ENME 744: ADDITIVE MANUFACTURING

Course Syllabus

Spring 2019

CATALOG DESCRIPTION

Additive Manufacturing; (3 Credits) Grade Method: REG/P-F/AUD.
Prerequisites: ENME 272 and ENME 331 (or Equivalent)

Provide an introduction to a wide range of fundamental additive manufacturing (often referred to as "three-dimensional (3D) printing") approaches, including extrusion-based deposition, light-based photocuring, powder bed-based processes, and inkjet-based methods. Cultivate a "design-for-additive manufacturing" skillset that leads to successful 3D prints. Combining computer-aided design (CAD) and computer-aided manufacturing (CAM) methodologies to produce 3D printed designs. Fabricate 3D mechanical objects using two of the 3D printing technologies on campus. Execute a final project that demonstrates how additive manufacturing technologies can overcome critical limitations of traditional manufacturing processes.

COURSE INFORMATION

This course serves as a general introduction to the underlying concepts of state-of-the-art 3D printing technologies. Students will utilize CAD software to design demonstrative 3D objects. Students will submit CAD designs, which will be printed by Terrapin Works using two distinct 3D printing technologies on campus: Fused Deposition Modeling (FDM) and Polyjet Printing. The projects will provide students with an opportunity to observe print differences in terms of feature resolution, geometric complexity, and material versatility. Students will leverage these experiences to execute a final project that takes advantage of the unique capabilities of additive manufacturing. Students will also gain experience with *soft* skills through course deliverables including a "conference-style" oral presentation and a "journal-style" written manuscript.

COURSE FORMAT

The course will meet three times a week: MWF 1:00-1:50PM | JMP 2222

INSTRUCTOR

Ryan D. Sochol, Ph.D.
Email: rsochol@umd.edu
Room 2147 Glenn L. Martin Hall, Building 088
Office Hours: Wednesday 2:00-3:00 PM

TEACHING ASSISTANTS

N/A

COURSE SLACK

Students are expected to join the course Slack at: https://go.umd.edu/ENME416-744Slack
Note: The vast majority of communications regarding the course will be handled through Slack.

ASSESSMENT/GRADING POLICY

It is the policy of the course instructors to apply the same performance expectations to all course participants regardless of their academic, employment, or linguistic background. Student grades* will be assessed as follows:

Graduate Students | ENME 744

- **Individual Effort (50% of Grade):**
  - 5% Quizzes
  - 30% Midterm Exam
  - 5% Journal Paper Presentation
  - 10% Individual Contribution to Team
    - Peer Evaluation 1: 2.5%
    - Peer Evaluation 2: 2.5%
    - Peer Evaluation 3: 5%
- **Team Effort (50% of Grade):**
  - 20% Project Challenges
    - (1) 10%
    - (2) 10%
  - 30% Final Project Performance
    - Abstract: 5%
    - Oral Presentation: 12.5% (Skype or In-Person are OK!)
    - Journal Paper: 12.5%

*All assignments are graded on a curve with respect to the class.

TEXTBOOK/READINGS

Due to the evolving nature of additive manufacturing technologies, no single textbook currently covers all of the topics that will be discussed in this course. As such, there is no required textbook for the class. The vast majority of course content will be freely available *via* course lecture notes, website content, and academic papers accessible through the UMD network. For a deeper understanding of the course subject matter, optional recommended texts include:

1. Ian Gibson *et al.*, "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing," Springer, 2015, ISBN 9781493921126.
2. Andreas Gebhardt, "Understanding Additive Manufacturing," Hanser, 2011, ISBN 9783446425521.

ACADEMIC INTEGRITY AND STUDENT CONDUCT

Please review the university policy on academic integrity and academic dishonesty at http://www.ugst.umd.edu/courserelatedpolicies.html. Additionally resources can be found at http://www.jpo.umd.edu/ and http://www.studenthonorcouncil.umd.edu/code.html. Also note that all work of anyone other than the student(s) must be referenced appropriately. The course instructor may use plagiarism checking software and/or request evidence of references for any submitted work and deliverables. To read more about avoiding plagiarism, please visit the Purdue Online Writing Lab (http://owl.english.purdue.edu/owl/resource/589/01/).

