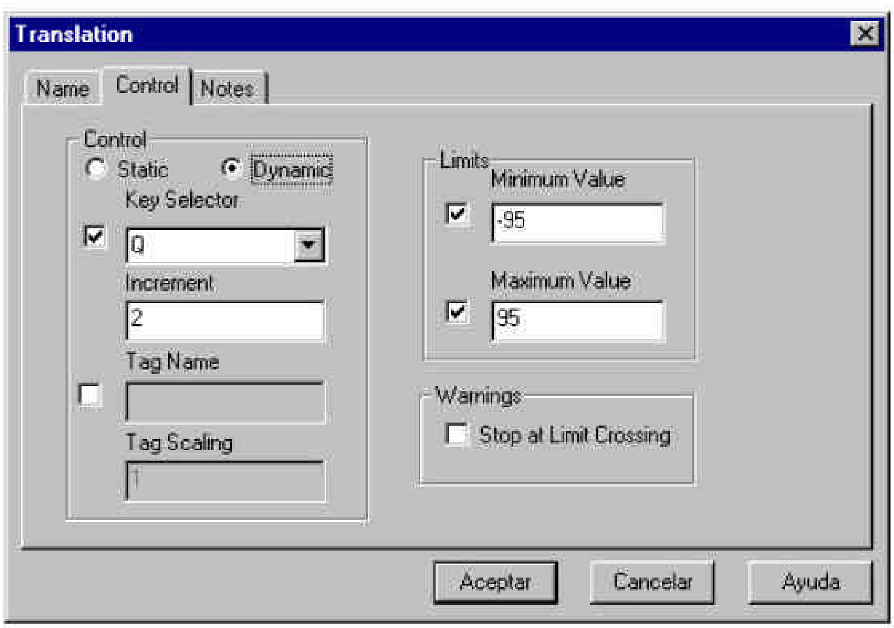
Place a rotational dynamic transformation between the platform and the base and another between the base and the cylinder and now the model is ready to begin animation!

ANIMATION

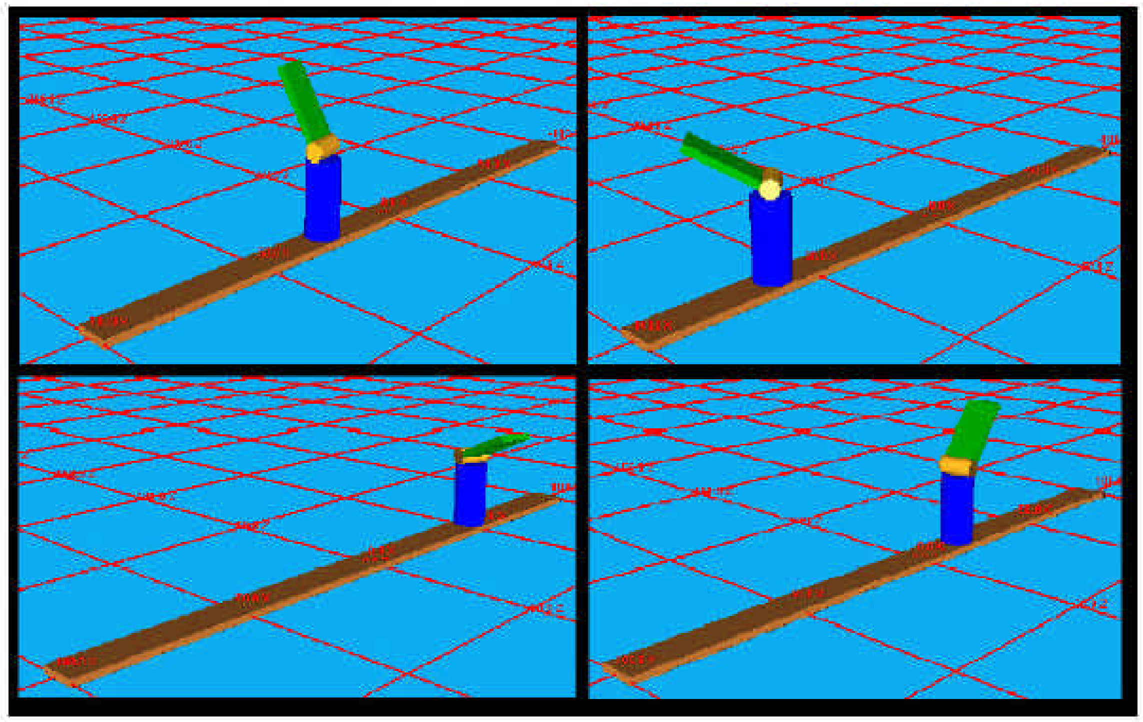
As previously mentioned, there exist three types of animation: through the keyboard, through a file of data or through another program. We will start with the easiest, animation via the keyboard.

Animation Via The Keyboard

To create any animation, the properties of the dynamic transformations must be modified. We will continue from the previous example. In the Control tab select "Key Selector" and the in the options select any letter or number from the keyboard. Underneath, specify the magnitude of the increment you want to achieve with this transformation. Select OK. You are now able to animate your model via the keyboard.



Try this with the previous example. Give the dynamic transformations a letter and with the 3D view window selected, press the letters to move the model. To move in the opposite direction, press the key and Shift simultaneously. Your model should now be moving! If your rotations are not moving in the appropriate axes, remember that you must define the axis of rotation by means of a static transformation before your dynamic rotation. If you do not do this, the model will rotate with respect to the origin.

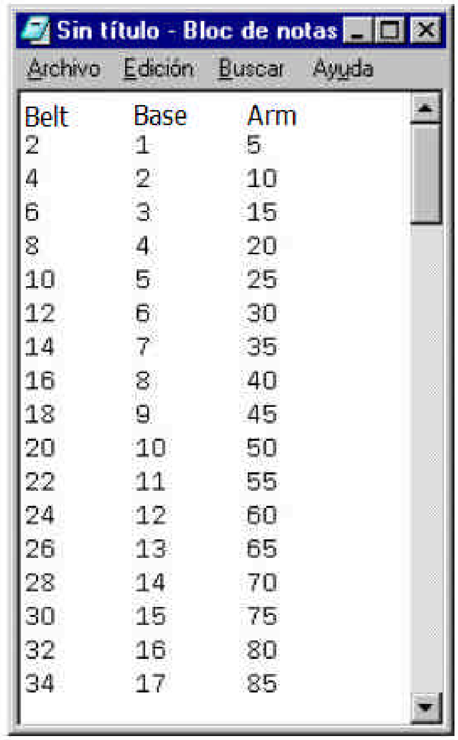


Now we will move on to animations by means of a file.

