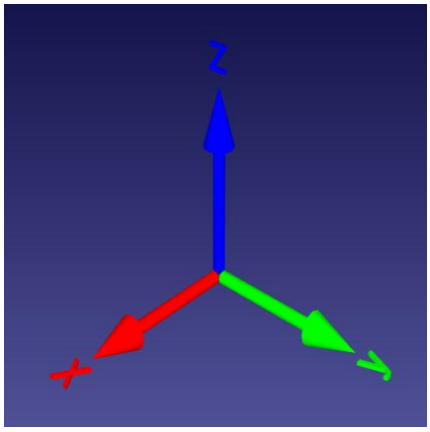
1 Coordinate Frames

In robotics or with any mechanical system, coordinate frames act as a key element in defining pose information with respect to their own local reference frame or any other. There exist numerous frames such as global reference frame or universal reference frame, base reference frame, joint reference frame, end-effector reference frame, object reference frame etc. The reference frames are attached to any object of interest and move along with the object or vice versa. Reference frames are mostly defined in 3D space, but for understanding it can be reduced to 2D space. As in 3D space, any reference frame can experience six types of motions, three dedicated to translation, and the rest for rotation.

1.1 Reference Frame

1.1.1 Translation

The position information of the desired reference frame can be updated either from the configuration panel or by pressing ALT key and performing the desired action. The frame can be translated independently along the X, Y, and Z axes and in the XY, YZ, XZ plane.



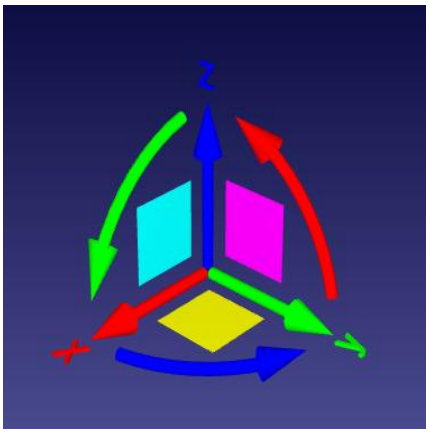
Note

In order to precisely place the reference frame at the desired X, Y, Z location in 3D space, it is recommendable to use configuration panel.

1.1.2 Rotation

Similar to translation, rotation can also be performed in two possible ways: through the configuration panel or by pressing ALT key. On pressing ALT key,

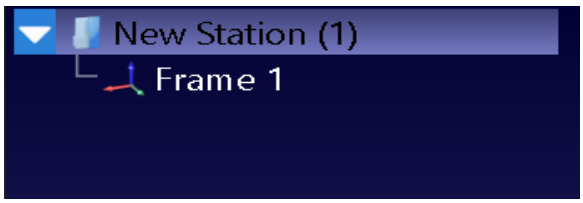
arrows appear that gives the information along which axis, rotation is applied. Same color code is used as the axis to specify the rotation, moreover the positive direction of motion can also be learned from the arrow direction. It is possible to independently perform the orientation operation, the order of the orientation can be critical if the orientation is applied with respect to some other reference frame.



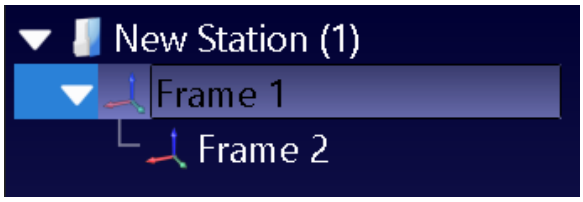
1.1.3 Add Reference Frame

A reference frame can be easily introduced by either accessing menu option Program → Add Reference Frame or from the toolbar  .

