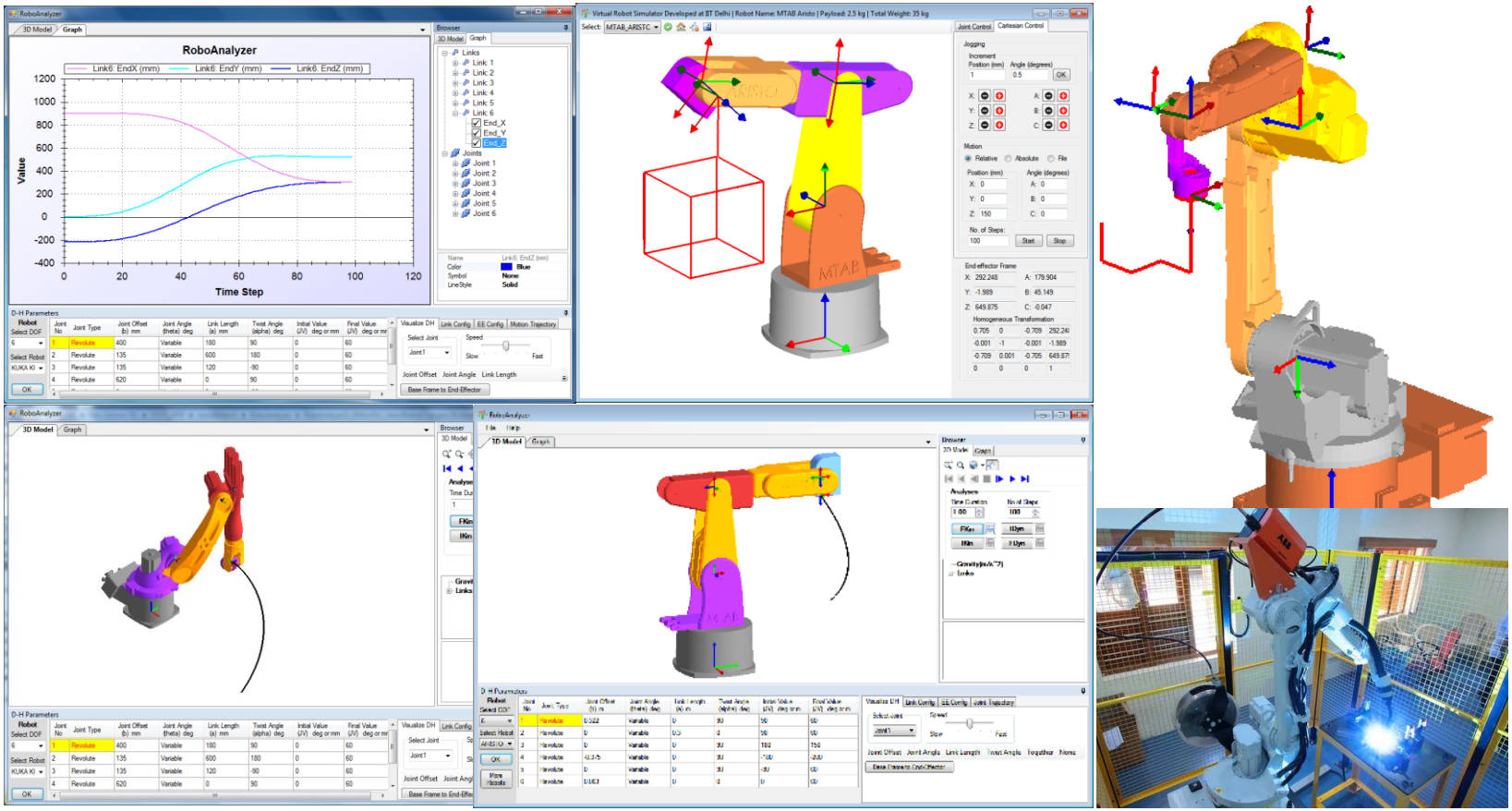
Workshop on
Learning Robot Kinematics using RoboAnalyzer*



Mr. Rajeevlochana G. Chittawadigi
PhD Scholar at IIT Delhi/ Asst. Professor, Dept of Mech Engg.
Amrita Vishwa Vidyapeetham, Bengaluru

Nov 14, 2018: ISIPS 2018, Waseda IPS, Kitakyushu, Fukuoka, Japan

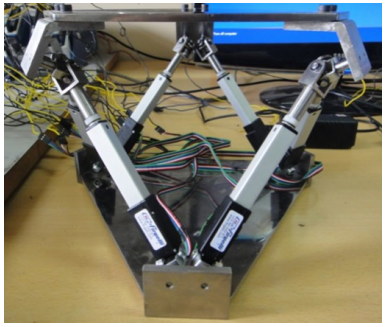
*Developed at IIT Delhi

Contents

- Introduction
- Robotics Education
- Kinematics
- Motion Planning
- RoboAnalyzer
- Tasks (Hands On)
- Feedback

Robotics

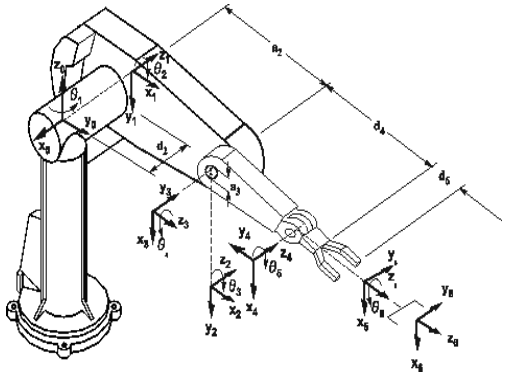
- Design, development, control and application
  - Industries
  - Academics
  - Research
  - Entertainment
  - Medical applications etc.
- Included in curriculum of universities



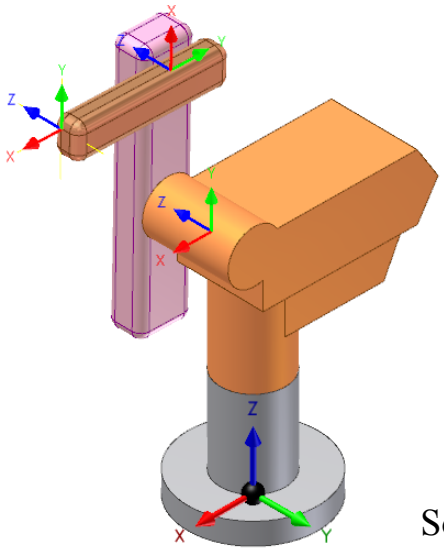
Robotics Education

Courses* usually include:

