Intelligent Systems and Sensors
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Wireless Sensor Network for Border Surveillance

Reconfigurable and Programmable Automotive Smart Sensors (Driver Safety)

Intelligent Sensors for Remote Screening and Self-Monitoring for Vision Loss Diseases

Sensor Mote Processor Chip Layout

Intelligent Sensors for Remote Screening and Self-Monitoring for Vision Loss Diseases

Ophthalmoscope Imaging Sensors
Integrated Optics and Nanophotonics Lab
Prof. Ivan Avrutsky [ivan.avrutksy@wayne.edu]
http://ece.eng.wayne.edu/~avrutsky/

- Integrated devices and systems to control light at deep subwavelength to nanoscale dimensions
- Resonantly enhanced optical interactions using highly confined guided and localized optical modes
- Design, fabrication, and characterization of waveguide grating based devices
- Applications in optical communication, all-optical signal processing, optical sensors, lab-on-a-chip systems
- Recent collaboration projects include NSF Center for Photonic and Multiscale Nannomaterials, with U of Michigan and Purdue; Air Force Research Lab at Wright-Patterson AFB.
Microfluidics and Lab-on-a-chip instruments for high throughput biology
- Fluidic computers
- Digital assays
- Optofluidic tweezers
- Multiphase microfluidics
- Interfacial phenomena

Wearable sensors for health monitoring
- Athletic training
- Focus and fatigue
- Wireless health
Material and Device Research
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- Nanophotonics and Nano-optics
- Plasmonics and optical metamaterials
- Nonlinear and quantum optics
- Nano-optoelectronics based on graphene and beyond
- Electromagnetics & High-Frequency Electronic Devices/Circuits
- RF/THz front-end modules: antennas, devices and circuits
- Electromagnetic field theory
- Nanomaterial-based wireless sensors “Internet-of-nanothings”
Dr. Han’s current focus is on sensing technologies for advanced materials to improve product quality, a multi-disciplinary research area involves:

- Physical principals
- Sensing and imaging
- Electronics and controls
- Optics
- Acoustics
- Precise measurement
- Materials Science
- Fracture Mechanics
- Digital Signal Processing
- Digital Imaging Processing
- Computing & Simulation

Applications

IR images shows cracks in a turbine disk.

a. Showing cracks with their locations in the part.
b. Processed images showing the cracks as a dark-field detection.
Artificial Neural Networks
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Machine Learning & Neural Networks
- Artificial Neural Systems
- Associative Memories
- Face Recognition
- Application to Physiologic Signal Processing
- Application to optimization
• Theory of Discrete Event Systems
  – Models of discrete event systems
  – Supervisory control of discrete event systems
  – Controllability, observability, and co-observability
  – Decentralized control and hierarchical control
  – On-line control and lookahead control
  – Robust and adaptive control
  – Diagnosis and diagnosability
  – Opacity and detectability
  – Control of fuzzy discrete event systems
  – Networked control with communication delays and losses

• Applications of Discrete Event Systems Theory
  – Control and diagnosis in smart grids: safety control, load balance, equipment protection, fault diagnosis and allocation
  – Control and diagnosis of battery management systems: over-charging and under-charging protection, system re-configuration, fault diagnosis and allocation
  – Control of manufacturing systems: machine coordination, job scheduling, nonblocking
  – Control of networked vehicle systems: vehicle control, infrastructure control
  – Control of information flow: secrecy, security and opacity
  – Self-learning fuzzy discrete event system for HIV/AIDS treatment regimen selection
» **Energy storage systems** for electrification of vehicles, next generation of batteries, supercapacitors & fuel cells, wireless chargers, and battery state of charge estimators.

» **Alternative energy sources** including; solar, wind, geothermal, ocean-tidal waves, and nuclear energy.

» **Real-time non-destructive techniques** for evaluation of materials and devices, including in-situ x-ray and neutron diffraction, spectroelectrochemistry, magneto-inductive defectometry, photo thermal imaging.

» **Nano materials and applications**, including quantum dots, 2-D nanosheets, magnetic hypothermia, x-ray detectors, gas sensors, and solid state micro batteries.
Signal Processing in Sensor Networks
- Sensor nodes collect **distributed** measurements
- Nodes communicate via **wireless**
- We want to compute a **linear function** of the measurements (target tracking, spectrum sensing)
- How to share measurements to minimize the **time**, **bandwidth**, and **energy** consumed?
- Answer: a **hierarchical** message-passing algorithm is nearly optimal!

