Faculty Research Profiles
2012-13

Electrical Engineering
Industrial & Systems Engineering
Mechanical Engineering

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Mission Statement

USD Engineering is distinguished by student-centered education that emphasizes modern engineering skills and development of the whole person. We are dedicated to innovative teaching, meaningful scholarship, and compassionate service.

Message from the Director

I am proud to present this report that introduces our well qualified faculty and their meaningful scholarship by providing an overview of the research topics currently being pursued in Engineering at USD. Engineering research lays the groundwork for the innovations of tomorrow that can improve the lives and the livelihood of many.

Faculty areas of research include advances technology and processes in wide array of topics in Electrical, Industrial & Systems, and Mechanical Engineering with applications to healthcare & medicine, telecommunications, manufacturing, aerospace, and more. Scholarship in engineering education helps to address the engineering workforce crisis by providing innovations in teaching and learning that help students succeed in the demanding preparation needed to become the engineers of tomorrow.

-Kathleen A. Kramer

Faculty and Their Research Interests

Electrical Engineering Faculty

Ernest M. Kim, P.E.
Ph.D. New Mexico State University
Radio Frequency Design, Optical Transmission Systems, Embedded Systems, Analog Circuits, RF circuits, Optoelectronic circuits, Fiber Optics, Cable Television

Kathleen A. Kramer
Ph.D. California Institute of Technology
Sensor Data Fusion, Kalman Filters, Neural Networks, Evidence Accrual, System Identification, Fuzzy Logic

Susan M. Lord
Ph.D. Stanford University
Engineering Education, Persistence of Women in Engineering, Lifelong Learning, Feminist and Liberative Pedagogies, Cooperative Learning, Service learning, Optoelectronic Materials and Devices

Mikaya L.D. Lumori
Ph.D. University of Arizona
Nonlinear System Identification Techniques, Electromagnetic Hyperthermia

Michael Steven Morse
Ph.D. Clemson University
Biological Effects of Electricity, Diffuse Electrical Injury, Modeling of Current Pathways, Carpal Tunnel Syndrome, Electrical Injury and Safety, Electromechanical Product Failure

Thomas F. Schubert
Ph.D. University of California, Irvine
Fourier Optics, Wave Propagation, Analog Electronics, Communication Systems, Engineering Education.

Industrial & Systems Engineering Faculty

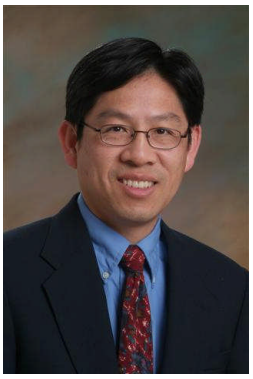
Bradley Chase
Ph.D. University of Louisville
Human Factors Engineering, Ergonomics, Electrophysiological Measures and Cognitive Performance, Environmental Stress and Performance, Healthcare Performance Improvement, Occupational Safety, Work Design, and Application of Industrial Engineering Techniques in the Service Sector

Rick T. Olson
Ph.D. University of Illinois at Urbana-Champaign
Operations Research, Heuristic Optimization, Scheduling, Health Systems, Decision Support Systems

Leonard A. Perry
Ph.D. Arizona State University
Design of Experiments (DOE), Six Sigma, Quality, Process Improvement, Statistical Process Control (SPC)

Truc T. Ngo
Ph. D. Georgia Institute of Technology
Research Areas: Biodegradable Polymers and Composites, Material Processing with Supercritical Carbon Dioxide

Mechanical Engineering Faculty



Ming Z. Huang
Ph. D. Ohio State University
Mechanical Design, CAD/CAE,
Kinematics and Dynamics of Machinery, Robotics,
Manufacturing Automation, Engineering Pedagogies

Frank G. Jacobitz
Ph.D. University of California, San Diego
Fluid Mechanics and Turbulence, Geophysical Flow, Bio-Fluid Mechanics, Microcirculation, Hemo-Dialysis, Virus Removal, Student Learning

James G. Kohl
Ph.D. Rensselaer Polytechnic Institute, NY
Coating Characterization, Foul Release Coatings,
Mechanical Properties of Polymers, Adhesion, Tribology

David Malicky
Ph. D. University of Michigan
Biomechanics, Soft-tissue mechanics, Finite Element Analysis, Silicone Coatings, Guitar Engineering and Acoustic, Experimental Methods, Pedagogy,

Matthew McGarry
Ph. D. University of Vermont
Design of PEM fuel cells,
Heat Transfer Enhancement,
Bio-Fluid Mechanics, Fluid Mechanics of the systemic circulatory system

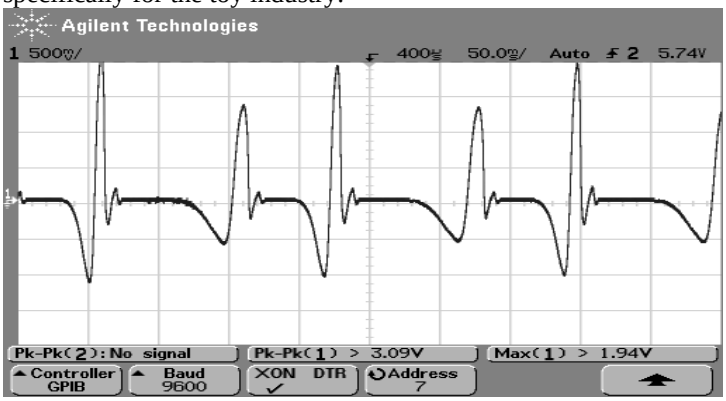
Recent Project Topics in Electrical Engineering

Adaptive Neural Network Target Tracking (K. A. Kramer)
The concept of target tracking, a part of Level 1 data fusion, is to combine measures from various sensors to form a coherent picture of the scene. It has become an important field of research as its applications in robotics, space systems, and missile defense have grown. Target tracking systems are usually based on estimation techniques such as the extended Kalman filter (EKF) that use sensor measurements over time and a model of the kinematics of the target. Such tracking systems, although widely used, have difficulty when the target being tracked undergoes a maneuver. The neural extended Kalman filter (NEKF) is an adaptive EKF that uses functions approximation to learn the error between the true target dynamics and the mathematical model used in the prediction states of the EKF. The NEKF is the focus of several research efforts to improve and analyze tracking performance, perform system identification, and assist in improving control performance. The NEKF uses an artificial neural network that does not use a priori training sets common to most neural network techniques as a function approximation technique. Instead, it adapts and trains as the target is moving using the same residuals as the Kalman filter of the track estimation.

