Breadth of Opportunities in Electrical and Systems Engineering

Arye Nehorai
Chair, The Eugene and Martha Lohman Professor of Electrical Engineering

www.ese.wustl.edu
Research Areas

- Applied Physics
  - Advanced Materials
  - Integrated Photonics
  - Nano-fabrication
  - Devices

- Information
  - Imaging
  - Signal Processing
  - Information Theory
  - Communications

- Systems
  - Applied Math & Stat
  - Computational Math
  - Optimization
  - Control

Preston M. Green Dept. of Electrical & Systems Engineering
Preston M. Green, Dept. of Electrical & Systems Engineering

“I feel like I have a positive impact on people's lives because I’m helping them get where they need to go. It's exciting, hands-on work.”


BEST JOBS IN AMERICA

Money/PayScale.com's list of great careers 2009

1. Systems Engineer

Top 50 rank: 1
Sector: Information Technology

What they do: They’re the “big think” managers on large, complex projects, from major transportation networks to military defense programs. They figure out the technical specifications required and coordinate the efforts of lower-level engineers working on specific aspects of the project.

Why it’s great: Demand is soaring for systems engineers, as what was once a niche job in the aerospace and defense industries becomes commonplace among a diverse and expanding universe of employers, from medical device makers to corporations like Xerox and BMW.

Pay can easily hit six figures for top performers, and there’s ample opportunity for advancement. But many systems engineers say they most enjoy the creative aspects of the job and seeing projects come to life. “The transit system I work on really makes a tangible difference to people,” says Anne O’Neil, chief systems engineer for the New York City Transit Authority.
Electrical Engineering Examples

- Global Positioning System (GPS)
- Magnetic Resonance Imaging (MRI)
- Video Cameras
- Devices: iPads and iPhones
- Smart Grid
- Robots

Expected Growth in Electronics

Quote: “90% of all the innovations in cars will come from electronics,” Mathias Halliger, head of architecture, Man-Machine-Interface (MMI) systems Audi AG, NPR Morning Edition, January 6, 2014
Excluding software, **electrical engineering** continues to offer the most opportunities for American engineers, followed closely by **systems engineering**.

**Source:** ENGINEERJOBS.com, October 2014
Electrical Engineering was high on the list with average starting pay of $62,400. (Washington University Electrical Engineering students had average starting salaries of $65,000)

Source: USA TODAY, July 2014
Degrees We Offer

- **BS**
  - Electrical Engineering
  - Systems Science & Engineering
  - Applied Science Major in EE (ideal for 2nd degree)
  - Applied Science Major in SSE (ideal for 2nd degree)

- **Minors**
  - Electrical Engineering
  - Robotics
  - Mechatronics
  - Energy Engineering
  - Applied Physics and Electrical Engineering
**Why Electrical Engineering?**

- Wide employability (more EE jobs are available)
- You can do just about anything
- Even for computer engineering, we recommend double degree/major of EE (hardware in depth) and CS (software)
- Even for biomedical engineering, we recommend BS in EE (solid engineering foundation) and MS in BME (applications)
Why Systems Engineering?

• You like math and want to make a living by solving engineering problems using math
• You like a technically challenging job
• You like control engineering and operations research
• For an engineering management job, we recommend the BS in SSE (solid engineering closest to management) and an MBA
What Makes ESE Unique

- **Structure**: combination of Electrical & Systems Engineering
- **Education** and research are well grounded in: math, physics, statistics; as well as classical EE and control systems
- Providing in-depth, broad, and flexible education
- Preparing for adaptation to changes and global awareness
- **Applications** to solving societal problems in health, security, defense, energy and environment
Meet the Faculty

Applied Physics

Jung-Tsung Shen
Lan Yang

Signal Analysis and Imaging

R. Martin Arthur
Robert E. Morley
Arye Nehorai
Joseph A. O’Sullivan

Systems Science & Applied Mathematics

ShiNung Ching
Humberto Gonzalez
Jr-Shin Li
Hiro Mukai
Heinz M. Schaettler
ESE Welcomes New Professor in August 2014

Dr. Zachary Feinstein (BS SSE 2009 Valedictorian), joined ESE at Washington University in St. Louis in 2014.

Professor Feinstein works in the broad fields of operations research and financial engineering focusing on applications of set-optimization to finance.

Education
PhD, Princeton University, 2014
MA, Princeton University, 2011
BS, Washington University in St. Louis, 2009
Faculty Awards (2006 - )

- **Dr. ShiNung Ching** received the Burroughs-Wellcome Fund Career Award in 2013
- **Dr. Jung-Tsung Shen** received the NSF Faculty Early Career Development Award in 2013
- **Dr. Lan Yang** received the NSF CAREER Award in 2010 and the Presidential Early Career Award for Scientists and Engineers in 2011
- **Dr. Jr-Shin Li** received the NSF CAREER Award in 2007 and the AFOSR Young Investigator Award in 2010
- **Dr. Arye Nehorai** received the 2006 Technical Achievement Award and the 2009 Meritorious Service Award from the IEEE Signal Processing Society
- **Dr. T. J. Tarn** received the 2009 George Saridis Leadership Award in Robotics and Automation from the IEEE Robotics and Automation Society, the 2010 Einstein Chair Professorship Award from the Chinese Academy of Sciences, and the 2010 John R. Ragazzini Award from the American Automatic Control Council
ESE Professor Wins Presidential Early Career Award

