

# ScorBot Toolbox Quick Reference Guide

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## Units

Unless otherwise noted, the units used by the ScorBot Toolbox functions will be millimeters for linear measures, radians for angles, or unitless values (e.g. for elements of a rotation matrix).

## Common Variables

The most widely used variables in the ScorBot Toolbox are:

- **BSEPR** - a 1x5 array containing the joint angles of ScorBot in radians.
  - `BSEPR = ...`  
`[BaseAngle, ShoulderAngle, ElbowAngle, WristPitch, WristRoll];`
  - `BSEPR(1)` - Base Joint Angle (radians)
  - `BSEPR(2)` - Shoulder Joint Angle (radians)
  - `BSEPR(3)` - Elbow Joint Angle (radians)
  - `BSEPR(4)` - Wrist Pitch Angle (radians)
  - `BSEPR(5)` - Wrist Roll Angle (radians)
- **XYZPR** - a 1x5 array containing the position and orientation of the ScorBot end-effector in millimeters (for position) and radians (for orientation).
  - `XYZPR = ...`  
`[EndEffectorX, EndEffectorY, EndEffectorZ, ... % (mm)`  
`EndEffectorPitch, EndEffectorRoll]; % (radians)`
  - `XYZPR(1)` - X-position of the end-effector relative to the base frame (millimeters)
  - `XYZPR(2)` - Y-position of the end-effector relative to the base frame (millimeters)
  - `XYZPR(3)` - Z-position of the end-effector relative to the base frame (millimeters)
  - `XYZPR(4)` - End-effector pitch relative to the base frame (radians)
  - `XYZPR(5)` - End-effector wrist roll relative to a body-fixed frame\* (radians)

*\*NOTE: Wrist roll, and end-effector wrist roll are equal (`BSEPR(5) = XYZPR(5)`)*
- **Pose** or **H** - a 4x4 array containing translation and rotation information (in a homogeneous transformation) describing the position and orientation of the ScorBot end-effector
- **Grip** - scalar value describing the grip state of the ScorBot end-effector. Valid grip values range from 0 (fully closed) to 70 (fully open) millimeters
- **Confirm** - binary value ("true" or "false") indicating whether a specific function was executed successfully.

## Basic Function Naming Convention

### ScorBot Hardware Interaction

Most functions contained within the ScorBot Toolbox adhere to the following naming convention:

- `ScorGet*` - gets some measurement or quantity from the ScorBot (e.g. `ScorGetGripper` returns the amount the gripper is open in millimeters).
- `ScorSet*` - sets some measurement or quantity of the ScorBot (e.g. `ScorSetGripper(50)` sets the opening of the gripper to 50 millimeters).
- `ScorIs*` - returns a binary value describing some element of ScorBot (e.g. `ScorIsMoving` returns a “true” if ScorBot is moving, and a “false” otherwise).

### ScorBot Conversions

Conversions related to ScorBot and ScorBot kinematics adhere to the following naming convention:

- `Scor*2*` - converts the first parameter to the second (e.g. `ScorBSEPR2XYZPR(BSEPR)` returns the XYZPR values associated with the input BSEPR values).

### ScorBot Simulation

Both simplified and advanced kinematic simulations of ScorBot are available within the ScorBot Toolbox and generally adhere to the following naming convention:

- `ScorSimGet*` - gets some measurement or quantity from the ScorBot simulation (e.g. `ScorSimGetBSEPR(simObj)` returns the BSEPR values associated with the simulation specified using the variable `simObj`).
- `ScorSimSet*` - sets some measurement or quantity of the ScorBot simulation (e.g. `ScorSimSetBSEPR(simObj, BSEPR)` sets the BSEPR values of the simulation specified using the variable `simObj`).

