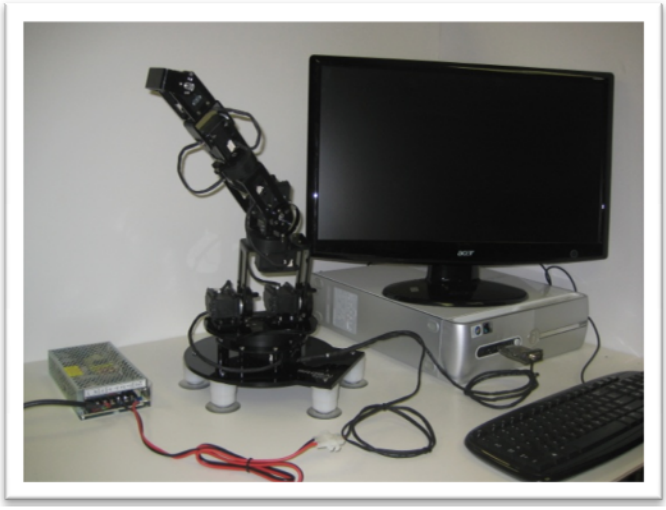
Cyton

User's Manual



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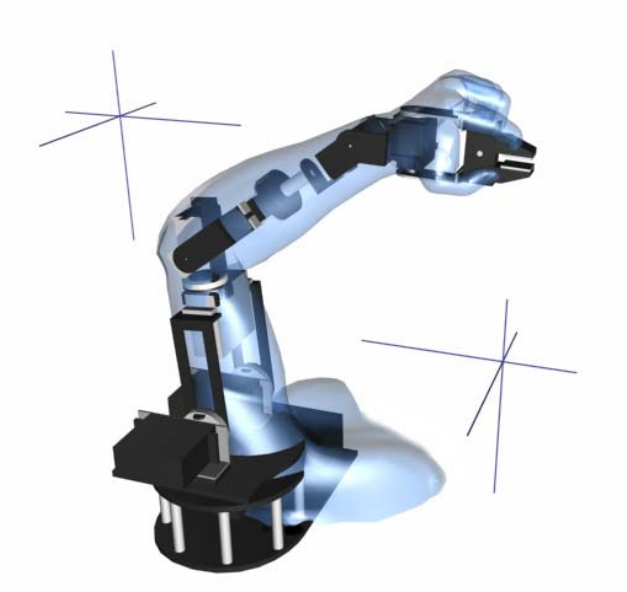
Introduction

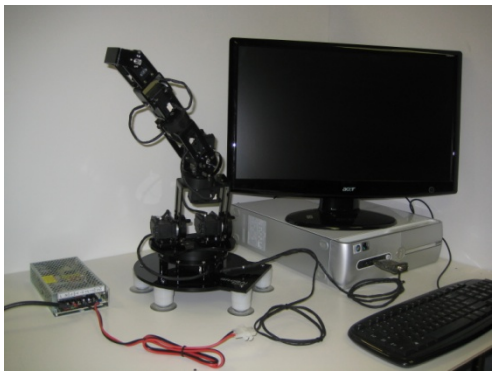
The Cyton is a seven degree of freedom manipulator arm with a gripper end effector. Humanoid manipulators offer profound advantages. With many degrees of freedom they are able to reach around obstacles, reconfigure for strength, improve accuracy, and manipulate objects with fluid motion. Cyton comes with configurable control software that makes it easy to exploit its kinematic redundancy with built-in interfaces to input devices, over the Internet, or using your own programs such as a USB joystick plugin. This software controls the Cyton arm in real time based on desired behaviors that are configured off line.



Combined with Actin SE visualization, reasoning, and control software, the Cyton performs advanced control by exploiting kinematic redundancy. With built-in networking software, it can be controlled remotely through a local area network or over the Internet.

Mechanical Structure:

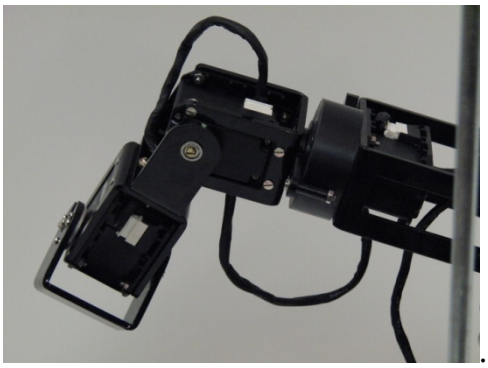
The Cyton provides robust, powerful, and intelligent manipulation for various applications. The V2 extends the capabilities of the Alpha is several ways.

Intelligent Actuators
The high performance, intelligent actuators give feedback and data values on position, speed, voltage, and temperature via the Cyton Control GUI.

USB Interface
The arm can be controlled through a USB 2.0 interface to a PC. Data transfer rates from the USB port to the arm are rated up to 1Mbps.

Training Mode
The arm can be put into a zero torque record mode allowing developers to script desired paths. End users can manually grab and move the gripper and record the paths for playback.




Cyton Wrist Yaw: Various Positions
(Cyton V2 without gripper shown)

Specifications:
Cyton Axes Range

- Shoulder base 300 degrees
- Shoulder Pitch 180 degrees
- Shoulder Yaw 300 degrees
- Elbow Pitch 240 degrees
- Wrist Roll 300 degrees
- Wrist Yaw 200 degrees
- Wrist Pitch 200 degrees

Other Specifications for:

Cyton Veta
- Rated Payload: 300 g
- Maximum Payload: 350 g
- Rated speed: 0.4 m/s
- Joint speed: 75 rpm
- Reach 48 cm
- Repeatability: 0.3cm

Cyton V2
- Rated Payload: 1 Kg
- Maximum Payload: 1.0 Kg
- Rated speed: 0.4 m/s
- Joint speed: 75 rpm
- Reach 43.4 cm
- Repeatability: 0.1cm

The Cyton comes with the Actin-SE software allowing it to perform advanced control by exploiting its many degrees of freedom. With available networking software, it can be controlled remotely through a local area network or over the internet.

The high performance servos and advanced kinematics combined with Energid's Actin-SE software give smooth, humanlike motion.

Setup Instructions

Hardware Setup

Components required (supplied in Kit)

- 16V DC power supply[1].
- USB2Dynamixel connector.

Setup Instructions

- Place the Cyton arm on firm level surface and make sure that the arm has at least 60 cm clearance all around it.
- Ensure that the vacuum cups at the bottom of the

[1] Includes a 12 V power supply for Cyton Veta

base of the arm are well engaged with the surface on which it is mounted.

[underside of Cyton]

- Use extension cable provided along with the arm to connect USB2 Dynamixel with the arm. The connector on the cable with power line missing goes into the USB2 Dynamixel.

[USB2 Dynamixel]

- The other connector of the cable is connected to the Cyton arm. While doing the connection at the arm end, make sure that the markings on the connector of the cable and the one fixed on the base of the arm are aligned.
- This cable also has one more branch onto which the DC supply for the arm is given. Once these connections are made, you can plug the USB2Dynamixel into your computer's USB port.

[16 V DC Power supply]

- Now you can power the arm by turning plugging in the DC supply. The LEDs located at the top of the arm's servos should blink once when power is turned ON.

[complete setup]

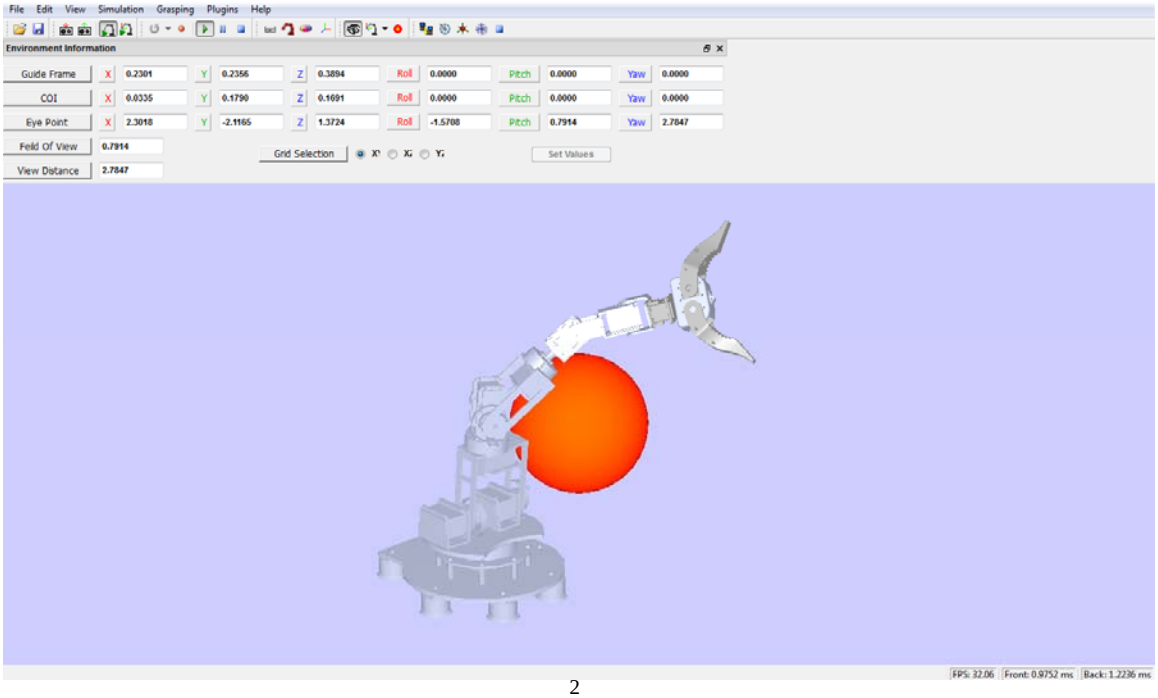
Software Installation

Insert the CD Disk into the CD drive. If the CD does not start automatically you should be able to browse to the CD folder and select cytonSetup.exe. This will start the installation program. Follow the instructions to complete installation.

The Cyton Viewer

Cyton Viewer Capabilities

The Cyton Viewer can be used to both simulate motion of the robot and to directly control the robot. It has several powerful features that allow for end-effector or joint level control the Cyton. The figure below shows the viewer with a Cyton model loaded.



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Changing perspective

- Eyepoint. The eyepoint icon changes the viewer into eyepoint mode. In this mode the eyepoint can be changed by dragging the mouse.

- Center of interest: The center of interest (i.e. the direction where the eyepoint is looking) can be changed by entering COI mode with the COI icon and dragging the mouse.

File Options

Shown are the options available within the file menu. These are described below.

Open
Opens in a Cyton model file. The Cyton viewer currently comes with one file called Cyton.ecz. In addition, new files can be created using the Cyton C++ API.

Save Image As
Save a snapshot of the current robot. Currently .tif is the only supported image format.

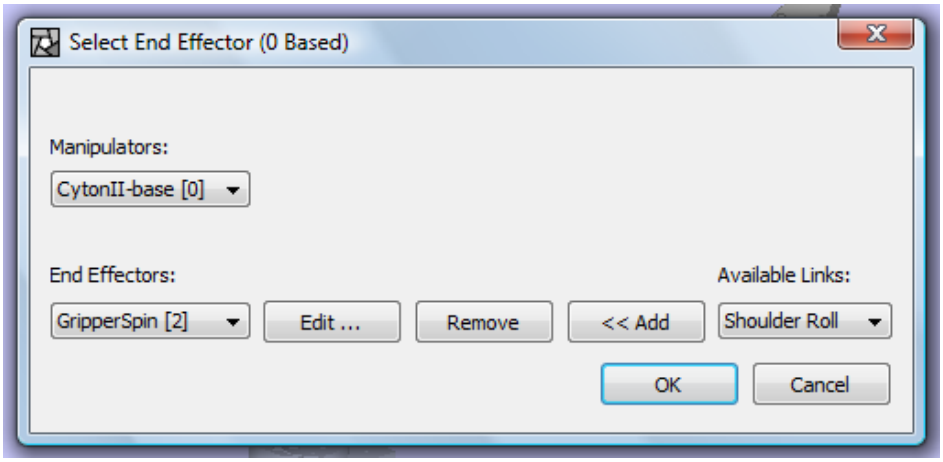
[2] Cyton V2 with custom gripper shown

Flying the Gripper

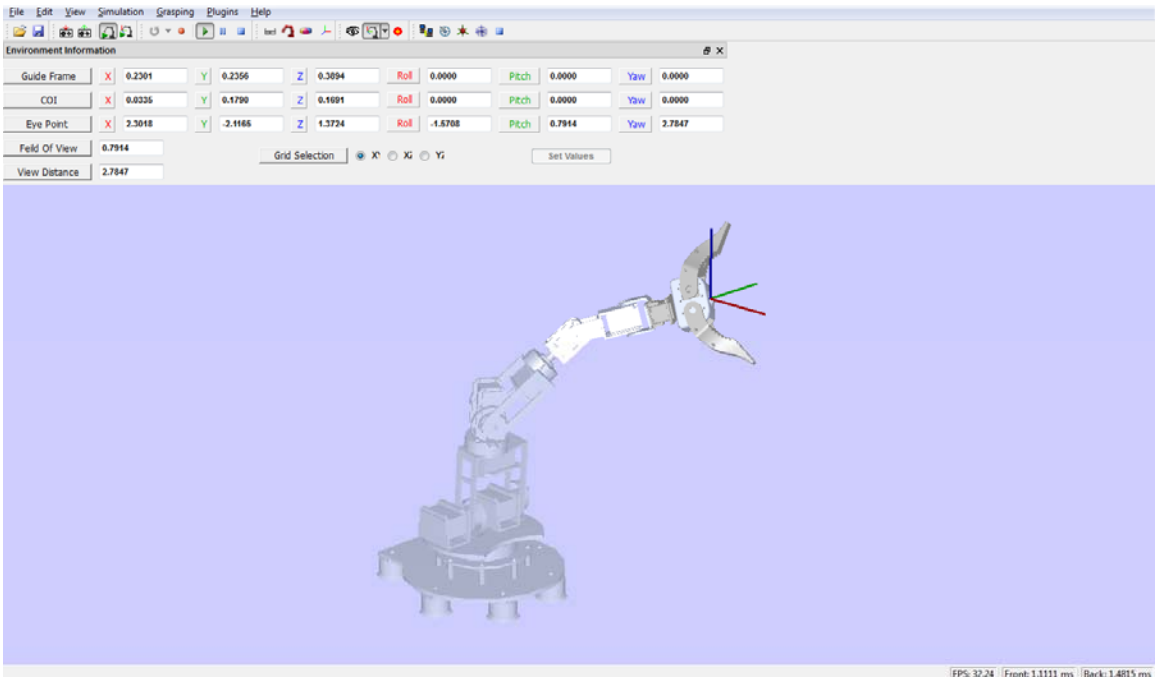
Using the Cyton Viewer, it is possible to command the gripper (or end-effector) to go to an arbitrary position and orientation in space as long as it's within the arms workspace. To do this it's important to calibrate the viewer view with the position of the actual robot.

The Guide Frame

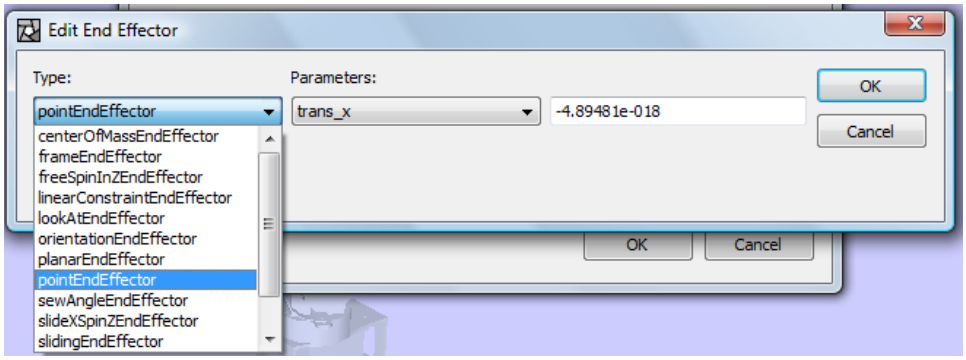
The Guide Frame is what the Cyton Viewer uses to specify the desired gripper position. The figure below shows a Guide Frame (with red, green, and blue axes) just in front of the gripper. You can move the Guide Frame by first selecting the set guide frame button  . This will bring up the following dialog box.



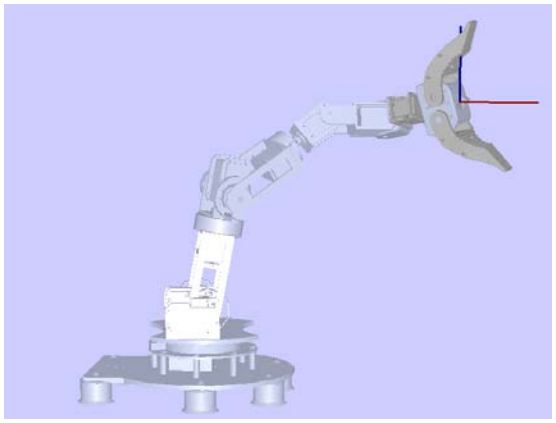
An end-effector can be placed on any link of the robot. By default the end-effector is placed at the gripper. Once the "OK" button is clicked you can move the Guide Frame within the viewer dragging with either the left or right mouse buttons depressed. Holding down the right mouse button will allow you to change the position of the Guide Frame and the left mouse button allows you to rotate the Guide Frame.

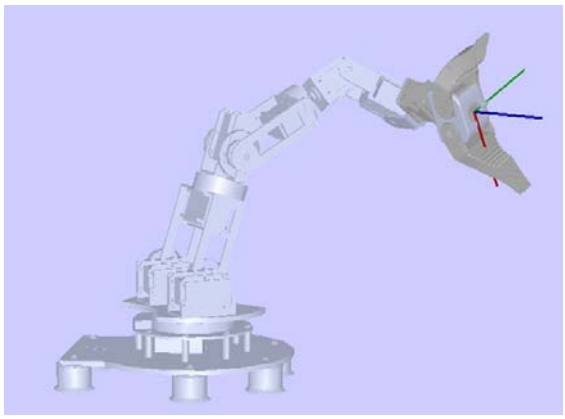


Depending on the type of end-effector selected the gripper will either move to a specific position in space (with a point end-effector) or position and orientation (with a frame end-effector). The type of end-effector can be selected with the drop-down list below under the Edit End-Effector.



The difference between a frame end-effector and a point end-effector can be seen in the images below. Note that with a point end-effector the orientation of the gripper is arbitrary—only the position of the Guide Frame is important). With a frame end-effector (shown on the right) both position and orientation are considered—note that the gripper is aligned along the red axis of the Guide Frame.





Left: The arm moved to the guide frame using a point end-effector (i.e. position only). Right: The arm moved to the guide frame using a frame end-effector (i.e. frame end-effector).

Working with Path Files

The Cyton Viewer allows you to capture paths of the robot for future playback. This is useful for certain applications.

 Recording a Path – Pressing the record button puts the viewer into record mode. When in this mode robot positions will be stored in memory until the stop button is pressed. Positions can be stored in one of two formats: Manipulator (Joint) mode, or Guide Frame mode. In Manipulator mode the viewer records all of the joint angels for the robot at each timestep, whereas in Guide Frame mode only the commanded gripper positions at each timestep are recorded.

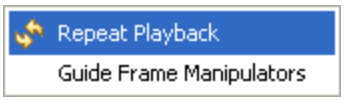
This means that a Guide Frame mode path file may result in different joint positions when rerun depending on the control method being used for the Cyton. For instance, a control system configured to minimize kinetic energy will result in different joint angle trajectories than a control system configured to minimize potential energy.

A path file recorded in Manipulator mode, by contrast, is guaranteed to always give the same joint trajectories. By default the Cyton Viewer records in Manipulator mode. You can enter Guide Frame mode by pressing  and can revert back to Manipulator Mode by pressing  .

 Save Path File – This allows you to save a path just recorded. A Save File dialog box will appear asking for the name and location of the file to be saved.

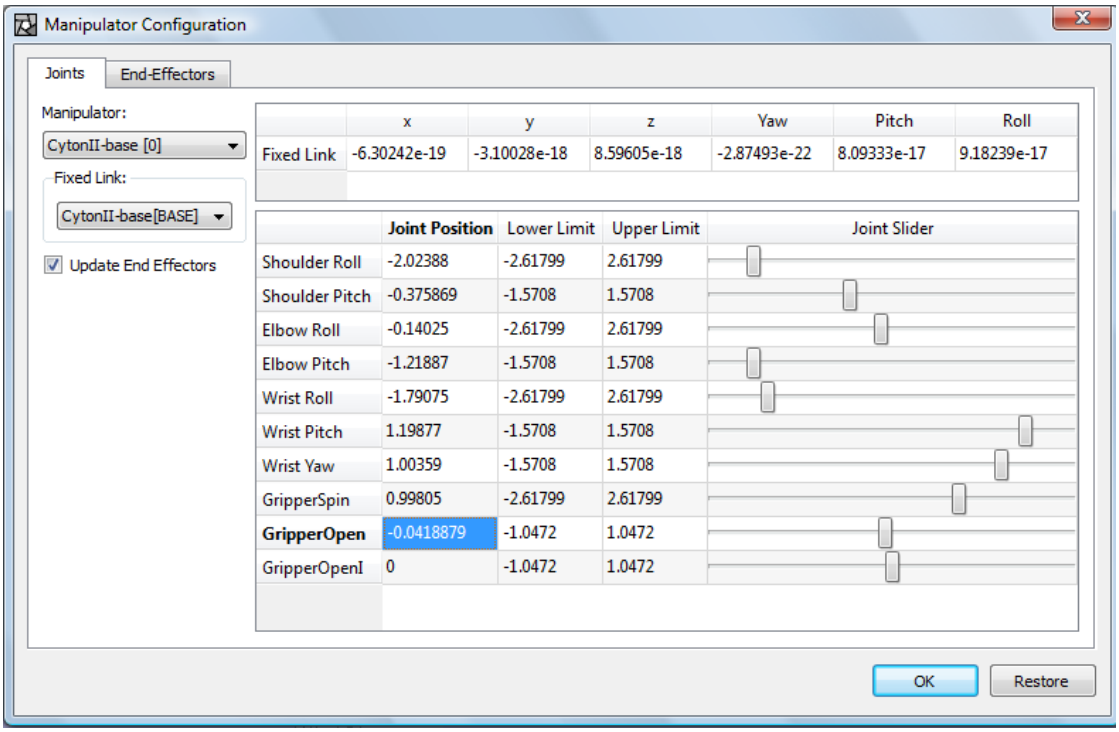
 Load Path File – This allows you to load a previously saved path file. Once loaded, the record mode buttons should automatically change to indicate whether the path is in Guide Frame mode or Manipulator mode.

