ME4853-JAJ / ME3110 Syllabus
AI for Design and Manufacturing 0-2-3-3

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Textbook: All course materials are available via Canvas. No textbook is required for the course.

Catalog Description
Fundamental AI methods and intelligent decision support techniques for creating, analyzing, synthesizing and implementing design solutions to open-ended problems in manufacturing system planning and operations optimization.

Pre-Requisites*
Junior or senior standing, ME2110 Creative Decisions and Design and ME 2016 Computing Techniques (for ME students), or by instructor approval (for non-ME majors).

Course Goals and Learning Outcomes
A junior-level course (50% lecture/studio and 50% lab, 0-2-3-3), e.g., ME3110 similar to ME2110.
Upon completion of this course, students will bridge the gap between creative decision-making in design (ME2110) and the practical application of engineering concepts in capstone design (ME4182). The syllabus will focus on AI-powered design for manufacturing automation, offering students hands-on experience with AI tools and techniques within the context of design in a smart factory setting. The focus is to learn and practice key data analytics and AI techniques for ME applications with tangible skills involving:

- Utilizing open-source LLMs (large language models) through APIs (application programming interfaces) and creating domain-specific SLMs (small language models) via prompt engineering/copilot. Students will learn to leverage these generative AI agents for informed decision-making in typical engineering design tasks, such as product planning, concept generation, CAE modeling and analysis, and DfX assessment.
- Designing and operating industrial robotic automation, involving simulating robot arm kinematics using AI tools. Students will also gain proficiency in machine vision and visual analytics using deep learning neural networks, as well as implementing smart manipulation strategies for robot end effectors (grippers) through AI-enabled model predictive control.
- Further to the current makerspace (mainly on machining and 3D printing), introduce ME students to a smart/AI makerspace experience (smart manufacturing operations on the shopfloor). The lab space is planned to utilize the robotics and mechatronics facility in MRDC.

Course Topics and Schedule:

1. Overview of AI and intelligent computational thinking, decision support systems, symbolic reasoning, expert system, domain knowledge acquisition and representation (2 lectures)
2. AI coding and metaprogramming, prompt engineering/copilot, GPT APIs, AI agent and SML as chatbot, GitHub Copilot, Generative AI for innovative design (2 lectures)
3. Domain knowledge engineering via LLMs and Neo4j, GPT-powered design engineering analysis, knowledge graph database (2 lectures, 5 hands-on labs)
4. Fundamentals of neural networks, GPT Vision, smart robot manipulation, design of manufacturing kitting operations (2 lectures, 5 hands-on labs)

5. Manufacturing system design and execution planning, task decomposition and dispatching, materials handling, assembly line balancing, scheduling and production control (2 lectures, 2 hands-on labs)

Course Requirements & Grading

Lab participation and deliverables: 30%
Assignment 1 (Requirement analysis): 10%
Assignment 2 (Use case UML): 10%
Mini-project 1 (AI-powered innovative design): 30%
Mini-project 2 (Smart robot manipulation and manufacturing): 20%

Assignments and lab work are individual work with assigned questions and defined deliverables
Mini-projects are team work with open problems identified by students within the topic scope
Mini-project deliverables include system running prototype, project report, and oral presentation

Grading Scale

Final grade will be assigned as a letter grade according to the following scale:

