Proposal for the new undergraduate major in Robotics Engineering

1. Name of the academic program and the department or unit that will administer the program.

Name: Robotics Engineering Undergraduate Major

Administration: The Robotics Engineering major will be administered jointly by the Department of Mechanical Engineering (ME), the Department of Electrical and Computer Engineering (ECE), and the Department of Computer Science and Engineering (CSE).

2. A thorough justification, including the motivation for the creation of the program in terms of student interest and professional or academic importance.

Robotics is one of the most frequently inquired-about majors from high school students considering applying to BCOE. The rise of K-12 extra-curricular and curricular activities involving aspects of robotics (such as those based on Arduino) has sparked an interest among high school students considering Engineering.

Robotics sits between a number of traditional engineering academic disciplines. While some universities have dedicated robotics departments (for instance, Carnegie Mellon University), this is not the norm, nor is it necessary to provide a rich robotics program. The current BCOE faculty span many aspects of robotics and have research and teaching interests that bridge multiple disciplines.

Specialization within an existing major would not provide the breadth necessary for understanding robotics. The breadth necessary, from mechanics to circuit design and software engineering cannot be worked into existing undergraduate majors. Yet, graduates with such skills would be in high demand in the job market. The US Bureau of Labor Statistics and the Projections Managing Partnership project 9% job growth in robotics from 2016-2026 in California, higher than the 4% projected over a similar period for the US as a whole (https://www.onetonline.org/link/localtrends/17-2199.08?st=CA&g=Go).

3. Relationship of the new program to existing programs.

The proposed program is different in its requirements from the traditional programs in Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering. For example, the Robotics Engineering program requires students to take classes in Computer Science and Electrical Engineering, which are not required for Mechanical Engineering students. Similarly, Computer Science and Electrical Engineering students need to take classes in Mechanical Engineering, which they do not need to take if enrolled in the classical programs.

With its interdisciplinary emphasis on programming, algorithms, engineering, and computer science, the Robotics Engineering program will provide the students with the necessary foundations to study and understand a broad range of topics that would not be accessible from any individual program.
4. **The proposed curriculum.** Great care should be given in this area, correct rubrics should be listed for courses, all cross listings should be listed, unit total considerations should be taken into account and totals should be verified by program staff, faculty, and appropriate Executive Committee personnel. A copy of the proposed program change should be provided for inclusion in the Catalog.

The proposed curriculum is detailed in Appendix A, and the catalog entry is in Appendix B.

5. **A list of faculty who will be involved in the program, including those teaching, advising, and administering.**

Below is the current list of faculty involved in the program (new faculty will be added as the program evolves):

**Professors:**
- Christian Shelton, CSE
- Amit Roy-Chowdhury, ECE
- Matt Barth, ECE
- Bir Bhanu, ECE
- Jay Farrell, ECE
- Wei Ren, ECE
- Philip Brisk, CSE

**Associate Professors:**
- Fabio Pasqualetti, ME
- Anastasios Mourikis, ECE
- Roman Chomko, ECE

**Assistant Professors:**
- Konstantinos Karydis, ECE
- Salman Asif, ECE
- Hyoseung Kim, ECE
- Samet Oymak, ECE
- Erfan Nozari, ME
- Jun Sheng, ME
- Luat Vuong, ME
- Jonathan Realmuto, ME
- Vagelis Papalexakis, CSE

6. For interdisciplinary programs, the degree of participation and the role of each department must be explicitly described. The chairs of all participating departments must provide written approval for the creation of the program and indicate their commitment to provide necessary resources including faculty release.

The program will be administered through a joint steering committee. The steering committee will consist of three faculty across the Departments of Computer Science and
Engineering, Mechanical Engineering, and Electrical and Computer Engineering. The Program Director and the program co-Director will be from different departments. The Director and co-Director are the coordinators of the program across the departments, and the Director will also be responsible for coordinating and/or resolving campus-level issues. Normal terms for the Director and co-Director are 3 years and at the end of the 3-year term the co-Director is expected to accede to the Director position. If the Director (or co-Director) is unable to complete their 3-year term, a faculty from the same department will be chosen to assume the duties until the end of that 3-year term. The co-Director will also serve as the undergrad student advisor for the program.

Directors and co-Directors will be appointed by the Dean in consultation with the joint steering committee and program faculty. Circumstances may intervene that call for consecutive terms of a Director or a co-Director, or consecutive Directors or co-Directors from within the same department. These situations will be recognized, agreed upon, and handled by the joint steering committee and the Dean on a case-by-case basis.

Director and co-Director stipend costs will be set by agreement with the Dean. Proposed changes to the program will need to be approved by the majority of the steering committee (including Director and co-Director). In the case of a tied vote, the Director makes the final decision. The proposed program change will then be reviewed by the College executive committee and then the committee on education policy. If these committees consider the change to be noncontroversial, the proposed change is placed on the Consent Calendar for a meeting of the Division of the Academic Senate.

Each department will be responsible for offering any of the program's core courses taught by that department at least once per year. The three departments will also cooperate in providing materials needed for any appropriate accreditation process (e.g., ABET or WASC.) The Director and co-Director will issue an annual report to the Dean to document the state of the program. Based on the report, the Dean can initiate procedures to modify or retire the program.

7. Projected enrollment in the program.

The projected enrollment at the start of the program is 25-30 students; we expect a target admission rate of 50 students per year at steady state.

8. Name of degree, if applicable, and the anticipated number of degrees to be granted when the program reaches steady state.

B.S. in Robotics Engineering, 40-50 degrees awarded per year.

9. Potential impact of the new program on existing programs. If the proposed program includes required courses from a department other than the administering department, the proposal must include a statement from the department indicating that it has been consulted and that it will provide access to the required courses.

The new major uses seven existing lower division courses offered by the Department of Mathematics (namely: MATH 009A, MATH 009B, MATH 009C, MATH 010A, MATH 011
/ CS 011, MATH 031, MATH 046) and three existing lower division courses offered by the Department of Physics & Astronomy (namely: PHYS 040A, PHYS 040B, PHYS 040C). All these courses are currently being used by CSE and/or ECE and/or ME for satisfying college/major requirements in the BS degrees offered currently by the CSE, ECE, and ME departments. Given that these courses are also used by many other departments to satisfy college requirements, we do not expect a major impact in their offerings by the new program.

The design of the new major led to the creation of one new upper division course (namely: EE 106). This course has been approved by the respective departments and will serve as an elective in the BS programs offered by the ECE and ME departments. All other upper division courses required for the major are currently being taught in the participating departments.

10. A full listing of resources required for start-up and for operations. In cases where no additional resources will be needed, this must be explicitly stated. This listing may include: personnel (faculty FTE or temporary positions, Teaching Assistants or Readers, administrative staff, technical support); support services including computer facilities and library resources; space requirements. A plan indicating how the resources will be obtained would also be helpful to the committee in reviewing the proposal. A letter of support from the College Dean and/or Executive Vice Chancellor-Provost indicating endorsement as well as a promise of support for the proposal also would be extremely helpful.

a. Faculty FTE: initially the program will use existing faculty from the three departments, since the program will have a small number of students.

As the program grows, the number of students in BCOE will also grow. This in turn will require an increase in our advising staff, and staff support to handle undergraduate payroll for paid laboratory positions, purchasing, faculty support. Although not technically defined as staff, TAs will be needed to support the increased number of students. BCOE has shifted to a shared staffing model for smaller departments. This approach has produced the capacity for more specialization through shared resources. This facilitates accommodating the new robotics program in the initial stages followed by staff additions as workload increases.

BCOE is committed to ensuring sufficient staffing for all of its programs. With the RCM budget model, additional tuition revenue will come from both the upcoming undergraduate BS Robotics Engineering students (including some non resident tuition), and from the MS Robotics students. The staff workload increases in proportion to number of students in the program. The RCM model at the MS level generates sufficient revenue to fund the necessary staffing increases as the program grows. At the undergraduate level the RCM, BCOE acknowledges that the RCM model does not return sufficient revenue to programs to fund faculty and staff positions unless class size is very large.

b. Teaching Assistants: at steady state the program will have approximately 200 students over the four years. Students will take 4 courses per quarter, resulting in about 25
lab/discussion sections per quarter (assuming a section contains 30-35 students). Since
students will enroll in existing courses (with the exception of EE 106), should enrollment
in the existing courses increase, TA resources will be allocated following the existing
policies. Similarly, additional TA resources for the new course EE 106 will be requested
based on enrollment and per existing policies. The costs for the additional TA resources,
however, will be easily covered by the tuition fees of the new students.
c. Administrative Staff: the program will be administered by existing staff in the three home
departments. Students enrolled in the Robotics Engineering program will be advised by
BCOE’s Office of Undergraduate Student Academic Affairs (OSAA). OSAA currently
has eight full time advisors that will initially accommodate the Robotics students.
d. Computer facilities and library resources: no new facilities required.
e. Space requirements: no new space requirements.

11. Both internal and external letters of support should be provided with the proposal. Internal
letters of support are often from UCR department chairs and faculty of related programs.
The external letters should be from other UC campuses or other peer institutions. Letters
from off-campus help to establish the quality of the program and its fit within the context of
related programs at other universities. Upon consultation with the CEP the demand for
external letters may be waived.

Support letters are included below in Appendix C (letters from Department Chairs at the time
of preparation of the proposal are enclosed; current Department Chairs have reviewed and
expressed support for the proposal via email.). It should be noticed that external letters were
requested from prominent members of the robotics community, including current Chairs of
the ECE Departments at the Georgia Institute of Technology and UC Santa Barbara, a former
Chair of the ME Department at UC Irvine, and one of the senior-most Computer Science
faculty from GRASP Lab, one of the most prestigious robotics lab in the world. All letters
are overwhelmingly supportive of the current proposal.

Some letters provide some detailed comments, which we briefly address next.

a. Adequacy of the sequence of physics courses. The proposed courses are standard in
our Engineering programs. Additionally, specific topics in electronics of interest to
Robotics will be also covered in a dedicated course, EE 005 (see below). Thus, the
topics covered in the current physics sequence and courses are deemed adequate for
robotics students, and in agreement with all other BCOE programs.
b. Three courses on programming. Three-quarter freshman programming sequence is
standard in our Computer Science and Engineering program, and any changes would
affect many majors. If accelerated options will become available in the future, we will
consider such options and revise or adjust the robotics requirements as appropriate.
c. Guidance for selecting elective courses. While the proposed curriculum leaves
freedom to the students to choose their preferred elective courses, guidance will be
provided to ensure that students’ selections maximize their preparation and career
possibilities. We believe that this formula will achieve the dual objective of
remaining flexible, hence more attractive, and ensuring high-quality education. We
will also periodically evaluate the performance of our students, and modify our
advising strategies as appropriate.

d. **Ethics and privacy issues.** Our senior design courses already include modules on
ethics. These will be automatically inherited by the Robotics program.

e. **ABET accreditation.** Based on our research, it seems that ABET does not currently
have a well-defined set of guidelines for undergraduate robotics programs. Given the
expected popularity of robotics programs, we expect precise guidelines to be released
in the future, and we plan to make any required changes when appropriate.

f. **Scheduling and organizational issues.** The proposed program consists, for the most
part, of courses that are currently being offered multiple times per year in the
participating departments. Some of the courses that are expected to receive higher
enrollment are also cross-listed across departments, making it simple to provide
additional offerings (for example, EE144/ME144, ME145/EE145, EE120A/CS120A,
EE120B/CS120B, EE142/CS171). The initial projected enrollment can certainly be
incorporated in the existing offerings. Additional offerings of key courses will be
discussed as enrollment grows, should the need arise. Finally, the three participating
Departments have already provided support letters, and have already committed
resources for the success of the proposed program. Formal collaboration and
coordination mechanisms, including mechanisms to grow or terminate the program,
will be detailed and agreed upon as appropriate as the need arise.

g. **MOUs.** Courses are "owned" by a particular department, which is responsible for
teaching it. For example, EE144/ME144 is owned by ECE, ME145/EE145 by ME,
EE120A/CS120A by ECE, EE120B/CS120B by CSE, EE142/CS171 by CSE but
with a plan for both ECE and CSE offering the course. These courses are offered
almost every year, and many of them multiple times per year. They are required in
EE, CE, CS and ME programs and there have not been problems in coordinating who
offers the courses. We do not expect such issues in the Robotics program either.

h. **Termination.** The structure of the Robotics program has been designed to be as
modular as possible, as it consists of courses that are already offered by the
participating departments and of independent interest within each department. Thus,
termination of the program would only remove the structure of the Robotics program,
but would leave intact the participating departments. Further, termination of the
program would likely arise if there are not enough enrolled students to justify the
existence of the program. For these cases, campus procedures will be followed, and
decisions will be taken in consultation with the Senate and administration.

12. **Approvals from program faculty, College faculty (if the new proposal affects a college
regulation), and the appropriate Executive Committee should be obtained before forwarding
the new program to the attention of the Senate Analyst for CEP.**

Approved by the Departments of Mechanical Engineering, Electrical and Computer
Engineering, and Computer Science and Engineering, as well as by the program faculty.
Letters from Department Chairs at the time of preparation of the proposal are enclosed;
current Department Chairs have reviewed and expressed support for the proposal via email.

13. **Contribution to diversity**
Recruitment: UCR is an accredited Hispanic Serving Institution (OPEID 00131600), with approximately 35% Hispanic enrollment. BCOE has a much higher proportion of undergraduates from underrepresented backgrounds compared to Engineering Schools at comparably-ranked R1 universities in the United States. Prior research has established that the hands-on aspects of robotics, coupled with clear workforce-related applications of the technology, appeal to students from underrepresented backgrounds and increase engagement, involvement, and retention [1-3]. The fast-growing nature of the field of robotics (and AI in particular) is a great motivating factor for students to complete a cross-disciplinary BS degree before entering the workforce or graduate studies. The BS Robotics Engineering program will recruit from schools in the Southern California region, the United States, and beyond. UCR is already one of America’s most diverse universities and of the most successful at graduating students from underrepresented groups and disadvantaged backgrounds. The BS Robotics Engineering program will further contribute to UCR’s mission by providing novel and very diverse career opportunities towards addressing the need for a larger, diverse, and globally engaged STEM workforce.

Curriculum and pedagogy: The cross-disciplinary nature of robotics creates the opportunity to build curriculum that is sensitive to the needs of diverse learners as well as diverse members of society. Of particular interest and concern is the subject of algorithmic bias in AI and machine learning. The design of AI systems has been primarily the domain of white, male engineers [4], and several scholars have suggested that efforts toward inclusion in the ranks of those who design AI systems could reduce bias [5, 6]. For example, just 12% of machine learning engineers are women [7], with Black AI leaders pointing to a “diversity crisis” in the field [8]. Critiques of simple inclusivity efforts suggest that diversity programs cannot address overlapping forms of inequality, and have called for applying a more deliberate lens of intersectionality to the algorithm design [9, 10]. To this end, the BS Robotics Engineering program will work closely with the CS and ECE Departments to update their AI, machine learning, and computer vision undergraduate-level curricula to address algorithmic bias, including how biased vs. unbiased robots may impact society as the technology evolves.

