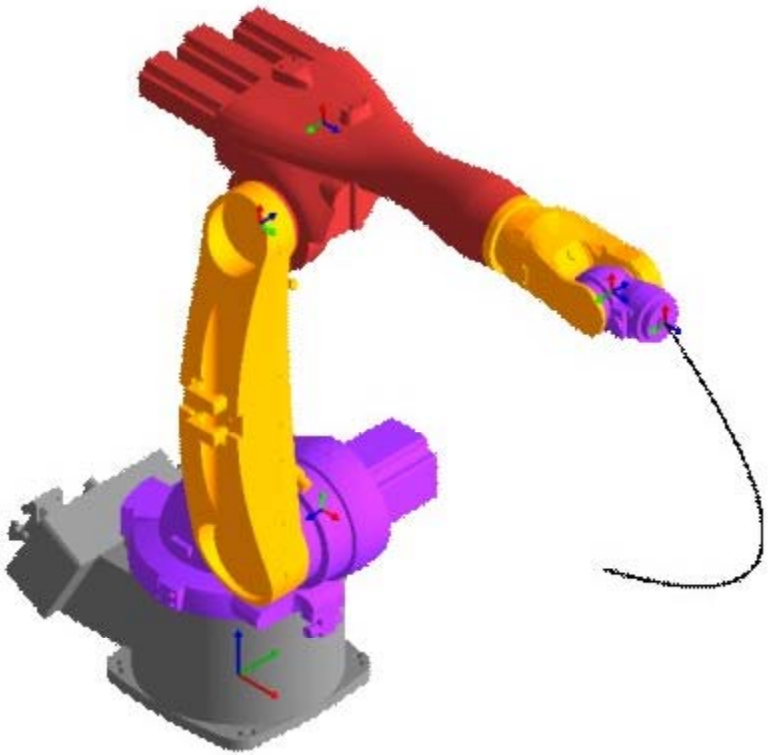
Proceedings



TTR-12

Workshop on

Trends in Teaching Robotics

to

UG/PG Students

December 22, 2012

Block II, #422, ME Seminar Hall
Mechanical Engineering Department
IIT Delhi

Sponsored by

CD Cell
Quality Improvement Programme
IIT Delhi

Foreword

The workshop on “Trends in Teaching of Robotics to UG/PG Students” held in the Department of Mechanical Engineering on December 22, 2012 (Saturday) has been conceived, mainly, to give directions to the faculty members of Robotics courses regarding the effective teaching of the course offered to UG/PG students of Mechanical and Electrical Engineering Departments. The area is growing fast in the country and there is a large demand for quality engineers. Hence, it is essential that the universities/colleges around the country find a minimum base that MUST be achieved to make those students ready to work with the subject of robotics, be in industry or in higher studies.

In order to fulfill the above objectives, it was planned that first we should hear about what different faculty members of robotics courses are teaching in their courses. Hence, in the first half of the workshop the presentations from different faculty will be heard. Later, in the next session, discussions on the books and aids/tools will take place. In the final session, it is expected that a well-groomed course contents and the aids/tools necessary will be evolved that will help all of us (the teachers) to teach the course in a useful manner. In particular, it is hoped that we should be able to answer the following questions at the end of the workshop:

1. What are the topics, e.g., kinematics, dynamics, control etc. that should be covered in a typical UG or PG course on Robotics?
2. What kind of books to be used to teach a typical course on Robotics?
3. How software should be used to aid the teaching of Robotics?
4. What kind and how many experiments should be included in the course?
5. How much self-study learning aspect in the form of reading or making robots (say, for a competition) should be included?

Based on the valuable inputs from all participating faculty members we should be able to formulate a road map for effective teaching learning of robotics in the country so that our industries and academia benefit immensely.

On behalf of IIT Delhi, I would like to thank all the participants to take the trouble of coming to IIT Delhi to participate in this workshop. I am grateful for their valuable inputs in the form of presentations and participations in the discussions. I also thank the Curriculum Development Cell of IIT Delhi to generously support today’s programme. Last but not the least, I convey my sincere thanks to all organizing people, mainly, the students of Mechatronics and Programme for Autonomous Robotics Laboratories for their meticulous planning during last two months, and the staff of Mechanical Engineering Department and the hostels for their kind help.

S.K. Saha

December 22, 2012

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 6 years]
[Total teaching experience: 17 years]

Subir Kumar Saha
Dept. of Mech. Eng., IIT Delhi
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Dec. 22, 2012

Course: Robotics Engineering (UG)/Robotics (PG)

SN	Lecture (3 hrs. module)	Lab. (2 hrs. module)
1	Applications; Types (Mobile, Parallel); Serial: Cartesian, Cylindrical, etc.	Demos of ER9 robot; Virtual Robotics Lab. in ADAMS
2	Sensors and actuators used in Robots	DH parameters of a real robot
3	Pose, DH Parameters, Homogenous Trans.	Forward kinematics in MATLAB
4	Forward and Inverse Kinematics	Inverse kinematics derivations
5	Jacobian: Velocity transformation	Programming in MATLAB
6	Statics: Use of Jacobian	Find Jacobian , singularity
7	Dynamics: Newton-Euler Recursive Algorithm	Class Project 1 Presentation
8	Euler-Lagrange Equations of motion/DeNOC	Control simulation (MATLAB)
9	Kinematic design: Singularity, Dexterity, etc.	DC motor control set-up
10	Mechanical design of robot links	Programming of ER9 robot
11	Control: Definition, closed-loop algorithm	Verify using RoboAnalyzer
12	Motion planning: Polynomial, Spline, etc	Dynamics of 3R robot
13	Parallel Robots: Inverse kinematics	Project 2 presentation
14	Forward Kinematics of parallel robots	Buffer class

Books/Software/Other Aids

- **Text Book**
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008
- **Other Books**
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Software**
  - RoboAnalyzer, MATLAB
- **Other Aids**
  - Class Projects: 1) Dynamics Model of RP manipulator; 2) Modeling of an AGV
  - Robocon competitions