Classifying Compressed Signals
- Want to **classify** a high-dimensional signal/image (faces, objects)
- For storage and processing, we prefer to **compress** the signal to a low-dimensional space
- How does this affect classification? **How low** can the dimension be?
- Answer: when signals lie near **subspaces**, we can express exactly how many dimensions are necessary for reliable classification
Computer-Assisted Robot-Enhanced Systems
Profs. Abhilash Pandya and Luke Reisner
ece.eng.wayne.edu/~apandya; youtube.com/careslab

Robotics & Automation:
Da Vinci surgery

Visualization: Virtual & augmented reality, medical imaging

Simulation: Automotive, NASA
Automated Video Surveillance (Sponsored by NSF, Patented Technology)

- Design of a large-scale and cost-effective AVS system, called Wayne State Automated Video Surveillance (WAVS)

Improved High Efficiency Video Encoding (HEVC)

- Project Objective: faster encoding without sacrificing the bitrate and distortion by efficient block partitioning
- Approaches: Information Theory (Entropy) and Machine Learning

Scalable Interactive Video Streaming (Sponsored by NSF)

- Project Objectives: efficient support of interactive operations, efficient support of heterogeneous receivers, efficient support of advertisements, improved cache management
DNA digital circuit design
DNA analog and fuzzy circuit design

Localized DNA Majority Gate
Monorail DNA logic inverter design

Quantum Cellular Automata (QCA) design
Majority / Minority synthesis

QCA pipeline array
Digital chip design

Fuzzy chips for automotive and defense applications
Fuzzy Models
Modeling and Control of Microgrid and Smart Grid
- Management of active distribution networks with PHEVs and PVs
- Transfer impedance based stability analysis
- Power flow tracing
- Modeling, analysis, design and control of alternative energy systems (wind, solar, tidal, fuel cells, etc.)

Characterization and Management of Large Scale Battery Systems
- Reconfigurable power electronic converters
- Reliability assessment of large scale battery systems
- Balanced charging/discharging control

Advanced Power Electronic Converters
- High-efficiency and high power density power converters
- High efficiency and misalignment robust wireless EV changer
- Integrated in-wheel electric drivetrain
- Reconfigurable power electronic converters

Environmentally Sensitive Energy Use
- Identification of generation and emission sources associated with individual loads
- Emission based optimal load management

Prototype: Rectifier V/I @500W, 15.5kHZ Efficiency = 85%. Target: 92% @ 3.3 kW

Voltage Management of Distribution Networks with High Penetration of PVs

33 – bus test system
Distributed team coordination in networked control systems

- UAV Team Deployment Planning
- UGV Platoon Formation
- Connected and Automated Vehicles
- Smart Grid Power Management
- Battery Network Control, Diagnosis

Distributed Control
  - Control/Communication Co-design
  - System Identification
  - State Estimation
  - Optimal Control
  - Robust Control
  - Diagnosis
**Micro/Nano Systems and Sensors**

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### Advanced neural probes

- **Integration of optical stimulation for optogenetic study:** (a) a 3D neural probe with 3 integrated optical fibers; (b) probe with 4 electrodes and optical stimulating capability; (c) average spiking rates recorded from the rat auditory cortex using our prototype optogenetic 3D neural probe.

### Smart yarns

- **Left-upper figure:** smart yarn fiber wrapped around the wrist for blood pulse measurement. The inset is an SEM image of a kink-free knot made by a smart yarn. **Right-upper figure:** representative arterial blood pulse data measured using the smart yarn.

### Unobtrusive cardiovascular monitoring enabled by ultrasensitive motion sensors

- **An ultrasensitive motion sensor in comparison with an iPhone 4.** Its noise is at 10 ng/√Hz level, 100,000 times better than typical MEMS accelerometers in smart phones (~ mg/√Hz)

- **Representative BCG pulses recorded.** Valuable clinical information, such as **myocardial strength**, can be derived from BCG waveforms.

- **The sensor can be conveniently attached to sofas or beds for unobtrusive recording of ballistocardiogram (BCG), the vibration caused by heart beat.**
• **Theory of Fuzzy Logic Systems**
  - Fuzzy modeling for complex systems
  - Fuzzy control that takes advantage of human knowledge and experience to deal with challenging real-world control problems
  - Fuzzy discrete event systems capable of modeling discrete event systems with uncertainties
  - Fuzzy hybrid systems to better model a mixture of systems represented by differential equations and discrete events with uncertainties
  - Fuzzy logic-based computational recognition-primed decision model

• **Applications of Fuzzy Logic Systems Theory**
  - Real-time feedback fuzzy control of mean arterial pressure in postsurgical patients in surgical intensive care unit
  - Fuzzy control for improving engine power and speed behavior in hybrid electric vehicles
  - Real-time closed-loop fuzzy control of resuscitation of hemorrhagic shock
  - Intelligent sepsis alert for patients in emergency room
  - Self-learning fuzzy discrete event system for HIV/AIDS treatment regimen selection
  - Distributed, collaborative intelligent agent system for proactive postmarketing drug safety surveillance
Nanoscale Optics
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Functional optical nanostructures
- Artificial materials with controlled refractive properties
- Negative refraction

Optical surface modification
- Building See-through Optical Sensors on display surface
- Artificial composite surface on transparent substrates

Optical nanostructure design and fabrication
- Nano-sphere lithography
- Scattering enhanced periodic structures