Industrial and Systems Engineering Research Projects 2005–06

ERGONOMICS AND HUMAN FACTORS RESEARCH

Ergonomic Interventions in the Furniture Industry

Gary A. Mirka
Furniture Manufacturing and Management Center (FMMC)
$31,926
7/1/02 – 6/30/06

The goal of this project is to perform field evaluation of previously developed ergonomic interventions for the furniture manufacturing industry. Of primary concern in these evaluations is their impact on the biomechanical loading on the worker. Impact on the productivity of workers using these interventions is also considered.

Ergonomic Interventions for the Agriculture Industry

Gary A. Mirka
National Institute for Occupational Safety and Health (NIOSH, CDC, NIH)
$649,138
9/30/01 – 9/29/06

The goal of this five-year project is to develop engineering solutions for agricultural workers performing jobs with high risk for

musculoskeletal disorders. The first step is identifying the high-risk jobs by evaluating local clinic-intake forms and identifying

crops and work activities that contribute to these disorders. These high-risk activities are then analyzed and the ergonomic risk factors identified. Based on this evaluation, prototype tools/work methods are designed to reduce exposure to these risk factors. These solutions are tested in the laboratory and in the field to document improvements in biomechanical loading and productivity resulting from these ergonomics interventions.

A Multidimensional Scaling Analysis of Display Clutter and Development of a Clutter Measure

David B. Kaber
NASA Langley Research Center (LaRC), Human Measures & Performance Element, Airspace Systems
$70,000
4/7/06 – 2/6/07

Display clutter can lead to increased information processing time and target detection errors, which may be critical under specific aircraft flight circumstances. In Phase I of the research, we define the physical dimensionality of clutter in visual displays. In Phase II, we determine the associated perceptual dimensionality of clutter for aviation display users. We use a psychophysical approach to describe perceptions of clutter. In Phase III, we establish threshold values for perceptual dimensions of clutter that might lead to degradations in performance. Threshold values may be used for decisions regarding designs of new synthetic vision displays for pilots.

Intelligent Human-Machine Interface and Control for Highly Automated Chemical Screening Processes

David B. Kaber
National Science Foundation, Information Technology Research Program
$798,132
10/1/04 – 9/30/07

This is a three-year research program to design and investigate intelligent and adaptive human-machine interfaces and automated control technologies for supporting supervisory controllers in biochemical screening (testing) processes towards development of new drug components. The project involves collaborative research with the University of Rostock, including: (i) cognitive task analysis of screening operations with biochemists; (ii) cognitive modeling of supervisory controller behavior; (iii) process interface prototyping and usability evaluation; (iv) development of remote process control applications; and (v) development of a user interface management system for adaptation of interface content during actual chemical screening operations.

Investigation of Manual Control Performance Deficits in Adaptive Automation and a Cognitive Modeling Explanation

David B. Kaber
NASA LaRC, Human Measures & Performance Element, Airspace Systems
$37,810
7/1/05 – 5/31/06

The objectives are: (i) to assess the impact of advanced warning cues on return-to-manual-control (RTMC) performance in human use of adaptively automated systems; and (ii) to develop a cognitive model-based theory of deficits in manual performance with or without warnings. We evaluate auditory and tactile cues presented shortly before control mode shifts in a multitask piloting scenario for ameliorating RTMC deficits compared with no cueing. Observations on subjects will be used to develop computational cognitive model explanations of RTMC deficits in using the adaptive system. Statistics on simulation output will be compared with performance data for subjects in the experiment.

Locomotion in Simulated Partial Gravity

Simon Hsiang
National Aeronautics and Space Administration (NASA)
$25,000
10/1/05 – 9/30/06

An optimal control model is developed to model human walking by tracking visual signals within conditions of normal and partial gravitational conditions. A virtual reality walkway with a synchronized three-dimensional rear projection and body suspension tool balancer system is designed and constructed for the experiment.