Dr. Lan Yang, associate professor of ESE, was named a recipient of the Presidential Early Career Awards for Scientists and Engineers (PECASE) in 2011.
Selected Recent Publications


Faculty Research and Leadership

MURI: Adaptive Waveform Design for Full Spectral Dominance

Arye Nehorai

- **Leading** multiuniversity research initiative (MURI), team from WUSTL, ASU, Harvard U, U of Maryland, Melbourne U*, Princeton U, Purdue U, UIC, and Raytheon*

- **Goal:** Adaptive optimal design waveforms for radar and communications

- **Approach:**
  - Electromagnetic modeling
  - Waveform mathematics
  - Statistical signal processing
  - Optimization

- **DoD/AFOSR funding:** $5.5M, 2005 to 2010

* Externally funded
Changes We Made (2006 - )

- Hired new faculty
- Improved the instruction
- Renovated our electronics lab
- Introduced new minors in Mechatronics and Energy
- Introduced and revised courses and labs
- Made EE senior design more flexible
- Expanded undergraduate research projects
- Collaborated with industry on projects
- Created study abroad programs
- Revitalized the IEEE student chapter
TOTAL: considers FR, SO, JR, SR, and GRAD students; GRAD: fifth-year students in BSMS programs.
ESE Undergraduate Enrollment (Cont.)
Note: Totals include only SO, JR, SR, and GRAD students
“… my one regret is not doing an electrical engineering degree. Keep pushing BME students to switch over or do a dual!” – Jasmine Kwasa (BS BME, 2013)
We introduced:

- ESE 101 Intro to Engineering Tools: Matlab and Simulink, Spring 2010
- ESE 103 Introduction to Electrical Engineering, Fall 2009
- ESE 251 Introduction to Systems Science and Engineering, Fall 2010
- ESE 297 Introduction to Undergraduate Research Projects
- ESE 437 Sustainable Energy Systems, Spring 2010
- ESE 497 Undergraduate Research, Fall 2007
Revised Courses

We revised:

- ESE 230 Intro to Electrical & Electronic Circuits (added lab), Fall 2008
- ESE 331 Electronics Laboratory, Fall 2010
- ESE 435 Electrical Energy Laboratory, Spring 2011
ESE Lab Renovation (2008)

Bryan 306:

- Renovated 16 stations
- Purchased oscilloscopes, function generators, spectrum analyzers, power supplies, computers, and digital multimeters
Bryan 316:

- Purchased state-of-the-art National Instruments NI-Elvis II teaching platform and a dual-channel USB-based oscilloscope.
- This enables students to master the concepts instead of dealing with the complexity of traditional equipment operation.

We spent $275k on the renovation ($114k for equipment).
ESE 331 Revitalization (2010)

**Goals:** Hands-on lab experience in the applications of electromagnetic principles, design challenges

**Cost:** We spent $60K on purchasing new commercial vector analyzers
ESE 331 Revitalization (2010) (Cont.)

Highlights:

• Familiarization with a commercial Vector Network Analyzer
  – calibration procedures
  – measurements of commercial components in 2-4 GHz

• Design, fabrication and testing of a microstrip 20 dB directional coupler for use on PCBs
  – microstrip 20dB directional coupler for use on PCBs
  – branch line microstrip quadrature hybrid

• Design, use, and testing of cell-phone band antennas
ESE Lab Renovation (2013)

Expansion of the Quanser™ Lab Hardware

- **Robotic educational systems:** from 4 workstations to 8 workstations
- Each workstation has an inverted pendulum (ESE 447) and ball and beam (ESE 448) control apparatus
- Accommodates growth in ESE
- Allows the students to model physical systems, design classical and state-space controllers, and verify their designs in both simulated and real-time environment
- Provides opportunity to students from other departments to enroll – encourages cross-disciplinary education
- **Cost:** $36K
ESE Lab Renovation (2013) (Cont.)

Expansion of the Quanser™ Lab Hardware
ESE Lab Renovation (2013) (Cont.)

Addition of FANUC robotic workcell

- **FANUC is an industrial robotic arm**
- Accommodates growth in ESE
- Serves as the platform for many undergraduate/graduate research projects (Robotic Fencing Trainer, and 3-D Bin Picking using the Kinect Camera)
- Provides experience in real-world industrial automation equipment
- Expands topics for ESE 447 Robotics Lab and 448 Systems Engineering Lab
- Provides future opportunity for certifications and independent studies
- **Cost: $36K**
Ignacio de Erausquin (BSSSE 2013, PhD student) fencing against the Fanuc robotic arm, in ESE557 Hybrid Dynamical Systems
Kinect Camera for Robotics

Matthew Johnson’s (BSBME 2013, MSEE 2014) experiments with FANUC and Kinect
ESE 435 Revitalization (2011) (Cont.)

