Department of Electrical Engineering, University at Buffalo, SUNY

EE 426/526 Wearable and Implantable Sensors

Days, Times, and Locations
Lecture M/W, 12:30-1:50 pm, NSC 205

Instructor
Prof. Kwang W. Oh, SMALL (Sensors & MicroActuators Learning Lab), EE & BME, 113C Davis Hall, kwangoh@buffalo.edu; Office Hours: M11-11:50a /W10-10:50a / by appointment (send an e-mail). Use the e-mail subject line wisely; please put "[EE 426] …" or "[EE 526] …" in the subject header!)

TA
Anyang Wang (anyangwa@buffalo.edu), Office Hours: M/W 2-3:30p, 233 Davis, or by appointment

SA
TBA (will assist Project 1)

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
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**	20%	○	○	Build your own Android or Apple App and demonstrate it on your OWN smartphone
Project 2***	20%	○	○	Submit an IEEE-style technical abstract
Project 3****	20%	○	○	3-min talk: present your idea(s) proposed in the abstract
Homework****	20%	○	○	4 HWs (5% per each)
Bonus******	10%	○	○	Attendance (pop-up attendance sign-up sheets) + Quality of Evaluation

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

** **Project 1 (20%); Due 10/14/Mon 11:59 pm**: **Build your own Android or Apple App** and demonstrate it **(10/21/Mon in Class; 1 min per student)** 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 cannot help at all.

- Examples:
  - 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) Basic (50%):
- Have a RIGHT NAME FORMAT? ((1) "StudentID_LastName.apk" → "12345678_Oh.apk", and (2) "StudentID_LastName.zip" → "12345678_Oh.zip" including all .apk, .xml, .java, …etc.) **(10%)**
- Show real-time data of AT LEAST 5 sensors (such as, Accelerometer, Magnetic Field, Light, Proximity, Microphone) from student's OWN smartphone? **(40%)**

(2) Plagiarism (25%):
- May start with source code(s) obtained from published example(s), and modify them. Reference(s) of all the original source codes (at the bottom of the App or in a separate page on the App) **(15%)**
- Also, put your name on the App **(10%)**

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

*** **Project 2 (20%); Due 11/04/Mon 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 (have to 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) **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).

- The grading for the Project 2 will be based on:

(1) **Uniqueness and originality of your selections (30%):** 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) **Realistic and detailed approach (30%):** 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) **Abstract format (40%):** 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 (20%); To Be Assigned from 11/11/Mon until 12/04/Wed: 3-min Oral 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 presentation structure should be with ONE-page slide (for example, poster-like):
  (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 (instructor: 50%, students: 50%) for the presentations will be based on:
  (1) **Uniqueness** and originality of your selections (30%): Is the proposed idea unique and original? Did he/she propose it for the first time? Is it really useful in some applications?
  (2) **Realistic** and detailed approach (30%): 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) **Presentation** skills (presentation structure, easy understanding, references, exact 3-min talk + 1-min questions/answers,…) (40%): 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?

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

- HW#1: TBD
- HW#2: TBD
- HW#3: TBD
- HW#4: TBD

****** **Bonus (a maximum of 10%):** A default is 10%.

(1) **Pop-Up Attendance (− 1%)**: Pop-up attendance sign-up sheets (a total of 10) will be given during any lecture. You have to send me an official email to grant an excuse (of course, due to official reasons, no personal things) for your absence. If granted, you will not have any point out.
(2) **Quality of Evaluation (+ (STDEV(Uniq) + STDEV(Real) + STDEV(Pres Skill))%):** You need to evaluate other student's presentation quality (Project 3) in terms of Uniqueness, Realistic, and Presentation Skill. Each session you need to grade using integer numbers between 5 and 10 (NOT between 9 and 10, Not between 10 and 10). Your bonus point will be based on the data that you grade other students, which will be the sum of each session's standard deviation.

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/homeowork, you will get 0% for each (sub)question and project/homeowork. Grades will be based on the total percentage accumulated from the course requirements:

Percentage (%)	Final Grade (EE 426)	Final Grade (EE 526)
93.490 - 110	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

Topics/Schedule covered

W	Lecture	Date		Title	Project
1	[01]	08/26/19	M	Syllabus / Introduction	
	[02]	08/28/19	W	Sensors Characteristics	
2		09/02/19	M	No Class (Labor Day)	
	[03]	09/04/19	W	Pressure Sensors	
3	[04]	09/09/19	M	Accelerometers	
	[05]	09/11/19	W	Gyroscopes	HW#1
4	[06]	09/16/19	M	Magnetometers / GPS	
	[07]	09/18/19	W	Proximity Sensors / Light Sensors / Cameras	
5	[08]	09/23/19	M	Touch Screen and ID Sensors	
	[09]	09/25/19	W	Acoustic Devices	
6	[10]	09/30/19	M	Humidity / Temperature	
	[11]	10/02/19	W	Electrochemistry	HW#2
7	[12]	10/07/19	M	Epidermis as Infomation Barrier	
	[13]	10/09/19	W	Biosignal	
8	[14]	10/14/19	M	Batteries / Wireless Charging	Project 1 Due: App
	[15]	10/16/19	W	Chemical / Gas Sensors	
9		10/21/19	M	Project 1: Smartphone Sensor App Demonstration	
	[16]	10/23/19	W	E-Nose / Electroanalytical Methods	
10	[17]	10/28/19	M	Bio Sensors	
	[18]	10/30/19	W	Nanobiosensors / Glucose Sensors	
11	[19]	11/04/19	M	Point-of-care Testing	Project 2 Due: Abstract
	[20]	11/06/19	W	IoT, Wireless Technologies and Sensors	
12	[21]	11/11/19	M	Wearable Sensors (1)	HW#3 | Project 3: 3-min talk. 1-7
	[22]	11/13/19	W	Wearable Sensors (2)	8-14
13	[23]	11/18/19	M	Implantable / Ingestible Sensors (1)	
	[24]	11/20/19	W	Implantable / Ingestible Sensors (2)	15-21
14	[25]	11/25/19	M	Implantable / Ingestible Sensors (3)	22-28
		11/27/19	W	No Class (Thanks Giving)	
15		12/02/19	M	Presentation	29-53, HW#4
		12/04/19	W	Presentation	54-77
16				Take-Home Final Exam	

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.	1.2, 2.1, 2.2, 3.1, 3.2, 7.2	Project 2, Project 3

** 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	0	3	0	2	0	2	2	2	2	0	0	0	0	0	0	0	0	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 the quiz
     - 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.