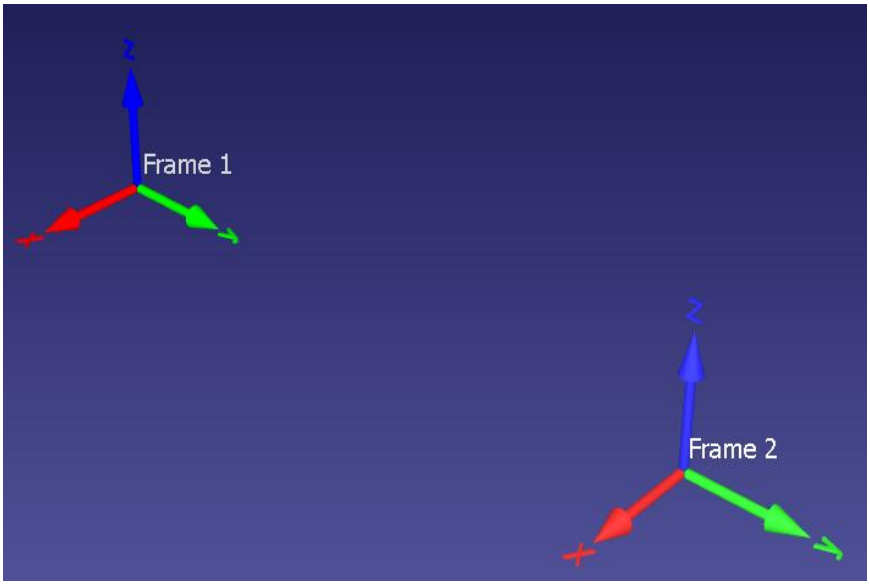
A new reference frame can be introduced to the workstation in another manner. If we right-click on the New Station (1) and add a reference frame, a new reference frame named Frame 1 is defined at the Universal reference frame.



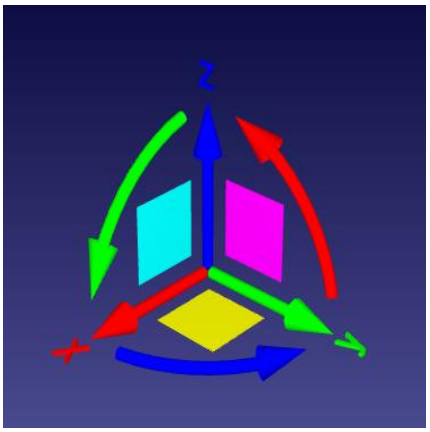
If you keep on adding new reference frames to the New Station (1), they all become children of New Station (1), defined as the same level as Frame 1. Instead, if you select Frame 1 and add a reference frame, a new frame, Frame 2, is defined as a child of Frame 1 and will move along with its parent.



By default, every newly added frame is positioned concerning the parent frame at (0, 1000, 0, 0, 0, 0).



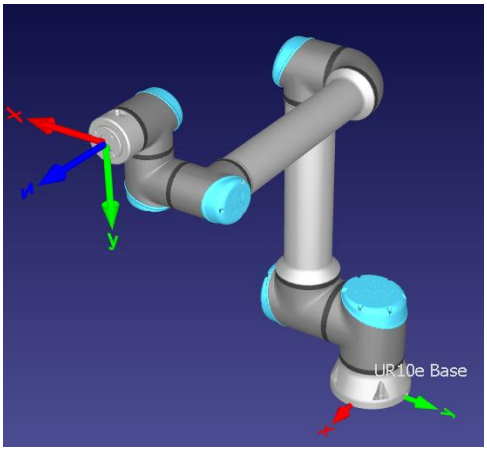
If you wish to modify the pose of any frame, double click on the frame from the tree or directly the frame in the scene to display frame details, from where you can edit the frame's name, its visibility, referencing, and pose. Another way of changing the pose of the frame is to press ALT, and it will change the display of the frame as



With the ALT key pressed, you can change the position and orientation of the frame more conveniently. But, to have exact pose parameters, it is suggested to use the Frame details window.