Renewable Energy and the Smart Grid

- Photovoltaics (PV) – characterization of single cells and operation in PV arrays
- Energy storage (batteries) – characterization and charging/discharging algorithms
- DC-AC Inverters – inverter algorithms, including pulse-width modulation (PWM)
- DC-DC converters – algorithms and implementation, adaptations for DC-AC
Flexible Curricula and Double Degrees


**BS EE Curriculum: Flexible**

### Bachelor of Science in Electrical Engineering (Sample Program)

<table>
<thead>
<tr>
<th>Year 1 Fall</th>
<th>Year 1 Spring</th>
<th>Year 2 Fall</th>
<th>Year 2 Spring</th>
<th>Year 3 Fall</th>
<th>Year 3 Spring</th>
<th>Year 4 Fall</th>
<th>Year 4 Spring</th>
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<tr>
<td>Math 132 Calculus II (3 Credits)</td>
<td>Math 233 Calculus III (4 Credits)</td>
<td>Math 217 Differential Equations (4 Credits)</td>
<td>ESE 317 Engineering Mathematics (4 Credits)</td>
<td>ESE 326 Probability and Statistics (3 Credits)</td>
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<td>ESE 498 Senior Design Laboratory (3 Credits)</td>
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<td>Physics 118A General Physics II (4 Credits)</td>
<td>ESE 230 Intro to Electric + Electronic Circuits (4 Credits)</td>
<td>ESE 232 Intro to Electronics Circuits (3 Credits)</td>
<td>ESE 330 Engineering Electromagnetics Principles (3 Credits)</td>
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<td>ESE 260 Intro to Digital Logic (3 Credits)</td>
<td>Chem 111A General Chemistry I (3 Credits)</td>
<td>ESE 351 Signals and Systems (3 Credits)</td>
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### Courses

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<th>Pre-Req/General:</th>
<th>Credits</th>
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<table>
<thead>
<tr>
<th>Required CS Course:</th>
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<td>CSE 131 or 126</td>
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<table>
<thead>
<tr>
<th>EE Breadth:</th>
<th>Credits</th>
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<tr>
<td>Chosen from engineering or sciences outside EE</td>
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<table>
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<tr>
<th>Required EE Courses:</th>
<th>Credits</th>
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<td>ESE 230, 232, 260, ESE 317, 326, 330, 351, ESE 498</td>
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<table>
<thead>
<tr>
<th>Upper-level EE Laboratories:</th>
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<td>Two chosen from: ESE 331, 435, 447, 448, 465, 488</td>
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<th>Elective EE Courses:</th>
<th>Credits</th>
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<tr>
<td>Chosen from: ESE 330-399, ESE 400, 402, 405, 407, 409, 425, 430-499, ESE 503-589</td>
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<table>
<thead>
<tr>
<th>Non-ESE Engineering Elective:</th>
<th>Credits</th>
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<tr>
<td>ESE 141 Intro. Robotics</td>
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<th>Humanities and Social sciences:</th>
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<tr>
<td>Free Electives</td>
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<th>Total</th>
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<tr>
<td></td>
<td>120</td>
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</table>

Students must complete a selection of courses for which the accumulated engineering topics is 45 units. Also certain restrictions apply about the total number of credits of ESE 400 (independent study) and ESE 497 (undergraduate research.)
**BS SSE Curriculum: Flexible**

Students must complete a selection of courses for which the accumulated engineering topics is 45 units. Also certain restrictions apply about the total number of credits of ESE 400 (independent study) and ESE 497 (undergraduate research.)

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credits</th>
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<td>Pre-Req/General:</td>
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<tr>
<td>MATH 132, 233, 217, PHYS 117A, 118A, ESE 317, CHEM 111A, 151, ENGR 310</td>
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<td>Required CS Courses:</td>
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<td>Two chosen from: CSE 126, 131, 132, CS 200, 241.</td>
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<tr>
<td>Outside focus:</td>
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<tr>
<td>Chosen from engineering or sciences outside EE</td>
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<tr>
<td>Required SSE Courses:</td>
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<tr>
<td>ESE 105 or 251, MATH 429 or ESE 309, ESE 317, 326, 351, ESE 403, 441, 448, 499</td>
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<tr>
<td>Upper-level SSE Laboratory:</td>
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<tr>
<td>One chosen from: ESE 447, 448, 488.</td>
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<tr>
<td>Elective SSE Courses:</td>
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<tr>
<td>Chosen from: ESE 400 - 429, 440 - 459, 470 - 489, 497, ESE 500 - 529, 540 – 559; Up to 3 credits from: OSCM 356, OSCM 458, OMM 576, 577,</td>
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<tr>
<td>Non-ESE Engineering Elective:</td>
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<tr>
<td>Humanities and Social sciences:</td>
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<tr>
<td>Free Electives:</td>
<td>6 or 7</td>
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<tr>
<td>Total</td>
<td>120</td>
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Double Degrees or Majors

• Due to the ESE curricula flexibilities, students can complete **double degrees** in 4 years with, e.g.:

  - **Biomedical Engineering**
    * BS in EE or SSE and BS in BME
  - **Computer Engineering & Computer Science**
    * BS in EE and BS in CoE or CSE
  - **Chemical Engineering**
    * BS SSE and BS ChemE

• Students can also complete **double majors** in 4 years, e.g.:
  - BS (in any other program) with second major in Systems Science
  - BS in SSE with second major in Finance

• Students can also complete a **pre-medicine program** while pursuing a degree in 4 years: BS in EE or SSE with pre-medicine

For details visit the ESE website
Preston M. Green Dept. of Electrical & Systems Engineering

Double Degrees: BS EE and BS BME
Double Degrees: BS SSE and BS BME
### Double Degree: BS in EE and BS in SSE

#### Bachelor of Science in Electrical Engineering and Bachelor of Science in Systems Science and Engineering (Sample Program)