Outreach: Students in the BS Robotics Engineering program will be encouraged to participate with ongoing efforts at UCR to provide mentorship and broaden participation in robotics-related activities. One recent example is UCR’s K-12 Lego Robotics Competition [11]. BCOE student organizations such as the IEEE@UCR (affiliated with the ECE Department) have a long and successful history of outreach efforts to the local community which bring K-12 students to campus. The BS Robotics Engineering program will work with BCOE student organizations to create new opportunities for undergraduate student leadership and participation surrounding community outreach events.

[1] H. Yi, “Robotics and kinetic design for underrepresented minority (URM) students in...


14. Program Educational Objectives (PEO)

Graduates of the UCR’s BS degree program in Robotics Engineering will meet high professional, ethical, and societal goals as demonstrated by accomplishing at least one different item in each of the following different categories:

1. Success in post-graduation studies as evidenced by:
a. Satisfaction with the decision to further their education
b. Advanced courses completed or advanced degree earned
c. Professional visibility (e.g., publications, patents, inventions, awards)
d. Professional responsibilities (e.g., professional mentoring, professional society memberships, reviewing and editorial work for professional journals)

2. Success in a chosen profession or vocation as evidenced by:
   a. Career satisfaction
   b. Promotions/raises (e.g., management leadership positions or distinguished technical positions)
   c. Entrepreneurial activities
   d. Consulting activities

3. Contributions to society and profession as evidenced by:
   a. Leadership roles
   b. Public service
   c. Outreach and volunteering activities
   d. Establishment and maintenance of professional networks

The PEOs are structured into three main objectives, with various specific examples of measurable evidence. It is not expected that students will achieve all of the three main objectives. Rather, the PEOs are designed to meet the needs of students with different interests within the Robotics Engineering program. The first set of PEOs is most relevant to students that pursue advanced degrees. The second set of PEOs is designed for students that instead prefer to enter the workplace immediately after graduation. Finally, we expect most of our students to make some societal contributions within 3-5 years after graduation.

The PEOs of the Robotics Engineering program are consistent and well-aligned with the mission of the Bourns College of Engineering.
Appendix A.

Robotics Engineering Undergraduate Major.

<table>
<thead>
<tr>
<th>Year 1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>MATH 009A</td>
<td>MATH 009B</td>
<td>MATH 009C</td>
</tr>
<tr>
<td>CS 010A</td>
<td>CS 010B</td>
<td>CS 010C</td>
</tr>
<tr>
<td>ME 009</td>
<td>PHYS 040A</td>
<td>PHYS 040B</td>
</tr>
<tr>
<td>ENGL 001A</td>
<td>ENGL 001B</td>
<td>BREADTH 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>PHYS 040C</td>
<td>MATH 046</td>
<td>MATH 011</td>
</tr>
<tr>
<td>MATH 010A</td>
<td>CS 061</td>
<td>EE 005</td>
</tr>
<tr>
<td>ME 010</td>
<td>EE 106</td>
<td>ME 120</td>
</tr>
<tr>
<td>CS 100</td>
<td>BREADTH 2</td>
<td>MATH 031</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 3</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>ME 103</td>
<td>EE 120A / CS 120A</td>
<td>EE120B / CS 120B</td>
</tr>
<tr>
<td>EE 111</td>
<td>EE 114</td>
<td>EE 132</td>
</tr>
<tr>
<td>TECH. ELEC. 1</td>
<td>TECH. ELEC. 2</td>
<td>TECH. ELEC. 3</td>
</tr>
<tr>
<td>BREADTH 3</td>
<td>BREADTH 4</td>
<td>BREADTH 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 4</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>EE 144 / ME 144</td>
<td>ME 145 / EE 145</td>
<td>EE 142 / CS 171</td>
</tr>
<tr>
<td>TECH. ELEC. 4</td>
<td>SENIOR DES. 1</td>
<td>SENIOR DES. 2</td>
</tr>
<tr>
<td>ENGR 180W</td>
<td>BREADTH 6</td>
<td>BREADTH 7</td>
</tr>
</tbody>
</table>

Comments:
One new course, EE 106 (Programming Practical Robotics).
MATH 009AH, 009BH, and 009CH can be used as alternatives for MATH 009A, 009B, and 009C, respectively.
Students will complete Senior Design courses in one of the participating Departments (Mechanical Engineering, Electrical and Computer Engineering, Computer Science and Engineering): CS 178A and CS 178B, or EE 175A and EE 175B, or ME 175B and ME 175C. Prerequisites to these courses will be adjusted to include senior standing in Robotics after approval of the Robotics program.

Transfer criteria:

BCOE Requirements:
- Minimum 2.8 cumulative GPA
- Minimum 2.5 GPA in the calculus series
• Minimum 2.5 in one of the following sequences:
  o CS 010A, 010B, 010C
  o PHYS 040A, 040B, 040C
  o MATH 010A, MATH 031, MATH 046

Minimum preparation for Robotics:
• CS 010A, CS 010B
• MATH 009A, 009B, 009C
• PHYS 040A

Must complete four of the following:
• CS 010C
• CS 061
• EE 005
• ME 010
• PHYS 040C
• MATH 031
• MATH 046

Strongly recommended courses:
• MATH 010A
• ME 009
• PHYS 040B

Course description:
MATH 009A First-Year Calculus (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 005 with a grade of “C-” or better or MATH 006B with a grade of “C-” or better or equivalent. Introduction to the differential calculus of functions of one variable. Credit is awarded for only one of MATH 008B, MATH 009A, or MATH 09HA.

MATH 009B First-Year Calculus (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 008B with a grade of “C-” or better or MATH 009A with a grade of “C-” or better or MATH 09HA with a grade of “C-” or better. Introduction to the integral calculus of functions of one variable. Credit is awarded for only one of MATH 009B or MATH 09HB.

MATH 009C First-Year Calculus (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009B with a grade of “C-” or better or MATH 09HB with a grade of “C-” or better. Further topics from integral calculus, improper integrals, infinite series, Taylor’s series, and Taylor’s theorem. Credit is awarded for only one of MATH 009C or MATH 09HC.

MATH 010A Calculus of Several Variables (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009B with a grade of “C-” or better or MATH 09HB with a grade of “C-” or better or equivalent. Topics include Euclidean geometry, matrices and linear functions, determinants, partial derivatives, directional derivatives, Jacobians, gradients, chain rule, and Taylor’s theorem for several variables.

MATH 011 Introduction to Discrete Structures (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009A (or MATH 09HA); CS 010 or CS 010V or MATH 009B (or
MATH 09HB). Introduction to basic concepts of discrete mathematics emphasizing applications to computer science. Topics include prepositional and predicate calculi, elementary set theory, functions, relations, proof techniques, elements of number theory, enumeration, and discrete probability. Cross-listed with CS 011.

MATH 031 Applied Linear Algebra (5) Lecture, 3 hours; discussion, 2 hours. Prerequisite(s): MATH 009A (or MATH 09HA) with a grade “C-” or better and CS 010 or CS 010V or MATH 009B (or MATH 09HB) with a grade of “C-” or better. A study of matrices and systems of linear equations, determinants, Gaussian elimination, vector spaces, linear independence and linear transformation, orthogonality, eigenvalues, and eigenvectors. Also examines selected topics and applications.

MATH 046 Introduction to Ordinary Differential Equations 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 007B or MATH 009B or MATH 09HB with a grade of “C-” or better or equivalent. Introduction to first-order equations, linear second-order equations, and Laplace transforms, with applications to the physical and biological sciences.

PHYS 040A General Physics 5 Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 007A or MATH 009A or MATH 09HA with a grade of “C-” or better; MATH 007B or MATH 009B or MATH 09HB with a grade of “C-” or better (MATH 009B or MATH 09HB may be taken concurrently). Designed for engineering and physical sciences students. Covers topics in classical mechanics including Newton’s laws of motion; friction; circular motion; work, energy, and conservation of energy; dynamics of particle systems; collisions; rigid-body motion; torque; and angular momentum. Laboratories provide exercises illustrating experimental foundations of physical principles and selected applications. Credit is not awarded for PHYS 040A if it has already been awarded for PHYS 002A, PHYS 02HA, PHYS 040HA, or PHYS 041A.

PHYS 040B General Physics 5 Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 009C or MATH 09HC (may be taken concurrently); PHYS 040A or PHYS 040HA with a grade of “C-” or better. Designed for engineering and physical sciences students. Covers topics in mechanics and thermodynamics including elasticity; oscillations; gravitation; fluids; mechanical waves and sound; temperature, heat, and the laws of thermodynamics; and the kinetic theory of gases. Laboratories provide exercises illustrating the experimental foundations of physical principles and selected applications. Credit is awarded for only one of PHYS 040B or PHYS 040HB.

PHYS 040C General Physics 5 Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 009C or MATH 09HC; PHYS 040B or PHYS 040HB with a grade of “C-” or better. Designed for engineering and physical sciences students. Covers topics in electricity and magnetism including electric fields and potential; Gauss’ law; capacitance; magnetic fields; Ampere’s law; Faraday’s law and induction; electromagnetic oscillations; dc and ac current; and circuits. Laboratories provide exercises illustrating the experimental foundations of physical principles and selected applications. Credit is awarded for only one of PHYS 040C, PHYS 040HC, PHYS 002B, PHYS 02HB, or PHYS 041B.

CS 010A Introduction to Computer Science for Science, Mathematics, and Engineering I (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): a college mathematics course (may be taken concurrently) or credit for MATH 009A from the Advanced Placement Examination or the Mathematics Advisory Examination. Covers problem solving through structured programming of algorithms on computers using the C++ object-oriented language. Includes variables, expressions, input/output (I/O), branches, loops, functions, parameters, arrays, strings, file I/O,
and classes. Also covers software design, testing, and debugging. Credit is not awarded for CS 010 if it has already been awarded for CS 010V or CS 030.

**CS 010B Introduction to Computer Science for Science, Mathematics, and Engineering II (4)** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010 or CS 010V with a grade of “C” or better; familiarity with C or C++ language. Covers structured and object-oriented programming in C++. Emphasizes good programming principles and development of substantial programs. Topics include recursion, pointers, linked lists, abstract data types, and libraries. Also covers software engineering principles. Credit is awarded for only one of CS 012 or CS 012V or CS 013.

**CS 010C Introduction to Data Structures and Algorithms (4)** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 012 or CS 012V with a grade of “C” or better or CS 013 with a grade of “C” or better; proficiency in C++. Topics include basic data structures such as arrays, lists, stacks, and queues. Covers dictionaries (including binary search trees and hashing) and priority queues (heaps). Offers an introductory analysis of algorithms, sorting algorithms, and object-oriented programming including abstract data types, inheritance, and polymorphism. Explores solving complex problems through structured software development.

**CS 061 Machine Organization and Assembly Language Programming 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010 with a grade of “C” or better. An introduction to computer organization. Topics include number representation, combinational and sequential logic, computer instructions, memory organization, addressing modes, interrupt, input/output (I/O), assembly language programming, assemblers, and linkers.

**CS 100 Software Construction (4)** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 014 with a grade of “C-” or better. Emphasizes development of software systems. Topics include design and implementation strategies; selection and mastery of programming languages, environment tools, and development processes. Develops skill in programming, testing, debugging, performance evaluation, component integration, maintenance, and documentation. Covers professional and ethical responsibilities and the need to stay current with technology.

**CS 120A Logic Design 5** Lecture, 3 hours; laboratory, 3 hours; individual study, 3 hours. Prerequisite(s): CS 061 with a grade of “C-” or better. Covers design of digital systems. Includes Boolean algebra; combinational and sequential logic design; design and use of arithmetic logic units, carry-lookahead adders, multiplexors, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Uses hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with EE 120A.

**CS 120B Introduction to Embedded Systems 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 120A or CS 120A. Introduction to hardware and software design of digital computing systems embedded in electronic devices (e.g., digital cameras or portable video games). Includes embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software trade-offs. Involves use of synthesis tools, programmable logic, microcontrollers, and developing working embedded systems. Cross-listed with EE 120B.

**CS 178A Project Sequence in Computer Science and Engineering 4** Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): CS 141, ENGR 180W; restricted to class level standing of senior. Under the direction of a faculty member, teams propose, design, build, test, and document software and/or hardware devices or systems. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on
economics, society, and the environment. Completed together, CS 178A and CS 178B may be applied as a substitute for the CS 179 (E-Z) CS major requirement. Graded In Progress (IP) until CS 178A and CS 178B are completed, at which time, a final letter grade is assigned.

**CS 178B Project Sequence in Computer Science and Engineering 4** Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): CS 178A; restricted to class level standing of senior. Under the direction of a faculty member, teams propose, design, build, test, and document software and/or hardware devices or systems. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment.

**ME 009 Engineering Graphics and Design 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): none. Covers graphical concepts and projective geometry relating to spatial visualization and communication in design. Includes technical sketching, computer-aided design with solid modeling, geometric dimensioning and tolerancing, and an introduction to the engineering design process.

**ME 010 Statics 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): MATH 009C, PHYS 040A or PHYS 040HA. Covers equilibrium of coplanar force systems; analysis of frames and trusses; noncoplanar force systems; friction; and distributed loads.

**ME 103 Dynamics 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): MATH 046, ME 010 with a grade of “C-” or better, ME 018B with a grade of C- or better. Topics include vector representation of kinematics and kinetics of particles; Newton’s laws of motion; force- mass-acceleration, work-energy, and impulse- momentum methods; kinetics of systems of particles; and kinematics and kinetics of rigid bodies.

**ME 120 Linear Systems and Controls 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): EE 001A, EE 01LA, ME 018B with a grade of C- or better. Introduces the modeling and analysis of dynamic systems, emphasizing the common features of mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical systems. Controls are introduced through state equations, equilibrium, linearization, stability, and time and frequency domain analysis.

**ME 145 Robotic Planning and Kinematics 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 120 or equivalent; or consent on instructor. Motion planning and kinematics topics with an emphasis in geometric reasoning, programming, and matrix computations. Motion planning includes configuration spaces, sensor-based planning, decomposition and sampling methods, and advanced planning algorithms. Kinematics includes reference frames, rotations and displacements, and kinematic motion models. **Cross-listed with EE 145.**

**ME 175B Mechanical Engineering Design 3** Lecture, 2 hours; laboratory, 2 hours. Prerequisite(s): senior standing in Mechanical Engineering. ME 113, ME 116A, ME 170A, ME 174, ME 175A (may be taken concurrently). Outlines the defining of a design problem and the conception and detail of the design solution. Explores design theory, design for safety, reliability, manufacture, and assembly. Graded In Progress (IP) until ME 175B and ME 175C are completed, at which time a final, letter grade is assigned.