 Playback Mode – Once a path is loaded it is still necessary to specify that you would like to playback the path. If the playback mode button is pressed hitting the play  button. Opening the dropdown list for the Playback mode button will allow you to select whether or not the playback should be repeated. If in Guide Frame mode the Cyton manipulator should be checked under the Guide Frame Manipulators dialog box—this should be the default.

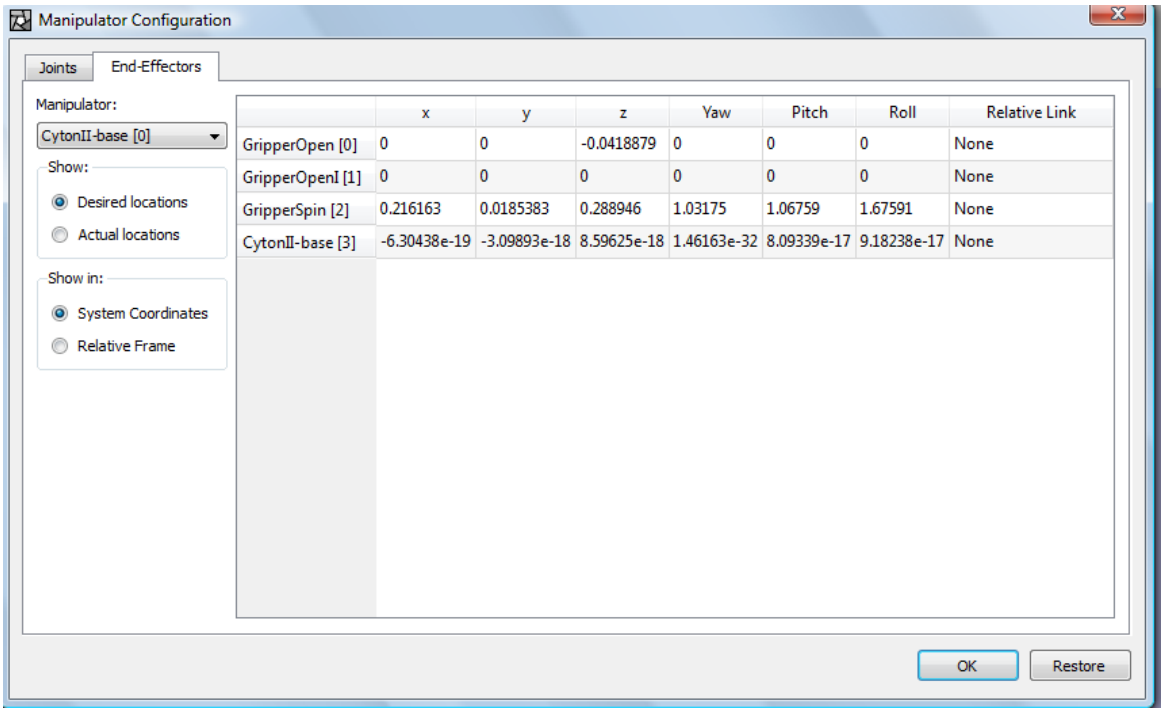


The Manipulator Configuration Tool

 Manipulator Configuration – More precise tasking of the robot can be achieved by using the manipulator configuration tool. This tool allows you to independently move each joint. It also lets you change the joint limits for each joint. Each joint on the robot can be moved using the slider bars on the right. The upper and lower joint limits can be set directly in the edit boxes at the left. The figure below shows the manipulator configuration tool with the Joints tab.



The End-Effectors tab (shown below) allows you to directly control the position and orientation of the end-effector. This is useful when a precision gripper position is required.



The Actin-SE Grasp Sequence Creator

The Grasping Tool Plugin allows the user to create grasp sequences entirely through the CytonViewer without having to write a single line of code. It can be used for rapidly creating and testing grasp sequences. Although the name implies an action of grasping, a grasp sequence that can be generated with this tool is more general and can be thought of as a path script or a collection of waypoints of end-effectors in a path.

Grasping Framework

To fully utilize the tool to create grasp sequences, understanding the concept of grasp sequences is required. A grasp sequence encapsulates a set of commands required to move the robot in the workspace and is subdivided into a number of grasp frames.

Grasp Frames

A grasp frame, which can be thought of as a waypoint in a path, must provide the following information:

1. The set of end-effectors that the frame is responsible for moving.
2. The offsets to assign for position controlling each end-effector.
3. Transition event for signaling the end of the frame.

Grasp Offsets

Grasp offsets help define desired position commands to the end-effectors. Different grasp offset types offer different behaviors. The following types of grasp offsets are currently available.

1. *Constant grasp offset*: This offset defines the end-effector location in the system coordinates and remains constant during the update loop of the grasp.
2. *Frame-relative grasp offset*: This is a grasp offset that is relative to a grasp offset defined in a different frame. This allows a frame to define position commands relative to a previous frame. For example, one may want a hand location in this frame to be 5 cm in the X direction from the previous frame. This CANNOT be used in the first grasp frame for the obvious reason.
3. *Object-relative grasp offset*: This offset defines a grasp offset relative to the primary coordinate system of the desired object to be grasped. If the object moves, the grasp frame will move with the object.
4. *Link-relative grasp offset*: This offset defines a grasp offset relative to the primary frame or the DH frame of a link in the grasp object. It can be thought of as a general case of the object-relative grasp offset.

Note that the object-relative and link-relative grasp offsets are specific to grasping (since they are defined relative to the object to be grasped) while the constant and frame-relative grasp offsets can be used generically to create end-effector paths.

Transition Events

A transition event is an indicator that signals when a grasp frame has completed its requirements. Once a frame is complete, the grasp sequence will transition to the next frame in the sequence. There are currently two types of transition events.

1. *Placement-achieved transition event*: This transition event is triggered when specified end effectors arrive within a specified tolerance of their desired positions. This event triggers a failure when the specified end effectors fail to converge on their desired positions.
2. *Time-duration transition event*: This transition event is triggered when the parent grasp frame has been running for a specified duration of time.

Grasping Tool Plugin

Now that the grasping framework has been laid out, it is time to discuss how the user can use the Grasping Tool Plugin to create grasp sequences. First, the plugin needs to be loaded. If Grasping is not displayed at the top level menu then you will need to manually load the plugin. This can be done via the Plugins => Load Plugin… menu of the CytonViewer. Once the plugin is loaded, the "Grasping" menu item will appear on the menu bar of the viewer. Under the Grasping menu, there are four actions as shown in Figure 1.

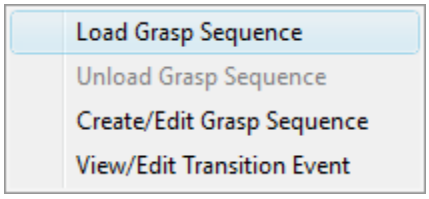


Figure 1: Grasping menu.

Their functions are summarized below.

(1) **Load Grasp Sequence.** This loads a previously created grasp sequence from a file. The loaded grasp sequence can be executed by pressing the Play button on the toolbar or it can be edited.

(2) **Unload Grasp Sequence.** This unloads the loaded grasp sequence so that the CytonViewer returns to its normal simulation, i.e. pressing the Play button will no longer execute the grasp sequence. Note that this item is disabled in Figure 1 since no grasp sequence is currently loaded. It will be enabled whenever a grasp sequence is loaded.

(3) **Create/Edit Grasp Sequence.** Selecting this option will bring up the Grasp Sequence Creation (GSC) tool that allows the user to create a new grasp sequence or edit the loaded grasp sequence. The GSC tool is the main component with which the user will interact and thus it will be discussed in detail later.

(4) **View/Edit Transition Event.** Selecting this option will bring up the Transition Event editor, which allows the user to modify how to transition from one grasp frame to another.

In addition to the Grasping menu, a grasping preference page is added to the Preference Dialog, which can be accessed via Edit =>Preferences… in the menu bar of the CytonViewer. The preference page for Grasping Tool Plugin is shown in Figure 2.

For convenience, the grasping preference page is where the user sets the default type for grasp offsets and the default type for transition events when creating grasp sequences. The user can later change the grasp offset type and transition event of any grasp frame. The process of how to change the grasp offset and transition event will be described later.

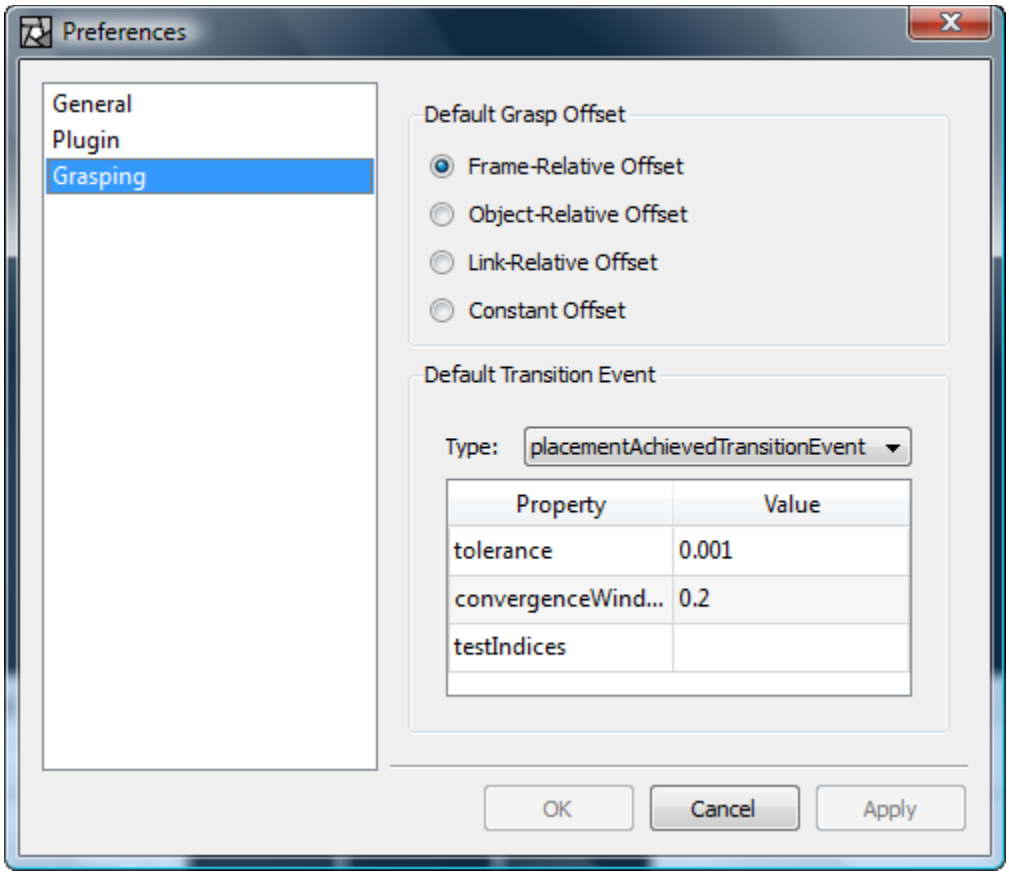


Figure 2: Preference page for grasping tool.

Creating a Grasp Sequence

The primary task of the plugin is to help the user create grasp sequences. To create a grasp sequence, the user must first load a Cyton simulation file. Upon loading the simulation, the user then selects Create/Edit Grasp Sequence from the Grasping menu, which will bring up the Grasp Sequence Creation (GSC) tool. Figure 3 shows the GSC tool, which is a docked window at the bottom of the main window in the CytonViewer. Now it's time to create a grasp sequence.

We start by selecting the grasp manipulator and the grasp object via a context menu. For example, to select the Cyton robot as the grasp manipulator (in Figure 3), the user can right-click on the Cyton robot to display the context menu shown in Figure 4. The user then selects Grasping => Select as Grasp Manipulator. If the user wants to create a grasp sequence for the tennis ball, then one can right-click on the ball and select Grasping => Select as Grasp Object. The names and indices of the grasp manipulator and grasp object are displayed in the top-left part of the GSC tool (see Figure 5). Note that by default, the first and second manipulators in the system will be selected as the grasp manipulator and grasp object, respectively.

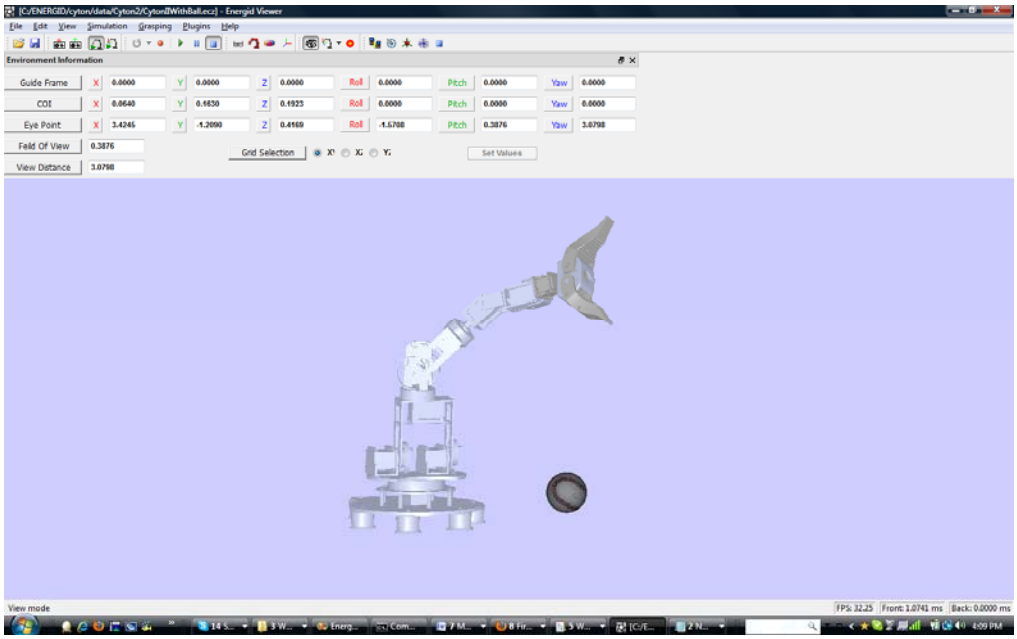


Figure 3: CytonViewer with Grasp Sequence Creation tool.

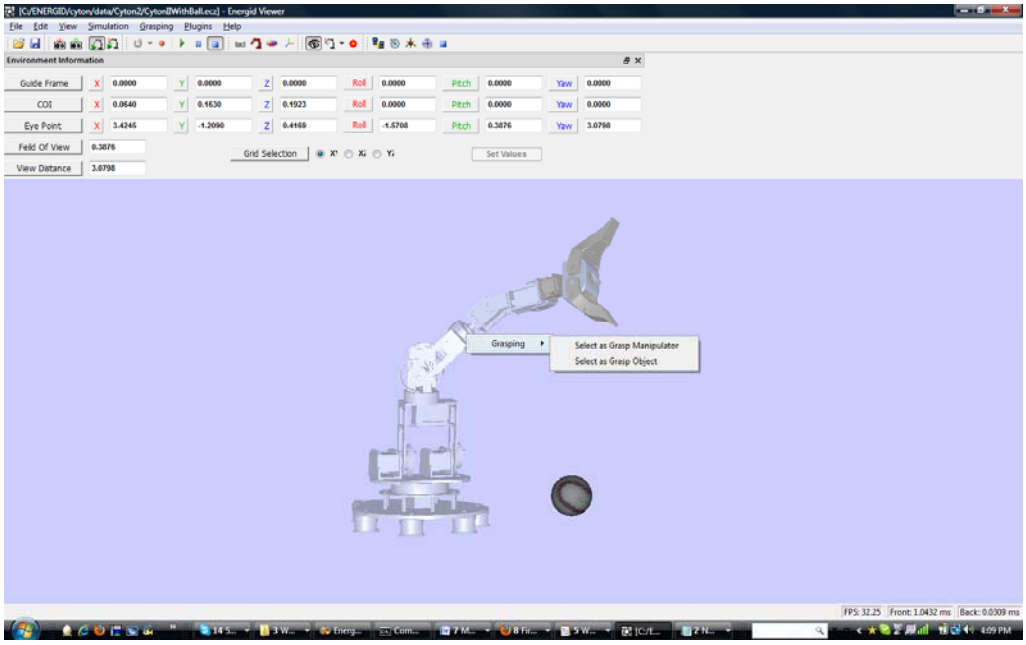


Figure 4: Select the grasp manipulator and grasp object.

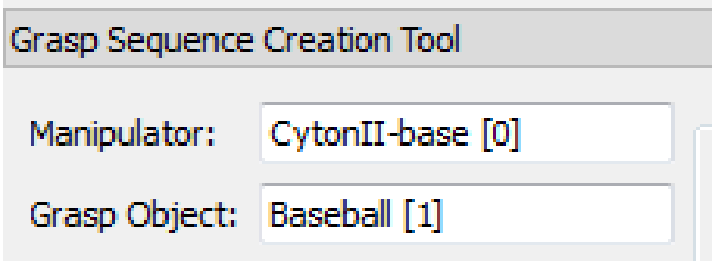


Figure 5: Names and indices of grasp manipulator and grasp object are displayed in the GSC tool.

Once the grasp manipulator and grasp object have been selected, one can start adding grasp frames. For convenience, before adding grasp frames, the user should set the default grasp offset type in the preference page (Figure 2) to the one that best fits the needs. In this example, we select the object-relative grasp offset as the default because we want to define our grasp sequence relative to the ball. Now, move the end-effector(s) of the robot to their desired locations as normally done in CytonViewer. Once the robot is at a desired location, click "Add Frame" button in the GSC tool to add a grasp frame. A grasp frame is then created and added into the grasp sequence. A thumbnail, which is a visual representative of a grasp frame, will be added to the "frame strip" (the right-hand side part) of the GSC tool. The user can repeat this process of adding grasp frames until the grasp sequence is completed.

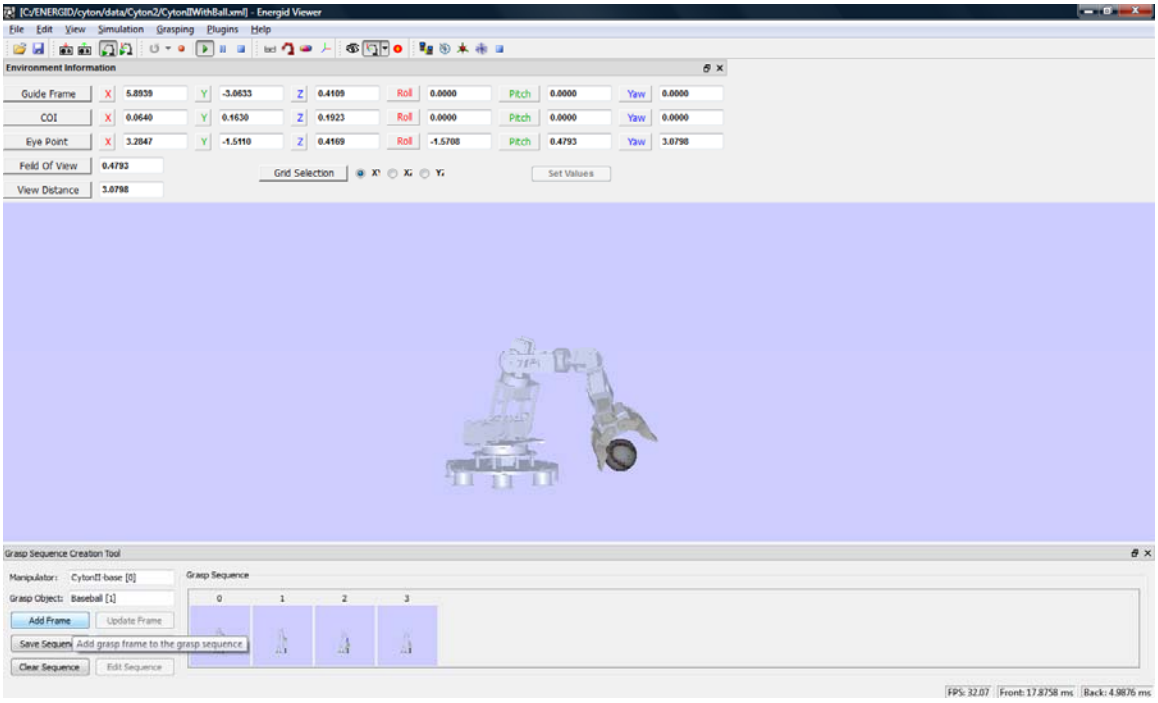


Figure 6: The GSC tool with thumbnails representing grasp frames in the grasp sequence.

Customizing Grasp Frames

Although one can create a grasp sequence by simply moving the robot and adding frames, the grasp frames in the sequence will possess the default properties. If those

default values are not appropriate for the task at hand, one can customize each of the grasp frames in the sequence to meet the needs.

