CEE 599 – Construction-Scale 3D Printing Fundamentals

Units: # 4
Term—Day—Time: Fall 2024 — Thursdays 6:30 - 9:50
Location: GFS 201

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Catalogue Description

Basics of construction 3D printing including technology components, and implementation considerations are covered in this project and laboratory-oriented course.

Course Description

Construction 3D printing (C3DP) is an emerging construction automation technology which is creating an entirely new industry in construction. Several companies have been formed for production of C3DP machines and many contractors around the world are building various types of building and infrastructure elements with the technology. Meanwhile, numerous civil engineering academic departments worldwide have started teaching courses on the subject and have created research and educational laboratories focusing on various aspects of the new approach including design, hardware, software, material, standards, structural testing, etc. The market is already seeking engineers and technicians who are familiar with the new technology field.

This course introduces to the students the basics of construction 3D printing and fundamentals of the related technologies. Students will be engaged in several hands-on projects which would use the new USC C3DP laboratory.

Learning Objectives

- To teach the students the fundamentals of C3DP technology and its application possibilities to be able to effectively respond to the related new construction industry needs
- To provide the student with the opportunity for hands-on experience with the related components of the technology for diverse domains of application
- To develop the student's ability to evaluate appropriate technologies, create and devise realistic solutions for each choice of technology and application scenarios

Pre-requisites: Undergraduate degree in an engineering field, as well as graduate student standing.
Co-Requisite(s): None
Concurrent Enrollment: None
Recommended Preparation: None

Course Notes

Letter grading will be used. Interactive lectures covering principles and case studies as well laboratory demonstrations will be the mode of teaching. All related presentation slides as well as several articles and hand-outs will be posted at the course Blackboard site.

Technological Proficiency and Hardware/Software Required

USC computer system and software including MATLAB, CAD, and hardware for prototyping at the Viterbi Fabrication lab are available to students. Following are links to other provisions that students can use: USC Computing Center Laptop Loaner Program, Zoom information for students, Blackboard help for students, Software available to USC Campus.]

Required Readings and Supplementary Materials

- Various articles posted at the class Blackboard site and referenced from Internet.
- Laboratory equipment training manuals
- Related multi-media sources

Description of Assignments and How They Will Be Assessed

Assignments in the course include Individual Assignment and Group Assignment.

Individual Assignments: These assignments are small and are supposed to be completed and submitted within one week. An individual assignment may be "what are the challenges of printing the second half of a structure to the already printed first half and what are the possible remedies?"

Group Assignments: At the beginning of the course students are given two weeks to form teams of no more than three members. Group Assignments involve laboratory projects, such as building specific specimens using 3D printing and cementitious materials and testing various performance aspects of the specimens. Group assignments will be given once every two weeks.

Participation

Students in this class get ample opportunity to be vocal and expressions of opinion are always encouraged. However, no portion of grades is allocated to such participation.

Grading Breakdown

1. Class non-attendance could result in grade loss of up to 15% Physically attending the class but mentally not being present because of preoccupation with laptop, tablet or smart phone will not count as attendance.
2. Performance in pop quizzes on reading materials and class lectures -- 15%
3. Performance in individual assignments and team projects -- 50%
    a. Methodology used
    b. Quality of solutions based on specific criteria for each assignment and project (e.g., cost, functionality, environmental impact, etc.)
    c. Quality of written and oral presentations

4. Extent of teamwork as evaluated by team members and reflected in students' extent of participation – 20%
    a. Evaluation will be based on questionnaire forms filled by team members
    b. Instructor's observation of student's performance in collaborative activities.

Assignment Submission Policy

Individual assignments are supposed to be submitted within one week. Group assignments are supposed to be submitted in two weeks.

Attendance

[No portion of the grade may be awarded for class attendance, but non-attendance can be the basis for lowering the grade, when clearly stated on the syllabus. Attendance policies may address student athletes with approved Travel Request Letters and students who give advance notice of religious observation.

Include information on alternative course work expectations for students who miss a class session.]

Academic Integrity

Unless otherwise noted, this course will follow the expectations for academic integrity as stated in the USC Student Handbook. The general USC guidelines on Academic Integrity and Course Content Distribution are provided in the subsequent "Statement on Academic Conduct and Support Systems" section.

- Collaboration: In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts.

- Group work: Unless specifically designated as a 'group project,' all assignments are expected to be completed individually.