**ME 175C Mechanical Engineering Design 3** Lecture, 1 hour; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): senior standing in Mechanical Engineering; ME 175B. Students create, test, and evaluate a prototype based on the project design generated in ME 175B. Lecture topics include prototyping techniques, design verification, and special topics in design. Satisfactory (S) or No Credit (NC) grading is not available.

**EE 005 Circuits and Electronics 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): PHYS 040C or PHYS 040HC. Introduces linear circuits analysis, semiconductor diodes and transistors,
analog amplifier circuits, operational amplifiers, and digital circuits. Does not confer credit towards a degree in Electrical Engineering and in Computer Engineering.

**EE 106 Programming Practical Robotics 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisites: MATH 031 or EE 020, CS 010A or ME 018A. Covers principles for simulating, programming, and deploying robots using modern robotics middleware. Includes reading/writing of robot programs; simulating robotic systems; interfacing robot sensors and actuators; and implementing introductory motion control algorithms. Teaches contemporary robotics open-source software (ROS, Gazebo), 3D environment creation, and sensor data processing libraries (OpenCV, OpenNI, PCL).

**EE 111 Digital and Analog Signals and Systems 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001B, EE 020, MATH 046; or consent of instructor. Covers continuous- and discrete-time signals and systems; linear time-invariant (LTI) systems; impulse response; Fourier analysis; frequency response; Laplace and Z-transforms; and sampling theorem and Nyquist rates. Includes laboratory experiments with signals, transforms, linear digital filtering, and sampling/aliasing.

**EE 114 Probability, Random Variables, and Random Processes in Electrical Engineering 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 110A or EE 111. Covers fundamentals of probability theory, random variables, and random processes with applications to electrical and computer engineering. Includes probability theory, random variables, densities, functions of random variables, expectations and moments, and multivariate distributions. Also addresses random processes, autocorrelation function, spectral analysis of random signals, and linear systems with random inputs.

**EE 132 Automatic Control 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 105 or ME 103 or equivalent; EE 110A or ENGR 118; or consent of instructor. Covers mathematical modeling of linear systems for time and frequency domain analysis. Topics include transfer function and state variable representations for analyzing stability, controllability, and observability; and closed-loop control design techniques by Bode, Nyquist, and root-locus methods. Laboratories involve both simulation and hardware exercises.

**EE 142 Pattern Recognition and Analysis of Sensor Data 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 114 or STAT 155 or consent of the instructor. Introduction to pattern recognition for multi-dimensional, multi-modal sensor data such as images, videos, and smart grids. Classification and decision functions, feature extraction, regression, and neural networks. Clustering and dimensionality reduction for unsupervised learning. Dynamic models and tracking. Applications of pattern recognition in computer vision, robotics, smart grids, etc.

**EE 144 Foundations of Robotics 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 020 or MATH 031 or ME 018B; CS 010A or ME 118; or consent of instructor. Provides foundational knowledge on analysis, control, and programming of robots. Considers configuration space, rigid body motion, forward, inverse and velocity kinematics, dynamics, trajectory planning, robot motion control, localization and mapping, and robot ethics. Integrates hands-on labs to program robots in simulation and experimentally by reading and interpreting sensor data. Cross-listed with ME 144.

**EE 175A Senior Design Project 4** Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): EE 120B or CS 120B; restricted to class level standing of senior; restricted to major(s) Electrical Engineering, Electrical Engineering BS + MS; or consent of instructor. Proposal of design of electrical engineering devices or systems under the direction of the instructor. Develops technical specification; considers design constraints and industry standards; emphasizes
ethical responsibilities; and promotes staying current on technology and its socioeconomic and environmental impact. Graded In Progress (IP) until EE 175A and EE 175B are completed, at which time, a final letter grade is assigned.

**EE 175B Senior Design Project 4** Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): EE 175A; senior standing in Electrical Engineering. Builds, tests, and redesigns electrical engineering devices or systems. Develops and carries out test plan according to design specification. Presents a demo of the design. Completes project testing and technical documentation. Presents a demo of the design. Satisfactory (S) or No Credit (NC) grading is not available.

**ENGR 180W Technical Communications 4** Lecture, 3 hours; workshop, 3 hours. Prerequisite(s): ENGL 001B with a grade of “C” or better; upper-division standing in the Bourns College of Engineering or consent of instructor. Develops oral, written, and graphical communication skills. Includes preparing and critiquing reports, proposals, instructions, and business correspondence. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment. Fulfills the third-quarter writing requirement for students who earn a grade of “C” or better for courses that the Academic Senate designates, and that the student’s college permits, as alternatives to English 001C.

Technical electives:

**CS 111 Discrete Structures 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 010; CS 011/MATH 011; MATH 009C (or MATH 09HC). A study of discrete mathematical structures emphasizing applications to computer science. Topics include asymptotic notation, generating functions, recurrence equations, elements of graph theory, trees, algebraic structures, and number theory.

**CS 122A Intermediate Embedded and Real-Time Systems 5** Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 012 or CS 013; CS 120B/EE 120B. Covers software and hardware design of embedded computing systems. Includes hardware and software codesign, advanced programming paradigms (including state machines and concurrent processes), real-time programming and operating systems, basic control systems, and modern chip and design technologies. Laboratories involve use of microcontrollers, embedded microprocessors, programmable logic and advanced simulation, and debug environments.

**CS 122B Advanced Embedded and Real-Time Systems 5** Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 122A. Explores state-of-the-art aspects of building embedded computer systems. Topics include real-time programming, synthesis of coprocessor cores, application-specific processors, hardware and software cosimulation and codesign, low-power design, reconfigurable computing, core-based design, and platform-based methodology.

**CS 135 Virtual Reality 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 100. Covers the development of virtual reality (VR) worlds, including motion and physics of VR worlds. Includes design practices for immersive experiences, human visual perception, environmental and social interactions. Also includes positional tracking with sensors, augmented and mixed reality, and storage and transmission of virtual reality worlds.

**CS 141 Intermediate Data Structures and Algorithms 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 014 with a grade of “C-” or better; CS 111; MATH 009C or MATH 09HC; proficiency in C++. Explores basic algorithm analysis using asymptotic notations, summation and recurrence relations, and algorithms and data structures for discrete structures including
trees, strings, and graphs. Also covers general algorithm design techniques including “divide-and-conquer,” the greedy method, and dynamic programming. Integrates knowledge of data structures, algorithms, and programming.

**CS 145 Combinatorial Optimization Algorithms** 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 141; MATH 031 or MATH 131. The study of efficient algorithm design techniques for combinatorial optimization problems. Topics include shortest paths, minimum spanning trees, network flows, maximum matchings, stable matchings, linear programming, duality, two-person games, algorithmic techniques for integer programming problems, NP-completeness, and approximation algorithms.

**CS 150 Automata and Formal Languages** 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 014 with a grade of “C-” or better; CS 111; MATH 009C (or MATH 09HC). A study of formal languages. Includes regular and context-free languages; computational models for generating these languages such as finite-state automata, pushdown automata, regular expressions, and context-free grammars; mathematical properties of the languages and models; and equivalence between the models. Also introduces Turing machines and decidability.

**CS 160 Concurrent Programming and Parallel Systems** 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 061, CS 100, CS 111. A study of concurrent and parallel systems. Topics include modular structure and design, interprocess communication, synchronization, failures, persistence, and concurrency control. Also covers atomic transactions, recovery, language support, distributed interprocess communication, and implementation mechanisms. Provides preparation for the study of operating systems, databases, and computer networking.

**CS 170 Introduction to Artificial Intelligence** 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 100 with a grade of “C-” or better, CS 111. An introduction to the field of artificial intelligence. Focuses on discrete-valued problems. Covers heuristic search, problem representation, and classical planning. Also covers constraint satisfaction and logical inference.

**CS 173 Introduction to Natural Language Processing** 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 150, may be taken concurrently. An overview of modern approaches for natural language processing. Focuses on major algorithms used in NLP for various applications such as part-of-speech tagging, parsing, named entity recognition, coreference resolution, sentiment analysis, and machine translation.

**ME 110 Mechanics of Materials** 4 Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): CS 009M or ME 018A; MATH 046, ME 010 with a grade of “C-” or better. Topics include mechanics of deformable bodies subjected to axial, torsional, shear, and bending loads; combined stresses; and their applications to the design of structures.

**ME 122 Vibrations** 4 Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): ME 103. Covers free and forced vibration of discrete systems with and without damping resonance; matrix methods for multiple degree-of-freedom systems; normal modes, coupling, and normal coordinates; and use of energy methods.

**ME 130 Kinematic and Dynamic Analysis of Mechanisms** 4 Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): ME 009, ME 103. Explores the kinematic analysis of planar mechanisms including linkages, cams, and gear trains. Introduces concepts of multibody dynamics.

**ME 131 Design of Mechanisms** 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 130. Involves design of planar, spherical, and spatial mechanisms using both exact and approximate graphical and analytical techniques. Requires a computer-aided design project.

**ME 133 Introduction to Mechatronics** 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 120. Introduces hardware, software, sensors, actuators, physical systems models, and control
theory in the context of control system implementation. Covers data acquisition (Labview),
sensors, actuators, electric circuits and components, semiconductor electronics, logic circuits,
signal processing using analog operational amplifiers, programmable logic controllers, and
microcontroller programming and interfacing. Uses MATLAB and Simulink.

**ME 153 Finite Element Methods 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ME
118. Covers weak form formulation, the Galerkin method and its computational implementation,
mesh generation, data visualization, as well as programming finite element codes for practical
engineering applications.

**EE 100A Electronic Circuits 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001B.
Electronic systems, linear circuits, operational amplifiers, diodes, nonlinear circuit applications,
junction and metal-oxide-semiconductor field-effect transistors, bipolar junction transistors,
MOS and bipolar digital circuits. Laboratory experiments are performed in the subject areas and
SPICE simulation is used.

**EE 115 Introduction to Communication Systems 4** Lecture, 3 hours; laboratory, 3 hours.
Prerequisite(s): EE 110B. Covers spectral density and correlation, modulation theory, amplitude,
frequency, phase and analog pulse modulation and demodulation techniques, signal-to-noise
ratios, and system performance calculations. Laboratory experiments involve techniques of
modulation and demodulation.

**EE 128 Data Acquisition, Instrumentation, and Process Control 4** Lecture, 3 hours;
laboratory, 3 hours. Prerequisite(s): EE 100B, EE 120B/CS 120B (EE 100B and EE 120B/CS
120B may be taken concurrently); or consent of instructor. Covers analog signal transducers,
conditioning, and processing; step motors, DC servo motors, and other actuation devices.
Explores analog to digital and digital to analog converters; data acquisition systems;
microcomputer interfaces to commonly used sensors and actuators; and design principles for
electronic instruments, real time process control, and instrumentation.

**EE 141 Digital Signal Processing 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE
110B. Transform analysis of Linear Time-Invariant (LTI) systems, discrete Fourier Transform
(DFT) and its computation, Fourier analysis of signals using the DFT, filter design techniques,
structures for discrete-time systems. Laboratory experiments on DFT, fast Fourier transforms
(FFT), infinite impulse response (IIR), and finite impulse response (FIR) filter design, and
quantization effects.

**EE 146 Computer Vision 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): senior
standing in Computer Science or Electrical Engineering, or consent of instructor. Imaging
formation, early vision processing, boundary detection, region growing, two-dimensional and
three-dimensional object representation and recognition techniques. Experiments for each topic
are carried out.

**EE 147 Graphics Processing Unit Computing and Programming 4** Lecture, 3 hours;
discussion, 1 hour. Prerequisite(s): EE 120B or CS 120B. Introduces principles and practices of
programming graphics processing units (GPUs) using the parallel programming environment.
Covers memory/threading models, common data-parallel programming patterns and libraries
needed to develop high-performance parallel computing applications. Examines computational
thinking; a broader range of parallel execution models; and parallel programming principles.
*Cross-listed with CS 147.*

**EE 150 Digital Communications 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE
114, EE 115. Topics include modulation, probability and random variables, correlation and
power spectra, information theory, errors of transmission, equalization and coding methods, shift
and phase keying, and a comparison of digital communication systems.

**EE 151 Introduction to Digital Control 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 132, EE 141. Review of continuous-time control systems; review of Z-transform and properties; sampled-data systems; stability analysis and criteria; frequency domain analysis and design; transient and steady-state response; state-space techniques; controllability and observability; pole placement; observer design; Lyapunov stability analysis. Laboratory experiments complementary to these topics include simulations and hardware design.

**EE 152 Image Processing 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B or EE 111 or consent of instructor. Digital image acquisition, image enhancement and restoration, image compression, computer implementation and testing of image processing techniques. Students gain hands-on experience of complete image processing systems, including image acquisition, processing, and display through laboratory experiments.

**ENGR 160 Introduction to Engineering Optimization Techniques 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 010A; CS 010 or EE 020 or ME 018A and ME 018B. ENGR 160 online section; enrollment in the Master-in-Science in Engineering program. Introduction to formulating and solving optimization problems in engineering. Includes single variable and multi-variable optimization; linear programming - simplex method; nonlinear unconstrained optimization - gradient, steepest descent, and Newton methods; and nonlinear constrained optimization - gradient projection methods. Addresses applications of optimization in engineering design problems. Solves various engineering optimization examples using MATLAB.
Appendix B.
Proposed catalog entry for the Robotics Engineering Undergraduate Major.

**Robotics Engineering Undergraduate Major** (catalog entry)

Major

Robotics studies the design, operation, and deployment of autonomous intelligent systems and mechanisms. Robotics is a fundamentally multidisciplinary field, with core components spanning engineering and computer science, and applications extending beyond science and technology. Courses in the B.S. in Robotics Engineering program focus both on the theory and the practice of contemporary robotics science and engineering, and prepare students for professional careers and graduate studies in robotics and beyond (e.g., autonomous systems, intelligent control systems, and decision making).

The B.S. in Robotics Engineering major is an interdepartmental program offered by the Marlan and Rosemary Bourns College of Engineering (BCOE), and involves the Departments of Mechanical Engineering, Electrical and Computer Engineering, and Computer Science and Engineering. Students are advised in and have their records maintained by the BCOE Office of Student Academic Affairs. Students must fulfill the breadth requirements of the Bourns College of Engineering.

**University Requirements**
See Undergraduate Students section.

**College Requirements**
For details on breadth requirements, see the Colleges and Programs section of this catalog. Students are encouraged to consult their advisor regarding requirements.

**Major Requirements**

1. Lower-division requirements (72 units)
   a. MATH 009A or MATH 009AH; MATH 009B or MATH 009BH; MATH 009C or MATH 009 CH; MATH10A; MATH 011; MATH 031; MATH 46.
   b. PHYS 040A; PHYS 040B; PHYS 040C.
   c. CS 010A; CS 010B; CS 010C; CS 061.
   d. ME 009; ME 010.
   e. EE 005.

