Computer Engineering Degree

Discussion Document for Joint CS-EE Task Force (Members: Abeer Alwan, Mario Gerla, Richard Korf, Greg Pottie, Glenn Reinman, David Smallberg, Mani Srivastava).

Background

Members of the joint CS-EE Task Force met to consider options for undergraduate degree programs in light of the name change of the EE Department to ECE, historical experience with the CE option in EE, and the high attrition rate in the CSE degree program now offered by CS. The members quickly came to consensus that a new CE degree will be established to be jointly administered by EE and CS. For it to be attractive, it will require a compelling narrative as to what tangible skills students pursuing it will acquire, with a capstone experience that showcases those skills.

New Directions in Computer Engineering

Computer Engineering degrees have historically focused upon the hardware and software aspects of the design of traditional microprocessors and general-purpose computer systems. However in recent years with the embedding of computational intelligence in all sorts of engineered and natural systems we have seen the emergence of new class of computing platforms and systems, such as the Internet of Things, Human-Cyber-Physical Systems, Mobile/Wearable/Implantable Systems, Robotic Systems, and more generally “Smart” Systems at all scales in diverse spheres. Indeed, it is in the design of hardware, software, and algorithmic elements of such system that represent an already dominant and rapidly growing part of the Computer Engineering profession. Computing embedded in and coupled to physical and human systems is now the new norm in computer systems.

These new realities and trends in computing represent an opportunity to create a new type of CE degree that embraces the new forms of computing as the driver, and equips students with fundamental concepts and skills necessary to imagine, architect, design, and implement these new forms of computing systems. Instead of a curriculum that is based solely a bottom-up composition of component and subsystem oriented courses, the CE degree that we envision will also permit students to focus on areas relating to the demands of new forms computing systems such as the design of embedded systems and the processing of massive analog and digital data from networks of such systems. Together these will be significantly more attractive than programs offered at many peer institutions. In the following, we present the proposed CE degree, describe tracks and new courses for CE, compare it to CSE and the CE track within EE, and propose a governance structure.

Proposed Computer Engineering Undergraduate Major

Preparation for the Major

CS 1,31,32,33,35L,M51A (or ECE M16); ECE 3,10,11L; Math 31A,31B,32A,32B,33A,33B,61; Physics 1A, 1B, 1C, 4AL; Engineering 96C. (76 units)

The Major

CS 111,118 (or ECE 132B),M151B (or ECE M116C),M152A (or ECE M116L),180; ECE 102,110,111L;113, one course from ECE 131A, Civil and Environmental Engineering 110, Mathematics 170A or Statistics 100A; 8 units of ECE electives and 8 units of CS electives from among upper division courses; 12 units TBA electives; 8 units capstone design from either ECE 180DA/DB or ECE 183DA/DB (72 units)

English, Ethics, 5xGE: 33 units

Total: 181 units

Notes:

- The program provides considerable student flexibility for students to choose a track embodying a specialization (see below), with 7 electives available, including the TBA. A flexible program is also easier to keep up to date on student needs, with less coordination required between the two departments regarding changes in required courses.
- Capstone design over two quarters enables much more ambitious and powerful systems to be built, allows time for fabrication of hardware elements, and leaves room for covering concepts that students may have seen but not in an integrated manner. For example, projects may include development of all elements of a new robotic systems or a new IoT system, spanning hardware, embedded software, cloud services, sensor data processing, control, and visualization. In order to scale the course to a large number of students, several possible models can be explored such as a common project specification with teams of students competing to multiple distinct projects around a theme developed by students and perhaps mentored by local researchers and industry.
- Students can further specialize in ECE or CS by taking their Technical Breadth Area (TBA) in either, or can choose to take their TBA in another major, according to their interests.

Exemplar Specializations

As noted earlier, the CE program would be structured around the concept of allowing students to specialize in areas that relate to emerging computing systems. The set of tracks will evolve over time, with the following initial set to be laid out in the Announcement. These tracks have been carefully selected as ones where UCLA CS and EE have significant number of faculty active which would facilitate tighter coupling of research with education and provide students with opportunities beyond coursework. Students will of course retain the option to select ad hoc tracks, for example, by choosing some electives from the other track.

