INDUSTRIAL & SYSTEMS ENGINEERING
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WORKING PAPER SERIES

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IE Working Paper 05-001

A Generalized Multistate Based Path Vector Approach for Multistate Two-Terminal Reliability

Jose E. Ramirez-Marquez, David W. Coit and Michael Tortorella

Abstract:

The two-terminal reliability (2TR) problem assumes a network and its elements can be in either a working or a failed state. However, many practical networks are built of elements that may operate in more than two states. Multistate two-terminal reliability at demand level *d* ($M2TR_d$) can be defined as the probability that system capacity, generated by multistate components is greater than or equal to a demand of *d* units. This paper presents a fully multistate based algorithm that obtains the multistate equivalent of binary path sets, namely, multistate minimal path vectors (MMPV), for the $M2TR_d$ problem. The algorithm mimics natural organisms in the sense that a select number of arcs inherit information from other specific arcs contained in a special set called "primary set." The algorithm is tested and compared with the results given in the literature. Two features of the algorithm make it relevant; first, unlike other approaches, it does not depend on the *a priori* knowledge of binary path sets for obtaining MMPV, and second, the information sharing approach and network reduction technique significantly reduce the number of vector analyses needed to obtain all component levels that guarantee system success. Additionally, complexities related to the computation of reliability have been discussed. The Monte-Carlo (MC) simulation approach presented by Ramirez-Marquez & Coit (2005) has been extended to obtain an accurate estimate of actual M2TR based on MMPV. Examples are used to validate the algorithm and the transformed simulation procedure.

IE Working Paper 05-002

A Note On Using A Counting Argument To Obtain The Life Distribution Of A *k*-Out-Of-*n* Cold Standby Ensemble

Michael Tortorella

Abstract:

This Note contains a derivation of the life distribution for a *k*-out-of-*n* cold standby system with perfect switching, subject only to the restriction that all primary units have the same reliability characteristics, all standby units have the same reliability characteristics (although these may be different from the primary units), and all units are mutually stochastically independent. The purpose of the Note is to highlight a counting argument that gets the results quickly and is also useful for pedagogical purposes.

IE Working Paper 05-003

Hard Turning Optimization Using Neural Network Modeling And Swarm Intelligence

Yigit Karpat and Tugrul Ozel

Abstract:

In this paper, multi-objective optimization of hard turning has been reported. A neural network model was developed in order to model the surface roughness and tool wear characteristics of hard turning when CBN tools are used. Objective is to obtain optimum process parameters, which satisfies given limit, tool wear and surface roughness values and maximizes the productivity at the same time. A recently developed optimization algorithm called particle swarm optimization is used to find optimum process parameters. Accordingly, the results indicate that a system where neural network is used to model and predict process outputs and particle swarm optimization is used to obtain optimum process parameters can be successfully applied to multi-objective optimization of hard turning.

IE Working Paper 05-004

Workpiece Material Model Based Predictions for Machining Processes

Yigit Karpat, Erol Zeren and Tugrul Ozel

Abstract:

In this paper, a methodology for work material constitutive model based calculations of forces, stress and temperature distributions in orthogonal machining are introduced. Oblique moving band heat source theory is utilized and combined with modified Oxley's parallel shear zone theory. Non-uniform heat intensity at the tool-chip interface is obtained from the predicted stress distributions utilizing slip line analysis of the modified secondary shear zone. Model validation is performed by comparing some experimental results with the predictions for machining of AISI 1045 steel and AL 6082-T6. Good agreements with the experiments are observed. A detailed stress and temperature distributions computed analytically is obtained.

IE Working Paper 05-005

Finite Element Method Simulation of Machining of AISI 1045 Steel with a

Round Edge Cutting Tool

Tugrul Ozel and Erol Zeren

Abstract:

In this paper, FEM modeling and simulation of orthogonal cutting of AISI 1045 steel is studied by using dynamics explicit Arbirary Lagrangian Eulerian method. The simulation model utilizes the advantages offered by ALE method in simulating plastic flow around the round edge of the cutting tool and eliminates the need for chip separation criteria. Johnson-Cook work material model is used for elastic plastic work deformations. A methodology developed to determine friction characteristics from orthogonal cutting tests is also utilized for chip-tool interfacial friction modeling. The simulation results include predicted chip formation as well as temperature and stress distributions. These results are highly essential in predicting machining induced residual stresses and other properties on the machined surface.