2. Upper-division requirements (65 units)
   a. CS 100; CS 120B / EE 120B.
   b. ME 103; ME120; ME 145 / EE 145.
   c. EE 106; EE 111; EE 114; EE 120A / CS 120A; EE132; EE142 / CS 171; EE 144 / ME 144.
   d. Four courses (at least 16 units) from the following list, none of which can also be used to satisfy other major requirements: CS 111; CS 122A; CS 122B; CS 135; CS 141; CS 145; CS 150; CS 160; CS 170; CS 173; ME 110; ME 122; ME 130; ME 131; ME 133; ME 153; EE 100A; EE 115; EE 128; EE 141; EE 146; EE 147; EE 150; EE 151; EE 152; ENGR 160.
   e. One of the following two-course sequences: CS 178A and CS 178B, or EE 175A and EE 175B, or ME 175B and ME 175C.
Dear members of the Academic Senate:

On behalf of the Mechanical Engineering department, I enthusiastically support the new BS in Robotics program. This program will be housed in the Bourns College of Engineering, across the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE), and Mechanical Engineering (ME). It will draw upon courses from the existing programs in the departments.

In the past decade or so, Robotics has become extremely popular amongst High School students who are interested in pursuing technological careers. Having this program will allow us attract high caliber and extremely motivated students to UCR. The ME program has recently invested heavily in a focus area related to robotics: Controls, Robotics and Automation. Since 2018, we have hired three faculty members in this area, who added to the two we already had, have formed a strong cluster of five ME faculty members plus at least a dozen more in CSE and ECE. In ME, plan to keep adding faculty to this area in the near future.

Robotics is a strategically important area for the country, technically challenging, and provides many opportunities to students after graduation. It is also an inter-disciplinary program which requires an equally inter-connected curriculum. This new program will allow us to provide that holistic training. The curriculum is structured so that graduating students will be competitive in the job market, as well as have the expertise for graduate studies.

Under the leadership of three ME faculty members, the rest of the ME faculty were closely involved in the development of the program and was extensively discussed in faculty meetings in the academic year 19/20. The final program was discussed with the ME undergraduate committee and during faculty meetings, and was unanimously supported by the ME faculty.

In summary, I am extremely supportive of this program and believe it will help in attracting high quality undergraduate students to UCR. Please do not hesitate to contact me should there be any questions.

Respectfully,

Guillermo Aguilar, Ph.D.
Professor and Chair
University of California Riverside
Department of Mechanical Engineering
A-345 Bourns Hall
Riverside CA, 92521
Off: 951-827-7717
gaguilar@engr.ucr.edu
October 23, 2020

Dear Members of the Academic Senate:

On behalf of the Electrical and Computer Engineering department, it is my pleasure to provide the strongest possible support for the BS in Robotics program. This program will be housed in the Bourns College of Engineering, and is cross-disciplinary, across the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE), and Mechanical Engineering (ME). It will draw upon courses from the existing programs in the departments.

Robotics is a strategically important area for the country, technically challenging, and provides many opportunities to students after graduation. High school students are extremely interested in this area, and having this program will allow us attract high caliber and extremely motivated students to UCR. The EE program has two technical focus areas related to robotics: Control and Robotics, which focuses on developing control strategies for robot locomotion, and Intelligent Systems, which focuses on the sensing and decision-making strategies that allows robots to understand their environment. The courses are of high interest, and the majority of the projects in the capstone Senior Design are related to some aspect of robotics. Students in the Computer Engineering program, which is jointly offered by ECE and CSE, have access to all these courses.

However, robotics is an inter-disciplinary program and having it as a specialization within an existing major does not provide students with the entire body of expertise required to work in this area in the future. For example, while EE students interested in robotics will gain some knowledge of the computational aspects of robotics, they will usually not study the mechanical design of robots or how to write and debug software efficiently. Having this inter-disciplinary program will allow us to provide that holistic training. The curriculum is structured so that graduating students will be competitive in the job market, as well as have the expertise to conduct graduate studies.

The faculty in ECE were closely involved in the development of the program. Two ECE faculty were members of the committee, and the program was discussed multiple times in faculty meetings in the 19-20 academic year. On Oct 21, 2020, the final program was discussed in the ECE faculty meeting and was unanimously supported by the faculty.

In summary, I am extremely supportive of this program and believe it will help in attracting high quality undergraduate students to UCR. Please do not hesitate to contact me should there be any questions. Sincerely,

Amit Roy-Chowdhury
Professor and Chair
Electrical and Computer Engineering
University of California, Riverside
November 1, 2020

Dear Members of the Academic Senate:

With this letter I would like to express the strong support of the Department of Computer Science and Engineering for the proposed B.S. degree in Robotics within the Bourns College of Engineering at UCR. This cross-disciplinary program will draw upon courses and research knowledge from the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE) and Mechanical Engineering (ME).

There is no doubt that robotics is rapidly becoming a very important field of engineering. Robotics requires multi-disciplinary breadth, well beyond what can be covered in courses in a single traditional discipline. The proposed Robotics program provides a comprehensive structure under which students can acquire the cross-disciplinary breadth required for this important and emerging field. It does so at very little expense, since the teaching and research infrastructure are already in place.

The proposed program emphasizes four focus areas: mechanical design and fabrication, embedded platforms and system design, control and navigation, and artificial intelligence and perception. These cover different aspects of robotics, from the design of the mechanical and electronic design to the cognitive aspects that enable decision making.

Within computer science and engineering the proposed B.S. in Robotics program relies on multiple disciplines including, but not limited to, artificial intelligence, machine learning, embedded and real-time systems, computer architecture, operating systems etc.

The CSE Department expects to interact extensively with the proposed Robotics program by participating in teaching the required and elective courses, in robotics research and the mentoring of students through projects and advising, and in helping with the program administration. The program will contribute in a great many positive ways to the CSE Department.

In summary, I am extremely supportive of this program and believe it will greatly benefit the students and will help raise UCR’s profile. Please do not hesitate to contact me should there be any questions.

Sincerely,

Walid A. Najjar
Professor and Chair
Department of Computer Science and Engineering
Bourns College of Engineering
University of California Riverside
March 4, 2021

Dear Members of the Academic Senate:

I am writing to express my strong support as Dean of the Bourns College of Engineering for the proposed B.S. degree in Robotics within the Bourns College of Engineering at UCR. This proposed interdepartmental program will draw from courses in the departments of Mechanical Engineering, Electrical and Computer Engineering, and Computer Science and Engineering.

Robotics is a fast-growing discipline in engineering, but does not fit within a single discipline. A full understanding of robotics requires the ability to couple mechanical systems with electrical sensing and actuation, feedback and control systems, embedded computer systems (the hardware/software interface), and advanced software and programming. The proposed Robotics program will provide the cross-disciplinary background needed for success in this emerging field. Most of the courses are already available within departments and thus launching this program will not be excessively expensive.

In this letter, I am committing to a course release for the chair of this program. As the program grows in numbers of students and the workload associated with running the program increases, I anticipate adding a stipend and other support. I am also committing to provide TA support as class sizes grow, commensurate with the existing BCOE TA assignment policy.

Sincerely,

Prof. Christopher S. Lynch
William R. Johnson Jr. Family Chair
Dean, Bourns College of Engineering
University of California, Riverside
Dear Members of the Review Board,

I am writing to support the proposal to initiate a BS in Robotics at the University of California, Riverside. I believe that this proposal addresses current needs in Industry and Academia for students with specialized training in the broad disciplines of artificial intelligence, control theory and algorithm design, among others, which blend together in the robotics discipline. The interdepartmental program proposed at the University of California, Riverside, will provide the students with the required technical knowledge to pursue their careers in the field of robotics. The proposed BS degree will be among the few available in the country, and will likely inspire other institutions to launch similar programs in the near future.

To calibrate my recommendation, I should note that I have seen this play out successfully at the graduate levels as, in the past, I served as the Director for Georgia Tech’s Institute for Robotics and Intelligent Machines, which is home to both multidisciplinary PhD and MS degrees. And it is clear that students and their future employers are highly enthusiastic about such programs.

The proposed curriculum is well-thought-out and balanced. In addition to the standard math and physics courses required by most engineering programs, students will need to complete a number of required classes from the three participating Departments, as well as a series of elective courses. This structure guarantees that graduating students will have the required engineering background and skills, but also the knowledge and flexibility to work and function in a multi-disciplinary environment. The proposed combination of courses from Electrical and Computer Engineering, Mechanical Engineering, and Computer Science and Engineering is truly unique to a curriculum in robotics, and particularly different from the coursework required for more classic engineering degrees.

The participating Departments at the University of California, Riverside, are well positioned to initiate, administer, and grow the proposed BS program. The majority of the courses needed for the new program are currently being offered, thus minimizing the time, effort and risks to launch the new program. The organizational structure of the program is also very reasonable and effective, with Director and Co-Directors roles that will oversee course offerings, scheduling, and other practical matters. The projected enrollment of approximately 50 students is easily manageable, although I foresee a higher student demand for this program.
March 16, 2021
Page 2

In summary, I have no reservations on the proposal, and I believe that this new program will attract numerous high quality students soon after its launch. Please do not hesitate to contact me should you need further information.

Sincerely,

[Signature]

Magnus Egerstedt, Ph.D
Steve W. Chaddick School Chair and Professor
School of Electrical and Computer Engineering, Georgia Institute of Technology
March 17, 2021

Dear Members of UCR Academic Senate Review Committee

RE: Proposed B.S. degree in Robotics at UCR

As a general rule, I am skeptical of non-traditional degrees, as they tend to be created based on temporary fads, but stay around for decades, far beyond their useful shelf-life. Often a degree in a traditional major with an expanded minor would be better.

I do think that Robotics has become an exception to that rule. The proposal describes the landscape well: tremendous interest among high school students, partly due to availability of exiting new hobby devices and accessibly of Arduino-type platforms, partly due to exciting new products of Boston Dynamics and similar. As the proposal states, it is hard to do a decent job training in robotics in a more traditional engineering major: mechanical engineers have a host of fluids, thermodynamics, heat-transfer, mechanics, etc., while EE and CS degrees have their own full requirements. The proposed degree, nestled among 3 departments and drawing courses from mostly existing courses, appears a low entry-cost way to provide this pathway for students. I do think it will be successful and, more importantly, would add a valuable option for students to choose. While I will list my concerns and suggestions below, I am fully supportive of the proposed degree and hope more universities would be able to get three departments to cooperate for such an undertaking. That is not easy and they should be commended.

Educational Aspects

- The physics sequence stops at 19th century. It seems to me that we should ensure engineering students are familiar with modern physics. On the other hand, there is a 3-course sequence in programing in the sophomore year, which might be somewhat excessive.

- There are 4 technical electives, which is a decent number but it would be in students’ interest if more ‘guided’ options are incorporated. Examples include a list of 4-7 courses in CS that do vision, autonomy, graphics or a similar list in EE option that would be focused on communication, networks, cooperative algorithms, and ME with on mobility, design, etc. Perhaps they could be designated that way formally to help...
students’ careers by giving them more options (so instead EE with Robotics options, it will be Robotics with EE option, implying strong EE background). It will result in a more tangible connection to a traditional degree and increase the chance that the ‘option’ department and faculty take interest in the students. Of course, a totally flexible option will be great to have, as well.

- Increasingly robotics, particularly the ‘automation’ side would open up a host of ethical and privacy issues, quite dissimilar to other engineering endeavors. It might be good to ensure that the senior design, or some other place, incorporates them. Maybe even a special breath course!

Administrative Aspects

- ABET: Does ABET have Robotics as a degree to review? Does it have minimum coverage of certain areas as requirement? I assume this is checked.

- I assume which department gets what credit (course units, majors, etc.) is clear and worked out. If not, it might be best to develop an MOU for that. As the saying goes, ‘if Chairs were angels, we would not need to …. have MOUs’

- Sunset: The program IS in response to current interests. The nature of robotics might change in a few years, some thought should be given on how the program is discontinued or a department might want to cease its participation.

- There is a statement that each department agrees to teach the key courses at least once a year. Unless they are offered multiple times, chances are some really have to be offered in specific quarter as well. Perhaps this is the kind of detail that cannot be worked out at this stage, but this would force restrictions for the other degrees and over time might become a headache.

The above suggestions/observations do not take away from a very well organized and sound program. They should be seen as simply friendly advice --- which of course can be (perhaps should be!) ignored.

Best of luck with your program.

Sincerely,

Faryar Jabbari
Professor and Senior Associate Dean
March 24, 2021

Dear Members of the Review Board,

The initiative to create a new undergraduate degree program in robotics at the University of California, Riverside, is timely, well-justified, and needed. The proposed structure and curriculum are carefully thought-out and effective. I have no doubt that this program will be in high demand, and I’m happy to provide this letter to express my full support. In this letter, I’m going to comment on three main aspects of the program:

Need: Demand for engineers that are well-trained in disciplines related to robotics is constantly raising, both from Academia and the Industry. It is undeniable that recent intellectual breakthroughs in Robotics and Artificial Intelligence have enabled important innovations in several technological areas including automated vehicles, rehabilitation and medical devices, and monitoring, to name a few. Yet, to sustain and further such progress, the need for highly trained engineers will only increase, thus guaranteeing the longevity of the pursued program.

Proposed curriculum: Robotics is an inherently multi-disciplinary field, making it virtually impossible to create a competitive program within any single classic department. To address this challenge, the proposed curriculum leverages courses offered in three participating departments, thus guaranteeing that subjects are presented in their “native” way, and that students become proficient in the different disciplines necessary for robotics. While coordinating courses from three different departments can be a challenge, the proposal presents a well-organized structure, with key representative members from all participating departments, that will ensure the well-functioning of this new program.

Capabilities and resources: The proposed curriculum hinges on courses, faculty members and lecturers that are already within the participating departments. Thus, the proposed program requires little new resources to run, mainly related to organizational roles, making it a small investment for the school. Among the three participating departments, the faculty members cover all the required expertise, ensuring the quality of the training that the students will receive.

To conclude, this is a strong proposal for a timely degree in robotics, with support from a well-qualified set of faculty members. I have no doubt that the program will attract strong interest and that it will keep growing over the years.

Sincerely,

B.S. Manjunath
Distinguished Professor and Chair
June 16, 2021

To: Philip Brisk  
Chair, BCOE Faculty Executive Committee

From: Jason Stajich  
Chair, Riverside Division

CC: Katelyn Robinson  
Advising Enrollment Support Specialist

RE: Proposal for New Undergraduate Major - Bachelor of Science in Robotics Engineering

Dear Philip,

I write to provide the consultative feedback regarding the proposed Bachelor of Science in Robotics Engineering. I have attached the comments of the tasked committees. I hope this feedback proves helpful to the proponents.