## Quick Reference for Commonly Used Functions

### ScorBot Hardware Interaction

#### Initialization and Shutdown

Function	Description and Syntax Example(s)
Initialization and Shutdown	
ScorInit	Loads DLLs, sets up USB communication, and enables control of ScorBot.  <code>ScorInit;</code> <code>confirm = ScorInit;</code>
ScorHome	Home the ScorBot to calibrate absolute joint measurements.  <code>ScorHome;</code> <code>confirm = ScorHome;</code>
ScorSafeShutdown	Move the ScorBot to the home position, disables control, and unloads libraries.  <code>ScorSafeShutdown;</code> <code>confirm = ScorSafeShutdown;</code>

#### General Utilities

General Utilities	
ScorGoHome	Move ScorBot back to the home configuration.  <code>ScorGoHome;</code> <code>confirm = ScorGoHome;</code>
ScorGetControl	Get the current control state of ScorBot (“On” is ScorBot’s control is enabled or “Off” is ScorBot’s control is disabled).  <code>cState = ScorGetControl;</code>
ScorSetControl	Enable or Disable control of ScorBot.  <code>ScorSetControl('On');</code> <code>ScorSetControl('Off');</code> <code>confirm = ScorSetControl( );</code>

## Get Movement Speed

Get Movement Speed	
ScorGetSpeed	<p>Get the current joint speed as a percent of maximum (from 0 to 100). If a move time is set, this function returns an empty set. This remains fixed until a new speed or move time is declared.</p> <p>Note: Changes made to the speed using the Teach Pendant do not update the speed recorded in the toolbox. Speed must be updated using <code>ScorSetSpeed</code> for this function to work correctly.</p> <pre>Speed = ScorGetSpeed;</pre>
ScorGetMoveTime	<p>Get the time for moves (from start to finish) in seconds. If a speed is set, this function returns an empty set. This remains fixed until a new speed or move time is declared.</p> <p>Note: Changes made to the move time using the Teach Pendant do not update the move time recorded in the toolbox. Move time must be updated using <code>ScorSetMoveTime</code> for this function to work correctly.</p> <pre>MoveTime = ScorGetMoveTime;</pre>

## Set Movement Speed

Set Movement Speed	
ScorSetSpeed	<p>Set the allowable joint speed to a percent of maximum (from 0 to 100). This remains fixed until a new speed or move time is declared.</p> <pre>ScorSetSpeed(Speed); confirm = ScorSetSpeed( );</pre>
ScorSetMoveTime	<p>Set the total time for moves (from start to finish) to a value in seconds. This remains fixed until a new speed or move time is declared.</p> <pre>ScorSetMoveTime(MoveTime); confirm = ScorSetMoveTime( );</pre>

## Arm Measurements

Arm Measurements	
ScorGetBSEPR	Get a 1x5 array containing the current joint angles of ScorBot in radians.  BSEPR = ScorGetBSEPR;
ScorGetXYZPR	Get a 1x5 array containing the current end-effector position and orientation of ScorBot in millimeters (for position) and radians (for orientation).  XYZPR = ScorGetXYZPR;
ScorGetPose	Get a 4x4 array containing the homogeneous transformation describing the end-effector position and orientation relative to the base frame of ScorBot.  H = ScorGetPose;

## Absolute Arm Movements

Absolute Arm Movements	
ScorSetBSEPR	Set the ScorBot joint configuration (in radians) to the values specified in a 1x5 array.  ScorSetBSEPR(BSEPR); ScorSetBSEPR(BSEPR, 'MoveType', 'LinearTask'); ScorSetBSEPR(BSEPR, 'MoveType', 'LinearJoint'); confirm = ScorSetBSEPR( );
ScorSetXYZPR	Set the ScorBot end-effector position (in millimeters) and orientation (in radians) to the values specified in a 1x5 array.  ScorSetXYZPR(XYZPR); ScorSetXYZPR(XYZPR, 'MoveType', 'LinearTask'); ScorSetXYZPR(XYZPR, 'MoveType', 'LinearJoint'); confirm = ScorSetXYZPR( );
ScorSetPose	Set the ScorBot end-effector position and orientation using a 4x4 homogeneous transformation specified relative to the ScorBot base.  ScorSetPose(H); ScorSetPose(H, 'MoveType', 'LinearTask'); ScorSetPose(H, 'MoveType', 'LinearJoint'); confirm = ScorSetPose( );