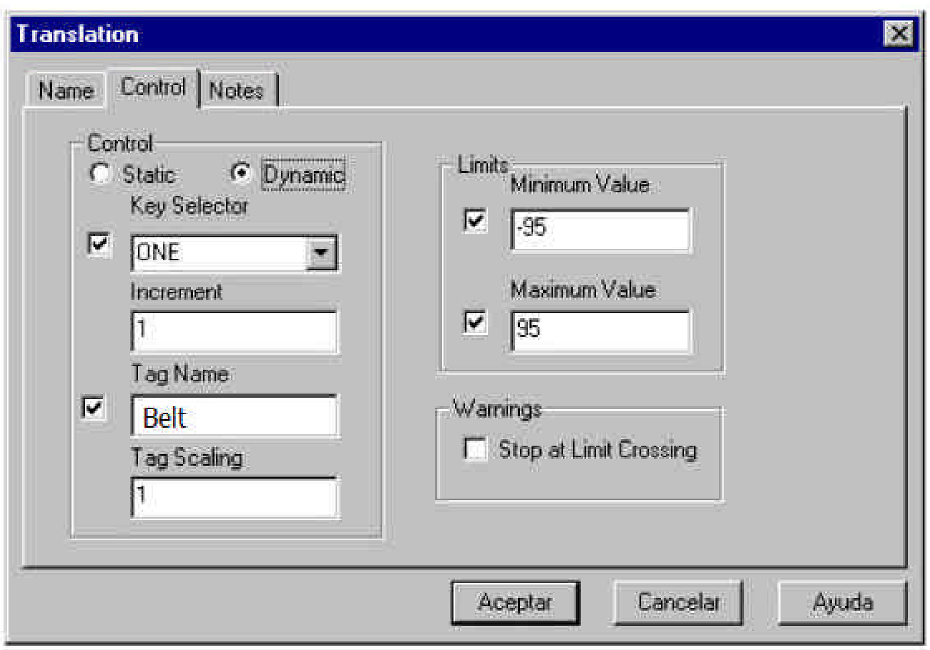
Animation Via A File

In this type of animation you must generate a trajectory for each of your dynamic transformations that have been created producing a list of points. This means that if you want to move the arm 30 degrees, you must create a list that contains points from 0 to 30 in N-number of steps.

Below you can see an example of a list for possible trajectory. To use this file, you must save the document with extension .dat. In the list, each row represents a moment in time.

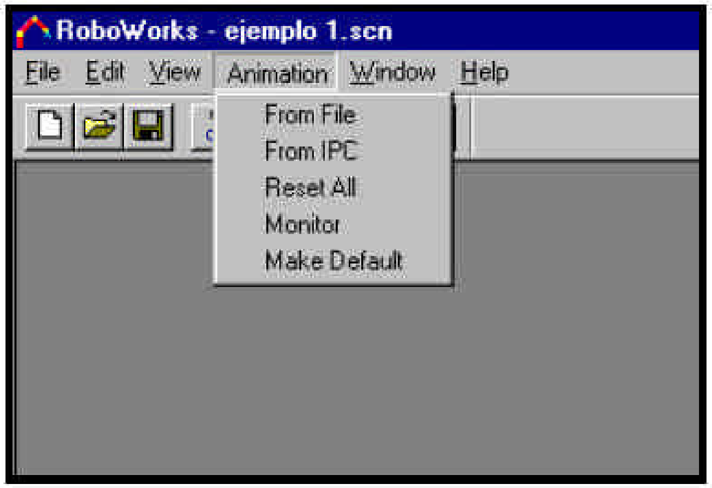


Now to animate, you must configure the dynamic transformations to allow RoboWorks to read the .dat file you have created.

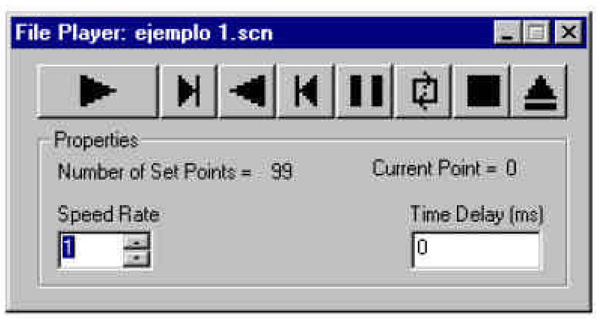


You must select a “Key Selector” that corresponds to a number to identify each transformation created. You must also give each transformation a “Tag Name” to identify the column of data that corresponds to that transformation. At the beginning of each .dat file, you must type the Tag Names given to the transformations, remembering which column corresponds to which transformation.

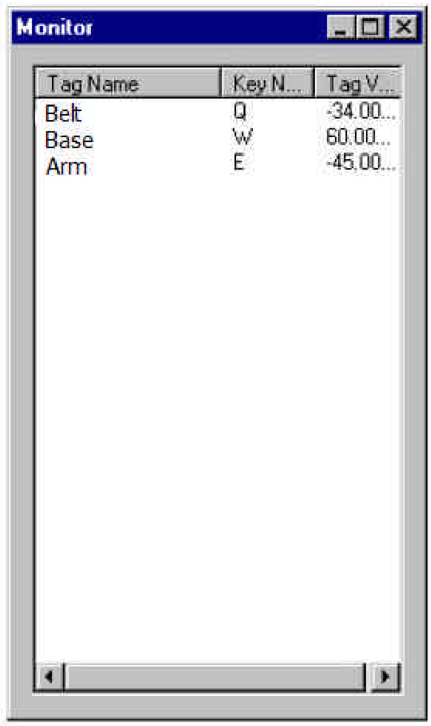
Now let's explore the Animation Menu. Click on this menu to view the options:



The first is animation from file. This option is the one that will be used to tell RoboWorks you will be animating via a file of data. When this option is selected, a window will appear asking for the file location. After selecting the file, another window will appear allowing you to run the trajectory planned in the file.



The second option, "From IPC," allows you to animate from another program. For now, do not select this option. "Reset All" resets the animation to its initial point. If "Monitor" is selected, a window will appear showing the position of all the dynamic transformations that is updated continuously.



"Make Default" allows you to change the initial point of the animation, allowing you move the model to a more convenient point.

It is not necessary to know anything more to create an animation from a file. You simply need to generate the .dat file, modify the properties of the dynamic transformations and select the file that contains the information for the animation in "From File" from the animation menu.

Now we will dedicate some time to animations using another program, for example, C++, Visual Basic, LabView, etc.

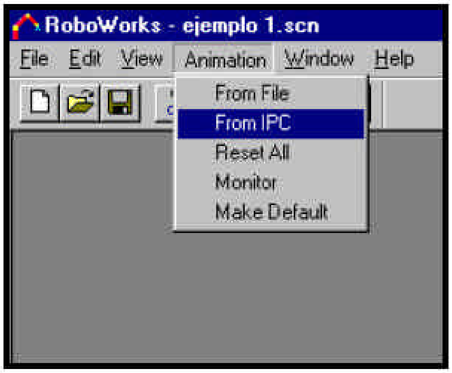
Animation Via Another Program

This option is the greatest achievement of RoboWorks. It is called RoboTalk and it consists of a series of libraries that allow you to generate the trajectories from another program. With RoboTalk you can program a trajectory for a machine in programming software and see in RoboWorks how it will react to given commands. This is very useful because it allows you to program the movement of a machine without the need to physically move it, hence reducing the possibilities for collisions due to errors in the programming.

