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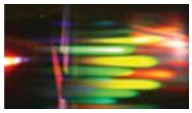

# Lecture 1: Introduction

**MRes in Medical Robotics and Instrumentation**

Guang-Zhong Yang, Imperial College London

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## Course Structure and Objectives

- To provide an overview of the current technology used in medical robotics and smart surgical instruments;
- To underpin the theoretical foundation of kinematics, mechanics, control and navigation required for the understanding and future development of surgical robots;
- To establish seamless links to other Lectures of the MRes course, particularly in surgical imaging, image guided intervention, and perception and ergonomics;
- To introduce advanced topics in medical robotics and prepare the candidates for their individual projects and with skills required for their future industrial or research career.

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## References


- *John J Craig, Introduction to robotics – mechanics and control, 3rd Edition, Pearson Education International, London, ISBN 0-13-123629-6.
- *Siciliano & Khatib Eds, Handbook of Robotics, Springer ISBN: 978-3-540-23957-4.
- **Robotic Toolbox** - http://petercorke.com/Robotics_Toolbox.html
- Reza N Jazar, Theory of applied robotics, 2nd Edition, Springer, ISBN 978-1-4419-1749-2.
- Appin Knowledge Solutions, Robotics, Infinity Science Press, ISBN 978-1-934015-02-5.
- Other specific research publication or online materials used will be referenced in each lecture.


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**1920** Czechoslovakian playwright Karel Capek introduces the word robot in the play R.U.R. - Rossum's Universal Robots. The word comes from the Czech robota, which means tedious labour.

...

1962 General Motors purchases the first industrial robot from Unimation and installs it on a production line. This manipulator is the first of many Unimates to be deployed.

...

**1995** Intuitive Surgical formed by Fred Moll, Rob Younge and John Freud to design and market surgical robotic systems. Founding technology based on the work at SRI, IBM and MIT.

...

2003 Perceptual Docking

**2010** i-Snake®

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## Asimo: A self regulating machine…


Video Source from BBC 4

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## Isaac Asimov's "Three Laws of Robotics"

- "A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law".


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## 4A for 4D – 3D3H

- 4A Performance: Automation, Augmentation, Assistance, Autonomous;
- 4D Environments: Dangerous, Dirty, Dull, and Difficult;

- 3D: Dull, Dirty, and Dangerous;
- 3H: Hot, Heavy, and Hazardous.

- What's your term for Medical Robotics?

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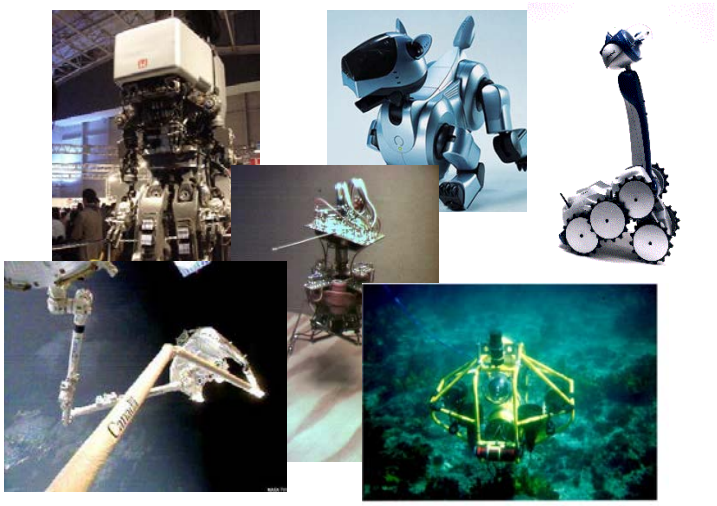

