Department of Electrical Engineering, University at Buffalo, SUNY

EE 426/526 Wearable and Implantable Sensors

Days, Times, and Locations
Lecture M/W, 12:45 - 2:00 pm, Remote (no in-person component required).

Join Zoom Meeting for Synchronous Lecture

Instructor
Prof. Kwang W. Oh, SMALL (Sensors & MicroActuators Learning Lab), EE & BME, kwangoh@buffalo.edu; Office Hours (Zoom): F12:45-2:00 pm / by appointment (send an e-mail then I will invite you for individual Zoom meeting. Use the e-mail subject line wisely; please put "[EE 426] …" or "[EE 526] …" in the subject header!)

TA
Office Hours: or by appointment

Course Description
In this course, students will learn the basic sensing theory behind the wearable and implantable sensing technology. A variety of advanced physical, chemical, bio sensors will be introduced, including pressure, acceleration, gyroscope, magnetometer, GPS, proximity, light, camera, touch screen, identification, acoustic, humidity, temperature, biosignal, heartbeat, gas, chemical, infrared, sweat, glucose, and biomedical sensors. In the class, students will propose and/or present a concept of their own unique wearable and implantable device/system using multiple sensors. Recent and future trends in wearable and implantable sensor technology will be discussed too. Students will gain a broad perspective in the area of sensors and wearable and implantable technology for healthcare and appealing applications.

Prerequisite(s)
MTH 141, PHY 107, PHY 108, CHE 107, or permission of the department

Textbook and/or Other Required Materials
Recorded lecture video clips will be available after each class. Class notes and handouts (see UBLearns).

Course Requirements/Grading Policy:

Requirement	%	EE 426	EE 526	Materials Covered
Final Exam*	20%	○	○	Take-Home Final Exam
Project 1**	30%	○	○	Build your own Android or Apple App and demonstrate it on your OWN smartphone (1-min ZOOM demonstration).
Project 2***	15%	○	○	Submit an IEEE-style technical abstract
Project 3****	15%	○	○	Present your idea(s) proposed in the abstract (3-min ZOOM presentation)
Project 4***** (Optional)	(30%)	○	○	(Optional) You are allowed to replace both the Project 2 and the Project 3. Build your own Arduino (or something equivalent)-based PULSE OXIMETRY (3-min ZOOM demonstration/presentation).
Homework******	20%	○	○	4 HWs (5% per each)

[*] **Final Exam (20%); Due 12/16/Wednesday 11:59 pm**: A final exam is a **take-home exam**.

[**] **Project 1 (30%); Due 10/19/Mon 11:59 pm**: **1-min Zoom Demonstration. Build your own Android or Apple App** and demonstrate it (1-min Zoom demonstration) on your OWN smartphone (if you don't have one, you can buy a pre-owned or refurbished one under $75 or so from eBay). You have to build an App something similar to "Sensors Toolbox (by EXA Tools)". **You must do a SELF-STUDY to build your own smartphone App. TA/instructor will not help at all.**

- Examples/Related Links:
  - https://play.google.com/store/search?q=sensor%20test&c=apps&hl=en;
  - https://play.google.com/store/apps/details?id=com.exatools.sensors
  - https://developer.android.com/training/index.html; http://stackoverflow.com
  - https://developer.android.com/samples/
  - https://github.com/googlesamples/android-ndk/tree/master/sensor-graph/#readme
- The grading for the Project 1 will be based on:
  (1) (50%) Basic:
  - **(10%) File submission (all three files with right naming?):**
    - a. "StudentID_LastName.apk" → "12345678_Oh.**apk**" for Android App or "12345678_Oh.ipa" for iPhone App
    - b. "StudentID_LastName.**zip**" → "12345678_Oh.zip" including all source codes/files, such as .apk, .xml, .java, …etc.
    - c. A short video clip (less than 1 min) demonstrating your App: "12345678_Oh.**mp4**"
  - **(40%) Real-time data of AT LEAST 5 sensors** from student's OWN smartphone (such as, Accelerometer, Magnetic Field, Light, Proximity, Microphone)

  (2) (25 %) Plagiarism:
  - **(15 %) Acknowledgement:** May start with source code(s) obtained from published example(s), and modify them. You have to put the list of reference(s) of all the original source codes/websites/books (at the bottom of the App or in a separate page on the App)
  - **(10 %) Identification:** Your full name on the App

  (3) (25 %) Additional:
  - **(15 %) Additional (of course your own) features and/or functions:** using the real-time data from the sensor(s) on the App
  - **(10 %) Quality:** have enough quality (e.g., features, functions, designs, …) to be listed on the Google Play Store or Apple App Store?