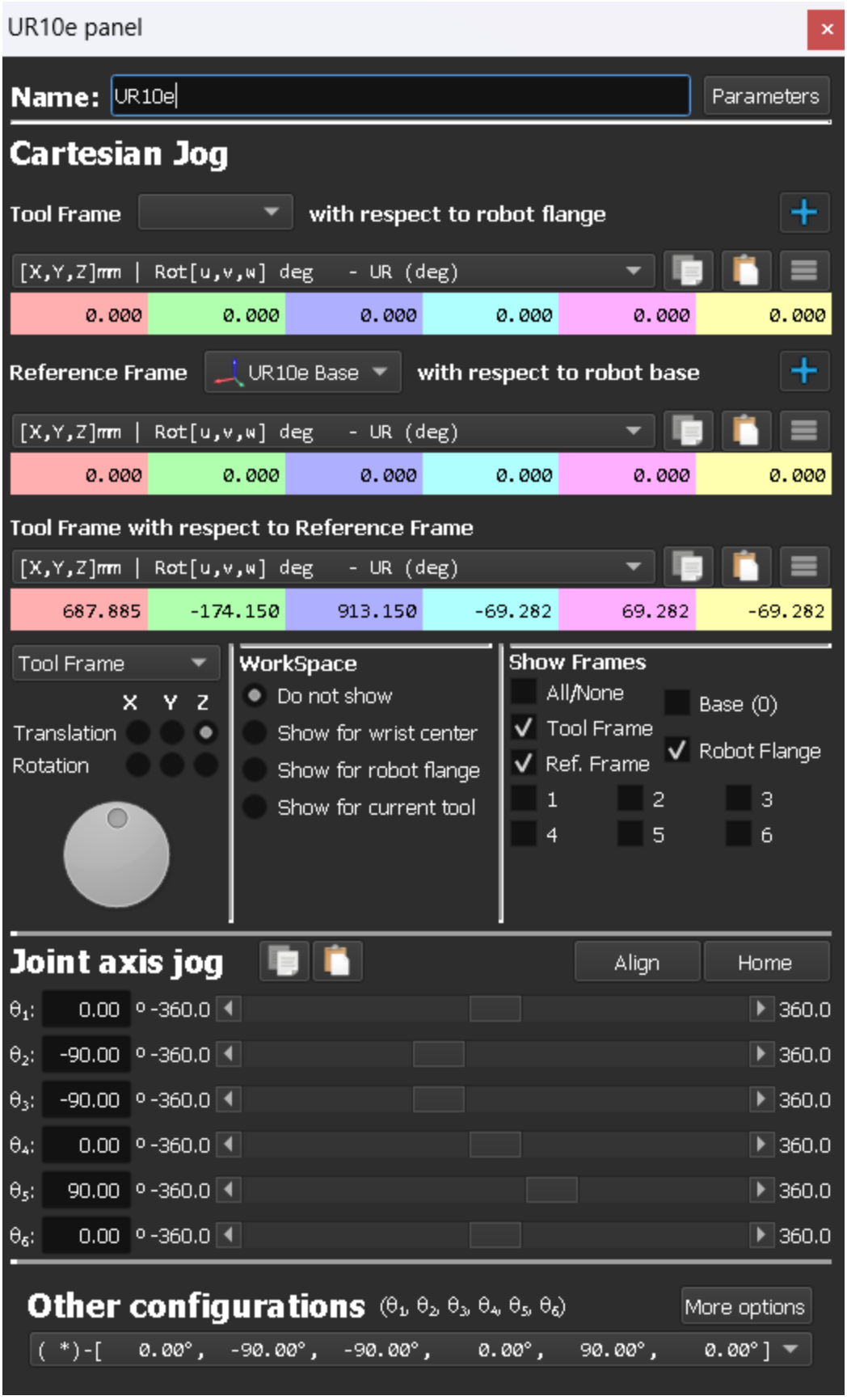
1.1.4 Basic positioning of the frames

The position of the frame is better understandable with some manipulators. For this example, we add UR10e robot from the RoboDK library



By default, it will be referenced to its own base reference frame; hence, if you move the base reference frame, whole body will move. In addition, a reference frame can be observed at the tip of the robot to easily control the movements of the tip. It is a preferred way for performing pick and place operations or similar.

