Cornell University | Human Centered Design | Syllabus

DEA 6210: Architectural Robotics

- 3 credits; letter grade only; no final exam; priority given to DEA, FSAD, and MAE majors.
- Recommended prerequisite: permission of instructor (cap of 15 students)

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NOTE: The most current and complete documentation for this course is found online at https://arl.human.cornell.edu/DEA6210_Arch_Robotics.htm.
This pdf is for basic information; some aspects (e.g., grading, policies) may not be current.

1. Course Description
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 a working prototype, an architectural robotic artifact at a scale of the Internet of Things, or furniture, or the room or building, or the metropolis.

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
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 robotic artifacts are intimately bound together with their users and local conditions in a designed *performance*.

Architectural Robotics is defined by the movement of physical mass and by their interactivity with and adaptivity to things outside them (e.g. people, other life forms, objects, information). The prospect of this kind of environment was anticipated some forty years ago by MIT Media Lab founder Nicholas Negroponte 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], William Mitchell, the late Dean of MIT's *School of Architecture and Planning* and director of its Media Lab, 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?*

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
[1] Feenberg, A. *Transforming Technology, A Critical Theory Revisited* (Oxford University Press, 2002), 8.
[2] Gates, B. "A Robot in Every Home," *Scientific American*, December 16, 2006.
[3] Kelly, K. *Out of Control: The New Biology of Machines, Social Systems* ….(Cambridge, MA: Perseus, 1994), 472.
[4] Mitchell, W.J. *e-topia* (Cambridge, MA: MIT Press, 2000), 59.
[5] Negroponte, N. *Soft Architecture Machine* (Cambridge, MA: The MIT Press, 1975), p.x.

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*, Rethinking the Machines in Which We Live.. I also co-authored with Mark Gross (then, of CMU) an overview of Architectural Robotics for ACM interactions.

5. Organization

I will present the case study of the day.

We will consider an assigned reading.
• **Every student** will read the reading listed for each class **ahead** of that class meeting.
• **Every student** will upload to our shared Google or Box folder, **ahead** of that class meeting, **a review** of the assigned reading. This review is **a Word document of no more than two pages** that includes the following headings (some headings may be omitted if the reading is not reporting design research/experimentation):

- The **key research question** of the research reported in the reading.
- The **theoretical position and/or context** of the research reported in the reading.
- The **experimental design** (if any): What was done, collected, and analyzed?
- The "**take away**": What do we learn from this paper?
- The **significance** of the paper for Architectural Robotics and for your work.
- **Three questions, insights, and/or critiques** that you would share in class.

• **One student will be assigned one reading for a given class meeting**, and will present this reading in class. The presentation will cover the above (6) requirements of the review. Here is a great example of slides prepared tor a presentation for this course.

Every student will present status reports and demos **on their design activities, as per the weekly schedule (below) under the heading, "In class."** Your report can be a powerpoint slide, a digital image, a Word document, or other document appropriate to what is being presented. For demos, you can simply share your current physical prototype, held up to the camera for us; or you can take a smartphone video of your working prototype, upload the video (or a URL to it) to our shared folder, and share the video with us. The latter is a good idea, as robotics demos often fail! **Reports are uploaded to the shared class folder ahead of class presentations.**

Students will also...
- Benefit from **informal exchanges** with peers.
- Organize a **panel, debate, or some other team activity**.
- Deliver **formal presentations** at designated milestones throughout the semester.
- **Work with shop staff** in the D2FS on fabricating your project.

6. Assessment of Student Performance and Grading Policies
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.

The deliverables are the same for both assignments:
- **(45 points) your prototype, video, and documentation of your design**.
  For the video, **include in your paper a URL link** to your video in Vimeo or YouTube; **and upload**

to our shared folder an MP4 file reduced to < 30MB using, e.g., Handbrake (see my video guide). The video will otherwise adhere to the requirements for the Video Showcase submission to the ACM conference CHI (a benchmark for design research), where you will also find example videos.

For your documentation, include, all of the headings presented in this example from a previous class and this one: (**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 (better) Vimeo, and (**j**) the code. Your documentation must also include **photos** of your prototype (**jpg, 300 dpi**) including an "artist's visualization" (e.g., a 3D model, drawing, collage) of how your design ideally would look.

Review carefully **my grading rubric** for course deliverables.