Double-clicking on a thumbnail in the grasp sequence frame strip will bring the Grasp Frame Editor that displays the details of that grasp frame. A grasp frame consists of a set of end-effectors of the robot, each of which has its own grasp offset. The end-effectors table shows the details of each of the end-effectors, including its type, whether the end-effector is relative to another link, and if so which link it is relative to, and the type of the grasp offset associated with that end-effector.

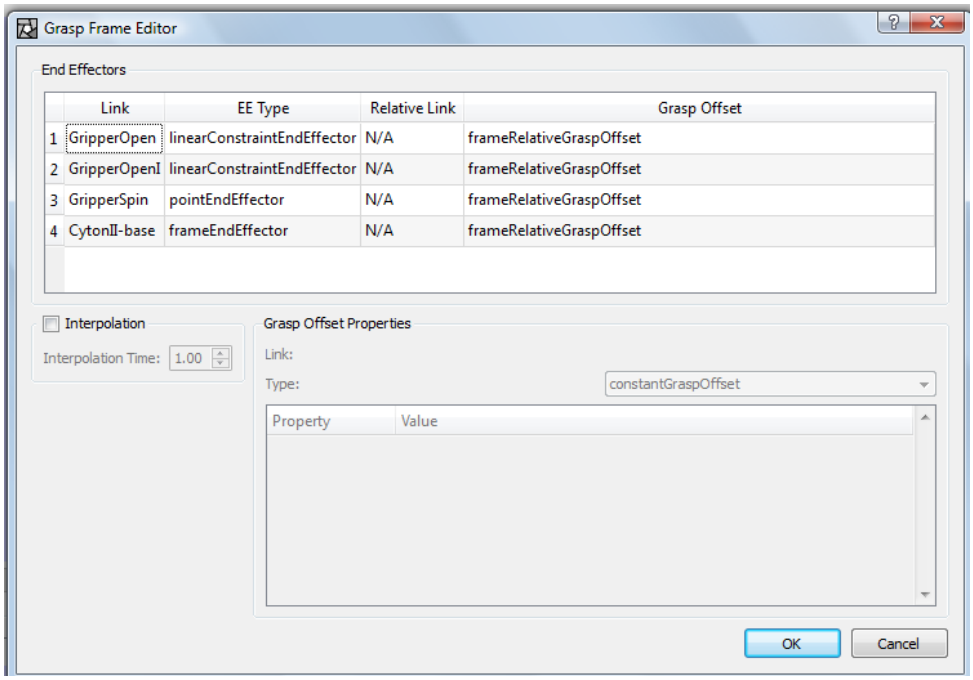


Figure 7: Grasp Frame Editor.

The user can click on any row to view or edit the details of the grasp offset. The user can change the grasp offset type by selecting the type from the combo box. Note the following restrictions:

1. If the system has only one manipulator (i.e. there is no grasp object), then object-relative and link-relative grasp offsets are not allowed.
2. If the end-effector is relative to another link, then it cannot have an object-relative or link-relative grasp offset.
3. Some end-effector types, such as linear-constraint or planar, cannot have an object-relative or link-relative grasp offset.
4. If the grasp frame is the first grasp frame in the sequence, all end-effectors cannot have frame-relative grasp offsets.

These restrictions are enforced in the combo box by the fact that incompatible grasp offset types are grayed out and cannot be selected. For example, let's assume that we are editing the first grasp frame. If the user tries to change the grasp offset type of the second end-effector, one cannot do that since the end-effector is a linear-constraint end-effector

(so it cannot have an object-relative or link-relative grasp offset) and this is the first grasp frame (so it cannot have a frame-relative grasp offset).

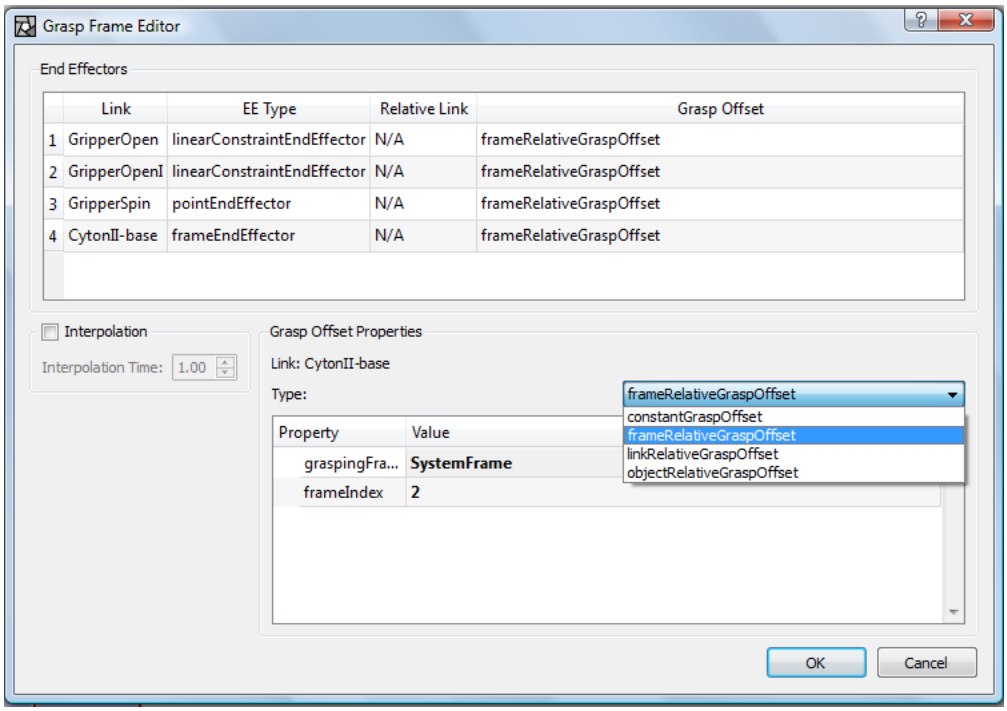


Figure 8: Incompatible grasp offset types are grayed out in the Type combo box and cannot be selected.

The user can also select the minimum time at which this grasp frame will take to execute (measured from the end of the previous grasp frame) by checking the Interpolation check box and change the value in the Interpolation Time (Note that if the Interpolation check box is unchecked, the Interpolation Time is disabled). This will effectively generate a linearly interpolated path from the previous grasp frame to this grasp frame using the interpolation time. This can be quite useful if the user wants to slow down the grasp execution, for example, to gently grasp a brittle object like an egg.

Customizing Grasp Offsets

Due to its simplicity, the constant grasp offset has no property to customize. For the relative grasp offset types, the grasping frame can be set relative to an object, a link, or a previous grasp frame. For object-relative or link-relative grasp offsets, the grasping frame can also be represented in the system frame, the object frame, or any valid combination of the two frames. For frame-relative grasp offsets, the grasping frame must be represented in either the system frame or the previous end-effector frame.

Object-Relative Grasp Offset

The Grasp Offset Properties group in the bottom-right corner of Figure 7 shows the properties of the selected object-relative grasp offset (the following descriptions also apply to link-relative grasp offsets). Here, the user can select the system or object frame as the grasping frame by clicking the check box in the right column next to

systemFrameAsGraspingFrame or objectFrameAsGraspingFrame, respectively. Note that if either the system or object frame is selected, the next few rows in the table are disabled. If the user wants to custom-define the grasping frame, then he needs to uncheck both systemFrameAsGraspingFrame and objectFrameAsGraspingFrame check boxes. This will enable the next six rows in the table and allows the user to define the X, Y, and Z axes of the grasping frame as depicted in Figure 9.

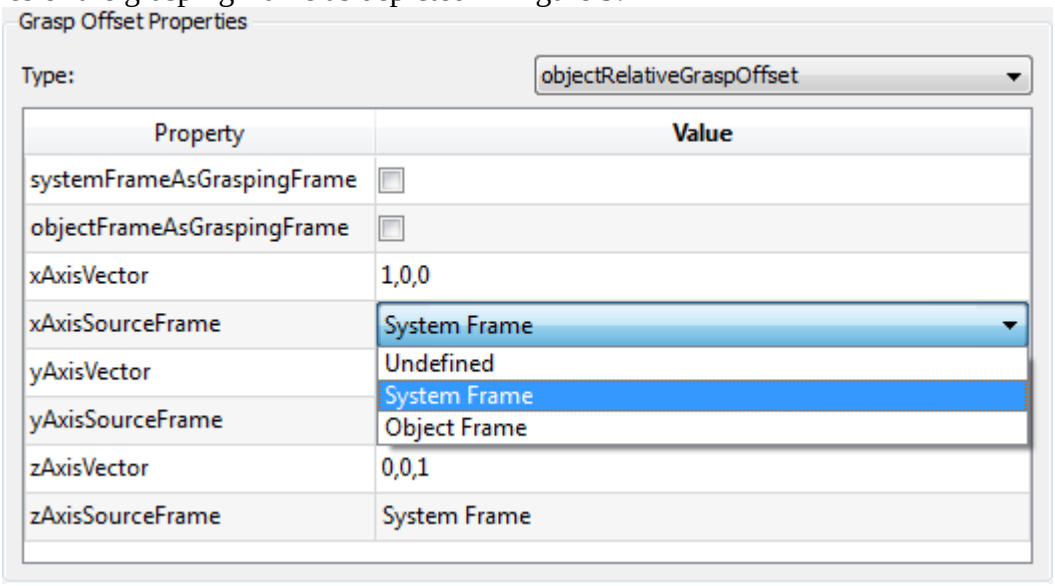


Figure 9: Object-relative grasp offset.

In this case, the user can use any combination of the system frame and object frame to define the grasping frame but the user is responsible for defining a valid grasping frame. For each axis (X, Y, or Z), the user can define the numerical value of the axis by editing the vector using the comma-separated notation and define in which frame (undefined, system frame, or object frame) this axis is represented with the drop down box. For example, if the X axis vector is defined as 0.5, 0.5, 0 and the X axis source frame is System Frame, that means the X axis of the grasping frame is rotated 45 degrees about the Z axis of the system frame.

Although the user is responsible for defining a valid grasping frame, the plugin does check for validity of the user-defined grasping frame. If it determines that the grasping frame is invalid, a warning message box is displayed whenever the user tries to move on to edit another grasp offset or when the user clicks OK. Figure 10 shows a couple of examples of these warning messages.

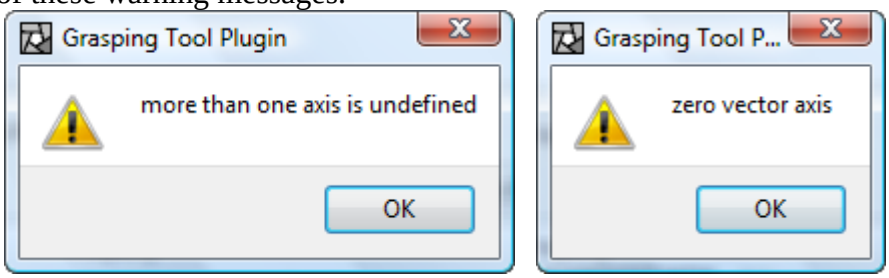


Figure 10: Examples of warning messages for invalid grasping frame.

Link-Relative Grasp Offset

The link-relative grasp offset can be customized the same way as the object-relative grasp offset. The only two additional properties are linkFrameType and linkIdentifier as depicted in the last two rows of the table in Figure 11. For linkFrameType, the user can select either 'Primary Frame' or 'DH Frame' from the drop-down box to indicate which frame of the link to be used as the reference frame. The user can also select which link of the grasp object (in case the grasp object is articulated) to be the reference link using the drop-down box on the right side of linkIdentifier.

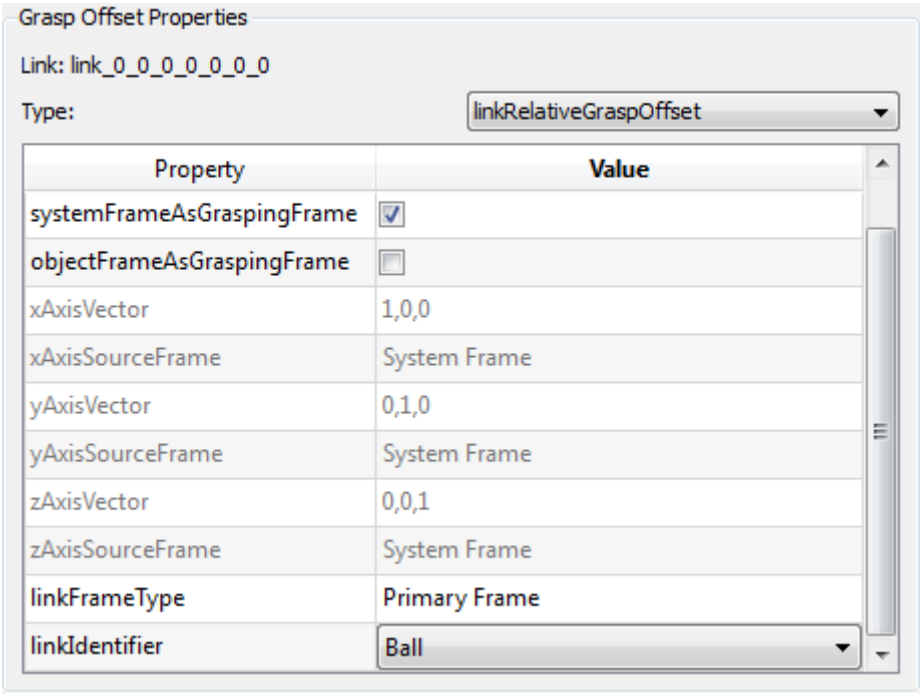


Figure 11: Link-relative grasp offset.

Frame-Relative Grasp Offset

For frame-relative grasp offsets, custom-defined grasping frames are not supported. The user has only two options: either use the system frame or the end-effector frame in the previous grasp frame as the grasping frame. The GUI is therefore simpler than that of object- or link-relative grasp offsets. The user can choose the index of the grasp frame to which this grasp frame is relative by changing the value of frameIndex. FrameIndex must be less than the current grasp frameIndex. For example, if the current grasp frame index is 5 (i.e. this is the sixth grasp frame in the sequence), then frameIndex must be between 0-4.

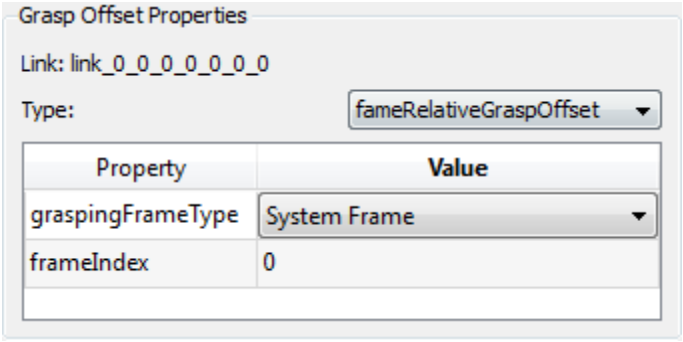


Figure 12: Frame-relative grasp offset.

Customizing Transition Events

Another way to customize a grasp frame is to change its transition event. The Transition Event editor can be accessed via the Grasping => View/Edit Transition Event menu. When a thumbnail in the frame strip is clicked, the transition event editor will show the properties of the transition event associated with that particular grasp frame. The user can then edit the transition event by directly changing the values of the transition event properties.

Placement-Achieved Transition Event

The placement achieved transition event checks to see if end effectors of a particular grasp frame have converged on their desired placement. Figure 13 shows the transition event editor for the placement achieved transition event. There are several variables that allow for customizing this event: tolerance, convergence window, and test indices.

Test indices are used to specify which end-effectors should be tested for convergence. This is a comma-separated list of indices. If test indices are not specified (blank), then all end effectors of the corresponding grasp frame will be tested for convergence. In the figure, the indices 0 and 1 are specified. This means that only the first two end effectors will be tested for convergence. It is important to note that "soft constraint" end effectors will be skipped when testing for convergence.

During each update of the event, each hard constraint end-effector included in test indices will be compared to its desired placement and a delta value will be computed. This delta value depends on the end-effector type. For instance, a point end-effector delta value is calculated as the distance between the current point and the desired point. A frame end-effector must include orientation and position differences in the calculated delta value. When the delta value is less than the specified tolerance value (0.001 in the figure), the end-effector has sufficiently converged on its desired placement. When all of the end effectors have converged within the specified tolerance, the placement achieved transition event is triggered. If the event is not triggered, all of the delta values are summed into a single "convergence value". This convergence value is tested against previous convergence values in order to determine if overall progress is being made in achieving the desired placement. The convergence value should always get smaller if progress is being made on the grasp. If the convergence value increases, a convergence window timer is started. If the convergence value does not get smaller within the

specified convergence window time frame (5 seconds in the figure), then the event fails, and the grasp is halted.

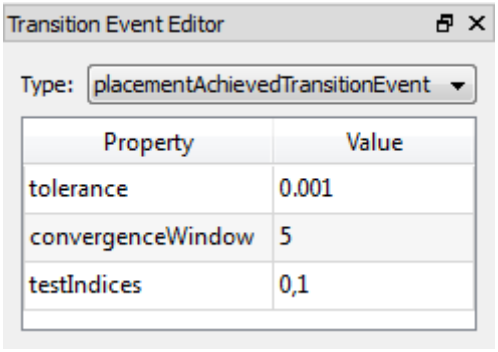


Figure 13: Placement-achieved transition event.

Time-Duration Transition Event

The time duration transition event checks to see if a specified period of time has passed since the current grasp frame has started. Figure 14 shows the transition event editor properties for the time duration transition event. This event only has one variable for customization and time duration. In the figure below, the time duration is set to 3 seconds; therefore, the corresponding grasp frame will run for 3 seconds prior to transitioning to the next grasp frame.

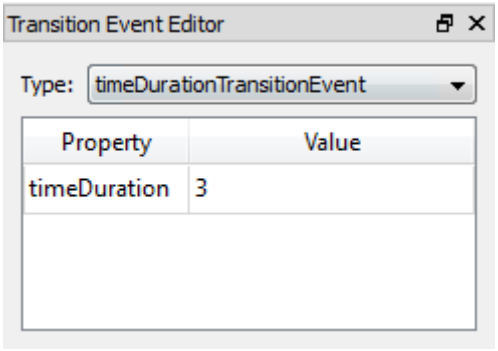


Figure 14: Time-duration transition event.

Updating and Deleting Grasp Frames

After a grasp frame has been added, the user may wish to change the end-effector locations of the grasp frames. This can be done via the process of updating a grasp frame. To update a grasp frame, the user must first click on the thumbnail of the grasp frame to be update. The thumbnail will be highlighted by a red border (see Figure 15) and the robot in the main window will move to location specified in that grasp frame. The user can then move the robot to a new desired location. Once satisfied with the new location, click the Update Frame button to save the new location for this grasp frame. Care must be taken when updating a grasp frame if any of the following frames contains frame-relative grasp offsets that reference this frame.

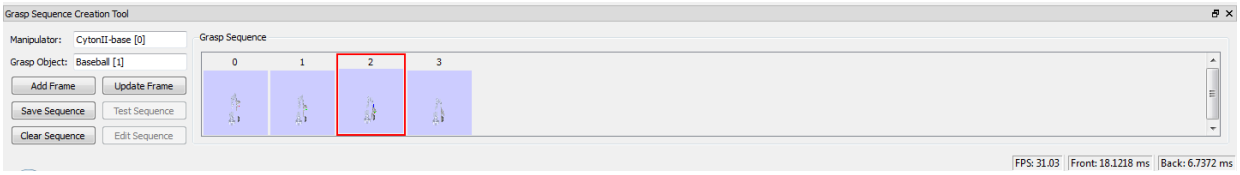


Figure 15: The selected grasp frame is highlighted by the red border.

The user may also delete a grasp frame from the grasp sequence by right-clicking on the desired frame and select Delete Frame from the context menu as shown in Figure 16. Note that currently only the last frame in the sequence can be deleted.

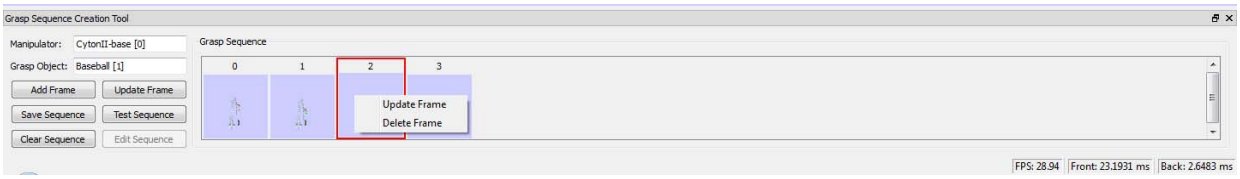


Figure 16: Context menu to update or delete a grasp frame.

Managing a Grasp Sequence

Once the grasp sequence is created, the user can save the grasp sequence to a file for later execution and modification using the Save Sequence button on the left part of the GSC tool. If the user wishes to start over with the grasp sequence creation process, he can remove all the grasp frames in the grasp sequence by clicking the Clear Sequence button.

Executing a Grasp Sequence

The user can execute a grasp sequence in two ways. He can either execute or test the grasp sequence he has just created (but not saved) with the GSC tool or execute a grasp sequence previously saved to file. For the former, the user only needs to press the Test Sequence button on the left part of the GSC tool. For the latter, the user can load a grasp sequence by selecting Grasping => Load Grasp Sequence from the menu. In either case, after pressing the Test Sequence button or loading a sequence, the CytonViewer will enter a grasp execution mode. In this mode, when the Play button is clicked, the grasp sequence will be executed. The user can pause the execution by pressing the Pause button or stop the execution by clicking the Stop button. Once the execution is stopped, it can be restarted by clicking the Play button again. At the end of the grasp sequence, the user can interact with the simulation as if CytonViewer were not in the grasp execution mode. The user can exit the grasp execution mode and returns to the normal operation of CytonViewer by selecting the Unload Grasp Sequence from the menu.