If we double click either robot's body or its reference name from the tree, a dialog box will open as


UR10e panel
Name: UR10e
Parameters
Cartesian Jog
Tool Frame
with respect to robot flange
[X,Y,Z]mm | Rot[u,v,w] deg - UR (deg)
0.000 0.000 0.000 0.000 0.000 0.000
Reference Frame
UR10e Base
with respect to robot base
[X,Y,Z]mm | Rot[u,v,w] deg - UR (deg)
0.000 0.000 0.000 0.000 0.000 0.000
Tool Frame with respect to Reference Frame
[X,Y,Z]mm | Rot[u,v,w] deg - UR (deg)
687.885 -174.150 913.150 -69.282 69.282 -69.282
Tool Frame
X Y Z
Translation
Rotation
WorkSpace
Do not show
Show for wrist center
Show for robot flange
Show for current tool
Show Frames
All/None
Base (0)
Tool Frame
Robot Flange
Ref. Frame
1 2 3
4 5 6
Joint axis jog
Align
Home
θ1: 0.00 ° -360.0 360.0
θ2: -90.00 ° -360.0 360.0
θ3: -90.00 ° -360.0 360.0
θ4: 0.00 ° -360.0 360.0
θ5: 90.00 ° -360.0 360.0
θ6: 0.00 ° -360.0 360.0
Other configurations (θ1, θ2, θ3, θ4, θ5, θ6)
More options
(*)-[0.00°, -90.00°, -90.00°, 0.00°, 90.00°, 0.00°]

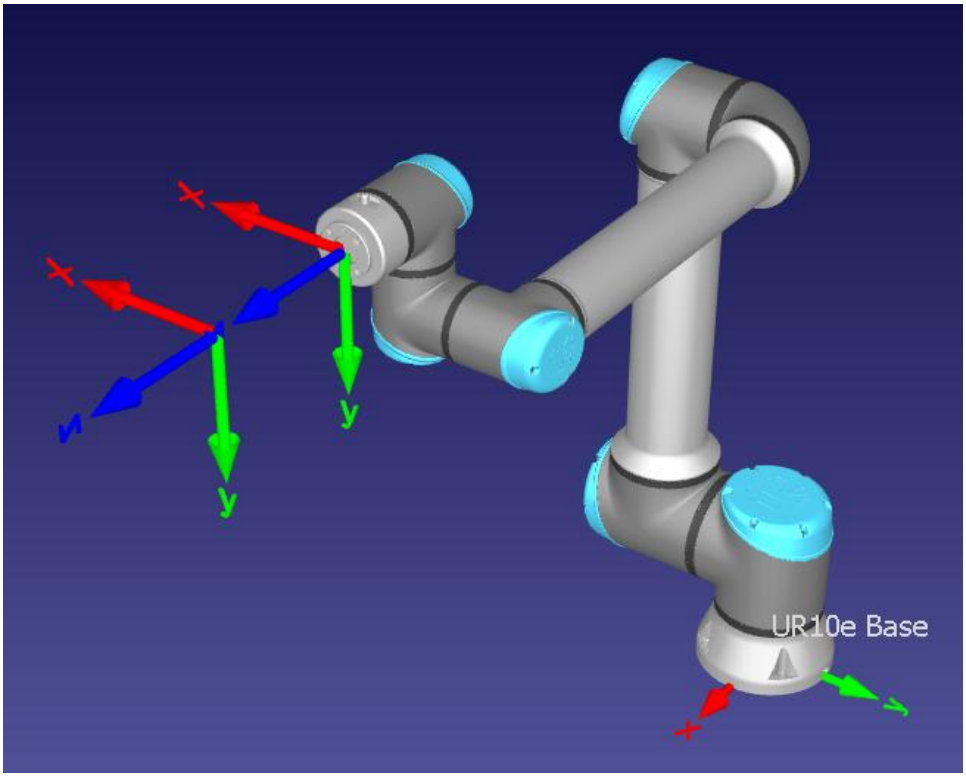
Let’s us try to decode it from top to bottom.

