Breadth of Opportunities in Electrical and Systems Engineering

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

www.ese.wustl.edu
Outline

• ESE areas and applications
• Our faculty
• Changes we made since 2006
• Flexible curricula and double degrees
• Undergraduate research projects
• Study abroad program
• Career opportunities
Research Areas & Applications

**Energy**
- Storage, Photovoltaic Cells
- Sensor Networks
- Smart Grid, Efficiency
- Power Electronics

**Medicine**
- Sensors
- Imaging
- Proteomics
- Genomics

**Security & Defense**
- Radar, Sonar
- Sensors, Networks
- Information Analysis
- Environment Monitoring

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

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

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

**Robotics**
- Control, Mechatronics
- Surgery

**Systems Applications**
- Biology, Medicine
- Operations Research
- Management
- Finances
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.
Degrees We Offer

• **BS**
  – Electrical Engineering
  – Systems Science & Engineering
  – Applied Science Major in EE
  – Applied Science Major in SSE

• **Minors**
  – Electrical Engineering
  – Robotics
  – Mechatronics (new)
  – Energy Engineering (in development)
Department of Electrical & Systems Engineering

Meet the Faculty

Applied Physics

Daniel L. Rode
Jung-Tsung Shen
Barry E. Spielman
Lan Yang

Information Processing

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

Systems Science and Applied Mathematics

I. Norman Katz
Jr-Shin Li
Hiro Mukai
Ervin Y. Rodin
Heinz M. Schaettler
Tzyh-Jong Tarn
Awards (2006 - 2009)

- **Dr. Arye Nehorai** received the 2006 Technical Achievement Award from the IEEE Signal Processing Society.

- **Dr. Jr-Shin Li** received the NSF CAREER Award: "Ensemble Control with Applications to Spectroscopy, Imaging, and Computation," 2007.

- **Dr. Chris Byrnes** is awarded the 2008 Hendrik W. Bode Lecture Prize by the IEEE.

- **Dr. T. J. Tarn** received the 2009 George Saridis Leadership Award in Robotics and Automation from the IEEE Robotics and Automation Society, in May 2009.

- Several faculty members have given a total of 10 keynote or plenary lectures in major conferences.

- **Joshua York** (BSEE 2009), won First Place Award in the St. Louis Area Undergraduate Research Symposium (STLAURS) under the guidance of **Dr. Nehorai**, 2009.
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

- Hired new faculty
- Improved the instruction
- Renovated our electronics lab
- Introduced new minors in Mechatronics and Energy (soon)
- Added lab to ESE 230 Intro to Electrical & Electronic Circuits
- Made EE senior design more flexible
- Expanded undergraduate research projects
- Collaborated with industry on projects
- Created a study abroad program in summer 2009, 2010
- Revitalized the IEEE student chapter
Changes We Made (Cont.)

- Revitalize dual degrees
- Communicate with prospective students
- Promote programs on web:
  - Descriptions and opportunities
  - Flexible curricula
  - Double majors
  - Highlight achievements
  - Alumni news
Electronics Lab Renovation

**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 $114k on the renovation
New Courses

We introduced:

• ESE 102 Introduction to Engineering Tools: Matlab and Simulink, Spring 2010
• ESE 103 Introduction to Electrical Engineering, Fall 2009
• ESE 105 Introduction to Electrical & Systems Engineering, Fall 2007
• ESE 107 Introduction to Sustainable Energy, Fall 2008
• ESE 230 Introduction to Electrical & Electronic Circuits, Fall 2008 (new version)
• ESE 437 Sustainable Energy Systems, Spring 2010
• ESE 497 Undergraduate Research, Fall 2007
Flexible Curricula and Double Degrees
### Courses

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<tr>
<th>Credits</th>
<th>Courses</th>
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<tr>
<th>4 or 3</th>
<th>Required CS Course:</th>
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<tr>
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<td>CSE 131 or 126</td>
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<tr>
<th>9</th>
<th>EE Breadth:</th>
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<td>Chosen from engineering or sciences outside EE</td>
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<tr>
<th>26</th>
<th>Required EE Courses:</th>
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<th>6</th>
<th>Upper-level EE Laboratories:</th>
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<tr>
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<td>Two chosen from: ESE 331, ESE 435, 447, 448, 465, 488</td>
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<tr>
<th>15</th>
<th>Elective EE Courses:</th>
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<td>Chosen from: ESE 330-399, ESE 400, 402, 405, 407, 409, 425, 430-499, ESE 503-589</td>
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<th>3</th>
<th>Non-ESE Engineering Elective:</th>
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<tr>
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<td>ESE 141 Intro. Robotics:</td>
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<tr>
<th>18</th>
<th>Humanities and Social sciences:</th>
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<tbody>
<tr>
<td></td>
<td>Free Electives:</td>
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<td>11 or 12</td>
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</table>

| 120    | Total                           |

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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.)
**Department of Electrical & Systems Engineering**

