Summer Session 2020

BIOB 491 Sensor Design, Fabrication, and Field Deployment for Real-Time Networks and Data Loggers

Syllabus and Schedule

3 credits; Lectures, Labs, Field Work
Course dates: June 22–July 3, 2020
Instructor: Dr. A. Cody Youngbull
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https://flbs.umt.edu/urls/peo

Prerequisites: completed two semesters of undergraduate course work in a science, technology or engineering major; or consent of instructor.

Course Description:
Autonomous environmental sensors are increasingly being used to collect real-time data about the natural world. Accordingly, there is a wide array of commercially available environmental and biological sensors but unfortunately they are sold for commercial monitoring applications and are often outside the price range of ecological study. Understanding how to design and produce appropriate sensors to answer specific scientific questions is therefore highly desired but requires knowledge from a broad range of disciplines.

The Flathead Lake Biological Station's SensorSpace (https://sensorspace.tech) is a cutting edge facility that enables scientists and engineers to design and manufacture their own environmental sensor networks. This course is designed for both engineering and ecology students to work on small team projects to learn about, design, manufacture, and deploy robotic environmental sensor networks. This course will include instrumentation design/manufacturing, and wireless network communications in the field.

This is a practical field course in which ecology and engineering students will come together in teams to design and deploy sensors related to aquatic and terrestrial ecology. Data from the sensors will be collected and used to answer specific ecological/environmental questions. Example analytes for which cost-effective fieldable sensors can be produced by researchers include pH, $O2$, $CO2$, nutrients, temperature, light levels, accelerations, GPS, and more.

Through their specific team projects students will be introduced to methods of manufacturing including: 3D model design, CNC machining, additive manufacturing with 3D printing, laser cutting, and microlithography. Students will learn about various concepts associated with sensor design such as: sensitivity, dynamic range, specificity, stability, repeatability, and compatibility. Specific focus will be placed on those sensor technologies being used in their overarching project including chemical and physical sensors that operate by optical and voltammetric principals. Students will be introduced to key embedded systems concepts for field deployed electronics: power systems, microcontrollers, I/O, and various communication technologies to enable the inclusion of data logging and networking modules in their deployed sensor systems.

Course Themes:

Theme #1 Building Sensors and Instrumentation. Designing, modelling, and manufacturing prototypes sensors. Using these sensors to connect to an internal data logger, your computer, and live in the cloud.

Theme #2: Data Collection, Processing, and Publication Display. Students will explore the data, prepare it for publication, or upload it to the cloud using a live-network that they build themselves.

<u>Design Challenge: To engineer environmental sensors that can be deployed successfully in the field.</u>
We are going to be building sensors that are designed for field-deployment in both wet and dry environments. The environments will include lakes, streams, and forests. We will be learning by a process of applied, iterative debugging, with limited resources and a strict deadline.

Student Learning Objectives:

After taking this course students will be able to:

1) design sensors and components, source materials, identify best approaches to sensor production given environmental and engineering constraints
2) produce sensor components using a variety of tools available in the SensorSpace
3) build microfluidic chips for optical sensing of oxygen, CO_2, pH. temperature, soil moisture, and nutrients
4) program microcontrollers.
5) design electronic controls of field sensors
6) deploy and collect data from class-built sensors

Required Texts:

All reference materials, handouts, and electronic resources for this course will be pre-loaded onto a USB flashdrive. Therefore, all students will be <u>REQUIRED</u> to purchase the flash drive from our FLBS bookstore (~$27) upon arrival here.

<u>**Course and Field Supplies/Equipment**</u> (*available for purchase at the FLBS Bookstore)

- Rite in the Rain 8.5" by 11"*
- Lab notebook*
- Binder or clipboard (optional)*
- 128GB SanDisk 2.0 Flash Drive* (THIS MUST BE PURCHASED HERE AT THE FLBS BOOKSTORE.)
- Pencils*
- Laptop Computer
- Hot/cold mug*
- Plastic, resealable containers for lunch pack-up
- Warm jacket
- Mess kit
- Rain gear
- Water bottle
- Wading shoes and/or waders
- Clothes that can get muddy
- Flashlight or headlamp with batteries

- Note: There is no required overnight field gear for this course.