The tag names given to the transformations allow you to control the resulting motion in RoboWorks from another program. RoboTalk is installed like a .dll and along with this file come the files to program in Windows via C++ or Visual Basic. Also, a .vi file is included to program via LabView. If you wish to program from a different platform than Windows, RoboTalk code is available so you can program the functions in another platform that does not understand .dll.

RoboWorks also allows you to control the simulation of the trajectory from a TCP/IP, as long as these are connected through the internet.

To run a simulation you must activate the option “From IPC” from the animation menu and then run the program (already compiled) and the simulation will show in RoboWorks.



The description of the main commands of RoboTalk will now be discussed.

CONNECT

int Connect(char* filename, char* ipAddress);

This function establishes a connection between the controller program and RoboWorks. For this connection to work, you must have the simulation option and the option “From IPC” activated.

DISCONNECT

int Disconnect();

This function disconnects the program from RoboWorks and it should be called before finishing the program.

GET TAG VALUES

int GetTagValues(char ** tagNames, float* tagValues, unsigned int noTags);

This function gets the values of the tags defined in the transformations.

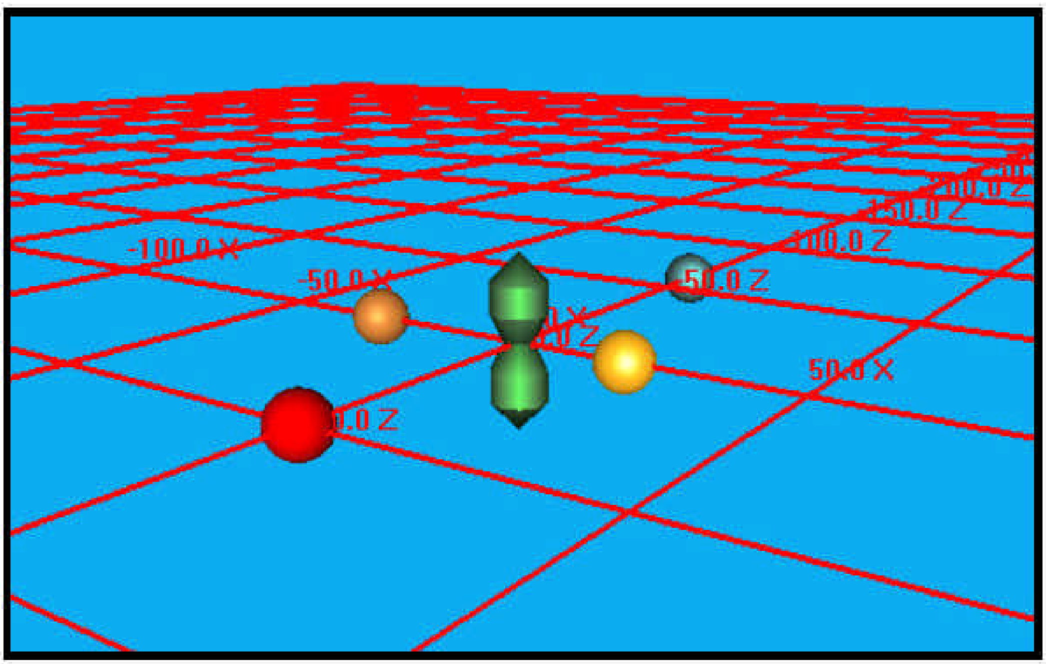
SET TAG VALUES

int SetTagValues(char** tagNames, float* tagValues, unsigned int noTags);

This function sends the tags the corresponding value to animate the model in RoboWorks.

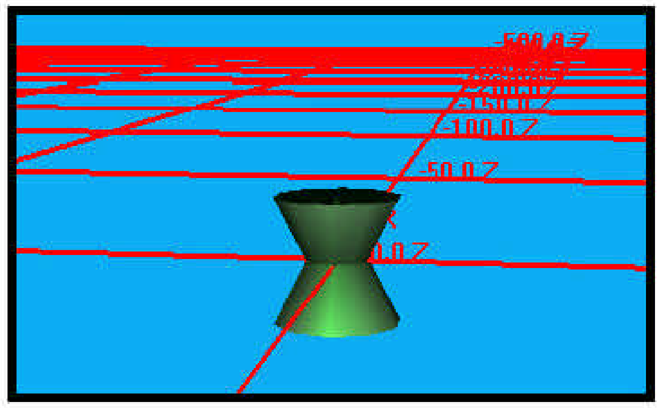
PRACTICAL EXERCISES

Planetary Spheres

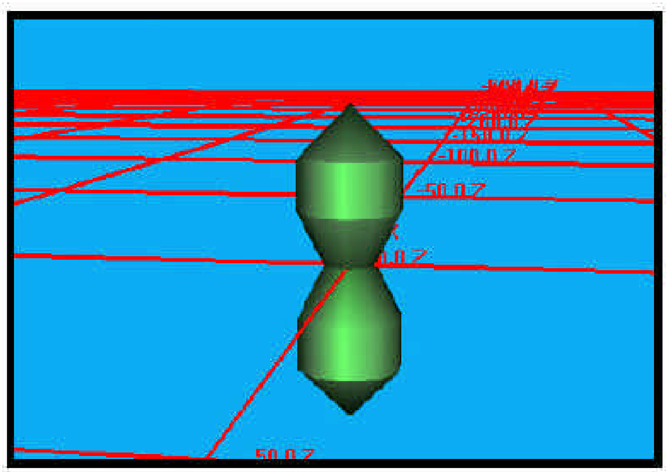


In this exercise, the colored spheres rotate about the green column with different velocities and directions. This should be achieved by only pressing the letter Q in the keyboard.

First begin with the model. To simplify things, create a group for each element and define a new material for each. As you can see in the figure above, there are five groups of solids, so the transformations that affect each solid should not affect the others. Hence, a Start and Stop Transformation should be created for each solid. To create the green column, you will initially need two cones with height 5 units and radius of 5 units (one being inverted with respect to the other). To get the inverted cone, you will need to invert the coordinate system by rotating about the X- or Z-axis.