1. Theory:
   - Design and working of robot in the form of drawing and pictures
   - Mathematically intensive



2. Practical:
   - CAD modeling and simulation
   - Real robots in action
   - Not many institutes have facilities



*Mechanical Engineering

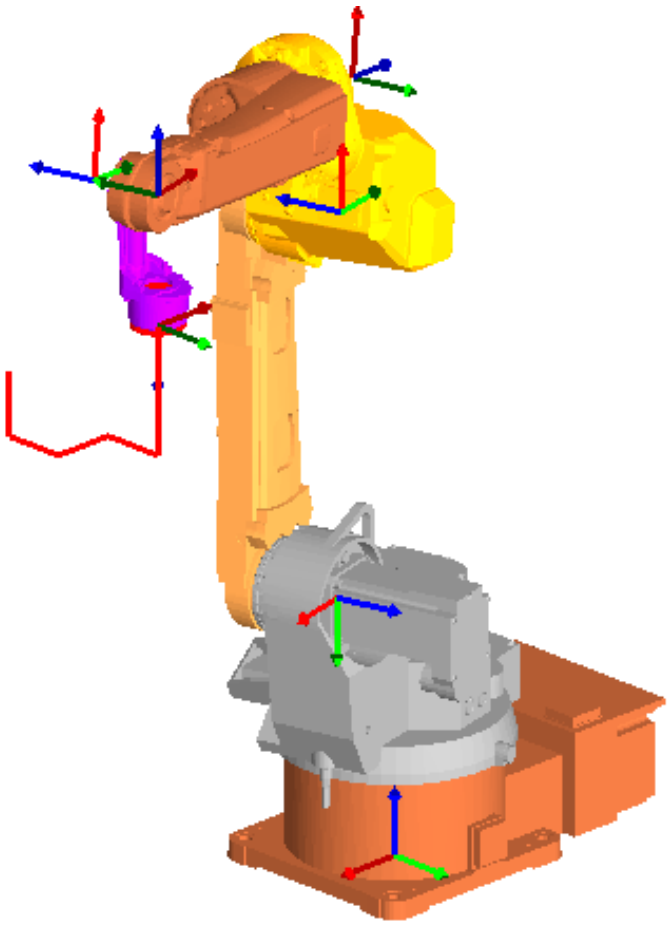
Source: http://images.google.com

Robotics Concepts

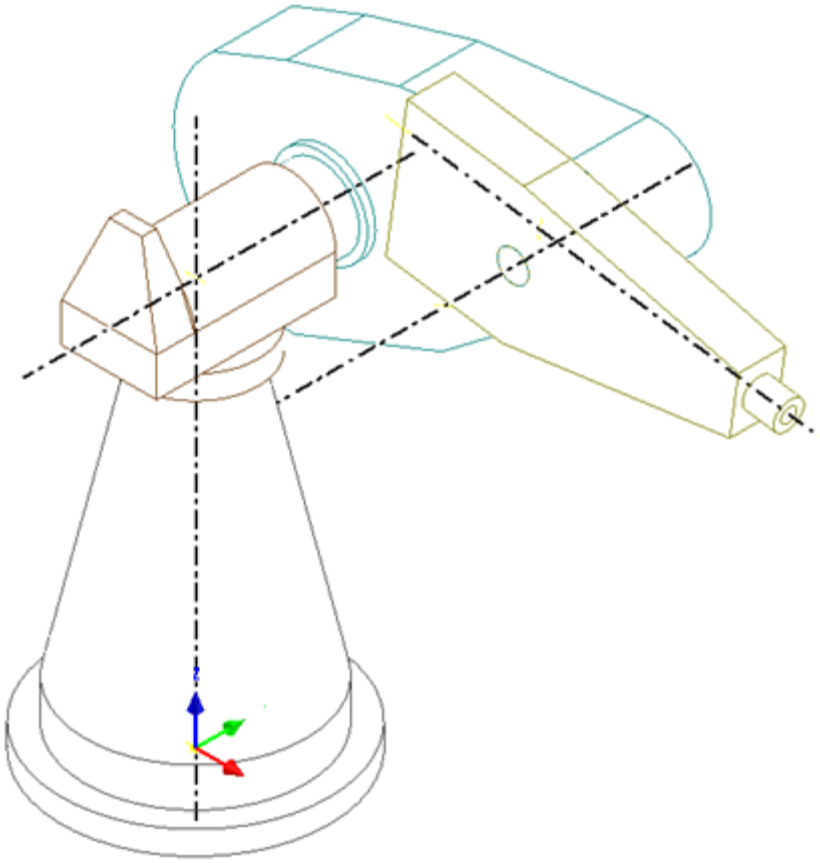
- DH Parameters
- Transformations
- Kinematics
- Dynamics
- Motion Planning
- …

Geometric Model

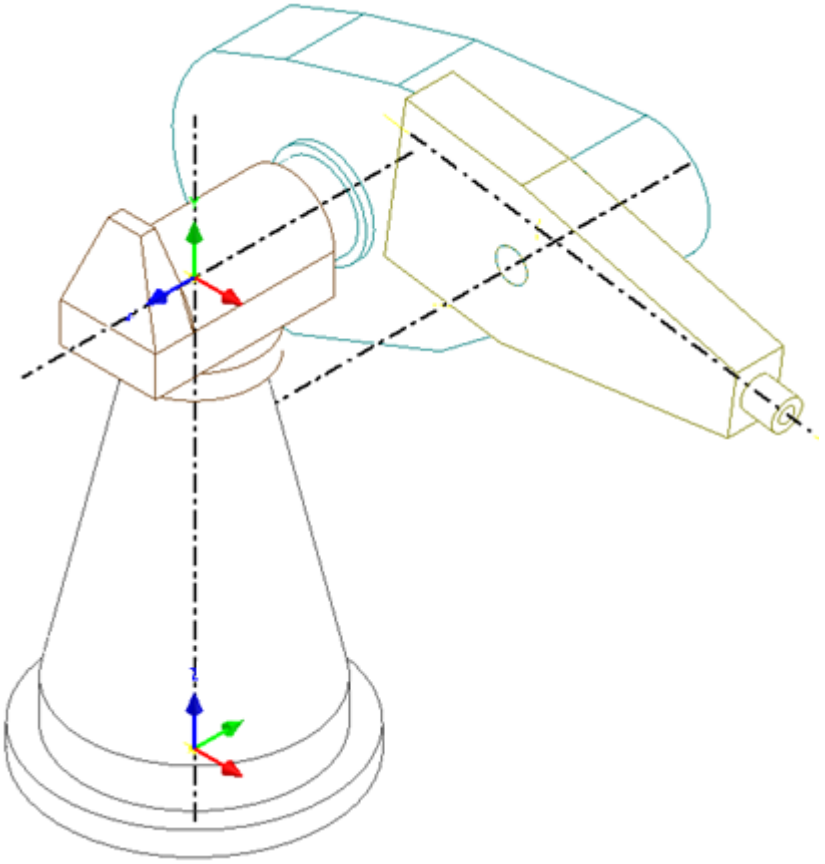
- Robot
  - moves in Cartesian frame
  - controlled at joints
- Mapping
  - Geometric model
  - Robot Architecture
  - Denavit-Hartenberg (DH) Parameters