## Relative Arm Movements

Relative Arm Movements	
ScorSetDeltaBSEPR	<p>Set the ScorBot joint configuration (in radians) relative to the current joint configuration.</p> <pre>ScorSetDeltaBSEPR(dBSEPR); ScorSetDeltaBSEPR(dBSEPR, 'MoveType', 'LinearTask'); ScorSetDeltaBSEPR(dBSEPR, 'MoveType', 'LinearJoint'); confirm = ScorSetDeltaBSEPR( );</pre>
ScorSetDeltaXYZPR	<p>Set the ScorBot end-effector position (in millimeters) and orientation (in radians) relative to the current end-effector position and orientation.</p> <pre>ScorSetDeltaXYZPR(dXYZPR); ScorSetDeltaXYZPR(dXYZPR, 'MoveType', 'LinearTask'); ScorSetDeltaXYZPR(dXYZPR, 'MoveType', 'LinearJoint'); confirm = ScorSetDeltaXYZPR( );</pre>
ScorSetDeltaPose	<p>Set the ScorBot end-effector position and orientation using a 4x4 homogeneous transformation specified relative to the current position and orientation of the ScorBot end-effector.</p> <pre>ScorSetDeltaPose(dH); ScorSetDeltaPose(dH, 'MoveType', 'LinearTask'); ScorSetDeltaPose(dH, 'MoveType', 'LinearJoint'); confirm = ScorSetDeltaPose( );</pre>

## Undo Arm Movements

Gripper Measurements	
ScorSetUndo	<p>Set the ScorBot to the previously set joint configuration.</p> <pre>ScorSetUndo; confirm = ScorSetUndo;</pre>

## Gripper Measurements

Gripper Measurements	
ScorGetGripper	<p>Get the current gripper state of the ScorBot in millimeters. The gripper state is measured by the distance between the gripper fingers.</p> <pre>grip = ScorGetGripper;</pre>
ScorGetGripperOffset	<p>Get the approximate offset between the gripper fingertip and the end-effector frame along the z-axis.</p> <p>Note: This value changes as the gripper is opened and closed due to the four-bar linkage design of the gripper fingers.</p> <pre>gOffset = ScorGetGripperOffset;</pre>



## Gripper Movements

Gripper Movements	
ScorSetGripper	<p>Set the current gripper state of the ScorBot in millimeters. The gripper state is measured by the distance between the gripper fingers.</p> <pre>ScorSetGripper(grip); ScorSetGripper('Open'); ScorSetGripper('Close'); confirm = ScorSetGripper( );</pre>

## Movement Utilities

Movement Utilities	
ScorIsMoving	<p>Check if ScorBot is currently executing a move. Returns a “true” if ScorBot is moving, and a “false” otherwise.</p> <pre>bin = ScorIsMoving;</pre>
ScorWaitForMove	<p>Wait for ScorBot to complete a move.</p> <p>NOTE: This is a very powerful function that enables data collection and/or visualization during movements of the ScorBot in addition to blocking MATLAB from executing commands while ScorBot is moving.</p> <p>NOTE: When collecting waypoint information using <code>ScorGetBSEPR</code> or <code>ScorGetXYZPR</code>, adding <code>pause(2)</code> following <code>ScorWaitForMove</code> will ensure the ScorBot has fully executed the move and come to rest prior to acquiring the point.</p> <p><b>Basic Functionality:</b></p> <pre>ScorWaitForMove; confirm = ScorWaitForMove;</pre> <p><b>Basic Syntax:</b></p> <pre>ScorWaitForMove('PropertyName','PropertyValue');</pre> <p><b>Plotting/Visualization:</b></p> <pre>ScorWaitForMove('XYZPRPlot','On'); ScorWaitForMove('BSEPRPlot','On'); ScorWaitForMove('RobotAnimation','On'); ScorWaitForMove('XYZPRPlot','On',...     'BSEPRPlot','On','RobotAnimation','On'); [~,h] = ScorWaitForMove(___, 'PlotHandle',h);</pre> <p><b>Data Collection:</b></p> <pre>[confirm,~,data] = ...     ScorWaitForMove('CollectData','On');</pre>

## Teach Pendant Utilities

Teach Pendant Utilities	
ScorGetPendantMode	Get the current teach pendant mode ('Auto' or 'Teach').  <code>pMode = ScorGetPendantMode;</code>
ScorSetPendantMode	Set the teach pendant mode (through a user prompt).  <code>ScorSetPendantMode('Auto');</code> <code>ScorSetPendantMode('Teach');</code> <code>confirm = ScorSetPendantMode( );</code>