IE Working Paper 05-006

Northern Pacific Airspace Cost Effectiveness (NPACE) Study: Modeling and Simulation of the Impact of ADS Communication Technology

Elsayed A. Elsayed, Theresa Brewer, Christina Schroepfer
Brian Colamosca, Dale Livingston, Lauren Martin and Christine Gerhardt-Falk

Abstract:

This report details the procedures used to investigate the impact of the Automatic Dependence Surveillance (ADS) aircraft communication technology. ADS is an aircraft surveillance technique through which an aircraft can provide position reports containing identification, latitude, longitude, altitude, speed, and heading to the ground ATC system as well as nearby aircraft.

Flight events are generated for the traffic densities in the years 2005, 2010, 2015, 2020, and 2025, and the optimal minimum fuel flight plans are found for all flights. Each optimal flight plan file for each traffic density scenario is then run through the flight tracking program, designating 0%, 35%, 65%, and 100% of the flights as ADS-equipped to compare the performance of the system as the percentage of ADS-equipped flights increases. The simulation is conducted applying different longitudinal separations associated with the Required Navigational Performance standards 10 and 4 (RNP-10 and RNP-4) to investigate the system performance as the percent of ADS-equipped flights increases with reduced longitudinal separation. Lateral separation of 30 nm is accounted for by using current track definitions, and the vertical separation is 1000 feet.

To determine the effect of the different longitudinal separation for ADS and Non-ADS flights, the following performance measures are compared: (i) percent of flights delayed from their optimal oceanic entry time, (ii) average delay time of these flights, (iii) percent of flights with entry level changed from optimal, (iv) percent of flights with deviations from their optimal flight profile, (v) average increase in optimal fuel consumption.

IE Working Paper 05-007

Detection of Linear Trends in Process Mean

Hesham Fahmy and Elsayed A. Elsayed

Abstract:

In this paper we develop a process control approach to detect linear trends in the process mean. A statistic based on the deviation between the target mean and the expected mean of the process is used in the development of the new approach. The statistic is shown to have a Chi-square distribution. The approach is described and its performance is compared with Cumulative Sum (CUSUM), Exponentially Weighted Moving Average (EWMA), and Shewhart charts in detecting linear trends in the process mean. The results indicate that proposed approach is effective in detecting small to large trends. We also investigate the run length properties of the proposed approach under linear trends and compare its values with simulation results.

Finally, we analyze the performance of the proposed approach in detecting the time when a drift occurs in the process and compare it with CUSUM and EWMA estimators. The results show that the proposed approach is more effective in detecting drift time for moderate and large trends.

IE Working Paper 05-008

Multi-Objective Optimization using Genetic Algorithms: A Tutorial

Abdullah Konak, David W. Coit and Alice E. Smith

Abstract:

Multi-objective formulations are a realistic models for many complex engineering optimization problems. Customized genetic algorithms have been demonstrated to be particularly effective to determine excellent solutions to these problems. In many real-life problems, objectives under consideration conflict with each other, and optimizing a particular solution with respect to a single objective can result in unacceptable results with respect to

the other objectives. A reasonable solution to a multi-objective problem is to investigate a set of solutions, each of which satisfies the objectives at an acceptable level without being dominated by any other solution. In this paper, an overview and tutorial is presented describing genetic algorithms developed specifically for these problems with multiple objectives. They differ from traditional genetic algorithms by using specialized fitness functions, introducing methods to promote solution diversity and other approaches.

IE Working Paper 05-009

Pruned Pareto-optimal Sets for the System Redundancy Allocation Problem Based on Multiple Prioritized Objectives

Sadan Kulturel-Konak, David W. Coit and Fatema Baheranwala

Abstract:

Multi-objective problems are often solved by modifying them into equivalent single objective problems using pre-defined weights or utility functions. Then, a multi-objective problem is solved similar to a single objective problem returning a single solution. These methods can be problematic because assigning appropriate numerical values (i.e., weights) to an objective function can be challenging for many practitioners. On the other hand, methods such as genetic algorithms and tabu search often yield numerous non-dominated Pateto optimal solutions, which makes the selection of one single best solution very difficult. In this paper, a new methodology is presented to solve different versions of multi-objective system redundancy allocation problems. A tabu search meta-heuristic approach is used to initially find the entire Pareto-optimal front, and then a Monte-Carlo simulation provides a decision maker with a pruned and prioritized set of Pareto-optimal solutions based user-defined objective function preferences. The purpose of this study is to create a bridge between Pareto optimality and single solution approaches.