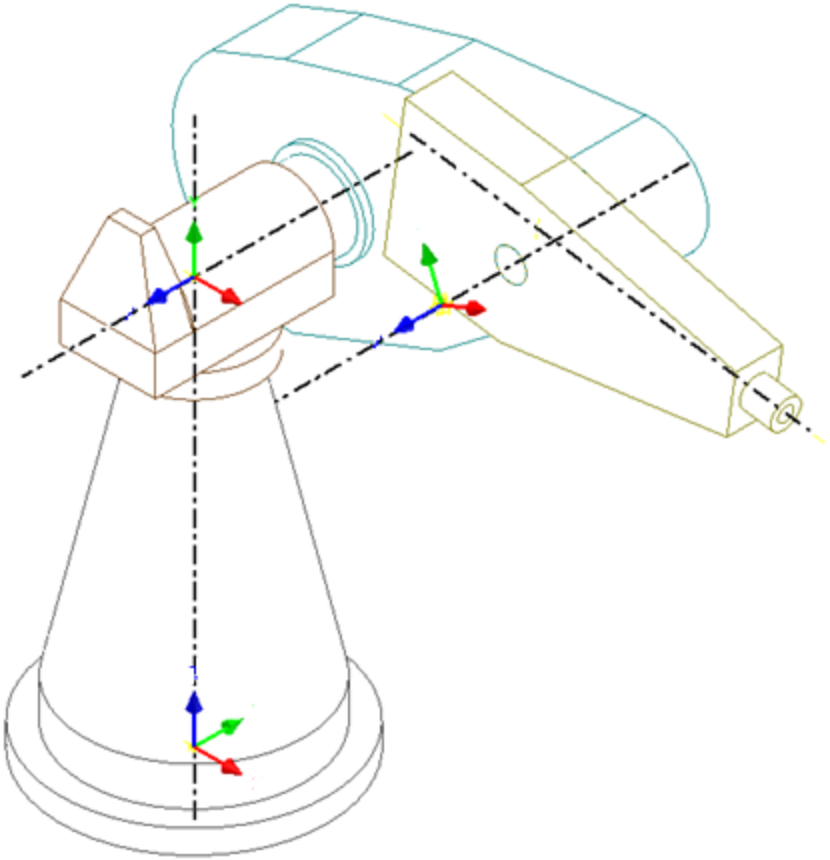
Joint Axes



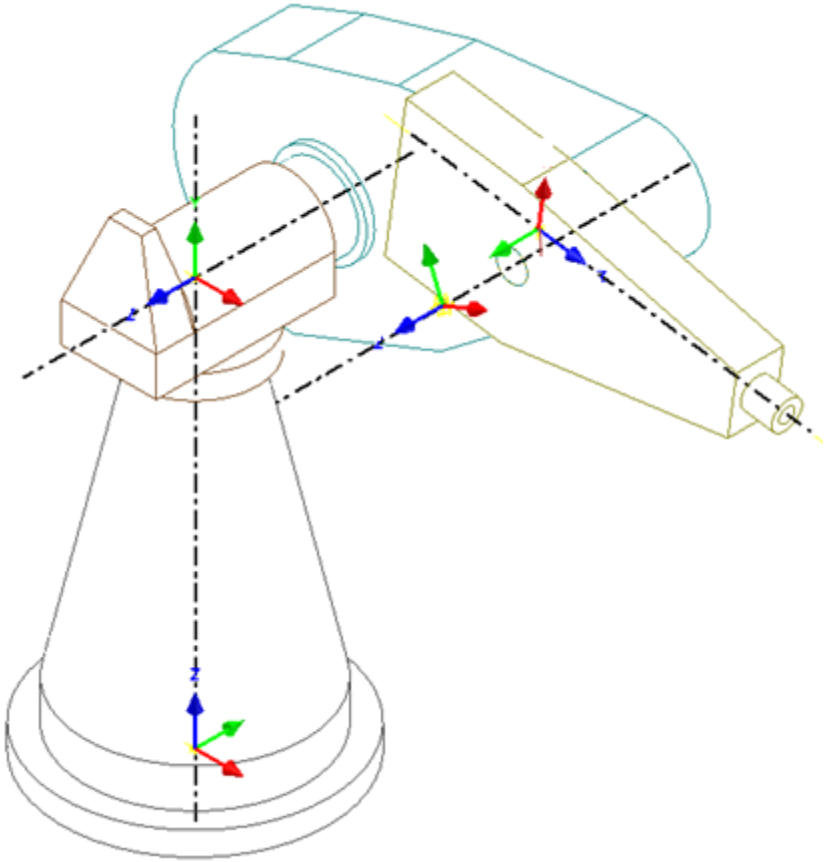
Joint Axes



Joint Axes

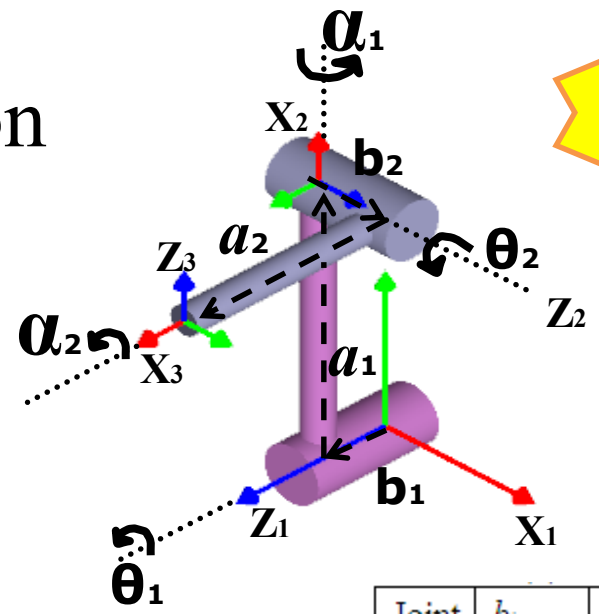


Joint Axes



DH Parameters

- Geometrical description
- 4 parameters
  - Joint offset (b)
  - Joint angle (θ)
  - Link length (*a*)
  - Twist angle (α)
- Relates frames attached on consecutive links



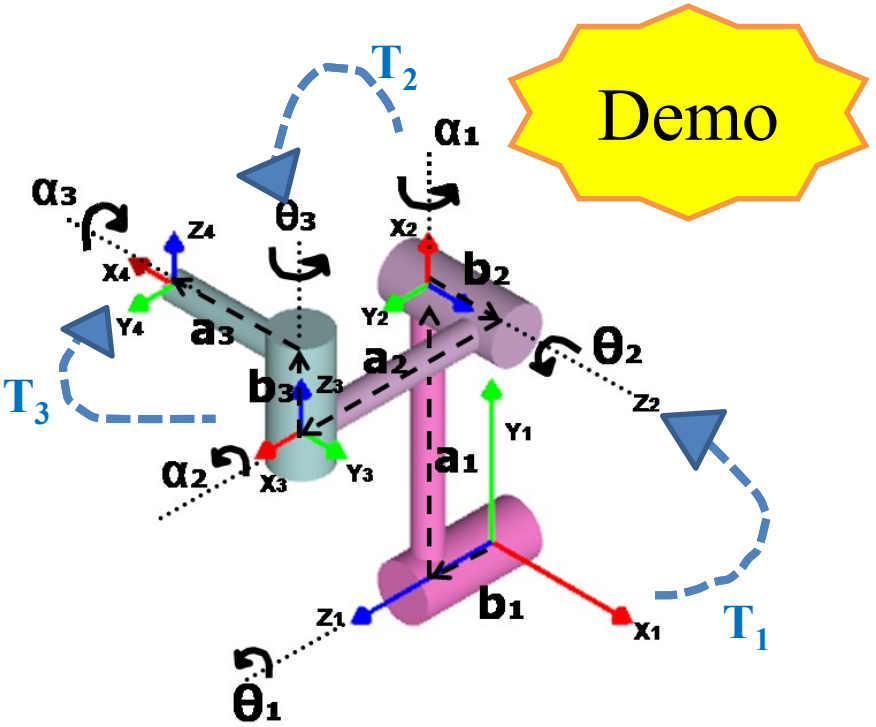
Demo

Joint	b_i	θ_i	a_i	α_i
1	50 mm	90°	200 mm	90°
2	50 mm	90°	150 mm	90°

$$T_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & b_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformations

- Joint to Cartesian space
- End-effector configuration in base frame



$$T_{ee} = T_1\, T_2\, T_3 = \begin{bmatrix} Q & \begin{matrix} P_x \\ P_y \\ P_z \end{matrix} \\ \begin{matrix} 0 & 0 & 0 \end{matrix} & 1 \end{bmatrix}$$

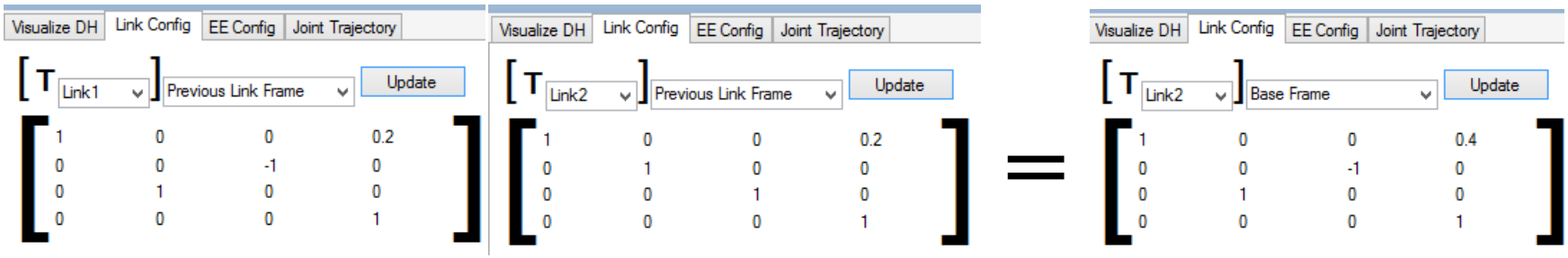
Joint	b_i	θ_i	a_i	α_i
1	50 mm	90°	200 mm	90°
2	50 mm	90°	150 mm	90°
3	50 mm	-90°	100 mm	0°

Task 1: Transformations

- 2R Robot (Spatial)
- DH Parameters

Joint No	Joint Type	Joint Offset (b) m	Joint Angle (theta) deg	Link Length (a) m	Twist Angle (alpha) deg	Initial Value (JV) deg or m	Final Value (JV) deg or m
1	Revolute	0	Variable	0.2	90	0	180
2	Revolute	0	Variable	0.2	0	0	90

