

Generative Design: Design of Complex and Origami Structures

Description: This graduate-level course introduces principles in art and engineering analysis and optimization with focus on design of complex, irregular (organic), free-form, and origami structures. This course provides a sound grasp of structural analysis and design optimization methods, the origami arts, and fundamental creative strategies used in the design thinking process.

Prerequisite: ME 26200 – Mechanical Design I
ME 27200 – Mechanics of Materials
ME 27400 – Basic Mechanics II
Recommended: A course in Finite Element Analysis, CAD, and Programming or Numerical Methods

Recommended books:

Adriaenssens, Block, Veenendaal, Williams (Eds). Shell Structures for Architecture: Form Finding and Optimization. Routledge, Taylor & Francis Group, 2014.

Robert Lang, Twists, Tilings, and Tessellations. Mathematical Methods for Geometric Origami. CRC Press, 2018

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Outcomes:

1. Predict strains and stresses in structures subjected to mechanical loads.
2. Apply form-finding approaches to the design of structural layouts.
3. Explain the mathematical and physical principles for the design of origami structures.
4. State and solve structural optimization problems using mathematical programming.
5. Explain the effect of manufacturing, material, and design in the structure's lifecycle and sustainability.

Topics:

1. Numerical modeling and analysis of trusses, beams, and shells
2. Physical modeling and form finding methods
3. Origami structures
4. Model-based design
5. Design and analysis of computer experiments
6. Structural optimization methods

Course content and methodology

The first part of the course will be conducted in “hands-on” interdisciplinary art and design studios in which studio-based pedagogy will be emphasized in order to cultivate students’ identities as designers, develop their conceptual understanding of design and the design process, and foster their design thinking.

Student participation, collaboration and peer learning will be stressed as an important part of a studio culture ethos. The students will meet (physically or virtually) in large design studios on both the IUPUI and Bloomington campuses.

The design studios in Bloomington have flexible and modular furniture layouts allowing for fluid movement between one-on-one discussion and critique, small group collaboration, and large group critique. In addition, the students will have access to technological resources, such as laptops, digital cameras and printers. Since the design studios are located in close proximity to the fabrication labs, students will have access to digital fabrication tools including a laser cutter, digital cutter, and CNC machine tools, allowing them to experiment with material and making techniques in various stages of design processes.

The students will apply such studio-based experiences in generating creative solutions for the problems posed in the course project. Specifically, students will be asked to come up with irregular, free-form, and origami designs in the context of material, construction, artistic form finding, and form making. They will do so in response to an open-ended problem related to sustainability and product lifecycle. Students will first be introduced to origami art and techniques of using paper folding as a means for form finding and form making. Students will then conduct research on aspects of product lifecycles including production, distribution, use, and disposal.

The students will develop schematic designs with multiple visual ideas and experiment with tangible materials, inspired by the art of origami, in order to identify the environmental issues in the current product lifecycle. They will further develop their ideas via iterative designs in a series with each version suggesting subsequent problems to explore in order to address the issues they identified earlier in the schematic design phase. At the end, students will professionally present their work and communicate their ideas to the general public, as well as professionals.

Evaluation Methods:

This is a project-based class. There are about eight projects assigned in the semester. The grade is distributed among these projects (average of 12.5% per project). Project briefs with detailed description and a course outline with dates and scheduled course activities will of each project will be delivered the first week of classes.

Completion of assigned projects

The primary requirement in this course will be the competent completion of assigned projects. Each of these projects will have interim outcomes intended to teach you specific skills and methods, as well as helping you create the final portfolio. Completion of each interim activity will be considered in determining your grade for each project. These interim activities will compose part of your final project grade. Preparedness and participation in all activities, and in critiques is essential.

- absences are not “excused”
- you are expected to attend all classes, arriving promptly and staying until dismissed
- you are responsible for acquiring and mastering all information, handouts, materials, etc., missed because of lateness or absence; no other person is responsible for seeing that you obtain or master this material
- assignments are to be handed in on the dates and times scheduled
- incomplete work is not accepted
- work submitted by others is not accepted
- extensions are not granted
- make-ups are not granted

Project evaluation

The following metrics will be used to evaluate the overall student learning outcomes. Specifically, the metrics will evaluate students’ design thinking ability, interdisciplinary collaboration, and participation in group critiques. Some metrics overlap performance criteria that are outlined in professional design educational organizations, such as the National Architectural Accrediting Board.