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 1</th>
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<th>Year 3</th>
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<tbody>
<tr>
<td><strong>Fall</strong></td>
<td><strong>Spring</strong></td>
<td><strong>Fall</strong></td>
<td><strong>Spring</strong></td>
<td><strong>Fall</strong></td>
<td><strong>Spring</strong></td>
<td><strong>Fall</strong></td>
<td><strong>Spring</strong></td>
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<tr>
<td>Math 132</td>
<td>Math 233</td>
<td>Math 217</td>
<td>ESE 317</td>
<td>Laboratory</td>
<td>ESE 448</td>
<td>ESE 498</td>
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<td>Calculus II</td>
<td>Calculus III</td>
<td>Differential Equations</td>
<td>Engineering Mathematics</td>
<td>EE</td>
<td>Systems Engineering Lab</td>
<td>EE and SSE</td>
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<tr>
<td>(4 Credits)</td>
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<td>(3 Credits)</td>
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<td><strong>Physics 1</strong></td>
<td><strong>Physics 2</strong></td>
<td><strong>ESE 230</strong></td>
<td><strong>ESE 232</strong></td>
<td><strong>ESE 260</strong></td>
<td><strong>Engr 310</strong></td>
<td><strong>ESE 499</strong></td>
<td><strong>Elective</strong></td>
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<tr>
<td>General Physics I</td>
<td>General Physics II</td>
<td>Intro to Electric + Electronic Circuits</td>
<td>Intro to Digital Logic</td>
<td>Technical Writing</td>
<td>Systems Engineering Design Project</td>
<td>EE and SSE</td>
<td>Free</td>
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<tr>
<td>(4 Credits)</td>
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<td><strong>Intro</strong></td>
<td><strong>Chem 111A</strong></td>
<td><strong>ESE 326</strong></td>
<td><strong>ESE 403</strong></td>
<td><strong>ESE 441</strong></td>
<td><strong>Undergraduate Research EE/SSE</strong></td>
<td><strong>Elective</strong></td>
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<td>Computer Science I</td>
<td>Engineering Course</td>
<td>General Chemistry I</td>
<td>Probability and Statistics</td>
<td>Operations Research</td>
<td>Control Systems</td>
<td>EE and SSE</td>
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<td>(3 Credits)</td>
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<td><strong>Chem 151</strong></td>
<td><strong>CSE 241</strong></td>
<td><strong>Undergraduate Research EE/SSE</strong></td>
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<td>Engineering Courses</td>
<td>Matrix Algebra</td>
<td>General Chemistry Laboratory I</td>
<td>Algorithms and Data Structures</td>
<td>EE and SSE</td>
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<td>ESE 351</td>
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<td>Engr 4501</td>
<td>Undergraduate Research EE/SSE</td>
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<tr>
<td>Social Science or Humanities</td>
<td>Intro to Systems Science and Engineering</td>
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<td>Signals and Systems</td>
<td>Social Science or Humanities</td>
<td>Social Science or Humanities</td>
<td>Engineering Ethics and Sustainability</td>
<td>Social Science or Humanities</td>
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**Updated to Fall 2011 requirements**
Advantages of Double Degrees

Graduates with double degrees benefit from the following advantages compared with their single-major peers.

- They have more job options and they stand out.
- They are in greater demand as new technologies require multi-disciplinary knowledge.
- With broader knowledge, they will be more creative.
- They will be able to adapt more easily to changes in the market.
Undergraduate Research Projects
Undergraduate Research Projects

Recent changes:

• We expanded the number and scope of undergraduate research projects

• Created collaborations with industry (Boeing, Brasch Manufacturing, LS Power, TranSwitch Corporation)

• Created multi-team Robotic Sensing projects

• Created ESE297: Introduction to Undergraduate Research Projects

Awards:

• Joshua York (BSEE 2009) received the First Place Award in the Saint Louis Area Undergraduate Research Symposium, April 2009
ESE Laboratories

State of the art facilities:
(a), (b) Renovated electronics laboratory
(c) Robotics laboratory
(d) Micro/nano photonics laboratory
ESE297 Introduction to Undergraduate Research Projects

- 2 Credits – open to students at all levels – CSE131 is the only pre-requisite
- Hands on experience robots, computers, acoustic sensors, EEG sensors and 3D cameras
ESE297 Introduction to Undergraduate Research Projects

- Implement real-time signal processing algorithms, with data acquisition on computers and robots
- Learn to use LabVIEW, LabVIEW Real-Time, Matlab and BCI2000
- Design, build and verify an acoustic source location project and a Brain Computer Interface project
- Good design experience for subsequent semesters
Acoustic Source Localization
Joshua York, Patricio S. La Rosa, and Arye Nehorai

**Goal:** Build an experimental setup for estimating the acoustic-source position using a microphone array

**Applications:** Teleconferencing, assisted navigation

Diagram of experimental setup and graphical user interface (GUI)

First Place Award, St. Louis Area Undergraduate Research Symposium, April 2009
ESE Launching Multi-team Robotic Sensing Project

• We created a new multi-team undergraduate project entitled Robotic Sensing
• Students will take leadership roles in multi-semester projects
• Students will implement sensor systems for mobile robots that make autonomous decisions based on the sensed environment
• These systems include acoustic, chemical, RF electromagnetic, infra-red, and visual sensors
• The project is multidisciplinary, involving hardware, signal processing, imaging, control, communications, and computer interfaces
• It is led by the department chair, Dr. Arye Nehorai, with the help of our engineer Ed Richter and PhD students
Robotic Sensing – Multi-Team Project