Sincerely,

/s/ Jason
COMMITTEE ON EDUCATIONAL POLICY

May 10, 2021

To: Jason Stajich, Chair
Riverside Division

From: Stefano Vidussi, Chair
Committee on Educational Policy

RE: Proposed B.S. in Robotics Engineering

The Committee on Educational Policy reviewed the proposal for a B.S. in Robotics Engineering at their May 7, 2021 meeting and are generally supportive of the proposal. The Committee does recommend that the proposal be updated to respond to the concerns and suggestions included in the letters of support, with particular regard for the letter from Professor and Senior Associate Dean Faryar Jabbari from UC Irvine.
COMMITTEE ON DIVERSITY, EQUITY, & INCLUSION

May 11, 2021

To: Jason Stajich, Chair
Riverside Division Academic Senate

From: Xuan Liu, Chair
Committee on Diversity, Equity, & Inclusion

Re: Proposal: New Undergraduate Major: Bachelor of Science in Robotics Engineering

The Committee on Diversity, Equity, and Inclusion reviewed the proposed Bachelor of Science in Robotics Engineering and was in support of the proposal.
COMMITTEE ON COURSES

May 5, 2021

To: Jason Stajich, Chair
   Riverside Division

From: Ming Lee Tang, Chair
       Committee on Courses

Re: Proposal for a B.S. in Robotics Engineering

The Committee on Courses reviewed the proposal for a B.S. in Robotics Engineering at their May 5, 2021 meeting and did not find any concerns with the proposal related to the Committee’s charge of courses and instruction.
May 18, 2021

To: Jason Stajich, Chair
   Riverside Division

From: Katherine Kinney, Chair
       Committee on Planning and Budget

RE: [Campus Review] Proposal: New Undergraduate Major: Bachelor of Science in Robotics Engineering

Planning & Budget (P&B) discussed the proposed undergraduate major in Robotics Engineering at their May 18, 2021 meeting. While the committee was supportive of the new major, members did want to raise concern over the lack of added staff resources that will surely be required. The proposal mentioned that existing staff will be used to support this program, will staff be taken away from supporting other programs? There will be an increase in students but not an increase to staffing, any growth throws the understaffing situation into greater crisis. This issue should be addressed and explained in detail in the proposal.
COMMITTEE ON UNDERGRADUATE ADMISSIONS

May 27, 2021

To: Jason Stajich, Chair
    Riverside Division

From: Sheldon Tan, Chair
      Committee on Undergraduate Admissions

RE: CR. Proposal for the new undergraduate major in Robotics Engineering

The Committee on Undergraduate Admissions reviewed the proposal for the new undergraduate major in Robotics Engineering and are generally supportive of the proposal. The committee has the following questions/suggestions:

1) The committee suggests the transfer admission requirements (major preparation) be more explicit for new students transferring into the major from a CCC.

2) What is the minimum GPA for transfer students?

3) How are students selected into the program?
Proposal for the new undergraduate major in Robotics Engineering

1. Name of the academic program and the department or unit that will administer the program.

   Name: Robotics Engineering Undergraduate Major

   Administration: The Robotics Engineering major will be administered jointly by the Department of Mechanical Engineering (ME), the Department of Electrical and Computer Engineering (ECE), and the Department of Computer Science and Engineering (CSE).

2. A thorough justification, including the motivation for the creation of the program in terms of student interest and professional or academic importance.

   Robotics is one of the most frequently inquired-about majors from high school students considering applying to BCOE. The rise of K-12 extra-curricular and curricular activities involving aspects of robotics (such as those based on Arduino) has sparked an interest among high school students considering Engineering.

   Robotics sits between a number of traditional engineering academic disciplines. While some universities have dedicated robotics departments (for instance, Carnegie Mellon University), this is not the norm, nor is it necessary to provide a rich robotics program. The current BCOE faculty span many aspects of robotics and have research and teaching interests that bridge multiple disciplines.

   Specialization within an existing major would not provide the breadth necessary for understanding robotics. The breadth necessary, from mechanics to circuit design and software engineering cannot be worked into existing undergraduate majors. Yet, graduates with such skills would be in high demand in the job market. The US Bureau of Labor Statistics and the Projections Managing Partnership project 9% job growth in robotics from 2016-2026 in California, higher than the 4% projected over a similar period for the US as a whole (https://www.onetonline.org/link/localtrends/17-2199.08?st=CA&g=Go).

3. Relationship of the new program to existing programs.

   The proposed program is different in its requirements from the traditional programs in Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering. For example, the Robotics Engineering program requires students to take classes in Computer Science and Electrical Engineering, which are not required for Mechanical Engineering students. Similarly, Computer Science and Electrical Engineering students need to take classes in Mechanical Engineering, which they do not need to take if enrolled in the classical programs.

   With its interdisciplinary emphasis on programming, algorithms, engineering, and computer science, the Robotics Engineering program will provide the students with the necessary foundations to study and understand a broad range of topics that would not be accessible from any individual program.
4. The proposed curriculum. Great care should be given in this area, correct rubrics should be listed for courses, all cross listings should be listed, unit total considerations should be taken into account and totals should be verified by program staff, faculty, and appropriate Executive Committee personnel. A copy of the proposed program change should be provided for inclusion in the Catalog.

The proposed curriculum is detailed in Appendix A, and the catalog entry is in Appendix B.

5. A list of faculty who will be involved in the program, including those teaching, advising, and administering.

Below is the current list of faculty involved in the program (new faculty will be added as the program evolves):

Professors:
Christian Shelton, CSE
Amit Roy-Chowdhury, ECE
Matt Barth, ECE
Bir Bhanu, ECE
Jay Farrell, ECE
Wei Ren, ECE
Philip Brisk, CSE

Associate Professors:
Fabio Pasqualetti, ME
Anastasios Mourikis, ECE
Roman Chomko, ECE

Assistant Professors:
Konstantinos Karydis, ECE
Salman Asif, ECE
Hyoseung Kim, ECE
Samet Oymak, ECE
Erfan Nozari, ME
Jun Sheng, ME
Luat Vuong, ME
Jonathan Realmuto, ME
Vagelis Papalexakis, CSE

6. For interdisciplinary programs, the degree of participation and the role of each department must be explicitly described. The chairs of all participating departments must provide written approval for the creation of the program and indicate their commitment to provide necessary resources including faculty release.

The program will be administered through a joint steering committee. The steering committee will consist of three faculty across the Departments of Computer Science and
Engineering, Mechanical Engineering, and Electrical and Computer Engineering. The Program Director and the program co-Director will be from different departments. The Director and co-Director are the coordinators of the program across the departments, and the Director will also be responsible for coordinating and/or resolving campus-level issues. Normal terms for the Director and co-Director are 3 years and at the end of the 3-year term the co-Director is expected to accede to the Director position. If the Director (or co-Director) is unable to complete their 3-year term, a faculty from the same department will be chosen to assume the duties until the end of that 3-year term. The co-Director will also serve as the undergrad student advisor for the program.

Directors and co-Directors will be appointed by the Dean in consultation with the joint steering committee and program faculty. Circumstances may intervene that call for consecutive terms of a Director or a co-Director, or consecutive Directors or co-Directors from within the same department. These situations will be recognized, agreed upon, and handled by the joint steering committee and the Dean on a case-by-case basis.

Directors and co-Directors will be appointed by the Dean in consultation with the joint steering committee and program faculty.

Proposed changes to the program will need to be approved by the majority of the steering committee (including Director and co-Director). In the case of a tied vote, the Director makes the final decision. The proposed program change will then be reviewed by the College executive committee and then the committee on education policy. If these committees consider the change to be noncontroversial, the proposed change is placed on the Consent Calendar for a meeting of the Division of the Academic Senate.

Each department will be responsible for offering any of the program's core courses taught by that department at least once per year. The three departments will also cooperate in providing materials needed for any appropriate accreditation process (e.g., ABET or WASC.) The Director and co-Director will issue an annual report to the Dean to document the state of the program. Based on the report, the Dean can initiate procedures to modify or retire the program.

7. Projected enrollment in the program.

The projected enrollment at the start of the program is 25-30 students; we expect a target admission rate of 50 students per year at steady state.

8. Name of degree, if applicable, and the anticipated number of degrees to be granted when the program reaches steady state.

B.S. in Robotics Engineering, 40-50 degrees awarded per year.

9. Potential impact of the new program on existing programs. If the proposed program includes required courses from a department other than the administering department, the proposal must include a statement from the department indicating that it has been consulted and that it will provide access to the required courses.

The new major uses seven existing lower division courses offered by the Department of Mathematics (namely: MATH 009A, MATH 009B, MATH 009C, MATH 010A, MATH 011
/ CS 011, MATH 031, MATH 046) and three existing lower division courses offered by the Department of Physics & Astronomy (namely: PHYS 040A, PHYS 040B, PHYS 040C). All these courses are currently being used by CSE and/or ECE and/or ME for satisfying college/major requirements in the BS degrees offered currently by the CSE, ECE, and ME departments. Given that these courses are also used by many other departments to satisfy college requirements, we do not expect a major impact in their offerings by the new program.

The design of the new major led to the creation of one new upper division course (namely: EE 106). This course has been approved by the respective departments and will serve as an elective in the BS programs offered by the ECE and ME departments. All other upper division courses required for the major are currently being taught in the participating departments.

10. A full listing of resources required for start-up and for operations. In cases where no additional resources will be needed, this must be explicitly stated. This listing may include: personnel (faculty FTE or temporary positions, Teaching Assistants or Readers, administrative staff, technical support); support services including computer facilities and library resources; space requirements. A plan indicating how the resources will be obtained would also be helpful to the committee in reviewing the proposal. A letter of support from the College Dean and/or Executive Vice Chancellor-Provost indicating endorsement as well as a promise of support for the proposal also would be extremely helpful.

a. Faculty FTE: the program will use existing faculty from the three departments.
b. Teaching Assistants: at steady state the program will have approximately 200 students over the four years. Students will take 4 courses per quarter, resulting in about 25 lab/discussion sections per quarter (assuming a section contains 30-35 students). Since students will enroll in existing courses (with the exception of EE 106), should enrollment in the existing courses increase, TA resources will be allocated following the existing policies. Similarly, additional TA resources for the new course EE 106 will be requested based on enrollment and per existing policies. The costs for the additional TA resources, however, will be easily covered by the tuition fees of the new students.
c. Administrative Staff: the program will be administered by existing staff in the three home departments. Students enrolled in the Robotics Engineering program will be advised by BCOE’s Office of Undergraduate Student Academic Affairs (OSAA). OSAA currently has eight full time advisors that will initially accommodate the Robotics students.
d. Computer facilities and library resources: no new facilities required.
e. Space requirements: no new space requirements.

11. Both internal and external letters of support should be provided with the proposal. Internal letters of support are often from UCR department chairs and faculty of related programs. The external letters should be from other UC campuses or other peer institutions. Letters from off-campus help to establish the quality of the program and its fit within the context of related programs at other universities. Upon consultation with the CEP the demand for external letters may be waived.
Support letters are included below in Appendix C. It should be noticed that external letters were requested from prominent members of the robotics community, including current Chairs of the ECE Departments at the Georgia Institute of Technology and UC Santa Barbara, a former Chair of the ME Department at UC Irvine, and one of the senior-most Computer Science faculty from GRASP Lab, one of the most prestigious robotics lab in the world. All letters are overwhelmingly supportive of the current proposal. Some letters provide some detailed comments, which we briefly address here:

a. **Adequacy of the sequence of physics courses.** The proposed courses are standard in our Engineering programs. Additionally, topics in electronics, which will be crucial to robotics students, will be also covered in a dedicated course, EE 005 (see below). The topics covered in the physics sequence are deemed adequate for robotics students.

b. **Guidance for selecting elective courses.** While the proposed curriculum leaves freedom to the students to choose their preferred elective courses, guidance will be provided to ensure that students’ selections maximize their preparation and career possibilities. We believe that this formula will achieve the dual objective of remaining flexible, hence more attractive, and ensuring high-quality education.

c. **Ethics issues.** Our senior design courses already include modules on ethics. These will be automatically inherited by the Robotics program.

d. **Three courses on programming.** Three-quarter freshman programming sequence is standard, and any changes affect many majors. If accelerated options are available in the future, we will consider such options and revise or adjust the Robotics requirements as appropriate.

e. **ABET accreditation.** Based on our research, it seems that ABET does not currently have a well-defined set of guidelines for undergraduate robotics programs. Given the expected popularity of robotics programs, we expect precise guidelines to be released in the future, and we plan to make any required changes when appropriate.

f. **Scheduling and organizational issues.** The proposed program consists, for the most part, of courses that are currently being offered multiple times per year in the participating departments. Some of the courses that are expected to receive higher enrollment are also cross-listed across departments, making it simple to provide additional offerings (for example, EE144/ME144, ME145/EE145, EE120A/CS120A, EE120B/CS120B, EE142/CS171). The initial projected enrollment can certainly be incorporated in the existing offerings. Additional offerings of key courses will be discussed as enrollment grows, should the need arise. Finally, the three participating Departments have already provided support letters, and have already committed resources for the success of the proposed program. Formal collaboration and coordination mechanisms, including mechanisms to grow or terminate the program, will be detailed and agreed upon as appropriate as the need arise.

12. **Approvals from program faculty, College faculty (if the new proposal affects a college regulation), and the appropriate Executive Committee should be obtained before forwarding the new program to the attention of the Senate Analyst for CEP.**

Approved by the Departments of Mechanical Engineering, Electrical and Computer Engineering, and Computer Science and Engineering, as well as by the program faculty.
13. Contribution to diversity

Recruitment: UCR is an accredited Hispanic Serving Institution (OPEID 00131600), with approximately 35% Hispanic enrollment. BCOE has a much higher proportion of undergraduates from underrepresented backgrounds compared to Engineering Schools at comparably-ranked R1 universities in the United States. Prior research has established that the hands-on aspects of robotics, coupled with clear workforce-related applications of the technology, appeal to students from underrepresented backgrounds and increase engagement, involvement, and retention [1-3]. The fast-growing nature of the field of robotics (and AI in particular) is a great motivating factor for students to complete a cross-disciplinary BS degree before entering the workforce or graduate studies. The BS Robotics Engineering program will recruit from schools in the Southern California region, the United States, and beyond. UCR is already one of America’s most diverse universities and of the most successful at graduating students from underrepresented groups and disadvantaged backgrounds. The BS Robotics Engineering program will further contribute to UCR’s mission by providing novel and very diverse career opportunities towards addressing the need for a larger, diverse, and globally engaged STEM workforce.