[***] **Project 2 (15%); Due 11/11/Wed 11:59 pm**: **Abstract Submission.** Students will submit **an IEEE-style technical abstract** (both ".docx" and ".pdf"). Students will pick any **US patent(s)**, related to wearable/implantable sensor technology, from https://www.uspto.gov/ and/or https://patents.google.com/.

- The abstract structure could be (must use the suggested abstract template format):
  (1) **Introduction:** Briefly introduce their key claims/technology and analyze Pros and Cons in their claims/technology. You have to use schematics/drawings/diagrams from the patent(s) to do this.
  (2) **Idea:** Then come up with detailed solution(s) that are better than the existing one(s) to overcome the Cons (but keep the Pros). You must use your own schematics/drawings/diagrams (hand-drawn and/or computer-aided) to illustrate your ideas/solutions. You have to provide sound information on your proposed idea by using the schematics/drawings/diagrams. Avoid any ambiguous and/or impractical ideas. Remind that you have to propose both INNOVATIVE and PRACTICAL (not incremental) ideas that are better than the existing one(s) published in the patents.
  (3) **Outcome/Challenge:** Discuss the technical challenges and potential solutions to realize the proposed idea(s). You may use additional schematics/drawings/diagrams to support these.
  (4) **Conclusion:** So what? Summary and impacts of your proposed idea(s).
  (5) **Reference:** If there are no references, people will assume things (patents, backgrounds, ideas, images, photos,…) belong to you 100%. Otherwise, make a list of references…

- The grading for the Project 2 will be based on:
  (1) **(40 %) Uniqueness and originality of your selections:** Is the proposed idea unique and original? Did he/she propose it for the first time as far as you know? Is it really useful in some applications? Please google/search articles, journals, patents, products,…, if someone already did similar thing you propose or not. If you want to have higher points, propose a quantum jump idea, not an incremental idea.
  (2) **(40 %) Realistic and detailed approach:** Are there enough discussions on challenges and solutions to be able to make/fabricate/realize the idea(s)? The topic should be "narrow and specific". You have to illustrate your proposed idea(s) as detailed as possible.
  (3) **(20 %) Abstract format:** Does he/she follow the suggested abstract template format (available from UBLearns)? Does he/she demonstrate a good quality in terms of format, writing skills, sound logics, supporting tables/drawings/figures, **references**?

**** **Project 3 (15%); To Be Assigned from 11/30/Mon until 12/09/Wed: 3-min Zoom Presentation.** Students need to present their idea(s) proposed in the abstract (Project 2). This will give students more chances to improve not only their ideas (**you may modify/improve the proposed idea(s) if you need to do so**), but also oral presentation skills, in addition to the abstract writing skills.

- The power point presentation structure should include the followings (ZOOM presentation):
  (1) Introduction: Patent(s), Pros and Cons in their technology.
  (2) Your unique approach/design/solution. You must illustrate your proposed idea(s) using sketches/drawings/schematics/tables/etc. Hand-drawing is okay. If you don't know how to visualize any details, you have no idea what you are proposing.
  (3) What are the technical challenges and potential solutions to realize the proposed idea? Detailed plan to challenge/solve the idea.
  (4) So what? Summary and impacts of your proposed idea(s).
  (5) Reference (please list all references in EACH presentation page if they (photos, images, ideas, data,…) are not from your own ones. Do not list all on the last page!!!)
- The grading for the presentations will be based on:
  (1) **(30 %) Uniqueness** and originality of your selections: Is the proposed idea unique and original? Did he/she propose it for the first time? Is it really useful in some applications?
  (2) **(30 %) Realistic** and detailed approach: Are there enough discussions on challenges and solutions to be able to make/fabricate/realize the idea? The topic should be "narrow and specific". So you may be able to realize your ideas within 2 years (or 4-5 years). I don't want to hear broad ideas or concepts.
  (3) **(30 %) Presentation** skills (presentation structure, easy understanding, references, exact 3-min talk + 1-min questions/answers,…): Does he/she entertain, inform, persuade, and/or sell the proposed idea effectively within the given time? You have to convince your idea to students and of course entertain them too. Does he/she provide all references in EACH presentation page?
  (4) **(10%) Participation: Does he/she participate all presentation?**

***** **Project 4 (30%): 3-min Zoom Demonstration/Presentation.** Build **your own Arduino-based PULSE OXIMETRY.** You are allowed to replace both the Project 2 and the Project 3.