Hardware Design

- Physical/Chemical/Biological Background
- Transducer/Sensor Selection
- Signal Conditioning (analog filter, signal amplifier)
- Data Acquisition System (sampling rate and resolution)
- Microcontroller
- Actuators (motors)

Robotic Platform

Software/Interface Design

- Graphical display of variables of interest
- Graphical User Interface (GUI) Design
- User-defined System and Algorithms parameters
- Real-time Data Processing Arquitectures

Central Processing

Algorithm Design

- Preprocessing Algorithms (Digital filters: FIR, IIR)
- Statistical Signal Processing Algorithms

Communication
Robotic Sensing – Multi-Team Project (Cont.)

- Microphones
- Chemical Sensors
- Ultrasound Sensors
- Infrared Sensors
- Acoustic Vector Sensors
- Processor and Data Acquisition Board
- Servo Motor
- Camera Sensors

Robotic Platform
Robotic Sensing – Multi-Team Project (Cont.)

Advisor: Dr. Arye Nehorai

Engineer: Ed Richter

Microphones

Adaptive Source Position Estimation
Raphael Schwartz and Zachary Knudsen
Guide: Phani Chavali

Ultrasound Sensors

Real-time Tracking
Andrew Weins
Guide: Sandeep Gogineni

Robotic Platform

Processor and Data Acquisition Board

Camera Sensors

Visual Navigation
Evan Nixon and Alex Benjamin
Guides: Sandeep Gogineni

Chemical Sensors

Chemical Source Position Estimation
Anisha Rastogi and Jessi Mischel
Guide: Vanessa Tidwell
Robotic Microphone Sensing: Robotic Platform Design and Adaptive Control Algorithms

Chase LaFont and Arye Nehorai

**Goal:** Design robotic platform for the microphone array and develop controller algorithms to optimize source estimation position.

**Applications:** Acoustic surveillance and video conferencing
Robotic Microphone Sensing (Cont.)
Ultrasonic Robot Tracking
Andrew Wiens and Arye Nehorai

**Goal:** Develop an algorithm for mobile robot tracking using ultrasonic transducers

**Applications:** Autonomous robotics, defense

Andrew Wiens
EE and CoE Class of 2013

Robot with mono-pulse tracking algorithm and implementation in Labview
Ultrasonic Robot Tracking (Cont.)

Video of demonstration at the ESE Undergraduate Research Expo, April 30th, 2010
Chemical Sensing: Odor Identification and Source Localization

Joy Chiang and Arye Nehorai

**Goal:** Identify odors using a chemical sensor array; estimate direction to a chemical source; and guide a robot in seeking out the source

**Applications:** Detecting and locating chemical leaks or chemical weapons, monitoring food freshness
Source Localization using Chemical Sensing
Jessi Mischel, Anisha Rastogi, Vanessa Tidwell and Arye Nehorai

**Goal:** Develop a mobile platform to localize and pursue chemical source.

**Approach: Biological**
- Mimic shark olfactory system by creating sensor array to localize chemical sources using positional data
- Interface sensor array to mobile platform

Generating Light Sources on a Silicon Chip

Kim Venta and Lan Yang

**Goal**: Achieve ultra-high-quality micro-lasers on a silicon chip.

**Applications**: Communications and biomedicine

High throughput and high sensitivity on-chip sensing based on microlasers

Pulse-echo Methods for Determination of Broadband Ultrasonic Attenuation to Image Temperature in Tissue

Chris Reale and R. Martin Arthur

**Goal:** Maximize the echo signal bandwidth of a programmable pulser/receiver designed at WUSTL to improve ultrasonic thermometry

**Experimental setup**
Automated Music Generation for Sight Reading

Kevin McKee and Boaz Porat

Goal: Develop a computer program that automatically generates music

Application: Musical education

Kevin Mckee, EE Class of 2008, presenting his project at the Spring UGR Symposium 2008

Graphical user Interface (GUI) illustrating an example of a generated music by the software
Renewable Energy Resources: A Feasibility Study
Naitik Bhatt, Jessica Stigile, Joshua York, and Arye Nehorai

In collaboration with LS Power

Goal: Determine feasible sites for wind/PV solar development considering the availability of resources, current land use, legislation, environmental impacts, load demand, and cost

Experimental Process

NREL Wind Generation Tables
NREL Solar Irradiance Maps
MATLAB: Calculate actual Capacity Factor (CF)
Excel: Calculate CF from actual Irradiance
Database Data and zone by CF
Define/Quantify Obstacles to green energy development
Create Map/Rating System for developers

NREL Resource Availability Raw Data Maps
Optimal Policy Design on Carbon-Climate
Jessica Stigile, Alexandra Silva, Lindsay Aronson, Justin Ruths and Jr-Shin Li

Goal: Construct an optimal control model to derive optimal emission policies for mitigating climate change

Sample output of the webservice built to perform the optimizations

Jessica Stigile
SSE 2010

Alexandra Silva
SSE 2012

Lindsay Aronson
SSE 2012
Autonomous E-Car
Evan Nixon, Alex Benjamin, Sandeep Gogineni and Arye Nehorai

Goals:
• Navigate campus autonomously
  – Obstacle avoidance
  – Road detection
  – Irregular intersections
  – Differing light conditions
• GPS, Compass and Camera integration

Approach:
• Interface car with computer
• Sensors to get car information
• Edge detection algorithms

Alex Benjamin and Evan Nixon
SSE and EE Class of 2012
Brain-computer Interfaces

Goal: Detect signal features of intents from EEG

Applications: Rehabilitation, assistive technology, remote control

Approach:
• Develop statistical protocols to analyze EEG
• Implement and optimize spectral estimation
• Demonstrate performance via mobile robotic platform control
Brain Computer Interface (BCI)

(a) Student collecting EEG signals

In ESE 297, students learn how to collect EEG signals and teach the robot to move when a fist clench is detected.