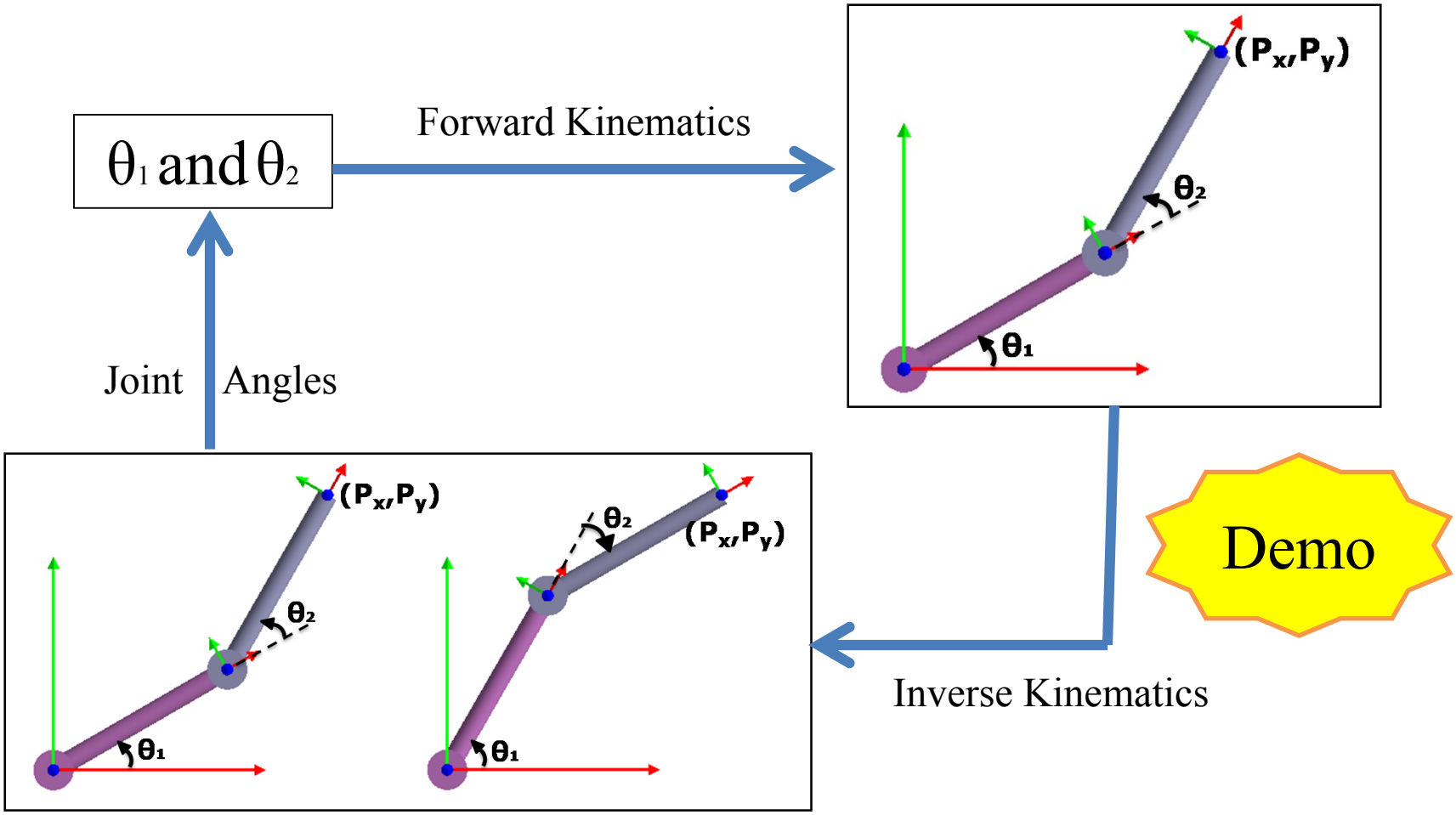
- Verify Transformation



- Try for Different Joint Angles

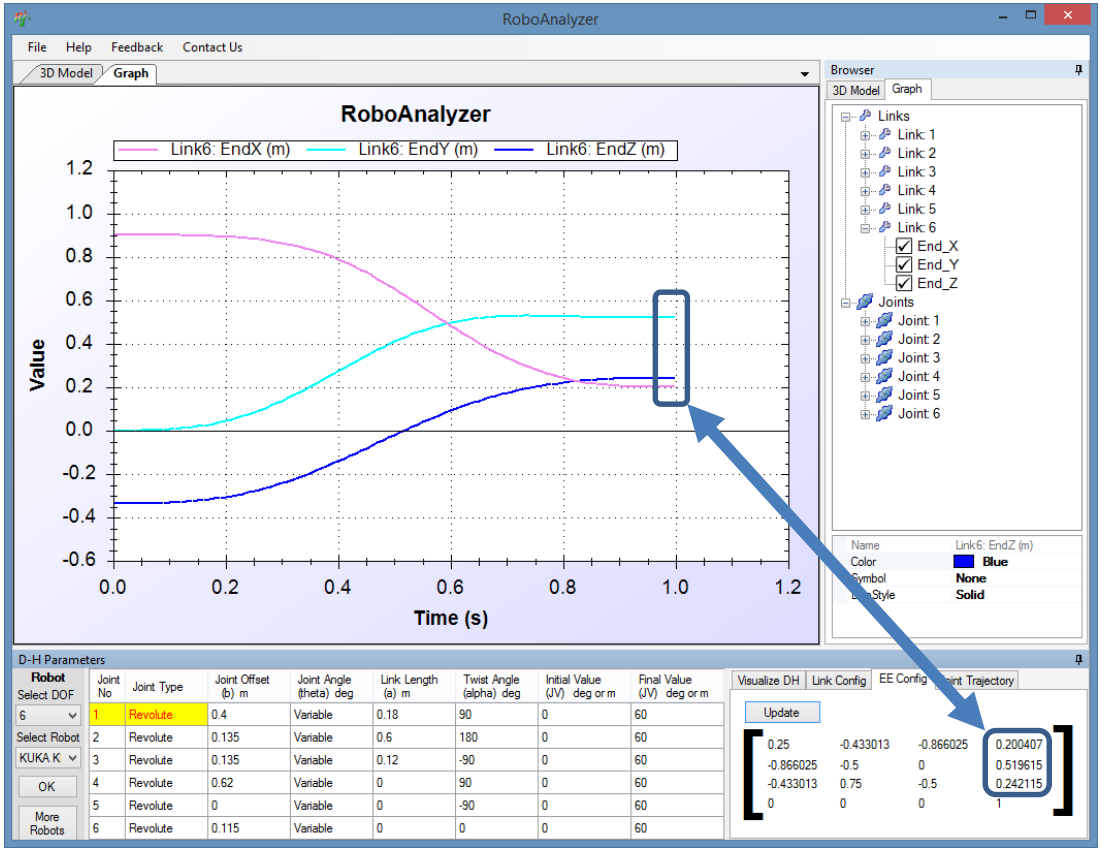
Kinematics

Study of motion of links without considering the forces



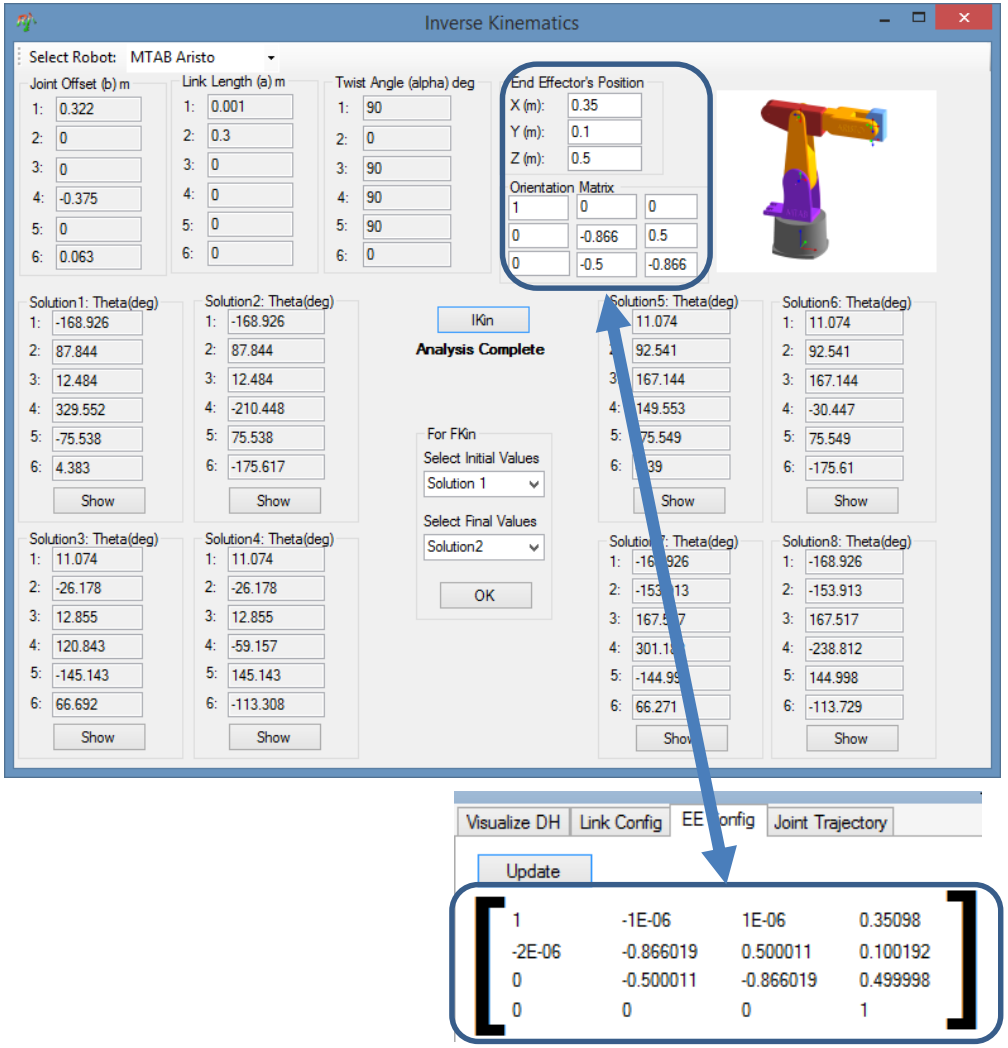
Task 2: Forward Kinematics

- KUKA KR5 Arc
- FKin
- Animation
- Plots
- Verify Position of EE Config
- Try Different Motion



Task 3: Inverse Kinematics

- IKin
- MTAB Aristo Robot
- IKin: 8 Solutions
- Verify in RA
- Visualize in RA
- Try Different Robots