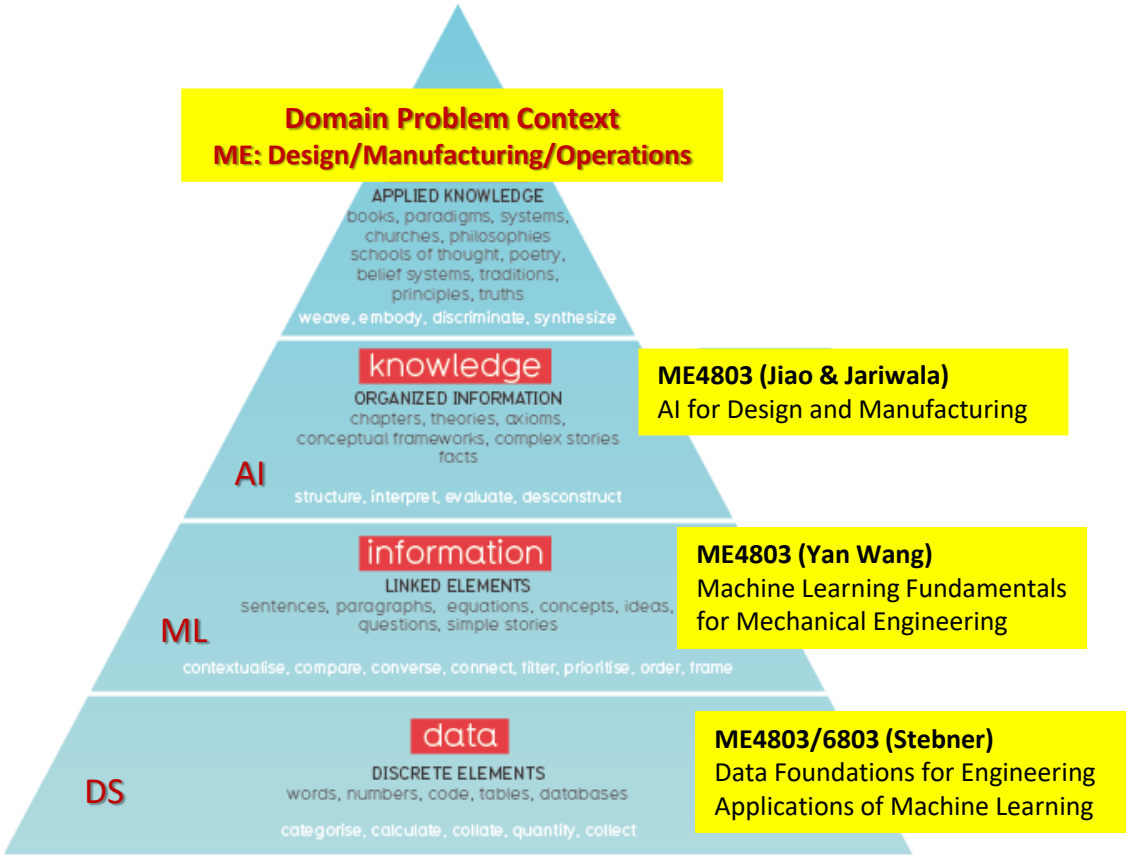
A	90-100%
B	80-89.99%
C	70-79.99%
D	60-69.99%
F	0-59.99%

Course Expectations & Guidelines

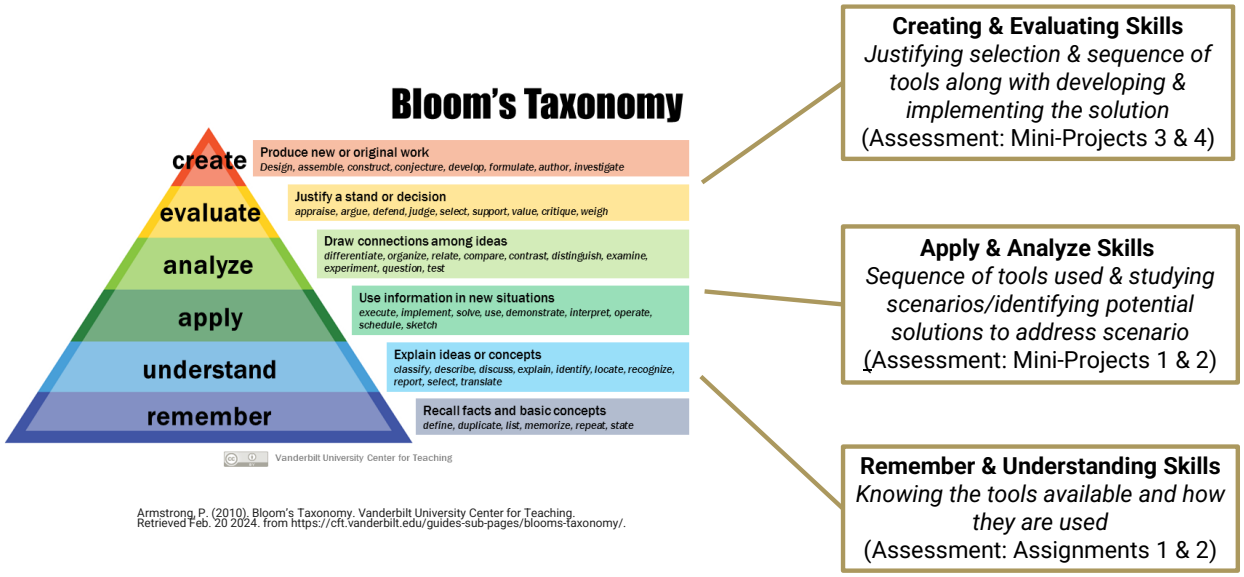
- Academic Integrity
  - Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.
  - Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.
- Accommodations for Students with Disabilities
  - If you are a student with learning needs that require special accommodations, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodation letter. Please also e-mail faculty as soon as possible in order to set up a time to discuss your learning needs.
- Absence from Class
  - Class attendance is not required, but is strongly recommended. In the case of medical illness or family emergencies, please work with the Office of VP for Student Life (Dean of Students) with documentation that supports your situation. If the illness or family emergency is deemed serious enough, the Dean's office will then contact me and your other instructors with recommendations on how to proceed. Students who are absent because of participation in a particular religious observance will be permitted to make up the work missed during their absence with no late penalty, provided the student informs me of the upcoming absence, in writing, within the first two weeks of class, and provided the student makes up the missed material within the established timeframe.

