DEA 6210: Architectural Robotics
MW 8:40-9:55
- 3 credits; letter grade only; no final exam; priority given to DEA and MAE students.
- Encouraged to enroll: students from MAE, IS, CS, ECE, PSYCH, COGSCI, FSAD, ARCH, ART, COMM.
- Recommended prerequisite: permission of instructor (15 student cap)
- course webpage: (linked from https://arl.human.cornell.edu/academics.htm).

Keith Evan Green, RA, Phd, Professor, DEA & MAE, keg95@cornell.edu, office hr. tbd in MVR 2421.

NOTE: This pdf file for the syllabus is comprehensive; however, the active and most complete documentation for this course is found in the course guide provided online at https://arl.human.cornell.edu/DEA6210_Arch_Robotics.htm. Here, you will find all the information contained in this pdf file, links to most all required readings, and additional supporting documents.

1. Course Description (50 words max.)
Embedding robotics into the fabric of architecture fosters a more interactive and potentially more intimate relationship between the built environment and us, and represents a new frontier for design, computing, and psychology. Part-seminar, part-lab, this course considers the design, technical, social, ecological, and ethical challenges and opportunities of architectural robotics.

2. Course Objectives and Learning Outcomes
"Architectural Robotics" aims to cultivate new vocabularies of design and new, complex realms of understanding towards realizing artifacts and systems responsive to people and the planet. Four learning outcomes are expected of this course.

Outcome 1: To understand the design, technical, social, ecological, and ethical challenges and opportunities of architectural robotics, and demonstrate this understanding in written form and presentations.

Outcome 2: To conceptualize and evaluate design alternatives responsive to the challenges and opportunities of an ecosystem that is biological, artificial, and increasingly digital, using a variety of design strategies.

Outcome 3: To demonstrate an ability to iterate, in design prototypes, an architectural robotic artifact (from furniture to the metropolis in scale).

Outcome 4: To demonstrate the ability to communicate the motivations for, iterative development of, and expected use of the Architectural Robotic artifact that was prototyped, as well as assessing its shortcomings (through the vehicle of a video).

3. Background and Definitions
While Information Technology [IT] can control digital bits on the display-screen surfaces of buildings, or temperature in building interiors, IT also has the capacity to move physical mass to create interactive, and adaptive cyber-physical, built environments—Architectural Robotics. The prospect of this kind of
environment was anticipated by Nicholas Negroponte, an MIT Media Lab founder, some forty years ago in his vision of “a man-made environment that responds to and is ‘meaningful’ for him or her” [5].

*Wired* editor Kevin Kelly has since imagined a “world of mutating buildings” and “rooms stuffed with co-evolutionary furniture” [3]. And while Bill Gates envisions “a robot in every home,” [2] the late William Mitchell, former Dean of MIT’s School of Architecture and Planning, envisioned homes “as robots for living in” [4].

Architectural Robotics meanwhile raises such critical questions as:

- How will we program the built environment, from furniture to cities?
- How will Architectural Robotics recognize activities taking place inside and surrounding them?
- How will designers (which may include end-users) associate particular human and ecological conditions with desired built environment configurations?
- How to design cross-operability and collective interactivity/intelligence of multiple Architectural Robotic artifacts (furnishings, furniture, rooms, buildings, cities) operating together as cyber-physical “ecosystems”?
- What are the safety, security and privacy issues related to Architectural Robotics, and how do designers design Architectural Robotics to protect property and living things from hackers, operating failures, and other harmful impacts?

In the act of designing, designers typically anticipate in the form and function of their artifacts how people will use them and how these artifacts will respond to a range of possible, local conditions. In designing Architectural Robotics, however, there is a fundamental difference: investigators are engineering a responsive system that actively engages and interacts with inhabitants and local conditions in real time. So, unlike a conventional building that has a limited range of responses to dynamic, changing conditions, Architectural Robotics artifacts are intimately bound together with its users and local conditions in a designed *performance*.

Architectural Robotics must go beyond simplistic formal achievements; they must instead explore ways for improving life, enhancing existing places, and supporting human interaction. This is no utopian dream in which technology or design transforms completely our everyday reality. Instead, design and technology together – a cyber-physical hybrid – supports human activity, responds naturally, and performs according to our needs and wants. Architectural Robotics, when employed, must also complement and redefine our urban living patterns. Answers to life problems and opportunities will come not from computational or design solutions alone, but through the way computation, embedded in the physical, built environment, helps support and enhance the interactions across people and their surroundings to create places of social and psychological significance.