Curriculum and pedagogy: The cross-disciplinary nature of robotics creates the opportunity to build curriculum that is sensitive to the needs of diverse learners as well as diverse members of society. Of particular interest and concern is the subject of algorithmic bias in AI and machine learning. The design of AI systems has been primarily the domain of white, male engineers [4], and several scholars have suggested that efforts toward inclusion in the ranks of those who design AI systems could reduce bias [5, 6]. For example, just 12% of machine learning engineers are women [7], with Black AI leaders pointing to a “diversity crisis” in the field [8]. Critiques of simple inclusivity efforts suggest that diversity programs cannot address overlapping forms of inequality, and have called for applying a more deliberate lens of intersectionality to the algorithm design [9, 10]. To this end, the BS Robotics Engineering program will work closely with the CS and ECE Departments to update their AI, machine learning, and computer vision undergraduate-level curricula to address algorithmic bias, including how biased vs. unbiased robots may impact society as the technology evolves.

Outreach: Students in the BS Robotics Engineering program will be encouraged to participate with ongoing efforts at UCR to provide mentorship and broaden participation in robotics-related activities. One recent example is UCR’s K-12 Lego Robotics Competition [11]. BCOE student organizations such as the IEEE@UCR (affiliated with the ECE Department) have a long and successful history of outreach efforts to the local community which bring K-12 students to campus. The BS Robotics Engineering program will work with BCOE student organizations to create new opportunities for undergraduate student leadership and participation surrounding community outreach events.


14. Program Educational Objectives (PEO)

Graduates of the UCR’s BS degree program in Robotics Engineering will meet high professional, ethical, and societal goals as demonstrated by accomplishing at least one different item in each of the following different categories:

1. Success in post-graduation studies as evidenced by:
   a. Satisfaction with the decision to further their education
   b. Advanced courses completed or advanced degree earned
   c. Professional visibility (e.g., publications, patents, inventions, awards)
   d. Professional responsibilities (e.g., professional mentoring, professional society memberships, reviewing and editorial work for professional journals)

2. Success in a chosen profession or vocation as evidenced by:
   a. Career satisfaction
   b. Promotions/raises (e.g., management leadership positions or distinguished technical positions)
   c. Entrepreneurial activities
   d. Consulting activities

3. Contributions to society and profession as evidenced by:
   a. Leadership roles
   b. Public service
   c. Outreach and volunteering activities
   d. Establishment and maintenance of professional networks

The PEOs are structured into three main objectives, with various specific examples of measurable evidence. It is not expected that students will achieve all of the three main objectives. Rather, the PEOs are designed to meet the needs of students with different interests within the Robotics Engineering program. The first set of PEOs is most relevant to students that pursue advanced degrees. The second set of PEOs is designed for students that instead prefer to enter the workplace immediately after graduation. Finally, we expect most of our students to make some societal contributions within 3-5 years after graduation.

The PEOs of the Robotics Engineering program are consistent and well-aligned with the mission of the Bourns College of Engineering.
Appendix A.

Robotics Engineering Undergraduate Major.

<table>
<thead>
<tr>
<th>Year 1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>MATH 009A</td>
<td>MATH 009B</td>
<td>MATH 009C</td>
</tr>
<tr>
<td>CS 010A</td>
<td>CS 010B</td>
<td>CS 010C</td>
</tr>
<tr>
<td>ME 009</td>
<td>PHYS 040A</td>
<td>PHYS 040B</td>
</tr>
<tr>
<td>ENGL 001A</td>
<td>ENGL 001B</td>
<td>BREADTH 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>PHYS 040C</td>
<td>MATH 046</td>
<td>MATH 011</td>
</tr>
<tr>
<td>MATH 010A</td>
<td>CS 061</td>
<td>EE 005</td>
</tr>
<tr>
<td>ME 010</td>
<td>EE 106</td>
<td>ME 120</td>
</tr>
<tr>
<td>CS 100</td>
<td>BREADTH 2</td>
<td>MATH 031</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 3</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>ME 103</td>
<td>EE 120A / CS 120A</td>
<td>EE120B / CS 120B</td>
</tr>
<tr>
<td>EE 111</td>
<td>EE 114</td>
<td>EE 132</td>
</tr>
<tr>
<td>TECH. ELEC. 1</td>
<td>TECH. ELEC. 2</td>
<td>TECH. ELEC. 3</td>
</tr>
<tr>
<td>BREADTH 3</td>
<td>BREADTH 4</td>
<td>BREADTH 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 4</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
</tr>
<tr>
<td>EE 144 / ME 144</td>
<td>ME 145 / EE 145</td>
<td>EE 142 / CS 171</td>
</tr>
<tr>
<td>TECH. ELEC. 4</td>
<td>SENIOR DES. 1</td>
<td>SENIOR DES. 2</td>
</tr>
<tr>
<td>ENGR 180W</td>
<td>BREADTH 6</td>
<td>BREADTH 7</td>
</tr>
</tbody>
</table>

Comments:
One new course, EE 106 (Programming Practical Robotics).
MATH 009AH, 009BH, and 009CH can be used as alternatives for MATH 009A, 009B, and 009C, respectively.
Students will complete Senior Design courses in one of the participating Departments (Mechanical Engineering, Electrical and Computer Engineering, Computer Science and Engineering): CS 178A and CS 178B, or EE 175A and EE 175B, or ME 175B and ME 175C.
Prerequisites to these courses will be adjusted to include senior standing in Robotics after approval of the Robotics program.

Course description:
**MATH 009A First-Year Calculus (4)** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 005 with a grade of “C-” or better or MATH 006B with a grade of “C-” or better or
equivalent. Introduction to the differential calculus of functions of one variable. Credit is awarded for only one of MATH 008B, MATH 009A, or MATH 09HA.

**MATH 009B First-Year Calculus (4)** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 008B with a grade of “C-” or better or MATH 009A with a grade of “C-” or better or MATH 09HA with a grade of “C-” or better. Introduction to the integral calculus of functions of one variable. Credit is awarded for only one of MATH 009B or MATH 09HB.

**MATH 009C First-Year Calculus (4)** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009B with a grade of “C-” or better or MATH 09HB with a grade of “C-” or better. Further topics from integral calculus, improper integrals, infinite series, Taylor’s series, and Taylor’s theorem. Credit is awarded for only one of MATH 009C or MATH 09HC.

**MATH 010A Calculus of Several Variables (4)** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009B with a grade of “C-” or better or MATH 09HB with a grade of “C-” or better or equivalent. Topics include Euclidean geometry, matrices and linear functions, determinants, partial derivatives, directional derivatives, Jacobians, gradients, chain rule, and Taylor’s theorem for several variables.

**MATH 011 Introduction to Discrete Structures (4)** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 009A (or MATH 09HA); CS 010 or CS 010V or MATH 009B (or MATH 09HB). Introduction to basic concepts of discrete mathematics emphasizing applications to computer science. Topics include propositional and predicate calculi, elementary set theory, functions, relations, proof techniques, elements of number theory, enumeration, and discrete probability. Cross-listed with CS 011.

**MATH 031 Applied Linear Algebra (5)** Lecture, 3 hours; discussion, 2 hours. Prerequisite(s): MATH 009A (or MATH 09HA) with a grade “C-” or better and CS 010 or CS 010V or MATH 009B (or MATH 09HB) with a grade of “C-” or better. A study of matrices and systems of linear equations, determinants, Gaussian elimination, vector spaces, linear independence and linear transformation, orthogonality, eigenvalues, and eigenvectors. Also examines selected topics and applications.

**MATH 046 Introduction to Ordinary Differential Equations 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 007B or MATH 009B or MATH 09HB with a grade of “C-” or better or equivalent. Introduction to first-order equations, linear second-order equations, and Laplace transforms, with applications to the physical and biological sciences.

**PHYS 040A General Physics 5** Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 007A or MATH 009A or MATH 09HA with a grade of “C-” or better; MATH 007B or MATH 009B or MATH 09HB with a grade of “C-” or better (MATH 009B or MATH 09HB may be taken concurrently). Designed for engineering and physical sciences students. Covers topics in classical mechanics including Newton’s laws of motion; friction; circular motion; work, energy, and conservation of energy; dynamics of particle systems; collisions; rigid-body motion; torque; and angular momentum. Laboratories provide exercises illustrating experimental foundations of physical principles and selected applications. Credit is not awarded for PHYS 040A if it has already been awarded for PHYS 002A, PHYS 02HA, PHYS 040HA, or PHYS 041A.

**PHYS 040B General Physics 5** Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 009C or MATH 09HC (may be taken concurrently); PHYS 040A or PHYS 040HA with a grade of “C-” or better. Designed for engineering and physical sciences students. Covers topics in mechanics and thermodynamics including elasticity; oscillations; gravitation; fluids; mechanical waves and sound; temperature, heat, and the laws of
thermodynamics; and the kinetic theory of gases. Laboratories provide exercises illustrating the experimental foundations of physical principles and selected applications. Credit is awarded for only one of PHYS 040B or PHYS 040HB.

**PHYS 040C General Physics 5** Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): MATH 009C or MATH 09HC; PHYS 040B or PHYS 040HB with a grade of “C-” or better. Designed for engineering and physical sciences students. Covers topics in electricity and magnetism including electric fields and potential; Gauss’ law; capacitance; magnetic fields; Ampere’s law; Faraday’s law and induction; electromagnetic oscillations; dc and ac current; and circuits. Laboratories provide exercises illustrating the experimental foundations of physical principles and selected applications. Credit is awarded for only one of PHYS 040C, PHYS 040HC, PHYS 002B, PHYS 02HB, or PHYS 041B.

**CS 010A Introduction to Computer Science for Science, Mathematics, and Engineering I** (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): a college mathematics course (may be taken concurrently) or credit for MATH 009A from the Advanced Placement Examination or the Mathematics Advisory Examination. Covers problem solving through structured programming of algorithms on computers using the C++ object-oriented language. Includes variables, expressions, input/output (I/O), branches, loops, functions, parameters, arrays, strings, file I/O, and classes. Also covers software design, testing, and debugging. Credit is not awarded for CS 010 if it has already been awarded for CS 010V or CS 030.

**CS 010B Introduction to Computer Science for Science, Mathematics, and Engineering II** (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010 or CS 010V with a grade of “C” or better; familiarity with C or C++ language. Covers structured and object-oriented programming in C++. Emphasizes good programming principles and development of substantial programs. Topics include recursion, pointers, linked lists, abstract data types, and libraries. Also covers software engineering principles. Credit is awarded for only one of CS 012 or CS 012V or CS 013.

**CS 010C Introduction to Data Structures and Algorithms (4)** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 012 or CS 012V with a grade of “C” or better or CS 013 with a grade of “C” or better; proficiency in C++. Topics include basic data structures such as arrays, lists, stacks, and queues. Covers dictionaries (including binary search trees and hashing) and priority queues (heaps). Offers an introductory analysis of algorithms, sorting algorithms, and object-oriented programming including abstract data types, inheritance, and polymorphism. Explores solving complex problems through structured software development.

**CS 061 Machine Organization and Assembly Language Programming 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010 with a grade of “C” or better. An introduction to computer organization. Topics include number representation, combinational and sequential logic, computer instructions, memory organization, addressing modes, interrupt, input/output (I/O), assembly language programming, assemblers, and linkers.

**CS 100 Software Construction (4)** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 014 with a grade of “C-” or better. Emphasizes development of software systems. Topics include design and implementation strategies; selection and mastery of programming languages, environment tools, and development processes. Develops skill in programming, testing, debugging, performance evaluation, component integration, maintenance, and documentation. Covers professional and ethical responsibilities and the need to stay current with technology.

**CS 120A Logic Design 5** Lecture, 3 hours; laboratory, 3 hours; individual study, 3 hours. Prerequisite(s): CS 061 with a grade of “C-” or better. Covers design of digital systems. Includes
Boolean algebra; combinational and sequential logic design; design and use of arithmetic logic units, carry-lookahead adders, multiplexors, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Uses hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with EE 120A.

**CS 120B Introduction to Embedded Systems** 4
Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 120A or CS 120A. Introduction to hardware and software design of digital computing systems embedded in electronic devices (e.g., digital cameras or portable video games). Includes embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software trade-offs. Involves use of synthesis tools, programmable logic, microcontrollers, and developing working embedded systems. Cross-listed with EE 120B.

**CS 178A Project Sequence in Computer Science and Engineering** 4
Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): CS 141, ENGR 180W; restricted to class level standing of senior. Under the direction of a faculty member, teams propose, design, build, test, and document software and/or hardware devices or systems. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment. Completed together, CS 178A and CS 178B may be applied as a substitute for the CS 179 (E-Z) CS major requirement. Graded In Progress (IP) until CS 178A and CS 178B are completed, at which time, a final letter grade is assigned.

**CS 178B Project Sequence in Computer Science and Engineering** 4
Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): CS 178A; restricted to class level standing of senior. Under the direction of a faculty member, teams propose, design, build, test, and document software and/or hardware devices or systems. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment.

**ME 009 Engineering Graphics and Design** 4
Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): none. Covers graphical concepts and projective geometry relating to spatial visualization and communication in design. Includes technical sketching, computer-aided design with solid modeling, geometric dimensioning and tolerancing, and an introduction to the engineering design process.

**ME 010 Statics** 4
Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): MATH 009C, PHYS 040A or PHYS 040HA. Covers equilibrium of coplanar force systems; analysis of frames and trusses; noncoplanar force systems; friction; and distributed loads.

**ME 103 Dynamics** 4
Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): MATH 046, ME 010 with a grade of “C-” or better, ME 018B with a grade of C- or better. Topics include vector representation of kinematics and kinetics of particles; Newton’s laws of motion; force-mass-acceleration, work-energy, and impulse-momentum methods; kinetics of systems of particles; and kinematics and kinetics of rigid bodies.

**ME 120 Linear Systems and Controls** 4
Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): EE 001A, EE 01LA, ME 018B with a grade of C- or better. Introduces the modeling and analysis of dynamic systems, emphasizing the common features of mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical systems. Controls are introduced through state equations, equilibrium, linearization, stability, and time and frequency domain analysis.

**ME 145 Robotic Planning and Kinematics** 4
Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 120 or equivalent; or consent on instructor. Motion planning and kinematics
topics with an emphasis in geometric reasoning, programming, and matrix computations. Motion planning includes configuration spaces, sensor-based planning, decomposition and sampling methods, and advanced planning algorithms. Kinematics includes reference frames, rotations and displacements, and kinematic motion models. Cross-listed with EE 145.

ME 175B Mechanical Engineering Design 3 Lecture, 2 hours; laboratory, 2 hours.
Prerequisite(s): senior standing in Mechanical Engineering. ME 113, ME 116A, ME 170A, ME 174, ME 175A (may be taken concurrently). Outlines the defining of a design problem and the conception and detail of the design solution. Explores design theory, design for safety, reliability, manufacture, and assembly. Graded In Progress (IP) until ME 175B and ME 175C are completed, at which time a final, letter grade is assigned.

ME 175C Mechanical Engineering Design 3 Lecture, 1 hours; discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): senior standing in Mechanical Engineering; ME 175B. Students create, test, and evaluate a prototype based on the project design generated in ME 175B. Lecture topics include prototyping techniques, design verification, and special topics in design. Satisfactory (S) or No Credit (NC) grading is not available.