- Collaboration & Group Work
  - The course project deliverables are to be submitted as a team. Students are encouraged to seek advice and guidance from people and learning materials outside of the class. Students will be required to submit peer-evaluations as individuals to score the contribution from themselves as well as their team members.
- Student-Faculty Expectations Agreement
  - At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of faculty and that faculty have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, we encourage you to remain committed to the ideals of Georgia Tech while in this class.
- Campus Resources for Students
  - All students are welcome to visit the makerspaces on campus, including Flowers Invention Studio, IDC, MILL, etc. to get trained on the fabrication tools.
  - Visit this page https://ctl.gatech.edu/sites/default/files/documents/campus_resources_students.pdf for a list of relevant campus resources available to Georgia Tech students.
- Mental Health & Wellness
  - As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, depression, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. GT offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know is experiencing any of the issues noted above, consider utilizing the confidential mental health services available on campus. I encourage you to reach out to GT CARE (www.care.gatech.edu, 404-894-3498) or the Counseling Center (www.counseling.gatech.edu, 404-894-2575) for support. An on-campus counselor or after-hours services are available to assist you.

Appendix A: Coherence among three ME courses on DS/ML/AI



Appendix B: Course learning outcomes and assessment goals in line with the Bloom's Taxonomy



Armstrong, P. (2010). Bloom's Taxonomy. Vanderbilt University Center for Teaching. Retrieved Feb. 20 2024. from https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

(Jariwala, A.S., ISAM2024)

Learning Outcomes (Aligned with Bloom's Taxonomy):

Upon successful completion of this course, students will be able to:

1. **Understand and Explain AI-powered Design Concepts**
   - *Cognitive Level*: **Understand**
   - *Outcome*: Explain the principles of AI-powered design, robotic automation, and smart factory operations, identifying their roles in modern manufacturing processes.

2. **Apply AI Tools in Engineering Design Tasks**
   - *Cognitive Level*: **Apply**
   - *Outcome*: Use open-source LLMs and develop domain-specific SLMs via prompt engineering to assist in product planning, concept generation, CAE modeling, and DfX assessment for typical engineering design tasks.

3. **Design and Operate Industrial Robot Tasks**
   - *Cognitive Level*: **Apply**
   - *Outcome*: Simulate robot arm kinematics using AI tools and implement machine vision and smart manipulation strategies for robotic end-effectors using deep learning and model predictive control.