**Double Degree: BS EE and BS BME**

![Course Chart](image)

**Total number of credits: 146**
Double Degree: BSAS EE and BS CoE
BSAS EE with Second Major in CS
BS SSE Curriculum: Electives

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.)
Double Degree: BSAS SSE and BS BME
Department of Electrical & Systems Engineering

Double Degree: BS SSE and BS BME

Total number of credits: 142
Undergraduate Research Projects
State of the art facilities:

(a), (b) Renovated electronics laboratory
(c) Robotics laboratory
(d) Micro/nano photonics laboratory
<table>
<thead>
<tr>
<th>Advisor</th>
<th>Currently Available Projects</th>
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<tbody>
<tr>
<td>R. Martin Arthur</td>
<td>Temperature Imaging Using Change in Backscattered Ultrasound Energy</td>
</tr>
<tr>
<td></td>
<td>Body-surface and Inverse Electrocardiography for Assessing Risk of VT and Electrical Consequences of Diabetes</td>
</tr>
<tr>
<td>Jr-Shin Li</td>
<td>Feedback Control of Climate Dynamics</td>
</tr>
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<td>Development of Control and Optimization Methods for NMR and MRI Systems</td>
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<tr>
<td>Paul Min</td>
<td>Indoor Location of Wireless Devices</td>
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<tr>
<td>Arye Nehorai</td>
<td><strong>Robotic Sensing -- Multi-Team Project</strong></td>
</tr>
<tr>
<td></td>
<td>Microphone Array Processing for Source Localization</td>
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<td></td>
<td>Classification of Smells Using New &quot;Electronic Nose&quot; Sensors</td>
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<tr>
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<td>Renewable Energy Resources <em>(with LS Power)</em></td>
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<tr>
<td></td>
<td>Microphone Amplifier for Photo-acoustic Infrared Gas Detector <em>(with Brasch Manufacturing)</em></td>
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<td>MIMO Radar Using Acoustic Vector Sensors</td>
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<td>Modeling 3D Distortion of a Fluorescence Microscope and CCD Imaging: Theory to Practice</td>
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<tr>
<td></td>
<td>Automated Music Generation for Sight Reading</td>
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<tr>
<td></td>
<td>Design Assistive Technology for People with Cognitive Disabilities</td>
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<tr>
<td>Advisor</td>
<td>Currently Available Projects</td>
</tr>
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<td>------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
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<tr>
<td>William Pickard</td>
<td>Independent Learning Group on Sustainable Energy</td>
</tr>
<tr>
<td>Barry Spielman</td>
<td>Electromagnetic Analysis of Metamaterials</td>
</tr>
<tr>
<td>Lan Yang</td>
<td>A Novel Photonic Tool for Sensing</td>
</tr>
<tr>
<td>Ed Richter</td>
<td>Novel Photonic Structure to Enhance Solar Energy Conversion for Electricity and Hydrogen Production</td>
</tr>
<tr>
<td></td>
<td>MPEG-4 Decoder with the Tilera 64 Processor (with TranSwitch Corporation)</td>
</tr>
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</table>
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
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)

Software/Interface Design

- Graphical display of variables of interest
- Graphical User Interface (GUI) Design

Algorithm Design

- Preprocessing Algorithms (Digital filters: FIR, IIR)
- Statistical Signal Processing Algorithms
- User-defined System and Algorithms parameters
- Real-time Data Processing Architectures

Central Processing

Robotic Platform

- Central Processing

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

- Microphones
- Chemical Sensors
- Ultrasound Sensors
- Infrared Sensors
- Acoustic Vector Sensors
- Camera Sensors
- Servo Motor
- Processor and Data Acquisition Board
Robotic Sensing: Current Projects

Advisor: Dr. Arye Nehorai

Microphones
Adaptive source position estimation
(Raphael Schwartz and Zachary Knudsen)

Robotic Platform
Processor and Data Acquisition Board

Chemical Sensors
Chemical source position estimation
(Joy Chiang)

Ultrasound Sensors
Real-time tracking
(Andrew Weins)

Acoustic Vector Sensors
Acoustic vector sensors for source location
(Evan Nixon)
Robotic Microphone Sensing: Data Processing Architectures for Real-Time Acoustic Source Position Estimation
Raphael Schwartz, Zachary Knudsen, and Arye Nehorai

**Goal:** Develop data processing architectures to estimate the location of an acoustic source and adaptively alter microphone array geometry to improve estimation in real time

**Applications:** Acoustic surveillance, videoconferencing, and robotic navigation

![Multiple parallel processes](image)

![Closed loop diagram](image)
Goal: Design robotic platform for the microphone array and develop controller algorithms to optimize source estimation position.