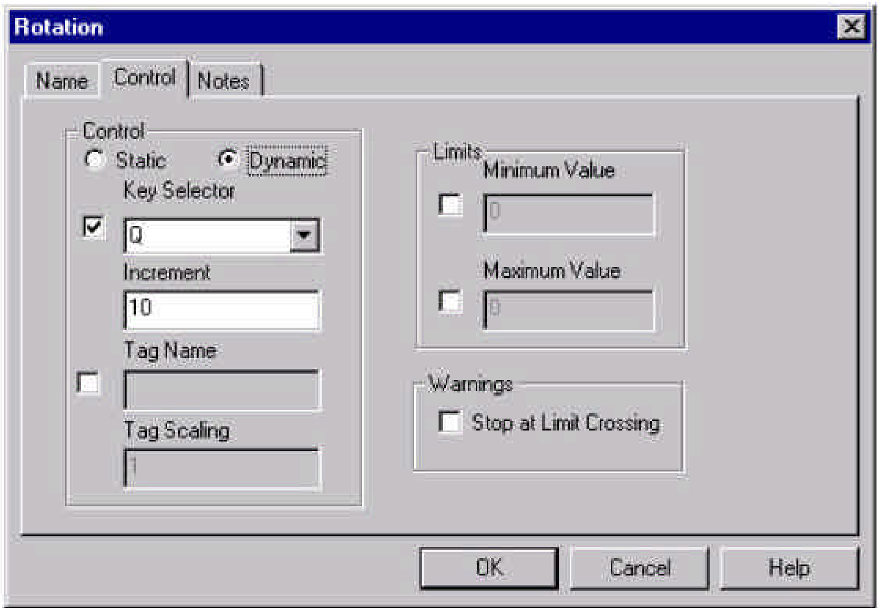


Create cylinders with 5 unit height and 5 unit radius and then another two cones (5 unit height and 5 unit radius) to finish the column off. The result should be as follows:



Remember, since the column was created within a Start and Stop Transformation sequence, the coordinates will return to the original orientation. Each sphere rotates about the same axis, and it is wise to leave them referenced to this axis.

The yellow sphere has a 5 unit radius with its center located at the point (X,Y,Z)=(20,0,0) with respect to the origin. Do not displace the sphere by means of a static transformation to conserve the origin so the sphere will rotate about the reference axis. You will need a rotation about the Y-axis achieved by pressing the letter Q with an increment of 10 degrees per second.



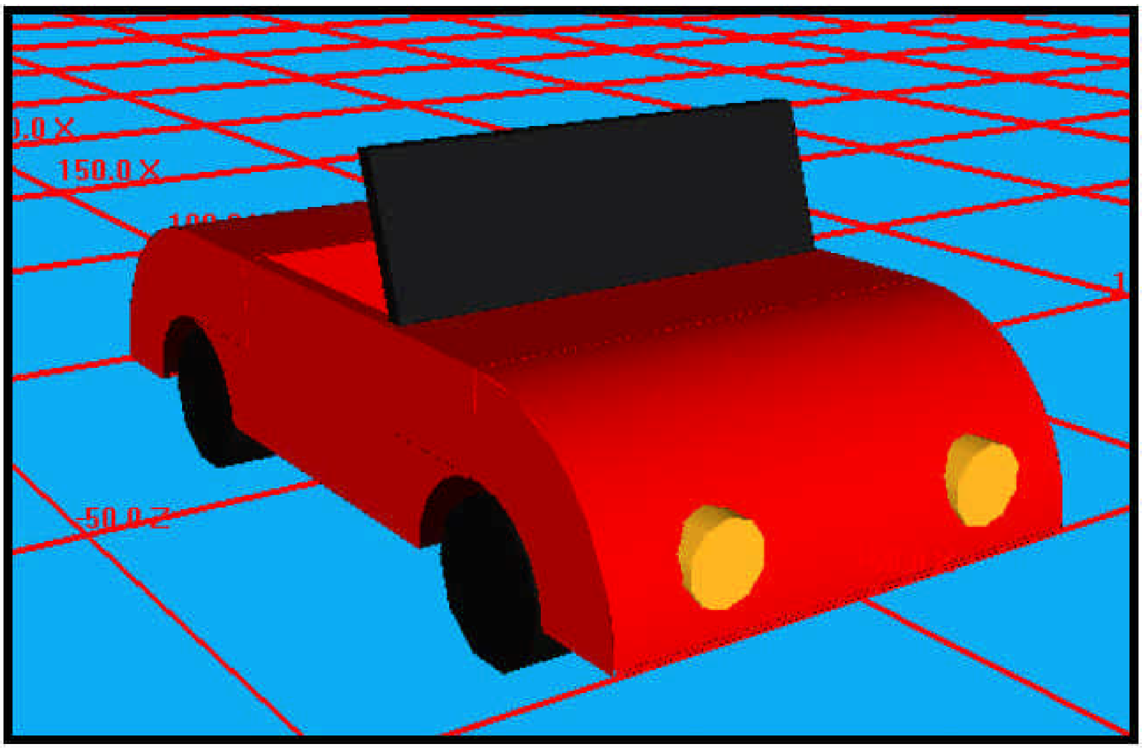
Now you can test how the sphere rotates about the column by pressing the letter Q. Create the other spheres in the same manner changing the positions and the increments of the angle of rotation according the following table:

Sphere Color	Position X Y Z	Increment of Rotation
Yellow	20 0 0	10
Red	0 0 50	-6
Bronze	-30 0 0	-2
Blue	0 0 -60	5

All of the transformations should move by pressing Q.

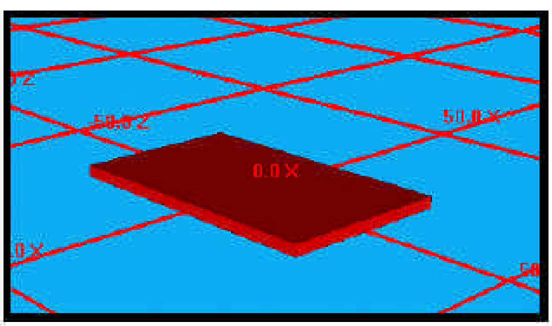
Answer the following question: What would happen if the Start and Stop Transformation sequence are not placed before and after each sphere?