Diffuse Electrical Injury (DEI) (M. S. Morse)
Tissue damage from electrical contact has historically been thought to arise from resistive heating of tissues along the current pathway. A more modern view has accepted that tissue damage can result from cellular rupture (electroporation) induced by the presence of an electric field. In rare electrical contacts, diffuse symptomatology arises that does not fit well within either model. Such disproportionate, remote electrical injury is most notable when the contact voltage is low (120 and 240 V). Symptoms occur, absent diagnostic evidence, which defy explanation as organic injury. Research has been undertaken that statistically suggests that there is a common symptomatology, called Diffuse Electrical Injury (DEI) that is neither linked to voltage nor loss of consciousness at the time of contact.

Semiconductor Laser Beam Shaping using Magnetic Fields (E. M. Kim) Preliminary tests on shaping the radiation pattern of laser diodes using magnetic fields have been completed. Radiation patterns at both below and above threshold are being studied. Dependence on laser structure is being considered. Potential applications include beam shaping and beam steering of the exit radiation from semiconductor diodes.

Eco-Responsible Product Design (E. M. Kim)
Over 2 billion batteries end up in landfills yearly. Unlike glass, paper, and plastic, which fill up landfills, but are relatively benign, batteries are filled with reactive chemicals. Eco-responsible electrical designs are being developed specifically for the toy industry.



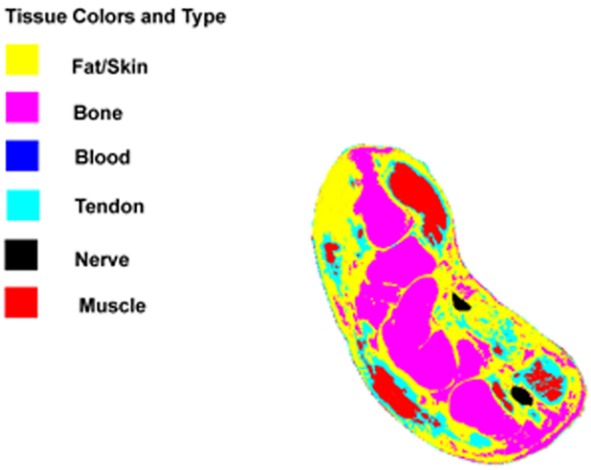
Faraday Effect Charging Cycle

Electromagnetic Hyperthermia (M. L. D. Lumori)
Research Focus: Gaussian Beam Modeling of Field Sources. There are several types of electromagnetic radiating antennas used for localized or regional hyperthermic treatment of tumors. These are based on waveguiding structures that may be used individually or as phased arrays. However, their performance must be ascertained by application of 3-D numerical models to the *electric field integral-equation* (EFIE), the *magnetic field integral-equation* (MFIE), etc., to simulate *specific absorption rates* (SAR) in a tumor. Gaussian Beam modeling of the field sources improves SAR simulations considerably. The Gaussian Beam Model (GBM) is the exact solution to the Schrödinger-type equation which is an approximation to the scalar wave equation.

Embedded Control of Optoelectronic Devices (E. M. Kim)
An EDFA can be used to directly amplify optical signals, avoiding signal conversion to-from electrical, and a microprocessor can be programmed to control and monitor this amplification. The microprocessor makes digital data available to an external computer via standard serial link, and it may also receive external digital commands via the same path. A principal control function of the microprocessor is to determine the current of either laser, independently, by setting or varying a reference voltage to which the backface control photodiode output of the laser is compared. The systems involved to control vary with either one or two pump lasers and supporting analog circuitry present, and in the various numbers of monitor detectors and associated analog circuitry. Such differing configurations require different designs for the embedded control system.

Finite Element Analysis of the Internal Current Pathway (M. S. Morse)
An active area of research focuses on trying to distinguish the *real* current path from the theoretical path during an electrical contact. A variety of mathematical techniques, including the Finite Element Method (FEM), have been applied to this

problem to determine current distribution within the human body. Specific efforts to date have included evaluating current distribution in the carpal tunnel region with the specific intent of explaining post-electrical-contact carpal tunnel syndrome (CTS). CTS has been diagnosed in as many as 10% of the hand-involved electrical contacts; such a diagnosis typically indicates median nerve compression, which would not be consistent with the known apparatus of electrical injury. Using FEM, current density has been evaluated in the carpal tunnel region during an electrical contact. Results of research have indicated that while the majority of current does not transverse the nerve tissue, the current density is significantly elevated in the nerves as they traverse the carpal tunnel region. Such a localized current elevation could cause nerve damage which would masquerade as CTS when diagnostically tested.

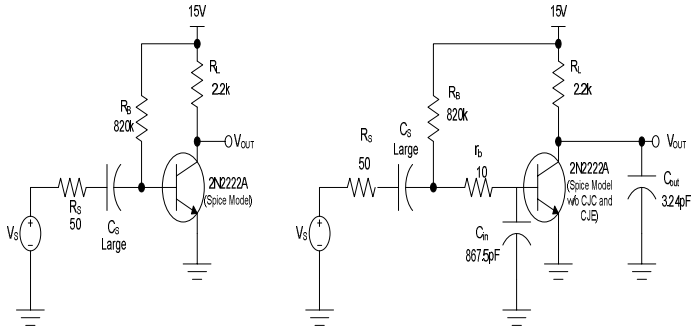


Finite Element Model of Human Tissue

Persistence of Women in Engineering (S. M. Lord)
"The Effect of Climate and Pedagogy on Persistence: A Longitudinal Study of Women in Undergraduate Engineering Programs," capitalizes on a unique opportunity to conduct a longitudinal, multi-institutional, and multivariate study determining how climate and pedagogy affect the persistence of women in undergraduate engineering programs to an extent never before possible. We focus on the nine partner institutions that comprised the NSF-funded Southeastern University and College Coalition for Engineering Education (SUCCEED) Coalition and account for 1/12 of the engineering bachelor's degrees awarded from 1987 to 2004. A key benefit of the choice of this population is three key overlapping sources of data: 1) the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), 2) climate surveys and 3) teaching practices surveys. We are conducting new analyses on this existing data as well as new studies focusing on our research questions. Such a triangulated approach provides a powerful historical context to explain changes and successes in persistence. *This project is funded by the National Science Foundation (NSF) Research on Gender in Science and Engineering (GSE) program and is in collaboration with Dr. M. Camacho in Sociology at USD and Drs. M. Ohland and M. Wasburn at Purdue University.*

