1. What is the purpose of this object?

The Articulated Robot object (AR) was derived from the need to have a more visually accurate representation of a commonly used multi-axis robot. It is important to note that a Flexsim user can perform a complete robot production line study with the standard Processor and MultiProcessor objects, however the AR aids the verification process and increases the believability of your model.

FAQ

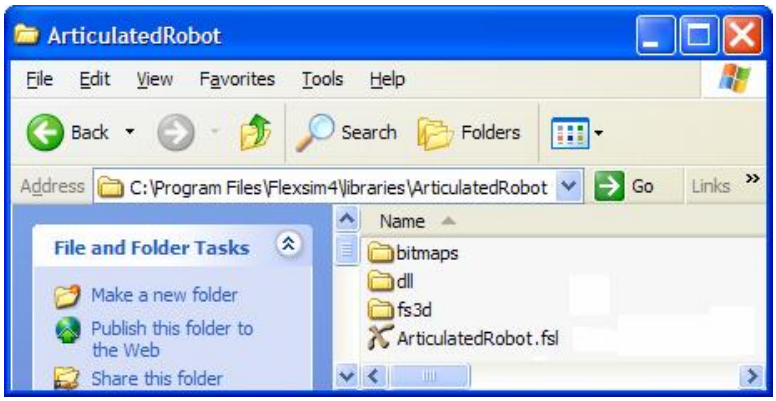
-What classification of object is the AR?
The AR is a Task Executer class of object (just like the Operator, Crane, etc.)

-Does the AR estimate cycle times based on desired movements?
No. The user specifies the cycle time of a given movement as collected from the real robot. Robot manufactures offer workcell planning simulation tools that incorporate the motion planning algorithms that are coded into the robot controller. These algorithms vary based on the given make and model of the robot. Flexsim's strength lies in its ability to simulate a complete process of multiple robots, other machines, equipment failures and human dependencies.

-The only AR in the library looks like a Fanuc model, can you assemble other robot brands and models?
Yes. Please contact Flexsim Software Products for more information.

2. Installing the Articulated Robot library

a. Download the Articulated Robot zip file from the Downloads > Libraries area of the Flexsim Community Forum.
b. Extract the 'ArticulatedRobot' **folder** from the zip file to the Flexsim4\libraries folder on your computer. The folder structure should look similar to the following screenshot.

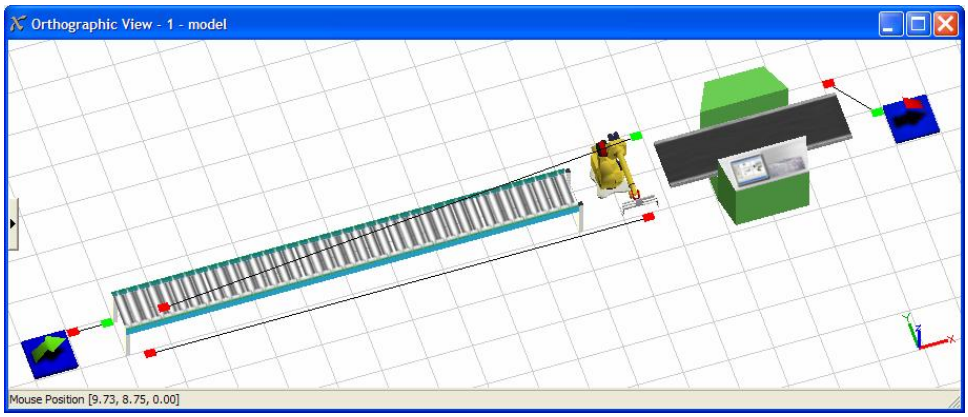


c. Launch Flexsim
d. In the Library window go to File > Load Library… then browse for the ArticulatedRobot.fsl file.
e. Articulated Robot should now appear in the library selector drop down list.