Editing a Grasp Sequence

After a grasp sequence has been created and saved to a file, it is often useful to be able to edit the grasp sequence, perhaps to make minor adjustments to some of the frames. To do this, the user must first load a saved grasp sequence, select Grasping => Create/Edit Grasp Sequence from the menu, and then click the 'Edit Sequence' button in the GSC tool. This will cause the GSC tool to populate the grasp sequence frame strip with the

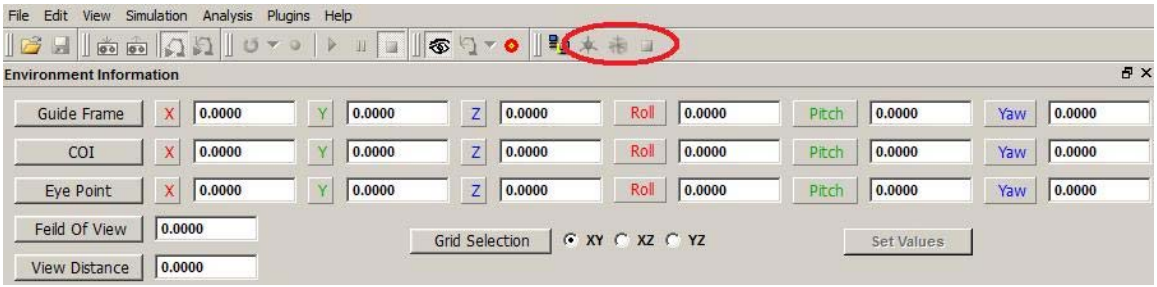
grasp frames from the loaded sequence. The sequence and its grasp frames are then ready to be edited. The user should refer to Customizing Grasp Frames and Updating Grasp Frames sections for ways to edit grasp frames.

When a grasp sequence is loaded, the CytonViewer is entered into the grasp execution mode (as previously explained). The user may need to 'unload' the grasp sequence (via Grasping => Unload Grasp Sequence) after he clicks the Edit Sequence button if he plans to change end-effector locations in some of the grasp frames. Unloading the grasp sequence will cause CytonViewer to go back to the normal mode, which allows the user to use the mouse to move the robot.

I. How to use the Environment Info Plugin

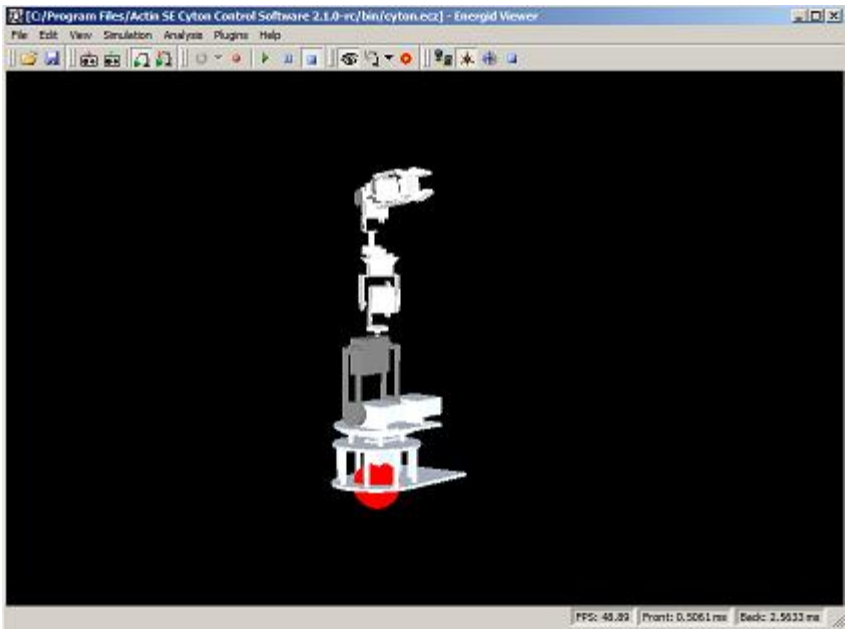
EnvironmentInfoPlugin gives a user an idea of the environment inside the Cyton Viewer. It displays to the user the origin and XYZ-planes. It also gives the user information of the visualization parameters like Eye point, Center of interest, field of viewer and view distance. It also provides the user with information about the location of guide frame in the environment. The plugin also helps a user to set Eye point, Center of Interest and guide frame location.

Once the plugin is loaded into the viewer, you will have 3 new buttons in the toolbar and new tab called **Environment Information**.



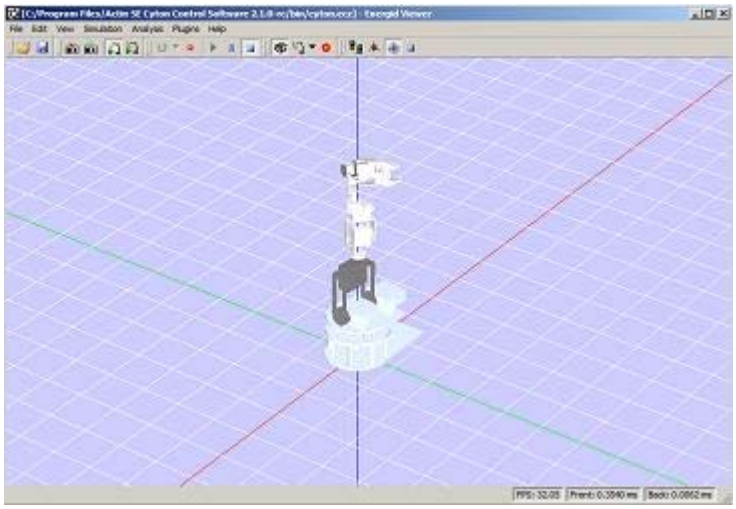
In the **Environment Information** tab, the location of the Guide Frame, Center Of Interest(COI), Eye Point, Field of View and View Distance are displayed. The 3 new buttons on the viewer as part of environment info plugin are **Show Origin** , **Show Axis** and **Set Values** . These buttons will be enabled only after model is loaded into the viewer.

When **Show Origin** button is clicked, it will display the location of origin(0,0,0) in the viewer environment. The origin is displayed as a red ball.

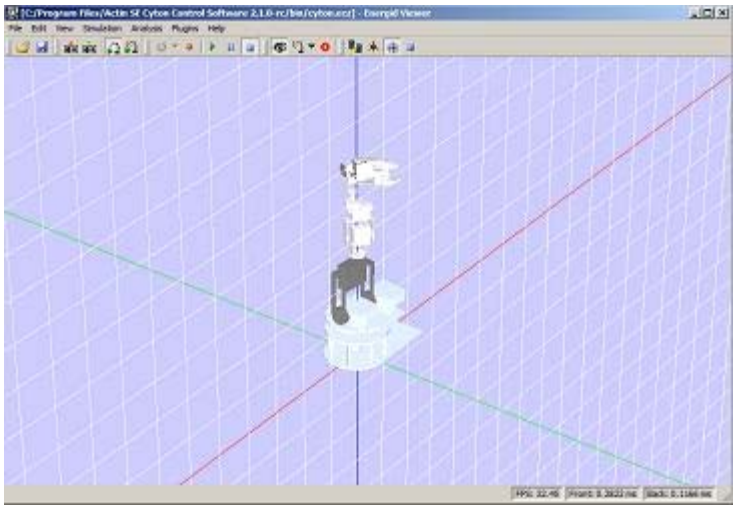


When **Show Axis** button is clicked, it will display the XY grid by default. To display the required grid you will have to change the selection in **Grid Selection** 

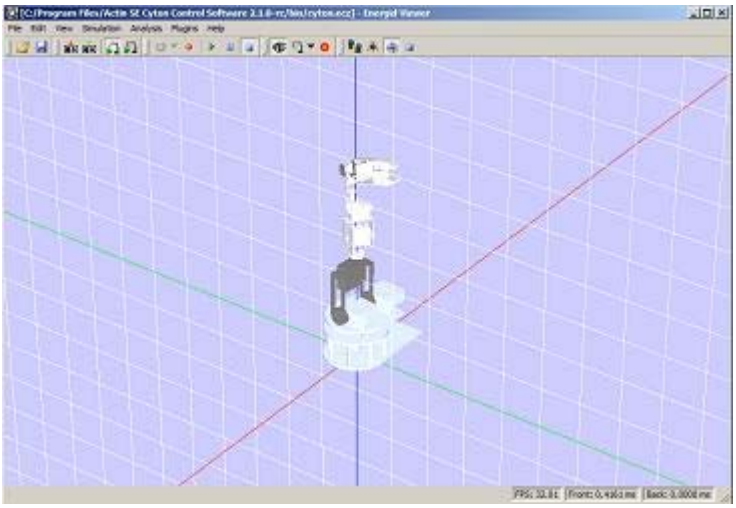
in the **Environment Information** tab.



XY-Grid



XZ-Grid



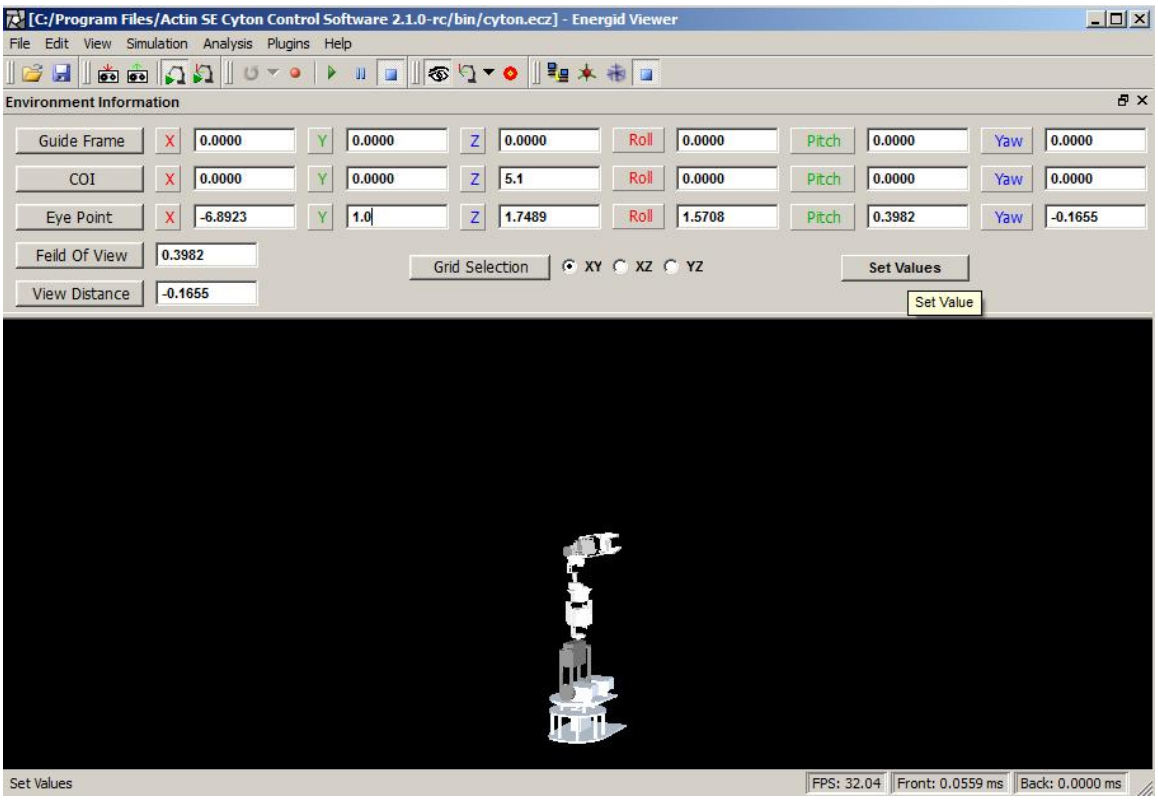
YZ-Grid

The red, green and blue lines are X,Y and Z axis respectively passing through the origin.

When **Set Values** button is clicked, we will be able to edit the Guide Frame location, COI and Eye Point values that are being displayed on the **Environment Information** tab.

A user can edit these values to desired ones and click **Set Values** 

in the **Environment Information** tab for it to come into action.



II. How to use the 3 Axis View Plugin

Introduction

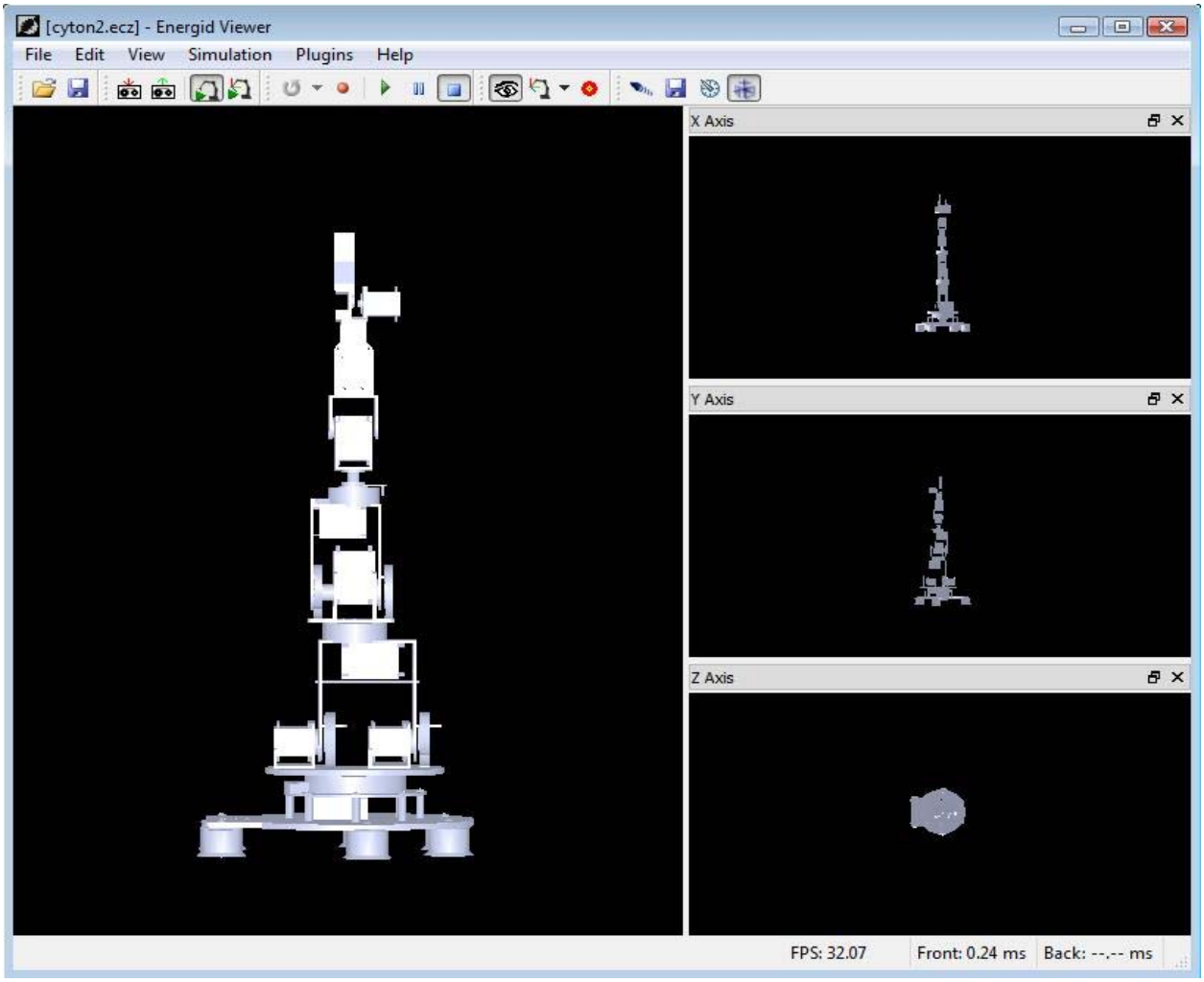
This plugin displays 3 separate views along X, Y and Z axis in the viewer. Using this plugin you will be able to have a better views on the robot and in turn better control of it.

Description

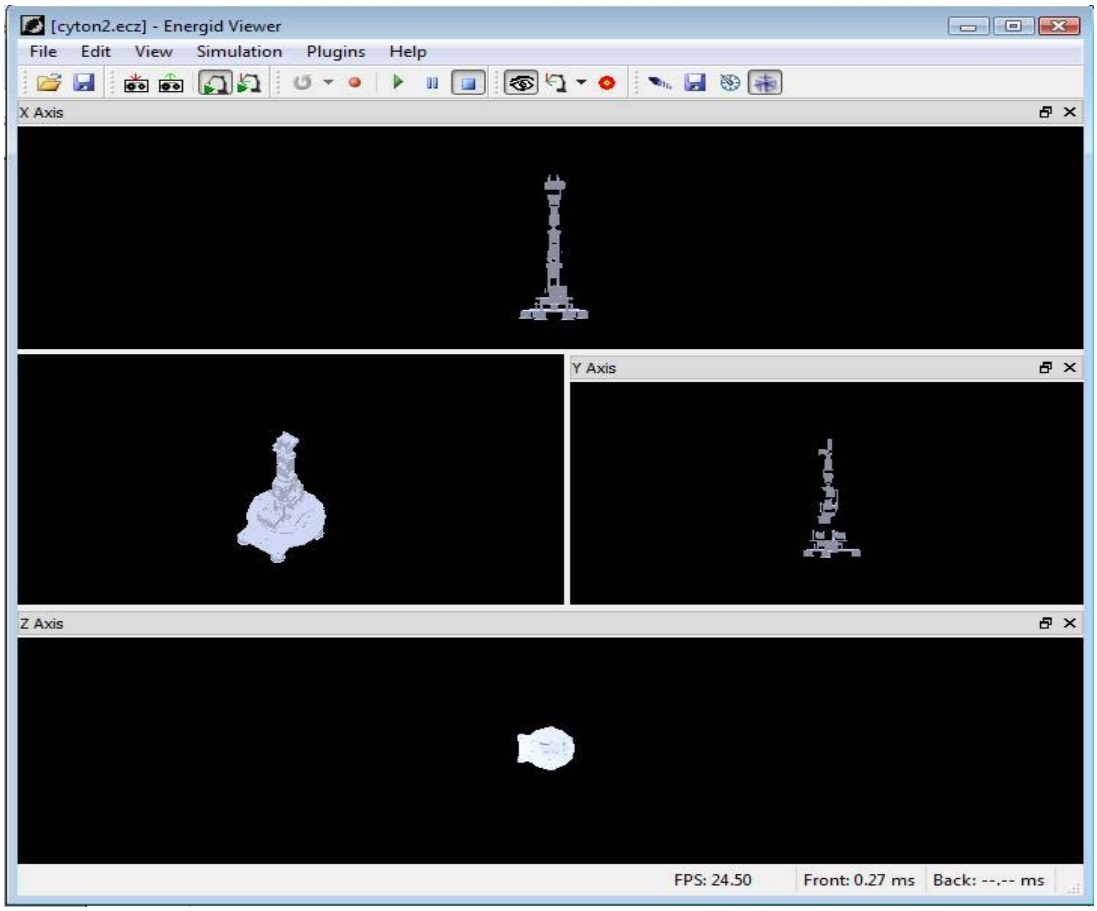
When the plugin is loaded into the viewer; a button called

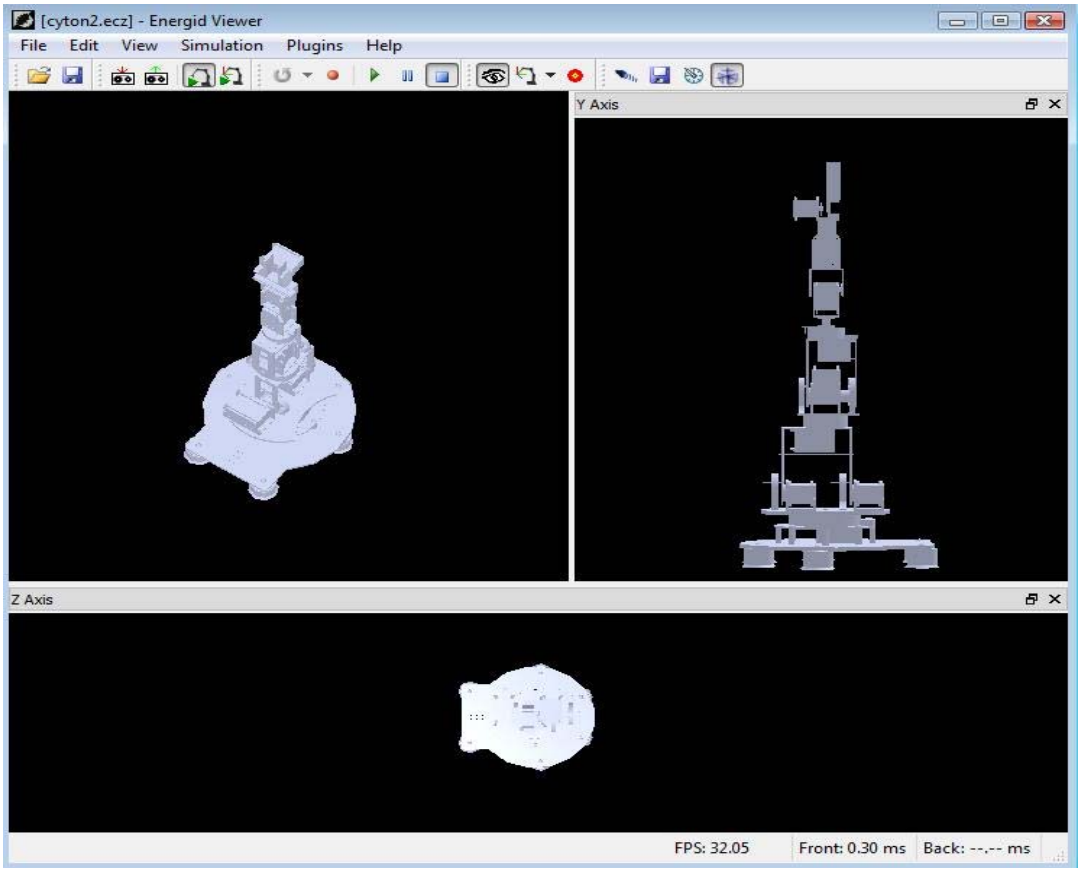
 **Three-Axis View Mode** gets displayed on the toolbar. By clicking this button you will enable Three-Axis View mode in the viewer.