Video Source - Google

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## Navigation Challenges


Video Source from BBC 4

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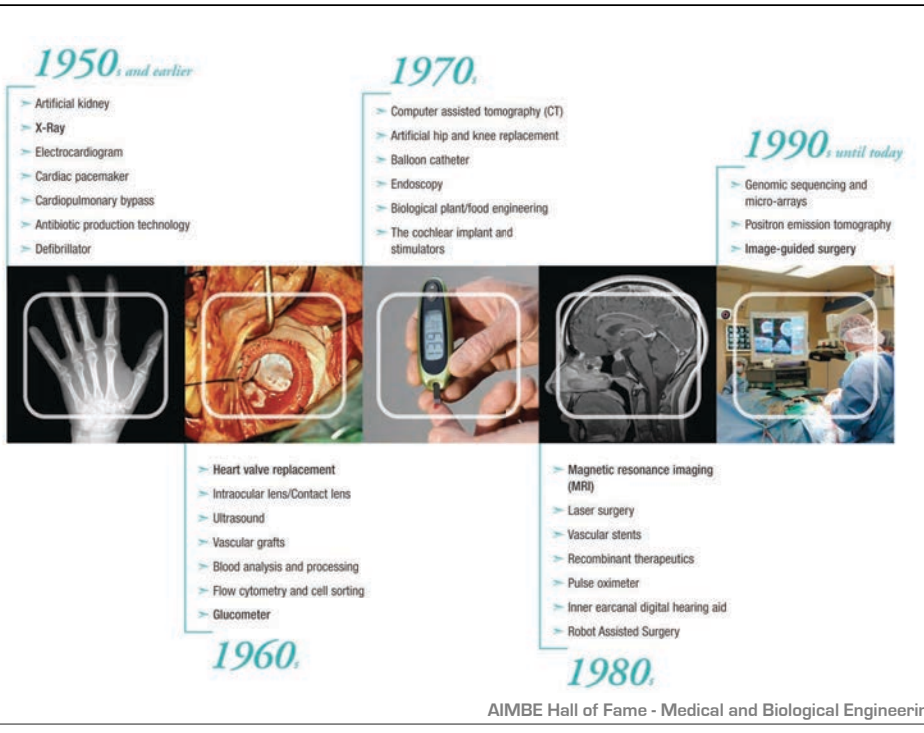


AIMBE Hall of Fame - Medical and Biological Engineering

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## Central Research Laboratories (1950s-60s)

- Used in nuclear/chemical sites to handle hazardous materials


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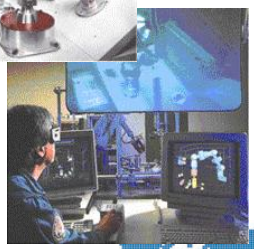
## Space Systems (1980s-1990s)

**JPL ATOP** (NASA/JPL-CALTECH)

- Simulating teleoperation in space

**Rotex** (German Aerospace Center, DLR)

- First telerobotic system in space



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## Robotic MIS (2000s)

- Small incision, reduced trauma, shorter recovery time, improved prognosis
- Dexterity Enhancement
  - rigid instrument
  - fulcrum effect
  - microprocessor controlled mechanical wrist
- Image Guidance
  - poor hand-eye coordination
  - *in situ* visualization of preoperative or intraope data
  - augmented reality

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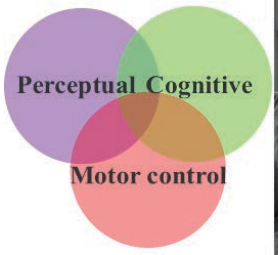
## Key Challenges of MIS