IE Working Paper 05-010

Solution of Stochastic Multi-objective System Reliability Design Problems using Genetic Algorithms

David W. Coit and Fatema Baheranwala

Abstract:

A methodology is presented to solve multiple-objective system reliability design problems with some (or all) stochastic objectives. For these problems, the objective is to determine the maximum system reliability, but at a minimum cost and weight without explicit constraint limits. The reliability and cost objectives are not known exactly due to estimation

uncertainties and cost fluctuations, respectively. Objective function variance measures are explicitly included in the formulation as additional objectives to be minimized for risk-averse decision makers. A multi-objective genetic algorithm is used to initially find Pareto optimal solutions, which are then prioritized based on the decision makers objective function preferences. The methodology is demonstrated on several test problems.

IE Working Paper 05-011

Practical Solutions of Multi-objective System Reliability Design Problems using Genetic Algorithms

Heidi A. Taboada, Fatema Baheranwala,David W. Coit and Naruemon Wattanapongsakorn

Abstract:

Two methods are presented as practical approaches to reduce the size of the Pareto optimal set of multiple-objective system reliability design problems. The first method is a pseudo-ranking scheme that helps the decision-maker select solutions that reflect his/her preferences. In the second approach we used clustering techniques used in data mining, to group the data by using the *k*-means algorithm to find clusters of similar solutions, which allows the decision-maker to have just *k* solutions to choose from without using any objective function preference information. Under this second method, from the clustered Pareto optimal set, we attempted to find solutions which are likely to be more relevant to the decision-maker, which are solutions where a small improvement in one objective would lead to a large deterioration in at least one other objective. To show how these methods work, the well-known Redundancy Allocation Problem was solved as a multiple objective problem by using the NSGA genetic algorithm to initially find the Pareto optimal solutions, and then, the two proposed methods are applied to prune the Pareto set.

IE Working Paper 05-012

Reliability Modeling of Electricity Transmission Systems: An Adaptation of Traditional Reliability Methods

Jose Francisco Espiritu Nolasco, David W. Coit, Upyukt Prakash
and Jose Emmanuel Ramirez-Marquez

Abstract:

For power industry systems, reliability is related to the ability of the system to provide an adequate supply of electrical energy [2-5]. However, reliability related measures are fundamentally different to those used in traditional reliability practice. System reliability is related to the probability that a product/service will operate properly for a specified period of time under the design operating conditions without failure [1]. In standard reliability theory, this probabilistic perspective has been generally used to model and analyze the reliability of

a product/service. Reliability related measures such as availability, mean time of failure, importance measures, etc. are also based on such probabilistic perspective. When considering electric power system reliability, researchers and analysts are interested in how component outages and repair rates affect the associated overall system rates. Primary interest is devoted to the quantification of system failures; this quantification is then translated to expected system outage rates, mean outage duration and overall downtime.

IE Working Paper 05-013

Detection of Linear Trends in Process Mean

Hesham M. Fahmy and Elsayed A. Elsayed

Abstract:

In this paper, we develop a process control approach to detect linear trends in the process mean. A statistic based on the deviation between the target mean and the expected mean of the process is used in the development of the new approach. The statistic is shown to have a Chi-square distribution. The approach is described and its performance is compared with Cumulative Sum (CUSUM), Exponentially Weighted Moving Average (EWMA), Shewhart, and Generalized Likelihood Ratio (GLR) charts in detecting linear trends in the process mean. The results indicate that proposed approach is effective in detecting small to large trends. We also investigate the run length properties of the proposed approach under linear trends and compare its values with simulation results. Finally, we analyze the performance of the proposed approach in detecting the time when a drift occurs in the process and compare it with CUSUM and EWMA estimators. The results show that the proposed approach is more effective in detecting drift time for moderate and large trends.