## Controller Peripherals

Teach Pendant Utilities	
ScorSetDigitalOutput	Set the 8-channel digital output of the controller.  <code>ScorSetDigitalOutput(i,state);</code> <code>ScorSetDigitalOutput(v);</code> <code>confirm = ScorSetDigitalOutput( );</code>

## ScorBot Conversions

### BSEPR Conversions

Function	Description and Syntax Example(s)
BSEPR Conversions	
ScorBSEPR2XYZPR	Convert a 1x5 array defining a ScorBot joint configuration (in radians) to a 1x5 array defining the associated ScorBot end-effector position (in millimeters) and orientation (in radians).  <code>XYZPR = ScorBSEPR2XYZPR(BSEPR);</code>
ScorBSEPR2Pose	Convert a 1x5 array defining a ScorBot joint configuration (in radians) to a 4x4 homogeneous transformation defining the associated ScorBot end-effector position (in millimeters) and orientation.  <code>H = ScorBSEPR2Pose(BSEPR);</code>

## XYZPR Conversions

XYZPR Conversions	
ScorXYZPR2BSEPR	<p>Convert a 1x5 array defining a ScorBot end-effector position (in millimeters) and orientation (in radians) to one or more 1x5 arrays defining the associated ScorBot joint configuration (in radians).</p> <p>NOTE: The default returned solution is associated with the elbow-up configuration of ScorBot.</p> <p>NOTE: Multiple solutions are returned as a cell array.</p> <pre>BSEPR = ScorXYZPR2BSEPR (XYZPR) ; BSEPR = ScorXYZPR2BSEPR (____, 'ElbowUpSolution') ; BSEPR = ScorXYZPR2BSEPR (____, 'ElbowDownSolution') ; BSEPRs = ScorXYZPR2BSEPR (____, 'AllSolutions')</pre>
ScorXYZPR2Pose	<p>Convert a 1x5 array defining a ScorBot end-effector position (in millimeters) and orientation (in radians) to one or more 4x4 homogeneous transformation defining the associated ScorBot end-effector position (in millimeters) and orientation.</p> <p>NOTE: Multiple solutions are returned as a cell array.</p> <pre>H = ScorXYZPR2BSEPR (XYZPR) ; H = ScorXYZPR2BSEPR (____, 'AllSolutions')</pre>

## End-effector Frame Conversions

End-effector Frame Conversions	
ScorPose2BSEPR	<p>Convert a 4x4 homogeneous transformation defining the associated ScorBot end-effector position (in millimeters) and orientation to one or more 1x5 arrays defining the associated ScorBot joint configuration (in radians).</p> <p>NOTE: The default returned solution is associated with the elbow-up configuration of ScorBot.</p> <p>NOTE: Multiple solutions are returned as a cell array.</p> <pre>BSEPR = ScorPose2BSEPR (H) ; BSEPR = ScorPose2BSEPR (____, 'ElbowUpSolution') ; BSEPR = ScorPose2BSEPR (____, 'ElbowDownSolution') ; BSEPRs = ScorPose2BSEPR (____, 'AllSolutions')</pre>
ScorPose2XYZPR	<p>Convert a 4x4 homogeneous transformation defining the associated ScorBot end-effector position (in millimeters) and orientation to one or more 1x5 arrays defining a ScorBot end-effector position (in millimeters) and orientation (in radians)</p> <p>NOTE: Multiple solutions are returned as a cell array.</p> <pre>XYZPR = ScorPose2XYZPR (H) ; XYZPRs = ScorPose2XYZPR (____, 'AllSolutions')</pre>

## General Conversions

General Conversions	
rad2deg	Convert a scalar value or array of values from radians to degrees.  <code>deg = rad2deg(rad);</code>
deg2rad	Convert a scalar value or array of values from degrees to radians.  <code>rad = deg2rad(deg);</code>

## ScorBot Simulation

### Initialization

Function	Description and Syntax Example(s)
Initialization	
ScorSimInit	Initialize the basic ScorBot kinematic simulation containing a basic representation of the manipulator and relevant reference frames.  <code>simObj = ScorSimInit;</code>