Undergraduate Research Projects that use the BCI include:

- Development of Portable Visualization Suite for Low Cost EEG Systems (Professor: ShiNung Ching)
- Decoding EEG For Prosthetics And Brain Computer Interfaces (BCI) (Professor: Arye Nehorai)
Head-computer Interface for Robot Control
Sam Fok (BS EE & BME, 2011), Amanda Spencer (BS EE & BME, 2013), and Yongjia Liu (BS EE, 2013)
Preston M. Green Dept. of Electrical & Systems Engineering

Inertial Movement Units (IMU)

(a) Foot Tracking measurements  (b) Jogging in place with IMU on foot  (c) IMU measurements while jogging

IMU determines velocity and acceleration of movements, can be used to track position of a hiker or jogger (for example).

Undergraduate Research Project: Tremor Detection in Parkinson’s Disease patients
  • Study the typical tremor patterns in Parkinson’s patients
  • Stream IMU measurements to a computer from a healthy human imitating the tremor.
  • Develop signal processing algorithms to automatically detect the tremor
  • Modify the open-source data acquisition system to stream data over Bluetooth at 1000 samples/sec. Currently it only works at 100 samples/sec.
Eye Tracking to Help ALS Patients with Writing
Sana Naghipour, Saba Naghipour, Phani Chavali and Arye Nehorai

**Goal**: Develop a device for tracking pupil position

**Applications**: Help a patient write or draw using his/her eye movements

**Approach: Color Intensity Based**
- Divide each frame into several blocks of smaller sizes
- Compute the average intensity of each block
- Compute the centroid of the block with smallest intensity and declare that as the location of pupil

August 2011: Preliminary results obtained using a 15sec video recorded using an infrared camera.
RF antennas directionally transmit and receive RF signals; waveforms are designed to detect the Doppler Shift in the received signal, so both position and velocity can be determined simultaneously.

**Undergraduate Research Project: Fall Detection for Elderly Patients**
- Detect fall of an elderly subject by without requiring them to wear anything.
- Doppler shift detected in reflected signal off of a moving body.
Undergraduate Research Project: Source Localization using RF Transceivers

- 10 frequency division multiplexed RF transmitters and 10 RF receivers measuring changes in the received power due to a person standing in the Electromagnetic field.

- Cameron Fleming (BS EE, SSE, 2014) shown here in the center of the array. The orange square on the video behind her is showing her location.
Radio Tomographic Imaging for Fall Detection

Cameron Fleming, Daniel Lazar, Christine Weston, Jichuan Li, Robert Morley, Arye Nehorai

**Goal:**

- Use radio tomography to accurately determine the location and position (upright, prone) of a person within a room

**Applications:**

- Emergency alert systems for the elderly and disabled
Microphone Array

A 16 element microphone array can be cascaded into a 64 element array, linear or square arrangement. Beamforming can be used to spatially amplify the signal or detect the direction of an audio signal.

Undergraduate Research Project: Cocktail Party Hearing Aid using a Microphone Array

- Place the array in the center of a table and spatially amplify the array signal based on the direction the listener is looking.
- Transmit the spatially amplified signal to the listener’s smart phone.
The robot arm can be taught how to do complex maneuvers, and then controlled by computer to do complex moves and pick up objects.

Undergraduate Research Project: Robotics 3D Bin-Picking Optimization

- Empirically compute the transformation matrix to calibrate the 3D Kinect Camera Coordinate system to the Robot Coordinate system.
- Develop image processing algorithm to detect the “best” object for the robot to pick up.
- Using the transformation matrix and the ethernet interface on the robot, direct the robot to that position and pick of the object.
Autonomous Quadrocopter
Dr. Humberto Gonzalez's Lab

Goal:
• Implement low-level (stability) and high-level (positioning) control strategies for a quadrotor helicopters
• Provide no-collision safety guarantees of operation regardless of human input

Approach:
• Design data fusion algorithms to process data from accelerometers, gyroscopes, a pressure sensor, an electronic compass, and a motion capture system
• Design control strategies to find the correct actuation for each of the motors in the helicopter
• Implementation in Arduino and Embedded Linux environments
Students demonstrating their projects at the Engineering Expo (Spring 2014)
Measuring Localized CO₂ in Microgravity

Christie Powers, Andrew Wiens, Alex Mentch, Katie Burlingame, John Menze, Hans Runge, and Ricky Marcus

**Goal:** To determine the persistence of exhaled CO₂ in the oral/nasal region in microgravity

**Applications:** Environmental and astronaut health monitoring onboard the International Space Station

**Approach:**
- Develop system to measure CO₂ cloud in 1-g and microgravity environments
- Collect data from both environments
- Analyze to determine persistence relative to ambient conditions
Recent Undergraduate Research Projects (Fall 2012 – Spring 2015)