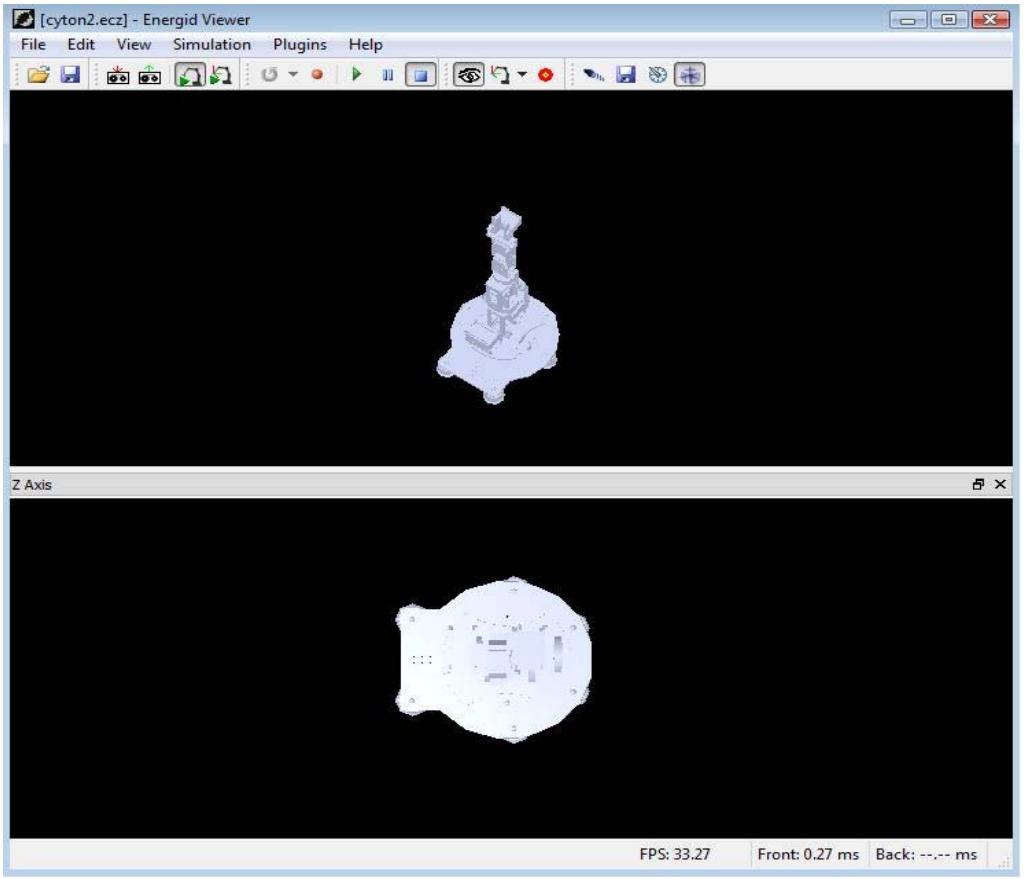
When Three-Axis View mode is enabled, the viewer gets additional windows\widgets which displays views along X, Y and Z axis.



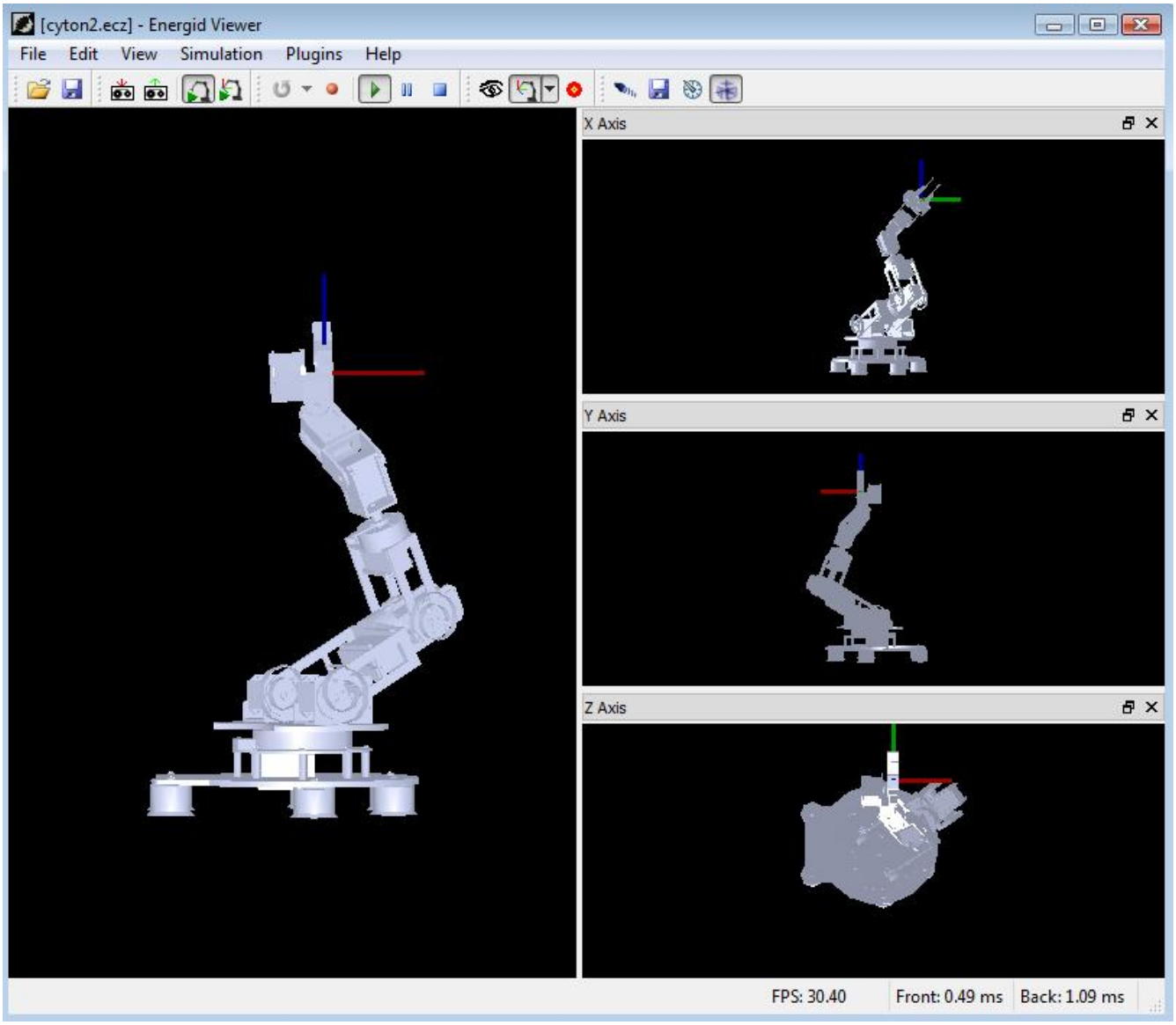
The Eye Point and the Center Of Interest of the robot can only be changed in the main window. However the robot's view can be zoomed in the X Axis, Y Axis and Z Axis windows by using scroll of the mouse. The three axis(X Axis, Y Axis and Z Axis) windows can be removed or separated from the main window; as well as be docked at different locations along the main window as per user convenience.







The Guide Frame set on the end effector of the robot can be controlled effectively from three axis(X Axis, Y Axis and Z Axis) windows in addition to the main window. This will help a user to control\move the robot's end effector more precisely to a location.



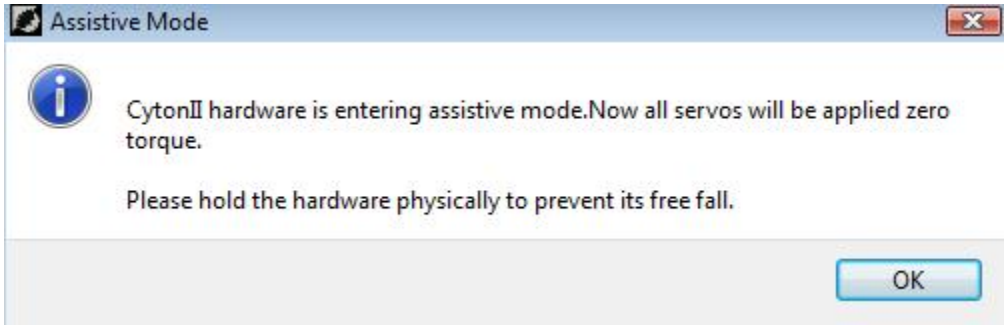
III. How to use the Assistive\Teach Mode

Introduction
This is a special feature associated with the Cyton arm. In this mode a user can train the arm to move in any desired trajectory to do a task and this trajectory will be recorded by the Cyton viewer as a path file. This recorded path file can be saved and be reused later in time to perform that task again.

Description

 **Assistive\Teach Mode**

When you press this button that appears on the Cyton Viewer toolbar, the cyton arm will enter into assistive\teach mode. Once the button is pressed; following message box will be displayed asking the user to be ready for assistive\teach mode operation.



During assistive/teach mode, all the servos of the arm are applied with zero torque. So if the arm is in an upright position, it could collapse and damage itself. So this message box prepares the user to be ready to hold the arm for assistive\teach mode operation. Once the user presses OK button of this message box, zero torque will be applies to all joints of the arm and the arm enters the assistive\teach mode during which the arm loose its stiffness and it becomes free to move.

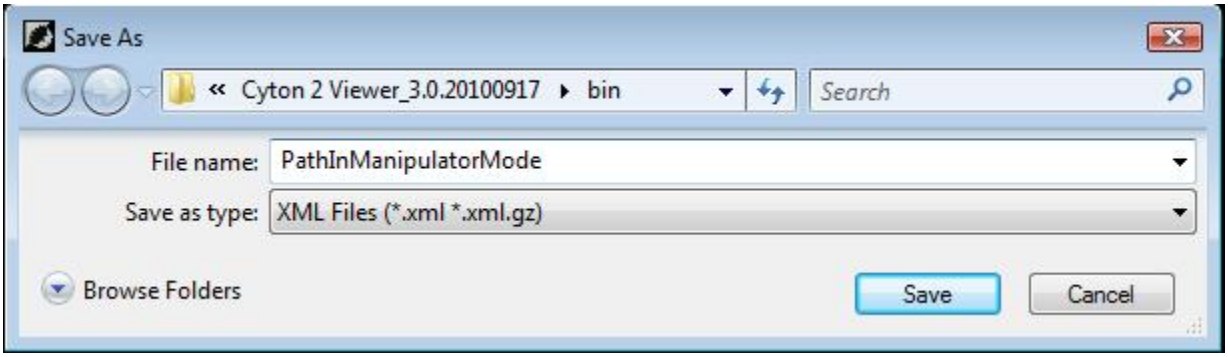
Once the arm is in assistive\teach mode, the user will be able to physically move the arm in desired trajectory or make it perform a task. During assistive\teach mode operation, the movement of the actual arm will be reflected in the Cyton Viewer. The Cyton model in the viewer will reproduce the movement of the actual Cyton hardware in real time.

Once the desired trajectory is traced or task is performed by the arm, the assistive mode can be exited by pressing(or unchecking) the **Assistive\Teach Mode** button on the toolbar of Cyton Viewer.

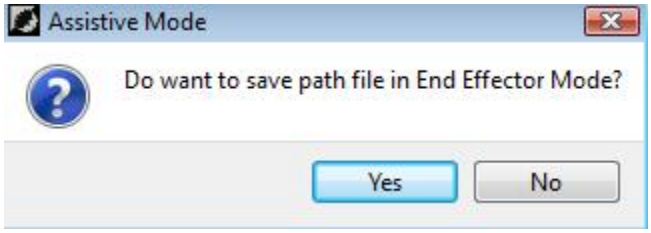
The path file recorded during assistive\teach mode can be saved by clicking

 **Save Assistive Mode Path** button on the toolbar of Cyton Viewer. This button is located next to the **Assistive\Teach Mode** button in the viewer.

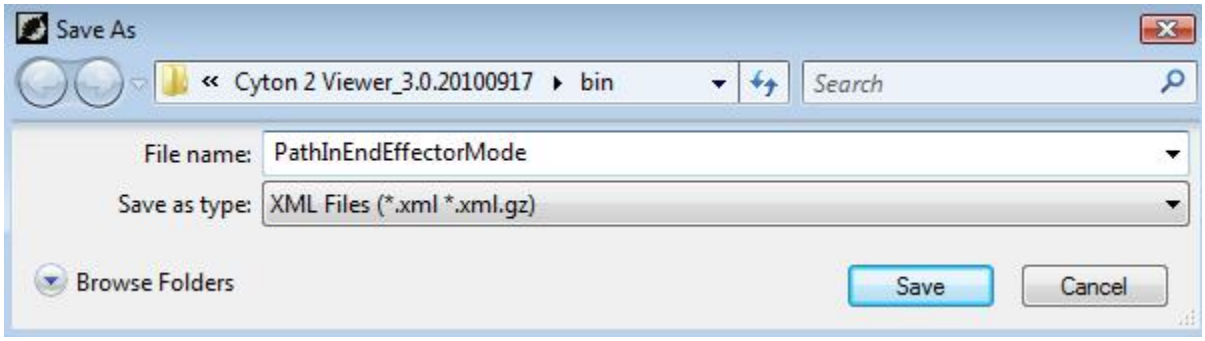
When **Save Assistive Mode Path** button is clicked, the user will be asked the location and file name with which the file has to be saved. This path file saved is recorded in Manipulator\Joint mode.



Once this file is saved, a message box asking whether to save the path file in End Effector mode pops up.



If Yes is clicked, the user will be asked the location and file name with which the file has to be saved. This path file saved is recorded in End Effector Mode.



These path file generated can be treated like normal path files. They can be loaded into viewer and replayed as usual.

Manipulator\Joint Mode Vs End Effector Mode Recording
In Manipulator\Joint mode recording, the joint position(angle) and joint velocity of each joints are recorded into the path file for each time step. When the path is replayed, inverse kinematics computation is not required as joint positions and velocities can be directly feed to the hardware.

In End Effector mode recording, the end effector coordinate and orientation of the arm is recorded for each time step. When the path is replayed, inverse kinematics computation is done to convert end effector coordinate and orientation value to joint positions and velocities for the hardware.

IV. How to use the Overlay Plugin

Introduction

In cyton viewer you can display some information visually by overlaying it on the robot and these information are displayed with the help of Overlay Plugin. The information that are displayed by Overlay Plugin are the following:

a)Bounding Volumes Of Links
b)Mass Distribution Of Links
c)Frames Of Links

When the Overlay Plugin is loaded into the viewer, an overlay toolbar that accomodates 4 buttons are formed on the viewer.

These 4 new buttons formed as part of Overlay Plugin are

 **Stereo**

 **Show Bounding Volume**

 **Show Mass Property Ellipsoids**

 **Show Frames**

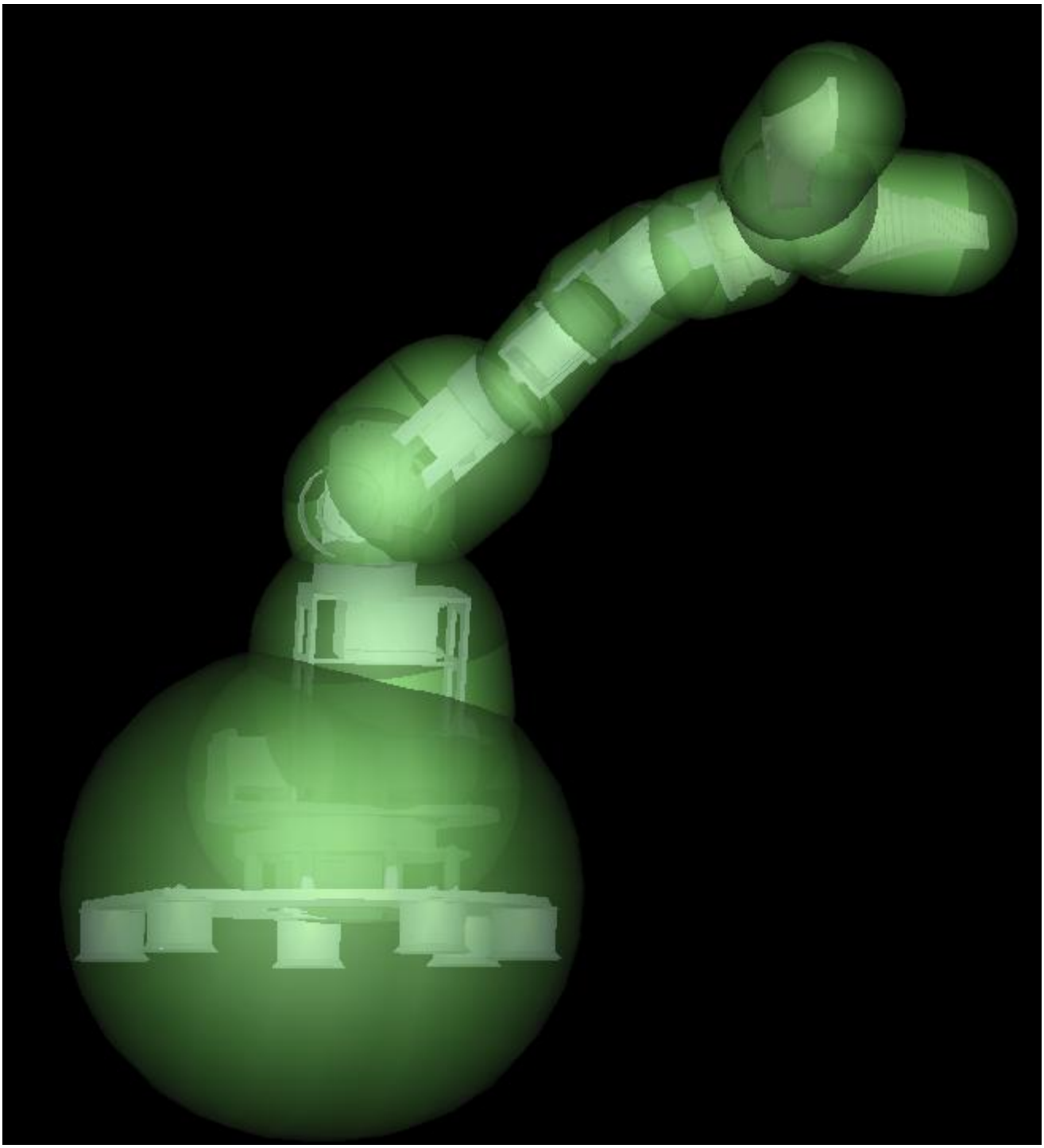
Description

 **Stereo**

Normally Stereo button is disabled, but when a usb shutter glass is connected to your computer, this button will be enabled in the viewer. By clicking the button then, you will be able to view the simulation in the viewer in 3D.

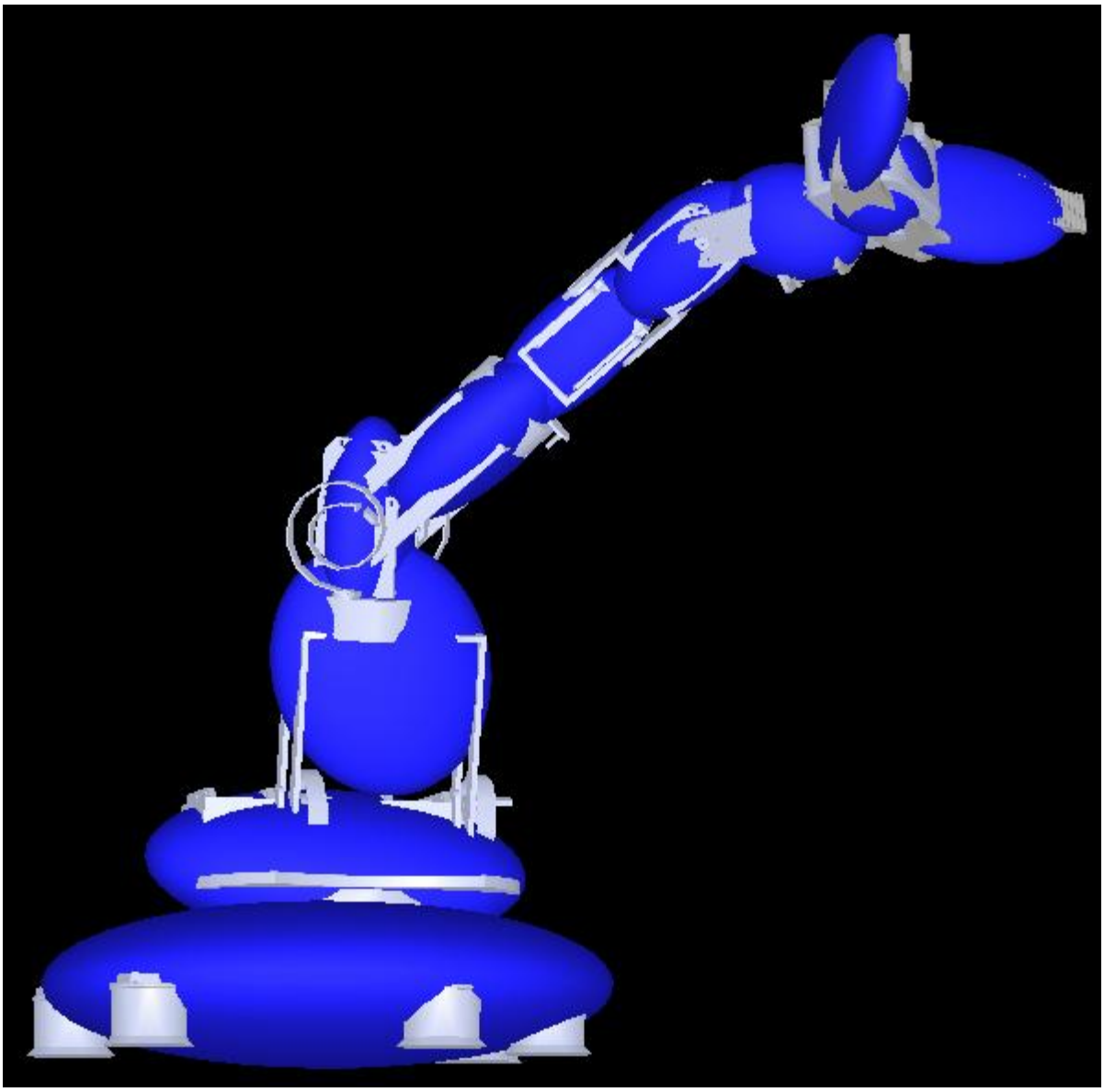
 **Show Bounding Volume**

Pressing the Show Bounding Volume button on the toolbar shows the bounding volumes of all links of all manipulators in the system. Bounding volumes are displayed in a transparent green color. Bounding volumes can be of any shape but the most common is the capsule. Bounding volumes are used in collision reasoning to speed up distance calculations.