### General Utilities

General Utilities	
ScorSimPatch	Add a visualization of ScorBot to the basic ScorBot simulation.  <code>ScorSimPatch(simObj);</code>
ScorSimGoHome	Move the ScorBot simulation to the home position.  <code>ScorSimGoHome(simObj);</code>

### Arm Measurements

Arm Measurements	
ScorSimGetBSEPR	Get a 1x5 array containing the current joint angles of the ScorBot simulation in radians.  <code>BSEPR = ScorSimGetBSEPR(simObj);</code>
ScorSimGetXYZPR	Get a 1x5 array containing the current end-effector position and orientation of the ScorBot simulation in millimeters (for position) and radians (for orientation).  <code>XYZPR = ScorSimGetXYZPR(simObj);</code>
ScorSimGetPose	Get a 4x4 array containing the homogeneous transformation describing the end-effector position and orientation relative to the base frame of ScorBot.  <code>H = ScorSimGetPose(simObj);</code>

## Absolute Arm Movements

Absolute Arm Movements	
ScorSimSetBSEPR	<p>Set the ScorBot simulation joint positions (in radians) to the values specified in a 1x5 array.</p> <pre>ScorSimSetBSEPR(simObj, BSEPR);</pre>
ScorSimSetXYZPR	<p>Set the ScorBot simulation end-effector position (in millimeters) and orientation (in radians) to the values specified in a 1x5 array.</p> <pre>ScorSimSetXYZPR(simObj, XYZPR);</pre>
ScorSimSetPose	<p>Set the ScorBot simulation end-effector position and orientation using a 4x4 homogeneous transformation specified relative to the ScorBot base.</p> <pre>ScorSimSetPose(simObj, H);</pre>

## Relative Arm Movements

Relative Arm Movements	
ScorSimSetDeltaBSEPR	<p>Set the ScorBot simulation joint positions (in radians) relative to the current joint positions.</p> <pre>ScorSimSetDeltaBSEPR(simObj, dBSEPR);</pre>
ScorSimSetDeltaXYZPR	<p>Set the ScorBot simulation end-effector position (in millimeters) and orientation (in radians) relative to the current end-effector position and orientation.</p> <pre>ScorSimSetDeltaXYZPR(simObj, dXYZPR);</pre>
ScorSimSetDeltaPose	<p>Set the ScorBot simulation end-effector position and orientation using a 4x4 homogeneous transformation specified relative to the current position and orientation of ScorBot.</p> <pre>ScorSimSetDeltaPose(simObj, dH);</pre>

## Gripper Measurements

Gripper Measurements	
ScorSimGetGripper	<p>Get the current gripper state of the ScorBot simulation in millimeters. The gripper state is measured by the distance between the gripper fingers.</p> <pre>grip = ScorGetGripper(simObj);</pre>
ScorSimGetGripperOffset	<p>Get the approximate offset between the gripper fingertip and the end-effector frame along the z-axis.</p> <p>Note: This value changes as the gripper is opened and closed due to the four-bar linkage design of the gripper fingers.</p> <pre>gOffset = ScorSimGetGripperOffset;</pre>

## Gripper Movements

Gripper Movements	
ScorSimSetGripper	<p>Set the current gripper state of the ScorBot simulation in millimeters. The gripper state is measured by the distance between the gripper fingers.</p> <pre>ScorSimSetGripper(simObj,grip); ScorSimSetGripper(simObj,'Open'); ScorSimSetGripper(simObj,'Close');</pre>

## Simulation Teach User Interface

Simulation Teach User Interface	
ScorSimTeachBSEPR	<p>Set the ScorBot simulation to BSEPR teach mode. This enables joint-level control of the ScorBot simulation using a prescribed set of keys.</p> <pre>ScorSimTeachBSEPR(simObj);</pre>
ScorSimTeachXYZPR	<p>Set the ScorBot simulation to XYZPR teach mode. This enables control of the ScorBot simulation end-effector position and orientation using a prescribed set of keys.</p> <pre>ScorSimTeachXYZPR(simObj);</pre>