1. Networked Embedded Systems: This track targets two related trends that have been a significant driver of computing, namely stand-alone embedded devices becoming networked and coupled to physical systems, and the Internet evolving towards a network of “things” (the IoT). These may broadly be classified as cyber physical systems, and includes a broad category of systems such as smart buildings, autonomous vehicles, and robots, which interact with each other and other systems. This trend in turn is driving innovation both in the network technologies (new low-power wireless networks for connecting things, and new high-speed network and computing infrastructure to accommodate the transport and processing needs of the deluge of data resulting from continual sensing), and in embedded computing (new hardware and software stack catering to requirements such as ultra-low power operation, and embedded machine learning). Students pursuing this track are strongly encouraged to take “Fundamentals of Networked Embedded Systems” (ECE/CS M119) in junior year, and to then choose three electives from courses such as

Computer Science 130, 131, 132, 133, 136, 181, 188

Electrical and Computer Engineering 2, 115A, 115B, 115C, M117, 132A, 133A, 141, 142, 188

Students may also pursue technical breadth area in either Electrical and Computer Engineering or Computer Science to choose an additional three courses from this list.

2. Data Science: The second track targets the trend towards the disruptive impact on computing systems, both at the edge and in the cloud, of massive amounts of sensory data being collected, shared, processed, and used for decision making and control. Application domains such as health, transportation, energy etc. are being transformed by the abilities of inference-making and decision-making from sensory data that is pervasive, continual, and rich. This track will expose students to the entire data-to-decision pathway spanning the entire stack from hardware and software to algorithms, applications, and user experience. Students pursing this track are strongly advised to take Computer Science 143 and the new course “Introduction to Machine Learning” (ECE/CS M146), and to additionally choose two electives from courses such as

Computer Science CM121, 136, 144, 145, 161, 188

Electrical and Computer Engineering 114, 133A, 133B, 134, 188

Students may also pursue technical breadth area in either Electrical and Computer Engineering or Computer Science to choose an additional three courses from this list.

Students following different tracks will come together as teams in an integrated two-quarter capstone course sequence where they will integrate the conceptual knowledge they acquired and design skills they learned into an ambitious systems design project involving hardware and software platforms, sensing and control, and applications and user interaction. Presently ECE 180DA/DB and 183DA/DB include such elements. We anticipate additional courses will be developed over time that will provide a suitable computer engineering focus. The proposed syllabi for the two proposed new courses are provided at the end of this document.

Comparison of CSE, CE and EE Degrees

CSE	CE (Proposed)	EE with CE Track
CS 1 CS 31	CS 1 CS 31	 CS 31

CS 32 CS 33 CS 35L CS M51A (ECE M16) ECE 3 ECE 10 ECE 11L Math 31A Math 31B Math 32A Math 32B Math 33A Math 33B Math 61 Physics 1A Physics 1B Physics 1C Physics 4AL Physics 4BL	CS 32 CS 33 CS 35L CS M51A (ECE M16) ECE 3 ECE 10 ECE 11L Math 31A Math 31B Math 32A Math 32B Math 33A Math 33B Math 61 Physics 1A Physics 1B Physics 1C Physics 4AL Engineering 96C	CS 32 CS 33[4] CS 35L[4] CS M51A (ECE M16) ECE 2 ECE 3 ECE 10 ECE 11L Math 31A Math 31B Math 32A Math 32B Math 33A Math 33B Physics 1A Physics 1B Physics 1C Physics 4AL Physics 4BL Chem 20A
CS 111 CS 118 CS 131 CS M151B (ECE M116C) CS M152A (ECE M116L) CS 180 CS 181 ECE 102 ECE 110 ECE 111L ECE 131A or equivalent[1] 4 units ECE electives[2] 12 units CS electives[3] 12 units TBA electives CS M152B (4 unit capstone)	CS 111 CS 118 or ECE 132B CS M151B (ECE M116C) CS M152A (ECE M116L) CS 180 ECE 102 ECE 110 ECE 111L ECE 113 ECE 131A or equivalent[1] 8 units ECE electives 8 units CS electives 12 units TBA electives ECE 180DA/DB or 183DA/DB (8 unit capstone)	ECE 101A ECE 102 ECE 110 ECE 111L ECE 113 ECE 131A 5 courses from ECE 101B, 115A, 132A, 133A, 141, 170A 12 units ECE electives (up to 4 units in CS) 12 units TBA (CS) electives 8 units of ECE capstone
English, Ethics, 5 GE	English, Ethics, 5 GE	English, Ethics, 5 GE