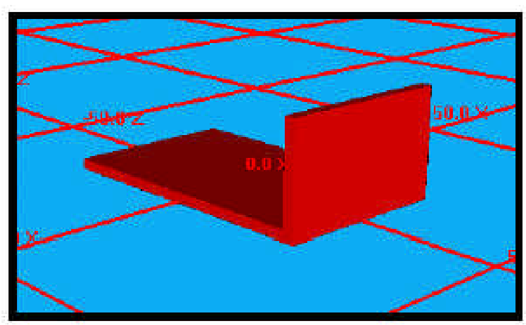
Car

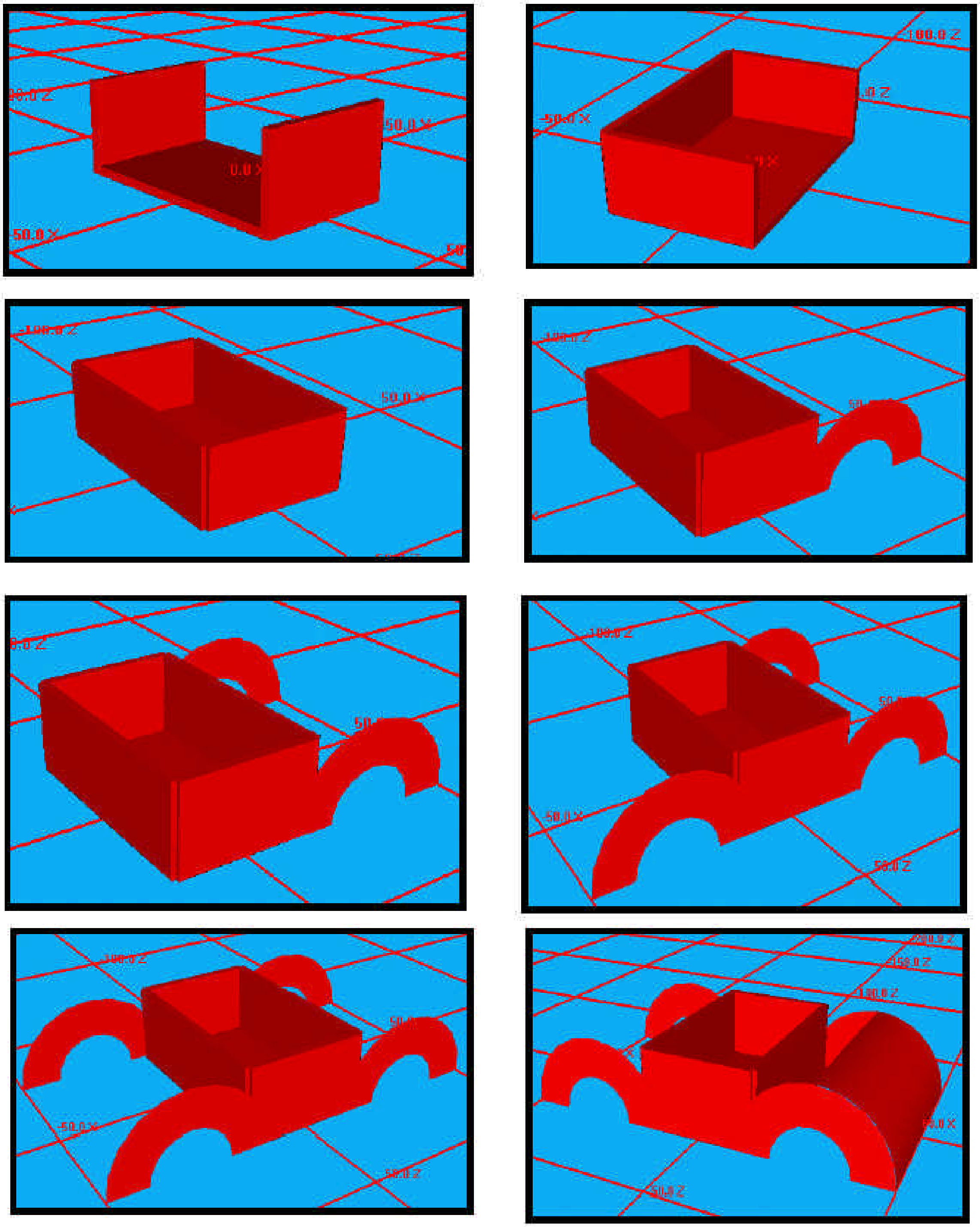


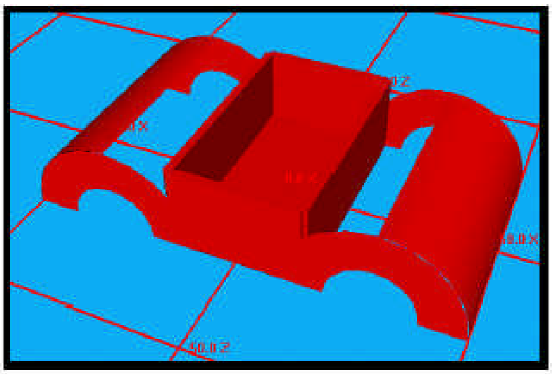
To practice modeling of complex objects, try to model the car in the figure above.

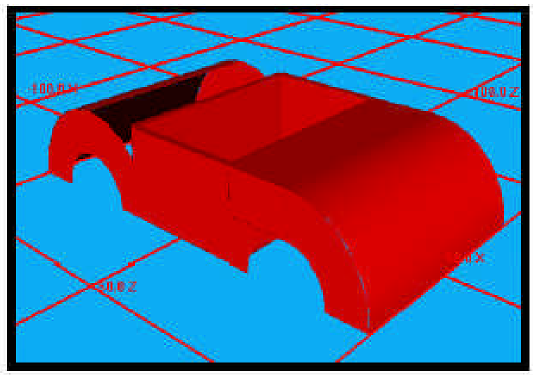
Begin with the cabin. First define the material; the color of the model is bright red, but define the color you prefer. Next, create the cavity in which the seats will be placed. In the figures that follow you will be able to see the sequence in which the model was created. Also, tables with the positions and dimensions of each element are given. It is recommended that you use your own dimensions to create a car that fits your own style.