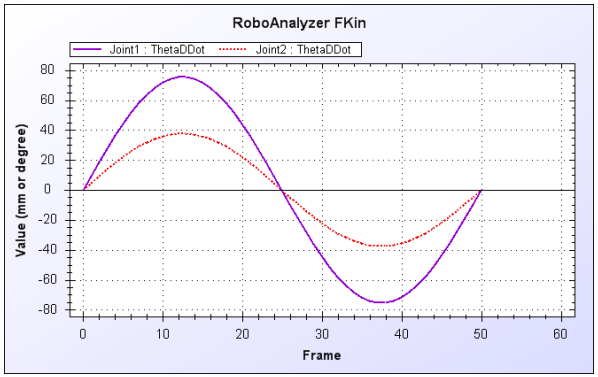


Dynamics

Study of forces and moments causing the motion of links

Forward Dynamics **Inverse Dynamics**

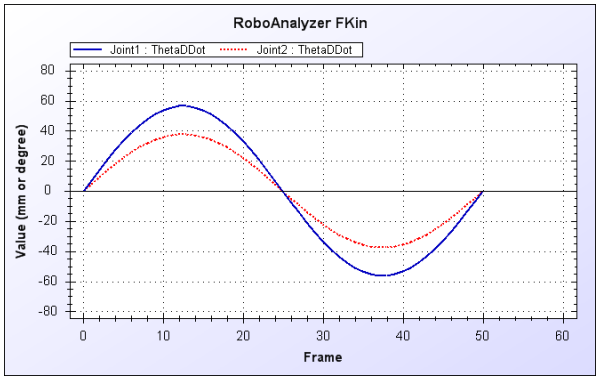
Joint Force



Forward Dynamics

Inverse Dynamics

Joint Accl.

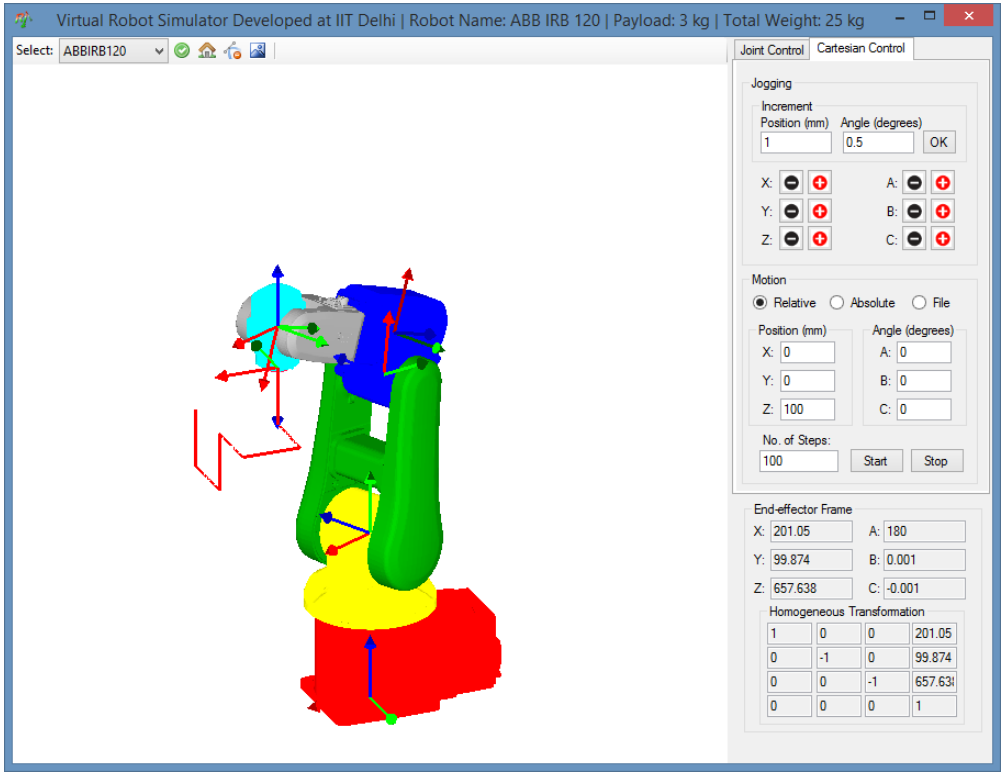


Demo

Due to complexity, these are usually not taught in most of the UG courses

Virtual Robot Module

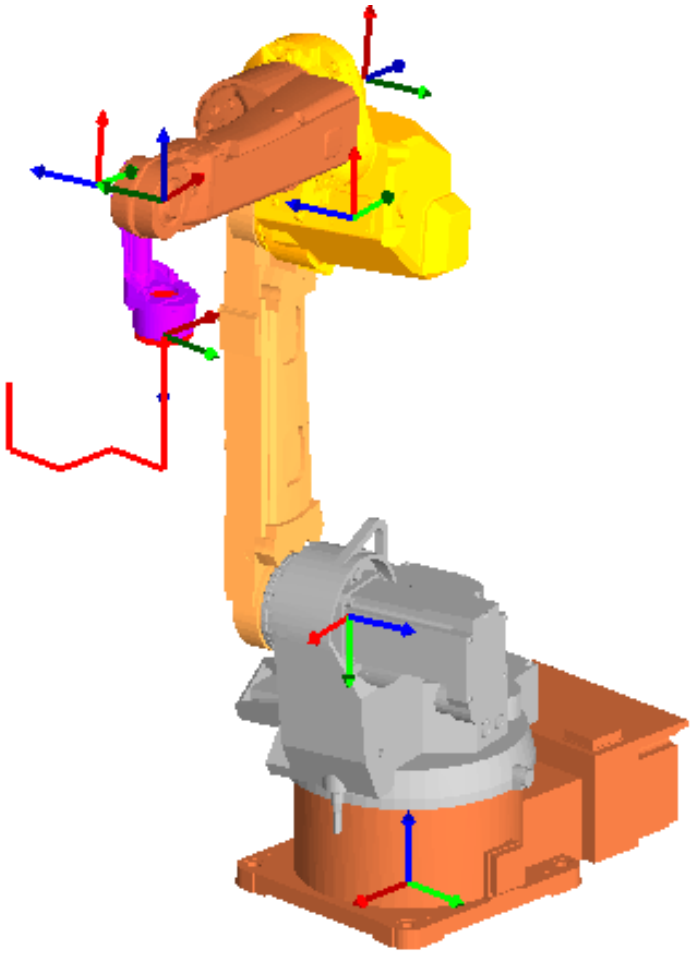
- Joint Jogging
- Cartesian Jogging
- 17 Robots
- Integration with MATLAB
- Interface with Physical Teach Pendant