For philosopher Andrew Feenberg, “technology is not simply a means but has become an environment, a way of life” [1]. Architectural Robotics is more than an aesthetic search, a stylistic possibility, or a technological quest; it is, instead, a way to develop new spatial patterns in support of human activities. This course, “Architectural Robotics,” aims to cultivate new vocabularies of design and new, complex realms of understanding towards novel, computational and bio-centric design propositions.

**References**

4. Nota bene:

- This course is the “next chapter” of a course that I taught for many years that was cross-listed in Architecture and Electrical & Computer Engineering under the same title. The course pedagogy has been the subject of a paper presented at ICRA (the IEEE International Conference on Robotics and Automation), and a paper published in RAS (IEEE Robotics and Automation).
- On the course webpage, in the upper-left corner, “Documents” links to a webpage of downloadable readings supporting this course. To enter this “Documents” page, you will need to enter the case-sensitive password, ARDUINO, when prompted.
- This syllabus is subject to revision; revisions will be dated and distributed online.

5. Organization

- **One class meeting per week is focused on readings and discussion.**
  
  One or more students from the class (to be assigned) will offer a presentation on a key reading (as listed above for each week). Please have these presentations ready to present for Monday's class in case time permits for it. For some of these sessions, we will organize a panel, debate, or like team activity.

- **The other class meeting per week is focused on assignments.**
  
  Students will frequently be asked to deliver a brief status report on their developing projects. Here is an example from previous class of the document supporting such a status report.

You will also...

- Benefit from informal exchanges with peers
- Deliver formal presentations at designated milestones throughout the semester.
- Advance your project through conversations with the professor and peers.
- Work with shop staff in the D2FS on fabricating your project.
- Engage in peer-to-peer grading and user studies.
- Consider formal responses and assigned grades to your assignments.

6. Assessment of Student Performance and Grading Policies

There are two assignments for this course. The first assignment is accomplished individually and is focused on concept generation; the second assignment is developed in teams of two, three, or four students assembled with respect to affinities found in the concepts generated and presented by individual class members. Topics either will be inspired by the class readings and discussions, or be responses to needs and opportunities identified from current events of fiction. For the latter, you may find inspiration in my paper (co-authored by IS MPS alum, Eric Gendreau, Configurative Design: Reshaping Dystopian Fiction as Preferred, Future States.

Throughout this course—an intimate and intensive “conversation” across students and the professor—students will have ample opportunity to receive feedback on their work. Grading is based on a 100-point scale, as follows....

**Assignment 1 | Concept Generation** (30% of the course grade; individual effort)

- (15 points) your scenario or storyboard
- (15 points) your GIF (How to) or video

**Assignment 2 | Prototype, Video, Docs** (60% of the course grade; team effort)
• (20 points) **your working prototype**
• (20 points) **your video and digital photos of your prototype**
• (20 points) **documentation of your design.** Documentation includes all of the headings presented in this example from a previous class: (a) a unique name for your prototype, (b) an abstract, (c) a scenario, (d) the operation of the prototype, (e) a list of components, (f) the process of construction, (g) a discussion (of what worked and didn't work), (h) proposal of future work (as a response to your discussion), (i) a link to your video uploaded to YouTube or Vimeo, and (j) the code. Upload your documentation to our shared Google Drive. *Failure to concisely organize your uploaded digital files will lower your course grade 2 points out of 100 points total.*

Requirements for the prototype:

- It must be to-scale (i.e. "model-size," to permit free exploration across physical scales as compared to a full scale, fully-functional prototype).
- It must be made interactive by way of sensors and actuators to create combinations of movement, lighting, displays, and sound. You may integrate any manner of input device, actuator, hacked device (e.g. a toy, a camera) and any technological approach (e.g. machine learning, computer vision, AR, ...).
- It must communicate or otherwise work with at least one project made by another team.
- The use of digital fabrication is not required to produce the prototype. It's however easy to digitally fabricate components for your prototypes! Our partners for this course are the very friendly and capable **D2FS** staff in the shop in HEB 2L31. See my course page for **DEA 5210** under the heading **DIGITAL FABRICATION** for instructions on preparing files and requesting an appointment for laser cutting and 3D printing them.

Review carefully **the grading rubric** for Assignment 2 deliverables.