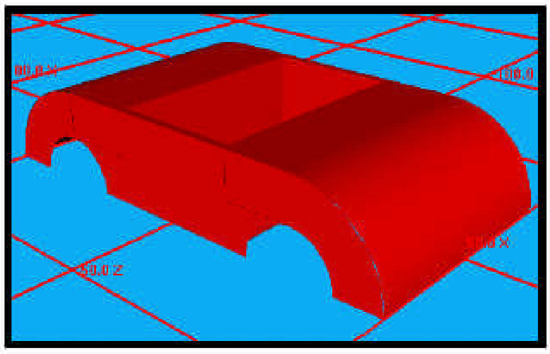






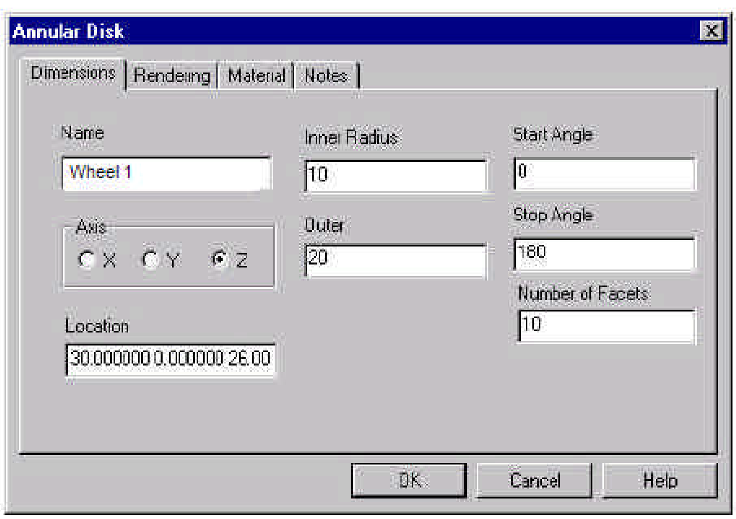




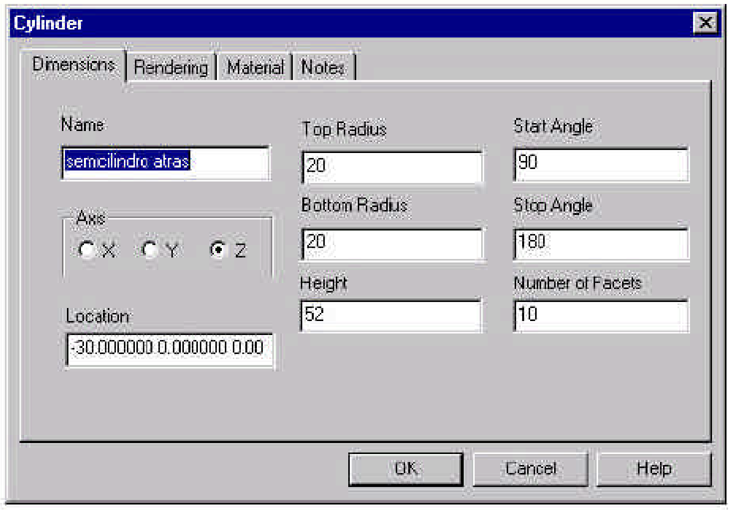


Shortly, you will be able to see how the annular disks and the quarter cylinders are created. The other figures are rectangles, and all the dimensions are found in the table below.

The annular disks were created in the following manner. Define an inner and outer diameter and position the disk in the same plane as the door. Also, only half the circumference of the disk is needed, so define the stop angle to be 180 degrees.



The cylinders function in the same manner. You must define an initial and final angle.



If you have problems with the color of the disks, check that the property of the rendering of the object is the correct one.

Rectangular Elements of the Model:

Name	Dimension			Position		
	X	Y	Z	X	Y	Z
Below	30	2	50	0	1	0
Right Door	30	20	2	0	10	25
Left Door	30	20	2	0	10	-25
Front Plate	2	20	50	-15	10	0
Back Plate	2	20	50	15	10	0
Front Cube	15	10	52	22.5	15	0
Back Cube	15	10	52	-22.5	15	0

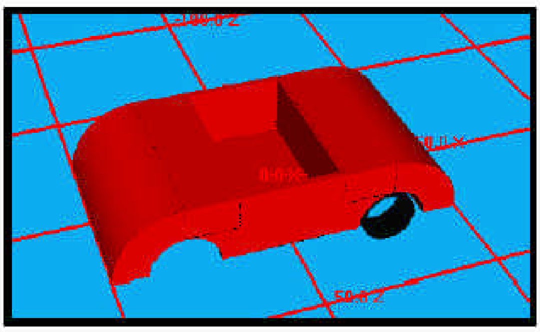
Annular Disks:

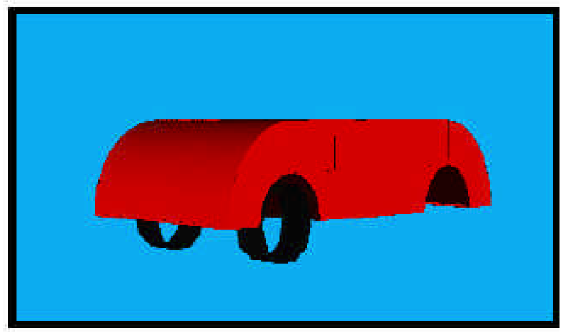
Name	Dimension					Position		
	Axis	Ext. Radius	Int. Radius	Initial <	Final <	X	Y	Z
Wheel 1	Z	20	10	0	180	30	0	26
Wheel 2	Z	20	10	0	180	-30	0	26
Wheel 3	Z	20	10	0	180	30	0	-26
Wheel 4	Z	20	10	0	180	-30	0	-26

Cylinders:

Name	Dimension					Position		
	Axis	Radius	Intial <	Final <	Depth	X	Y	Z
Front	Z	20	0	90	52	30	0	0
Back	Z	20	90	180	52	-30	0	0

Now lets finish the car. The figures that follow illustrate the creation of the final elements of the car.





The tires are created by inserting cylinders made of a black rubber material with a pair of disks to cover the ends.

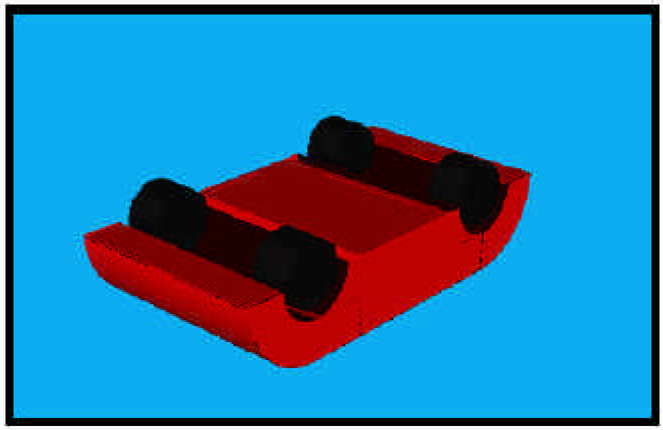
Wheel Cylinders:

Name	Dimension			Position		
	Axis	Radius	Length	X	Y	Z
Wheel 1	Z	8	10	30	0	20
Wheel 2	Z	8	10	-30	0	20
Wheel 3	Z	8	10	30	0	-20
Wheel 4	Z	8	10	-30	0	-20

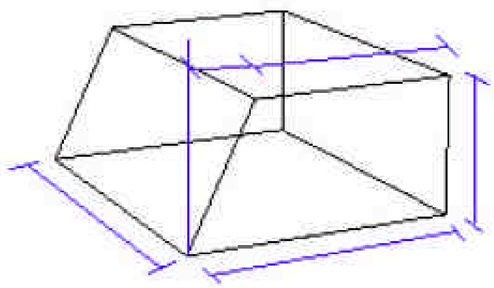
Wheel Disks:

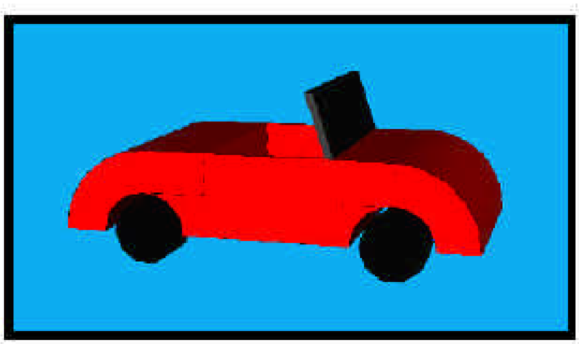
Name	Dimension		Position		
	Axis	Radius	X	Y	Z
Wheel 1 Ext.	Z	8	30	0	25
Wheel 1 Int.	Z	8	30	0	15
Wheel 2 Ext.	Z	8	-30	0	25
Wheel 2 Int.	Z	8	-30	0	15
Wheel 3 Ext.	Z	8	30	0	-25
Wheel 3 Int.	Z	8	30	0	-15
Wheel 4 Ext.	Z	8	-30	0	-25
Wheel 4 Int.	Z	8	-30	0	-15

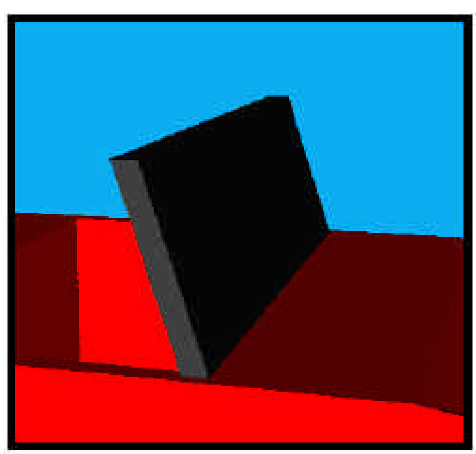
Create some covers under the car so it can look completely sealed.