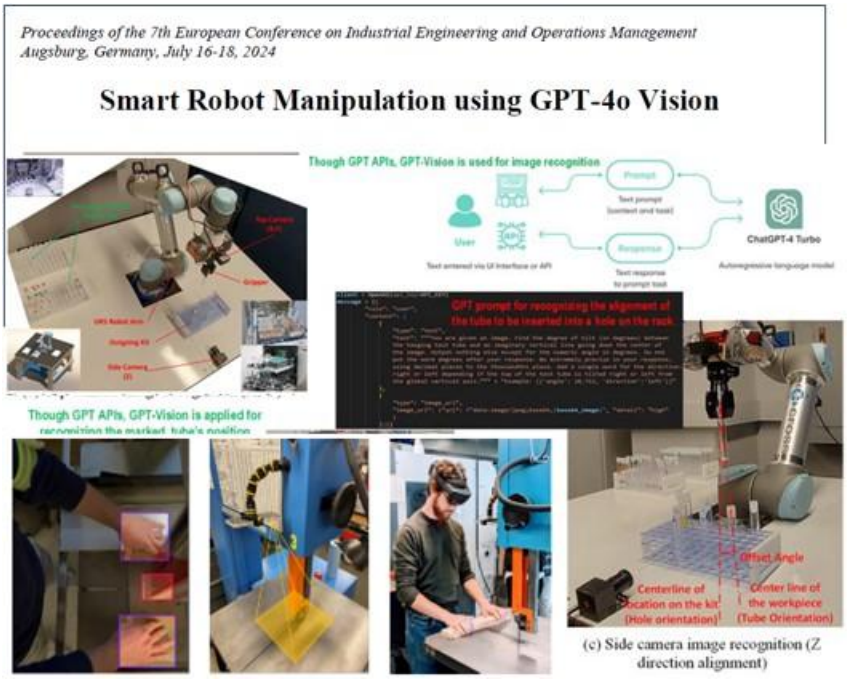
4. **Analyze and Optimize Manufacturing System Design and Operations Planning**
   - *Cognitive Level*: **Analyze**
   - *Outcome*: Analyze manufacturing execution tasks such as job sequencing, scheduling, and assembly line balancing, using data-driven decision support systems and predictive analytics for optimization on the shop floor.

5. **Evaluate the Effectiveness of AI-Enabled Manufacturing System Design**
    - *Cognitive Level*: **Evaluate**
    - *Outcome*: Evaluate the performance of smart manufacturing operations, including inventory management, material handling, and logistics optimization, through predictive analytics and decision-support systems.

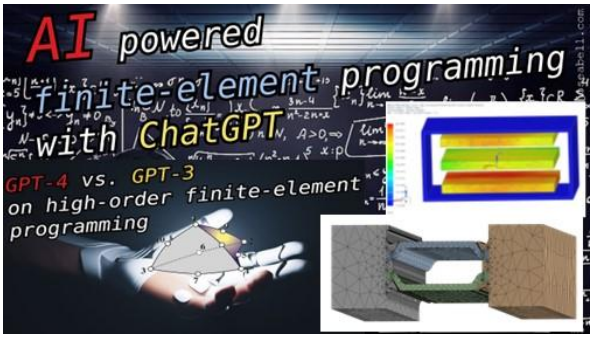
6. **Design Smart/AI Makerspace Workflows**
    - *Cognitive Level*: **Create**
    - *Outcome*: Design and plan an AI-enabled smart manufacturing workflow within a makerspace environment, integrating smart operations into machining, 3D printing, assembly, material handling, capacity planning, and robotic processes.

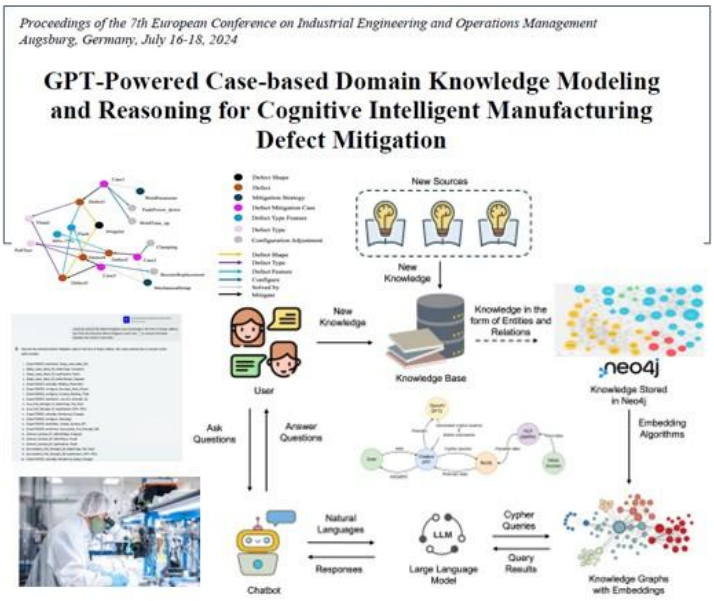
These outcomes span Bloom's Taxonomy, ranging from understanding foundational concepts to applying and creating solutions using advanced AI tools, ensuring a comprehensive learning experience in AI-powered design and manufacturing.

Appendix C: Some examples of testing cases for the lab session of the course



(c) Side camera image recognition (Z direction alignment)





Planning of AI Makerspace: a Mini Smart Factory