The final 10% of your course grade is for:

- (5 points) attendance, participation, and documentation
- (5 points) peer-evaluation of your work as a team member

**Documentation** includes your best photos, sketches, and other visual and written products, and the URL to your video - to our shared Google Drive folder. Name files and folders clearly with your name or team name. **Peer-evaluation of your work as a team member** is done by online survey at the near-end of the semester.

The **video** [my guide](#) communicates the full, cohesive story of the designed artifact your team produced, answering **why, for whom, and how it was developed**, including an overview of the methods used to design and evaluate it. The video will adhere to the requirements for the **Video Showcase** submission to the benchmark HCI conference, CHI (Human Factors in Computing Systems). Here are videos from previous CHI Video Showcases: [2018](#), [2017](#); here are examples from my lab and from my various courses: **Helping Hand**, **ART**, **AWE**, **CyberPLAYce**, **home+**, **Xtinguish**; and here is an example of a hand-drawn WOz video: **Marble Answering Machine** (Bishop, 1995). Format for video: H.264 encoded MP4, at least 1280px x 720px, at most 5 minutes (2-3 minutes is a more common length), captioned for accessibility in .srt or .sbv format (example video from my lab). Format for the poster: A1 portrait.

In past deliveries of this course, students submitted videos, posters, and papers of individual or collected projects to **ACM** conferences like **DIS** (Designing Interactive Systems), **TEI** (Tangible, Embedded and Embodied Interaction), **IDC** (Interaction Design and Children), **CHI** (Human-Computer Interaction), and **HRI** Human-Robot Interaction; and to **IEEE** conference like **ICRA** Robots & Automation, **IROS** Intelligent
Robots & Systems, and RO-MAN Robot-Man-Systems. We've had some successes, despite stiff competition. For ACM submissions, the calls for the Arts Track and Demos are especially suited to our course products; these calls require a short paper, a video, and the promise to exhibit the project at the conference. For each project, the student designer(s) will be designated first authors and the TA and professor will be designated as, respectively, second-to-last and last author for any conference submission.

**By 8:30am on December [Monday after last class], you will have uploaded digital files of each required deliverable to our class Box file or Google Drive. This time and date is mandated by the department of DEA and will not be changed.**

**7. Materials**
- Sketchbook like this one or a comparable one found in our bookstore.
- Prototyping materials. You may elect to build hardware to partly satisfy the requirements for this course. A list of materials for building hardware and an extensive guide to building hardware can be found at my DEA 5210 course page.

**8. Reading List**
One book is required for this course:
Additional reading materials for this course are listed and downloadable from the on-line course page, [https://arl.human.cornell.edu/academics.htm](https://arl.human.cornell.edu/academics.htm). Key titles include:

**9. Topical Outline By Week**

**Week 01 | TYPES**
Robots for Living In: Reconfigurable, Distributed, and Transfigurable
- Readings - *Architectural Robotics*: Ch.s 1 and 2.
- Readings - Key:

**Week 02 | PATTERNS**
Compressed Pattern Spaces, Heat Maps, Typology, and Pattern Recognition
- Readings - *Architectural Robotics*: Ch.s 4, 5, 8, 11, and Ch. 7 to p. 103.
- Readings - Key:

**Week 03 | INTERACTIONS**
Interactions All Around Us.
- Readings - Key:
Week 04 | CONTROLS
User, Interactive, and Autonomous Controls for Architectural Robotics (AR)
• Readings - Architectural Robotics: Ch. 1; Ch. 7 to p. 103.
• Readings - Key:
• Readings - Reference

Week 05 | I ROBOT (I)
Body-Building Robots: Organic-Mechanical, Prosthetic, Dismembered
• Readings - Architectural Robotics: Ch. 3, pp. 26-34; Ch. 6; Ch. 12 pp. 180-193.
• Readings - Key:
• Readings - Reference

Week 06 | I ROBOT (II)
Body-Building Robots: Pygmalion, Protean, Posthuman
• Readings - Architectural Robotics: Ch. 3, pp. 34-39; Ch. 9, pp. 129-135.
• Readings - Key:
  > Ovid. "Pygmalion" from the Metamorphoses (8 AD).