1. Civil and Environmental Engineering 110, Mathematics 170A or Statistics 100A

2. Selected from ECE 113, 115A, 115C, 132A, 141
3. Selected from CS 111 through CM 187 or EE 133A, at least one which must be CS CM121, CM122, CM124, 143, 161 or 174A
4. These courses need to be selected to enable suitable CS upper division electives; 35L represents extra units.

Governance

A six-person oversight committee with equal membership from the two Departments will be established for running the program. It will have the basic function of a courses and curriculum committee, but additionally will be charged with recruitment of students into the program. This includes organization of contacts of students before, during and after Open House, running Town Halls to get student feedback, nominating outstanding students for honors, etc. The undergraduate vice chairs of each Department will serve on the committee, and deal with petitions related to their courses. Among the six members, a CE Vice-Chair shall be appointed by mutual agreement between the ECE and CS chairs with overall responsibility for the program, including such matters as taking care of ABET accreditation. The responsibilities of the oversight committee and, in particular, of the CE Vice-Chair will include a detailed procedure for assessing the quality of the Computer Engineering degree every year and taking the necessary actions to improve it when deemed necessary. Specifically, the committee will evaluate the digital sequence and circuits courses with the view to supporting the unique needs of computer engineering. The impact of this new degree on the overall ranking of the Departments should be assessed yearly and corrective actions taken as needed. The respective department chairs will have responsibility for raising funds for scholarships for the program, and for requesting sufficient teaching resources from the School for its operation as part of their ordinary course staffing process.

Faculty advisors will be appointed to have an equitable burden among the CS, CSE, EE, and CE degrees. Students will be free to choose alternative advisors, as now.

Proposed New Courses

Two new courses will be created to provide a focused combination of theory and practice within the tracks that will assist in building towards a meaningful capstone experience. Each of these courses will include projects that involve collecting data, communicating with the cloud, processing the data, and acting upon it, with different emphasis on the parts most relevant to the course. In this way, students will see theory and practice together, and will have composed end-end systems before graduating.

ECE/CS M119. Fundamentals of Embedded Networked Systems. (4)
Lecture: four hours; discussion: one hour; outside study: seven hours. Enforced requisites: course ECE 131A, Civil and Environmental Engineering 110, Mathematics 170A or Statistics 100A; course CS 118 or ECE 132B; course CS 33. Design tradeoffs and principles of operation of cyber physical systems such as the devices and systems constituting the Internet of Things. Topics include signal propagation and modeling, sensing, node architecture and operation, and applications. Letter grading. Mr. Pottie, Mr. Sarrafzadeh

Syllabus

Lecture Sequence

1. Basic design tradeoffs for cyber physical systems; examples. (Ch. 1)

Unit 1: Sensing

2. Signal models (Ch. 2)
3. Signal propagation (Ch. 3)
4. Sensor figures of merit (Ch. 4)
5. Sensor transduction principles (Ch. 4)
6. Detection of signals (Ch. 5)
7. Estimation of signals (Ch. 5)
8. Design example: Sensor fusion in a network (Ch. 5)

Unit 2: Signal source and sensor network interactions

9. Interference of sources (Ch. 7)
10. Separation of sources (Ch. 7)
11. Midterm (covers sensing unit)
12. Interaction of processing and networking (Ch. 8)
13. Localization techniques (Ch. 9)
14. Design example: location finding (Ch. 9)