3. Quick Start: Getting the Robot to move FlowItems

The robot object is used in your model in the same way that a standard Operator object is used.

a. Create a model: Source-Conveyor-Processor-Sink connected using the 'A' key.
b. In the Parameters Window of the Conveyor, under the Flow tab check the 'Use Transport' checkbox.
c. Drag the AR into your model and position between the Conveyor and Processor objects.
d. Make 'S' connection between the Conveyor and the AR.
e. Press Reset. Your model should look like the following screenshot.



f. Press Run!
What you should see…
   i. When the first FlowItem reaches the end of the conveyor the will respond by performing a series of movements.
   ii. At the end of the first set of movements, the AR gripper closes and the FlowItem is then transferred to the end effector of the AR.
   iii. The AR performs a second series of movements with the FlowItem in its gripper.
   iv. At the end of the second set of movements, the AR gripper opens and the FlowItem is then transferred to the Processor object.

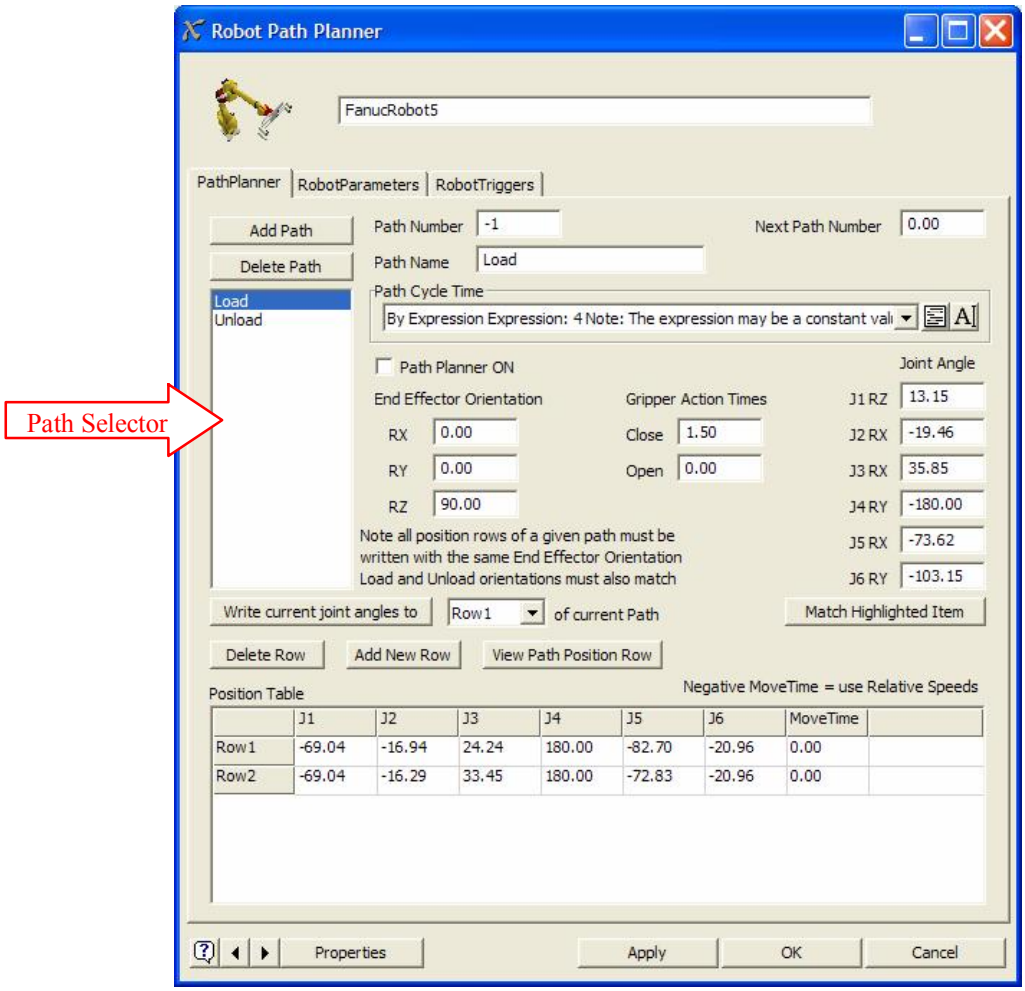
The next section explains how you can customize the robot movements and their timing.