 **Show Mass Property Ellipsoids**

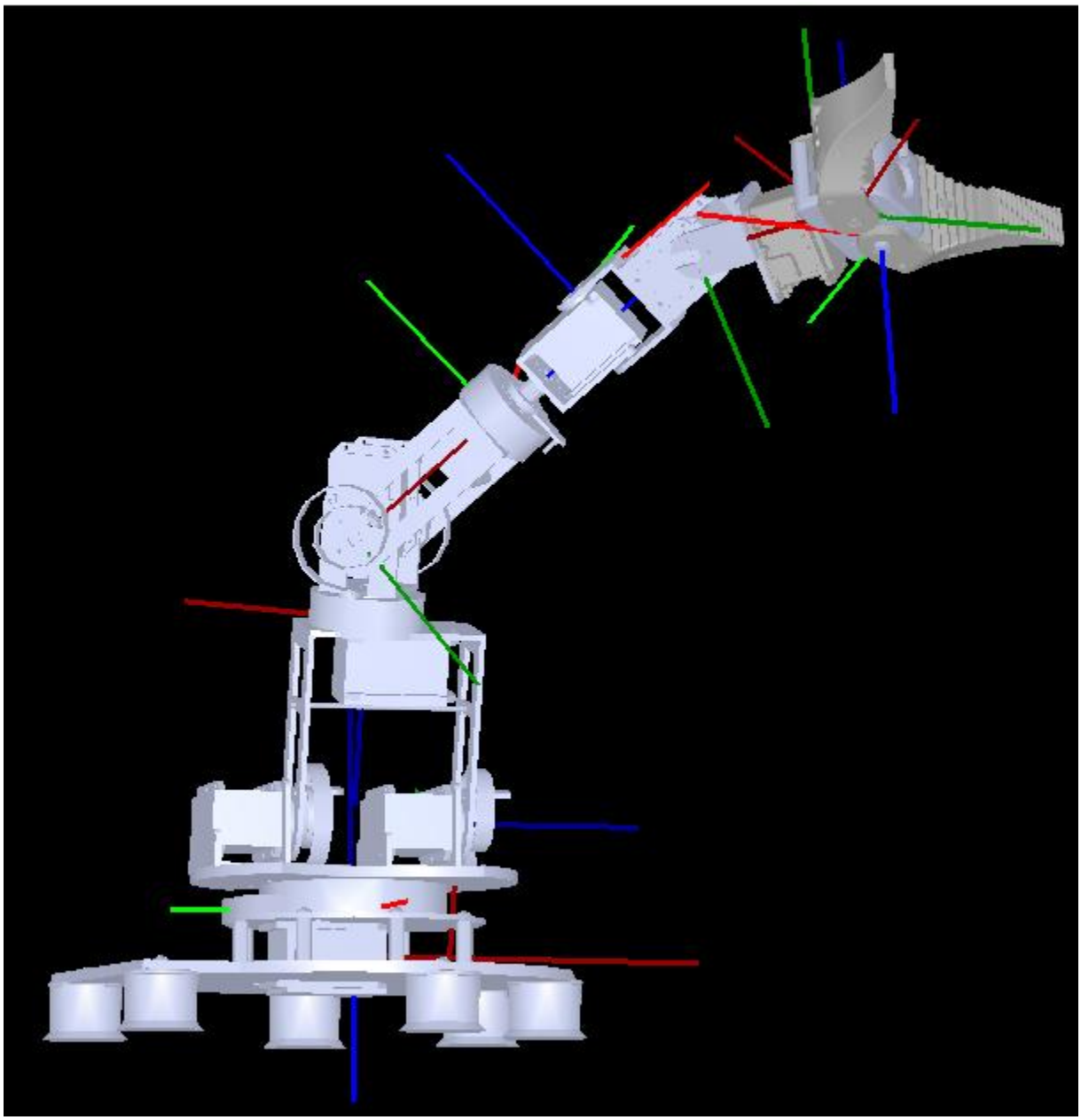
Pressing the Show Mass Property Ellipsoids button will overlay the mass property ellipsoids onto the links of manipulators. This is a great visualization tool to help verify whether the mass properties (inertia matrices) are reasonable.



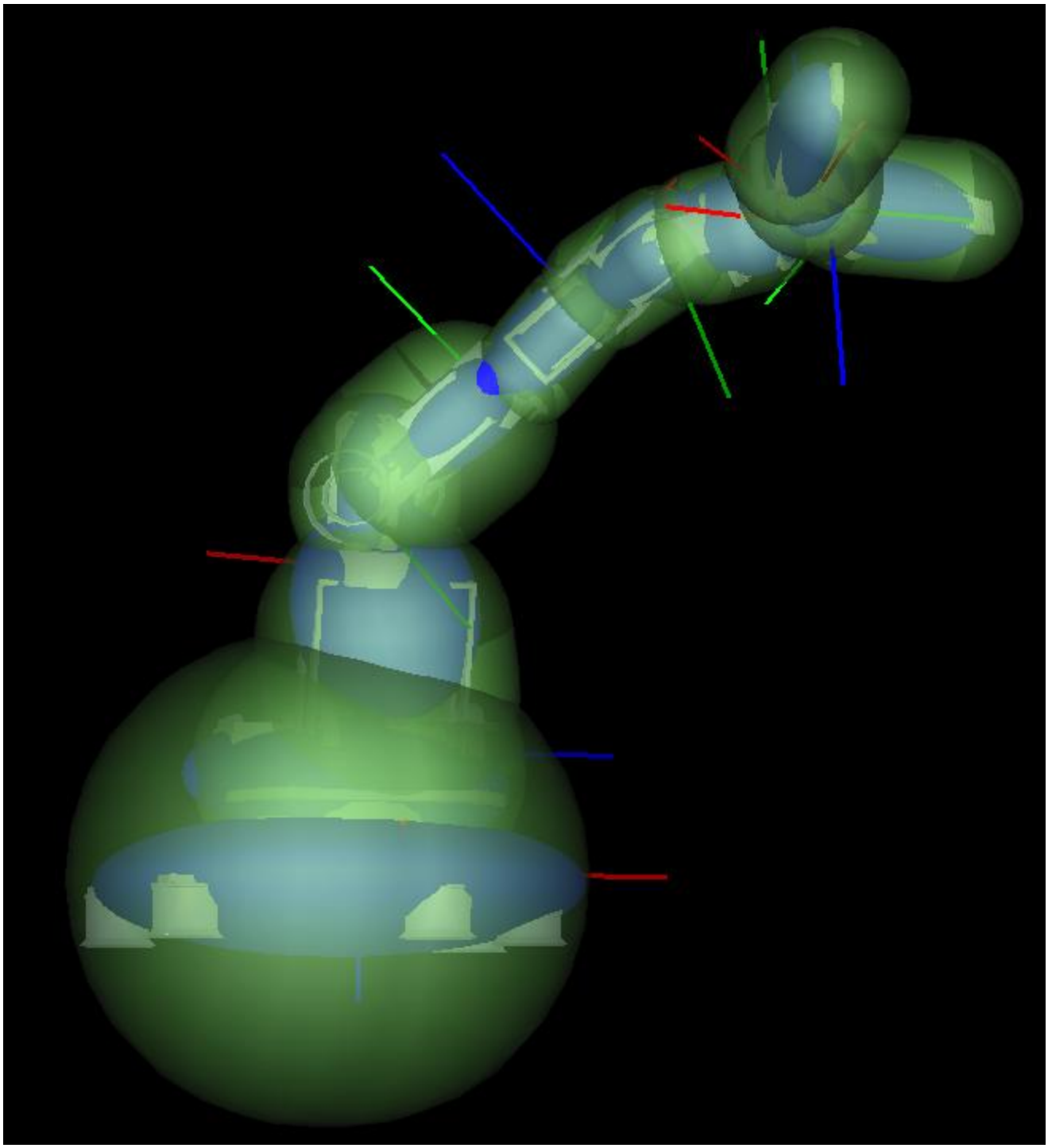
Show Frames

Sometimes it is very insightful to be able to see all the frames (primary and D-H) of the robot. Clicking on the Show Frames button will show all those frames as well as the world coordinate frame. The world coordinate frame is typically designated by the frame with the longest axes.

For all frames, the red, green, and blue axes represent the X, Y, and Z axes, respectively. The primary frame and the D-H frame of a link can occasionally coincide so they will appear as one frame.



Naturally, these information overlays can be turned on/off independent of one anther and therefore can be combined as shown below.



Cyton Spec Tests

Introduction

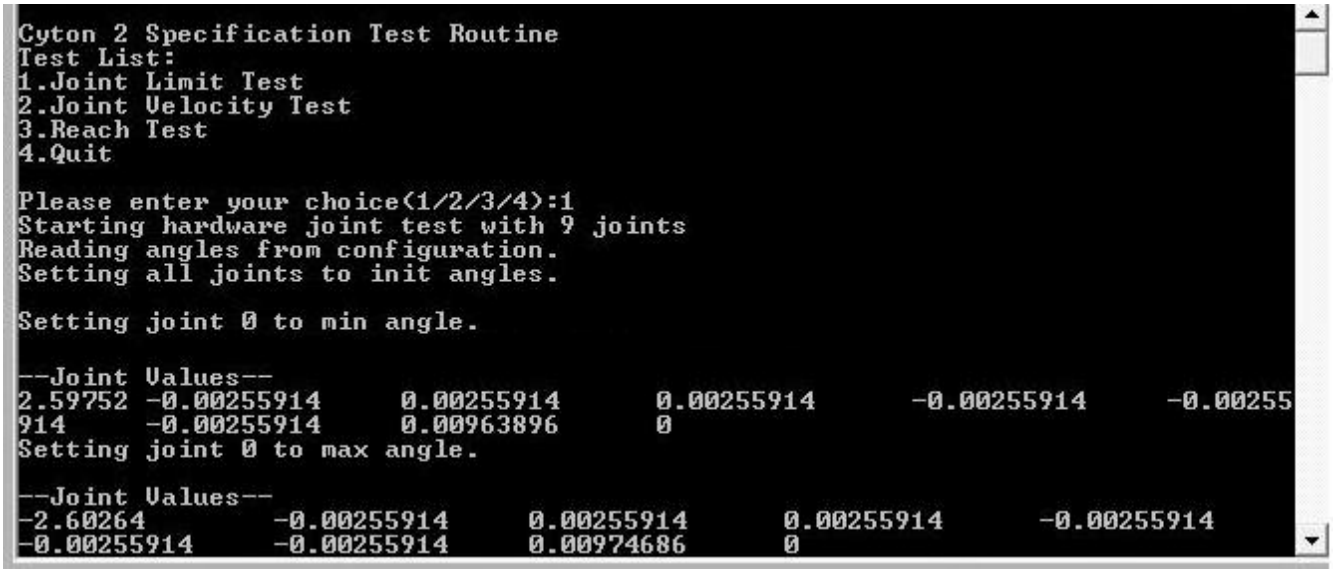
A set of tests called spec-tests can be conducted on the Cyton arms in order to verify their specification. The following are the tests presently available for verifying some of the specification of the arm:

- Joint Limit Test
- Joint Velocity Test
- Reach Test

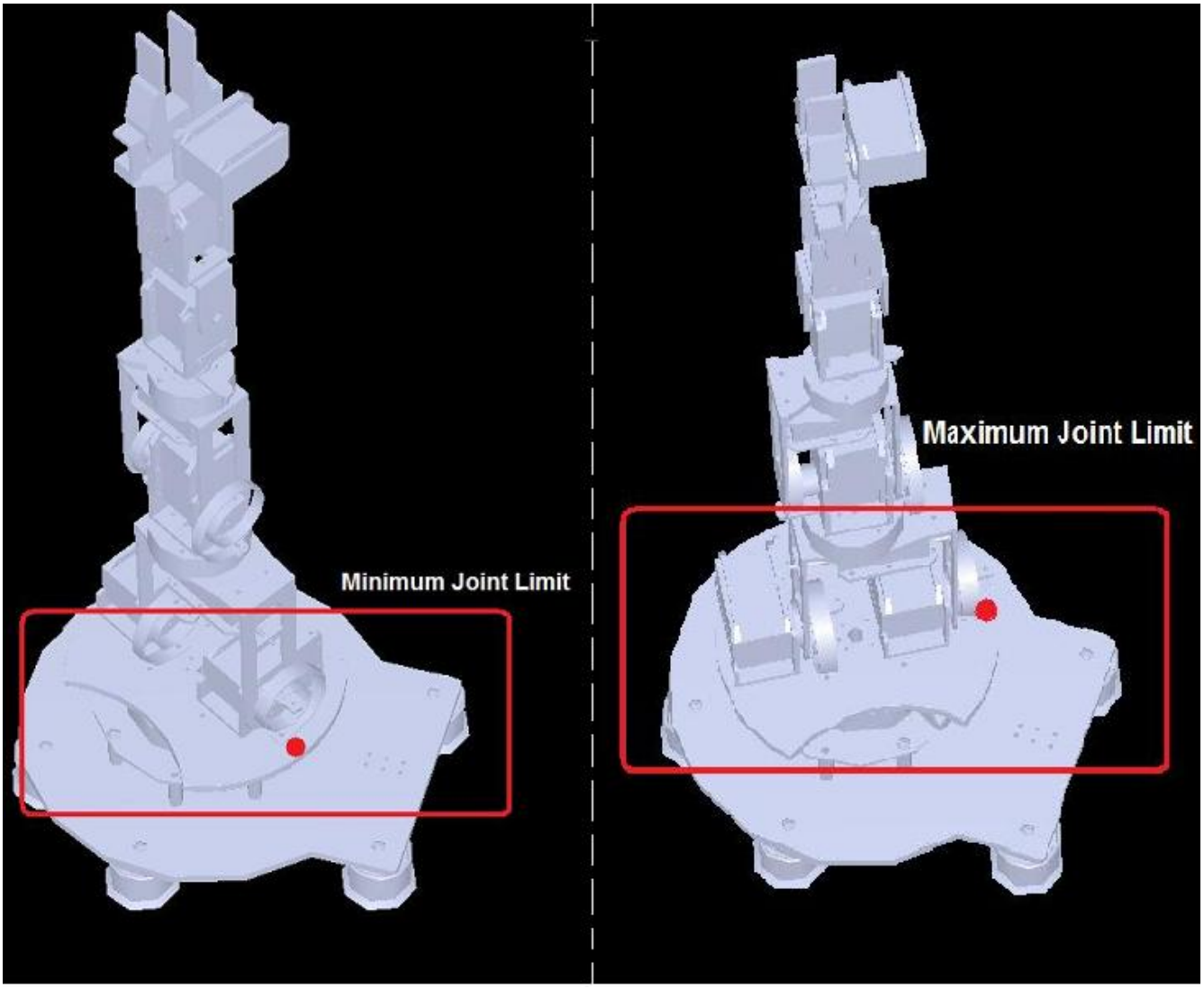
Test Description

1)Joint Limit Test

Joint Limit test is conducted in order to verify the joint limits of all the joints in the Cyton arm. During this test each of the joints of the Cyton arm is made to move to its minimum and maximum joint limits one after the other. When a joint reaches its minimum/maximum joint limit, the joint values of all the joint from the arm are read and displayed on the console screen.



Screen shot of console screen while Joint Limit test is being run for a Cyton V2.

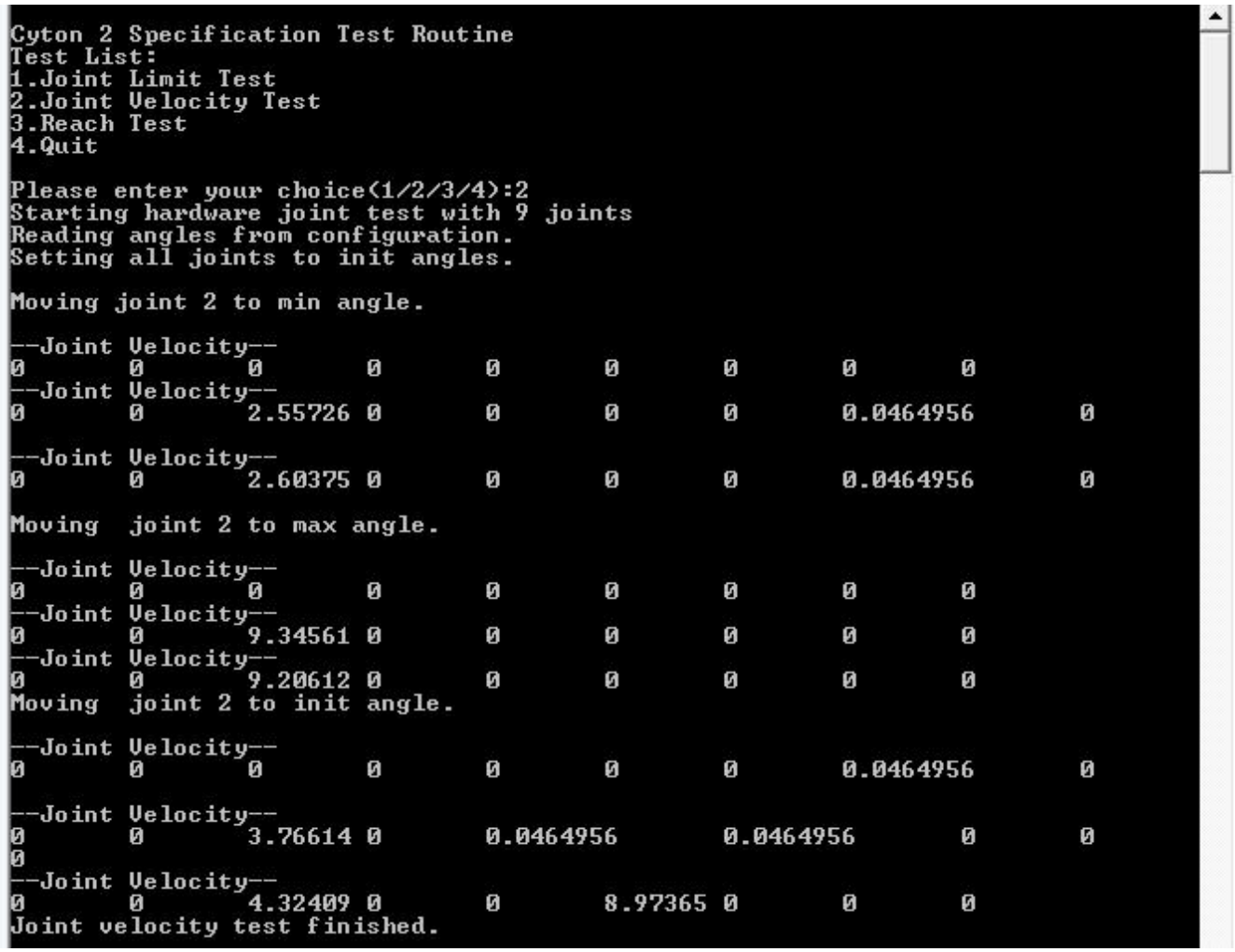


State of hardware based on the values in the above console screen picture.

2) Joint Velocity Test

Joint Velocity test is conducted in order to verify if the hardware is capable achieving the specified joint velocity. During this test, one of the joints of the Cyton V2 arm is made to move at different joint velocities and during the movement, joint velocities of all the joints are read back from the hardware and displayed on the console screen.

In this test we will only be moving the Elbow Roll joint at different speeds between initial to minimum joint limit, minimum to maximum joint limit and maximum to initial joint limit.



Screen shot of console screen while Joint Velocity test for a Cyton V2 is run.

3) Reach Test

Reach test is conducted in order to verify the physical reach of the Cyton arm. During this test the Cyton arm is made to stretch itself in four directions(one after the other). During this stretch, the reach of the Cyton arm can be measured using a measuring tape from the base of the Cyton arm.