IE Working Paper 05-014

Drift Time Detection and Adjustment Procedures for Processes Subject to Linear Trend

Hesham M. Fahmy and Elsayed A. Elsayed

Abstract:

In this paper, we consider production processes when the mean of a quality characteristic is drifted linearly with time. First, we introduce a procedure to detect the drift time of the process mean as early as possible. Then, based on the estimate of the drift time, a new adjustment procedure based on the maximum likelihood estimate of the drift time is developed to keep the process mean on target. We analyze and compare the performance of the proposed estimator with cumulative sum (CUSUM) and exponentially moving average

(EWMA) change point estimation procedures. It is observed that the proposed procedure indeed estimates the drift time effectively for moderate and large trend rates. However, there is a noticeable decrease in its ability to detect drift time at small trend rates. Furthermore, the performance of the new adjustment procedure is compared with EWMA controllers. It is shown that the new procedure is more stable through a wide range of trend rates and its performance does not depend on any parameters of the process.

IE Working Paper 05-015

Post-Pareto Optimality Analysis to Efficiently Identify Promising Solutions for Multi-Objective Problems

Heidi A. Taboada and David W. Coit

Abstract:

Techniques have been developed and demonstrated to efficiently identify particularly promising solutions from among a Pareto-optimal set or sub-set. Multi-objective optimization problems can be solved by combining the objectives into a single objective, using utility theory, etc., or by determination of a Pareto-optimal set. This paper focuses on the second general approach. Pareto-optimal sets or representative sub-sets can be found by using a multi-objective evolutionary algorithm (MOEA) or by other means. Then, in practice, the decision-maker ultimately has to select one solution from this set for system implementation. However, the Pareto-optimal set is often large and cumbersome, making the post-Pareto analysis phase potentially difficult, especially if the number of objectives is large. Our research is focused on the post-Pareto analysis phase, and two methods are presented to intelligently filter or reduce the size of the Pareto-optimal set. The first method is pruning using non-numerical objective function ranking preferences. It is a pseudo-ranking scheme that assists the decision maker to select solutions that reflect his/her preferences. The second approach involves pruning by using data clustering. The *k*-means algorithm is used to find clusters of similar solutions in the Pareto-optimal set. The clustered data allows the decision maker to have just *k* general solutions to choose from, without using any objective function preference information. To demonstrate these methods, two multi-objective problems were analyzed, (1) the reservoir operating rules, and (2) the scheduling of the bottleneck operation of a Printed Wiring Board (PWB) manufacturing line.

IE Working Paper 05-016

A Note on Two-Person Zero-Sum Communicating Stochastic Games

Zeynep Muge Avsar and Melike Baykal-Gursoy

Abstract:

For undiscounted two-person communicating stochastic games with finite state and action spaces, a solution procedure is proposed that exploits the communication property, i.e., working with irreducible games over restricted strategy spaces. The proposed procedure gives the value of the communicating game with an arbitrarily small error when the value is independent of the initial state.

IE Working Paper 05-017

Workbook for Designing Distributed Control Applications using Rockwell Automation's HOLOBLOC Prototyping Software

John Fischer and Thomas O. Boucher

Abstract:

A new paradigm for creating distributed control applications is currently being proposed under the IEC 61499 standard. This standard emphasizes formal methods based on Unified Modeling Language and object oriented concepts. It makes a separation between events, data, and algorithms. Algorithm execution is initiated by the arrival of events and the algorithm uses the current values of data elements available when the event occurs. The programming is done using function blocks, a modeling formalism originally proposed under the standard IEC 1131-3, but extended under the current standard. Event propagation is accomplished by connecting events among the various function blocks.

IEC 61499 was developed to support distributed control. Distributed control is distinguished from purely hierarchical control by the fact that the decision processes associated with an application are not running under a single processor. Rather, the decision processes are divided among several processors, each having their own thread of control. However, in order to execute the application, these processors must exchange data and state information with each other.

This document explains the concepts of distributed control and provides seven examples at various levels of complexity using IEC 61499. It includes an explanation of distributed control and seven tutorials that enable students to do hands on development of basic control applications, client/server applications, and integrated database applications.