[Include information regarding grade outcomes a student may expect if found in violation, such as: If found responsible for an academic violation, students may be assigned university outcomes, such as suspension or expulsion from the university, and grade penalties, such as an "F" grade on the assignment, exam, and/or in the course.]

Please ask the instructor [and/or TA(s)] if you are unsure about what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

You may not record this class without the express permission of the instructor and all other students in the class. Distribution of any notes, recordings, exams, or other materials from a university class or lectures — other than for individual or class group study — is prohibited without the express permission of the instructor.

Use of Generative AI in this Course

Generative AI is encouraged**.** You are free to use AI (e.g., ChatGPT, image generation tools, etc.) in this class. Being able to use AI is an emerging skill. This is an opportunity for you to discuss with the instructor appropriate use of these tools. Keep in mind the following:

- AI tools are permitted to help you brainstorm topics or revise work you have already written.
- If you provide minimum-effort prompts, you will get low-quality results. You will need to refine your prompts to get good outcomes. This will take work.
- Proceed with caution when using AI tools and do not assume the information provided is accurate or trustworthy If it gives you a number or fact: assume it is incorrect unless you either know the correct answer or can verify its accuracy with another source. You will be responsible for any errors or omissions provided by the tool. It works best for topics you understand.

Note: AI is a tool, but one that you need to acknowledge using. Please *include a paragraph at the end of any assignment explaining if, how, and why you used AI and indicate/specify the prompts you used to obtain the results*. Failure to do so is a violation of academic integrity policies.

Course Evaluations

Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. The process and intent of the end-of-semester evaluation is to provide feedback to the instructor with the aim of improving future offerings of the course. In addition, a mid-semester evaluation may be performed for early course correction.

Course Schedule

The attached table provides a weekly schedule of the course.

Week	Topic
1	Manufacturing vs Construction, Manufacturing automation
2	**Neso-scale 3D printing**
3	**Construction advancement and automation efforts**
4	**Automation in construction**
5	**Emergence of construction0scale 3D printing**
6	**Large-scale 3D printing components (1)**
7	**Large-scale 3D printing components (2)**
8	**Basics of motion control systems**
9	**Basics of mechatronics (1)**
10	**Basics of mechatronics (2)**
11	**Materials for construction 3D printing**
12	**Building design considerations for 3D printing**
13	**Regulatory standards. Logistics of construction 3D printing**
14	**Space applications; other application domains**
15	**Economics of construction 3D printing; future prospects of the technology**

COURSE CONTENTS

Manufacturing vs construction - similarities and contrasts

Manufacturing:

- Manufacturing fabrication categories
- Automation of manufacturing fabrication & assembly technologies
- Emergence of meso-scale 3D printing and impact on manufacturing

Construction:

- Large-scale fabrication categories
- Automation in construction
- Emergence of construction-scale 3d printing, impact on construction, barriers and future projections

Meso-scale 3D Printing processes – overview

Construction-scale 3D printing processes

- Extrusion based processes
- Powder bonding processes
- Other possible processes

Large-scale 3D printing technology components

- Large-scale robotic systems: options, factors to consider, mechanical, electrical, electronic and control system design challenges

- Software systems: Building design interpretation, slicing CAD model, tool-path generation, printing simulation
- Dry material transportation and on-site storage options
- Material preparation/batch vs continuous mixing technologies pros and cons
- On-site material transport technology options
- Material printing components: material flow-regulating components, components for print form control
- Integration of auxiliary modules for automated reinforcement, plumbing, electrical, tiling, etc.

Technical fundamentals

Basics of mechatronics and robotics:

- Introduction to mechatronics
- Mechanical Components
- Electrical/Electronic Components
- Sensors (proximity, flow rate, viscosity, rheology, vision, etc.)
- Actuators
- Programmable motion control
- Open/Closed loop control
- Micro Controller, Programmable Logic Controller (PLC),
- Numerical Control and CAD/CAM
- Robotics – alternative configurations
- Process Control

Materials for construction 3D printing:

- Material choices for construction 3D Printing
- Required material characteristics
- Material testing requirements
- Cementitious material choices

Building design

- Architectural design considerations
- Structural design considerations

Regulatory standards

- Current standards and ongoing effort toward comprehensive standards
- Structural and material testing requirements for meeting standards

Logistics of using construction 3D printing

Application domains

- Building construction
- Infrastructure construction
- Planetary and in-space construction

Economics of construction 3D printing

Future prospects of the technology

Statement on Academic Conduct and Support Systems

Academic Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been

distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call

Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.