In Next 10 Years

- Use more of RoboAnalyzer/MATLAB software to understand the concepts.
- Do more assignments
- Use software/build hardware for class projects
- Emphasize on mathematical formulations and design aspects.
- Consider credits in the Robocon type of activities

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 11 years]
[Total teaching experience: 11 years]

Ashish Dutta
Dept. of Mech. Eng., IIT Kanpur
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Dec. 22, 2012

Course 1: Introduction to Robotics (UG/PG)

SN	Lecture topics	Assignments
1	Introduction, Joints, links	
2	Transformations, DH Parameters	
3	Forward / Inverse kinematics	
4	Jacobians, Singularity	
5	Trajectory Planning	
6	Sensors & Actuators	Lab visit to see working components
7	Dynamics of serial links	
8	Linear control issues	
9	Non- linear control issues	
10	Manipulator design	
11	Project work	Groups of students make a small project
12	Programming of Robots using VAT - II	Write a program and test it on a real robot

Course 2: Advanced Robotics (UG/PG)

SN	Lecture topics	Assignments
1	Introduction and review of basics	
2	Singular value Decomposition / pseudo inverses	use of Matlab in computation of SVD, P-inverses
3	Kinematic Redundancy in multi DOF System	Assignments
4	Redundancy Resolution in serial manipulators	
5	Dynamics of serial manipulators	
6	Control of redundant manipulators	
7	Control of flexible manipulators	
8	Advanced applications : mobile robots, bipeds etc.	
9	Optimization in robotic systems	Use of software in optimization in robotic systems
10	Future robotics: robot human cooperation, swarm robotics, etc.	
11	Project work	A group makes a small working model of a root

Books/Software/Other Aids

- **Text Book**

  Course 1: Introduction to Robotics, by John Craig
  Robotics engineering, by Richard Klafter

  Course 2: Advanced Robotics: Redundancy and optimization, by Yoshihiko Nakamura.
  Robotics: by Ashitava Goshal
  Robotics: T. Yoshikawa

- **Other Books**

  Hand book on Robotics, Springer

- **Other Aids**

  Project work, laboratory experiments, robotics club

In Next 10 Years

- Focus on hands on learning aids
- Simulations for kinamatics and dynamics
- Experiment with real works robots.
- Resource sharing .

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

C S Kumar
Dept. of Mech. Eng., IIT Kharagpur

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Dec. 22, 2012

Course: Robotics

S.No.	Lecture
1	Design of Robots – Mechanical, Electronics and Control
2	Modelling
3	Kinematics
4	Forward and Inverse Kinematics
5	Dynamics and Control
6	Motion and Path Panning
7	Applications

Softwares - Virtual Labs

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 3 years]
[Total teaching experience: 5.5 years]

Sandipan Bandyopadhyay
Department of Engineering Design
Indian Institute of Technology Madras
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Dec. 22, 2012

ED5260 – Mechanics of Robot Manipulators (UG/PG)

Spatial motion of robot links; descriptions of link orientation; homogeneous transformations; elementary types of joints; DH parameters; velocity and acceleration analysis of robot manipulators; **introduction to singularities and isotropy**.

The virtual work principle and its applications to robot statics; **constraint forces in robot mechanisms**.

Inertia of the robot links; formulation of the equation of motion via the Lagrangian approach; **constrained Lagrangian formulation for parallel robots**; **simulation exercises and case studies.**

ED5260 – Mechanics of Robot Manipulators (UG/PG)

Text books

John J. Craig, "Introduction to Robotics: Mechanics and Control", Prentice Hall (2003)

Ashitava Ghosal, "Robotics: Fundamental Concepts and Analysis", Oxford University Press (2006)

Subir Kumar Saha, "Introduction to Robotics", McGraw Hill (2008)

References

Richard M. Murray, Zexiang Li, S. Shankar Sastry, "A Mathematical Introduction to Robotic Manipulation" CRC Press, (1994)

Lung-Wen Tsai, "Robot Analysis: The Mechanics of Serial and Parallel Manipulators", Wiley Interscience (1999)

ED5314 – Design, Analysis and Control of Robot Manipulators

Kinematic and dynamic objectives in design: mobility, workspace, singularities, isotropy and dynamic manipulability; case studies in planar manipulators, e.g., 3-RRR and spatial parallel manipulators, e.g., Gough-Stewart platforms.

Control and path-planning: trajectory-tracking control schemes using dynamic models; trajectory-tracking control in the presence of singularities; control schemes in the task-space and the joint space; case studies in planar and spatial parallel manipulators.

ED5314 – Design, Analysis and Control of Robot Manipulators

Text books

Ashitava Ghosal, "Robotics: Fundamental Concepts and Analysis", Oxford University Press (2006)

Richard M. Murray, Zexiang Li, S. Shankar Sastry, "A Mathematical Introduction to Robotic Manipulation" CRC Press, (1994)

Jean-Jacques E. Slotine, Weiping Li, "Applied Nonlinear Control", Prentice Hall (1991)

Rafael Kelly, Victor Santibanez, Antonio Loria, "Control of Robot Manipulators in Joint Space", Springer-Verlag (2005)

References

J. P. Merlet, "Parallel Robots", Kluwer Academic Publishers (2006)

Suggested publications from journals and conference proceedings.

Books/Software/Other Aids

- **Software**
  - Mathematica, MATLAB, C/C++
- **Other Aids**
  - Class projects
  - Demonstration of robot manipulators developed in the Robotics Laboratory, IIT Madras
  - Mathematica demonstrations (virtual models)

In the Next 10 Years

- Use more of modelling tools, e.g., Mathematica, Matlab, RoboAnalyzer etc.
- Introduce parametric analysis/design tools (built in-house) in the class
- Encourage design projects
- Integrate some laboratory components in the courses

Thank you for your attention!
Any questions/comments?