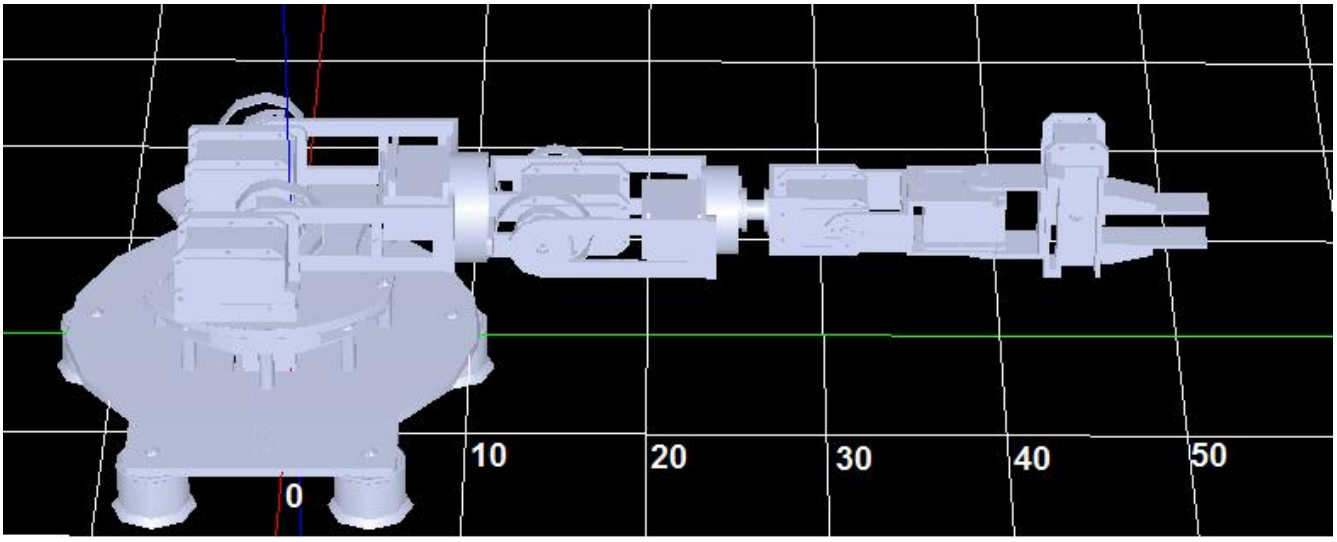
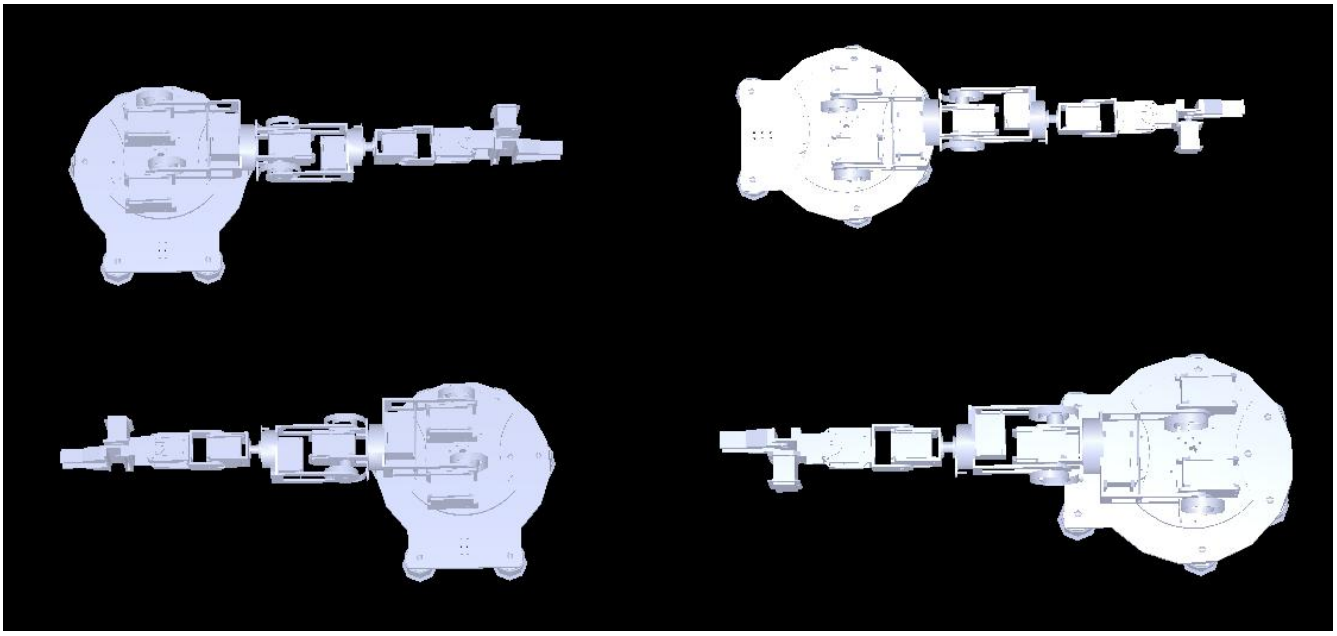


Illustration of how reach can be measured during Reach test.



Four directions in which Cyton V2 arm stretch's during the Reach test.

Using the Cyton C++ API

The available API for the Cyton hardware is made up of two components, 1) a control-based calculation API used to perform inverse-kinematics calculations and other associated commands, and 2) a hardware API to directly control the Cyton arm via code. The control API uses ActinSE, a lightweight and easy to use version of Energid's complete Actin toolkit. Ultimately, the output of ActinSE is a set of joint positions that

can then be fed to the hardware API to command a new position. The summary of the available methods for both ActinSE and the hardwareInterface is given in **Appendix A**. Figure 17 below shows the fundamental classes used within ActinSE.

actinSE::Array3	A three-element vector
actinSE::ControlSystem	Basic interface to the Cyton control system
actinSE::CoordinateSystemTransformation	A rotation and a translation describing a new frame
actinSE::EndEffector	End-effector interface
actinSE::Orientation	Description of a 3D rotation

Figure 17:ActinSE fundamental classes

Cyton Code Example

Below is a section of code showing the ActinSE and hardware interface API in use. The complete source code is provided with the installation in examples/cytonControlExample.cpp.

```
EcBoolean
testControlAndHardware
   (
   actinSE::ControlSystem& control,
   cyton::hardwareInterface& hardware,
   const EcU32 endEffectorId
   )
{
   EcRealVector jointAngles;
   EcRealVector jointRates;

   // Pull the starting position.
   CoordinateSystemTransformation initialPose, currentPose;
   EndEffectorVector eeVec;
   control.getParam<ControlSystem::EndEffectors>(eeVec);
   eeVec[endEffectorId].getParam<EndEffector::ActualPose>(initialPose);
   Array3 pos = initialPose.translation();
   std::cout << "Getting current end-effector position " << pos << std::endl;

   // Desired pose is located 10cm away along X and Y.
   CoordinateSystemTransformation desiredPose = initialPose;
   pos = desiredPose.translation() + Array3(0.1,0.1,0.0);
   desiredPose.setTranslation(pos);
   std::cout << "Attempting to move EE(" << endEffectorId <<") to position " << pos <<
std::endl;

   // Set the desired final position.
   EcBoolean passed =
eeVec[endEffectorId].setParam<EndEffector::DesiredPose>(desiredPose);
```

```
   // move to the desired pose.  If running the rendered version, it will display the
progress.
   const EcU32 steps = 200;
   const EcReal simRunTime = 2.0;
   const EcReal simTimeStep = simRunTime/steps;

   for(EcU32 ii=0; ii<steps; ++ii)
   {
      // get the current time
      EcReal currentTime = simTimeStep*ii;

      /// calculate new joint values
      passed = control.calculateToNewTime(currentTime);
      passed &= control.getParam<ControlSystem::JointAngles>(jointAngles);
      if(!passed)
      {
         std::cerr << "Unable to calculate new joint values.\n";
         break;
      }
      std::cout << "Step: " << ii << " Joint Angles: " << jointAngles << "\n";

      // Pass joint values to the hardware.
      passed = hardware.setJointCommands(currentTime, jointAngles,
cyton::JointAngleInRadiansBiasScale);
      if(!passed)
      {
         std::cerr << "Unable to set joint angles to hardware.\n";
         break;
      }

      // Check to see if we have reached our destination
      eeVec[endEffectorId].getParam<EndEffector::ActualPose>(currentPose);
      if(currentPose.approxEq(desiredPose, 1.0e-3))
      {
         std::cout << "Reached goal position in " << currentTime << " seconds (" << ii <<
" steps)\n";
         break;
      }
   }

   return passed;
}
```

Listing-1. Sample code utilizing ActinSE and Cyton hardwareInterface. It attempts to move the designated end-effector 10cm in X and Y. It will use ActinSE to calculate a new position at each timestep, pass it to the hardwareInterface, and then check to see if the position has reached the desired final position.

The Cyton Config file (*CytonConfig.xml*)

In the folder holding the test applications and the Cyton Viewer you will see a file called ***CytonConfig.xml*** This file is used for specifiy the serial port to use and various parameters for calibration. Note that generally all default settings should be sufficient. The format of the file is as follows:

The Cyton2Config.xml file contains values for various parameters for each servo in Cyton arm. Each servo in the arm is configured based on these values. The parameters in the config file are explained below:

```
m_ftdiSerialNum    : Serial no. of the USB2Dynamixel.
m_bps              : Baud rate in bits per second for communication.
m_readTimeoutms    : Read time out in milliseconds.
m_writeTimeoutms   : Write time out in milliseconds.
m_positionThreadHz : Speed of refreshing status data from dynamixel in hertz.
m_openLoop         : Flag for open and closed loop operation. When set 1,
                     operates in open loop. When set 0,operates in closed loop.
m_realTime         : If this flag is set as 1, joint rate will be computed.If
                     the flag is set as 0, joint rate will be taken from the
                     config XML.
```

count : Number of servos connected.

m_id : Servo id.
m_goalPosition : Goal position to move to while configuring the servos in radians. Value range from -2.617 to 2.617 radians(ie from -150 to 150 degrees).
m_LEDState : Sets the required LED state. When set 0,LED turns OFF. When set 1,LED turns ON.
m_returnDelay : Sets the return delay time in milliseconds. Value ranges from 0 to 500 ms.
m_cwlimit : Sets clockwise angle limit in radians. Value ranges from -2.617 to 2.617 radians(ie from -150 to 150 degrees).
m_ccwlimit : Sets counter clockwise angle limit in radians. Value ranges from -2.617 to 2.617 radians(ie from -150 to 150 degrees).
m_angleOffset : Sets an angular offset to the servo. The value is set in radians and can be positive or negative. However using angular offset can reduce the angular working range of the servo by the offset applied.
m_maxTorque : Sets percentage of torque limit to be used. It only gets set on re-powering the servo.
m_movingSpeed : Velocity with which servos move while the arm is controlled in radians per second. Value ranges from 0 to 11.9 radians per second (ie 0 to 114 RPM).
m_setupMovingSpeed : Velocity with which servos move during startup and stop in radians per second.Its value ranges from 0 to 11.9 radians per second (ie 0 to 114 RPM).
m_torqueLimit : Sets percentage of torque limit to be used. The Value gets set immediately as it is set unlike m_maxTorque.
m_baudRate : Baud rate in bits per second for the servo. It must be same as that of the m_bps.
m_tempLimit : Sets the temperature limit in degree Celsius. Value ranges from 10 to 99 degree Celsius.
m_torqueEnable : Flag to enable and disable torque. When set 1,torque is enabled. When set 0,torque is disabled or is in 0 torque mode.
m_lvlimit : Sets lower voltage limit. Values range from 5 to 25V.
m_alarmLED : Sets alarm LED. Values range from 0 to 126.
m_alarmShutdown : Sets alarm shutdown. Values range from 0 to 126.
m_hvlimit : Sets higher voltage limit. Values range from 5 to 25V.
m_srlevel : Sets status return level. When set 0,no status return. When set 1,status return only for read packet. When set 2,status return for all packets.
m_punch : Sets punch for dynamixel servos. Values range from 0 to 1023.
m_cwcm : Sets clockwise compliance margin. Value ranges from 0 to 254.
m_ccwcm : Sets counter clockwise compliance margin. Value ranges from 0 to 254.
m_cwcs : Sets clockwise compliance slope. Values range from 0 to 254.
m_ccwcs : Sets counter clockwise compliance slope. Value ranges from 0 to 254.
m_lock : Sets lock on dynamixel servos. When set 1, restricts writing data into dynamixel from address location 0x18 to 0x23.
m_invert : Sets invert flag. When set 1,servos move in the actual

direction. When set -1,servos move in the reverse direction.

m_map : Used to map joint angle and joint velocity of one servo to another. If map of a servo with id 4 is set as 3 then servo with id 4 will function same as the servo with id 3.

m_servoType : It's a flag indicating the type of the servo used. If its value is 0,it indicated RX/DX series servos are used. If its value is 1,it indicates EX series servos are used.

m_isGripper : It's a flag indicating if the servo is gripper servo. If its value is 0,it indicates it is not a gripper servo. If its value is 1,it indicates it is a gripper servo.

For more information on these parameters please see the manual provided by the manufacturer. These can be obtained for the RX-10, Rx-28, and RX-64 servos at http://www.robotis.com/zbxe/dynamixel_en .

Tech Support and Contact Info

For tech support contact :

By email:

support@robai.com

By phone:

412-307-3050
(between 9 a.m. and 5 p.m. Eastern Standard Time)

By standard mail:

Robai
PO Box 37635 #60466
Philadelphia, PA 19101-0635

www.robai.com

Appendix A: Software API and Class Reference :

This appendix describes the C++ API delivered with the Cyton robots. An HTML version of the class reference is kept online at: http://robai.com/php/developers.php?linkid=4

---

cyton::hardwareInterface

cyton::hardwareInterface Class Reference

Public Types

enum	**OverrideEnum** {
	OverrideNone = 0x0,
	OverridePort = 0x1,
	OverrideReset = 0x2
	}

typedef EcU32	**OverrideType** Variable type to hold override options.

Public Member Functions

	hardwareInterface (const EcString &pluginName, const EcString &configFile="")
virtual	**~hardwareInterface** ()
virtual void	**setPort** (const EcString &port)
virtual EcStringVector	**availablePorts** () const
virtual void	**setResetOnShutdown** (const EcBoolean resetOnShutdown)
virtual EcBoolean	**resetOnShutdown** () const
virtual EcBoolean	**init** ()
virtual EcBoolean	**reset** ()
virtual EcBoolean	**shutdown** ()
virtual EcBoolean	**setJointCommands** (const EcReal timeNow, const EcRealVector &jointCommands, const **StateType** stateType=JointAngleInRadians, const EcRealVector &jointVelocities=EcRealVector())
virtual EcBoolean	**getJointStates** (EcRealVector &jointStates, const **StateType** stateType=JointAngleInRadians) const
virtual EcBoolean	**waitUntilCommandFinished** (const EcU32 timeoutInMS) const
virtual EcU32	**numJoints** () const
virtual EcBoolean	**setLowRate** (const EcBoolean lowRate)
Ec::Plugin *	**plugin** ()

Detailed Description

Member Typedef Documentation

typedef EcU32 cyton::hardwareInterface::OverrideType

Variable type to hold override options.

Member Enumeration Documentation

enum cyton::hardwareInterface::OverrideEnum

Bitfield options that hold whether or not to override parameters within the configuration file when initializing hardware. Currently the only override parameters are the port device and resetOnShutdown flag.

Enumerator:

OverrideNone	Pull everything from config file.
OverridePort	User specified port.
OverrideReset	User specified reset.

Constructor & Destructor Documentation

```
cyton::hardwareInterface::hardwareInterface ( const EcString &  pluginName,
                                              const EcString &  configFile = ""
                                            )
```

Constructor. Does not initialize hardware.

Parameters:

[in]	*pluginName*	Name of hardware plugin to utilize
[in]	*configFile*	Optional hardware configuration file

```
virtual cyton::hardwareInterface::~hardwareInterface (       )
```

Destructor. Shuts down device driver if loaded.

Member Function Documentation

```
virtual EcStringVector cyton::hardwareInterface::availablePorts (   )  const
```

Examine current hardware configuration to list available ports.

Returns:

EcStringVector A vector of string representing the port names of the devices available. Platform dependent. Empty list returned if not available, or plugin not loaded.

```
virtual EcBoolean
cyton::hardwareInterface::getJointStates   ( EcRealVector &      jointStates,
                                             const StateType     stateType = JointAngleInRadians
                                           )
```

Retrieve servo information. Depending on the stateType parameter it will return the last commanded position (default) or any of the configuration parameters for the servos (joint bias, min angle, max angle, reset angle, max joint rate, joint scale).

Parameters:

[out] *jointStates* Vector of returned values
[in] *stateType* Type and unit of requested values

Returns:

EcBoolean Success or failure of query command

virtual EcBoolean cyton::hardwareInterface::init ( )

Initialize hardware, which includes reading in configuration file, opening the port and resetting hardware to a known good state.

Returns:

EcBoolean Success or failure of initialization

virtual EcU32 cyton::hardwareInterface::numJoints ( ) const

Retrieve the number of joints currently configured.

Returns:

EcU32 Number of joints in the loaded system

Ec::Plugin* cyton::hardwareInterface::plugin ( )

Retrieve a handle to the loaded plugin.

Returns:

Ec::Plugin* The loaded plugin

virtual EcBoolean cyton::hardwareInterface::reset ( )

Send a reset command to the hardware to move joints back to resting position.

Returns:

EcBoolean Success or failure of reset command

virtual EcBoolean cyton::hardwareInterface::resetOnShutdown ( ) const

Accessor to retrieve state of whether reset will occur before power down.

Returns:

EcBoolean EcTrue if a reset will occur or EcFalse if not

```
virtual EcBoolean
cyton::hardwareInterface::setJointComman (const EcReal   timeNow,
ds
                                          const
                                          EcRealVector   jointCommands,
                                          &
                                          const          stateType =
                                          StateType      JointAngleInRadians,
                                          const
                                          EcRealVector   jointVelocities =
                                          &              EcRealVector()
                                         )
```

Sends commands to Cyton hardware to move joints to a specified location. A time difference is calculated from the previous command to determine the rate at which to move the joints.

Parameters:

[in]	*timeNow*	Current time
[in]	*jointCommands*	Vector of joint angles to move servos to
[in]	*stateType*	Optional unit conversion for input jointCommands
[in]	*jointVelocities*	Vector of joint velocities

Returns:

EcBoolean Success or failure of set command

virtual EcBoolean cyton::hardwareInterface::setLowRate (const EcBoolean lowRate)

Give the ability to rate limit the joints. If enabled, it will limit the arm at 25% of max rate.

Parameters:

[in]	*lowRate*	Turn rate limiting on or off

Returns:

EcBoolean Success or failure of command

virtual void cyton::hardwareInterface::setPort (const EcString & port)

Specify a port to use for the connection to the hardware.

Parameters:

[in]	*port*	String name of port to use. Platform dependent

virtual void cyton::hardwareInterface::setResetOnShutdown (const EcBoolean resetOnShutdown)

Flag indicating whether or not to reset Cyton joints to their initialization position before powering down.

Parameters:

[in]	*resetOnShutdown*	Whether or not to reset on power down

virtual EcBoolean cyton::hardwareInterface::shutdown ( )

Unloads plugin device driver.

Returns:

EcBoolean Success or failure of shutdown command

virtual EcBoolean cyton::hardwareInterface::waitUntilCommandFinished (const EcU32 timeoutInMS)

Wait for the last command to finish, up to a specified maximum time in milliseconds.