Nonlinear System Identification Techniques
(M. L. D. Lumori)
Research Focus: Measurement, Modeling and Identification of Dynamic Systems. A typical nonlinear complex system is often decomposed into subsystems that are then characterized using dedicated tools. Experimental data, sometimes obtained from poor measurement/simulation sources, are used by the designer to extract a wide variety of models that must meet specific requirements. Since most systems are nonlinear in nature, the best linear approximation (BLA) is often sought to give an insight into the dynamics of a nonlinear system. System Identification is via use of the appropriate estimators (e.g. least squares, weighted least squares, Maximum likelihood, or Bayes estimators) for each system and associated environment (e.g. errors on the input and output data).

Analog Circuit Design (E. M. Kim)
Detailed investigation of Miller's Theorem as it applies to transistor amplifier design has yielded results that are counter to the Miller effect pole that is used in many electronics circuit textbooks as the only pole of significance. In fact, careful application of Miller's theorem provides pole locations that accurately represent true circuit behavior.

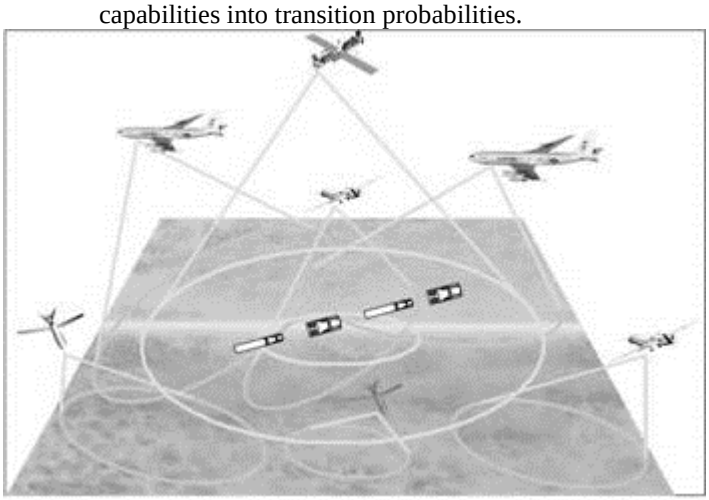


Miller Effect Model of a BJT Amplifier using SPICE Circuiit Parameters

Sensor Data Fusion (K. A. Kramer)
Multi-sensor data fusion is the process of combining, comparing and interpreting information across a number of disparate sensors. Often, in a sensor fusion environment, the sensors are of a wide variety providing a diverse set of measurement types. Level 1 fusion identifies and tracks entities, while Level 2 fusion, also known has Situational Assessment, develops and interprets relationships among the entities, including such concepts as group kinematics, group

formation, and group composition. Research is being undertaken to apply a variety of techniques to these complex problems including:

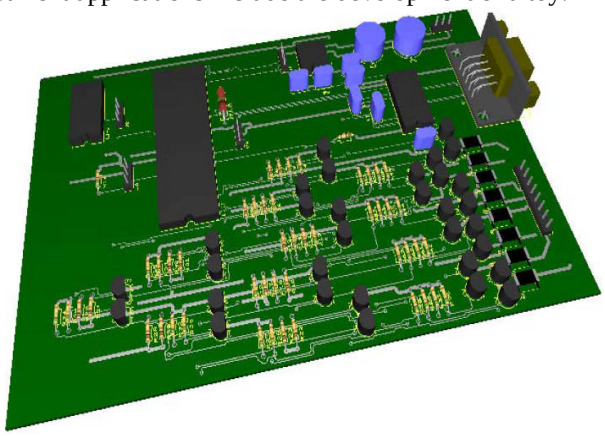
- For classification, methods to better interpret measurements of from various sensors that have different degrees and types of uncertainty, accrue disparate evidence over time, and apply fuzzy logic.
- For L1 association, application of a fuzzy-logic based method that emulates the chi-squared metric for both Gaussian and non-Gaussian measurements for data association.
- For group composition, Markov chain methods that make use of multiple composition hypotheses and incorporate terrain, group dispersion, and sensor capabilities into transition probabilities.



Multi-Sensor Data Fusion – information from different sensors fused together to provide assessment of situation.

Evidence Accrual (K.A. Kramer)
In many fusion problems observations provide indirect, rather than direct, evidence. In such cases, the measurements affect the evidence level through a functional relationship, such as speed being measured through the functional relationship between it and position observations over time. A general evidence accrual system that incorporates indirect observations into the evidence generation is being developed. The technique, based on the concepts of first-order and reduced-order observer theory, can incorporate both observation quality and level of doctrine understanding in the uncertainty measure of the evidence. The technique uses a network structure with links and propagation of evidence, but, unlike a Bayesian taxonomy, it does not rely upon the strict probabilistic underpinnings. The technique is based upon a Level 1 fusion target classification evidence accrual algorithm and uses a fuzzy Kalman filter to inject new evidence into the nodes of interest to modify the level of evidence. Using the fuzzy Kalman filter allows for the level of evidence to incorporate an uncertainty or quality measure into the report.

Embedded Control of Magnetics Circuits (E.M.Kim)
Magnetics circuits can be energized in sequence using embedded controllers. User interfaces are employed that allows for sequence modifications in pattern and time. Current applications include the development of a toy.