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 2 years]
[Total teaching experience: 18 years]

P. M. Pathak
Dept. of Mech. & Indu. Eng., IIT Roorkee
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Dec. 22, 2012

Course: Robotics (PG)

SN	Lecture (3 hrs), Tutorial – 1 hrs
1	**Introduction**: Definition, structure, classification and specifications of robots, industrial robots.
2	**Robot Elements and Control**: Manipulators, drives, sensors, end effectors, configuration, force/torque relationship, trajectory planning, position control, feedback system, digital control.
3	**Modeling of Robots**: Coordinate frames, mapping and transformation; Direct and Inverse kinematics; Manipulator differential motion; Static analysis, Jacobian.
4	**Manipulator Dynamics**: Acceleration of a rigid body, mass distribution, Newton's equation, iterative Newton Euler dynamic formulation, Lagrangian formulation of manipulator dynamics, trajectory planning.
5	**Linear and Non Linear Control of Manipulators**: Control law partitioning, trajectory following control, multi input multi output control systems, Cartesian based control scheme, fuzzy logic control.
6	Hybrid position/force control of manipulators
7	Robot Programming and robot integration with CAD/ CAM.

SN	Lab. (2/2 hrs)
1	Study of ER4U 5 DOF manipulator
2	Study of Robocell virtual workstation
3	Study and programming of Toddler robot (parallex)
4	Study of Hexapod robot (Lynaxmotion)
5	Study of various motions and sensors of LEGO NXT
6	Study of Haptic robot
7	Learning PID control through Ball & Beam Control System
8	Modeling of DC motor control system in MATLAB-SIMULINK
9	Bondgraph modeling of a two link planar manipulator

Books/Software/Other Aids

- **Text Book**
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Other Books**
  - Niku, S. B., "Introduction to Robotics: Analysis, Systems, Applications", Prentice Hall, 2001
  - Schilling, R. J., "Fundamentals of Robotics Analysis and Control", Prentice Hall.
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008.
- **Softwares**
  - MATLAB, SYMBOLS SHAKTI
- **Other Aids**
  - Student presentations on recent developments in robotics area.
  - Robocon competitions

In Next 10 Years

- Use more of software MATLAB and simulations
- to understand the concepts.
- Do more assignments
- Use software/build hardware for class projects
- Emphasize on Mathematical formulations, Design and Control aspects
- Consider credits in the Robocon type of activities

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 19 years **]**

Anand Vaz

Department of Mechanical Engineering

Dr. B. R. Ambedkar National Institute of Technology
Jalandhar, Punjab 144011, India

Dec. 22, 2012

ME-680 Robotics: Mechanics & Control [3 – 0 – 0 = 3]

Main Topics	Course outline	Lectures
Introduction to Robotics		
	Historical perspective, applications, discussion on outline of topics	1
Kinematics of Robotic linkages (open ended type manipulators)		
	Description of position, orientation and frame	1
	Mappings: Translation and rotation Properties of the orientation matrix	2
	Homogeneous transformations	1
	Orientation: Fixed angles and Euler angles	1
	Denavit-Hartenberg parameters	1
	Link transformations	1
	Forward Kinematics	2
	Inverse Kinematics	2
	Translational and angular velocities	2
	Accelerations	1
	Velocity propagation from link to link	1
	Jacobians	1
	Singularities	1
	Static forces	1

Dynamics of Robotic linkages (open ended type manipulators)		
	From system of particles to rigid bodies	2
	Derivation of the inertia tensor its properties, transformation to different frames	2
	Newton-Euler formulation of dynamics	2
	Lagrange-Euler formulation	
	Manipulator dynamics	2
	Simulation of dynamics: Multibond graph and MATLAB	2
Trajectory planning and generation		2
Manipulator design		
	Task requirements, Configuration	1
	Quantitative measures efficiency well-conditioned workspace manipulability	1
	Redundant and closed chain structures	1

Sensors and actuators		
	Strain gauge, resistive potentiometers, Tactile and force sensors, tachometers, LVDT, Piezo electric accelerometer, Hall effect sensors, Optical Encoders	2
	DC motor, stepper motor, drives, Pneumatic and Hydraulic actuators, servo valves and systems	2
Control of Manipulators		
	Ways of decoupling dynamics of manipulators Feedback control of II order Linear systems	1
	Joint control, Trajectory control, Force control, Impedance control	2
	Controllers PID control	2
Integration of robotic systems		1
		44

Books/Software/Other Aids

- **Text Book**
  - John J. Craig, *Introduction to Robotics: Mechanics and Control*, Addison-Wesley, 2005.
  - Anand Vaz, Lecture notes, *Rigid body mechanics: A bond graph perspective*
- **Other Books**
  - Tsuneo Yoshikawa, *Foundations of Robotics*, MIT Press, 1990.
  - Saeed B. Niku, *Introduction to Robotics: Analysis, Systems, Applications*, Pearson Education Inc., 2001
  - Spong M. W., and Vidyasagar M., *Robot Dynamics and Control*, John Wiley & Sons, 1989.
  - Murray R. M., et al, *A Mathematical Introduction to Robotic Manipulation*, CRC Press, 1994.
  - Waldron K. J., and Kinzel G. L., *Kinematics, Dynamics and Design of Machinery*, John Wiley & Sons, 2004.
  - Eronini Umez-Eronini, *System Dynamics & Control*, Brooks/ Cole Publishing Company, 1999.
  - Amalendu Mukherjee, Ranjit Karmakar and Arun Kumar Samantaray, *Bond Graph in Modeling, Simulation and Fault Identification*, I. K. International Publishing House Pvt. Ltd, 2006.
- **Software**
  - MATLAB
- **Other Aids**
  - Power point presentations: (1) System Dynamics & Control; (2) Introduction to Robotics
  - Assignments: 1) Kinematics; 2) Dynamics Model of RP manipulator; 3) Control simulation
  - Setup of computer control of hand prosthesis
  - Lab work 'Industrial Automation'

In Next 10 Years

- Convert existing MATLAB based programs to SCILAB.
- Prepare a 'moodle' based site for courses and study materials
- Continue applying principles of Robotics to Prosthesis development
- Application of bond graphs to Dynamics and Control of Robotic systems, and Biomechanics
- Increase BTech and MTech participation in research projects
- Promote student learning through ASME Student section activities
- Develop a strong group for Mechatronics, Robotics, System Dynamics and Control, with industrial participation

Thank you!

Questions?