4. Path Planning - Customizing robot movements

You got the robot to move… now you want it to move like the real thing!

a. What is a Path?

A Path is a series of movements as defined by a series of robot positions. The AR stores robot positions in a tabular format (see PositionTable below) where each row is a record of the 6 joint angles that make-up the given position. Double-click on the AR to access the Robot Path Planner window. Click on a path listed in the Path Selector to view its position sequence.



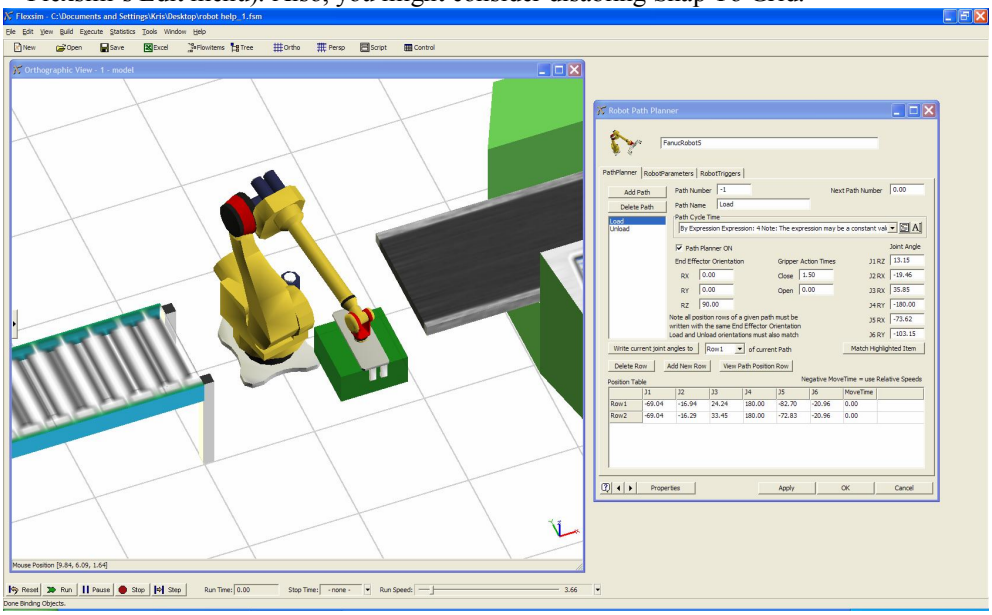
b. How does the AR choose which Path to use?

By default, the robot responds to requests to load and unload FlowItems by applying ***Automatic Path Selection***; it chooses the path with an end position (last position row) which results in the smallest distance between the robot's end effector and the ***involved*** object. See table below for definition of the involved object. See Section 5 for advanced options.

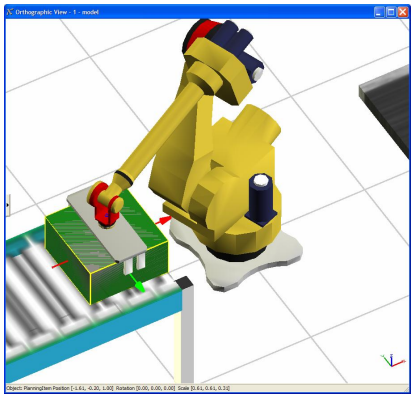
TASK	*Involved* Object
Moving to load a FlowItem	the FlowItem to be picked up
Moving to unloading a FlowItem	the object that the FlowItem is to be delivered to