EE 005 Circuits and Electronics 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): PHYS 040C or PHYS 040HC. Introduces linear circuits analysis, semiconductor diodes and transistors, analog amplifier circuits, operational amplifiers, and digital circuits. Does not confer credit towards a degree in Electrical Engineering and in Computer Engineering.

EE 106 Programming Practical Robotics 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisites: MATH 031 or EE 020, CS 010A or ME 018A. Covers principles for simulating, programming, and deploying robots using modern robotics middleware. Includes reading/writing of robot programs; simulating robotic systems; interfacing robot sensors and actuators; and implementing introductory motion control algorithms. Teaches contemporary robotics open-source software (ROS, Gazebo), 3D environment creation, and sensor data processing libraries (OpenCV, OpenNI, PCL).

EE 111 Digital and Analog Signals and Systems 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001B, EE 020, MATH 046; or consent of instructor. Covers continuous- and discrete-time signals and systems; linear time-invariant (LTI) systems; impulse response; Fourier analysis; frequency response; Laplace and Z-transforms; and sampling theorem and Nyquist rates. Includes laboratory experiments with signals, transforms, linear digital filtering, and sampling/aliasing.

EE 114 Probability, Random Variables, and Random Processes in Electrical Engineering 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 110A or EE 111. Covers fundamentals of probability theory, random variables, and random processes with applications to electrical and computer engineering. Includes probability theory, random variables, densities, functions of random variables, expectations and moments, and multivariate distributions. Also addresses random processes, autocorrelation function, spectral analysis of random signals, and linear systems with random inputs.

EE 132 Automatic Control 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 105 or ME 103 or equivalent; EE 110A or ENGR 118; or consent of instructor. Covers mathematical modeling of linear systems for time and frequency domain analysis. Topics include transfer function and state variable representations for analyzing stability, controllability, and observability; and closed-loop control design techniques by Bode, Nyquist, and root-locus methods. Laboratories involve both simulation and hardware exercises.
EE 142 Pattern Recognition and Analysis of Sensor Data 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 114 or STAT 155 or consent of the instructor. Introduction to pattern recognition for multi-dimensional, multi-modal sensor data such as images, videos, and smart grids. Classification and decision functions, feature extraction, regression, and neural networks. Clustering and dimensionality reduction for unsupervised learning. Dynamic models and tracking. Applications of pattern recognition in computer vision, robotics, smart grids, etc.

EE 144 Foundations of Robotics 4 Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 020 or MATH 031 or ME 018B; CS 010A or ME 118; or consent of instructor. Provides foundational knowledge on analysis, control, and programming of robots. Considers configuration space, rigid body motion, forward, inverse and velocity kinematics, dynamics, trajectory planning, robot motion control, localization and mapping, and robot ethics. Integrates hands-on labs to program robots in simulation and experimentally by reading and interpreting sensor data. Cross-listed with ME 144.

EE 175A Senior Design Project 4 Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): EE 120B or CS 120B; restricted to class level standing of senior; restricted to major(s) Electrical Engineering, Electrical Engineering BS + MS; or consent of instructor. Proposal of design of electrical engineering devices or systems under the direction of the instructor. Develops technical specification; considers design constraints and industry standards; emphasizes ethical responsibilities; and promotes staying current on technology and its socioeconomic and environmental impact. Graded In Progress (IP) until EE 175A and EE 175B are completed, at which time, a final letter grade is assigned.

EE 175B Senior Design Project 4 Lecture, 1 hour; laboratory, 3 hours; practicum, 6 hours. Prerequisite(s): EE 175A; senior standing in Electrical Engineering. Builds, tests, and redesigns electrical engineering devices or systems. Develops and carries out test plan according to design specification. Presents a demo of the design. Completes project testing and technical documentation. Presents a demo of the design. Satisfactory (S) or No Credit (NC) grading is not available.

ENGR 180W Technical Communications 4 Lecture, 3 hours; workshop, 3 hours. Prerequisite(s): ENGL 001B with a grade of “C” or better; upper-division standing in the Bourns College of Engineering or consent of instructor. Develops oral, written, and graphical communication skills. Includes preparing and critiquing reports, proposals, instructions, and business correspondence. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment. Fulfills the third-quarter writing requirement for students who earn a grade of “C” or better for courses that the Academic Senate designates, and that the student’s college permits, as alternatives to English 001C.

Technical electives:

CS 111 Discrete Structures 4 Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 010; CS 011/MATH 011; MATH 009C (or MATH 09HC). A study of discrete mathematical structures emphasizing applications to computer science. Topics include asymptotic notation, generating functions, recurrence equations, elements of graph theory, trees, algebraic structures, and number theory.

CS 122A Intermediate Embedded and Real-Time Systems 5 Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 012 or CS 013; CS 120B/EE 120B. Covers software and hardware design of embedded computing systems. Includes hardware and software codesign, advanced
programming paradigms (including state machines and concurrent processes), real-time programming and operating systems, basic control systems, and modern chip and design technologies. Laboratories involve use of microcontrollers, embedded microprocessors, programmable logic and advanced simulation, and debug environments.

**CS 122B Advanced Embedded and Real-Time Systems** Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 122A. Explores state-of-the-art aspects of building embedded computer systems. Topics include real-time programming, synthesis of coprocessor cores, application-specific processors, hardware and software cosimulation and codesign, low-power design, reconfigurable computing, core-based design, and platform-based methodology.

**CS 135 Virtual Reality** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 100. Covers the development of virtual reality (VR) worlds, including motion and physics of VR worlds. Includes design practices for immersive experiences, human visual perception, environmental and social interactions. Also includes positional tracking with sensors, augmented and mixed reality, and storage and transmission of virtual reality worlds.

**CS 141 Intermediate Data Structures and Algorithms** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 014 with a grade of “C-” or better; CS 111; MATH 009C or MATH 09HC; proficiency in C++. Explores basic algorithm analysis using asymptotic notations, summation and recurrence relations, and algorithms and data structures for discrete structures including trees, strings, and graphs. Also covers general algorithm design techniques including “divide-and-conquer,” the greedy method, and dynamic programming. Integrates knowledge of data structures, algorithms, and programming.

**CS 145 Combinatorial Optimization Algorithms** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 141; MATH 031 or MATH 131. The study of efficient algorithm design techniques for combinatorial optimization problems. Topics include shortest paths, minimum spanning trees, network flows, maximum matchings, stable matchings, linear programming, duality, two-person games, algorithmic techniques for integer programming problems, NP-completeness, and approximation algorithms.

**CS 150 Automata and Formal Languages** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 014 with a grade of “C-” or better; CS 111; MATH 009C (or MATH 09HC). A study of formal languages. Includes regular and context-free languages; computational models for generating these languages such as finite-state automata, pushdown automata, regular expressions, and context-free grammars; mathematical properties of the languages and models; and equivalence between the models. Also introduces Turing machines and decidability.

**CS 160 Concurrent Programming and Parallel Systems** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 061, CS 100, CS 111. A study of concurrent and parallel systems. Topics include modular structure and design, interprocess communication, synchronization, failures, persistence, and concurrency control. Also covers atomic transactions, recovery, language support, distributed interprocess communication, and implementation mechanisms. Provides preparation for the study of operating systems, databases, and computer networking.

**CS 170 Introduction to Artificial Intelligence** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 100 with a grade of “C-” or better, CS 111. An introduction to the field of artificial intelligence. Focuses on discrete-valued problems. Covers heuristic search, problem representation, and classical planning. Also covers constraint satisfaction and logical inference.

**CS 173 Introduction to Natural Language Processing** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CS 150, may be taken concurrently. An overview of modern approaches for natural language processing. Focuses on major algorithms used in NLP for various applications.
such as part-of-speech tagging, parsing, named entity recognition, coreference resolution, sentiment analysis, and machine translation.

**ME 110 Mechanics of Materials 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): CS 009M or ME 018A; MATH 046, ME 010 with a grade of “C-” or better. Topics include mechanics of deformable bodies subjected to axial, torsional, shear, and bending loads; combined stresses; and their applications to the design of structures.

**ME 122 Vibrations 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): ME 103. Covers free and forced vibration of discrete systems with and without damping resonance; matrix methods for multiple degree-of-freedom systems; normal modes, coupling, and normal coordinates; and use of energy methods.

**ME 130 Kinematic and Dynamic Analysis of Mechanisms 4** Lecture, 3 hours, discussion, 1 hour. Prerequisite(s): ME 009, ME 103. Explores the kinematic analysis of planar mechanisms including linkages, cams, and gear trains. Introduces concepts of multibody dynamics.

**ME 131 Design of Mechanisms 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 130. Involves design of planar, spherical, and spatial mechanisms using both exact and approximate graphical and analytical techniques. Requires a computer-aided design project.

**ME 133 Introduction to Mechatronics 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): ME 120. Introduces hardware, software, sensors, actuators, physical systems models, and control theory in the context of control system implementation. Covers data acquisition (Labview), sensors, actuators, electric circuits and components, semiconductor electronics, logic circuits, signal processing using analog operational amplifiers, programmable logic controllers, and microcontroller programming and interfacing. Uses MATLAB and Simulink.

**ME 153 Finite Element Methods 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ME 118. Covers weak form formulation, the Galerkin method and its computational implementation, mesh generation, data visualization, as well as programming finite element codes for practical engineering applications.

**EE 100A Electronic Circuits 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001B. Electronic systems, linear circuits, operational amplifiers, diodes, nonlinear circuit applications, junction and metal-oxide-semiconductor field-effect transistors, bipolar junction transistors, MOS and bipolar digital circuits. Laboratory experiments are performed in the subject areas and SPICE simulation is used.

**EE 115 Introduction to Communication Systems 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B. Covers spectral density and correlation, modulation theory, amplitude, frequency, phase and analog pulse modulation and demodulation techniques, signal-to-noise ratios, and system performance calculations. Laboratory experiments involve techniques of modulation and demodulation.

**EE 128 Data Acquisition, Instrumentation, and Process Control 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 100B, EE 120B/CS 120B (EE 100B and EE 120B/CS 120B may be taken concurrently); or consent of instructor. Covers analog signal transducers, conditioning, and processing; step motors, DC servo motors, and other actuation devices. Explores analog to digital and digital to analog converters; data acquisition systems; microcomputer interfaces to commonly used sensors and actuators; and design principles for electronic instruments, real time process control, and instrumentation.

**EE 141 Digital Signal Processing 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B. Transform analysis of Linear Time-Invariant (LTI) systems, discrete Fourier Transform (DFT) and its computation, Fourier analysis of signals using the DFT, filter design techniques,
structures for discrete-time systems. Laboratory experiments on DFT, fast Fourier transforms (FFT), infinite impulse response (IIR), and finite impulse response (FIR) filter design, and quantization effects.

**EE 146 Computer Vision 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): senior standing in Computer Science or Electrical Engineering, or consent of instructor. Imaging formation, early vision processing, boundary detection, region growing, two-dimensional and three-dimensional object representation and recognition techniques. Experiments for each topic are carried out.

**EE 147 Graphics Processing Unit Computing and Programming 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 120B or CS 120B. Introduces principles and practices of programming graphics processing units (GPUs) using the parallel programming environment. Covers memory/threading models, common data-parallel programming patterns and libraries needed to develop high-performance parallel computing applications. Examines computational thinking; a broader range of parallel execution models; and parallel programming principles. Cross-listed with CS 147.

**EE 150 Digital Communications 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 114, EE 115. Topics include modulation, probability and random variables, correlation and power spectra, information theory, errors of transmission, equalization and coding methods, shift and phase keying, and a comparison of digital communication systems.

**EE 151 Introduction to Digital Control 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 132, EE 141. Review of continuous-time control systems; review of Z-transform and properties; sampled-data systems; stability analysis and criteria; frequency domain analysis and design; transient and steady-state response; state-space techniques; controllability and observability; pole placement; observer design; Lyapunov stability analysis. Laboratory experiments complementary to these topics include simulations and hardware design.

**EE 152 Image Processing 4** Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B or EE 111 or consent of instructor. Digital image acquisition, image enhancement and restoration, image compression, computer implementation and testing of image processing techniques. Students gain hands-on experience of complete image processing systems, including image acquisition, processing, and display through laboratory experiments.

**ENGR 160 Introduction to Engineering Optimization Techniques 4** Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 010A; CS 010 or EE 020 or ME 018A and ME 018B. ENGR 160 online section; enrollment in the Master-in-Science in Engineering program. Introduction to formulating and solving optimization problems in engineering. Includes single variable and multi-variable optimization; linear programming - simplex method; nonlinear unconstrained optimization - gradient, steepest descent, and Newton methods; and nonlinear constrained optimization - gradient projection methods. Addresses applications of optimization in engineering design problems. Solves various engineering optimization examples using MATLAB.
Appendix B.
Proposed catalog entry for the Robotics Engineering Undergraduate Major.

Robotics Engineering Undergraduate Major (catalog entry)
Major
Robotics studies the design, operation, and deployment of autonomous intelligent systems and mechanisms. Robotics is a fundamentally multidisciplinary field, with core components spanning engineering and computer science, and applications extending beyond science and technology. Courses in the B.S. in Robotics Engineering program focus both on the theory and the practice of contemporary robotics science and engineering, and prepare students for professional careers and graduate studies in robotics and beyond (e.g., autonomous systems, intelligent control systems, and decision making).

The B.S. in Robotics Engineering major is an interdepartmental program offered by the Marlan and Rosemary Bourns College of Engineering (BCOE), and involves the Departments of Mechanical Engineering, Electrical and Computer Engineering, and Computer Science and Engineering. Students are advised in and have their records maintained by the BCOE Office of Student Academic Affairs. Students must fulfill the breadth requirements of the Bourns College of Engineering.

University Requirements
See Undergraduate Students section.
College Requirements
For details on breadth requirements, see the Colleges and Programs section of this catalog. Students are encouraged to consult their advisor regarding requirements.
Major Requirements
1. Lower-division requirements (72 units)
   a. MATH 009A or MATH 009AH; MATH 009B or MATH 009BH; MATH 009C or MATH 009 CH; MATH10A; MATH 011; MATH 031; MATH 46.
   b. PHYS 040A; PHYS 040B; PHYS 040C.
   c. CS 010A; CS 010B; CS 010C; CS 061.
   d. ME 009; ME 010.
   e. EE 005.
2. Upper-division requirements (65 units)
   a. CS 100; CS 120B / EE 120B.
   b. ME 103; ME120; ME 145 / EE 145.
   c. EE 106; EE 111; EE 114; EE 120A / CS 120A; EE132; EE142 / CS 171; EE 144 / ME 144.
   d. Four courses (at least 16 units) from the following list, none of which can also be used to satisfy other major requirements: CS 111; CS 122A; CS 122B; CS 135; CS 141; CS 145; CS 150; CS 170; CS 173; ME 110; ME 122; ME 130; ME 131; ME 133; ME 153; EE 100A; EE 115; EE 128; EE 141; EE 146; EE 147; EE 150; EE 151; EE 152; ENGR 160.
   e. One of the following two-course sequences: CS 178A and CS 178B, or EE 175A and EE 175B, or ME 175B and ME 175C.
Dear members of the Academic Senate:

On behalf of the Mechanical Engineering department, I enthusiastically support the new BS in Robotics program. This program will be housed in the Bourns College of Engineering, across the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE), and Mechanical Engineering (ME). It will draw upon courses from the existing programs in the departments.