IE Working Paper 05-018

Modeling Low Probability/High Consequence Events: An Aviation Safety Risk Model

James T. Luxhoj and David W. Coit

Abstract:

In this paper, we present an overview of an Aviation System Risk Model (ASRM) that assesses the impact of new technology insertions or products designed to mitigate the likelihood or consequence of aviation accidents. In the aviation industry, accidents occur very infrequently, yet it is still critical to further reduce their rate of occurrence. There are analogous scenarios in many industries and organizations, which must aggressively analyze events that occur with a very low probability because the implications or repercussions are so very severe or extreme. While the occurrence of these events is already very rare, extensive effort and analysis is devoted to further reducing or eliminating the probability. Existing methods and models are already useful, but because of the importance of these failures, new modeling perspectives can add additional insights to further enhance safety. The ASRM, developed with joint support from the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA), is an example of a model devoted to this class of 'low probability-high consequence' events. The ASRM is demonstrated with a model developed for a certain aircraft accident type known as Controlled Flight Into Terrain (CFIT).

IE Working Paper 05-019

Data Clustering of Solutions for Multiple Objective System Reliability Optimization Problems

Heidi A. Taboada and David W. Coit

Abstract:

This paper proposes a practical methodology for the solution of multi-objective system reliability optimization problems. The new method is based on the sequential combination of multi-objective evolutionary algorithms and data clustering on the prospective solutions to yield a smaller, more manageable sets of prospective solutions. Existing methods for multiple objective problems involve either the consolidation of all objectives into a single objective, or the determination of a Pareto-optimal set. In this paper, a new approach, involving post-Pareto clustering is proposed, offering a compromise between the two traditional approaches. In many real-life multi-objective optimization problems, the Pareto-optimal set can be extremely large or even contain an infinite number of solutions. Broad and detailed knowledge of the system is required during the decision making process in discriminating among the solutions contained in the Pareto-optimal set to eliminate the less satisfactory trade-offs and to select the most promising solution(s) for system implementation. The well-known reliability optimization problem, the redundancy allocation problem (RAP), was formulated as a multi-objective problem with the system reliability to be maximized, and cost and weight of the system to be minimized. A multiple stage process was performed to identify promising solutions. The Pareto-optimal set was initially obtained using the fast elitist nondominated sorting genetic algorithm (NSGA-II). The decision-making stage was then performed with the aid of data clustering techniques to prune the size of the Pareto-optimal set and obtain a smaller representation of the multi-objective design space; thereby making it easier for the decision-maker to find satisfactory and meaningful trade-offs, and to select a preferred final design solution.

IE Working Paper 05-020

Merging and Splitting Autocorrelated Arrival Processes and Impact on Queueing Performance

Baris Balcioglu, David L. Jagerman and Tayfur Altiok

Abstract:

We have proposed a three-parameter renewal approximation to analyze splitting and superposition of autocorrelated processes. We define the index of dispersion for counts of an ordinary process used in a new and more accurate technique to estimate the third parameter. Then, we express this newly defined index of dispersion for the superposition in terms of the ordinary as well as the stationary indices of dispersion of the originally autocorrelated component processes. Hence, even if the superposition data is not observable, as long as sufficient information exists on component processes, the parameters of the proposed renewal approximation can be estimated accurately. The accurate renewal approximation of a general process helps sustain accuracy if it is split, by-passing the need to sample from branched processes. We have tested the impact of our approximation on the accuracy of the mean waiting time, which compared favorably with simulation results of the original systems.

IE Working Paper 05-021

Analysis of Queues with Autocorrelated Times to Failures

Baris Balcioglu, David L. Jagerman and Tayfur Altiok

Abstract:

In this paper, we study process completion time analysis and propose an accurate approximation for the mean waiting time in queues with servers experiencing autocorrelated times to failure. To do this, we employ a three-parameter renewal approximation that represents the autocorrelated times to failure stream. The analysis is exact in the case of phase-type interruption processes if the arrival process is Poisson. We also propose an accurate approximation for systems with renewal arrival processes it the server interruption process is general.

IE Working Paper 05-022

Finite Element Modeling of Stresses Induced by High Speed Machining with Round Edge Cutting Tools

Tugrul Ozel and Erol Zeren

Abstract:

High speed machining (HMS) produces parts with substantially higher fatigue strength; increased subsurface micro-hardness and plastic deformation, mostly due to the ploughing of the cutting tool associated with residual stresses, and can have far more superior surface properties than surfaces generated by grinding and polishing.