**Signal Processing and Biomedicine**
- **Yuni Teh**, Classification of upper limb EMG signals to control a robotic exoskeleton (Spring 2015)
- **Rachel Blake**, Analyzing EEG data from the brain computer interface (Spring 2013)
- **Daniel He** and **Satcher Hsieh**, Pulse oximetry for the Apple iPhone (Fall 2012)
- **Cameron Fleming** and **Thomas Powers**, Pupil tracking for ALS patients (Fall 2012)
- **DoHyun Kim**, 2D cursor control by EEG signal with a fieldtrip buffer system (Fall 2012)

**Security**
- **Daniel Lazar**, Real-time RF source localization using the NI-USRP (Spring 2013)
- **Ann Kitzmiller, Allison Doren** and **Alexandra Lockhart**, Sniper localization using acoustic sensors (Fall 2013)
Recent Undergraduate Research Projects (Fall 2012 – Spring 2015)

Robotics and Imaging

- **Nick Brunner**, Obstacle avoidance algorithm (Spring 2015)
- **Stephen Gower**, Mobile robot equipped with ultra-sonic transducer array and Kinect camera (Spring 2015)
- **Wei Luo**, Robotic bin picking using 2 Kinect cameras simultaneously (Fall 2014)
- **Kjartan Brownell**, Image Processing for 3D Robot Bin Picking (Fall 2014)
- **Matthew Johnson**, Kinect: Controlling a Rhino XR-4 robotic arm (Fall 2012)
- **Joshua Remba** and **Andrew Schoer**, Kinect camera based control of the FANUC Robot (Fall 2013)
Recent Undergraduate Research Projects (Fall 2012 – Spring 2015)

Energy

• David Sehloff and Celso Torres, Electrical load analysis for prediction of blackouts (Spring 2015)
• Daniel Goldberg and Lauren Steimle, Demand response management using game theory for the smart grid (Spring 2013)
• Andrew Hess and Sam Donohue, Electric vehicle charging scheduling algorithms (Spring 2013)
• Chenlin Wu and Yuhan Lou, Predicting solar generation from weather forecasts (Fall 2013)
• Smart homes I-CARES project
Recent Undergraduate Research Projects (Fall 2012 – Spring 2015)

Machine Learning for Big Data

- Daniel Goldberg and Andrew Elstein, Traffic light control using reinforcement learning (Fall 2013)
- Ge Song and Lauren Steimle, Machine learning basics with applications to email spam detection (Spring 2014)
Recent Undergraduate Research Projects (Fall 2012 – Spring 2015)

Financial Engineering

- Kaitlyn Crawley, comparison of weighting methods for index funds (Spring 2015)
- Jacob Cavner, multi-factor models for estimating asset prices (Spring 2015)
- Sam Jones, contagion of financial distress in the financial sector (Spring 2015)
- Daniel Wasserman, search algorithms for set optimization problems (Spring 2015)
- Nongchao Li, Optimal and distributed demand response strategy under duopoly competition (Spring 2015), Current trends and applications in convex optimization (Fall 2014)

Other

- Deko Ricketts, 3D interactive laser light show (Spring 2015)
- Alden Welsch, Aquaponics system design for Tilapia and Lettuce in the Midwest (Fall 2014)
Undergraduate Research Projects (Cont.)

Total number of enrollment in ESE 297, ESE 400, and ESE 497

Students registered

- 2006/2007: Students registered in ESE 297
- 2007/2008: Students registered in ESE 297
- 2008/2009: Students registered in ESE 297
- 2009/2010: Students registered in ESE 297
- 2010/2011: Students registered in ESE 297
- 2011/2012: Students registered in ESE 297
- 2012/2013: Students registered in ESE 297
- 2013/2014: Students registered in ESE 297

- 2006/2007: Students registered in ESE 400 and 497
- 2007/2008: Students registered in ESE 400 and 497
- 2008/2009: Students registered in ESE 400 and 497
- 2009/2010: Students registered in ESE 400 and 497
- 2010/2011: Students registered in ESE 400 and 497
- 2011/2012: Students registered in ESE 400 and 497
- 2012/2013: Students registered in ESE 400 and 497
- 2013/2014: Students registered in ESE 400 and 497
“Your dreams, our reality” has become the club’s new motto. With all of the participating students contributing program ideas and getting involved in the planning process, so far Feiereisen and his team have turned several dreams into realities.

IEEE makes a comeback, Student Life
Goal: Design, build, and market an interactive LED dance floor that is sensitive to pressure as well as beats in music.