Demo

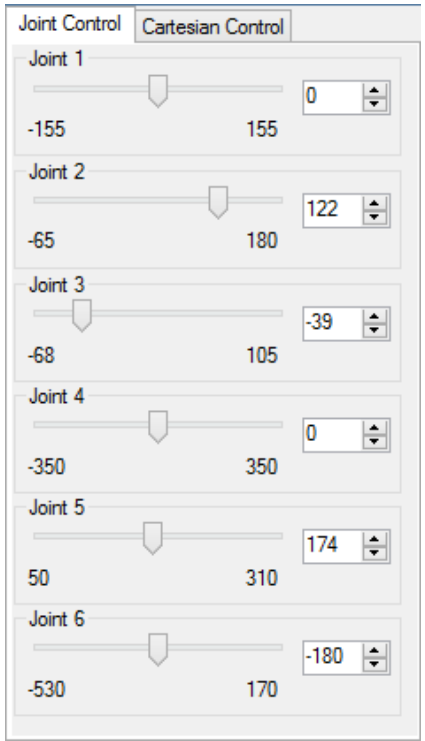
Task 4: Virtual Robot Module

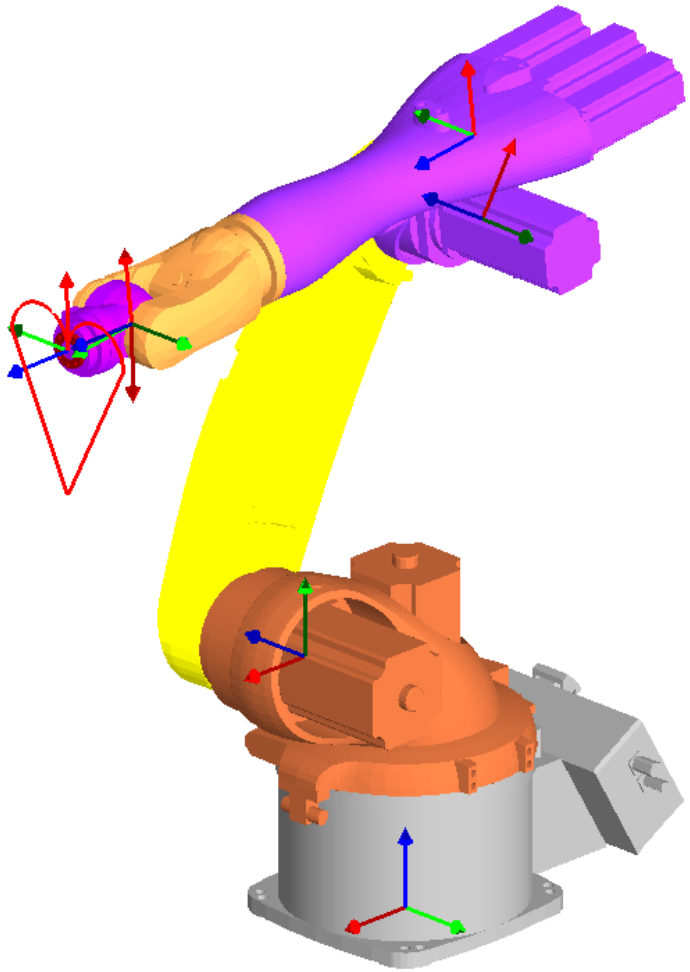
- VRM_XML…
- ABB IRB1520
- Start Record Motion
- Cartesian Control
- Draw a Square of Side 100mm
- Stop Record Motion
- Read and Playback



Task 5: Virtual Robot Module

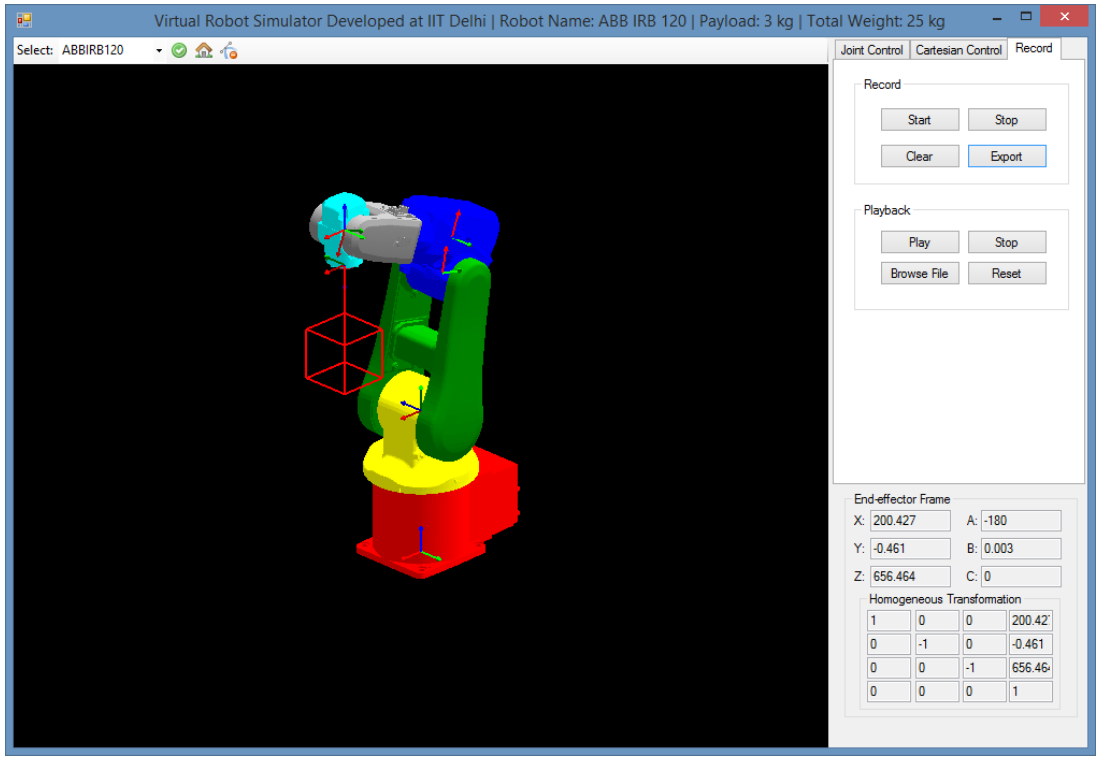
- Move Joints
- Cartesian Motion
- Motion from File "Heart_KUKAKR5.csv"





Contest: Virtual Robot Module

- VRM_XML…
- ABB IRB1520
- Start Record Motion
- Cartesian Control
- Draw a Cube of Side 100mm
- Stop Record Motion
- Read and Playback
- Least Number of Motion Sequences!!!



RoboAnalyzer Team

- Subir K. Saha (1996- present)
- S. Goel and S. Ramakrishnan (1996-97)
- A. Patle (2000-01)
- Rajat Jain (2009-10)
- Suril V. Shah (2007-11)
- Rajeevlochana G. Chittawadigi (2009 – 2013, 2015-present)
- Amit Jain (2010-11)
- Jyoti Bahuguna (2011-12)
- Ratan Sadanand (2012-15)
- Ravi Joshi (2014-15)
- Keshav Bimbraw and Ishaan Mehta (2016 Summer)