c. *How do I create my own Paths?*

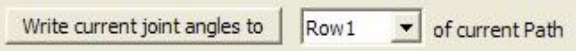
i. Double-click on the AR to launch the Path Planner window. Position and size the model view such that you can see the Path Planner and the robot without overlap of windows.
ii. Click 'Add Path'. This will create a duplicate of the currently selected path.
iii. In the Path Name field type a descriptive name for the path. Note that the name has no functional effect on the behavior of the AR.
iv. Turn ON the Path Planner by checking the 'Path Planner ON' checkbox. A green box called the *PlanningItem* will appear in the AR's gripper. Note that you can move and rotate the PlanningItem with your mouse and the robot will move accordingly. You might find it helpful having the 'Resize and Rotate Objects' feature checked (found under Flexsim's Edit menu). Also, you might consider disabling Snap To Grid.



v. Clear the Position Table by pressing Delete Row until there is only one row remaining.
vi. Begin by recording the end position of your path as it is the most important position. In this case, I wish to record a second path for the AR to follow before loading the FlowItem from the conveyor. Thus, the end position would have the robot gripped onto the FlowItem as it sits on the end of the conveyor.
    1. Press the Step button (simulation run panel) to advance the model run forward by event until a FlowItem appears at the end of the conveyor ready for pickup.
    2. Click once on the FlowItem such that it becomes highlighted.
    3. With the Path Planner still ON, click on the 'Match Highlighted' button. This action will move and orient the PlanningItem to match the properties of the highlighted FlowItem.



4. Before recording the first position you should decide on the orientation you want the gripper to handle the FlowItem. Modify the End Effector Orientation rotation angles (RX:0,RY:0,RZ:90) and press Apply. **Note A**: For a given path, use ONLY 2 of the 3 rotations to accomplish the desired orientation. Leave the third rotation set at 0. **Note B**: Once you have made this choice, all position rows of a given path must be recorded with the same End Effector Orientation values. Also, Load and Unload End Effector Orientation settings must match.
5. Record the AR position to the existing position Row1; Ensure that the Row Selector drop down is set at "Row1" and press the 'Write current joint angles to' button to overwrite the values.



vii. Now we are ready to record another position before the pickup position. In this case, we want a position directly above the pickup position.
   1. Simply click on the Planning Item and use your scroll wheel to levitate the AR. Note that you could also use the Properties window of the PlanningItem to adjust the Z location by a precise amount.
   2. Once you are satisfied with the AR position, press 'Add New Row' with the Row Selector still set at "Row1". This action will insert a new position row ABOVE the existing Row1 and populate it with the current AR position.

viii. Record a third position of your choice and insert it before Row1 as performed in the previous step.

ix. If you were to reset and run the model, the Automatic Path Selection would likely not choose your new path to load the flowitem because the old path that we duplicated to create our path still exists and is position higher in the Path Selector list. Click on the old path and press 'Delete Path'.

x. Reset, and Run.

d. Adding delay times to Paths

There are various options for assigning delay times to a path.

i. Path Cycle Time > 0

You can specify the length of time the AR takes to complete the entire path less the Gripper Action Time in the Path Cycle Time evaluation field. The MoveTime column in the Position Table affects the distribution of the delay time.

1. *Without Weighting*
   Leave the MoveTime column in the Position Table all zeros or equal values and the Path Cycle Time will be divided evenly amongst the number of positions in the path.
2. *With Weighting*
   Adjust the values in the MoveTime column to represent the ratio of the Path Cycle Time you wish to assign to each position row.
   Example: A path contains 3 position rows with 1, 1, 2 respectively in the MoveTime column and the Path Cycle Time was 5.2s. The AR would take 1/(1+1+2) * 5.2s to move to the first position, an equal time to move from the first position to the second position, and 2/(1+1+2) * 5.2s to move from the second position to the third position.