Approach:

- **Electrical Engineering:** Switching power supply design and schematic/PCB layout design

- **Computer Engineering:** Designed hardware communications module in VHDL

- **Computer Science:** High-level programming in Java to enable GUI control, custom animations, and detection of beats

- **Mechanical Engineering:** Designed plastic and wood structure in AutoCAD and manufactured parts on a homebuilt CNC machine
Demonstration at Vertigo, the Annual All-school Dance party hosted by WUSTL Engineering Council
IEEE Student Branch Awards

• The WUSTL branch was named the **IEEE Outstanding Student Branch** by:
  – EEE St. Louis Section, 2009
  – IEEE Region 5, 2010

• The WUSTL branch placed second in the **IEEE Region 5 Ethics Competition**, April 2010

• Jeffrey Feiereisen (BSEE 2010) received the **Outstanding Student Member Award** from:
  – IEEE St. Louis Section, 2009
  – IEEE Region 5, 2010

• Andrew Wiens and Aaron Mosher received **First Place** at the annual IEEE St. Louis Section Black Box Competition, December 2010
International Experience

International Contest:

ESE Study Abroad:
  - Summer 2009: Tubingen, Germany
  - Summer 2010: Haifa, Israel
  - Summer 2012: Tel Aviv, Israel
  - Summer 2014: Tel Aviv, Israel

Acknowledgement: Thanks to Charlie Simmons (BS EE 1970) for supporting the Study Abroad programs
Summer 2014: Tel Aviv, Israel

• Seven undergraduate students from the department participated in this international experience on May 20 – May 26, 2014
• Students visited Tel Aviv University to learn about the state-of-the-art research being performed there
• The group also visited three high-tech companies in the region: SolarEdge, Verint, Google Israel, and PrimeSense
• Students also toured the country and experienced local culture
Career Opportunities
Our graduates are highly sought after and have exciting positions in:

- Academia
- Aerospace
- Computers & communications
- Data storage
- Defense
- Electronics
- Energy and power
- Finances
- Medical imaging
- Physical layer communications
- Semi-conductors & solid-state electronics
Examples of Companies Employing ESE Graduates:

- **Energy:** Exxon
- **Defense:** Northrop Grumman, Raytheon, Boeing
- **SemiGov Lab:** APL, Lincoln Lab, JPL
- **Finance:** Bank of America, Citi Group, NISA Investment Advisors
- **Auto:** Honda of America
- **Consulting:** Accenture, Corporate Executive Board, Deloitte Consulting, CRB Consulting Engineering
- **Food:** Anheuser-Busch, Nestlé (USA & Canada)
- **Health Care:** Cerner, Proctor & Gamble, Computerized Medical Systems
- **Communications:** GeoEye
- **Engineering:** Burns & McDonnell, Jacobs Engineering
- **Government:** U.S. Patent & Trademark Office
Where are they now?
where recent graduates are working or studying

Andrew Wiens (BS EE, 2013) is a PhD student in EE at Georgia Tech
Evan Nixon (BS SSE, BSAS EE, 2012) is an MS student in Artificial Intelligence at Stanford
William Donnelly (BS EE, 2013) is a Site Reliability Engineer with Google
Hidemasa Kato (BS SSE, 2013) is a People Operations Analyst at Google
Jason Binder (BS EE, 2013) is an Electrical Engineer at Square
Sydney Saito (BS EE, MS SSM, 2013) is a Systems Engineer at Raytheon
Colleen Rhoades (BS BME, BSAS SSE, 2013) is a PhD student in Bioengineering at Stanford University
Taoridi Bello (MSEE 2013) is an Electrical Engineer at ExxonMobil
Yujing Lin (BS EE, MS SSM, 2013) is a PhD student in Industrial Engineering at Northwestern Univ.
Cameron Fleming (BS EE, BSAS SSE, 2014) is a Software Engineer at FactSet Research Systems
Calvin Murdock (BS EE, 2013) is a PhD student in Machine Learning at Carnegie Mellon University
Chen Zhao (BSAS EE, BS BME, 2014) is an MS student in Bioengineering at Johns Hopkins University
Daniel Goldberg (BS SSE, 2014) works for NASDAQ
Paula Avery (BS/MS EE, BSAS SSE, 2013) is an Engineer at Pacific Gas & Electric
Ge Song (BS SSE, 2014) is a Platform Software Engineer with Dell
Student Entrepreneurship

We encourage students to:

- Take relevant classes or programs
- Conduct innovative projects
- Participate in competitions

We also advertise entrepreneurship activities on the web
Successful Alumni Leaders

- Numerous are founders or CEO's of companies
- Dr. John Sommerer, was Head of Space Department, Johns Hopkins University Applied Physics Laboratory
- Mr. Zachary Lemnios, was Assistant Secretary of Defense for Research and Engineering of the US Department of Defense
- Dr. T. Alan Hurwitz, President of Gallaudet University
- Three are Deans of Engineering
- One faculty member at Harvard, UIUC, UCLA, Notre Dame, Texas A&M
- Two are faculty members at each of: Stanford, Georgia Tech, and Carnegie Mellon University
ESE Alumnus Wins Nobel Prize in Chemistry for 2014

Dr. W. E. Moerner (BS EE, Math, and Physics 1975) has been awarded the Nobel Prize in Chemistry for 2014 “for the development of super-resolved fluorescence microscopy.” He is the Chairman of the Department of Chemistry at Stanford University.
Preston M. Green Dept. of Electrical & Systems Engineering

Additional Information

• ESE department web site: http://www.ese.wustl.edu

• ESE undergraduate program: http://ese.wustl.edu/undergraduateprograms/Pages/default.aspx

• ESE undergraduate research: http://ese.wustl.edu/Research/Pages/undergraduate-research.aspx

• Hall of Fame: http://ese.wustl.edu/people/Pages/AlumniHallofFame.aspx

• Alumni news: http://ese.wustl.edu/people/Pages/Alumni.aspx
The Preston M. Green Hall
Questions?