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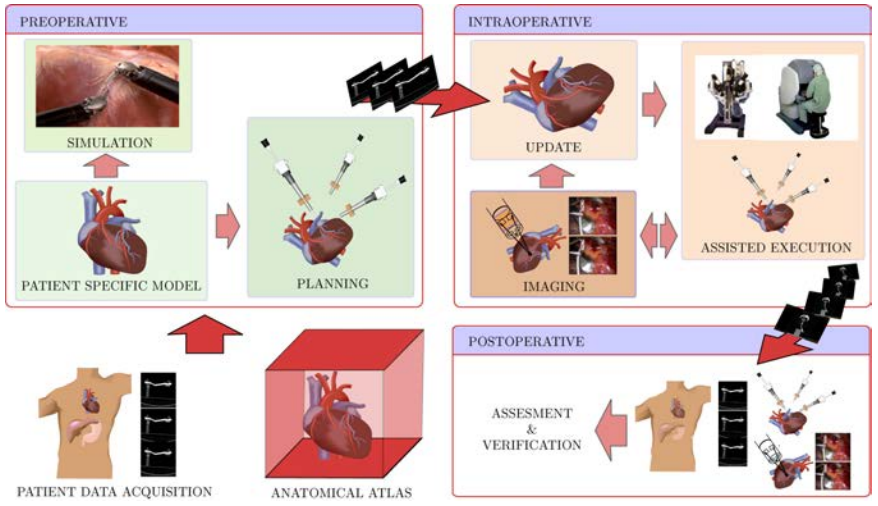


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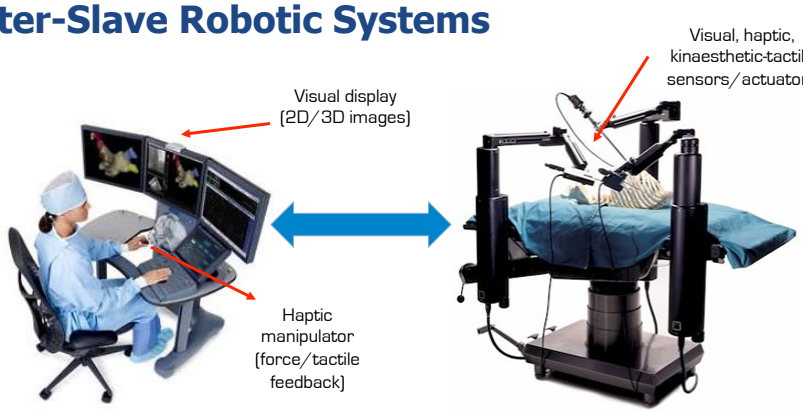
## Master-Slave Robotic Systems




**Master side**
controller workstation where an operator can provide position and orientation commands to actuate the manipulator

**Slave side**
mechanism/linkage system that replicates motions and forces from the operator in the work area, usually remotely located

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## Design Considerations

**Master side**

**Visualization System -** 3D and high resolution images (especially for surgical applications)
**Manipulation and Control -** Haptic interface with force feedback
**Ergonomics -** Comfort, look-down display

**Slave side**

**Compactness -** Especially for cluttered environment applications (search and rescue, surgery)
**Light-weight -** Easy transport and manipulation
**High dexterity -** High number of degrees of freedom (DOF)
**Back-drivability**

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## AESOP™

FDA approved in 1993, Voice controlled, 7 DOF

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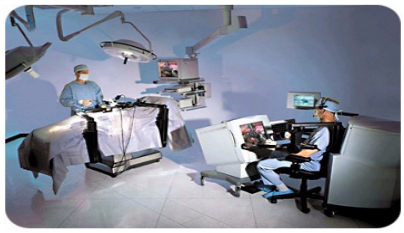
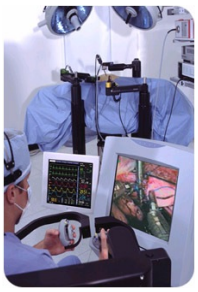
## The Zeus ™