MANUFACTURING RESEARCH

Measuring Product Quality in Furniture Supply Chains

Tom Culbreth
Furniture Manufacturing and Management Center
$221,897
7/01/04 – 8/31/07

Many domestic furniture manufacturers are sourcing product from foreign producers. Imported products must be manufactured, packaged, shipped, and received into a domestic warehouse, then staged along with domestic product for shipment to customers. There are potentially significant quality costs associated with each stage of the supply chain including production, transportation, storage, up-fitting, and distribution. This research develops formal methods for evaluating product/component quality in furniture manufacturing supply chains. Relevant quality costs are identified and quantified. Such measures should be useful in evaluating the performance of suppliers and in formulating supply chain management policies.

Development of Physical Models for Testing of Nasal Vaccine Using Biomodeling

Ola L. A. Harrysson
NIH and Pathology Department of Duke University Medical Center
$112,695
1/1/06 – 12/31/07

To develop and test new nasal vaccines, computer models and physical models are required. The new vaccines are currently being developed in the Pathology Department of the Duke University Medical Center. Biomodeling is being used to create computer models of the nasal cavity, and physical models will be developed using rapid prototyping and rapid tooling techniques.

Development of EBM Process Parameters and Material Testing for GRCop 84

Denis R. Cormier and Ola L. A. Harrysson
Crucible Research, Arcam AB
$7,000
4/1/05 – 4/1/06

GRCop 84 is a high-temperature copper alloy used for thrust nozzles in the aerospace and defense industry. The alloy is difficult to process using conventional manufacturing technologies. The Electron Beam Melting technology has been evaluated as a possible fabrication technique with good results.

The Effects of Neck Cut Resection Level on the Initial Torsional Stability of Cementless Total Hip Arthroplasty

Denis Marcellin-Little and Ola Harrysson
American College of Veterinary Surgeons
$7,340
05/01/06 – 12/31/06

We investigate the effect of high vs. low neck cut on the initial torsional stability of cementless total hip arthroplasty. A cadaver study is being conducted, where pairs of femurs are being resected, one with a high neck cut and one with a low neck cut. Hip stems are implanted and the initial torsional stiffness is measured using a rotational universal testing machine. The results from the testing will be used to develop a finite element analysis model that can be used to predict implant torsional stiffness.

Development of EBM Process Parameters and Material Testing for Combustion Synthesis of Titanium Aluminide

Ola L. A. Harrysson, Denis R. Cormier, and Harvey West
SIMTech, Singapore
1/1/06 – 6/1/06

Titanium aluminide is a light-weight, high-temperature alloy that is commonly used in the aerospace industry. Because of its specific material properties, titanium aluminide is difficult to use in conventional fabrication technologies; and self-propagating combustion synthesis is currently used as an energy-efficient production method. Only simple shapes can be fabricated using self-propagating combustion synthesis, and the EBM technology has been evaluated to produce freeform objects through layered manufacturing.

Splines-Based Geometric-Physics Modeling of Deformable Objects with Force-Torque Feedback

Yuan-Shin Lee and Shu-Cherng Fang
National Science Foundation (NSF)
$359,990
4/1/06 – 3/1/09

We develop splines for biological deformable object modeling for implementation in haptic devices having six degrees of freedom. Research issues of both geometry and physics are incorporated in an innovative integrated approach. We investigate the use of improved mathematical models of complex-shaped objects in developing better force-feedback haptic devices. Using splines yields more accurate and simultaneously less computationally expensive representations of the geometry and mechanics of irregularly shaped objects.

Planning and Optimizing Five-Axis High-Speed Machining with Feed Scheduling for Sculptured Surface Machining

Yuan-Shin Lee
National Science Foundation (NSF)
$338,964
6/1/03 – 5/31/06

The objective of this research is to investigate strategies and techniques for planning and optimizing five-axis tool paths required in high-speed machining of complex products. In this project, we combine an innovative machining potential-field analysis with mechanistic modeling to evaluate the impacts of tool-path patterns on cycle time reduction for five-axis high-speed machining. A robust modulated performance control system is developed to improve the computational efficiency of contour-curve interpolation for optimization of five-axis high-speed machining.