Week 07 | HABITATIONS
Architectural Robotics at Homes, Schools, Hospitals, Offices, Vehicles, Space
• Readings - Architectural Robotics: Ch.s 6, 7, and 8.
• Readings - Key:
**Week 09 | LIVING ROOMS**
Architectural Robotics as Monk's Cells, Boudoirs, and Palaces

- **Readings** - Architectural Robotics: Ch. 3, pp. 26-34, Ch. 6, Ch. 9.
- **Readings - Key:**

**Week 10 | LINES, SURFACES, AND FORMS**
Striated and Smooth; Physical Forms & Forms of Speech; Kinematics for AR

- **Readings - Key:**

**Week 11 | MEASURES**
Design Science, Design Metrics, Wicked Problems, and RtD for AR

- **Readings - Key:**

**Week 12 | COGNITION**
Distributed Cognition in AR; Cognitive Rooms

- **Readings - Key:**
  > Hutchins, E. *Distributed Cognition*.

**Week 13 | NETWORKS (No class Wednesday)**
The Digital Oligarchy, Weak Architecture, and Mesh Networks

- **Readings - Key:**

**Week 14 | ETHOS AND ECOSYSTEMS**
A Vision of Bits, Bytes and Biology: The Garden of Technology
• Readings - Architectural Robotics: Ch. 7, pp. 121-126; Ch. 12.

Readings - Key:

Final Class | DEMOS, POSTERS, SCREENINGS

9. Classroom Policies, including Attendance and Late Work
Required: attendance, timely arrival to class, participation, and the uploading of all documents to the course Box or Google Drive folder strictly adhering to all formatting requirement and specifications detailed here, on the course webpage, and in the ACM conference website(s). Failure to fulfill these requirements will reduce your grade up to 10% of the total grade at the discretion of the instructors. Attendance at the start of class will be taken for some class sessions without advanced notice. For each absence or late arrival, email the professor and TA with an explanation, attaching supporting documentation (e.g. doctor’s note); these will be considered as a valid excuse (hardship, medical appointment) without penalty, or not. It is your education, so you should take responsibility for yourself in attending all class sessions on time.

Late submissions will NOT be accepted, except with a doctor’s note or other proof of personal crisis or hardship. Failure to submit the printed documents and digital files on-time will reduce your final assignment grade 10 points.

Grading for this course is carefully determined by the professor (and TA, if any) with thoughtful consideration of student grading by your peers. If you believe the grade for any component of this class including the final grade is incorrect, you may submit a written argument along with the component-in-question for reassessment. The written argument must reference a specific issue with the graded component of the course and must be thoroughly substantiated. The professor (and TA, if any) will together consider the request, potentially with the assistance of other faculty with expertise in the area. The reassessment will result in any of the following outcomes: no change of grade, a change of grade for the better, or a change of grade for the worse. You understand that the grade for work submitted for reassessment may result in a grade lower than originally assigned.

10. Consent
To prepare the required paper and video for this course, enrolled students may conduct peer-to-peer participant studies using their peers, enrolled in the same course, as participants. These studies will use methods considered in my course DEA 2370, Human-Centered Design Methods, the new core course for all DEA students. These methods may include interviews, observations, surveys, co-design activity, heuristic evaluations, and cognitive walkthroughs. As part of this design research activity, students conducting these studies may take written notes, photographs, and/or video as a means of documentation. This documentation may be reproduced in the papers and videos for submission to CHI or a like conference, and may be presented at the conference. Student will not be identified by name in such submissions/presentations, and no aspect of these studies should cause discomfort or risk to participants; nevertheless, should any student in the class chose not to participate in any aspect of the study, or have questions about her/his participation, please make this known to the instructor prior to the start of such study. Non-participation will not impact your grade for this course in any way.

11. You are encouraged to join ACM SIGCHI and DRN
12. University Statement on Academic Integrity and Honesty
Each student in this course is expected to abide by the Cornell University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work, except in the cases of projects that are specifically structured as group endeavors. In compliance with the Cornell University policy and equal access laws, the faculty, teaching assistants, and teaching associates for this course are available to discuss appropriate academic accommodations that may be required for students with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances, so that arrangements can be made. Students are encouraged to register with Student Disability Services to verify their eligibility for appropriate accommodations.

13. DEA Statement
DEA is dedicated to fostering a respectful and accepting learning community in which individuals from various backgrounds, experiences, and perspectives can embrace and respect diversity. Everyone in this community is empowered to participate in meaningful learning and discussion, regardless of an individual's self-identified gender, sexual orientation, race, ethnicity, religion, or political ideology. We encourage students to share their uniqueness; be open to the views of others; honor and learn from their colleagues; communicate in a respectful manner; and create an inclusive environment.