Naming:

The robot can be renamed.

Cartesian Jog:

Tool frame with respect to the robot flange is (0, 0, 0, 0, 0, 0) means that they are both positioned at the same place. Let us try to change Z to 200 mm.



As we can observe, that now tool frame is now displaced concerning the flange.

The robot’s global reference frame is positioned exactly at the base reference frame, and hence no displacement along the X, Y, and Z axes. Similar to the tool frame, if we wish to change the origin of the reference frame, we can do so.

The tool frame with respect to the reference frame displays the pose of the tool concerning the reference frame, a base frame. This pose is obtained by calculating the forward kinematics of the manipulator.

The current pose of the robot can be referenced as the Home Position obtained when joint movements are (0, -90, -90, 0, 90, 0). The pose of the tool can be changed by either manipulating joint movements or directly from the tool's reference pose.

If you accidentally make some unwanted changes and revert to the original pose, there is a 'Home' button in the Joint axis jog section to return to the home position.

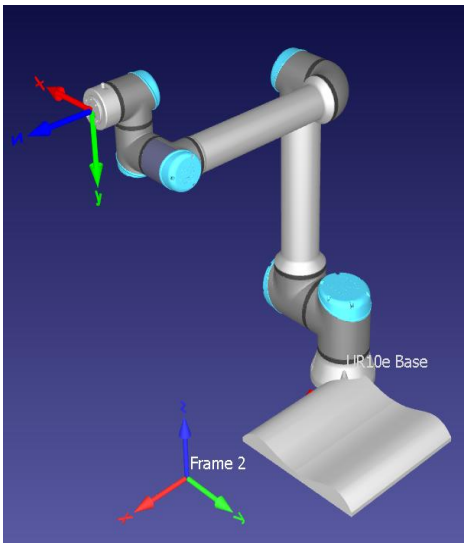
It is also possible to control the movements of the tool regarding its own frame, base frame, or others by using the dial and restraining the movements along one axis at a time to have more precise control.

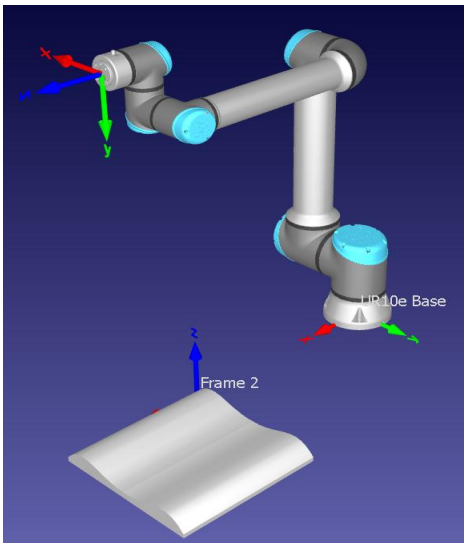
The workspace option can also be enabled to witness the reach and singularity of the tool/ robot flange or wrist center.

1.2 Attaching the reference frame to the Object

The purpose is to introduce a frame to the scene and attach an inspection tool to that frame.

1. With UR10e Base enabled, add a new reference frame. By default, named as Frame 2, is positioned at (0, 1000, 0, 0, 0, 0) for the base reference frame. Change this to (600, 0, 0, 0, 0, 0) to bring it more within reach of the tool.
2. Insert an object, Inspection Tool, from the library to the workstation. By default, it is placed with respect to the robot's base reference frame. It is desired to associate to attach this object to Frame 2, by nesting it under Frame 2.