- Examples/Related Links:
  - https://create.arduino.cc/projecthub/SurtrTech/measure-heart-rate-and-spo2-with-max30102-c2b4d8
  - https://create.arduino.cc/projecthub/gatoninja236/open-source-pulse-oximeter-for-covid-19-4764c5
  - https://create.arduino.cc/projecthub/martin-cornu/connected-oximeter-with-sms-alert-for-covid-19-538346
  - https://create.arduino.cc/projecthub/protocentral/using-the-max30100-wearable-pulse-sensor-with-arduino-9b6984
  - https://create.arduino.cc/projecthub/protocentral/pulse-transit-time-for-cuff-less-bp-from-ecg-and-ppg-06c229
  - https://create.arduino.cc/projecthub/jeffreymagee/attiny85-pulse-oximeter-and-photoplethysmograph-e3f907
- The presentation structure should be with the similar format as shown in the above examples.
  (1) Introduction

(2) Hardware: components and schematics
(3) Code: software
(4) Operation: video demonstration
(5) So what? Summary and impacts of your project.
(6) Reference (please list all references in EACH presentation page if they (photos, images, ideas, data,…) are not from your own ones. Do not list all on the last page!!!)

- The grading for the project 4 will be based on:
  (1) **Uniqueness** and originality of your selections (30%): Is the proposed approach unique and original?
  (2) **Details** (30%): Are there enough details on challenges and solutions to be able to build your pulse oximetry?
  (3) **Presentation** skills (presentation structure, easy understanding, references, exact 3-min talk + 1-min questions/answers,…) (30%): Does he/she entertain, inform, persuade, and/or sell the projects effectively within the given time? You have to demonstrate your pulse oximetry to students and of course entertain them too. Does he/she provide all references in EACH presentation page?
  (4) **(10%) Participation: Does he/she participate all presentation?**

****** **Homeworks (20%): 4 HWs**

Topics/Schedule covered

W	Lecture	Date		Title	
1	[01]	08/31/20	M	Syllabus / Introduction	
	[02]	09/02/20	W	Sensors Characteristics	
2	[03]	09/07/20	M	Pressure Sensors	
	[04]	09/09/20	W	Accelerometers	
3	[05]	09/14/20	M	Gyroscopes	HW#1 Due
	[06]	09/16/20	W	Magnetometers / GPS	
4	[07]	09/21/20	M	Proximity Sensors / Light Sensors / Cameras	
	[08]	09/23/20	W	Touch Screen and ID Sensors	
5	[09]	09/28/20	M	Acoustic Devices	
	[10]	09/30/20	W	Humidity / Temperature	
6	[11]	10/05/20	M	Electrochemistry	HW#2 Due
	[12]/[13]	10/07/20	W	Epidermis/Biosignal	
7	[14]	10/12/20	M	Batteries / Wireless Charging	
	[15]	10/14/20	W	Chemical / Gas Sensors	
8	[16]	10/19/20	M	E-Nose / Electroanalytical Methods	Project 1 Due: App
		10/21/20	W	Project 1: Sensor App Demo (1-30)	
9		10/26/20	M	Project 1: Sensor App Demo (31-60)	
	[17]	10/28/20	W	Bio Sensors	
10	[18]	11/02/20	M	Nanobiosensors / Glucose Sensors	
	[19]	11/04/20	W	Point-of-care Testing	
11	[20]	11/09/20	M	IoT, Wireless Technologies and Sensors	
	[21]	11/11/20	W	Wearable Sensors (1)	Project 2 Due: Abstract
12	[22]	11/16/20	M	Wearable Sensors (2)	
	[23]	11/18/20	W	Implantable / Ingestible Sensors (1)	HW#3 Due
13	[24]	11/23/20	M	Implantable / Ingestible Sensors (2)	
		11/25/20	W	No Class (Thanks Giving)	
14		11/30/20	M	Project 3/4: Presentation (1-15)	
		12/02/20	W	Project 3/4: Presentation (16-30)	
15		12/07/20	M	Project 3/4: Presentation (31-45)	HW#4 Due
		12/09/20	W	Project 3/4: Presentation (46-60)	
16				Take-Home Final Exam	

Grading Policy: If you do meaningful/appropriate effort for each (sub)question and project, you will get at least 50% of the assigned maximum point for each (sub)question and project. If you leave blank or do not submit the project/homework, you will get 0% for each (sub)question and project/homework. Grades will be based on the total percentage accumulated from the course requirements:

Percentage (%)	Final Grade (EE 426)	Final Grade (EE 526)
93.490 - 100	A	A
89.490 - 93.489	A-	A-
86.490 - 89.489	B+	B+
82.490 - 86.489	B	B
79.490 - 82.489	B-	B-
75.490 - 79.489	C+	C+
69.490 - 75.489	C	C
65.490 - 69.489	C-	C
61.490 - 65.489	D+	D
54.490 - 61.489	D	D
< 54.490	F	F

Incomplete Grades: A grade of incomplete ("I") indicates that additional course work is required to fulfill the requirements of a given course. Students may only be given an "I" grade if they have a passing average in coursework that has been completed and have well-defined parameters to complete the course requirements that could result in a grade better than the default grade. An "I" grade may not be assigned to a student who did not attend the course. Prior to the end of the semester, students must initiate the request for an "I" grade and receive the instructor's approval. Assignment of an "I" grade is at the discretion of the instructor. The instructor must specify a default letter grade at the time the "I" grade is submitted. A default grade is the letter grade the student will receive if no additional coursework is completed and/or a grade change form is not filed by the instructor. "I" grades must be completed within 12 months. Individual instructors may set shorter time limits for removing an incomplete than the 12-month time limit. Upon assigning an "I" grade, the instructor shall provide the student specification, in writing or by electronic mail, of the requirements to be fulfilled, and shall file a copy with the appropriate departmental office. Students must not re-register for courses for which they have received an "I" grade. Detailed information is available from the Undergraduate Course Catalog, https://catalog.buffalo.edu/policies/explanation.html.

Course Learning Outcomes: The following table lists learning outcomes for this course. The statements generally complete the sentence, "Upon completing this course, students will be able to..."

	Course Learning Outcome	**Program Outcomes****	**Assessment Methods**
1	understand a variety of advanced physical/chemical/bio sensors	1.2	Final exam
2	understand recent/future trends in wearable/implantable sensors	1.2	Final exam
3	develop an App showing real-time information about all sensors of student's smartphone	1.4, 2.2	Project 1
4	demonstrate creative ideas and solutions in the area of sensors and wearable/implantable technology for healthcare/appealing applications.	3.1, 3.2	Project 2, Project 3, Project 4

** The Student Outcomes from the Engineering Accreditation Commission of ABET have been adopted, see http://www.abet.org/

Program Outcome Support: (0: not covered, 1: introduced, 2: practiced, 3: mastered)

Program Outcome	1					2		3		4		5		6			7	
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2	6.3	7.1	7.2
Support Level		3		2			2	2	2									2

Expectations of Students:

- Students are expected to act in a professional manner. A student's grade may be reduced due to unprofessional or disruptive behavior. Examples include coming to class late, texting (or otherwise using your cell phone) during class, your cell phone ringing during class and/or exams, etc.
- Late submission of projects receive a grade of zero.
- Students are allowed to share ideas regarding projects, but each student must independently write and submit their own work.
- Makeup exams will be given in the following circumstances only:
  1. You contact the instructor prior to the exam
  2. You have a valid and documented reason to miss any assignment/exam/project
     - Serious illness or family emergency are acceptable excuses
     - Sleeping in, lack of preparation, ennui, grogginess, too-busy etc. are not acceptable excuses

Accessibility Services and Special Needs: If you have any disability which requires reasonable accommodations to enable you to participate in this course, please contact the Office of Accessibility Resources, 60 Capen Hall, 645-2608, and also the instructor of this course. The office will provide you with information and review appropriate arrangements for reasonable accommodations. Additional information is available at http://www.buffalo.edu/studentlife/who-we-are/departments/accessibility.html.

Diversity: The UB School of Engineering and Applied Sciences considers the diversity of its students, faculty, and staff to be a strength, critical to our success. We are committed to providing a safe space and a culture of mutual respect and inclusiveness for all. We believe a community of faculty, students, and staff who bring diverse life experiences and perspectives leads to a superior working environment, and we welcome differences in race, ethnicity, gender, age, religion, language, intellectual and physical ability, sexual orientation, gender identity, socioeconomic status, and veteran status.

Academic Integrity: Academic integrity is a fundamental university value. Through the honest completion of academic work, students sustain the integrity of the university while facilitating the university's imperative for the transmission of knowledge and culture based upon the generation of new and innovative ideas. The UB undergraduate academic integrity policy is available at https://catalog.buffalo.edu/policies/integrity.html.