## ScorBot Network Operation

### Initialization

Function	Description and Syntax Example(s)
Initialization	
ScorInitSender	<p>Initializes a UDP server for transmitting ScorBot information to a remote client. The server is specified using a port (recommended between 31000 and 32000) and IP address.</p> <pre>udpS = ScorInitSender(port,IP);</pre>
ScorInitReceiver	<p>Initializes a UDP receiver to receive ScorBot information from a remote server. The receiver is tied to a designated port that must match the port of the corresponding sender. This currently uses a default IP of 0.0.0.0 allowing data to be accepted from any remote IP address.</p> <pre>udpR = ScorInitReceiver(port);</pre>

## General Utilities

General Utilities	
ScorSendBSEPRG	<p>Sends the current or a specified BSEPR value and gripper state to a designated UDP server.</p> <pre>ScorSendBSEPRG(udpS); ScorSendBSEPRG(udpS,BSEPR); ScorSendBSEPRG(udpS,BSEPR,grip);</pre>
ScorReceiveBSEPRG	<p>Receives a BSEPR value and gripper state from a designated UDP receiver object.</p> <pre>[BSEPR,grip] = ScorReceiveBSEPRG(udpR);</pre>

## Update and Version Utilities

Update and Version Utilities	
ScorUpdate	<p>Update the ScorBot Toolbox to the latest version using an active internet connection.</p> <p>Note: This function requires that MATLAB be run in Administrator mode.</p> <p>Note: The update process includes a basic motion test of the ScorBot for operating systems that support ScorBot Controller interaction.</p> <pre>ScorUpdate;</pre>
ScorVer	<p>Check the current version of the ScorBot Toolbox.</p> <pre>ScorVer; verStruct = ScorVer;</pre>

## Basic Hardware Example

```
%% Initialize and home ScorBot
% Note: You only need to run this once! If you already ran ScorInit and
% ScorHome, you do not need to run them again.
ScorInit;
ScorHome;

%% Define desired waypoints as end-point XYZPR positions/orientations
XYZPRs(1,:) = [500.000,-200.000,570.000,0.000,-2*pi/2];
XYZPRs(2,:) = [500.000, 200.000,570.000,0.000,-1*pi/2];
XYZPRs(3,:) = [500.000, 200.000,270.000,0.000, 0*pi/2];
XYZPRs(4,:) = [500.000,-200.000,270.000,0.000, 1*pi/2];
XYZPRs(5,:) = [500.000,-200.000,570.000,0.000, 2*pi/2];

%% Convert XYZPR waypoints to BSEPR joint configurations
for wpnt = 1:size(XYZPRs,1)
    BSEPRs(wpnt,:) = ScorXYZPR2BSEPR(XYZPRs(wpnt,:));
end

%% Set speed and initialize arm configuration
ScorSetSpeed(100);
ScorSetXYZPR(XYZPRs(1,:));
ScorWaitForMove;

%% Move through end-point XYZPR positions/orientations
h = []; % initialize variable for plot handle
fprintf('Demonstrating XYZPR move with Animation Plots.\n');
for wpnt = 1:size(XYZPRs,1)
    ScorSetXYZPR(XYZPRs(wpnt,:));
    [~,h] = ScorWaitForMove('RobotAnimation','On','PlotHandle',h);
    if wpnt == 1
        title(h.RobotAnimation.Sim.Axes,'Movements using ScorSetXYZPR');
        ScorSimPatch(h.RobotAnimation.Sim);
    end
end
plot3(h.RobotAnimation.Sim.Axes,XYZPRs(1:4,1),XYZPRs(1:4,2),XYZPRs(1:4,3),'*k');

%% Open Gripper
ScorSetGripper('Open');
ScorWaitForMove;

%% Move through BSEPR joint configurations
fprintf('Demonstrating BSEPR move with Animation Plots.\n');
title(h.RobotAnimation.Sim.Axes,'Movements using ScorSetBSEPR');
for wpnt = 1:size(BSEPRs,1)
    ScorSetBSEPR(BSEPRs(wpnt,:));
    [~,h] = ScorWaitForMove('RobotAnimation','On','PlotHandle',h);
end
plot3(h.RobotAnimation.Sim.Axes,XYZPRs(1:4,1),XYZPRs(1:4,2),XYZPRs(1:4,3),'*k');

%% Open Gripper
ScorSetGripper('Close');
ScorWaitForMove;

%% Safe shutdown
% Note: You only need to run this when you are finished using MATLAB or
% finished using ScorBot! If you run ScorSafeShutdown and still need to use
% ScorBot, you will need to reinitialize using ScorInit, and rehome using
% ScorHome.
ScorSafeShutdown;
```



