

Spring 2003

Special Topics on Controls and Robotics:

24779-A: Micro/Nano-Robotics

9 Units

TuTh 1:30-2:50 pm, SH 212

Instructor: Metin Sitti, msitti@andrew.cmu.edu, SH 315, Phone: 8-3632

Course URL: <http://www-2.cs.cmu.edu/~msitti/24779/> (tentative)

Course Outline (tentative):

Introduction

- Micro/Nano-Robotic System Overview
- Scaling Effects in the Physical Parameters
- Micro/Nano-Robotic System Examples Around the World

Micro/Nano-Physics

- Micro/Nanoforces: Van der Waals, Capillary, Electrostatic, Double Layer, Hydration, etc. Forces
- Adhesion and Surface Energy
- Micro/Nano Scale Contact Mechanics: Hertz, DMT, JKR, and MD Contact Mechanics Approaches
- Micro/Nanotribology
- **Case Study: Adhesion and Friction Mechanisms in Nature: Geckos, Insects, etc.**

Micro/Nano-Sensors

- Imaging Sensors (Far-Field and Near-Field):
 - Optical Microscopy: Reflective, Inverted, Stereo, etc., Scanning Electron Microscopy (SEM), and Tunneling Electron Microscopy (TEM).

- Scanning Probe Microscopy (SPM)
 - Scanning Tunneling Microscope (STM)
 - Atomic Force Microscope (AFM)
 - **Case Study: Micro/Nanophysics Modeling for AFM Probes**
 - Magnetic, Capacitance, Thermal, etc. Microscopy
- Position Sensors: Capacitive Sensors, Linear Variable Differential Transformer, Interferometric Sensors, STM Tips based, etc.
- Force and Pressure Sensors: Strain Gauges, Deflection Based: AFM, etc., Visual Force Sensing: Bending Imaging, etc., Capacitive Force/Tactile Sensors
- Accelerometers, Gyroscopes, Chemical Sensors, Flow Sensors, etc.

Micro/Nano-Actuators

- Piezoelectric Actuators
 - Bending Type: Unimorph and Bimorphs
 - Stack Type: Piezotubes, Thin-Film Type: ZnO, etc. films, Surface Acoustic Waves, PZT actuators as also integrated sensors
- Electrostatic, Thermal, Ultrasonic, Electro/Magnetostrictive, and Shape Memory Alloy Based Actuators
- Polymer Actuators, Dielectric Elastomers, Carbon Nanotube (CNT) Actuators
- Biomolecular Motors

Energy (Power) Sources

- Lithium Thin Film Batteries, Solar Cells, Micro Fuel Cells, (Electro)Magnetic Energy, Molecular Energy (ATP), etc.
- **Case Study: Medical Microrobots inside the Human Body**

Micro/Nano-Manipulators

- SPM Probes and Micro/Nanogrippers
- **Case Study: Atomic Manipulation Using STM (IBM, DTU)**
Optical Tweezers, (Di)Electrophoresis
- **Case Study: Bio-Manipulation using Optical Tweezers and Dielectrophoresis**
Case Study: CNT Manipulation using Nanoprobes
Case Study: High Density Data Storage using Nanoprobes

Manufacturing Techniques

- Micro/Nanofabrication, Micro/Nanoassembly, Self-Assembly, Hybrid Integration, etc.
- **Case Study: Precision Micro/Nanoparticle Assembly** (Univ. of Tokyo, USC, DTU, etc.)
3D Assembly under SEM, AFM Based 2D Pushing, Challenges, and Applications
- **Case Study: Guided Self-Assembly**

Micro/Nano-Robot Design Strategies

- Biomimetics and Design Strategy
- **Case Study: Biomimetic Micromechanical Flying Insects** (UCB)
Learning from Nature, Design, Manufacturing, Sensors, Actuators, Control, Challenges, and Applications

Micro/Nano-Robot Control

- Kinematics and Dynamics, (Teleoperation Based, Task Based and Automatic) Control Approaches, Issues, Distributed Control, etc.

Literature Review Reports

Project Presentations (20-30 minutes/student)

Guest Speakers:

- To be arranged

Grading:

Final Project: 50%

Homework: 30%

Literature Review Report: 20%

Some Relevant Textbooks:

- M. Elwenspoek and R. Wiegerink, **Mechanical Microsensors**, Springer-Verlag Berlin, 2001.
- J. Israelachvili, **Intermolecular & Surface Forces**, Academic Press Ltd., 2nd Edition, 1992.
- M. Scherge and S. Gorb, **Biological Micro- and Nano-tribology: Nature's Solutions**, Springer Verlag, Berlin Heidelberg, 2001.
- V J Morris, A R Kirby, A P Gunning, **Atomic Force Microscopy for Biologists**, London, Imperial

College Press, 1999.

- Dror Sarid, **Scanning Probe Microscopy**, Oxford University Press, Revised Edition, 1994.
- S. Fatikow and U. Rembold, **Microsystem Technology and Microrobotics**, Springer, 1997.
- (Ed. by) H.-J. Güntherodt, D. Anselmetti, and E. Meyer, **Forces in Scanning Probe Methods**, NASA Science Series, 1995.
- B. Bhushan, **Handbook of Micro/Nanotribology**, CRC Press, 2nd Ed., 1999.
- D. Maugis, **Contact, Adhesion and Rupture of Elastic Solids**, Springer Verlag, Berlin, 2000.
- M. Madou, **Fundamentals of Microfabrication**, CRC Press, 1997.
- Elwenspoek & Jansen, **Silicon Micromachining**
- Ristic, **Sensor Technology and Devices**
- Senturia, **Microsystem Design**
- Sze, **Semiconductor Sensors**
- G. T. Kovacs, **Micromachined Transducers Sourcebook**, Mc-Graw-Hill Companies Inc., 1998.
- Tai-Ran Hsu, **MEMS and Microsystems Design and Manufacture**, McGraw-Hill Inc., 2002.

Relevant Journals:

Science, Nature, Scientific American, J. of MEMS, J. of Micromechanics and Microengineering, Nanotechnology, IEEE/ASME Trans. on Mechatronics, IEEE Trans. on Robotics and Automation, Advanced Robotics, J. of Micromechatronics, J. of Adhesion Science & Technology, Sensors and Actuators A/B, J. of Vacuum Science & Technology, Applied Physics Letters, J. of Applied Phys., Review of Scientific Instruments, ...

Relevant Conference Proceedings:

Proc. of the IEEE Nanotechnology Conference, IEEE International Conference on Robotics and Automation, IEEE/RSJ International Conference on Intelligent Robots and Systems, IEEE International Workshop on Micro Electro Mechanical Systems, Proc. of the SPIE - The International Society for Optical Engineering (Microrobotics and Microassembly), Proc. of the International Symposium on Micromechatronics and Human Science, Proc. of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics, ...

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