The windshield consists of a wedge. To construct it, it is necessary to specify a direction of extrusion, a height, the top and bottom lengths and the distance of deviation in such a way that you obtain a figure like this:







You can see that this type of figure must be used for the windshield. The top and bottom lengths are equal and small with a deviation to the right. The following are the specifications:

Name	Dimension						Position		
	Axis	Height	Bot. L	Top L	Difference	Depth	X	Y	Z
Windshield	Z	15	2	2	5	50	-15	27.5	0

Now, only the front lights are needed. These consist of two yellow cylinders. These are the specifications:

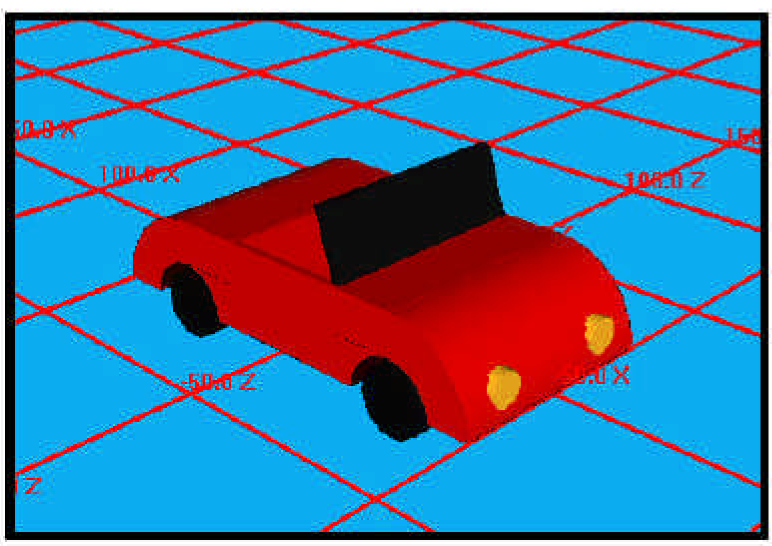
Cylinders

Name	Dimension			Position		
	Axis	Radius	Depth	X	Y	Z
Light 1	X	4	5	-47.5	7	15
Light 2	X	4	5	-47.5	7	-15

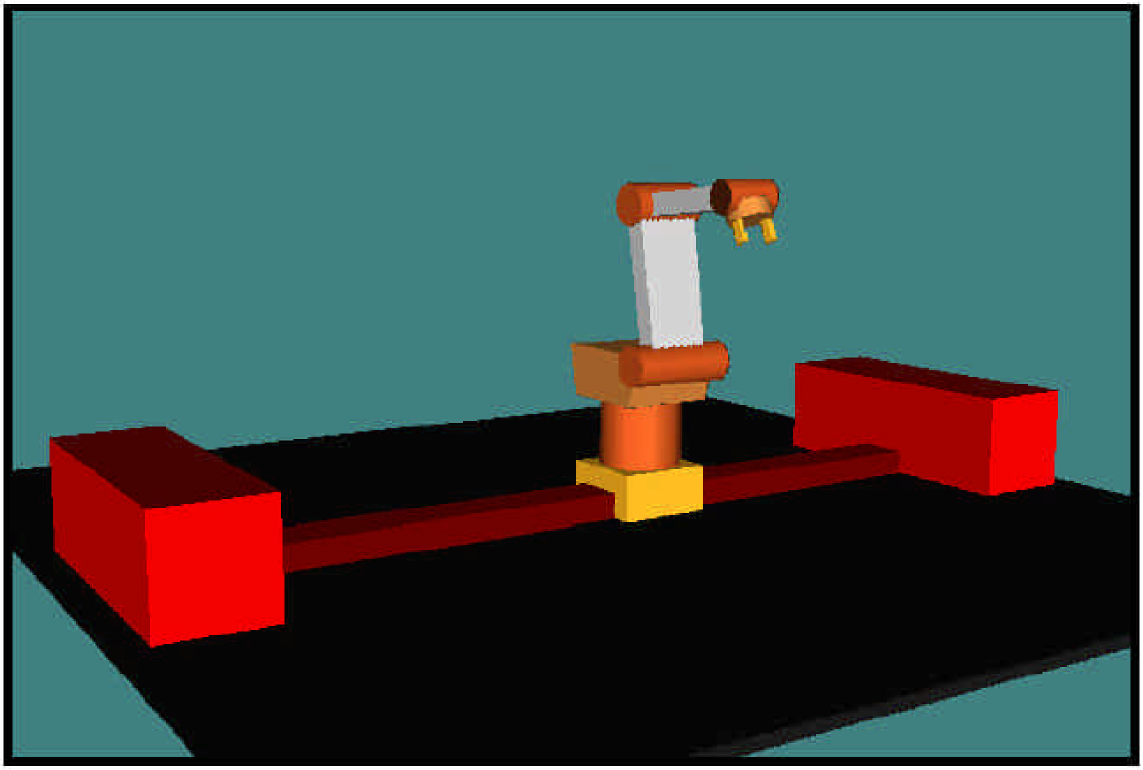
Disks

Name	Dimension		Position		
	Axis	Radius	X	Y	Z
Light 1	X	4	-50	7	15
Light 2	X	4	-50	7	-15

The car is now finished. As an exercise, add seats and mirrors.



Five Degree of Freedom Robot



Here you can see a five degree-of-freedom (DOF) robot that can displace along a belt so it can move objects from one red table to the other. The objective of this exercise is to simulate the movement of the robot with a .dat file. You should create a robot that displaces along the Z-axis, rotates about the Y-axis (the base), and three other rotations. You should also include a gripper that looks like a pair of pliers, with each having independent movement. It should also be able to rotate about its axis of symmetry. The gripper then adds 3 DOF, but two of these DOF will not affect the inverse kinematic calculations.

You should now be able to model the robot so we will concentrate on the animation.

The elements without animation are simple. The tables, the ground and the belt consist of cubes that are adequately sized for the robot. The robot is the most important element that contains the entire animation. To make the robot's movements independent from all the other elements, place a Start Transformation at the beginning of the robot model and at the end place a Stop Transformation.