The final 10% of your course grade is for:

- **(10 points) attendance, participation, and your assigned reading reviews / uploaded before each class.** An attendance sheet must be signed by you in the first ten minutes of class for you to be counted as present. If you expect to be later than 10 minutes on a given day, or if you are absent, email both the professor and the TA (if any) with the cause for your late arrival or absence; these will be considered as a valid excuse or not. To assess participation during class, names may be pulled "from a hat" to identify student critics who will then peer-review the developing work accomplished by other students; the quality of the student critique will form part of the 10 point assessment.

7. Assignment

The aim of the assignments are to provide members of the class a long, relatively deep development of the design, following this trajectory:

- Understanding the problem
- Conceptualization
- Lit Review / helpful digital archives: ACM DL and IEEE Xplore
- Ideation / Storyboarding, GIF, Scenarios, Morphological Chart
- Prototyping / Rapid, low-fidelity
- Prototyping / Physical Computing
- User Testing / UX
- Video making
- Documentation

8. Grading

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Review carefully **the grading rubric** for the course deliverables.

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9. Reading List

Readings for each class meeting are listed in the SCHEDULE below. All readings for the course are downloadable from this page except for my book, ***Architectural Robotics: Ecosystems of Bits, Bytes, and Biology*** **(MIT Press)**, which is available via the link or from the Cornell bookstore. All assigned readings for this course other than those from *Architectural Robotics* are downloadable from the links on this webpage. Additionally, references for programming robotic and interactive systems are found on our password protected page, **D O C U M E N T S**.

9. Topical Outline by Week [subject to revision]

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This pdf is for basic information; some aspects (e.g., grading, policies) may not be current.

I N T R O D U C T I O N -

Week 01 | ELASTIC SPACE
• Case Study:
M Gianni Colombo: *Spazio Elastico* [Elastic Space]: L'ultimo ambiente
W Gruppo T: Gli ambienti: le origini dell'arte interattiva
• Readings *(hereon presented by assigned student, one student per session)*
M Gianni Colombo
W Gruppo T
• In class:
M Review syllabus with focus on assignment-1.

W Design requirements: problem definition, lit. review, requirements; mind maps.
• Purchase: Aluminum foil, the book, and Grove kit & modules as per "Materials"

P A R T - 1 | C O N C E P T S -

Week 02 | TYPES
• Case Study:
M Ori Living product videos
W The Shed
• Readings
M *Architectural Robotics*: ch. 1 (link to this if you can't get the book in time).
W Negroponte, N. "Intelligent Environments" in *Soft Architecture Machines*, MIT, 1975.
• In class
M Rapid prototyping: make 5 prototypes with aluminum foil, paper, cardboard....
W Student progress reports and design development.

Week 03 | (ASSIGNMENT 1: EARLY IDEAS & DEMO) *(*No class Monday)*
• In class:
W Present in slides: (a) your problem definition (in words) and (b) design concept(s) for the assignment, using any combination of mind mapping, sketching, rapid prototyping, diagramming, lit review, requirements (i.e., specifications; guidelines).

Week 04 | PATTERNS
• Case Study:
M Hyperbody/TU Delft. Pop-Up Apartment.
W eva/TODO/Blackboard, Kinetic Wall; Reconfigurable facades.
• Readings:
M *Architectural Robotics*: ch. 2.
W Alexander, C., et al. *A Pattern Language*,"Using this Book" *to the end of p. xliv and patterns 45, 69, 124 on PDF pages 93, 115, 178.)*; Wang, Y. and Green, K. E. 2019. A Pattern-Based, Design Framework for Designing Collaborative Environments,*TEI 2019.*
• In class:
M Physical computing; WOz (e.g. *Nest*); Marvel app.
W Demo your developing hardware prototypes (using Grove or a breadboard) with at least one input and one output (i.e., one sensor, one actuator).

Week 05 | INTERACTIONS
• Case Study:
M W. Ju. Mechanical Ottoman; Aarhus Univ., coMotion.
W M. Goulthorpe/dECOi/MIT, HypoSurface.
• Readings:
M *Architectural Robotics*: ch. 3.
W Pask, G. 1969. The Architectural Relevance of Cybernetics. *Architectural Design*.
• In class:
M GIFs; Photoshop to make GIFs; ex.s 1, 2, 3, 4, 5, 6.
W Screening of a walk through Parc Güell; student progress reports.

Week 06 | BODY BUILDING

• Case Study:
M N55 Walking House; Doris Sung's Living Architecture.
W Holger Schnädelbach. ExoBuilding
• Readings:
M *Architectural Robotics*: ch.s 5, 8, 11.
W McHale, J. 1969. Man Plus.; J. Rykwert. 1992. "Organic and Mechanical." *Res.*
• In class:
M Making videos [my guide]; ex.s: CHI17, CHI18, GrowBot; student progress reports.
W Steve Jobs on presenting.

