2.76 / 2.760 Lecture 1: Logistics & Intro

Tablet PCs

Goals
- Perception
- Design approach
- Manufacturing
- Integration

Activities
- Topical overview
- Project overview
- Literature review

Thanks to:
NSF CAREER: Nanomanufacturing Program

Macro-scale Hexflex Nanomanipulator

Student-built Scanning Tunneling Microscope (STM)

Micro-scale Hexflex Nanomanipulator
Tools and resources

Tablet PCs

- SolidWorks
- Unigraphics
- ProE
- Matlab
- MathCad
- Excel 2003
- CoMeT
- CosmosWorks
- OMAX layout
- Word 2003
- PPT 2003

To do:

- Wireless set up
- Sign agreement
- Expected to have your Tablets at each class
What is a multi-scale system?

Systems are characterized by:

- Component functions
- Component interfaces
- Component arrangements (parallel, series, sub-systems)

For MuSS, not well understood / covered in literature

Multi-scale systems

Span size scales of several orders of magnitude (OOM)
What can be coupled?

Is it as simple as saying connection pts?

Connecting points important but not all

Cross-scale interactions

- Function
- Form
- Flows
- Physics
- Fabrication
Cross-scale coupling

Macro

Meso

Micro

Nano

- Function
- Form
- Flows
- Physics
- Fabrication

Function

Form

Flow

Physics

Fabrication

<table>
<thead>
<tr>
<th>What</th>
<th>Geometry</th>
<th>Mass</th>
<th>Application</th>
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### Cross-scale coupling

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Figure by MIT OCW.
Why 2.76 / 2.760?

Components

- Machine elements
- Electronics
- Fabrication

Integration

- No MS integration edu
- No MS mfg. edu

Range: .05 nm – 10cm
Ratio: 2 000 000 000

What are the consequences of this?
E.g. say errors which scale with size?
Thermal, vibration, gravity, electrical, sound, noise, etc…
Why now?

Isn’t this “careful” design of each part & & using precision assembly (PA)?

Careful design with the wrong perspective leads to bad FRs and CSs?

PA often needed to cross scales, BUT goal is to eliminate need for PE!!!

We want to manufacture not fabricate
George Patton had his perspective right

"No “body” ever won a war by dying for his country. He won it by making the other poor dumb “guy” die for his country."

Get everything you want with minimal effort while maintaining future productivity:

- Maximize use/re-use of complimentary parts
- Minimize conflicts / incompatibilities
Semester at a glance

Sept.
- Design
  - Perception
  - Approach

Oct.
- Model
  - Components
  - Interfaces
  - System
  - Examples

Nov.
- Project
  - Model
  - Design
  - Integration
  - Validation
  - Characterize

Dec.
- PSets
  - 3 p. max!
  - Schedule
  - Risk
  - Mitigation

2.76 Multi-scale System Design & Manufacturing
Course goals

Inter and intra-scale perspective

- MoSS modeling
- MuSS modeling
- Error modeling
- Cross-scale interfacing
- Application & examples

Fabricating MuSS

- MuSS DFM
- Process compatibility
- Characterization
- Calibration
- Integration

Our focus is on mechanical aspects
Our Research

<table>
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<tr>
<th></th>
<th>Culpepper</th>
<th>Kim</th>
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### Examples

#### Things Natural

<table>
<thead>
<tr>
<th>Human heart</th>
<th>Human hair ~ 10-50 mm wide</th>
<th>red blood cell ~5 µm</th>
<th>bacteria 1 µm</th>
<th>DNA proteins nm</th>
</tr>
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</table>

#### The Microworld

- $10^{-2} m$ = 1 cm = 10 mm
- $10^{-3} m$ = 1 mm
- $10^{-4} m$ = 0.1 mm = 10 µm
- $10^{-5} m$ = 100 nm = 0.1 µm
- $10^{-6} m$ = 1 µm
- $10^{-7} m$ = 100 nm = 0.1 µm
- $10^{-8} m$ = 1 nm

#### The Nanoworld

- $10^{-9} m$ = 1 nanometer (nm)
- $10^{-10} m$ = 0.1 nm

#### RF Switch

- $10^0 m$ = 1 meter
- $10^1 m$ = 10 meters
- $10^2 m$ = 100 meters

#### Nanopipette

- $10^3 m$ = 1 kilometer

#### Biomedical Manipulators

- $10^4 m$ = 10 kilometers

#### Nano manipulation

- $10^5 m$ = 100 kilometers

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Diagrams removed for copyright reasons.
How can you engineer (not just model!) the small-scale with no experience?

Should we:

Applied math & modeling = “idea”

Or should we:

Do fundamentals
Learn to design small to large
Use the STM to learn about the small!!!
Examples: STM

Bias voltage (mV – few volts) applied between tip and sample

At ~10 Ångstroms current (nA) flows

Overlapping tip-sample atom wave functions

Electrons “tunnel” across the gap

\[ i(gap) \sim e^{-2K \text{ gap}} \]

Figure by MIT OCW.

Two images removed for copyright reasons.
Source: IBM Almaden Research Center
http://www.almaden.ibm.com
Examples: STM

\( i(gap) \sim e^{-2K \text{gap}} \) drives coupled scale ratio

Why this project

- Learn how to model/apply lecture
- Investigate small-scale (get a feel for small-scale)
- Prepare you for research/experiment/industry
Examples: STM

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Examples: STM

Is this an overly ambitious project?

Yes, but...

our freshman engineering students do...
Problem sets

Two birds with one stone
- Ambitious project
- Problem set = project steps

Quality:
- Typed, stapled, neat sketches
- 3 page maximum

On time, every time
- No late work for credit
- Must hand in all work to pass
- Submission

<table>
<thead>
<tr>
<th>Component</th>
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<tbody>
<tr>
<td>Assignment</td>
<td>35%</td>
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<tr>
<td>Project</td>
<td>35%</td>
</tr>
<tr>
<td>Participation</td>
<td>20%</td>
</tr>
<tr>
<td>Critique</td>
<td>10%</td>
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Literature critique

Logistics
- 3 papers per team, 2 papers per student
- 3 page critique per paper
- 10 minute presentation

Guidelines
- Scientific/scholarly merit
- Impact and importance
- Scientific and engineering approaches

Purpose
- Extend knowledge beyond pure mechanical
- Project suggestions
- Professional preparation
What is important for 2.76 / career?

Identifying & prioritizing importance

Nice vs. necessary & moving fast

Qualitative, but rational modeling

Quantitative modeling

Concise communication (3 pagers)
Assignment

E-mail resume to Course Secretary

Don’t forget tablet agreement form!!

Reading: Design & Complexity