Evaluation and Grading:
Grades will be earned based on three criteria:

1) Regular attendance and participation in course activities;
2) A short oral presentation summarizing the group project sensor creation, deployment and results; and
3) Completion and quality of laboratory write-ups summarizing the development and deployment of the field sensor.

Grades will be weighted as follows:

1) Attendance and participation in class lectures, discussions, and labs (20%),
2) Performance on oral presentation summarizing group projects (40%), and
3) Performance on write-ups of laboratory training exercises (40%).

Graduate Increment:

1) Graduate students will be required to install individual software components onto their instruments (whereas undergraduates will be given a ready to go installation package).
2) Graduate students will also choose their own application which likely dictates a unique deployment location and results in unique data visualization requirements. Graduate students will therefore be required to analyze and display their own data using software package of their choosing (Python, R, etc.) and to present that data as part of an oral (15 min total: 12-minute talk with 3 minutes for questions) presentation summarizing their (group) project/experiment.
3) The instructor also expects a higher degree of class leadership and logistical support from graduate students.

Course Policies:
Students will adhere to University of Montana Student Conduct Code and Discrimination, Harassment, Sexual Misconduct, Stalking, and Retaliation Policy (UM policy website: http://www.umt.edu/safety/policies/). Students must also adhere to the FLBS Code of Conduct and FLBS Rules and Regulations, as well as abide by the Safety Orientation Checklist.

FLBS students are required to complete University of Montana Prevention Education Program courses: AlcoholEdu and Sexual Assault Prevention for Adult Learners after coursework begins and prior to completion of coursework.

Schedule: The schedule below is subject to change.
Note: Make sure you pack your brown bag lunch each day at breakfast!

Date	Topic(s)	Location	Lectures/Lab/Field Work
22-Jun-2020 (M)	What motivates ecological sensing? Introduction to Sensor Concepts. Team Project Selection	Classroom	Welcome & Introduction What motivates ecological sensing? Identify the ecological context and problem sets we will be using as the backdrop for the sensors we are building and deploying. Install the software that will be necessary for completing the next few days of work. Team Project Selection
23-Jun-2020 (T)	Current Sensing Science and Methods	Classroom / SensorSpace	Design and Modeling Fusion360 - The Virtual SensorBox
24-Jun-2020 (W)	Data to Publication/ Presentation	Classroom / SensorSpace	Manufacturing CAD-CAM Additive Manufacturing / Subtractive Manufacturing 3D Printing CNC Mill Drill Laser Cutter
25-Jun-2020 (Th)	Network Backbone	Classroom / SensorSpace	Assembly Day 1
26-Jun-2020 (F)	Embedded Systems	Classroom / SensorSpace	Assembly Day 2 (Programming Programming 1 (Initializing Arduino)
29-Jun-2020 (M)	Field Reconnaissance	Classroom / SensorSpace	Final Assembly Programming 2 (Modifying Arduino), and Calibration
30-Jun-2020 (T)	Field Deployment	SensorSpace / FLBS Station Grounds	Field Deploy 1 Programming 3 (Live Network Data Flow)
1-Jul-2020 (W)	Field Deployment 2.0 Fixing and Responding	SensorSpace / FLBS Station Grounds	Field Deploy 2 (Extending, Fixing and Responding) Modify and maintaining the sensor network. Change positions to extend coverage
2-Jul-2020 (Th)	Data Processing and Interpolation	Classroom / SensorSpace	Data Processing, and Visualization Read data from live network and interpolate between values with a scientific model function. Learn curve fitting methods. Learn the essentials of error propagation and error reporting.
3-Jul-2020 (F)	Presentation and Reporting	Classroom	Presentation and Reporting FINAL EXAM: Present results of work to the class. Large format poster print. COURSE REVIEW HANDOUT

Students with disabilities may request reasonable modifications by contacting the instructor. The University of Montana assures equal access to instruction for students with disabilities in collaboration with instructors and Disability Services for Students (406.243.2243, http://www.umt.edu/dss/default.php). The University does not permit fundamental alterations of academic standards or retroactive modifications.