Welcome to
CEE 201L. Uncertainty, Design, and Optimization

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Uncertainty, Design, and Optimization

Elements

- **Design**: open-ended problems requiring creative solutions and iterative analyses (C.A.D.).
- **Numerical Optimization**: methods to iteratively “improve” a solution.
- **Uncertainty Quantification**: methods to describe what we don't know.

Homework and Projects

- Optimize a statically determinate truss.
- Minimum Total Potential Energy.
- Supply enough clean drinking water.
- Trade stocks to make money.
- Structural dynamics.
- Protect buildings and contents from earthquakes.

Lessons

- The value of a highly-refined optimization result is mediated with uncertainties inherent in the design problem.
- Increasing the robustness of an optimized performance incurs a cost.
- Them: “We optimized this!!” You: “. . . oh, really?”
CEE 201L will develop your understanding of . . .

- Computer Programming (Matlab)
- Solid Mechanics (EGR 201L) or Electrical Engineering (ECE 110L)
- Linear Algebra (Math 218-2)
- Probability and Statistics (EGR 238, EGR 305)

. . . through the development of solutions to realistic and relevant engineering challenges

. . . involving the assembly of complex mathematical models from self-evident principles

CEE 201L will teach you to think like an engineer.
Numerical Optimization

minimize \( J = f(x_1, x_2, \ldots, x_n) \), such that

\[ g_1(x_1, x_2, \ldots, x_n) \leq 0 \]
\[ g_2(x_1, x_2, \ldots, x_n) \leq 0 \]
\[ \vdots \]
\[ g_m(x_1, x_2, \ldots, x_n) \leq 0 \]
Optimizing Important Things

\[ y'_L = \frac{dy}{dt} \bigg|_{t=t_L} \]

\[ \beta \]

\[ -y'_L = \tan \beta \]

\[ s = \sin \beta \]

\[ c = \cos \beta \]

\[ L - \frac{ds}{2} - \frac{(L + d/2 - H)}{y'_L} \]

\[ L + \frac{ds}{2} - \frac{(L - d/2 - H)}{y'_L} \]

\[ \frac{L - D/2}{L - ds/2} \]

\[ \frac{L + ds/2}{L + D/2} \]

\[ y_{L+dc/2} \]

\[ y_L \]

\[ y_{L-dc/2} \]

\[ H \]

... how Paolo Banchero thinks?

... how Paolo Banchero sinks.
Simulation with Quantified Uncertainty

Simulation of Uncertain Variables ➞ Analysis ➞ Risk Assessment

E = W - R

W

R

50

40

30

-100

0

100

200 k

Y = g(X₁, X₂, X₃)

X₁: normal

X₂: log-normal

X₃: Rayleigh

CEE 201L.
Supply Power through a Grid . . . \[ \sum (P_{\text{in}} - P_{\text{out}}) \approx 0 \]
Optimize a truss . . . \( \sum F = 0 \)

\[ F = 3.5 \text{kN} \]

- Bar 1 Buckles
- Bar 2 Yields
- Bar 2 Buckles

\( x_C \), m

\( F = 3.5 \text{kN} \)

\( x_B, h \)

\( x_C, 0 \)

\( X \)

\( R_{AS} \)

\( R_{CS} \)

\( Y \)

\( P \)

\( T_1 \)

\( T_2 \)

\( R_{AT} \)

\( R_{CT} \)

\( B \)

\( C \)

\( A \)

\( (0,0) \)

\( (x_B, h) \)

\[ p.d.f., f_{G}(g) \]

\[ c.d.f., F_{G}(g) \]

\( \text{yielding of bar 1} \)

\( \text{yielding of bar 2} \)

\( \text{buckling of bar 1} \)
Supply enough clean drinking water . . . \( \Delta V = (Q_{in} - Q_{out})(\Delta t) \)
Trade stocks to make as much money as possible . . . “buy low, sell high?”
Protect buildings and contents from earthquakes.

![Diagram of earthquake protection]

- Strength, $F_p$, kN
- Stiffness, $K$, kN/m

$H = 3.999$
Optimization with Uncertainty
Course Information

▶ http://www.duke.edu/~hpgavin/cee201/
▶ T.A.: Boyang Zhang boyang.zhang@duke.edu
▶ Install matlab or octave
▶ Grading

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<thead>
<tr>
<th>Component</th>
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<tr>
<td>Homework</td>
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<tr>
<td>Group Projects</td>
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<tr>
<td>Take-Home Final</td>
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<tr>
<td>Participation</td>
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▶ Read the syllabus for:
  - collaboration policy
  - homework extension policy
  - late-work policy
  - neatness expectation and points
  - group work peer evaluation formula
  - reading assignments, due-dates, and test dates
Organizing folders (directories) for CEE 201L.

- cee201
  - cee201/m-files ... for general-purpose matlab files
  - cee201/Syllabus
  - cee201/HW
  - cee201/Uncertainty
  - cee201/Optimization
  - cee201/PowerGrid
  - cee201/Truss
  - cee201/Water
  - cee201/StockExchange (?)
  - cee201/Earthquake (?)

In Matlab ... Home > Environment > Set Path

- click Add with Subfolders ... 
- navigate to your cee201/m-files folder and add it to the path
- click Save

... Home > Environment > Preferences > Numeric Display > Compact
How to find me . . . Room 162 Hudson Annex