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## da Vinci ™

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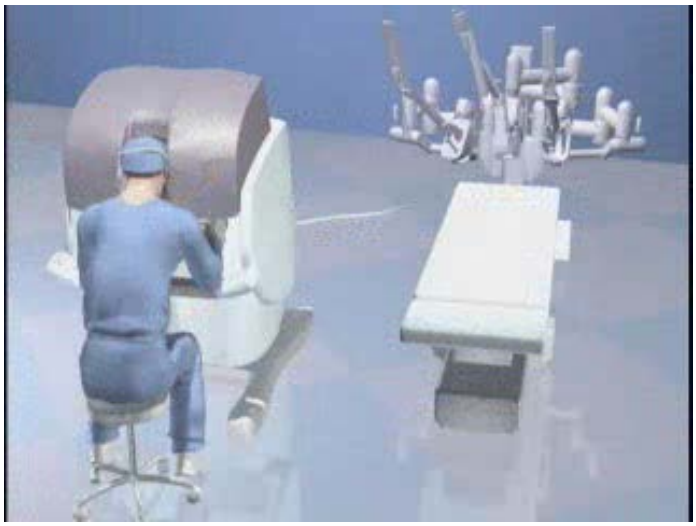

Video Courtesy Intuitive Surgical Inc

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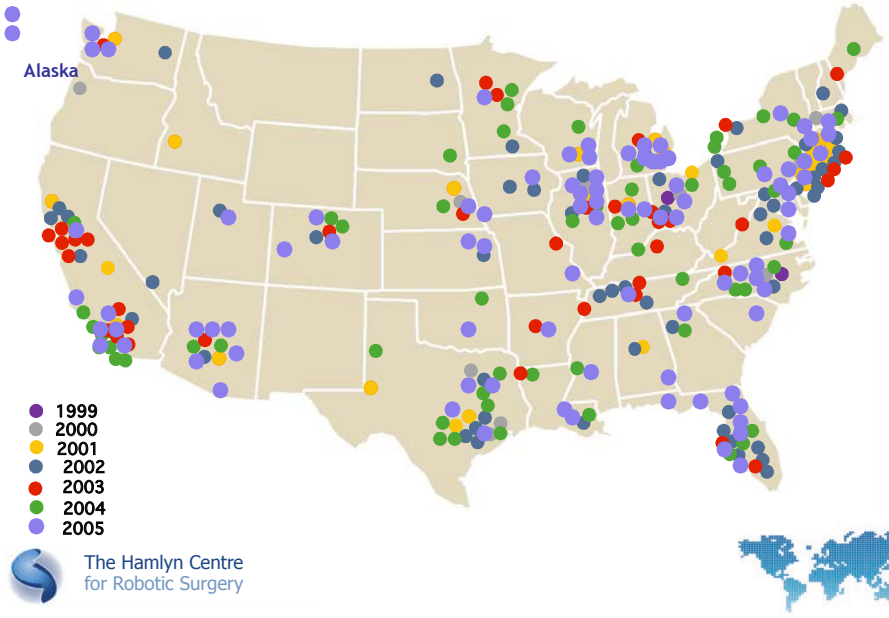


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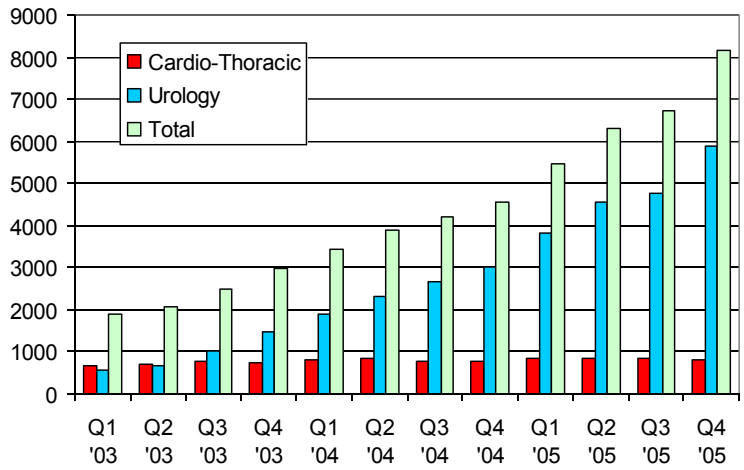


