Department of Electrical Engineering, University at Buffalo, SUNY

EE 426/526 Wearable and Implantable Sensors

Course Meeting Days, Times, and Locations

Lecture M/W, 12-1:20 pm, Knox 04

Instructor: Prof. Kwang W. Oh, SMALL (Sensors & MicroActuators Learning Lab), EE & BME, 113C Davis Hall, kwangoh@buffalo.edu; Office Hours: W2-3:30p / F12-10p / by appointment (send an e-mail). Use the e-mail subject line wisely; please put "[EE 526] …" in the subject header!)

TA: Anyang Wang (anyangwa@buffalo.edu), Office Hours: M/W 2-3:30p, 233 Davis, or by appointment
SAs: You will get extra help about the Project #1.

- Anupriya Sahu (asahu@buffalo.edu): Off Hr: M/W/F 5-6:30, W9-11; Davis 2F Glass Atrium
- Karthik Radhakrishna (k27@buffalo.edu): Off Hr: M/W/F 5-6:30, W9-11;Davis 2F Glass Atrium

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:

Requirement	Quantity	Material Covered	Date
Exam	1	Final exam from all lecture notes	05/08/2019/Wed
Project 1*	1	Build your own Android or Apple App and demonstrate it on your own smartphone	03/27/2019/Wed 04/08/2019/Mon
Project 2**	1	Submit an IEEE-style technical abstract (both ".docx" and ".pdf")	04/24/2019/Wed
Project 3*** (EE 526 only)	1	Present their idea(s) proposed in the abstract (Project 2).	05/15/2019/Wed 11:45-2:45p

* **Project 1**: Build your own Android or Apple App and demonstrate it on your own smartphone. Also upload all your source code (e.g., .xml, .java, "StudentID_LastName.apk" → "12345678_Oh.apk", etc.). You have to build an App something similar to "Sensors Test (by Ettore Zaffaroni)". More details will be provided during class. You have to do a SELF-STUDY to build your own smartphone App.
Examples:

1. https://play.google.com/store/search?q=sensor%20test&c=apps&hl=en;
2. play.google.com/store/apps/details?id=com.chrystianvieyra.physicstoolboxsuite&hl
3. https://developer.android.com/training/index.html; http://stackoverflow.com
4. https://developer.android.com/samples/
5. https://github.com/googlesamples/android-ndk/tree/master/sensor-graph/#readme

The grading for the Project 1 will be based on:

1. Basic (50%): Does the App show real-time information about all sensors of student's smartphone?
2. Plagiarism (25%): You may start with source code(s) obtained from published example(s), and modify them. However, if you do so, you must make reference(s) of all the original source codes (at the bottom of the App or in a separate page on the App).
3. Additional (25%): Are there additional features and/or functions on the App? Does the App have enough quality (e.g., features, functions, designs, …) to be listed on the Google Play Store or Apple App Store?

** **Project 2**: Abstract Submission. Students will submit an IEEE-style technical abstract (both ".docx" and ".pdf") on the UBLearns website by the due date (04/24/2019/Wed). Students will design a concept of their own *unique wearable and implantable sensor/device/system* using (multiple) available sensing techniques for healthcare or appealing applications. *Or* they can propose *a new type of sensors and/or wearable or implantable applications*. You have to provide sound information on the working principle of your proposed idea. Avoid any ambiguous and/or impractical idea. Remind that you have to propose both INNOVATIVE and PRACTICAL (not incremental) ideas that someone has not proposed yet to the world, in terms of SENSING technologies and/or HEALTHCARE or APPEALING WEARABLE/ IMPLANTABLE applications. (Example: https://youtu.be/Jc4JbKVZYw0).

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? The topic should be "narrow and specific". I don't want to hear broad ideas or concepts. You can hand-draw your proposed idea 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**: 4-min Oral Presentation (for EE526 only). Graduate 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, but also oral presentation skills, in addition to the abstract writing skills.

The presentation structure could be (for example):

1. Your unique approach/design/solution. You must show your own sketch/drawing/schematic of your proposed idea. Hand-drawing is okay. If you don't know how to visualize any details, you have no idea what you are proposing.
2. What are the technical challenges and potential solutions to realize the proposed idea?
3. Detailed plan to challenge/solve the idea
4. Conclusion and impact (so what?)
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 4-min length, 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.

Grading Policy: Grading for EE426 will be done within the pool of "undergraduate students". Grading for EE526 will be done within the pool of "graduate students". Grades will be based on the total percentage accumulated from the course requirements distributed as follows:

Course Requirement	Points	Percent of Final Grade
Final Exam	100	30% (EE 426) / 25% (EE 526)
Project 1	10	30% (EE 426) / 25% (EE 526)
Project 2	10	30% (EE 426) / 20% (EE 526)
Project 3	10	0% (EE 426) / 20% (EE 526)
Professionalism/Attendance	10	10% (if you miss one lecture -0.5%)

Percentage	Final Grade (EE 426)	Final Grade (EE 526)
93-100	A	A
90-92	A-	A-
87-89	B+	B+
83-86	B	B
80-82	B-	B-
76-79	C+	C+
70-75	C	C
66-69	C-	C
62-65	D+	D
55-61	D	D
<55	F	F