In the past decade or so, Robotics has become extremely popular amongst High School students who are interested in pursuing technological careers. Having this program will allow us attract high caliber and extremely motivated students to UCR. The ME program has recently invested heavily in a focus area related to robotics: Controls, Robotics and Automation. Since 2018, we have hired three faculty members in this area, who added to the two we already had, have formed a strong cluster of five ME faculty members plus at least a dozen more in CSE and ECE. In ME, plan to keep adding faculty to this area in the near future.

Robotics is a strategically important area for the country, technically challenging, and provides many opportunities to students after graduation. It is also an inter-disciplinary program which requires an equally inter-connected curriculum. This new program will allow us to provide that holistic training. The curriculum is structured so that graduating students will be competitive in the job market, as well as have the expertise for graduate studies.

Under the leadership of three ME faculty members, the rest of the ME faculty were closely involved in the development of the program and was extensively discussed in faculty meetings in the academic year 19/20. The final program was discussed with the ME undergraduate committee and during faculty meetings, and was unanimously supported by the ME faculty.

In summary, I am extremely supportive of this program and believe it will help in attracting high quality undergraduate students to UCR. Please do not hesitate to contact me should there be any questions.

Respectfully,

Guillermo Aguilar, Ph.D.
Professor and Chair
University of California Riverside
Department of Mechanical Engineering
A-345 Bourns Hall
Riverside CA, 92521
Off: 951-827-7717
gaguilar@engr.ucr.edu
October 23, 2020

Dear Members of the Academic Senate:

On behalf of the Electrical and Computer Engineering department, it is my pleasure to provide the strongest possible support for the BS in Robotics program. This program will be housed in the Bourns College of Engineering, and is cross-disciplinary, across the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE), and Mechanical Engineering (ME). It will draw upon courses from the existing programs in the departments.

Robotics is a strategically important area for the country, technically challenging, and provides many opportunities to students after graduation. High school students are extremely interested in this area, and having this program will allow us attract high caliber and extremely motivated students to UCR. The EE program has two technical focus areas related to robotics: Control and Robotics, which focuses on developing control strategies for robot locomotion, and Intelligent Systems, which focuses on the sensing and decision-making strategies that allows robots to understand their environment. The courses are of high interest, and the majority of the projects in the capstone Senior Design are related to some aspect of robotics. Students in the Computer Engineering program, which is jointly offered by ECE and CSE, have access to all these courses.

However, robotics is an inter-disciplinary program and having it as a specialization within an existing major does not provide students with the entire body of expertise required to work in this area in the future. For example, while EE students interested in robotics will gain some knowledge of the computational aspects of robotics, they will usually not study the mechanical design of robots or how to write and debug software efficiently. Having this inter-disciplinary program will allow us to provide that holistic training. The curriculum is structured so that graduating students will be competitive in the job market, as well as have the expertise to conduct graduate studies.

The faculty in ECE were closely involved in the development of the program. Two ECE faculty were members of the committee, and the program was discussed multiple times in faculty meetings in the 19-20 academic year. On Oct 21, 2020, the final program was discussed in the ECE faculty meeting and was unanimously supported by the faculty.

In summary, I am extremely supportive of this program and believe it will help in attracting high quality undergraduate students to UCR. Please do not hesitate to contact me should there be any questions. Sincerely,

Amit Roy-Chowdhury
Professor and Chair
Electrical and Computer Engineering
University of California, Riverside
November 1, 2020

Dear Members of the Academic Senate:

With this letter I would like to express the strong support of the Department of Computer Science and Engineering for the proposed B.S. degree in Robotics within the Bourns College of Engineering at UCR. This cross-disciplinary program will draw upon courses and research knowledge from the departments of Computer Science and Engineering (CSE), Electrical and Computer Engineering (ECE) and Mechanical Engineering (ME).

There is no doubt that robotics is rapidly becoming a very important field of engineering. Robotics requires multi-disciplinary breadth, well beyond what can be covered in courses in a single traditional discipline. The proposed Robotics program provides a comprehensive structure under which students can acquire the cross-disciplinary breadth required for this important and emerging field. It does so at very little expense, since the teaching and research infrastructure are already in place.

The proposed program emphasizes four focus areas: mechanical design and fabrication, embedded platforms and system design, control and navigation, and artificial intelligence and perception. These cover different aspect of robotics, from the design of the mechanical and electronic design to the cognitive aspects that enable decision making.

Within computer science and engineering the proposed B.S. in Robotics program relies on multiple disciplines including, but not limited to, artificial intelligence, machine learning, embedded and real-time systems, computer architecture, operating systems etc.

The CSE Department expects to interact extensively with the proposed Robotics program by participating in teaching the required and elective courses, in robotics research and the mentoring of students through projects and advising, and in helping with the program administration. The program will contribute in a great many positive ways to the CSE Department.

In summary, I am extremely supportive of this program and believe it will greatly benefit the students and will help raise UCR’s profile. Please do not hesitate to contact me should there be any questions.

Sincerely,

Walid A. Najjar
Professor and Chair
Department of Computer Science and Engineering
Bourns College of Engineering
University of California Riverside
March 4, 2021

Dear Members of the Academic Senate:

I am writing to express my strong support as Dean of the Bourns College of Engineering for the proposed B.S. degree in Robotics within the Bourns College of Engineering at UCR. This proposed interdepartmental program will draw from courses in the departments of Mechanical Engineering, Electrical and Computer Engineering, and Computer Science and Engineering.

Robotics is a fast-growing discipline in engineering, but does not fit within a single discipline. A full understanding of robotics requires the ability to couple mechanical systems with electrical sensing and actuation, feedback and control systems, embedded computer systems (the hardware/software interface), and advanced software and programming. The proposed Robotics program will provide the cross-disciplinary background needed for success in this emerging field. Most of the courses are already available within departments and thus launching this program will not be excessively expensive.

In this letter, I am committing to a course release for the chair of this program. As the program grows in numbers of students and the workload associated with running the program increases, I anticipate adding a stipend and other support. I am also committing to provide TA support as class sizes grow, commensurate with the existing BCOE TA assignment policy.

Sincerely,

Prof. Christopher S. Lynch
William R. Johnson Jr. Family Chair
Dean, Bourns College of Engineering
University of California, Riverside
RE: BS in Robotics at the University of California, Riverside

Dear Members of the Review Board,

I am writing to support the proposal to initiate a BS in Robotics at the University of California, Riverside. I believe that this proposal addresses current needs in Industry and Academia for students with specialized training in the broad disciplines of artificial intelligence, control theory and algorithm design, among others, which blend together in the robotics discipline. The interdepartmental program proposed at the University of California, Riverside, will provide the students with the required technical knowledge to pursue their careers in the field of robotics. The proposed BS degree will be among the few available in the country, and will likely inspire other institutions to launch similar programs in the near future.

To calibrate my recommendation, I should note that I have seen this play out successfully at the graduate levels as, in the past, I served as the Director for Georgia Tech’s Institute for Robotics and Intelligent Machines, which is home to both multidisciplinary PhD and MS degrees. And it is clear that students and their future employers are highly enthusiastic about such programs.

The proposed curriculum is well-thought-out and balanced. In addition to the standard math and physics courses required by most engineering programs, students will need to complete a number of required classes from the three participating Departments, as well as a series of elective courses. This structure guarantees that graduating students will have the required engineering background and skills, but also the knowledge and flexibility to work and function in a multi-disciplinary environment. The proposed combination of courses from Electrical and Computer Engineering, Mechanical Engineering, and Computer Science and Engineering is truly unique to a curriculum in robotics, and particularly different from the coursework required for more classic engineering degrees.

The participating Departments at the University of California, Riverside, are well positioned to initiate, administer, and grow the proposed BS program. The majority of the courses needed for the new program are currently being offered, thus minimizing the time, effort and risks to launch the new program. The organizational structure of the program is also very reasonable and effective, with Director and Co-Directors roles that will oversee course offerings, scheduling, and other practical matters. The projected enrollment of approximately 50 students is easily manageable, although I foresee a higher student demand for this program.
In summary, I have no reservations on the proposal, and I believe that this new program will attract numerous high quality students soon after its launch. Please do not hesitate to contact me should you need further information.

Sincerely,

Magnus Egerstedt, Ph.D
Steve W. Chaddick School Chair and Professor
School of Electrical and Computer Engineering, Georgia Institute of Technology
March 17, 2021

Dear Members of UCR Academic Senate Review Committee

RE: Proposed B.S. degree in Robotics at UCR

As a general rule, I am skeptical of non-traditional degrees, as they tend to be created based on temporary fads, but stay around for decades, far beyond their useful shelf-life. Often a degree in a traditional major with an expanded minor would be better.

I do think that Robotics has become an exception to that rule. The proposal describes the landscape well: tremendous interest among high school students, partly due to availability of exiting new hobby devices and accessibly of Arduino-type platforms, partly due to exciting new products of Boston Dynamics and similar. As the proposal states, it is hard to do a decent job training in robotics in a more traditional engineering major: mechanical engineers have a host of fluids, thermodynamics, heat-transfer, mechanics, etc., while EE and CS degrees have their own full requirements. The proposed degree, nestled among 3 departments and drawing courses from mostly existing courses, appears a low entry-cost way to provide this pathway for students. I do think it will be successful and, more importantly, would add a valuable option for students to choose. While I will list my concerns and suggestions below, I am fully supportive of the proposed degree and hope more universities would be able to get three departments to cooperate for such an undertaking. That is not easy and they should be commended.

Educational Aspects

- The physics sequence stops at 19th century. It seems to me that we should ensure engineering students are familiar with modern physics. On the other hand, there is a 3-course sequence in programing in the sophomore year, which might be somewhat excessive.

- There are 4 technical electives, which is a decent number but it would be in students’ interest if more ‘guided’ options are incorporated. Examples include a list of 4-7 courses in CS that do vision, autonomy, graphics or a similar list in EE option that would be focused on communication, networks, cooperative algorithms, and ME with on mobility, design, etc. Perhaps they could be designated that way formally to help
students’ careers by giving them more options (so instead EE with Robotics options, it will be Robotics with EE option, implying strong EE background). It will result in a more tangible connection to a traditional degree and increase the chance that the ‘option’ department and faculty take interest in the students. Of course, a totally flexible option will be great to have, as well.

- Increasingly robotics, particularly the ‘automation’ side would open up a host of ethical and privacy issues, quite dissimilar to other engineering endeavors. It might be good to ensure that the senior design, or some other place, incorporates them. Maybe even a special breath course!

Administrative Aspects

- ABET: Does ABET have Robotics as a degree to review? Does it have minimum coverage of certain areas as requirement? I assume this is checked.

- I assume which department gets what credit (course units, majors, etc.) is clear and worked out. If not, it might be best to develop an MOU for that. As the saying goes, ‘if Chairs were angels, we would not need to …. have MOUs’

- Sunset: The program IS in response to current interests. The nature of robotics might change in a few years, some thought should be given on how the program is discontinued or a department might want to cease its participation.

- There is a statement that each department agrees to teach the key courses at least once a year. Unless they are offered multiple times, chances are some really have to be offered in specific quarter as well. Perhaps this is the kind of detail that cannot be worked out at this stage, but this would force restrictions for the other degrees and over time might become a headache.

The above suggestions/observations do not take away from a very well organized and sound program. They should be seen as simply friendly advice --- which of course can be (perhaps should be!) ignored.

Best of luck with your program.

Sincerely,

Faryar Jabbari
Professor and Senior Associate Dean
March 24, 2021

Dear Members of the Review Board,

The initiative to create a new undergraduate degree program in robotics at the University of California, Riverside, is timely, well-justified, and needed. The proposed structure and curriculum are carefully thought-out and effective. I have no doubt that this program will be in high demand, and I’m happy to provide this letter to express my full support. In this letter, I’m going to comment on three main aspects of the program:

**Need:** Demand for engineers that are well-trained in disciplines related to robotics is constantly rising, both from Academia and the Industry. It is undeniable that recent intellectual breakthroughs in Robotics and Artificial Intelligence have enabled important innovations in several technological areas including automated vehicles, rehabilitation and medical devices, and monitoring, to name a few. Yet, to sustain and further such progress, the need for highly trained engineers will only increase, thus guaranteeing the longevity of the pursued program.

**Proposed curriculum:** Robotics is an inherently multi-disciplinary field, making it virtually impossible to create a competitive program within any single classic department. To address this challenge, the proposed curriculum leverages courses offered in three participating departments, thus guaranteeing that subjects are presented in their “native” way, and that students become proficient in the different disciplines necessary for robotics. While coordinating courses from three different departments can be a challenge, the proposal presents a well-organized structure, with key representative members from all participating departments, that will ensure the well-functioning of this new program.

**Capabilities and resources:** The proposed curriculum hinges on courses, faculty members and lecturers that are already within the participating departments. Thus, the proposed program requires little new resources to run, mainly related to organizational roles, making it a small investment for the school. Among the three participating departments, the faculty members cover all the required expertise, ensuring the quality of the training that the students will receive.

To conclude, this is a strong proposal for a timely degree in robotics, with support from a well-qualified set of faculty members. I have no doubt that the program will attract strong interest and that it will keep growing over the years.

Sincerely,

B.S. Manjunath
Distinguished Professor and Chair
Hello all,

Beth, thank you for clarifying this process.

Dr. Stajich and Dir. Cortez, please see the attached proposal for a new BS in Robotics Engineering, approved by the BCOE Executive Committee on April 9, 2021. If this is not the proper process for submitting this, please let me know and I will follow your guidance.

Best,
Katelyn Robinson, M.S.
Advising and Enrollment Specialist
BCOE Office of Student Academic Affairs
she, her, hers
BCOEscheduling@engr.ucr.edu
keeplearningucr.edu
student.engr.ucr.edu

Dear Katelyn,

Many thanks for your message. Proposals for new undergraduate programs need to be submitted to the Senate Chair (Jason.stajich@ucr.edu) and Senate Director (Cherysa.cortez@ucr.edu) as they require review by Committees other than the Committee on Educational Policy.

Best,
Beth
Hi Beth,

Please see the attached proposal for a new BS in Robotics Engineering. Let me know if you see any potential issues.

Best,

Katelyn Robinson, M.S.
Advising and Enrollment Specialist
BCOE Office of Student Academic Affairs
she, her, hers
BCOEscheduling@engr.ucr.edu
keeplearningucr.edu
student.engr.ucr.edu