PROJECT CHALLENGES

Two 3D printing project challenges will be assigned as homework, with students working in teams of four. **(Challenge 1)** Students will design a lightweight bridge structure for 3D printing *via* Fused Deposition Modeling (Makerbot Replicator). The goal is for the bridge to support a weight of 20 lbs., while the bridge itself should weigh as little as possible. A key component of the grade will be based on the demonstrated "Minimum Weight" compared to the rest of the class. **(Challenge 2)** Students will design a reconfigurable structure that comprises one continuous, multi-material member of 30 cm in length for 3D printing *via* Polyjet Printing (Objet500 Connex3). The goal is for the print to support a weight of 1 lb. at the tallest point possible, yet reconfigure into the smallest *square* volume possible. Students must use SolidWorks CAD software (available on campus and *via* the UMD Virtual Computing Laboratory) to design their components and submit their STL files. The main final deliverable for both assignments will be a 20-minute oral presentation, which also includes a live demonstration of the print.

ONLINE QUIZZES

Five short online quizzes will be accessible through Canvas. Students will have the option of taking the exam at any point during an assigned 24-hour period; however, quizzes may not be taken during class time. The quizzes enable students to assess how well they understand the concepts associated with various additive manufacturing technologies. Due to the abstract nature of such questions, the quizzes will be open-book and open-note; however, no collaboration of any kind is allowed with anyone else during the entire day of the quiz.

ONLINE MIDTERM EXAM

The midterm exam is a 1.5-hour online exam taken through Canvas. Students will have the option of taking the exam at any point during an assigned 24-hour period; however, students are invited to take the exam in class during the allotted class time, which will provide an opportunity to ask questions if needed. The exam is designed to enable students to apply their knowledge of the manufacturing technologies covered in the course, drawing from course-based experiences to think critically and apply a "design-for-additive manufacturing" skillset. Due to the abstract nature of such questions, the midterm exams will also be open-book and open-note; however, no collaboration of any kind is allowed with anyone else before (*i.e.*, on the day of the exam), during, or after the midterm exam (until after the lecture covering the midterm solutions).

FINAL DESIGN PROJECT

Students (in teams of four) will propose and provide a proof-of-concept demonstration of an additive manufacturing-enabled technology that exemplifies how the unique capabilities of a specific additive technology can overcome critical limitations of a conventional manufacturing approach. At the end of the semester, students will present their designs, methods, results, and conclusions as both a 'conference-style' oral presentation and a 4-page 'journal-style' written manuscript. The journal manuscript must be formatted as a *Communication* for an RSC journal (http://www.rsc.org/journals-books-databases/journal-authors-reviewers/author-tools-services/).

Journal Paper Presentations

Students will survey the literature and select one paper from a peer-reviewed academic journal that was published within the last two years. Each student will then deliver a 5-minute presentation summarizing the key contributions of the paper to either the rest of the class or directly to the instructors corresponding to the in-class or online section, respectively.

Course Content

The course will cover a variety of topics related to advanced manufacturing, broadly divided into four core themes:

1. **Review of General Manufacturing Approaches**
    - Conventional Manufacturing (Casting; Molding; Machining; Joining/Assembly)
    - Computer-Aided Design (CAD); 3D Modeling
2. **Computer-Aided Manufacturing (CAM) for Additive Manufacturing**
    - Layer Slicing; Infill Structure, Density, and 'Shell' Selection; Support Structure Integration; Voxel/Deposition Point Considerations
3. **Fundamental Additive Manufacturing Approaches**
    - Extrusion-Based Deposition
        - Fused Deposition Modeling (FDM); Fused Filament Fabrication (FFF); Direct Ink Writing (DIW); Robocasting; Bioprinting
    - Light-Based Photocuring
        - Stereolithography (SLA); Digital Light Processing (DLP); Direct Laser Writing (DLW); Continuous Liquid Interface Production (CLIP);
    - Laser-Based Melting
        - Selective Laser Sintering (SLS); Direct Metal Laser Sintering (DMLS); Selective Laser Melting (SLM); Electron-Beam Melting (EBM);
    - Inkjet-Based Deposition and Fusion
        - Multijet Modeling (MJM); Polyjet Printing; Nanoparticle Jetting; Binder Jetting; Multi Jet Fusion; Colorjet Printing (CJP);
4. **Special Topics for Additive Manufacturing**
    - Post-Processing; Support Removal; 4D Printing
    - Industrial, Research, Consumer & Sustainability Applications