Week 07 | (ASSIGNMENT-1 WORKSHOP & DEMOS)
• In class:
M Present draft videos; Advance final prototypes and supporting documents.
W Demo day.

P A R T - 2 | S C A L E S & I M P A C T S -

Week 08 | FURNITURE & FURNISHINGS
• Case Study:
M ARL's ART and its pneumatic surface; TU Delft's IneractiveWall.
W Aarhus University's, Kirigami Table; Bill Gaver's Drift Table: pdf and video.
Readings:
M *Architectural Robotics*: ch. 6.
W *Architectural Robotics*: ch. 7.
• In class:
M Write a scenario, more on scenarios;, scenario-based design.
W Morphological charts; ex.s 1, 2, 3, and one from class. Note (and make) cell paths.

Week 09 | WORKSTATIONS
• Case Study:
M ARL's AWE; Roomware.
W ARUP's Smart Desks/Workplaces.
• Readings:
M *Architectural Robotics*: ch. 4.
W Houayek, H, Green, K. E., et al. 2014. AWE. *Jrnl. of Personal and Ubiquitous Comp*.
• In class:
M Storyboard.
W Student progress reports and design development.

Week 10 | HABIT-ATIONS *(*No class Wednesday)*
• Case Study:
M Futuristic Kitchen (1970).
• Readings:
M *Architectural Robotics:* ch. 9.
• In class:
M Design development.

Week 11 | LIVING ROOMS
• Case Study:
M ARL's LIT ROOM, LIT KIT.
W bumblebee spaces; more, homepage.
• Readings:
M *Architectural Robotics*: ch. 10.
W Schafer. G, Green, K. E., et al. 2018. LIT ROOM. DIS '18.
• In class:
M Hardware-prototype development.
W Hardware demos (part of a 10-point package - see, below)

Week 12 | CITIES
• Case Study:
M Futuristic City of Tomorrow (1960s); Intel smart city.
W The Experimental City. Google's Quayside, its termination, and lessons learned.
Readings:
M McCullough, M. 2004. *Digital Ground* (excerpts). MIT Press, Cambridge, MA.
W Dourish, P. 2001. *Embodied Interaction*. MIT Press, Cambridge, MA (paper).
• In class:
M User Experience (UX) Survey; outside class: conduct a UX survey with 5 peers.
W Student progress reports and design development.

Week 13 | ECOSYSTEMS OF BITS, BYTES, & BIOLOGY
• Case Study:
M IBM TRIRIGA
W ARL's Soft Robotic Wall for wellbeing in tight confines.
Readings:
M *Architectural Robotics*: ch. 12.
W Green, K. E. 2022. Robots in the Room, Robots are the Room. In *Ecological Design Thinking*. Rutledge.
• In class:
M Student progress reports and design development informed by UX results.
W Student design development informed by UX results.

P A R T - 3 | M O V I N G & T H I N K I N G -

Week 14 | [WORKSHOP] *(No class Wednesday)*
• In class:
M Advance your final prototype and supporting documents.

Week 15 | INTELLIGENT?
M The Chinese Room; ARL's Space-Making Robot Agency.
W ARL's MAPLE
• Readings:
M From *The Singularity: Special Report*, *IEEE Spectrum*, Vol. 45:
- Zorpette, G. "The Rapture of the Geeks"," pp. 34-35.
- Nordmann, A. "Singular Simplicity," pp. 60-63.
- Brooks, R. "I, Rodney Brooks, Am a Robot," pp. 71-75.

W Hayles, N. K. 1999. *How We Became Posthuman* (excerpt). U. Chicago.

• In class:
M Present draft videos; Advance final prototypes and supporting documents.
W Debate: *How intelligent, architectural robotics? When? Where? For whom? Why?*

Week 16 | DEMOS, DRAFT VIDEO SCREENING *(Last class Monday)*
M Demo day.
By Monday Dec. [tbd], 9am, you will have uploaded digital files of your video and documentation to our class shared drive for final grading.

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 5 points (5%) of the total grade at the discretion of the instructors. Attendance at the start of class will be taken by class attendance sheet. 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
Students enrolled in this course are encouraged to join email postings (aka listservs) for ACM SIGCHI ANNOUNCEMENTS and DESIGN RESEARCH NEWS (both of these for design opportunities) and also ACM SIGCHI JOBS. Students are also encouraged to become a student member of SIGCHI which brings you a 1-year subscription to interactions magazine [print] and discounts on ACM conferences. Directions for joining these.

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.