Embedded Controller for Magnetics Circuits

Electrical Machines and Energy Conversion for Lower-Division Engineering Students
(T.F. Schubert, F.G. Jacobitz, E.M. Kim)
In order to meet changing curricular and societal needs as well as a resurgence in interest concerning basic electric machines and their control, a number of electrical machine laboratory experiences for sophomore students are under development. These experiences are unusual in that they are placed early in the curriculum and utilize subfractional-horsepower (< 5 W) electrical motors. Motor topics include modeling of electric motors, predicting motor performance, and experimentally obtaining relevant motor performance constants. The efficiency of converting electrical energy into mechanical energy is measured with a unique and simple small-scale dynamometer developed by the team comprised of an optoswitch-based tachometer and torque measurements obtained with a slipping-clothespin lever arm and a linear spring scale.

While subfractional-horsepower DC motors can commonly be found in toy applications, subfractional-horsepower AC motors are not as obviously located. However, the duality of motors and generators leads to finding synchronous AC machines as generators in many low-power "green" applications. Use of these AC machines as motors requires the development of low power – low voltage, three-phase power sources. Currently under development is one such three-phase power synthesizers based on: up-down digital counters, D/A conversion and wave-shaping. Such stand-alone, low-power, three-phase sources provide an added bonus of facilitating the study of three-phase systems at very safe voltages and currents.

Initial assessments of student learning and confidence in applying the concepts relevant to electrical machines and energy conversion have shown significant increases in each category.

Recent Project Topics in Engineering Education

Enhancing Student Learning (S. M. Lord)
Current research areas in engineering education include investigating a range of strategies for enhancing student learning including cooperative learning, hands-on laboratories, and using Tablet PCs. The researcher is a leader in the field actively involved with the Educational Research Methods division of ASEE and the Education Society (EdSoc) of IEEE. Leadership positions include General co-Chair of the 2006 Frontiers in Education Conference, IEEE EdSoc President for 2009 and 2010, and Guest Co-Editor of Special issue of *International Journal of Engineering Educatio*n. Another area of interest is an investigation of the potential benefits of feminist pedagogy for engineering education, a joint effort which received the Helen Plants Award in 2004.

Lifelong Learning (S. M. Lord)
"Role of faculty in supporting lifelong learning: An investigation of self-directed learning environments in engineering undergraduate classrooms" examines how faculty choices in the classroom influence students' lifelong learning skills. Lifelong learning is a critical skill for engineering graduates. While the literature on self-directed learning offers insight into how to develop lifelong learning skills, engineering educators have focused more on assessing lifelong learning than on understanding how instructors can foster such skills. With a project team from engineering and education at four different institutions, we are well positioned to investigate a variety of learning environments making results useful to the wider engineering education community. *This project is funded by the National Science Foundation (NSF) ECC Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI) program and is in collaboration with Drs. M. Prince, C. Stefanou, K. Nottis of Bucknell University, Dr. J. Stolk of Olin University, and Dr. J. Chen of CalPoly San Luis Obispo.*

Engineering Mathematics Education (S. M. Lord, R. T. Olson)
The inability of incoming students to successfully advance past the traditional freshman calculus sequence is a primary cause of attrition in engineering programs across the country. Engineering faculty at Wright State University have developed a new paradigm that introduces students to all of the essential mathematics needed to succeed in the first two years of engineering. In the one quarter class, students meet for six hours each week in lecture and laboratory settings. This model has been shown to improve retention at schools where the entering students are not well-prepared for calculus. USD's contribution to the project is to assess the mathematics difficulties of early engineers at a university where most students are calculus-ready and to determine whether two one-unit elective engineering mathematics classes will also improve improve student retention. *This project is funded by the National Science Foundation (NSF) as part of a DUE - CCLI Phase III implementation project that is being led by Dr. N. Klingbeil of Wright State University.*

Assessment of Student Perceptions of Multiple Textbook Editions Use to Reduce Cost to Students (F. G. Jacobitz, T. F. Schubert, E. M. Kim)
Motivated by a potential reduction in cost to students, the concurrent use of multiple textbook editions is studied in engineering courses. The student learning environment is assessed and evaluated for a potential negative impact. The fundamental hypothesis of this study is concurrent use of multiple textbook editions significantly reduces student cost without negative impact on the student learning environment. Students are asked to complete a three part survey assessing various aspects of using multiple textbook editions as well as their textbook purchasing and return habits. Overall the choice of multiple textbook editions is welcomed by the students. This survey results show that the cost for students was reduced appreciably. A majority of students report no negative impact of their learning, thought that instruction is edition-neutral, and generally appreciate the choice between textbook editions.

Studies of the Engineering Design Process in Novice Designers (T. F. Schubert, F. G. Jacobitz, M. S. Morse, T. T. Ngo, E. M. Kim)
The engineering design process is a central theme in the engineering profession and essentially all engineering curricula. There are currently two studies underway by the team: (1) to investigate if a single lecture on engineering design and a short laboratory exercise early in the semester can help develop student knowledge about and student confidence in applying the engineering design process, and (2) to assess the impact of the presence of a prototype exemplar on novice designers prior to asking those designers to engage in an engineering design exercise. Initial studies have shown that a short presentation on the engineering design process followed by a simple laboratory exercise is a meaningful technique to teach the basics of engineering design. Student knowledge of and confidence in applying the engineering design process increased upon completion of a simple design exercise as evidenced in the assessment study. Analysis of data concerning whether the presence of a prototype exemplar results in significant "design fixation" in a multi-stage design process is currently underway.

Compact International Experiences (T. F. Schubert, F. G. Jacobitz)
The efficacy of delivering upper-division engineering electives as study-abroad, short-term courses is under study primarily through the experiences gained by considering two distinct three-semester-unit courses in a three-week time frame in France and Australia, respectively. Initial results show that the Compact International Experience course format has proved to be an effective format for the delivery of two senior elective engineering courses. Despite the short timeframe of delivery, all evidence collected (student course evaluations, instructor observations and course grades, student weekly reflection papers, and an assessment of the international experience) point to an educational experience equivalent in course content and depth of coverage to that of typical semester long courses delivered at the home institution coupled with an enriching international experience. The courses will be repeated in January 2013 and assessment of the format will continue.

