AAE 590 Data Science Applications in Mechanics of Materials
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Description

Focus of this course is on exploring applications of data science to mechanics of materials related models and experiments. Emphasis is on (a) hands on use of finite element related models for formulating data science problems (e.g. n-point correlation functions to describe material microstructures, data science procedures to formulate material constitutive behavior etc.) and (b) on correlating design of experiments with automated data extraction in high throughput experiments such as indentation experiments and sensor data fusion type of experiments. A third part of course is focused on analyzing available options in high volume data processing and analytics with emphasis on mechanics of materials applications. In a typical 14 week semester, data science analyses procedures using mechanics of materials simulations will be typically done in 7 weeks, and experimental data science procedures will be focused upon for 7 weeks. In the following specific topical breakdown is presented:

1. Data Science for Mechanics of Materials Simulations; (7 weeks)
    a. Process-structure-property (PSP) linkages at atomistic and mesoscopic length scales and the relation of such linkages to macroscale structural properties
    -Focus here is on learning how one can use n-point correlation schemes in combination with convolution neural network based schemes to correlate processing-structure-property databases for specific target properties. Specific physical property of focus here will be fracture resistance defined with specific terminology related to each scale. Case studies for materials will be picked from literature.
    b. High throughput material informatics and material screening for specific properties (e.g. ductility)
    -Focus here is on establishing physical principles based screening protocols for specific physical properties of fracture toughness and cohesive traction-separation relations. Assignments will focus on connecting physical principles of other phenomenon such as creep or fatigue with fundamental affecting parameters such as microstructures, environment, or changing boundary conditions.
    c. Microstructural image analytics and database generation
    -Focus here is on extending parts- and b above to specific examples of microstructure imaging during manufacturing and using that as an underlying thread to connect manufacturing parameters with final fracture resistance and to other properties such as fatigue life. Part-C is used mainly as a case study type of part to round off the first 7 weeks of the class. Ultimate goal is to introduce material mechanics knowledge systems that connect mechanical and structural properties with manufacturing using data science principles.

2. Data Science for Design of High Throughput Mechanics Experiments and Sensor Fusion Problems; (7 weeks)
    a. High-throughput experimental assays for PSP linkages
    -Focus here is on using principles developed in part-a above to dwell on design of experiments schemes that lead to optimal design of high throughout experiments. Specific physical property emphasis again is fracture resistance defined with specific terminology related to scale of experiments. Unlike conventional design of experiments focus here is on a common thread for optimal revision of experiments using data science approaches that can be identified for target PSP linkages.
    b. Fusion framework for large scale data generation on online PSP integration
    -Building on the above part emphasis is on integrating experimental assay with correlation schemes identified in part-1 to identify determinants of quality of high throughput data generation for specific properties such as fracture toughness, microstructural dependent elastic modulus, interface strength etc.
    c. Automation and autonomy in mechanics of material experiments

-Emphasis of this part is on introducing how correlation schema can be used for autonomy approaches with case studies of mechanics of materials studies where autonomy based on data science has been used.

d. Cyberinfrastructure problems for collaborative material innovation

   -Finally, the last part of course will focus on using cyberinfrastructure principles to incorporate autonomous high throughput experiments.

Evaluation:

There will be bi-weekly assignments (30%). Besides assignments, the course will have two mid-term exams (40%) and one final exam (30%).

Prerequisites:

Finite element Method for Aerospace Structures; Elasticity; Mechanical Behavior of Materials

Learning Goal:

By the end of course students are expected to understand fundamental insights into the following questions:

1. How different data science procedures are related to mechanics of materials simulations and how students can benefit from them in their own research?
2. How they can design high throughput experimental data collection to feed into data science based improvements?
3. How a combination of simulations and high throughput experiments can be useful for engineering problem solving?

   The course is expected to fill gap between data science method development and realistic applications of data science by adopting a practical approach/