Topics/Schedule covered

Wk01 [01] Syllabus / Introduction
Watching: Lec01-SteveJobs-iPhone2007.mp4 (01:19)
[02] Sensors Characteristics
Reading: Lec02-EE526-SUNYBuffalo-Characteristics
Wk02 [03] Pressure Sensors
Review: Lec03-ProfOhLabNoteforSiLabforMEMS1999.pdf
[04] Accelerometers
Watching: Lec04-MEMS accelerometer 3 axis accelerometer and scaling.wmv
Watching: Lec04-MEMS accelerometer basics and 2 axis accelerometers.wmv
Wk03 [05] Gyroscopes
Watching: Lec05-Apple WWDC 2010 - iPhone 4 Introduction.mp4
Watching: Lec05-How do MEMS gyroscopes work.mp4
[06] Magnetometers / GPS
Watching: Lec06-How does an electronic compass work.mp4
Watching: Lec06-SimpleGuideAcceloroMagnetoDigitalGyroGPSBaro.mp4
Wk04 [07] Proximity Sensors / Light Sensors / Cameras
Watching: Lec07-Galaxy S9 Teardown - Variable Aperture Camera lens.mp4

[08] Touch Screen and ID Sensors
Reading: Lec08-Trueprinttechnology.ppt

Wk05 [09] Acoustic Devices
Reading: Lec09-Prof.Horsley_seminar_slides170428.pdf

[10] Humidity / Temperature
Review: Lec10-AnalogDesignHandbookSensorsChapter3.pdf

Wk06 [11] Electrochemistry
Review: Lec11-ElectrochemistryReferencech21_electrochem_6e_final.ppt

[12] Epidermis as Information Barrier
Reading: Lec12-WearableSensorsModalitiesChallengesLabChip2018.pdf

Wk07 [13] Biosignal
Watching: Lec13-The Mind-Controlled Bionic Arm With a Sense of Touch.mp4

[14] Batteries / Wireless Charging
Review: Lec11-ElectrochemistryReferencech21_electrochem_6e_final.ppt

Wk08 No Class (Spring Recess)

Wk09 [15] Chemical / Gas Sensors
Watching: Lec15-Potentiometric pH measurement.mp4

[16] E-Nose / Electroanalytical Methods
Reading: Lec16-The Evolution Of Sensor Analog Front Ends.pdf
Project 1 Due: Smartphone Sensor App (03/27/2019/Wed)

Wk10 [17] Bio Sensors
Reading: Enzyme-Linked Immunosorbent Assay (en.wikipedia.org/wiki/ELISA)

[18] Nanobiosensors / Glucose Sensors
Reading: Lec18-DisposableSmartLabonaChipforPOC2004ProcIEEE.pdf

W	Lecture	Date		Title	
1	[01]	01/28/19	M	Syllabus / Introduction	
	[02]	01/30/19	W	Sensors Characteristics	
2	[03]	02/04/19	M	Pressure Sensors	
	[04]	02/06/19	W	Accelerometers	
3	[05]	02/11/19	M	Gyroscopes	
	[06]	02/13/19	W	Magnetometers / GPS	
4	[07]	02/18/19	M	Proximity Sensors / Light Sensors / Cameras	
	[08]	02/20/19	W	Touch Screen and ID Sensors	
5	[09]	02/25/19	M	Acoustic Devices	
	[10]	02/27/19	W	Humidity / Temperature	
6	[11]	03/04/19	M	Electrochemistry	
	[12]	03/06/19	W	Epidermis as Infomation Barrier	
7	[13]	03/11/19	M	Biosignal	
	[14]	03/13/19	W	Batteries / Wireless Charging	
8		03/18/19	M	No Class (Spring Recess)	
		03/20/19	W	No Class (Spring Recess)	
9	[15]	03/25/19	M	Chemical / Gas Sensors	
	[16]	03/27/19	W	E-Nose / Electroanalytical Methods	Due: Smartphone App
10	[17]	04/01/19	M	Bio Sensors	
	[18]	04/03/19	W	Nanobiosensors / Glucose Sensors	
11		04/08/19	M	Project 1: Smartphone Sensor App Demonstration	
	[19]	04/10/19	W	POCT	
12	[20]	04/15/19	M	IoT, Wireless Technologies and Sensors	
	[21]	04/17/19	W	Wearable Technology	
13	[22]	04/22/19	M	Wearable Sensors	
	[23]	04/24/19	W	Implantable / Ingestible Sensors (1)	Due: Abstract Submission
14	[24]	04/29/19	M	Implantable / Ingestible Sensors (2)	
	[25]	05/01/19	W	Implantable / Ingestible Sensors (3)	
15	[26]	05/06/19	M	Implantable / Ingestible Sensors (4)	
		05/08/19	W	Final Exam	
16		05/15/19	W	Presentation (05/15/2019/Wed, 11:45AM - 2:45PM, Knox 04)	

Wk11 **Smartphone Sensor App Demonstration (04/08/2019/Monday)**
[19] POCT (point-of-care test)
Reading: Lec19-Smartphone_lab_on_a_chip2014.pdf
Wk12 [20] IoT (internet of things), Wireless Technologies and Sensors
Web-surfing: https://www.ces.tech/ as much as possible (>2 hrs)
[21] Wearable Technology
Watching: Lec21-6CoolInventions6CoolWearableTechYouNeedToSee.mp4
Wk13 [22] Wearable Sensors
Leading: Lec22-BuildWristHeart-RateMonitorUltra-Low-PowerMCU.pdf
[23] Implantable / Ingestible Sensors (1)
Watching: Lec23-EMBC2014KeynoteDr.StephenOesterle.mp4
Project 2 Due: Abstract Submission (04/24/2019/Wed)
Wk14 [24] Implantable / Ingestible Sensors (2)
Web-surfing: www.medel.com/about-hearing, www.medel.com/hearing-solutions
[25] Implantable / Ingestible Sensors (3)
Wk15 [26] Implantable / Ingestible Sensors (4)
Final Exam (05/08/2019/Wed)
Wk16 **Project 3: Presentation (05/15/2019/Wed, 11:45AM - 2:45PM, Knox 04)**

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 and implantable technology for healthcare and 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 exam
     - 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.