Recent Project Topics in Industrial & Systems Engineering

Cognitive Performance under Stress (B. Chase)
The environment in which we work can place many constraints upon our ability to perform both physical and cognitive tasks. For nearly five decades researchers have investigated thermal stress effects on human cognitive performance. Although much data have been collected, relatively little consensus was reached with regard to either the true nature of thermal stress effects, or an existing mechanism for predicting human performance under thermal stress. Several factors have likely contributed to the substantial variation in the findings of previous thermal stress investigations. Research in this area attempts to quantify cognitive deficits due to thermal stress, develop interventions and inform both task redesign and policy decisions.

Design of Experiments (L. A. Perry)
Experimental design is a systematic approach to planning and analyzing experiments so that meaningful results can be obtained in an efficient and timely manner. Design of Experiments (DOE) can be used to reduce product development time or improve a manufacturing or service process. In design of experiments, the experimenter is concerned with processes of planning and conducting an experiment; once the experiment is conducted, the resulting data can be analyzed so that legitimate, objective conclusions can be made. The application of DOEs in the engineering discipline has become a critical tool for developing and improving manufacturing processes and systems as well as the product development cycle. If a process exists, DOEs can be used to improve it. Currently, experimental design methods are being used to improve yields and reduce variability in products in local biotech, pharmaceutical, and telecom companies.

Electrophysiological Measures of Cognitive Performance (B. Chase)
Research in this area is based on the understanding that numerous cognitive processes are ongoing in parallel. There are externally measurable reflections of these processes available to us including: measurable movement behaviors (button presses), recordable brain activity measures (such as the electroencephalogram (EEG)) and eye movement behavior. While eye movement behavior is perhaps the most information impoverished of these measures, it is the most unobtrusive measure that can provide millisecond-to-millisecond reflections of underlying cognitive processes. While there are tasks that are obviously reflected in eye movement activity (e.g. visual searching paradigms), nearly all cognitive processes have at least some indirect influence on eye movement behavior. The eye movement behaviors can be analyzed in terms of the neuro-dynamics, the system-wide behavior of the brain in action. This capability is largely based on advanced EEG recording and analysis techniques. The goal is to elucidate the neuro-dynamic behaviors in eye movement activity as it relates to cognitive processes. With input concerning operator state available to an adaptive system, the task itself could be modified to account for operator fatigue, attentional state, and other performance characteristics of interest.

Healthcare Operations (B. Chase, L. A. Perry)
Several projects have been undertaken in the area of management engineering where Industrial Engineering concepts and techniques are applied within the health care arena. Projects include hospital staffing, discrete event simulation, lean and six sigma, supply chain management, reduction of wait times, operational performance improvement, electronic medical record implementation, occupational safety, and work and workstation design.

Six-Sigma (L. A. Perry)
Six-Sigma is a systematic, data-driven quality improvement methodology that has proven quite effective in recent years. Specifically, it is an approach by which a cohesive collection of quality improvement tools is utilized to reduce process variation. More broadly, it is a managerial and cultural directive toward achieving near-perfect quality, only 3.4 defects per million opportunities (DPMO). Six-Sigma is becoming commonplace in the manufacturing sector due to the benefits that are undeniable, but still there exists an element of skepticism that prevents its widespread use in the service sector. Continuous improvement initiatives still have plenty of growth potential in health care, financial, and defense industries as Six-Sigma becomes more visible and cost savings are identified.

Processing Behaviors of Thin-Film Pentacene and Benzene-1,4-Diboronic Acid in Supercritical Carbon Dioxide (T. T. Ngo, J. Keegan–USD Undergraduate, R. D. George–SPAWAR)
This research investigates the feasibility of using supercritical carbon dioxide ($scCO_2$) as a green solvent for processing organic thin film semiconductor, such as pentacene, and a potential molecular modifier for use in electronic device applications. Benzene-1,4-diboronic acid (BDBA) was selected as a molecular modifier in this work due to its electron deficient nature, which can potentially enhance pentacene's physical, chemical or electronic properties by changing its structure in the solid state. In this study, the solubilities of BDBA and pentacene in $scCO_2$ are measured as individual compounds and as co-solutes, at 313 K, using ultraviolet (UV) spectroscopy. Methanol co-solvent effects on solubility have also been characterized for each compound. The results show that BDBA is insoluble in pure $scCO_2$ up to 1.82×10^7 Pa. However, with a small amount of methanol added to the mixture, BDBA becomes soluble in solution with a solubility of 3.81×10^{-4} mol/l at 9.00×10^6-Pa-pressure. In contrast, pentacene is only soluble in $scCO_2$ at pressures above 1.10×10^7 Pa, and its solubility is decreased upon addition of methanol due to the non-polar nature of pentacene. When a pentacene thin film is treated with BDBA in $scCO_2$/methanol solution, BDBA sorption is observed at pressures as low as 8.80×10^6 Pa. Based on these results, it is concluded that treatment of pentacene thin films in $scCO_2$ is a promising approach that can be optimized for BDBA and other similar molecular modifiers, to produce multi-component organic thin film devices.

Green Surfboards: Investigation of Product Biodegradability at End of Life (T. T. Ngo, J. A. Hall–USD Undergraduate, J. G. Kohl, L. A. Perry)
As the world becomes more environmentally conscious, companies find ways to make products and manufacturing processes greener. This work examines an innovative surfboard product that uses bio-based fiber-reinforced polymers to address product disposal issues and to lower the toxicity associated with some of its components and manufacturing processes. The goal of this work is to characterize the biodegradability of the "green" surfboards at end of life, focusing on the fiber-reinforced composite laminate covering the surfboard and the core of the board. Different laminate types, with various combinations of resins (polyester, epoxy, and a bio-resin) and reinforcing fibers (fiberglass, organic hemp, and organic cotton), were tested. Polystyrene core was compared with the green alternative balsa wood core. Degree and rate of biodegradability of materials were evaluated by measuring weight change and material hardness over 56 days under controlled composting conditions. The results suggest that the resin component in the composite laminate is the key factor that controls the rate of biodegradation of the material. In addition, different resins exhibit different degradation mechanisms, depending on the chemical and biological nature of the materials.