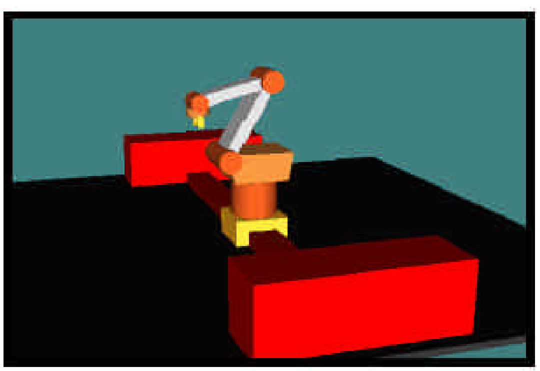
The first joint will be called the Base, the second Rotator and the third, fourth and fifth joints will be called Axis 1, 2 and 3, respectively. The rotational joint of the gripper will be Base 2 and the displacements of the fingers will be called Gripper 1 and 2.

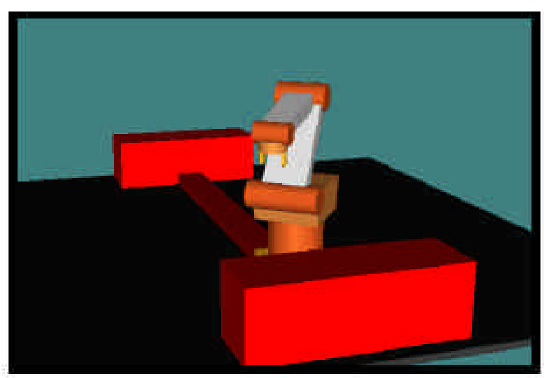
Place a dynamic transformation that allows displacement of the Base in the Z-axis (along the belt). Also, a dynamic transformation allowing rotation of the Rotator joint about the Y-axis is needed. Finally, Axis 1, 2 and 3 should rotate about the Z-axis (in the zero position). After the Rotator joint is modeled, a static displacement is needed to move the coordinate frame to the location of Axis 1 joint. After drawing Axis 1 joint and the link, insert another static displacement to again move the coordinate to the location of Axis 2 joint. Follow this process until you reach Axis 3. Next, to create the gripper you should insert the fingers between a Start and Stop Transformation. This is needed because although the fingers position should depend on the potion of the rest of the robot, each finger's position should be independent of the position of the other. However, you can give them the same tag name, with one having the negative value of the other. This way you synchronize the motion of the gripper.

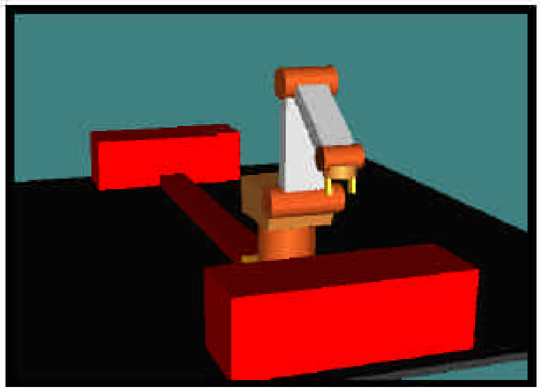
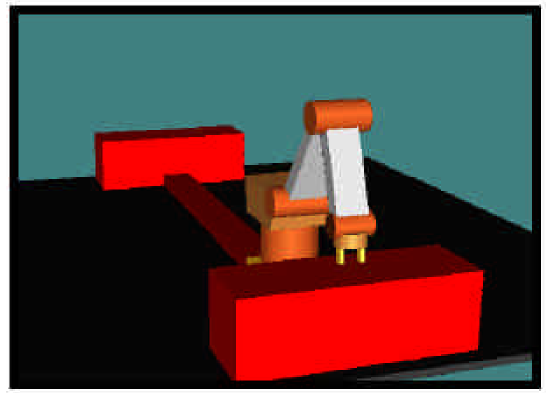
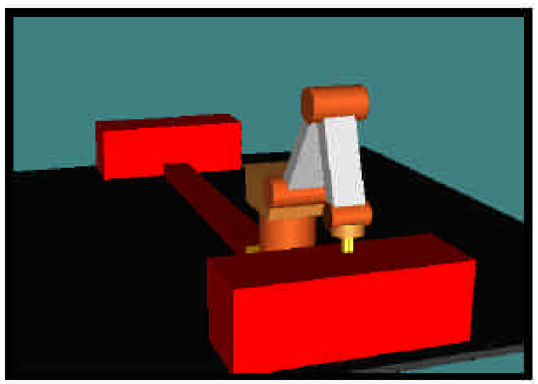
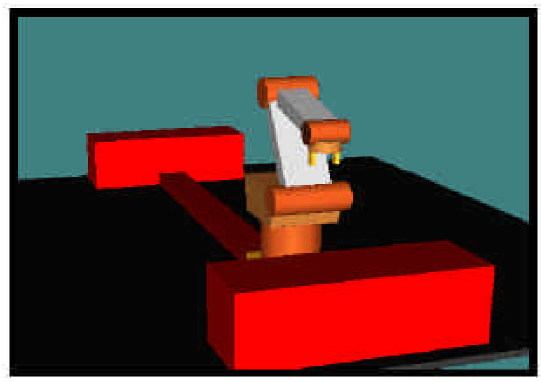
Now generate the .dat file for your animation. The following is part of a .dat file of an animation. Remember that the dimensions used to generate the numbers below are probably not the same as yours so it is better to generate your own animation file.

Base	Rotator	Axis1	Axis2	Axis3	Base2	Gripper2	Gripper1
5.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
10.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
15.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
20.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
25.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0

30.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
35.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
40.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
45.0	0.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	5.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	10.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	15.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	20.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	25.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	30.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	35.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	40.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	45.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	50.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	55.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	60.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	65.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	70.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	75.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	80.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	85.0	-30.0	135.0	80.0	0.0	0.0	0.0
50.0	90.0	-25.0	130.0	75.0	0.0	0.0	0.0
50.0	90.0	-20.0	125.0	70.0	0.0	0.0	0.0
50.0	90.0	-15.0	125.0	65.0	0.0	0.0	0.0
50.0	90.0	-10.0	125.0	60.0	0.0	0.0	0.0
50.0	90.0	-5.0	125.0	55.0	0.0	0.0	0.0
50.0	90.0	0.0	125.0	50.0	0.0	0.0	0.0
50.0	90.0	5.0	125.0	45.0	0.0	0.0	0.0
50.0	90.0	10.0	125.0	40.0	0.0	0.0	0.0
50.0	90.0	15.0	125.0	35.0	0.0	0.0	0.0
50.0	90.0	20.0	125.0	30.0	0.0	0.0	0.0
50.0	90.0	25.0	125.0	25.0	0.0	0.0	0.0
50.0	90.0	30.0	125.0	20.0	0.0	0.0	0.0
50.0	90.0	35.0	125.0	15.0	0.0	0.0	0.0





The RoboWorks Manual ends with this exercise. You should now be an expert with RoboWorks, now enjoy its many applications.