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Trends in Teaching Robotics to UG/PG students

E Vijay Prakash
Robotics Research Center, IIIT Hyderabad
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Dec. 22, 2012

Course: Introduction to Robotics (UG and PG)

SN	Lecture (3 hrs Module)	Lab. (2 hrs. module)
1	Pose, DH Parameters, Homogenous Trans.	Forward kinematics in MATLAB and VISUAL NASTRAN
2	Forward and Inverse Kinematics	Inverse kinematics derivations
3	Jacobian: Velocity transformation	Programming in MATLAB and VISUAL NASTRAN
4	Statics and Quasi-statics	Find Jacobian , singularity
5	Dynamics: Newton-Euler Recursive Algorithm	
6	Euler-Lagrange Equations of motion	Control simulation (MATLAB)
7	Partition Control	SIMULINK Model and Control of a pendubot
8	Modelling and Control of an Inverted Pendulum	Control Simulation in MATLAB and VISUAL NASTRAN

Books/Software/Other Aids

- **Text Book**
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Other Books**
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Murray ,Li and Sastry ,A Mathematical Introduction to Robotic Manipulation , CRC Press, 1994
- **Software**
  - MATLAB and MSC VISUAL NASTRAN

In Next 2 Years

- Develop a course which integrates the tools used in Robotics to design control algorithms
- We have introduced a course “Advances in Robotics and Control” where we plan to teach modeling , simulation and control of Quad-rotor
- Develop hardware realization of the control laws for Quad-rotor

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 1 year]
[Total teaching experience: 1 year]

Shubhendu Bhasin
Dept. of Electrical Engg., IIT Delhi
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Dec. 22, 2012

Course: Robotics and Automation (UG)/(PG)

S.No.	Lecture (3 hrs. module)
1	Introduction, History, Motivating Robot Videos, Current Research Areas, Robot Manipulator: Definition, Components, Types
2	Reference frames, Coordinate Systems, Generalized Coordinates, DOF, Vectors and Points
3	Pose, Coordinate Transformations, Rotation Matrices, Quaternions
4	Labelling the kinematic chain, DH parameters
5	Forward and Inverse Kinematics
6	Velocity Kinematics, Jacobian, Singularities
7	Statics
8	Dynamics: Newton-Euler, Lagrange Methods
9	Control: Position Control, Trajectory Tracking, Force Control, Control Techniques - PD control, Computed Torque, Feedback Linearization, Task Space Control, Nonlinear and Adaptive Control
10	Optional topics (time permitting): Path Planning, Wheeled Mobile Robots, Parallel Robots
11	Term paper

Books/Software/Other Aids

- **Text Book**
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Other Books**
  - M.W. Spong, S. Hutchinson and M. Vidyasagar, Robot Modeling and Control, John Wiley & Sons, Inc.
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008
- **Software**
  - MATLAB

In Next 10 Years

- Class projects, assignments based on robots in the lab – industrial, mobile, quadrotors.
- A separate course on building robots – mechanical, electrical, software.
- Use of visualization software, like RoboAnalyzer etc.

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 2 years]
[Total teaching experience: 7 years]

Shital S. Chiddarwar
Dept. of Mechanical Engg.
Visvesvaraya National Institute of Technology, Nagpur
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22.12.2012

Course: Industrial Robotics(UG & PG)

SN	Lecture (3 hrs. module)
1	Introduction, types, geometry, workspace, work volume
2	Industrial applications of robot (fixed base + mobile)
3	Sensors and actuators used in Robots
4	Introduction to machine vision for industrial applications
5	Pose, DH Parameters, Homogenous Trans.
6	Forward and Inverse Kinematics
7	Jacobian: Velocity transformation
8	Statics: Use of Jacobian
9	Dynamics :Euler-Lagrange Equations of motion
10	Kinematic design: Singularity, Dexterity, etc.
11	Control: Definition, types, closed-loop algorithm
12	Trajectory planning: Joint angle, Cartesian using Polynomial, Spline, etc
13	Use of Symbolic and Robot toolbox of MATLAB
14	Demonstration of 3dof fixed base robot and mobile manipulator

Books/Software/Other Aids

- **Text Book**
  - Robotics and Control, R.K. Mittal and I.J. Nagrath, McGraw Hill, New Delhi, 2011
- **Other Books**
  - Introduction to Robotics: Mechanics and Control, Craig, J.J., Pearson Education, 2009
  - Robotics: control, sensing, vision, and intelligence, King Sun Fu, Rafael C. González, C. S. George Lee, McGraw Hill, New Delhi, 2010
- **Software**
  - MATLAB, ADAMS
- **Other Aids**
  - Case Study : A group of 2 students is allotted with a typical industrial application of fixed base (single, multiple) industrial robot at the beginning of the course. The case study includes 1. Study of given application 2. Work cycle 3. selection of robot (either available or conceptual) 4. Justification for selected robot 5. Determination of D-H parameters and workspace of robot 6. forward kinematics 7. sensors to be used 8. control logic 9. feasibility study

In Next 10 Years

- Use of MATLAB and Simulink for better understanding of control aspects
- Modeling of robot workcell in ADAMS
- Study of holonomic and non-holonomic mobile manipulators
- Laboratory work
  - Hardware (structure + mechanical, electrical drives + sensors)
  - Learning by demonstration
  - Customized grippers for industrial applications
  - Multiple robot coordination and cooperation

THANK YOU

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 3 years]
[Total teaching experience: 4 years]

M.Santhakumar
Mechanical Engineering
Indian Institute of Technology Indore
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Dec. 22, 2012

Course: Robotics (for both UG and PG)

S. No	Lecture (3 hrs/week)
1	Introduction and Types (Mobile, Parallel, Serial) and classification of Robots; Workspace, etc.
2	Robotic Sensors and Actuators
3	Representation of Pose, Homogenous Transformation, DH parameters
4	Forward and Inverse Kinematics (Examples, development of computer programs)
5	Velocity and Static Analysis: Use of Jacobian (velocity transformation) matrix
6	Singularity and Dexterity analysis
7	Dynamics: Newton-Euler Recursive Algorithm
8	Euler-Lagrange Equations of motion, State space representation of equations
9	Dynamic Simulation using MATLAB / ADAMS
10	Trajectory and Motion Planning, Joint space trajectory generation
11	Robotic Control: Kinematic and Dynamic Control
12	Nonlinear Control techniques
13	Kinematics of Mobile and Parallel Robots