Theory and Algorithms for L1 Splines Research

Shu-Cherng Fang and Yuan-Shin Lee
Army Research Office (ARO)
$332,397
6/1/04 – 5/31/07

In this project, we investigate and develop the theoretical properties of L1 splines and develop more efficient compu-

tational algorithms to calculate them. We are developing methods of creating computationally efficient nonlinear programming techniques for calculating Cartesian-coordinate cubic L1 splines by direct minimization of the spline functional without discretization. The results will be extended for calculating cubic L1 splines in curvilinear systems and Cartesian-coordinate L1 splines of degrees higher than three.

Automated Pencil Carving and Five-Axis High Speed Machining of STL Sculptured Surface Models with Automated Feed Scheduling

Yuan-Shin Lee
Forearn Company and PouChen Corporation
$215,484
1/1/02 – 12/31/05

The primary objective of this project is to develop a five-axis tool path optimization system with feed scheduling that will enable automated tool path generation for milling of STL models. This research will be useful in high-performance, multiaxis machining of advanced material used in manufacturing industries.

Excel Interface for Fuzzy Constraint Satisfaction Programming

Robert E. Young
Unfunded
Ongoing

This project involves building an Excel spreadsheet user interface for the fuzzy constraint satisfaction programming system for use in design and manufacturing. This is being done in conjunction with a former student who currently works at Intel and wants to use the system to do decision-making using imprecise information.

Fuzzy Configuration Systems

Robert E. Young
Unfunded
Ongoing

Product configuration has become a major issue as more and more product design is based upon consumers configuring their own products. A major unsolved problem is finding close matches to consumer requirements. An initial system to configure IBM PCs has been built and has led to the development of marginal fuzzy utility curves that identify proximity to requirements vs cost. These allow a customer to determine whether or not a higher cost match is justifiable based upon its proximity to the user's requirements (i.e., its fuzzy utility).

International Teams in Engineering Industrial Projects: A Cooperative Manufacturing and Production Engineering Program

Robert E. Young
U.S. Department of Education
$204,115
10/1/02 – 10/1/06

The objectives of the project are (1) to enable two universities in the U.S. and two universities in Brazil to promote international exchange of engineering students, (2) to enhance the foreign language skills and the ability of students to understand different social cultures and technical cultures, and (3) to learn how to work in a multi-national engineering design team. It is expected that students completing this program will be able to organize and participate in international engineering design teams since they will understand the cross-cultural issues that can impede successful team performance.

PRODUCTION RESEARCH

Quantifying the Value of Information in a Supply Chain

R.E. King, T.J. Hodgson, J. A. Joines, and K. A. Thoney
National Textiles Center
$548,438
5/1/03 – 4/30/06

The value of sharing inventory information in a make-to-stock environment is quantified, and operational control for a supply chain is optimized through appropriate information sharing. We consider a multistage serial supply chain with capacitated suppliers and a single retailer. Periodically each member of the supply chain makes replenishment decisions based on its inventory level. Different information sharing models are established for both two-stage and three-stage supply chains. We also analyze the effects of cost structure and demand variability on information sharing, and we analyze the transfer cost negotiation among a supply chain by identifying regions of profitability.

Strategic Analysis of Speed and Flexibility in Sourcing Textile Products

R.E. King and J.A. Joines
ITT
7/1/05 – 6/30/06

For effective sourcing of textile products, a decision maker must quantify the differences in performance between a cost-effective but long-lead-time supplier and one that is fast and responsive but not as cost-effective. Similarly, the decision maker must evaluate the advantages of dual sourcing—that is, purchasing initial inventory from a low-cost supplier and making replenishment orders with another supplier who is faster. We develop a software tool that allows detailed quantitative analysis of these sourcing decisions. We also perform analyses using the tool to understand the general conditions under which a faster, but more costly supplier provides a performance advantage.

Strategic Analysis of Furniture Supply Chains

R.E. King and M.G. Kay
Furniture Manufacturing and Management Center
7/1/05 – 1/30/06

Globalization in furniture manufacturing has adversely affected domestic furniture producers. The rapid movement of furniture production to offshore sources has significantly increased the need for efficient, reliable supply chains. In addition, because of the relatively longer supply lead times, inventory-control policies have become more critical for balancing customer service levels and inventory costs. The objectives of this project are to provide the following: (i) analyses of potential supply-chain configurations; (ii) analyses of inventory control policies of potential supply-chain

configurations; and (iii) training to industry personnel on supply-chain issues.