Applications: Acoustic Surveillance and Video Conferencing

Illustration of closed-loop for adaptively estimating source position
Demonstration at the WUSTL Undergraduate Research Symposium, October 24th, 2009
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

*Source: Nature Photonics, Vol. 4, pp. 46-49, Jan. 2010*
MPEG-4 Decoder with the Tilera 64 Processor

Whitney Flohr, Mark Franklin, and Ed Richter

In collaboration with TranSwitch Corporation

Goal: Create a parallel processing algorithm to speed up MPEG-4 decoding with the Tilera 64 core processor

Applications: Communications and multimedia

MPEG flow chart and its implementation on the Tilera 64 processor

Inter-processor communication
Designing a Codebook-Excited Linear Predictor (CELP) Speech Codec
Justin Lawler and Robert Morley

**Goal**: Build a Codebook-Excited Linear Predictor digital speech codec

**Application**: Cellular phones

Electronic circuit board used and encoder flow diagram
Breathing Motion Compensation for Medical Robots
Jason Hall and Eftychios Christoforou

**Goal**: Develop a method to allow robots in the medical field to adjust to the patient's breathing

Jason Hall calibrating the device. SSE Class of 2006

Experimental setup
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

Graphical user Interface (GUI) illustrating an example of a generated music by the software

Kevin Mckee, EE Class of 2008, presenting his project at the Spring UGR Symposium 2008
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 Resource Availability Raw Data Maps

NREL Wind Generation Tables

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
Study Abroad Program
Summer 2009: Tubingen, Germany

Introduction to Multimodal Imaging

- We created a study abroad program in summer 2009
- Six ESE undergraduate students participated
- **Topic:** Introduction to multimodal imaging
- **Host:** University of Tübingen MEG-Center, and the Max Planck Institute for Biological Cybernetics, Germany
Summer 2009: Tubingen, Germany (Cont.)

Program

• **Period:** May 11, 2009 – May 15, 2009

• One unit of credit, with the option to continue working on an independent study or undergraduate research course

• Lectures, projects, lab visits, and social programs

• Final report

• Acknowledgment: We are grateful to the donor for his generous support that made this program possible
Summer 2009: Tubingen, Germany (Cont.)

Exploring Tubingen downtown.
From left to right: Jennifer Sisto, Zeynep Esin, Michael Steinbock, Ian Beil, Patricio S. La Rosa, Jessica Stigile, and Jeffrey Feiereisen

Jeffrey Feiereisen (BSEE 2010) uses magnetoencephalography (MEG) device and Jennifer Sisto (BSSS 2010) tests a transcranial magnetic stimulation device (TMS).
We created a new study abroad program at the Technion, Israel, in May 2010.

Eleven students were selected to participate.

They will visit the laboratories of Control and Robotics, Signal and Image processing, and Network Biology in the Departments of Electrical Engineering and Mechanical Engineering of the Technion.

Also Aerospace Engineering, Biomedical Engineering, and Industrial Engineering and Management Departments of the Technion.
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
Successful Alumni Leaders

- Several are founders or CEO's of companies
- CTO of Johns Hopkins Applied Physics Lab
- CTO of MIT Lincoln Lab is now Director of Defense Research and Engineering of US Department of Defense (DOD)
- President of Gallaudet University
- Three are Deans of Engineering
- Two are faculty members at each of: UIUC, Georgia Tech, and Carnegie Mellon University
- One faculty member at Harvard
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

• Alumni news:
  
  http://ese.wustl.edu/people/Pages/Alumni.aspx
Summary

• Unique structure: EE and Systems
• Broad, in-depth, and flexible curricula allowing:
  – Double degrees with BME, CoE, ChemE
  – Double major with CS, Finance
  – Pre-Medicine program
• Growth in technologies and applications
• Graduates are highly sought after
• Department has strong reputation and alumni
Thanks!