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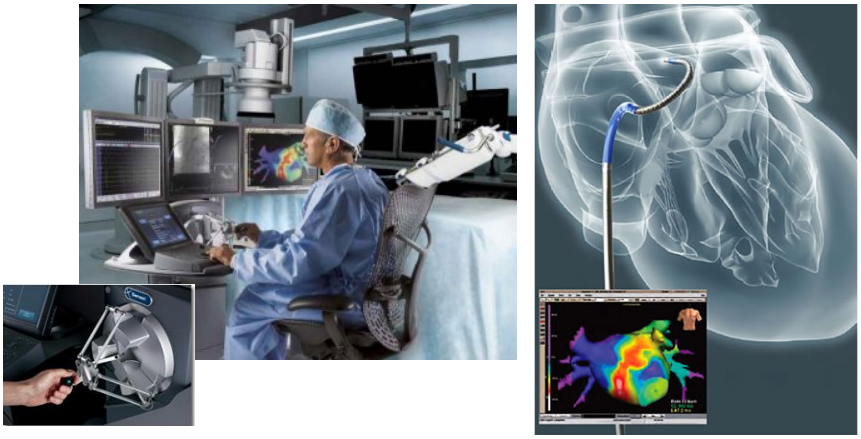
## Sensei Robotic Catheter System Hansen Medical



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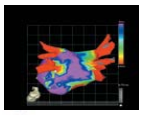
## Stereotaxis Catheter Navigation







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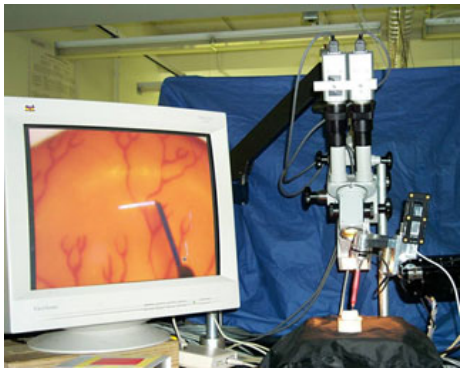
## Steady Hand Microsurgical Robot – JHU

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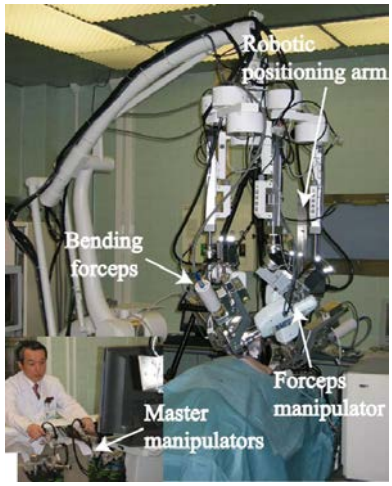
## Master-Slave Surgical System- University of Tokyo

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## MRI-guided Surgical System

Hitachi Medical Corporation

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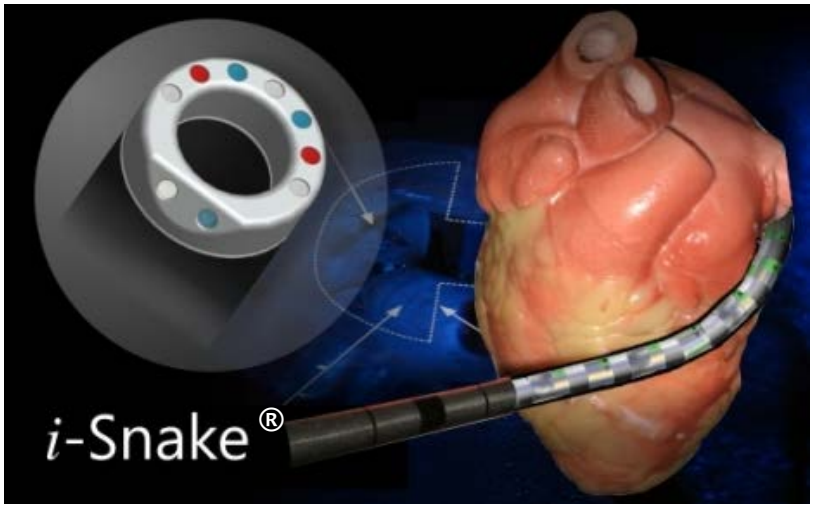