Optimal Coal Barge Scheduling

R.E. King and T.J. Hodgson
Progress Energy
5/16/06 – 5/15/07

We develop a coal-barge planning tool to evaluate site assignments for sources of future loads for each barge over a given time horizon. This tool includes the following elements: (i) a model to determine the optimal combination of load assignments for all barges for each specified performance criterion; and (ii) a spreadsheet for low-level user interface and data storage of model inputs and outputs coupled with a VBA graphical user interface to simplify the process of setting the model input values and displaying the model outputs.

Optimal Inventory Control in Remanufacturing Supply Chains

R.E. King
Unfunded

This project is concerned with the optimal control of inventory in a supply chain in which there is traditional production as well as remanufacture of returned inventory that is restored to "as new" condition. Markov decision processes are used to determine optimal control policies under a variety of operating conditions and supply-chain configurations.

Optimal Inventory Control for Seasonal Consumer Goods under Demand Uncertainty

R.E. King
Unfunded

An optimally controlled Markov decision process model is combined with a detailed simulation model to investigate inventory control policies for consumer products such as apparel. An underlying assumption of the model is that the forecast of seasonal demand is used to define parameters of stochastic distributions used in the model. The impact of forecasting error on performance is investigated.

SYSTEMS ANALYSIS AND OPTIMIZATION RESEARCH

Resource and Demand Allocation in Dynamic Environments

Xiuli Chao
National Science Foundation
$189,930
9/1/02 – 7/31/06

We develop a methodology for joint optimal capacity planning and customer allocation through the following steps. (i) Develop a mathematical model of the demand process, capacity planning, demand allocation, and service as well as cost to the firm and customers. (ii) Determine structural properties of several subcomponents of the problem, including capacity planning and demand allocation through pricing versus centralized control. (iii) Develop optimal combined capacity planning and demand allocation algorithms for use in diverse settings. The expected outputs include algorithms for capacity planning and demand allocation in dynamic environments typical of many different industries.

Competition and Coordination Issues in Supply Chain Management

Xiuli Chao
National Natural Science Foundation of China
$50,000
1/1/03 – 12/31/06

We study the inventory and production control problem under supplier incentive programs, in which the supplier offers pricing incentives to retailers and manufacturers, and the followers respond with their individually optimal strategies, resulting in a Stackelberg game. We also study equilibrium and coordination in supply chain management. A general mathematical formulation will be given based on conic programming and duality theory, and the objective is to devise cooperation mechanisms that induce each player to behave in such a way that when doing self and individual optimization, the global, social optimum is simultaneously achieved.

Joint Optimal Produciton and Weather Risk Hedging

Xiuli Chao and Frank Chen
Hong Kong Research Council
$75,000
1/1/05 – 12/31/08

We examine risk hedging for firms whose profitability is directly affected by weather conditions. The demand for a seasonal product depends on a weather index, such as the average seasonal temperature. The firm not only decides on production levels but also adopts a weather-hedging strategy to maximize its expected utility. We characterize the optimal joint strategy of production and weather hedging. Starting with the basic newsvendor-type production system, we extend the analysis to more general settings and show that the optimal production strategy is affected by hedging in a nonlinear, nonintuitive manner. This analysis yields insights into improved operating policies.

Splines-Based Geometric-Physics Modeling of Deformable Objects with Force-Torque Feedback

Shu-Cherng Fang and Yuan-Shin Lee
National Science Foundation (NSF)
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4/1/06 – 3/1/09

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Shu-Cherng Fang and Yuan-Shin Lee
Army Research Office (ARO)
$332,397
6/1/04 – 5/31/07

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Shu-Cherng Fang
SAS Institute, Inc.
$76,535
5/16/04 – 8/18/06

In this project we supervise industrial trainees and work closely with Trevor Kearney, Analytical Solutions Manager at SAS, for research that has been done in areas where SAS is currently active or considering research projects.