Parameters:

[in]	*timeoutInMS*	Maximum time to wait in milliseconds before failing

Returns:

EcBoolean Success or failure of wait command

---

actinSE::ControlSystem Class Reference

Public Types

enum	**ParamTypeEnum**
	{
	Rendering,
	SimulationTime,
	JointAngles,
	JointPose,
	JointVelocities,
	BasePose,
	EndEffectors,
	CraigDHParameters
	}

Public Member Functions

	ControlSystem () Constructor.
	~ControlSystem () Destructor.
	ControlSystem (const **ControlSystem** &orig)
ControlSystem &	**operator=** (const **ControlSystem** &orig)
EcBoolean	**operator==** (const **ControlSystem** &rhs) const
EcBoolean	**loadFromFile** (const **EcString** &fileName)
EcBoolean	**saveToFile** (const **EcString** &fileName)
template<ParamTypeEnum prm, typename ParamType > EcBoolean	**setParam** (const ParamType &value)
template<ParamTypeEnum prm, typename ParamType > EcBoolean	**getParam** (ParamType &value) const
template<ParamTypeEnum prm, typename ParamType > EcBoolean	**getParam** (ParamType &value, const **EcU32** subIndex) const
template<ParamTypeEnum prm, typename ParamType > const ParamType &	**param** () const
template<ParamTypeEnum prm, typename ParamType > ParamType	**param** ()
EcBoolean	**reset** ()
EcBoolean	**calculateToNewTime** (const **EcReal** timeInSeconds)

actinSE::EndEffector Class Reference

Public Types

enum	**EETypeEnum**
	{
	UnknownEndEffector = 0,
	PointEndEffector,
	OrientationEndEffector,
	FrameEndEffector,
	LinearConstraintEndEffector
	}

enum	**ParamTypeEnum**
	{
	DegreesOfConstraint,
	ActualPose,
	RelativeLink,
	MotionThreshold,
	DesiredPose,
	DesiredVelocity,
	Gain,
	HardConstraint
	}

enum	**EEStateFlagsEnum**
	{
	EmptyStateFlags = 0x0,
	RelativeLinkFlag = 0x1,
	HardConstrained = 0x2,
	Attached = 0x4
	}

typedef **EcU32**	**EEStateFlags**

Public Member Functions

	EndEffector (const **EETypeEnum** eeType)
	~EndEffector () Destructor.
	EndEffector (const **EndEffector** &orig)
EndEffector &	**operator=** (const **EndEffector** &orig)
EcBoolean	**operator==** (const **EndEffector** &rhs) const
template<ParamTypeEnum prm, typename ParamType > **EcBoolean**	**setParam** (const ParamType &value)
template<ParamTypeEnum prm, typename ParamType > **EcBoolean**	**getParam** (ParamType &value) const
template<ParamTypeEnum prm, typename ParamType > ParamType	**param** ()

EEStateFlags	**stateFlags** () const
EETypeEnum	**endEffectorType** () const
EcString	**name** () const

actinSE::Array3 Class Reference

Public Member Functions

	Array3 () constructor
	Array3 (const **EcReal** x, const **EcReal** y, const **EcReal** z) constructor from three reals
	~Array3 () destructor
	Array3 (const **Array3** &orig) copy constructor
Array3 &	**operator=** (const **Array3** &orig) assignment operator
EcBoolean	**operator==** (const **Array3** &orig) const equality operator
EcBoolean	**operator!=** (const **Array3** &orig) const inequality operator
Array3 &	**operator+=** (const **Array3** &v2) add another vector to this vector and set this vector to the result
Array3 &	**operator-=** (const **Array3** &v2) subtract another vector from this vector and set this vector to the result
Array3 &	**operator*=** (**EcReal** s) multiply this vector times a scalar and set this vector to the result
Array3	**operator+** (const **Array3** &v2) const returns a vector equal to this vector plus another
Array3	**operator-** (const **Array3** &v2) const returns a vector equal to this vector minus another
Array3	**operator*** (const **EcReal** a) const
Array3	**operator/** (const **EcReal** a) const
Array3	**cross** (const **Array3** &v2) const returns a vector equal to this vector cross another (vector cross product)
EcReal	**dot** (const **Array3** &v2) const

	returns a vector equal to this vector dot another (vector dot product)
EcReal	**mag** () const returns the magnitude of this vector
EcReal	**prod** () const returns the product of the three elements
EcReal	**magSquared** () const returns the magnitude squared of this vector (a fast operation)
Array3	**unitVector** () const returns a unit vector in the same direction as this vector
Array3 &	**normalize** () normalizes this vector
EcBoolean	**approxEq** (const **Array3** &v2, const **EcReal** tol) const tests that each element of this vector is within a tolerance of another
EcReal	**distanceTo** (const **Array3** &vec) const find the Euclidean distance to another point
EcReal	**distanceSquaredTo** (const **Array3** &vec) const find the Euclidean distance squared to another point
void	**computeDirectionalVector** (const **Array3** &destination, const **EcReal** mag, **Array3** &result) const compute a vector which points from this vector (point) to the other vector (point) with a given magnitude.
void	**set** (const **EcReal** x, const **EcReal** y, const **EcReal** z) sets the z value of the vector
const EcReal &	**operator[]** (const **EcU32** index) const returns a value by index (0, 1, or 2) - const version.
EcReal &	**operator[]** (const **EcU32** index) returns a value by index (0, 1, or 2) - nonconst version.

actinSE::CoordinateSystemTransformation Class Reference

Public Types

enum	**ModeEnum** {
	  NO_CHANGE,
	  ARBITRARY,
	  NO_TRANSLATION,
	  NO_ROTATION
	}

Public Member Functions

	CoordinateSystemTransformation () Default constructor.
	CoordinateSystemTransformation (const **Array3** &trans, const **Orientation** &orient)
	CoordinateSystemTransformation (const **Array3** &trans)
	CoordinateSystemTransformation (const **Orientation** &orient)
	~CoordinateSystemTransformation () Destructor.
	CoordinateSystemTransformation (const **CoordinateSystemTransformation** &orig)
CoordinateSystemTransformation &	**operator=** (const **CoordinateSystemTransformation** &orig)
EcBoolean	**operator==** (const **CoordinateSystemTransformation** &orig) const
ModeEnum	**mode** () const
const **Array3** &	**translation** () const
void	**setTranslation** (const **Array3** &value)
const **Orientation** &	**orientation** () const
void	**setOrientation** (const **Orientation** &value)
void	**outboardTransformBy** (const **Array3** &translation, const **Orientation** &orientation)
void	**outboardTransformBy** (const **Array3** &translation)
CoordinateSystemTransformation &	**operator*=** (const **CoordinateSystemTransformation** &xform2)
CoordinateSystemTransformation	**operator*** (const **CoordinateSystemTransformation** &xform2) const
Array3	**operator*** (const **Array3** &vec) const

void	**transform** (**Array3** &vec) const
void	**transform** (const **Array3** &from, **Array3** &to) const
void	**transform** (const **Array3** &firstFrom, **Array3** &firstTo, const **Array3** &secondFrom, **Array3** &secondTo) const
EcBoolean	**approxEq** (const **CoordinateSystemTransformation** &xform2, **EcReal** tol) const
CoordinateSystemTransformation	**inverse** () const
CoordinateSystemTransformation &	**invert** ()
EcBoolean	**interpolation** (const **CoordinateSystemTransformation** &coordSysxForm1, const **CoordinateSystemTransformation** &coordSysxForm2, const **EcReal** &factor)

actinSE::Orientation Class Reference

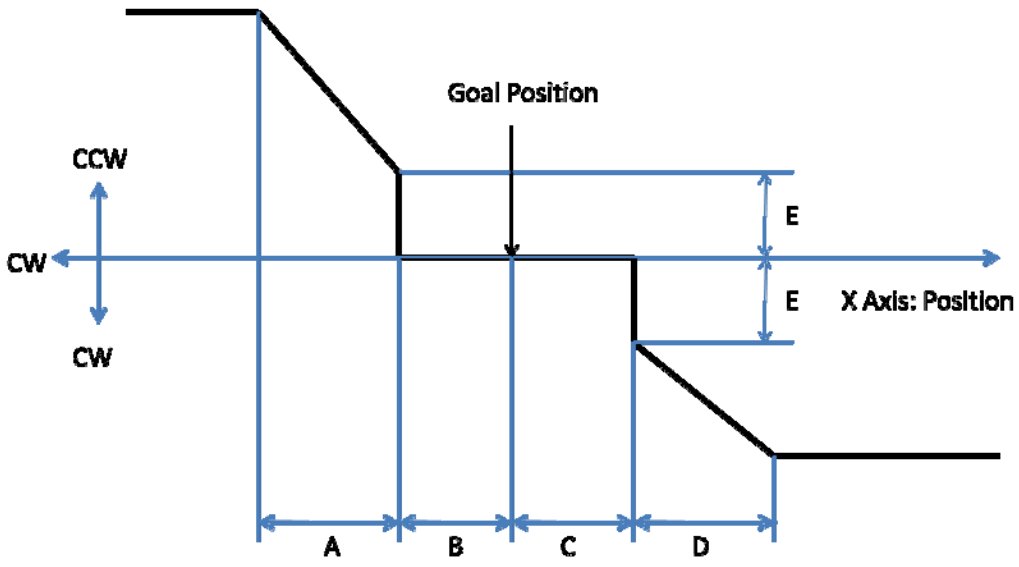
Public Member Functions

	Orientation () constructor
	Orientation (const **EcReal** w, const **EcReal** x, const **EcReal** y, const **EcReal** z) constructor from four reals: w, x, y, and z
	~Orientation () destructor
	Orientation (const **Orientation** &orig) copy constructor
Orientation &	**operator=** (const **Orientation** &orig) assignment operator
EcBoolean	**operator==** (const **Orientation** &orig) const equality operator
Orientation &	**operator*=** (const **Orientation** &orient2)
Orientation	**operator*** (const **Orientation** &orient2) const
Array3	**operator*** (const **Array3** &vec) const
void	**transform** (**Array3** &vec) const
void	**transform** (const **Array3** &from, **Array3** &to) const
void	**transform** (const **Array3** &firstFrom, **Array3** &firstTo, const **Array3** &secondFrom, **Array3** &secondTo) const
EcBoolean	**approxEq** (const **Orientation** &orient2, const **EcReal**

	tol=**EcTOLERANCE**) const
EcBoolean	**angleAxisBetween** (const **Orientation** &q2, **EcReal** &theta, **Array3** &axis) const
void	**interpolation** (const **Orientation** &orient1, const **Orientation** &orient2, const **EcReal** factor)
Orientation	**inverse** () const
Orientation &	**invert** ()
void	**set** (const **EcReal** w, const **EcReal** x, const **EcReal** y, const **EcReal** z)
void	**setFrom321Euler** (const **EcReal** psi, const **EcReal** theta, const **EcReal** phi)
void	**get321Euler** (**EcReal** &psi, **EcReal** &theta, **EcReal** &phi) const
void	**setFrom123Euler** (const **EcReal** phi, const **EcReal** theta, const **EcReal** psi)
void	**get123Euler** (**EcReal** &phi, **EcReal** &theta, **EcReal** &psi) const
void	**setFromAngleAxis** (const **EcReal** angle, const **Array3** &axis)
void	**getAngleAxis** (**EcReal** &angle, **Array3** &axis) const
void	**setFromRodriguesVector** (const **Array3** &vector)
void	**getRodriguesVector** (**Array3** &vector)
const **EcReal** &	**operator[]** (const **EcU32** index) const
void	**getDcmRows** (**Array3** &row0, **Array3** &row1, **Array3** &row2) const
void	**setFromDcmRows** (const **Array3** &row0, const **Array3** &row1, const **Array3** &row2)
void	**getDcmColumns** (**Array3** &col0, **Array3** &col1, **Array3** &col2) const
void	**setFromDcmColumns** (const **Array3** &col0, const **Array3** &col1, const **Array3** &col2)
Array3	**xAxis** () const
Array3	**yAxis** () const
Array3	**zAxis** () const

Punch: The limit value of torque being reduced when the output torque is decreased in the Compliance Slope area. It is the minimum torque. The default value is 32 (0x20) and can be extended up to 1023 (0x3FF).

Compliance: Compliance is to set the pattern of output torque. Making Margin & Slope well use of it will result in shock absorption, smooth motion, etc. The length of A, B, C, and D in the below graph (Position vs. Torque curve) is the value of Compliance. Compliance Margin is available from 0 to 254 (0xFE) while Compliance Slope is valid from 1 to 254 (0xFE).



A: CW Compliance Slope
B: CW Compliance Margin
C: CCW Compliance Margin
D: CCW Compliance Slope
E: Punch

B and C (Compliance Margin) are the areas where output torque is O.

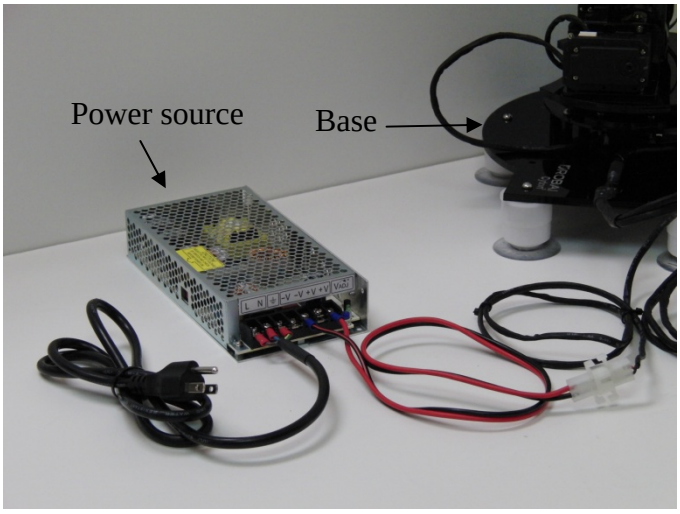
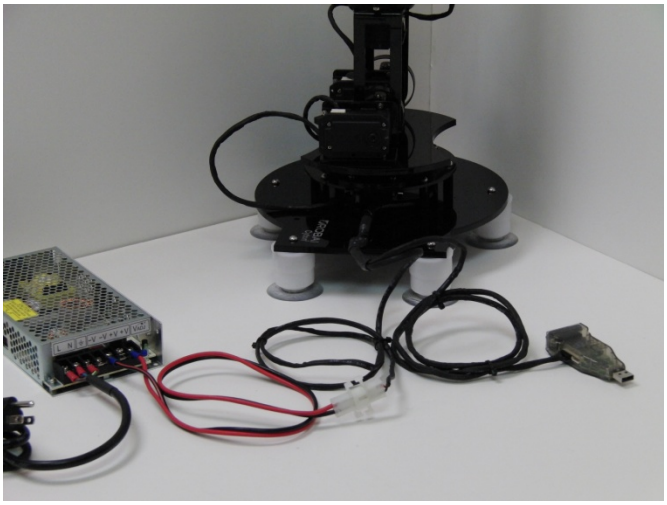
A and D (Compliance Slope) are the areas where output is reduced when they are getting close to Goal Position. The wider these areas are, the smoother the motion is.

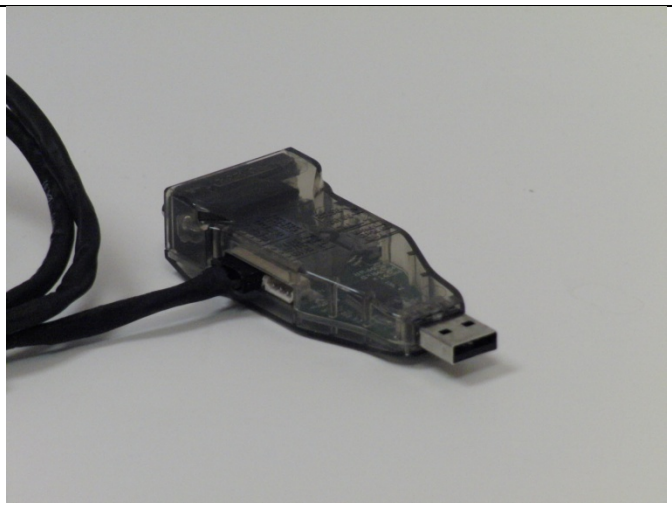
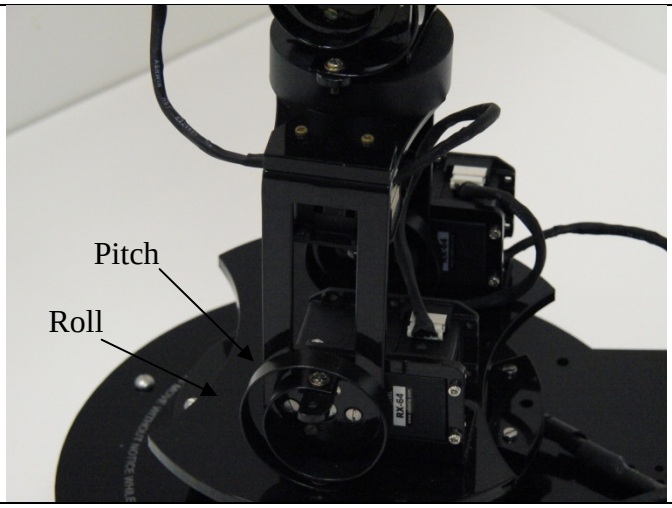
Appendix B: Photo Album

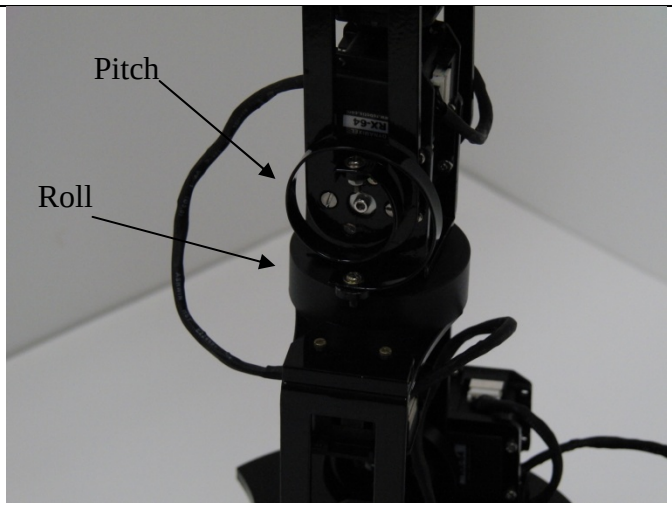
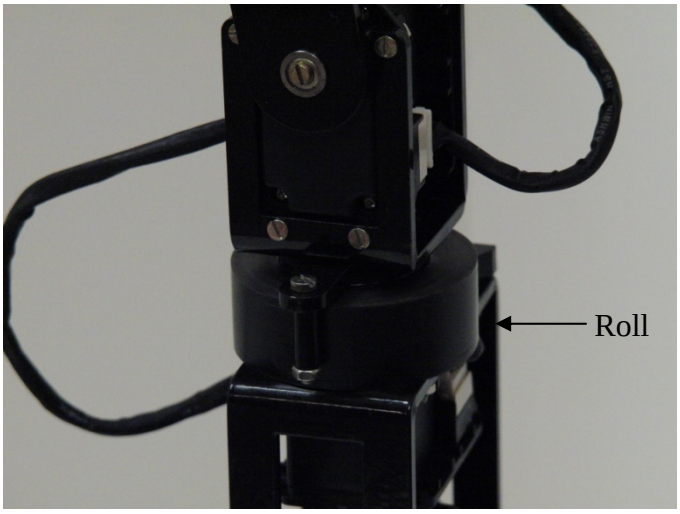
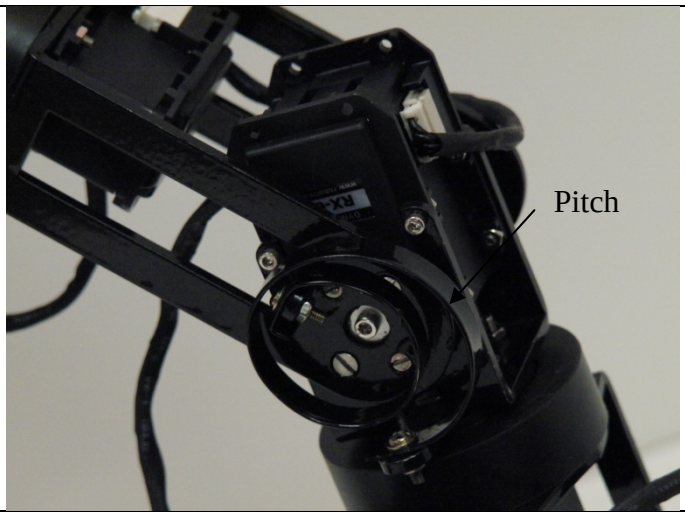
Cyton Photo Gallery

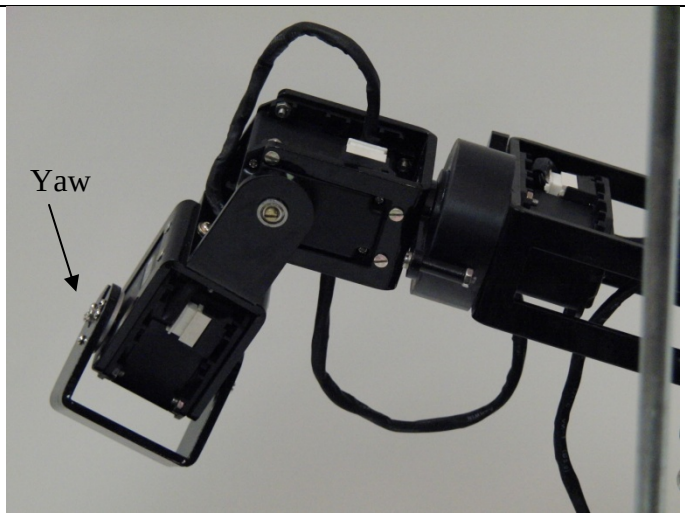
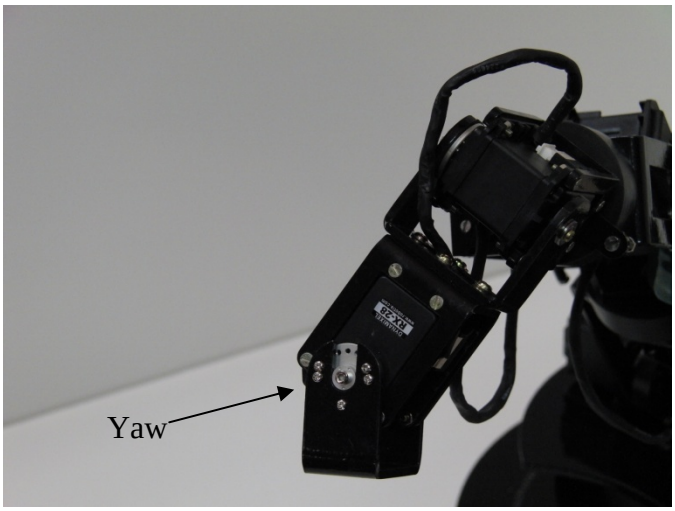
	***1) Box packaging of Cyton (offset view & unpacked)***
	***2) Box packaging and Contents (front view & unpacked)***

	***3) Box packaging and Contents (top view & packed)***
	***4) Cyton Arm, Wiring, Power Source (Front View & Power Off Position)***
	***5) Cyton Arm, Wiring Power Source & Dongle (Off set view & Zero Position)***

	***6) Cyton Arm, Wiring, Power Source & Dongle (Side view & Zero Position)***
	***7) Cyton Base, Wiring, Power Source (Off set & closeup view)***
	***8) Cyton Base, Wiring, Power Source & USB2 Dynamixel (offset & long shot view)***

	***9) Cyton USB2 Dynamixel (offset & closeup view)***
	***10) Cyton Arm Assembly (Zero Position & long shot view)***
	***11) Cyton Shoulder Roll & Pitch (Zero position & closeup view)***
	12) Cyton Elbow

	***(Zero position & closeup view)***
	***13) Cyton Wrist Roll (Zero position & closeup view)***
	***14) Cyton Wrist Pitch (125^0 position & closeup view)***
	15) Cyton Wrist Yaw

	***(35^0 position & closeup view)***
	***16) Cyton Wrist Yaw (125^0 position & offset view)***
	17) Elbow Roll & Pitch Assembly (Side & closeup view)