## Basic Simulation Example

```
%% Initialize simulation and visualize ScorBot
% Note: Each time you run this, you will create a new simulation figure
simObj = ScorSimInit;
ScorSimPatch(simObj);

%% Define desired waypoints as end-point XYZPR positions/orientations
XYZPRs(1,:) = [500.000,-200.000,570.000,0.000,0.000];
XYZPRs(2,:) = [500.000, 200.000,570.000,0.000,0.000];
XYZPRs(3,:) = [500.000, 200.000,270.000,0.000,0.000];
XYZPRs(4,:) = [500.000,-200.000,270.000,0.000,0.000];
XYZPRs(5,:) = XYZPRs(1,:);

%% Convert XYZPR waypoints to BSEPR joint configurations
for wpnt = 1:size(XYZPRs,1)
    BSEPRs(wpnt,:) = ScorXYZPR2BSEPR(XYZPRs(wpnt,:));
end

%% Interpolate between waypoint for animation
n = 50;
XYZPR_all = [];
BSEPR_all = [];
for jnt = 1:size(XYZPRs,2)
    for wpnt = 1:size(XYZPRs,1)-1
        XYZPR_all(n*(wpnt-1)+1:n*(wpnt-1)+n,jnt) = ...
            linspace(XYZPRs(wpnt,jnt),XYZPRs(wpnt+1,jnt),n);
        BSEPR_all(n*(wpnt-1)+1:n*(wpnt-1)+n,jnt) = ...
            linspace(BSEPRs(wpnt,jnt),BSEPRs(wpnt+1,jnt),n);
    end
end

%% Move through end-point XYZPR positions/orientations
plt = plot3(simObj.Axes,0,0,0,'.m'); % initialize waypoint plot handle
clear xData yData zData
fprintf('Demonstrating simulated XYZPR move.\n');
title(simObj.Axes,'Movements using ScorSimSetXYZPR (Magenta)');
for ipnt = 1:size(XYZPR_all,1)
    ScorSimSetXYZPR(simObj,XYZPR_all(ipnt,:));
    XYZPR = ScorSimGetXYZPR(simObj);
    xData(ipnt) = XYZPR(1);
    yData(ipnt) = XYZPR(2);
    zData(ipnt) = XYZPR(3);
    set(plt,'xData',xData,'yData',yData,'zData',zData);
end
plot3(simObj.Axes,XYZPRs(1:4,1),XYZPRs(1:4,2),XYZPRs(1:4,3),'ok');

%% Move through BSEPR joint configurations
plt = plot3(simObj.Axes,0,0,0,'.c'); % initialize waypoint plot handle
clear xData yData zData
fprintf('Demonstrating simulated BSEPR move.\n');
title(simObj.Axes,'Movements using ScorSimSetBSEPR (Cyan)');
for ipnt = 1:size(BSEPR_all,1)
    ScorSimSetBSEPR(simObj,BSEPR_all(ipnt,:));
    XYZPR = ScorSimGetXYZPR(simObj);
    xData(ipnt) = XYZPR(1);
    yData(ipnt) = XYZPR(2);
    zData(ipnt) = XYZPR(3);
    set(plt,'xData',xData,'yData',yData,'zData',zData);
end
plot3(simObj.Axes,XYZPRs(1:4,1),XYZPRs(1:4,2),XYZPRs(1:4,3),'+k');
```

## References

- [1] J. Esposito, C. Wick, & K. Knowles, "Matlab Toolbox for the Intelitek Scorbob: An open source robotics education library," in Proc. American Society of Engineering Education Annual Conference, Vancouver, BC, 2011.
- [2] C. Wick, J. Esposito, & K. Knowles, (2012, Aug 25) Matlab Toolbox for the Intelitek Scorbob (MTIS) [Online]. available: <https://www.usna.edu/Users/weapsys/esposito/scorbob-matlab.php>