Books/Software/Other Aids

- **Text Book**
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, New Delhi, 2009
- **Other Books**
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Spong, M.W., Seth Hutchinson, and Vidyasagar, M., Robot Modeling and Control, John Wiley & Sons Inc., New Delhi, 2004.
  - Schilling, J.R., Fundamentals of Robotics: Analysis and Control, Prentice Hall India, New Delhi, 1990.
- **Software**
  - ADAMS, MATLAB
- **Other Aids**
  - Course Projects:
    1) Development of Dynamic and simulation model of real robotic manipulators
    2) Development of simple planar robotic manipulators (both serial and parallel)
  - DARPA Challenge, Robocon competitions

In Next 10 Years

- Use more of ADAMS/MATLAB software to understand the concepts.
- Do more assignments (on MATLAB / Modelling package)
- Use of mechanism construction kit to build hardware for class projects
- Emphasize on mathematical formulations and design aspects.
- Consider credits in the robot competitions and similar type of activities
- Conducting few special workshops (hands on) on robotics

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG Students

[Teaching Robotics: 3 years]
[Total teaching experience: 7 years]

P.K. Rao
Dept. of Mech. Eng., OPJIT - Raigarh
Kameswara.rao@opjit.edu.in

Dec. 22, 2012

Course: Robotics (UG)

SN	Lecture (4 hrs. module)	Lab. (2 hrs. module)
1	Introduction to Robots & their evolution. Laws of Robotics, What is and what is not a robot, Progressive Advancement in Robots.	Demos of ER9 robot; Robotics Lab.
2	Design & Control Issues, Sensors and Vision, Programming Robots & the future prospects.	6 – Axis and Hex crawler Robot – Robotics Lab.
3	Coordinate frames , Mapping and Transformations.	Forward kinematics in Robotics Lab.
4	Forward and Inverse Kinematics	Inverse kinematics derivations – Robotics Lab
5	Modelling of Robots, Kinematic and Dynamic modelling of robots	Kinematics & Dynamics – Robotics Lab.
6	Denavit – Hartenberg Notation, Manipulator Transformation Matrix, Jacobians.	D – H Notation – Robotics Lab, Programming in MATLAB
7	Robotic Sensor & Vision, Image processing & Image acquisition, Architecture of robot vision systems.	Robot sensor & vision, Image processing – Robotics Lab.
8	Euler-Lagrange Equations of motion.	Control simulation (MATLAB)
9	Kinematic design: Singularity, Dexterity, etc.	DC motor control set-up – Robotics Lab.
10	Mechanical design of robot links	Programming of ER9 robot
11	Robot Applications: Industrial Applications like Material handling, Processing, Assembly and Inspection.	Application of KUKA SIMPRO Robot – Robotics Lab.
12	Justification of Robots, Robot Safety.	Safety precautions of ER9 & KUKA SIMPRO Robot – Robotics Lab.
13	Non – Industrial Applications of Robots like Domestic, Medical, Military operations, Children toys & Humanoids.	Humanoid Project Model – Robotics Lab.
14	Robotics Applications for Sustainable Development.	Practical Exposure of different robots in Industries.

Books/Software/Other Aids

- **Text Books**
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008.,
  - R.K. Mittal & I.J. Nagarath., Robotics And Control, Tata McGraw-Hill, New Delhi, 2011.,
- **Other Books**
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009.
  - Richard D. Klafter, Thomas A. Chmielewski, Michel Negin., Robotic Engineering An Integrated Approach.
- **Software**
  - Robo Analyzer, MATLAB, Stamp Editor v2.5.2.exe.
- **Other Aids**
  - Class Projects: 1) Dynamics Model of 6 – Axis Robot; 2) Modeling of an AGV; 3) Major Project of Humanoid; 4) Hex Crawler Robot.
  - Robocon & Roborollix competitions.

In Next 10 Years

- Use more of Robo Analyzer/MATLAB/ Stamp Editor v2.5.2.exe. software to understand the concepts.
- Do more assignments & Projects (Modeling & Fabrication).
- Use software/build hardware for class projects.
- Emphasize on mathematical formulations and design aspects.
- Consider credits in the Robocon & Roborollix type of activities.
- Replacing All Human Applications with Artificially Intelligent Robots especially at hazardous working environments.

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

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Dec. 22, 2012

Course: Robotics Engineering

S.No.	Lecture
1	Robot Systems
2	Sensors
3	Controllers
4	Degrees of Freedom
5	Mechanical Components in Robots
6	Mechanical Configuration of Robots
7	Workspace
8	Application of Robotics

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: First time]
[Total teaching experience: 6 years]

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Dec. 22, 2012

Course: Robotics(UG)

SN	Lecture (3 hrs. module) + Tutorial 1 hr	Details
1	Introduction	Automation and Robotics. Robotics trends, future prospects.
2	Fundamentals of Robot Technology	Robot Anatomy – Links, Joints and Joint Notation scheme,DOF, Required DOF in a Manipulator, Arm Configuration, Wrist Configuration; The End-effector, Human arm characteristics, Design & Control issues, Robot specification, Robot programming & work cell control.
4	Robot Motion Analysis	Introduction to co-ordinate frames mapping, Mapping
5	Kinematics Manipulators	Direct kinematics model mechanical structure
6	Robot end-effectors	Types of end-effector, methods of holding, Mechanical grippers, Mechanisms for grippers.
7	Differential Motion and Statics	Differentia kinematics, linear and angular velocity of a Rigid Body, Jacobian, Jacobian Inverse, Jacobian singularities, Static Analysis. Jacobian, Examples
8	Robot Control	Control of movements of mechanical joints,
9	Sensors in Robotics	Kinds of sensor used in Robotics, Tactile sensors Force-Torque sensors.
10	Robot Programming	Robot Programming issues, optimization position definitions
11	Machine Vision	Industrial application of vision controlled Robotic systems, Image processing and Analysis,,
12	Applications, Engineering and Social Issues (Self Study).	

