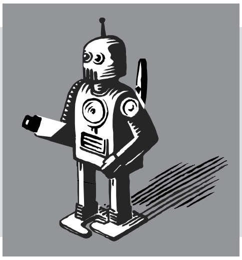
C

Use of RoboAnalyzer[1]



In this appendix, the steps to use the RoboAnalyzer software developed by the author and his students at IIT Delhi are explained. It is an improved version of the RIDIM (Recursive Inverse Dynamics for Industrial Manipulators) programs appeared in the first edition of this book in 2008. RoboAnalyzer (RA) has the visualization feature through 3-dimensional models of robots, including many standard robots like KUKA, ABB, Fanuc, and others. It can be used to learn DH parameters, kinematics, and dynamics of serial robots, and allows 3-dimensional (3D) animation and graph plots as outputs. In essence, learning the physics of robotics with joy is emphasized through RA, rather than only mathematics.

RoboAnalyzer can be installed on a computer with windows operating system by downloading from the website mentioned in the footnote.

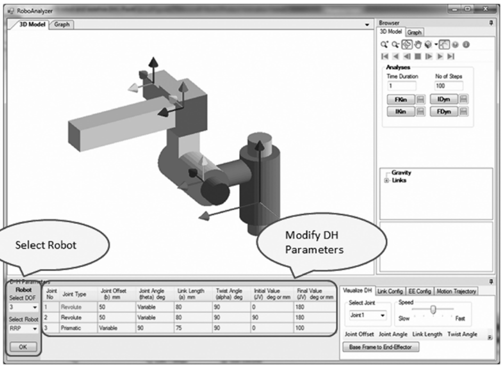


Fig. C.1 Robot-model selection and redefine the DH parameters

The following sections explain the main features of RoboAnalyzer.

C.1 VISUALIZE DENAVIT-HARTENBERG PARAMETERS

After selecting a robot and redefining its Denavit-Hartenberg (DH) parameters, as shown in Fig. C.1, users can visualize each DH parameter by selecting a joint and

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1 RoboAnalyzer (RA) software and the users' manual can be downloaded free from http://www.roboanalyzer.com. Also available from http://www.mhhe.com/saha/ir2. Several students since 2009 (Mr. C.G. Rajeevlochana and others) are sincerely acknowledged for their contributions to develop the RA software.

then selecting a DH parameter. Once it is done, the corresponding DH parameter is highlighted in the DH parameter input table and the corresponding coordinate frame moves in the 3D robot model.

Users can click on **Together** button and a coordinate frame moves covering all the four DH parameters corresponding to the selected joint. Users can also click on **Base Frame to End-Effector** button to see a coordinate frame moving from base frame to the end-effector frame covering all the DH parameters of the robot model.

C.2 FORWARD KINEMATICS

After selecting a robot and redefining DH parameters as explained in Section C.1, forward kinematics (FKin) is performed which updates the 3D model. Play button can be clicked to see the animation whereas clicking on **Graph** tab will allow the users to see various plots.

C.3 INVERSE KINEMATICS

To select a robot and view the solutions of its inverse kinematics, the following are the steps to be followed:

1. Click on **IKin** button. It shows a separate window (Fig. C.2).
2. Select a robot.
3. Enter input parameters.
4. Click on **IKin** button.
5. View the possible solutions.
6. Click on **Show** button. It shows the selected solution in the 3D model window. To see this, go back to the main window by minimizing IKin window.
7. Select any of the obtained solutions as initial and final solutions.
8. Click on **OK.** This step replaces the initial and final joint values in the DH parameters table (main window) by values selected in Step 7.
9. Click on **FKin** button to view animation, i.e., how the robot moves from one solution to another solution selected in Step 7.

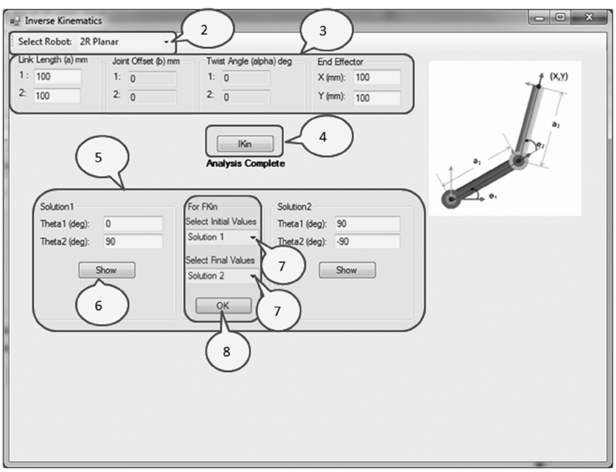

Fig. C.2 Inverse kinematics of a 2R planar robot manipulator

C.4 INVERSE DYNAMICS

Inverse Dynamics (IDyn) is a dynamics solver. Select a robot and redefine DH parameters as explained in Section C.1, if required, to solve for IDyn of the robot between the initial and final values of the joint variables. The following steps are followed to obtain the results:

1. Set the **initial** and **final** values of joint variables.
2. Set **Time Duration** and **Number of Steps**.
3. Set **Gravity** (all values should be in SI units, i.e., m/s^2).
4. Select a robot-link to enter its Center of Gravity (**CG**) location. It corresponds to a vector from the CG of the robot-link to the origin of the co-ordinate frame attached to that link measured in the coordinate frame attached to that link.
5. Select **Mass Properties** of a robot-link. Set **Mass** of each robot-link (values should be in SI units, i.e., kg) and set **Inertia** tensor of each robot-link with respect to the coordinate frame attached at the CG of the robot-link and the coordinate frame is parallel to the one attached to the robot-link (values should be in SI units, i.e., kgm^2). These values are to be entered manually and not calculated automatically from the shape of the robot-links.
6. Click on **FKin** button (required to populate the input joint trajectory).
7. Click on **Play** button to see the animation (only for visualization purpose, not necessary for IDyn).
8. Click on **IDyn** button to perform inverse dynamics.
9. Click on **Graph** tab to view the graph, as shown in Fig. C.3.

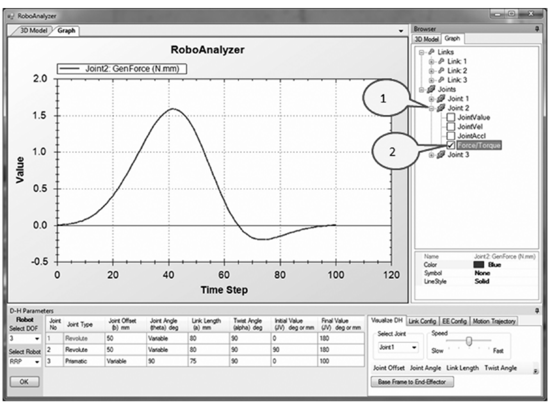

Fig. C.3 Graph plot of joint torque/force

C.5 FORWARD DYNAMICS AND SIMULATION

For Forward Dynamics (FDyn) and simulation, select a robot and redefine its DH parameters, if required. To solve for the FDyn of the robot for a given initial values of joint variables, the following steps are to be followed:

1. Set the **initial** value of joint variables.

2 to 5. Same as the steps in Section C.4.

6. Click on **FDyn** button to perform Forward Dynamics. The robot is simulated for free-fall due to the action of gravity. In future, joint torques/forces can be set as input.

7. Click on **Play** button to see the animation.
8. Click on **Graph** tab to view the graph.

C.6 JOINT TRAJECTORY

Select a robot, as explained in Section C.1. For given initial values of joint variables, motion planning of the selected robot can be performed by selecting a particular joint trajectory from the list available.

C.7 VIRTUAL ROBOT MODULE

The Virtual Robot Module inside RoboAnalyzer lets the user select an industrial robot model (CAD Model) and change the joint angles using a slider or using buttons. It can be used as a learning tool to teach joint-level jogging of robots. Several CAD models of industrial robots are stored. The following steps are to be followed:

1. Click on "More Robots" button appearing below "OK" of "Select Robots."
2. A new window/form is shown. By default CAD model of a robot is displayed, as shown in Fig. C.4.

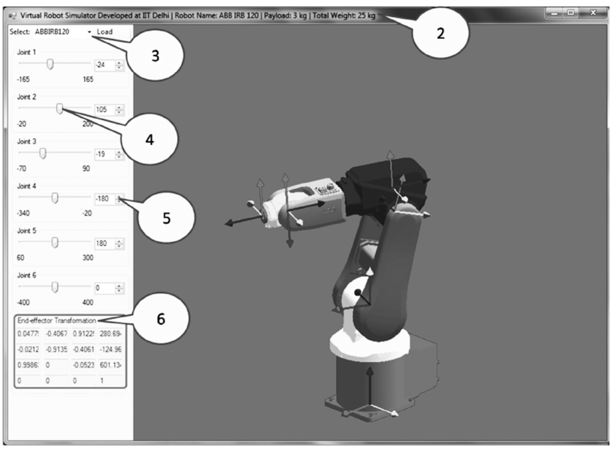

Fig. C.4 A robot in Virtual Robot Module

3. Select a robot from the drop-down and click on "Load".
4. Use the slider on the left to change each joint angle. Note that all the joint angles have minimum and maximum values as per their specifications (joint limit).
5. Buttons can also be used to change the value of the joint angle.
6. The end-effector transformation is updated with every change in the joint angle(s).

SUMMARY

In this appendix, the use of RoboAnalyzer software is explained so that the reader can download and install it for the visualization of a robot in motion. Plots from different analyses can also be made. Several industrial models are also made available to the readers to help them understand their motion characteristics as well.