Effects of Plant-Fibers and a Tertiary Oil Phase on the Compostability of Polyester- and Epoxy-Based Fiber-Reinforced Composites (T.T. Ngo, C.A. Lambert-USD Undergraduate, L. Benz, S. Morrison, M. Chau-USD Undergraduate)
This research investigates the effects of different plant-fibers on the compostability of polyester- and epoxy-based fiber-reinforced composites. Natural fibers, such as hemp, bamboo and cotton, are used as alternatives to fiberglass. A linseed oil-based resin is also used as an alternative to polyester and epoxy polymer matrix. In addition, a tertiary oil phase (either linseed oil or pine oil) is introduced into the polyester and epoxy matrix to improve the compostability and ductility of the material. Compostability experiment is performed in an aerobic environment with compost solution at 58°C for over 49 days. The morphology of material surface and cross-section is examined using scanning electron microscopy (SEM), and dissolvable by-products in composting solution are analyzed using liquid chromatography-mass spectroscopy (LCMS) method. The solid composites after composting treatment are also characterized using thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC) techniques. Rate of biodegradation and material degradation mechanisms are studied and compared among different sample types.

Characterization of the Mechanical Properties of Bio-Based Fiber-Reinforced Composites (T.T. Ngo, C.A. Lambert-USD Undergraduate, J.G. Kohl, M. Bliznyuk-USD Undergraduate)
This research focuses on the development and characterization of several new fiber-reinforced bio-composites. In the new composites, the traditional fiberglass is replaced with natural fibers such as hemp, bamboo and cotton. Also, the traditional polyester and epoxy resins are either totally replaced by linseed oil-based (UVL) resin, or mixed with linseed oil or pine oil to improve their compostability at end of use. Composite samples are prepared using the hand lay-up method. UVL-based samples were proven to be the easiest ones to prepare with fastest production time, ease of handling and most consistent in surface thickness and uniformity. On the other hand, surface uniformity becomes an issue for non-UVL samples when the mixed oil content is more than 10% by weight. Surface hardness and the tensile properties of the materials were measured to determine the effects of plant-fibers and a tertiary oil phase on the polymer matrix.

Recent Project Topics in Mechanical Engineering

Pedagogical Applications of Time Compression Technologies (M. Z. Huang)
Time compression technologies refer to the modern industry practices that integrate rapid prototyping with modeling, analysis, and simulation techniques, such as computer-aided design (CAD) and finite element analysis (FEA), for product design and development. This research aims to explore novel ways of incorporating these practices into existing undergraduate engineering curriculum. Application studies will be conducted using the CAD, FEA and rapid prototyping tools such as Pro/E and Z-Corp 3D Printer available at USD.

Performance-based Dimension Synthesis of RCM- and SL-Type Mechanisms (M. Z. Huang)
Special mechanisms, such as the remote center of motion (RCM) and the straight-line (SL) types, have seen increasing applications in medical automation and surgical procedures. In addition to their specific kinematic properties, other performance characteristics, such as stiffness and velocity, need to be considered in order to meet the rigorous requirements of precision and safety in the medical arena. This research aims to develop a performance-based dimension synthesis methodology using the RCM and SL-type mechanisms as the underlying structures. Works in this area include a recent study on dimension synthesis for the Peaucellier SL-mechanism and an ongoing project on development of an RCM-based mechanism for dental surgical applications.

Design Optimization of Hybrid Series-Parallel Robots (M. Z. Huang)
Robotic mechanisms traditionally are either of 'serial' or 'parallel' configurations. While a serial robot has larger workspace, it lacks stiffness inherently and thus has poor load carrying capability. A parallel robot, on the other hand, exhibits just the opposite to its serial counterparts. Robotic mechanisms with unconventional, hybrid series-parallel configurations could provide a natural compromise. This research addresses three areas: 1) coordination theory, which is the level of control where inputs to the actuators are determined given the geometric structure of a mechanism, 2) workspace characteristics, which encompass the study and characterization of the robot's reachability (see figure) as well as dexterity, and 3) task planning and simulation, which include the generation of trajectory, dynamic simulation and visualization. The work aims to develop a CAD/CAE environment whereby the kinematics, dynamics and workspace characteristics of hybrid mechanisms of different geometric structures may be evaluated for design and development of such systems.

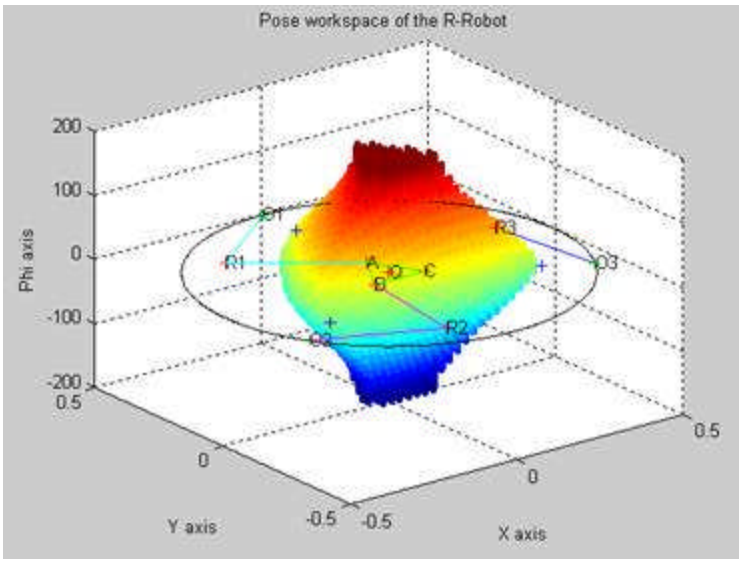


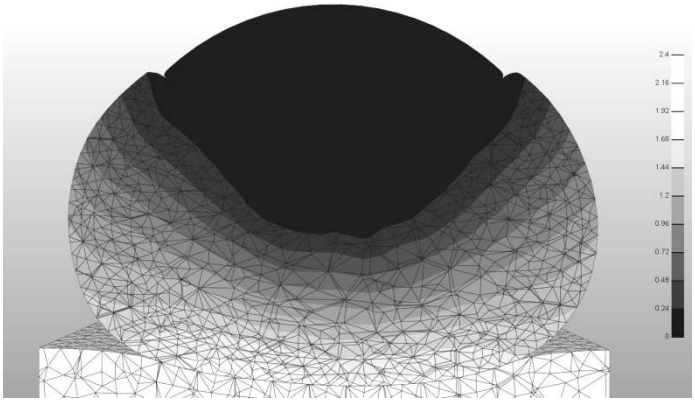
Figure: Complete pose workspace for a 3-DoF revolute-jointed planar parallel robot. The range of rotation is shown in a color spectrum from +180 (in red on top) to -180 (in blue at the bottom) degrees.