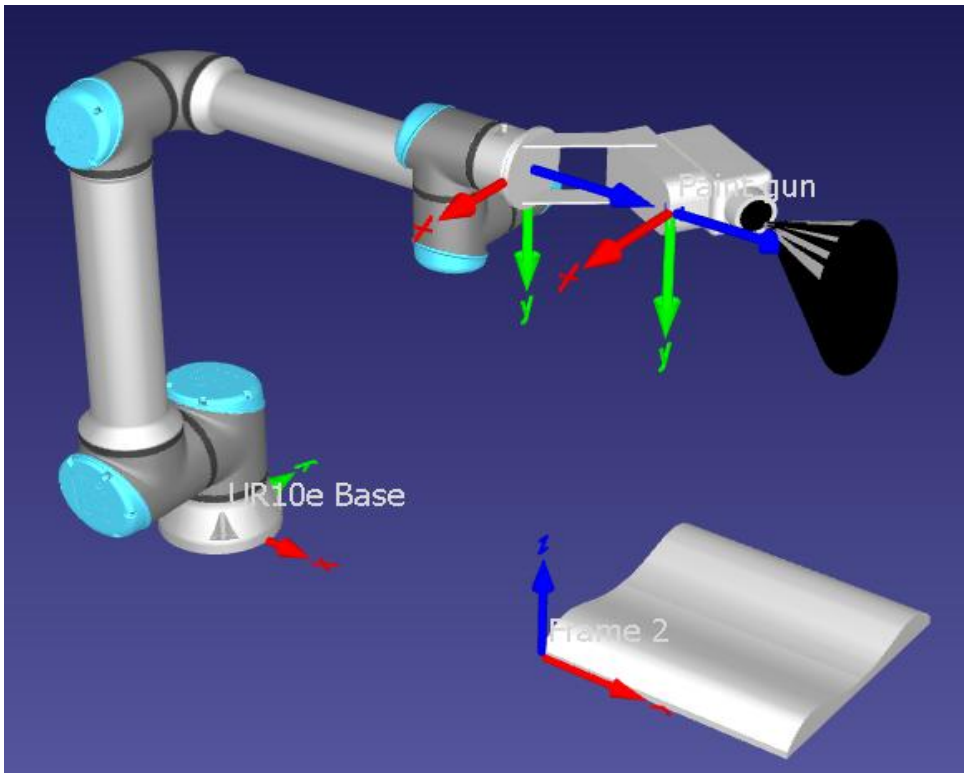


1.3 Attaching the tool to the robot

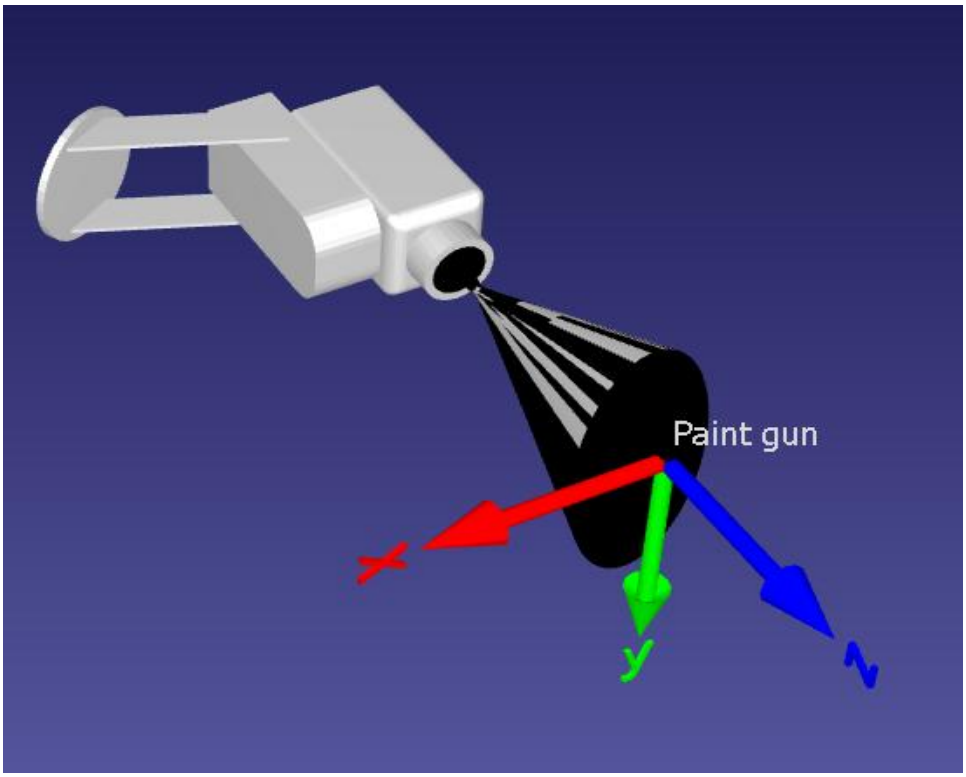
The objective is to attach a paint gun to the robot's end effector.