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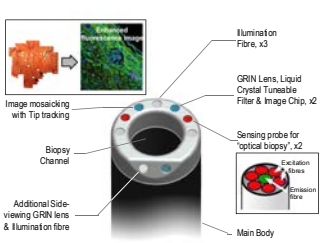
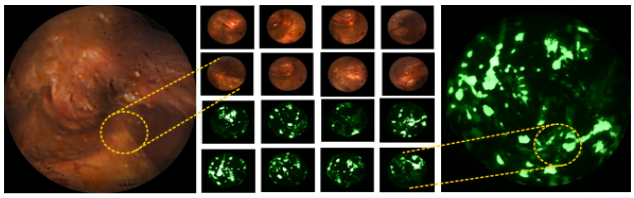
## i-Snake®



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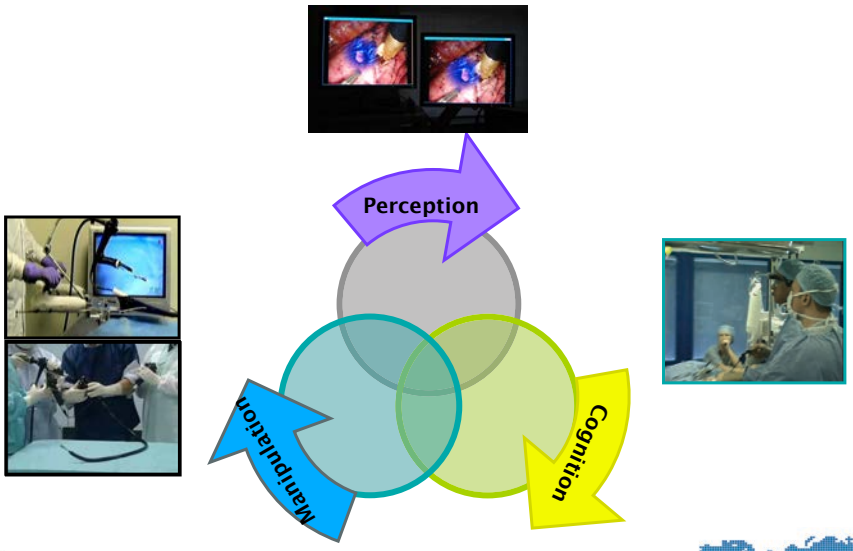


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## Lectures to be covered

- **Lecture 1** – Introduction to Medical Robotics
- **Lecture 2** – Basic Kinematics and Transformations (with tutorial)
- **Lecture 3** – Forward Kinematics (with tutorial)
- **Lecture 4** – Basic Mechanics
- **Lecture 5** - Inverse Kinematics (with tutorial)
- **Lecture 6** – Sensing and Actuators
- **Lecture 7** – Jacobian and Velocities (with tutorial)
- **Lecture 8** – Mechanism Analysis

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## Lectures to be covered

- **Lecture 09** – Safety and Path Planning (with tutorial)
- **Lecture 10** – Feedback Control
- **Lecture 11** – Visual Servoing (with tutorial)
- **Lecture 12** – Navigation and Deformation Tracking
- **Lecture 13** – Haptics and Virtual Fixtures (with tutorial)
- **Lecture 14**– Learning and Perceptual Docking
- **Lecture 15** – Biologically Inspired Robot (with tutorial)
- **Lecture 16** – Future of Robotic Surgery

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