Books/Software/Other Aids

- **Text Book**
  - Saha, S.K., Introduction to Robotics, Tata McGraw-Hill, New Delhi, 2008
  - Mittal R. K. & Nagrath I. J., "*Robotics and Control"*, TMH, 2003 (Reprint 2007 or later).
- **Reference Books:**
- (R1) Groover, M. P., et al., "*Industrial Robotics*", MGHISE, 1986.
- (R2) Fu, K. S., et al., *Robotic: Control, Sensing, Vision & Intelligence*, MGHISE, 1987.
- (R3) Robert J., Schilling, *Fundamentals of Robotics: Analysis and Control*, Prentice Hall, NJ, 2002.
- Ghosal, A., Robotics, Oxford, New Delhi, 2006
- Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Software**
  - RoboAnalyzer, MATLAB
- **Other Aids**
- Each student has to workout the given home assignments & work on a project assigned. The project will have seminar(s) and culminate with a written report and presentation of work done.
- Competitions

In Next 10 Years

- Create awareness and interest among students for the subject and their active participation in the same
- Develop a Robotics Lab at MNIT JAIPUR.

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 10 years]
[Total teaching experience: 13 years]

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Dec. 22, 2012

Course: Robotics Engineering (UG)/Robotics (PG)

SN	Lecture (3 hrs. module)	Lab. (2 hrs. module)
1	Introduction; Types (Mobile, Parallel,Serial: Cartesian, Cylindrical, etc.), History	Demos of ER9 robot; Virtual Robotics Lab. in ADAMS
2	Sensors and actuators used in Robots	DH parameters of a real robot
3	Pose, DH Parameters, Homogenous Trans.	Forward kinematics in MATLAB
4	Forward and Inverse Kinematics	Inverse kinematics derivations
5	Jacobian: Velocity transformation	Programming in MATLAB
6	Dynamics: Newton-Euler Recursive Algorithm	Class Project 1 Presentation
7	Euler-Lagrange Equations of motion/DeNOC	Control simulation (MATLAB)
8	Kinematic design: Singularity, Dexterity, etc.	DC motor control set-up
9	Mechanical design of robot links	Programming of ER9 robot
10	Control: Definition, closed-loop algorithm	Verify using RoboAnalyzer
11	Motion planning: Polynomial, Spline, etc	Dynamics of 3R robot
12	Parallel Robots: Inverse kinematics	Project 2 presentation
13	Forward Kinematics of parallel robots	Buffer class

Books/Software/Other Aids

- **Text Book**
  - M.P.Groover et al. Industrial Robotics, McGraw-Hill
- **Other Books**
  - Ghosal, A., Robotics, Oxford, New Delhi, 2006
  - Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009
- **Other Aids**
  - Class Projects: 1) Dynamics Model of RP manipulator; 2) Modeling of an AGV
  - Robocon competitions

In Next 10 Years

- Use of Visual simulation software to understand the concepts.
- Do more assignments
- Use hardware for class projects
- Emphasize on mathematical formulations and design aspects.
- Consider credits in the Robocon type of activities
- More importance to parallel planar manipulators

Thank you for your attention!
Any question/comment?

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 1year]
[Total teaching experience: 16 years]

Vishal S Sharma
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Dr B R Ambedkar National Institute of Technology Jalandhar
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Dec. 22, 2012

Sixth semester (UG) - IP-302 Robotics [3 0 0 3]

- **Fundamentals of Robotics:** Definition of a robot, types and technology levels of robots,
- classification of robots, parts of a robot, applications.
- **Dynamic modeling of Rigid Manipulators:** Kinematics modeling of manipulator arms, Denavit
  - Hartenberg notations, inverse kinematics, kinematics modeling of instantaneous motions, inverse
  - kinematics, Newton-Euler formulation for deriving the dynamics, Lagrangian formulation of
  - manipulator dynamics, inverse dynamics, trajectory planning.
- **Dynamics of flexible structures: Conventional Sensors and Actuators for Robots**
- **Smart Sensors and Actuators for Robots**
- **Control of Robots**

Books

1. Asada and Slotine, Dynamics and control of robot manipulators , Wiley, New York.
2. JS Rao , Advanced theory of vibrations, Wiley Eastern New Delhi.
3. AK Sawhney,A course in Mechanical Measurements and instrumentation, Dhanpat Rai

publication

4. H. Janocha , Adaptronics and Smart Structures, Springer, New York
5. JJ Craige, Introduction to Robotics, Pearson Education, New Delhi

In Next 10 Years

- Developing a Laboratory in the area of Industrial Automation & CAM
- Acquire experimentation Kits for Robotics
- Acquire simulation software's

Trends in Teaching Robotics to UG/PG Students

[Teaching Robotics: 6year]
[Teaching and Research Experience: 15 years]

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Dec. 22, 2012

Course ME7020: Robotics and Robot Applications (UG/PG)

SN	Contents
1	Applications, robot work cells
2	Sensors and actuators used in Robots
3	Pose, DH Parameters, Homogenous Trans.
4	Forward and Inverse Kinematics
5	Jacobian: Velocity transformation
6	Statics: Use of Jacobian
7	Dynamics: Newton-Euler Recursive Algorithm
8	Euler-Lagrange Equations of motion
9	Kinematic design: Singularity, Dexterity, etc.
10	Control: Definition, closed-loop algorithm
11	Motion planning: Polynomial, Spline, etc.
12	Vision system

Assignments
Seminars
Projects

Text Book
Robert J Schilling, Fundamentals of Robotics: Analysis and Control

Other Books
Craig, J.J., Introduction to Robotics: Mechanics and Control, Pearson Education, 2009

Course ED 5315: Introduction to Field and Service Robotics(UG/PG)

SN	Contents
1	Field and service robots: Classification, applications, social and ethical implications of robotics
2	Sensing and Perception: sensors, odometry, Inertial measurement, localisation, sensor fusion, Kalman filter, Markov localisation
3	Autonomous ground robots: Kinematics, locomotion, perception, motion planning and control, localization and mapping; Intelligent unmanned vehicles.
4	Underwater robots: Kinematics and dynamics, modeling and simulation, navigation, guidance and control
5	Medical Robots: Tele-operated surgical robots, Remote Centre of Motion, haptics for tele-operation, design and control
6	Introduction to aerial robots

Assignments
Seminars
Projects

Text Book:
R Siegwart, I. R. Nourobakhsh, Introduction to Mobile robotics, MIT Press, Cambridge, 2004.