Import an object, Paint gun to the station. By default, it is positioned at the robot's base reference frame. The paint gun must be defined as the child of UR 10e, so that it is positioned at the right place.

After defining the proper hierarchy, the paint gun must appear as



It is observed that the reference frame attached to the paint gun is positioned at the center of the gun. It is desired that this frame must be aligned with the surface of the spray. This can be achieved either through manually adjusting this frame's position and orientation while holding the ALT + SHIFT key, or directly from the Tool details dialog box. The reference frame most likely should resemble this



If you want to match this pose, then you can manually enter the pose from the dialog box as

1.4 Attach a relative Tool Center Point (TCP)

A tool center point (TCP) is useful for checking the contact of this reference frame with the desired object. It is useful for maintaining a relative offset from the desired object.

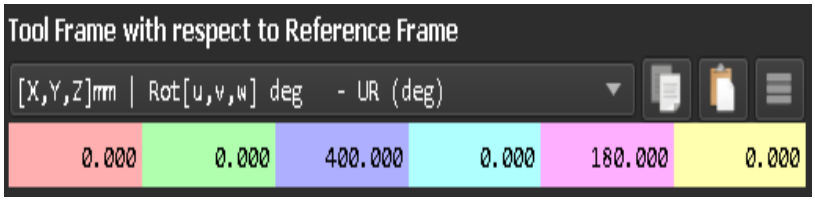
Right click on the robot's name, a menu will open, select 'Add Tool (TCP)'. By default, it is positioned w.r.t. the robot's flange at (0, 0, 200, 0, 0, 0). It is desired to place it in front of the paint gun at a relative distance of 200 mm along the Z-axis. For that purpose, define it w.r.t the paint gun and position it accordingly.

1.5 Control movements using Targets

In the existing project, remove TCP and paint gun. Instead of using a 3d model for the paint gun, a tool identified by RoboDK will be used. Add 'paint_gun.tool' to the project from the local Library folder inside the installed directory. By default, it appears as the object of the robot.

The starting Home position of UR10e is defined with joint angles (0, -90, -90, 0, 90, 0). Modify directly the flange reference frame by pressing the ALT key, so that its x-axis should be pointing downwards. Otherwise, the joint axis can be directly modified as (0, -90, -90, 0, 90, 90).

