EE 626 Syllabus: Rapid Prototyping and Electrophysical Devices

Lectures:	12:30-1:20 PM MWF in Holmes Hall 211
Instructor:	David Garmire, david.garmire@gmail.com, POST 201E, x6-7406
Office Hours:	1:30-2:30 PM MW in POST 415
Webpage:	http://mn.eng.hawaii.edu/~garmire/HTML/ee693i-sXX
Units:	3

Reading: Supplied weekly from sources available to UH students
E.g., Yan, Xue, and P. E. N. G. Gu. "A review of rapid prototyping technologies and systems." *Computer-Aided Design* 28.4 (1996): 307-318.
Sreetharan, Pratheev S., et al. "Monolithic fabrication of millimeter-scale machines." *Journal of Micromechanics and Microengineering* 22.5 (2012): 055027.
Mironov, Vladimir, et al. "Organ printing: computer-aided jet-based 3D tissue engineering." *TRENDS in Biotechnology* 21.4 (2003): 157-161.

Grading:
20% class participation
20% homework assignments
30% project presentation
30% project writeup

Course Objectives: A student should demonstrate mastery of the (i) principles of modern rapid-prototyping of electrophysical devices, (ii) the principles of design, fabrication, testing, and iteration within the context of an application domain, (iii) be proficient in building, measuring, and evaluating prototype performance, and (iv) professionally disseminating the results.

This course will provide a literature study on the emerging area of rapid-prototyping of microsystems and electrophysical devices with example applications in domains including renewable energy, robotics and drones, biomedicine, and wireless sensor networks. It will cover microfabrication technology, emerging maker technology, materials being used in this area, and various devices that have been created that can be applied to these areas. It will also cover modeling methods to gain a sense of the behavior of energy and how it converts between thermal, fluidic, magnetic, electrostatic, electromagnetic, chemical, and elastic domains. It will also cover integration of microsensors and devices at the systems level by discussing embedded system design, wireless networking, and enclosure fabrication techniques. Through student presentations and a final project, students will learn how to design and make their own microsystems and be competent in understanding microtechnology and its uses in sustainability. Students will enter industry, government, or academia with this initial experience and understanding.

The realm of miniaturization of electrophysical systems is rich because it can offer useful information about the availability and consumption of energy at a low cost per device. Microdevices require much less energy to actuate allowing them to be used in energy controlling and sensing applications while not consuming much energy themselves. The challenge in this domain is designing devices to give accurate information or control energy processes precisely while at the same time being inexpensive to mass produce and energy efficient in operation.

As an example, an application area that will be examined in detail is sustainability and renewable energy. As sustainability and renewable energies become more of a state and national priority, one quickly realizes the vastness of the opportunities available especially with regard to rapid prototyping of electrophysical devices. There are many ways in which energy may be created, transmitted, and stored as witnessed in the world around us by the vibrant array of biological niches utilizing different energy sources. There are parts of this emerging domain that have been studied for centuries (wind turbines and sails) and there are other parts just now dawning in our minds. It is likely that this domain will continue to grow exponentially from both the academic and industrial perspective over the next few years as we look for more effective and sustainable means of producing, transmitting, and storing energy.

Material and Schedule

A. History of manufacturing and introduction to light manufacturing, also known as rapid-prototyping or "making" including a discussion of contemporary application areas
1 week
B. An overview of three dimensional modeling tools, simulation, and computational geometry involved in rapid prototyping (path planning, multiple fabrication-step planning, and incorporation of physical forces involved)
1 week
C. Introduction to physical domains and mechanisms of energy transduction between domains (e.g., creation of an energy transduction matrix across domains) and history of innovation for each energy transduction element (e.g., Peltier cooling between thermal thermal and electric domains)
2 weeks
D. An overview of additive manufacturing including plastic extrusion, sintering, and deposition (e.g., chemical vapor deposition)
1 week
E. An overview of subtractive manufacturing including laser cutting, CNC milling, wet chemical etching, Deep / Reactive Ion Etching (D/RIE)
1 week
F. Printed circuit board fabrication including design, milling, silkscreening, solder masking, reflow, testing and evaluation and iteration on designs (e.g., students will learn layout tools such as Fritzing and Eagle, placement of components, proper mixing of analog and digital functionality)
2 weeks
G. Application area in renewable energy and sustainability covering wireless sensor weather/energy monitoring and prediction, and wind, ocean, solar, and thermal energy transduction
1 week
H. Application area in drone and robotic technology including stepper motor and brushless motor implementations, driving electronics, embedded systems, and linkage with controls
1 week

I. Application area in biomedical devices including 3D printing of organs, microfluidics, and biomedical sensing devices
1 week
J. Review, discussion, and specifics of rapid prototyping methodology applied to each class project, details on delivery of presentations and reports, and operating in teams
2-3 weeks

Activities

K. Weekly readings and write-ups during the first half of the semester
L. Periodic challenges which take less than a week to develop a particular prototype optimized for a particular task
M. One lecture period per week devoted to discussion (participation grade) and laboratory tutorials
N. Group project work on a selected electrophysical device and use of rapid-prototyping tools in fabricating it.
O. Group presentation for project proposals near the middle of the semester
P. Final professional-quality group presentation at the end of the semester
Q. Final camera-ready conference-quality project paper at the end of the semester

Outcomes

R. Understand principles and methodologies associated with rapid prototyping.
Material and Activities Supporting Course Outcomes (MA→CO): A-F, K-N
S. Demonstrate ability to design, fabrication, test, and iteration of electrophysical devices.
MA→CO: B-J, K-N
T. Demonstrate a contemporary understanding of rapid prototyping and be able to quickly relate present work to past work in the area.
MA→CO: A, G-J, K, M-P
U. Ability to work in teams to produce electrophysical devices employing rapid prototyping methodologies.
MA→CO: G-J, N-Q
V. Ability to articulate to audiences design rationales, justification, and results of prototyping.
MA→CO: A-J, M-Q

Relationship to Graduate Student Learning Outcomes (SLOs)

1. Demonstrate mastery of the methodology and techniques specific to the field of study.
Course Outcomes Supporting Program Outcome (CO→PO): R, S, T (Strength: 4[1])
2. Communicate both orally and in writing at a high level of proficiency in the field of study.
CO→PO: V (Strength: 3)
3. Conduct research or produce some other form of creative work.
CO→PO: U (Strength: 4)
4. Function as a professional in the discipline.
CO→PO: R-V (Strength: 4)

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[1] Strength is on a 1-4 scale where 1 means “not at all” and 4 means “very strong”