Jacob Rosen, Blake Hannaford, Richard M. Satava (Eds), Surgical Robotics: Systems, Applications and Vision, Springer, **2011.**

G. Antonelli: Underwater Robots, 2nd Edition, Springer-Verlag, Berlin Heidelberg, 2006

Reference:
B Scicilliano, O Khatib (Eds), Handbook of Robotics, Springer, 2008

In the next 10 Years

- Setup laboratories for the field and service robots course (AUV, UGV, medical robot)
- Introduce advanced courses in underwater robotics and medical robotics
- Develop software/build hardware for class projects
- Emphasize on design aspects and develop application oriented robot products.

Thank you for your attention!

Trends in Teaching Robotics to UG/PG Students

Books/Aids

Subir Kumar Saha
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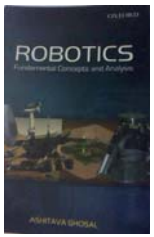
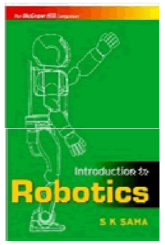
Dec. 22, 2012

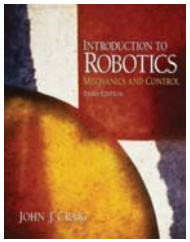
Books



10 Chapters
Introduction; Math. Rep. of Robots; Kin. of Ser. Rob.; Kin. of Par. Rob.; Vel. Ana. & Statics; Dynamics; Traj.; Pos./For. Cont.; Mod. & Cont. of Flex. Mani; Mod. & Ana. of WMR



12 Chapters
Introduction; Ser. Rob.; Actuators; Sensors; Trans.; Kinematics; Statics; Dynamics; Rec. Rob. Dyn.; Cont.; Mot. Plan.; Comp. for Rob.

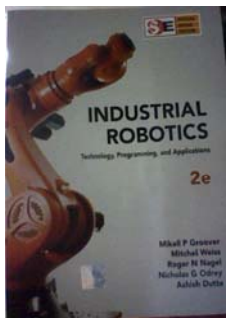


13 Chapters
Introduction; Spatial Des. & Trans.; Mani. Kin.; Inv. Kin.; Jacobian: Vel & Statics; Mani. Dyn.; Traj. Gen.; Mech. Des.; Lin. Cont.; Non-lin. Cont.; Force Cont.; Rob. Prog.; Off-line prog.;

- **Mathematical orientation**
- **Analysis**

More Books

10 Chapters
History, Status, Future; Rob. Kin. & Dyn.; Drives, Act. 7 Cont.; Rob. End-eff.; Sen.; Rob. Lang. & Prog.; Mechatronics and Comp. Inter.; Flexible Automation Tech.; Economic; Application

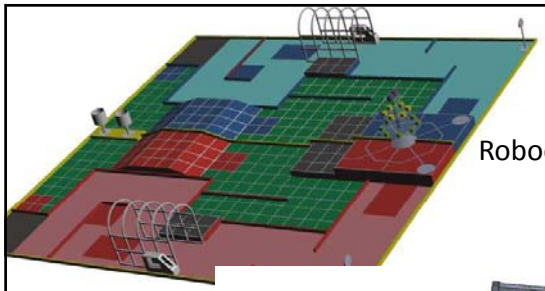


20 Chapters
Fund. of Rob.; Rob. Tech., Prog., Appln.; Cont. & Comp.; Mot. Ana.; End-eff.; Sen.; M/c Vis.; Prog.; Lang.; Cell. Des.; Eco.; Mat. Trans.; Proc. Op.; Assem.; Implem.; Safety; Social; Rob. for Future; Future Appln.

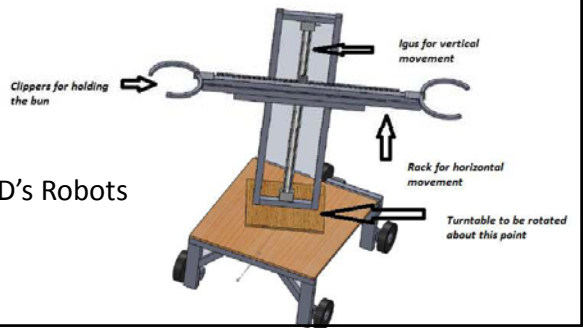
- **Descriptive type**
- **Easy for practicing engineers**

Projects/Robocon

- **Projects (Two Projects in a Semester)**
  - Kinematics (MATLAB/RoboAnalyzer)
  - Dynamics (RoboAnalyzer)
  - Control (MATLAB)
- **Robocon (Nat. Level Robotics Competitions)**
  - Annual event (March 1st weekend, Pune)
  - To make 3-4 robots (Manual + Automatic)
  - Design -> Hardware -> Software integration -> Debugging (robust and reliable)



Robocon 2012 Field



One of IITD's Robots

Thank you for your attention!

Any question/comment?

