Spring 2024

ECE 619: Intelligent Sensing for Smart Grid and Smart City

Philip Pong

Required Content Areas

Course number and name – ECE 619 Intelligent Sensing for Smart Grid and Smart City

Credits— 3 Credits

Contact hours— 3 contact hours

Name(s) of instructor(s) or course coordinator(s)— Philip Pong

Instructional Materials—

Specific course information (Brief description of the content of the course (catalog description))

This course introduces the fundamentals and applications of intelligent sensing technology to smart grid and smart city. The course covers the fundamental sensing principles, types and selection of sensors. Engineering design of sensing techniques, estimation and evaluation of sensor calibration and their responses by using finite element method, sensor noise and shielding design will be addressed. Signal analysis techniques such as wavelet analysis and sensor fusion will be discussed. Anomaly detection, fault classification and prediction and decision making on sensor data by machine learning, and the applications of electromagnetic sensing in power systems will be covered. Advanced sensor applications topics in smart grid and smart city will also be included.

Prerequisites or corequisites— None

Educational objectives for the course (e.g. The student will be able to explain the significance of current research about a particular topic.)—

The purpose of this course is to fulfill the growing need of learning and applying sensors in engineering. The 21st century is an age of sensors. We will soon be living in a world with trillions of sensors with connectivity. People are calling it an Internet of Things (IoT) or Internet of Sensors (IoS). Together with big data and machine learning, this new sensing paradigm is going to bring about revolutionary changes to smart grid and smart city. Sensors are going to play a major role in practical engineering projects as well as blue sky research.

Brief list of topics to be covered—

Topic 1:	Sensors: fundamentals • Sensors for realizing smart homes, autonomous vehicles, root of IoT • Sensors and transducers, common transduction principles, common sensor categories in IoT

	• Current status of power grids, autonomous energy grids, Monitoring challenges for the existing power grids • Electromagnetic sensors in smart phones, Comparison of magnetic sensors, Sensor applications in smart grid and smart city • Terminology, sensor classification, magnetic sensors
Topic 2:	Engineering design of sensing techniques • Sensor calibration and response • Design tool: finite element method (FEM) simulation • Physical phenomena can be solved by FEM • MATLAB partial differential equation (PDE) toolbox • FEM simulation of electrostatically actuated MEMS device
Topic 3:	Design consideration: noise and shielding • Nature of noise, why is noise a concern • Intrinsic noise • Extrinsic noise • Shieldings
Topic 4:	Sensor signal analysis • Time-frequency analysis, Morlet wavelet convolution, convolution in the time domain • Filter-Hilbert method • Basic frequency-domain manipulation • Multivariate time series analysis • Principal component analysis
Topic 5:	Sensor fusion • Sensor fusion, fusion architectures, approaches of sensor fusion • Least-square error method, maximum likelihood estimation, Bayesian inference, Kalman filter • Neural network, activation function, training, backpropagation, feed-forward neural network, recurrent neural network, recurrent neural network long short term memory, radial basis function neural network, convolutional neural network • Machine fault diagnosis • Voting methods, majority (plurality) vote, voting for fusion of ranked data, Condorcet criterion, Borda count, monotonicity criterion, instant runoff voting, Copeland's method, threat assessment problem, voting logic fusion
Topic 6:	Data analytic • Big data • K-nearest neighbor algorithm • Regression models

	• Density-based spatial clustering of applications with noise • Support vector machine classifier
Topic 7:	Finding answers from measurement: inverse problem & search algorithm • Inverse problem, unconstrained minimization, basic optimization, minimization with equality constraint, economic dispatch Lagrangian, • Newton-Raphson algorithm for root finding • Steepest descent method • Genetic algorithm • Particle swarm optimization