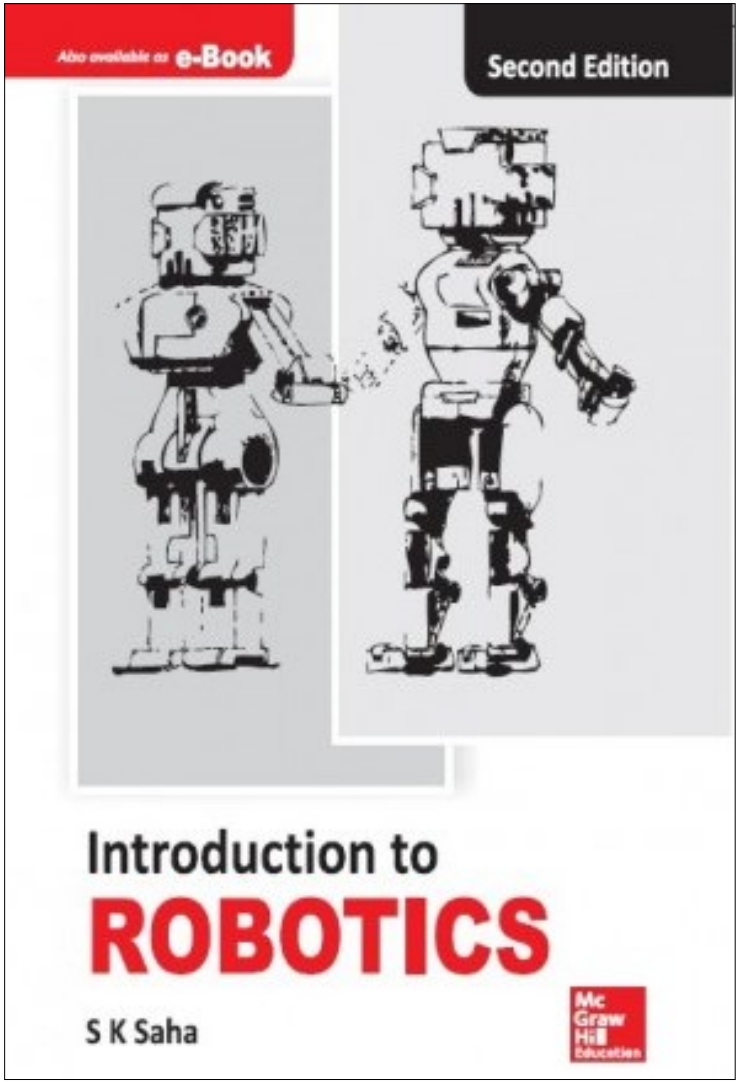
www.roboanalyzer.com

The feedback/suggestion of the below are sincerely acknowledged:

- Mr. Arun Dayal Udai (2010): Suggested importing of CAD files in STL format
- Dr. Sandipan Bandyopadhyay (2012): Suggested to make RA/VRM as an API/COM server to be integrated with other software
- Prof. Sudipto Mukherjee (2012-13): Suggested an interfacing with MATLAB
- Dr. Nayan Kakoty (2013): Suggested to have custom trajectory file input for joints
  Prof. Peter Corke (2015): Discussion on integration of RoboAnalyzer (VRM) with Robotics Toolbox
- Mr. Vinay Gupta (2016): Suggestion on having a link in the software for online feedback and contact form
- Mr. Dharmender Jaitly, Dr. Majid Koul, Mr. Aamir Hayat, Mr. Riby Boby, Mr. Sasanka Sinha

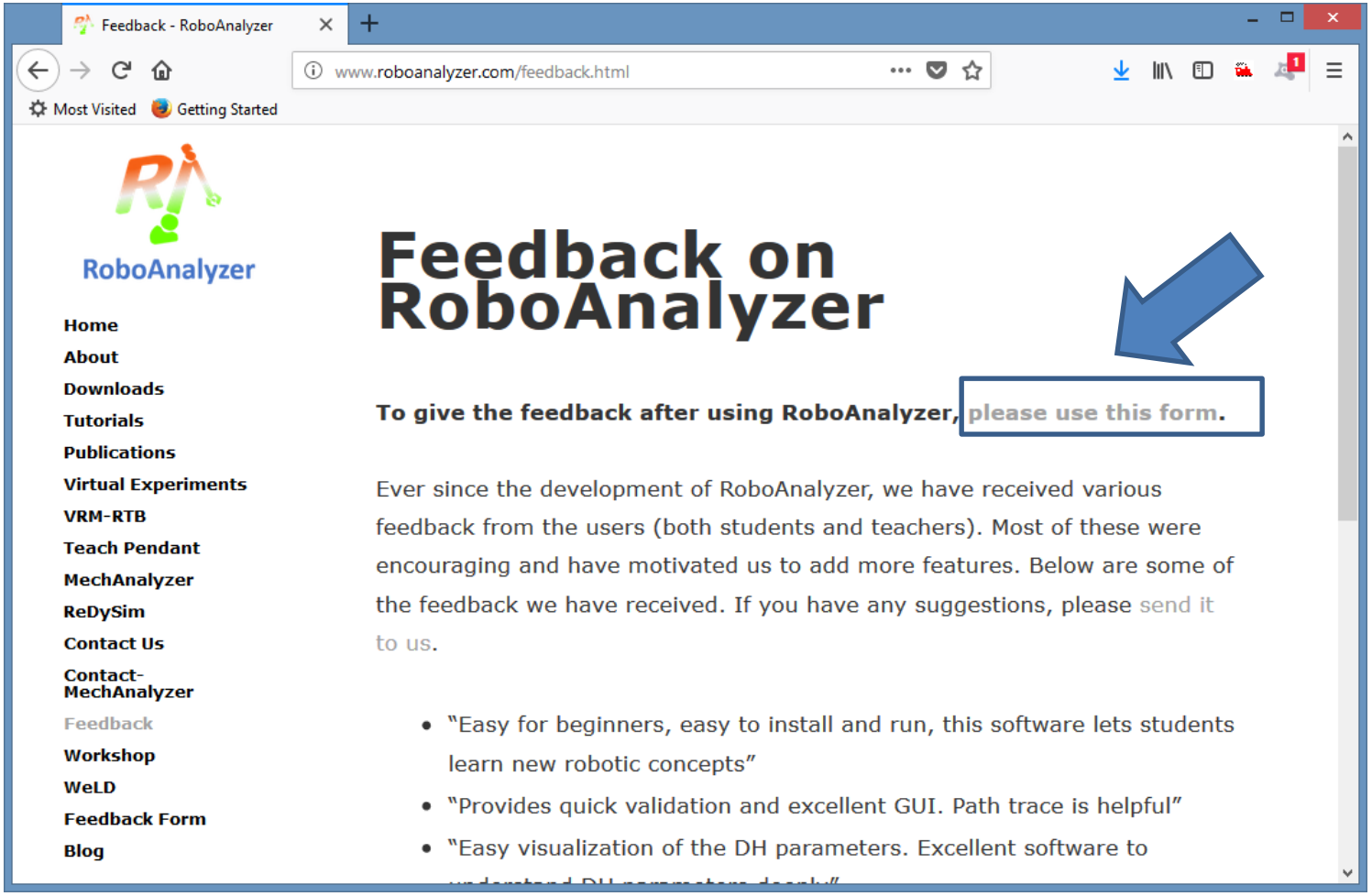
Complementary

- Illustrations
- Examples
- Effective!!!



Feedback

http://www.roboanalyzer.com/feedback.html



Thank You

- rg_chittawadigi@blr.amrita.edu
- saha@mech.iitd.ac.in
- roboanalyzer@gmail.com