Trends in Teaching Robotics to UG/PG Students

RoboAnalyzer: 3D Model Based Robotics Learning Software

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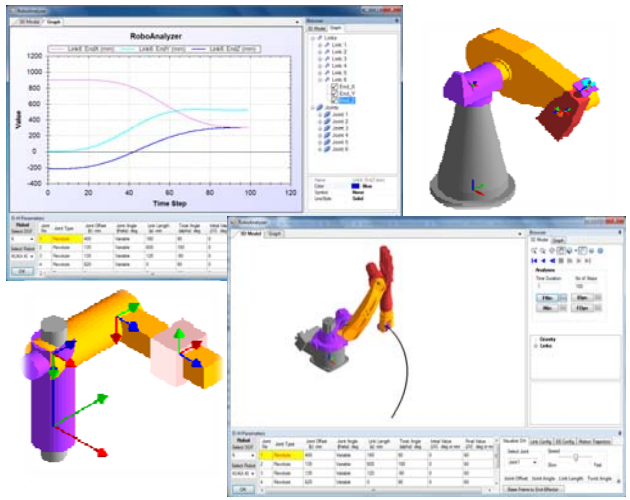
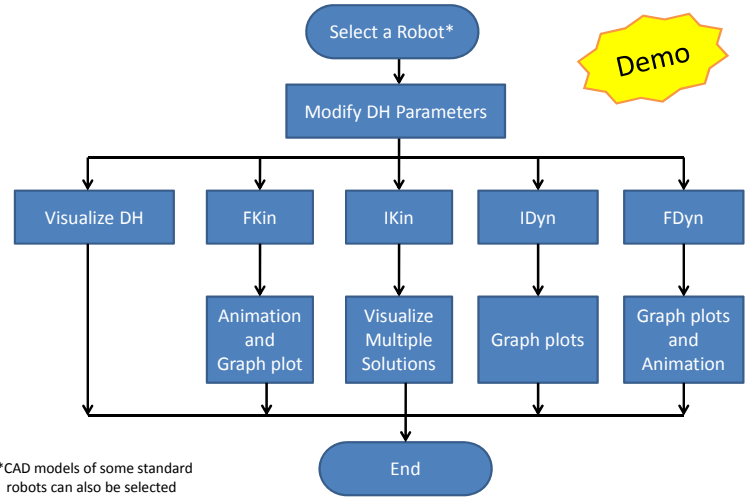
Dec. 22, 2012

RoboAnalyzer



RoboAnalyzer



Thank You

RoboAnalyzer Team

- Prof. S. K. Saha (1996- present)
- S. Goel and S. Ramakrishnan (1996-97)
- Patle (2000-01)
- Suril V. Shah (2007-11)
- Rajat Jain (2009-10)
- Rajeevlochana C.G. (2009 – present)
- Amit Jain (2010-11)
- Jyoti Bahuguna (2011-12)

Available for Free !!!

www.roboanalyzer.com

Trends in Teaching Robotics to UG/PG Students

Experiencing Mechanisms and Robotics through Virtual Labs for Engineering Education

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Dec. 22, 2012

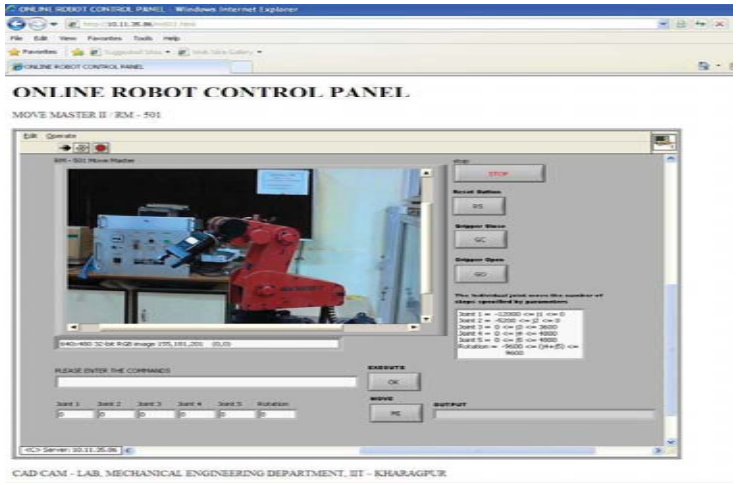
Visit to Various Virtual Labs Websites

- Main Website
  www.vlab.co.in
- Virtual Labs in Mechanical Engineering
  http://203.110.246.195
- Virtual Labs in Mechanisms and Robotics
  http://vlabs.iitkgp.ernet.in/MRLab
- Virtual Labs in Kinematics of Mechanisms
  http://vls-1.iitkgp.ernet.in/
- Virtual Labs in Robotics and Control Systems
  http://vlabs.iitkgp.ernet.in/r&c/index.html

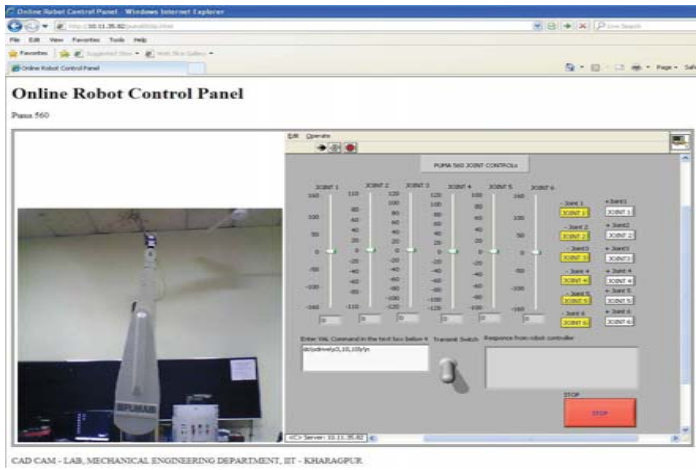
Some Robots in Virtual Labs

- SOME EXPERIMENTS ON ROBOTS
  - FORWARD KINEMATICS OF 5 axis robot (MOVEMASTER RM-501) http://iitkgp.vlab.co.in/index.php?sub=40&brch=129&sim=1271&cnt=2970
  - FORWARD KINEMATICS OF 6 Axis Robot (PUMA-560) http://iitkgp.vlab.co.in/index.php?sub=40&brch=129&sim=1270&cnt=2971
  - INVERSE KINEMATICS OF 6 Axis Robot (PUMA-560) http://iitkgp.vlab.co.in/index.php?sub=40&brch=129&sim=1269&cnt=2972

Online Robot Control of a 5 DOF Robot



Online Robot Control of a 6 DOF Robot



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6	P M Pathak	pushppathak@gmail.com	IIT Roorkee
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21	Raman	ramankanythia@gmail.com	LPU

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