Pedagogical Integration of Design Innovation Tools (M. Z. Huang)
Many of the problem-solving and design tools, such as TRIZ, Axiomatic Design, Exact Constraint Design, Kepner-Tregoe Method, have been well adopted in industries and considered important for innovations for years. However, their roles and inclusions in regular engineering curriculum still seem to be relatively obscure and slow. This pedagogical research initiative aims to 1) explore effective ways of integrating them into the engineering curriculum, and 2) develop appropriate pedagogical strategies and materials using, for examples, application modules and case studies.

Biomechanics (D. Malicky)

Patients with diabetes are susceptible to a number of foot lesions, which often leads to loss of tissue or appendage. Ulcers on the plantar surface of the great toe are the most commonly seen problem in patients with diabetic neuropathy. Onychocryptosis (ingrown toenail) is also common in these patients and the general population. The aim of this study is to develop an anatomical finite element model of the hallux (great toe) to elucidate its internal mechanical response to external loads. Anatomical slice images from the NIH Visible Human project were digitized and reconstructed, creating an anatomical 3D Pro/Engineer solid model of all tissues. The material properties of the skin, nail, bulk tissue, and bone are incorporated in a large-deformation analysis to elucidate the contributing factors toward peak skin stresses on the plantar surface, intradermal tissue, and the lateral nail fold. Various

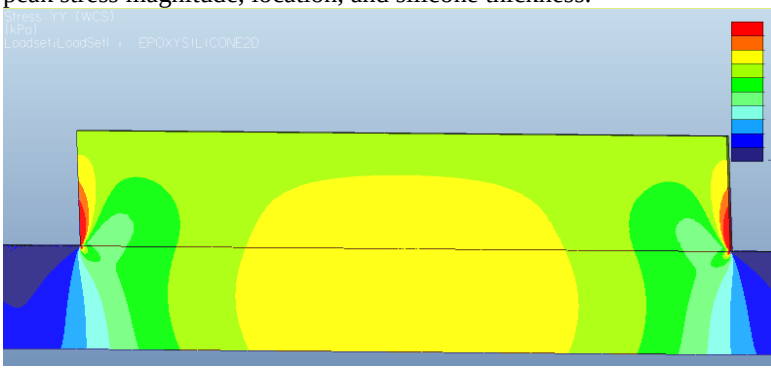
treatment options are examined for their relative efficacy at reducing peak stresses across the 3 regions.



Cross-section of toe showing vertical displacement field of tissue in response to plantar pressure loading from elastic footbed.

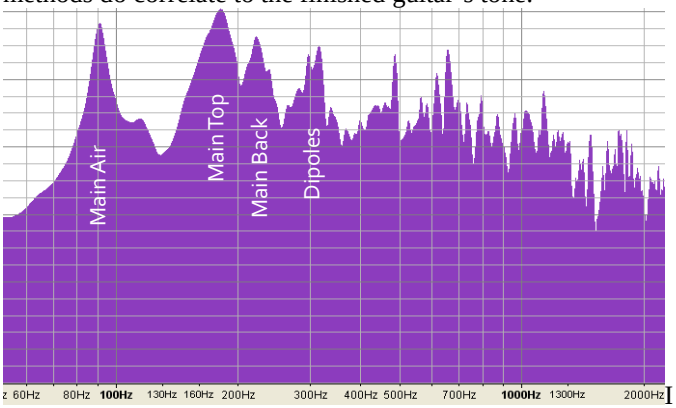
Durability of Elastomer Coatings (J. G. Kohl)
Silicone is currently being investigated for use as foul-release coatings. Silicone when used as a coating has been known to suffer from both poor adhesion and poor durability. Efforts are being directed at improving the toughness and adhesion of these coatings without reducing their foul release behavior. One method of evaluating the toughness and adhesion of these coatings is by means of a scratch tester. It was found in earlier work that the failure mode and durability of the coating depended on coating thickness. Current work is being performed in the identification and modeling of material parameters that contribute to the toughness and adhesion of these coatings. Nanoindentation techniques are used to determine the parameters under investigation.
J.G. Kohl, N.X. Randall, N. Schwarzer, T.T. Ngo, J.M. Shockley, and R.P. Nair, "An Investigation of Scratch Testing of Silicone Elastomer Coatings with a Thickness Gradient," *Journal of Applied Polymer Science*, Vol. 124, May 2012, pp. 2978–2986.

Silicone Coatings (D. Malicky)
Silicone coatings are widely used on ship's hulls to ease the release of barnacles, improving fuel efficiency. But, the interface stresses due to pull-off and shear forces are not well understood. With Dr. Kohl, this study develops a finite element model of a variable thickness silicone coating and pseudo-barnacle, examining the location and magnitude of peak interface stress under a wide range of silicone thicknesses. Specialized mesh refinement techniques have been developed to accurately characterize the stresses concentration near the edge of the pseudo-barnacle, which cannot be simulated by conventional elasto-plastic techniques. Results indicate a complex relationship between peak stress magnitude, location, and silicone thickness.



Cross-section of silicone coating with pseudo-barnacle under pull-off stress, showing stress distribution.