Define a new target as Target 1 at the existing location and rename it 'Home'. By default, it will appear under Frame 2. Now, a new target point is defined that acts as 'Approach'. Change the pose of the tool frame so that the z-axis of the paint gun is aligned with the z-axis of Frame 2, but opposite to each other. The new tool frame location is

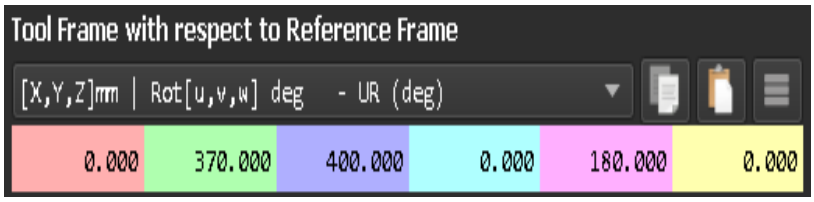


Rename this new target location as 'Approach'. Now, if any of these target points is picked, the tool will relocate itself to the target location.

Define another target point named 'Retract' on the other edge of the object. From the current 'Approach' location, it is shifted towards the right by 370 mm. The exact pose is defined as

Note

If you manually change the location of the tool pose by pressing the ALT key, it is advisable to hide the 'Home' target. Otherwise, you will relocate this target to a new location.

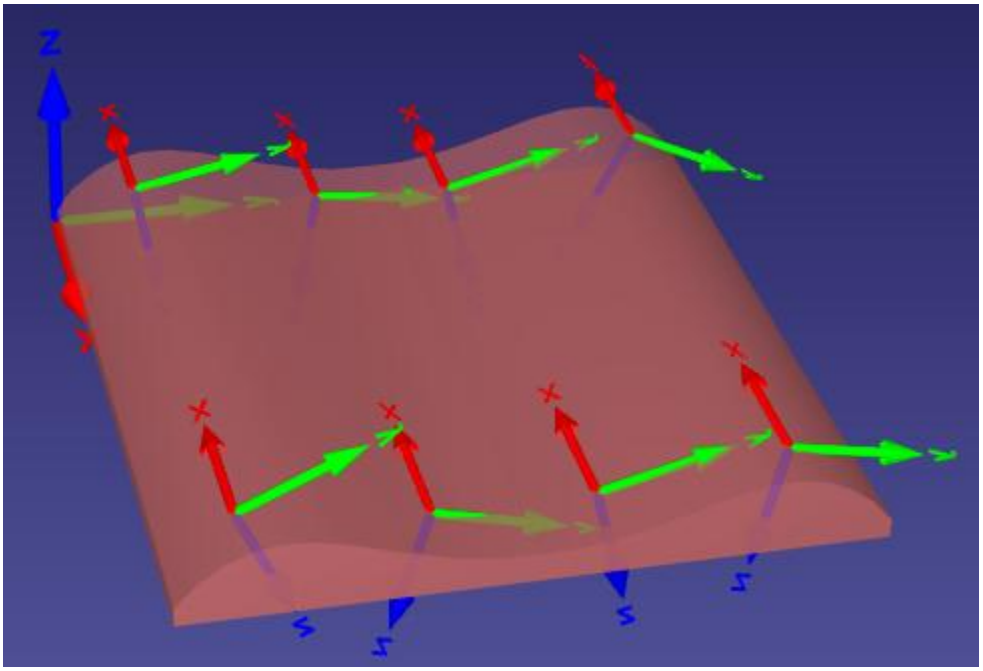


Note

If you accidentally placed the target at the wrong location or are not satisfied with the pose, right-click on the target name and access 'Options' from the menu. A dialog will open, and from there, the pose can be precisely defined.

1.6 Teach Target on Surface

In this paint application, where the surface has to be painted, the targets are defined at the surface of the object. For the purpose, select 'Teach Targets on Surface' from the Programs menu. A ghost robot will appear, and on every mouse click, a new target point is added. Try to define targets to cover the whole surface area. Eight target points are sufficient to cover whole area; the target points need not be precisely defined.



If the target points' pose must be modified, either access the dialog from the options or by directly pressing F3.

Select all the target points on the surface by holding CTRL key or by selecting the first target+ SHIFT+ last target on the list. Once all target points are selected, rename the group to Surface. Then all target points are renamed as Surface 1, Surface 2 and so on. The next chapter details as how to program your robot to traverse through all those defined points.