Unit 3: System operation

15. Energy management in IoT systems (Ch. 10)
16. Energy management II (Ch. 10)
17. Node architecture I (Ch. 13)
18. Node architecture II (Ch. 13)
19. Design example: mobile sensor networks (Ch. 12)
20. Review; research trends

Notes

This set of topics is supported by the textbook Principles of Embedded Networked Systems (Pottie and Kaiser, 2005). The topic sequence is arranged to show students the broad range of topics that must be mastered to actually design and build IoT systems. The three design examples pull together concepts from the unit to illustrate the set of tradeoffs. Discussion sections will be used for illustrative problems and assistance in debugging the projects (see below). The controls aspect of cyber physical systems will be only lightly touched upon given the breadth of material to be discussed, but examples will be discussed in the last week.

Grading

Weekly homework 15%
Project sequence 20%
Midterm exam 25%
Final exam 40%

Weekly homework assignments will consist of a small set of mathematically oriented problems, mainly from the textbook.

Project sequence

Over the quarter, students will have a series of small projects involving the Intel Edison or equivalent IoT platform with access to cloud services, together with a set of sensors. Students will collect sensor data, process it, explore localization within buildings using radio signals, and fuse data from other student's sensors (e.g., light levels, temperature). A simple interface will be constructed to show an end-end IoT application. Each of these steps will relate to a set of concepts covered in lecture, and will accumulate to produce the application. A reference application will be constructed prior to the offering of the course so that the TA will be able to give detailed guidance. This will include standards for data storage so that data can be shared easily among students. These projects will be updated as necessary in undergraduate projects (e.g., 199's, summer research).

ECE/CS M146. Introduction to Machine Learning. (4)

Lecture: four hours; discussion: one hour; outside study: seven hours. Enforced requisites: course ECE 131A, Civil and Environmental Engineering 110, Mathematics 170A or Statistics 100A; course CS 33. Introduction to breadth of data science. Foundations for modeling data sources, principles of operation of common tools for data analysis, and application of tools and models to data gathering and analysis. Topics include statistical foundations, regression, classification, kernel methods, clustering, expectation maximization, principal component analysis, decision theory, reinforcement learning and deep learning. Letter grading. Ms. Dolecek, Mr. Sankararman, Ms. Van der Schaar.

Motivation

Being able to make inferences from large quantities of data is quickly becoming the most sought-after skill in many professions. In this class, students 1) will learn mathematical fundamentals of machine learning through rigorous treatment of models and algorithms, and 2) will learn how to apply these fundamental tools in a carefully designed hands-on project that will involve collection and processing of real world data. This class will give our undergraduate students a unique opportunity to develop a strong foundation in mathematical reasoning about data as well as first-hand experience in applying these fundamentals to a variety of exciting new applications. This experience will position them well for a variety of professions that rely on data analysis.

Goals of the Course

The goals of this class are multifold

1. To teach students fundamentals of mathematical modeling and concepts underpinning modern data
2. To rigorously teach students key mathematical tools needed to process and store data
3. To teach students practical techniques for dealing with real-world data
4. To give students an opportunity to collect/generate data and process it using tools taught in the class

Course syllabus

- Lecture 1: Review of probability (Bishop ch.1)
- Lectures 2-3: Basics of information theory, statistics, and sampling (Bishop ch.1)
- Lecture 4: Gaussian random variables (Bishop ch.2)
- Lectures 5-6: Regression (Bishop ch.3)
- Lectures 7-8: Classification (Bishop ch.4)
- Lectures 9-10: Support Vector Machines and Kernel Methods (Bishop ch.7)
- Lectures 11-12: Clustering (Bishop ch.9)
- Lecture 13: Expectation Maximization
- Lectures 14-15: Principal Component Analysis (Bishop ch.12)
- Lecture 16-17: Decision theory (Markov Chains, Markov Decision Processes, Dynamic Programming) (van der Schaar notes)
- Lecture 18: Reinforcement Learning (van der Schaar notes)
- Lecture 19: Deep Learning (Bishop ch.5)

Assessment Procedure

- Weekly homeworks – 20%
- 2 Exams – 50%
- Class Project – 30%