Student Outcomes

The course primarily contributes to the following student outcomes at low (**L**), midrange (**M**), or high (**H**) levels, including an ability to:

- design and conduct experiments, as well as to analyze and interpret data (**H**)
- function on inter-disciplinary teams (**M**)
- identify, formulate, and solve engineering problems (**M**)
- understand professional and ethical responsibility (**L**)
- communicate effectively (**H**)
- use techniques, skills & modern engineering tools necessary for engineering practice (**M**)
- think critically about the design-for-manufacturing process with respect to non-traditional additive manufacturing technologies (**H**)
- provide constructive feedback to peers through peer-review processes (**M**)

COURSE SCHEDULE (*TENTATIVE*)

Week	Topics	Deliverable
1/28	• Pre-Class Review 1: SolidWorks Tutorial • Pre-Class Review 2: Conventional Manufacturing • Course Introduction and Overview	
2/4	• Extrusion-Based Deposition I & II • Extrusion-Based Deposition Guest Lecture (*2/8*)	
2/11	• Robocasting & Direct Ink Writing • Stereolithography (SLA) I & II	• ***DC 1 .STL/.TXT Files Due Feb. 11*** • ***Quiz 1 – Feb. 13***
2/18	• Stereolithography (SLA) Guest Lecture (*2/18*) • Direct Laser Writing (DLW) • Direct Laser Writing (DLW) Guest Lecture	• ***DC 1 Prints Returned*** • ***Quiz 2 – Feb. 22***
2/25	• Multijet/Polyjet Printing I & II • Presenting Scientific Content	• ***DC 1 – Iteration 2 Files Due Feb. 25***
3/4	• Remaining Light-Based Printing Concepts; Quiz 1-2 Review • Multijet/Polyjet Printing Guest Lecture (*3/6*) • **Design Challenge 1 Team Presentations & Demos**	• ***Quiz 3 – Mar. 4*** • ***DC 1 – Iteration 2 Prints Returned***
3/11	• **Design Challenge 1 Team Presentations & Demos** • Writing a Journal Paper	• ***HW 2 .STL Files Due Mar. 15***
3/18	[*Spring Break*]	
3/25	• Selective Laser Sintering (SLS) • Direct Metal Laser Sintering (DMLS) • Electron Beam Melting (EBM)	• ***Final Project Abstracts Due Apr. 27*** • ***Quiz 4 – Mar. 29***
4/1	• Binder Jetting & NanoParticle Jetting • 4D Printing • Direct Metal Laser Sintering (DMLS) Guest Lecture (*4/5*)	• ***DC 2 Prints Returned*** • ***Quiz 5 – Apr. 5***
4/8	• Midterm Exam – *Review Lecture* • **Midterm Exam (Apr. 10)** • Midterm Exam Solutions/Results	• ***Final Project .STL Files Due Apr. 8***
4/15	• **Journal Paper Presentations**	
4/22	• **Design Challenge 2 Team Presentations & Demos**	• ***Final Prints Returned***
4/29	• Additive Manufacturing for Social Change • Bioinspired Additive Manufacturing Applications	
5/6	• Additive Manufacturing Guest Lecture • **Final Project "*Conference-Style*" Oral Presentations**	
5/13	• **Final Project "*Conference-Style*" Oral Presentations**	• ***Final Journal Paper Due May 15***