Automation of the Crosscut Operation in a Wood Processing Mill

Yahya Fathi
National Science Foundation
$1,100,000
1/1/01 – 7/31/08

This project aims to design and develop models and algorithms for optimizing the crosscut operation in a wood-processing rough mill, and to incorporate these algorithms into an integrated software system for automatic process control of the automatic scanners, the automatic crosscut saw, and all associated conveyor belts and positioning devices. This software system should significantly improve the efficiency of the crosscut operation, leading to substantial reductions in the manufacturing cost as well as significant savings in the overall consumption of wood.

Design and Operation of a Genomic Database at Duke Hospital

Yahya Fathi
Duke Hospital
$25,000
7/1/04 – 8/31/05

The primary objective of this project is to create a genomics database, consisting of clinical information, cardiac catheterization results, and blood samples from a large number of patients across the country over a five-year period, and then store the data long term for research needs. Our goal is the design and analysis of the blood storage and retrieval system and its interaction with the clinical and catheterization database, with the primary objective of facilitating the overall operation of the system as a whole in response to potential queries.

Cluster Analysis with Categorical Data

Yahya Fathi
Unfunded
8/15/03 – 8/15/05

Cluster analysis with categorical data has a wide range of applications from electronics manufacturing to data mining and pattern recognition in genomics and proteomics. We employ statistical analysis as well as integer programming and combinatorial optimization techniques to solve this problem in its various contexts.

Cutting Plane Methods in Integer Programming

Yahya Fathi
Unfunded
8/16/04 – 8/14/07

We develop a new class of facet-defining valid inequalities for a general mixed integer programming problem, and we study their effectiveness both theoretically and empirically. We also analyze the relationship between these valid inequalities and facets of the master cyclic group polyhedra.

Optimal View Selection in Data Base Design

Yahya Fathi
Unfunded
8/15/04 – 5/15/09

We conduct a formal study of the following view-selection problem: given a set of queries and a database, return definitions of views that, when implemented in the database, will reduce the evaluation costs of the queries. Optimizing the layout of stored data using view selection has a direct impact on the performance of the entire database system. At the same time, the optimization problem is intractable, even under natural restrictions on the types of queries of interest. We study exact and inexact methods for solving this problem in various database environments.

Simulation Modeling of Colorectal Cancer

Stephen D. Roberts
National Cancer Institute
$241,131
4/01/02 – 8/18/06

A C++ simulation modeling platform is adapted to enable the development of a simulation model to describe the natural history of colorectal neoplasia and its relationship to the dissemination of cancer control interventions such as primary prevention, screening, treatment, and surveillance. This adaptation will require some extension of the present C++ platform. To be complete the extension must be documented, verified, and validated.

An Autoregressive–Batch Means Approach for Steady-State Simulation Output Analysis

James R. Wilson
SAS Institute
$47,000
6/1/06 – 5/31/07

We compute an asymptotically valid confidence interval for the steady-state mean of a simulation-generated output process by exploiting a first-order autoregressive model for a version of the target process that has been suitably aggregated into batch means and truncated so as to yield an approximately stationary Gaussian process. A stopping rule

adapted to this procedure yields confidence intervals satisfying a user-specified precision requirement. The robustness of the procedure is explored by a comprehensive experimental performance evaluation.

Overlapping Variance Estimators for Simulation Output Analysis and Statistical Process Control

James R. Wilson
Unfunded
1/1/05 – 12/31/06

To estimate the variance parameter (i.e., the sum of covariances at all lags) for a steady-state simulation output process, we formulate certain statistics that (i) are computed from overlapping batches separately and then averaged over all such batches; and (ii) are based on the method of standardized time series. Analytical and Monte Carlo results demonstrate that asymptotically, the new variance estimators achieve reduced variance while maintaining (nearly) the same bias as the sample size increases. These results also have direct application to statistical process control schemes for correlated processes.

CUSUM-Based Schemes for Statistical Process Control of Correlated Processes

James R. Wilson
Unfunded
1/1/05 – 12/31/06

The conventional tabular CUSUM procedure for statistical process control (SPC) of randomly sampled processes is generalized to handle correlated processes. Analytical and Monte Carlo results demonstrate the superior performance of this approach in comparison with conventional SPC procedures for correlated processes.

INDUSTRIAL AND SYSTEMS ENGINEERING FACULTY

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