Acoustic Guitars (D. Malicky)
Through trial-and-error, keen sensitivity, and some objective methods, individual luthiers and guitar factories have developed the design, materials, and manufacturing processes of the steel-string acoustic guitar to a relatively refined level. Sound quality variances are thought to be caused by variable wood properties but this has not been quantitatively demonstrated. The scientific relationship of the guitar's subjective sound qualities to material and component properties (stiffness, density, thickness, damping, resonance, etc) is poorly understood. The aim of this pilot study is to examine correlations among material properties, component properties, acoustic resonances, and the subjective sound qualities of the acoustic guitar. Each top's density, stiffnesses, damping, and tap tone were assessed. Tops were randomly assigned to students, who then constructed their guitars in the MENG 351 lab. Sound quality was assessed and FFT analysis showed the resonant frequencies of the air, top, and back modes. Regression analysis between input and output variables indicate the top and back frequencies were strongly correlated to air frequency, and that qualitative luthier methods do correlate to the finished guitar's tone.



mpulse frequency response of sample guitar body, showing first five resonances

Foul Release Coatings (J. G. Kohl)
It has been shown that the foul release properties of silicone elastomer coatings are related to not only the work of adhesion but also to bulk modulus and thickness. Thick and thin coatings have different release behavior. There is a thickness dependence for thin coatings whereas beyond a certain thickness the release properties are independent of thickness. This transition in behavior is currently being investigated.
J.G. Kohl, D.M. Malicky, A.M. Jones, S.L. McGee, and C. Bonilla, "Removal of Pseudobarnacles (Epoxy) from Silicone Coatings with a Thickness Gradient Due to an Applied Transverse Force," *Progress in Organic Coatings*, Vol. 71, July 2011, pp. 310-313.

Microcirculation (F. G. Jacobitz)
The microcirculation in rat skeletal muscle and skeletal muscle fascia is investigated. Tissue samples are prepared such that the micro-vessel network pattern can be reconstructed and studied. Those networks consist of arterial vessels supplying blood, capillaries for the exchange of nutrients and metabolites with the surrounding tissue, and venule vessels collecting blood. The vessel topology is used in computer simulations of the flow in the network that provide comprehensive information about pressure and velocity distributions in the network that is not available from experiments. The simulations take passive and active vessel properties into account. The non-Newtonian properties of blood are modeled as an apparent viscosity based on previous experimental data.

Micro-Vessel Network

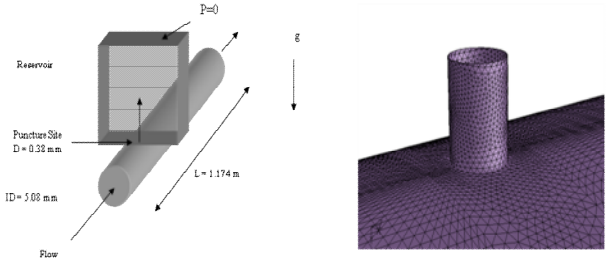
Turbulence in Stratified Rotating Shear Flows (F. G. Jacobitz)
The evolution of turbulence and turbulent mixing is investigated in stably stratified rotating shear flows using direct numerical simulations. Such flows are important in many engineering applications as well as in flows in the atmosphere and oceans. An understanding of the competing effects of shear, rotation, and stratification is required in order to quantify the transport of momentum, heat, pollutant, and nutrients in such flows. Most recently, wavelet-bases scale-dependent geometrical statistics have been employed to elucidate properties of turbulence structure and dynamics. The direct numerical simulations resolve all dynamically important scales of the motion and therefore require considerable computational resources. The simulations are carried out on a parallel computer with 12 64-bit CPUs and a total of 48GBytes of memory housed at USD and on the facilities of the San Diego Supercomputer Center. *This project is an international collaboration with Dr. K. Schneider (Marseille, France), Dr. W. J. T. Bos (Lyon, France), and Dr. M. Farge (Paris, France).*

Virus Removal from Blood (F. G. Jacobitz)
Research is currently underway to develop a mathematical model for the flow in hemo-dialysis cartridges. These cartridges are used to remove viruses and toxins from blood, such as HIV or hepatitis, and viruses which might be used in bioterrorism, such as smallpox. The mathematical model is developed in close collaboration with experiments performed at Aethlon Medical, Inc.. The model, once validated, will be used to optimize the filter design in order to minimize treatment time for patients.

Heat Transfer Enhancement (M. McGarry)
Natural convection plays an important role in many industrial processes where heat must be removed from objects that generate heat. In addition, liquid metals and alloys are used in numerous industrial processes due to their ability to remove large amounts of heat compared with other liquids. The coupling of natural convection with liquid metals occurs in a wide variety of industries such as; the nuclear industry for liquid metal fast breeder reactors (LMFBR), heat treatment and bright annealing furnaces, and the production of high-quality plate glass with the use of a molten metal bath. Our project seeks to create a model of a heated solid object that will be cooled with various liquid metals. The outcome of the project will be design equations that can be used for a wide range of operating conditions and liquid metals to determine the optimal design that will maximize heat transfer from the heated object.

Blood Flow (M. McGarry)
Physiological implications for the clotting of an artery, hemostasis, can be found by examining the time-averaged local strain rates in the vicinity of the puncture. The time-averaged leakage of fluid leaving a puncture in a pressurized vessel immersed in a quiescent, miscible medium is studied under pulsatile flow conditions. The time-averaged local strain rates at the puncture site can then be investigated. The time-averaged leakage and local strain rates at the puncture are characterized as functions of various hydrodynamic and geometric conditions. Dimensional analysis shows that the time-averaged leakage rate, Q*, is a function of the mean Reynolds number, the Womersely number, the pressure ratio between the center of the tube and the external hydrostatic

pressure, P*, and the hole-to-main tube diameter ratio, D*. A 3-D finite volume computational model is constructed for laminar flow of a Newtonian fluid under pulsatile conditions and validated with supporting experiments. The time-averaged fractional leakage rate Q* increases with P* and approaches a constant value at high P*. In addition, the largest Womersley number shows the smallest time-averaged leakage rate. The largest strain rates are associated with the highest Womersley number. The effect of the diameter ratio is examined and the largest diameter ratio contains the lowest time-averaged leakage rates. While the smallest diameter ratio has the largest time-averaged strain rates. These strain rates lead to dramatic variations in platelet deposition for a the different small arteries.



(a) (b)