ii. *Path Cycle Time = 0 with MoveTime > 0*

When the Path Cycle Time returns a 0, the AR will use the sum of the values in the MoveTime column as the cycle time for the path. In this way you have precise control of the move time from each position to the next.

iii. *Negative Move Time affects animation only (Relative Speeds)*

For a given movement within a path, if the MoveTime value is negative the AR will still treat it as if it were positive, however the joint rotations will be adjusted to the Relative Speeds entered in the RobotParameters tab. Note that this is purely a change in the

animation and does not affect the movement cycle time. Usually, entering the actual max speed of each joint (from manufacturer) into the Relative Speeds will give best results.

e. ***Changing the PlanningItem properties to match a FlowItem shape in your model***
The PlanningItem it simply another object in Flexsim, you may find it helpful to change its object properties to match a given FlowItem in your model.
   i. *Size*
   Right-click on the PlanningItem and go to the Properties Window to modify SX,SY,SZ.
   ii. *3D shape*
   Right-click on the PlanningItem and go to the Properties Window to modify 3D Shape.

5. Controlling the Path that the robot uses for a given FlowItem transport

There are two ways to override the Automatic Path Selection of the AR. It is helpful to understand that the default tasksequence that is generated when the Use Transport is checked on a Fixed Resource contains 2 tasks that the AR responds to (FRLOAD and FRUNLOAD tasks).

a. *Specify directly on a custom Task Sequence*
Knowledge of writing your own task sequences is assumed in this section. In short, specifying a negative end speed variable will tell the AR not to use Automatic Path Selection, but instead use the path number that matches this end speed (Path Number = end speed). The task types that the AR responds to are listed below with the location of the end speed.

TASKTYPE_	Location of end speed variable
LOAD / FRLOAD UNLOAD / FRUNLOAD	var2
TRAVELRELATIVE TRAVELTOLOC (for movements that don't involve FlowItems)	var4

b. *Next Path Number (great for known path sequences such as palletizing)*
Palletizing is simply a sequence of LoadPath1-UnloadPath1-LoadPath2-UnloadPath2… once the AR unloads the last FlowItem on the Pallet, the sequence repeats. Every Path has a 'Next Path Number' field in which you can specify the path number you want to be used following the currently selected path. When the AR executes a path that has a non-zero Next Path Number specified, it will store this path number into memory until the next time in the model run it performs a task that requires Automatic Path Selection (not specified on the task). Instead of searching for a suitable path, the AR will choose the path number stored in memory.

If during the model run you wish to clear the AR's Next Path Number memory, simply set its "nextpathselected" label to zero and the AR will return to conducting Automatic Path Selection for a best-fit path (if not specified on the task).

Using a combination of a custom task sequence and Next Path Number can save you a lot of time!
Take the example of a palletizing operation with 4 FlowItems per pallet.

i. Make 1 load path and 4 unique unload paths to show the positioning of FlowItem on the pallet. The load path will be Path Number 1, and the unload paths will occupy Path Numbers 2 through 5. Don't forget about the trick using the model 'Step' and the 'Match Highlighted Item' buttons we learned in "How do I create my own Paths?".
ii. The path sequence we want is LoadPath1-UnloadPath1-LoadPath1-UnloadPath2-LoadPath1-UnloadPath3- LoadPath1-UnloadPath4 or Path Numbers 1-2-1-3-1-4-1-5. Since the LoadPath1 is always used for the FRLOAD task, we can specify var2 as -1 on this task.
iii. In the Path Planner, go to the load path (Path Number 1 in this example) and specify a Next Path Number = 2, as this is the first unload path of the cycle.
iv. Go to the first unload path (Path Number 2 in this example) and specify a Next Path Number = 3 (-3 will work as well). Path Number 3 should have a Next Path Number = 4, and Path Number 4 should have a Next Path Number = 5. Path Number 5 should have a Next Path Number = 2 to complete the cycle.