- Pre-Design: Ability to conduct comprehensive research (lifecycle analysis), assess design problems, opportunities and needs; examine and comprehend fundamental principles.
- Schematic Design: Ability to refine design parameters by limiting variables and ID-ing problems, employing multiple visual ideas, and engaging in material and making to test initial designs.
- Design Development: Ability to develop the design through a reiterative open-end process and test alternative outcomes against relevant criteria.
- Professional Communication: Ability to write and speak effectively and use representational media to illustrate design solutions.
- Collaboration: Ability to work in an interdisciplinary team environment.
- Participation in Group Critiques: Ability to raise clear and precise questions, use abstract ideas to interpret information, consider diverse points of view, and reach well-reasoned conclusions.

Grading Scale:	97 = A+	77 = C+
	93 = A	73 = C

90 = A-	70 = C-
87 = B+	67 = D+
83 = B	63 = D
80 = B-	60 = D-

- Class Policies:**
- 1) No late homework will be accepted
 - 2) No make-up in-class work will be given
 - 3) No extra credit is possible

Standard Campus Policies (fine print):

Cheating / plagiarism is completely unacceptable. Please refer to:

<http://www.indiana.edu/~code/code/responsibilities/academic/index.shtml>

An Incomplete (I) grade will be given in this class only under these three conditions:

- Unusual circumstances such as illness prevent the student from completing the work.
- The student has successfully completed three-fourths (75%) of the required course work.
- The student is clearly passing the course.

Administrative Withdrawal: A basic requirement of this course is that you will participate in all class meetings and conscientiously complete all required course activities and/or assignments. Keep in touch with me if you are unable to attend, participate, or complete an assignment on time. If you miss more than half of the required activities within the first 25% of the course without contacting me, you may be administratively withdrawn from this course. Administrative withdrawal may have academic, financial, and financial aid implications. Administrative withdrawal will take place after the full refund period, and if you are administratively withdrawn from the course you will not be eligible for a tuition refund. If you have questions about the administrative withdrawal policy at any point during the semester, please contact me. (Source: <http://registrar.iupui.edu/withdrawal-policy.html>)

Everyone deserves to be treated with dignity and respect. Within this classroom, civility involves mutual respect for all class members and their knowledge and expertise. Civility requires mutual respect on the part of both the student and the instructor. All members of this class are responsible for and expected to promote respectful and courteous language, demeanor, and actions. Behavior that is offensive, disruptive, intimidating, dismissive, or condescending will not be tolerated.

Accommodations are available for students with special challenges or disabilities that may affect their performance in this class. To determine if you are eligible for accommodations, you must register with Adaptive Educational Services (AES), which can be reached at (317) 274-3241. You must let your instructor know you are registered with AES. For more information, visit the AES website at <http://aes.iupui.edu/>

During the semester, if you find that life stressors are interfering with your academic or personal success, consider contacting IUPUI's Counseling and Psychological Services

(CAPS). All IUPUI students are eligible for individual counseling services at minimal fees. Group counseling services are free of charge. CAPS also performs evaluations for learning disorders and ADHD; fees are charged for testing. CAPS is located in Walker Plaza, Room 220 (719 Indiana Avenue) and can be contacted by phone (317-274-2548). For more information, see the CAPS web-site at: <http://studentaffairs.iupui.edu/health-wellness/counseling-psychology/index.shtml>.

IUPUI does not tolerate acts of sexual misconduct, including sexual harassment and all forms of sexual violence. If you have experienced sexual misconduct, or know someone who has, the University can help. It is important to know that federal regulations and University policy require faculty to promptly report complaints of potential sexual misconduct known to them to their campus Deputy Title IX Coordinator(s) to ensure that appropriate measures are taken and resources are made available. The University will work with you to protect your privacy by sharing information with only those that need to know to ensure the University can respond and assist. If you are seeking help and would like to speak to someone confidentially, you can make an appointment with a Mental Health Counselor on campus (contact information available at <http://stopsexualviolence.iu.edu/employee/confidential.html>). Find more information about sexual violence, including campus and community resources at <http://stopsexualviolence.iu.edu/>.

Schedule

(subject to change)

Week	Content
1	Cellular automata 1D
2	Cellular automata 2D (game of life)
3	Generative design
4	Topology optimization 2D
5	Topology optimization 3D
6	Self-organizing systems (part 1)
7	Self-organizing systems (part 2)
8	Origami math and introduction to origami
9	Origami patterns and math
10	Fractals
11	Folding
12	Origami structure project
13	Pre-folded origami structures and Grasshopper
14	Folding in Matlab
15	Cellular Potts model