In this paper, a dynamics explicit Arbitrary Lagrangian Eulierian (ALE) based Finnite Element Method (FEM) modeling is employed. FEM techniques such as adaptive meshing, explicit dynamics and fully coupled thermal-stress analysis are combined to realistically simulate high speed machining with an orthogonal cutting model. The Johnson-Cook model is used to describe the work material behavior. A detailed friction modeling at the tool-chip and tool-work interfaces is also carried. Work material flow around the round edge-cutting tool is successfully simulated without implementing a chip separation criterion and without the use of a remeshing scheme.

Finite Element modeling of stresses and resultant surface properties induced by round cutting tools is performed as case studies for high speed machining of AISI 1045 and AISI 4340 steels, and Ti6A14V titanium alloy.

IE Working Paper 05-023

An Analytical-Thermal Modeling Approach for Predicting Forces, Stresses and Temperatures in Machining with Worn Tools

Yigit Karpat and Tugrul Ozel

Abstract:

In this paper, predictive modeling of cutting and ploughing forces, stress distributions on tool faces and temperature distributions in the presence of tool flank wear are presented. The analytical and thermal modeling of orthogonal cutting that is introduced in Karpat, Zeren and Ozel [3] extended for worn tool case in order to study the effect of flank wear on the predictions. Work material constitutive model based formulations of tool forces and stress distributions at tool rake and worn flank faces are utilized in calculating non-uniform heat intensities and heat partition ratios induced by shearing, tool-chip, interface friction and tool flank face-workpiece interface contacts. In order to model forces and stress distributions under the flank wear zone, a force model from Waldorf [4] is adapted. Model is tested and

validated for temperature and force predictions in machining of AISI 1045 steel and AL 6061-T6 aluminum.

IE Working Paper 05-024

Modeling Traffic Flow Interrupted by Incidents

Melike Baykal-Gursoy, Weihua Xiao and Kaan Ozbay

Abstract:

A steady-state M/M/C queueing system under batch service interruptions is introduced to model the traffic flow on a roadway link subject to incidents. When a traffic incident happens, either all lanes or part of a lane is closed to the traffic. As such, we model these interruptions either as complete service disruptions where none of the servers work or partial failures where servers work at a reduced service rate. We analyze this system in steady state and present a scheme to obtain the generating function of stationary number of vehicles on a like. For those links with large *C* values, the closed-form solution of M/M/∞ queues under batch service interruptions can be used as an approximation. We present simulation results that show the validity of our approximate model.

IE Working Paper 05-025

Probabilistic Programming Models for Dispatching and Resource Allocation in Traffic Incident Management

Kaan Ozbay, Weihua Xiao, Cem Iyigun and Melike Baykal-Gursoy

Abstract:

This paper proposes mathematical programming models with probabilistic constraints in order to address incident response and resource allocation problems for traffic incident management. In incident response problems, we introduce the concept of quality of service during a potential incident to give the operator the flexibility to determine dispatching policy in response to various situations. An integer programming model with probabilistic constraints is proposed to address the dispatching problem with consideration given to the stochastic resource requirements at the sites of the potential incidents. For the resource allocation problem, assuming that the stochastic distribution of incidents over a network is given, we introduce a mathematical model to determine the number of service vehicles allocated to each depot to meet the requirements of the potential incidents by taking into account the stochastic nature of the resource requirement and incident occurrence probabilities. For completeness, relevant concepts and solution algorithms in stochastic programming are also presented. Several examples are included to demonstrate the

applications of these models to real-world problems. This paper concludes with a summary of results and recommendations for future research.

IE Working Paper 05-026

Service Reliability of NCO Information Product Manufacturing Systems

Michael Tortorella and Patrick J. Driscoll

Abstract:

The Network-Centric Operations Conceptual Framework (NCO-CF) contains many factors pertaining to the use of information in NCO. Information plays such a central role, however, that the importance of high-quality information must not be overlooked. Information that is of poor quality (even in an informal sense) is at best distracting and at worst catastrophic to NCO. In addition, a key quality attribute for information is that consumers of the information must be able to access it reliably. The highest quality information is useless if it cannot be seen so that it can be acted upon. This paper discusses aspects of service reliability for NCO information distribution services that commanders and warfighters use to obtain information. A framework for thinking about these problems and several examples from recent case studies are discussed.

IE Working Paper 05-027

Redundancy Allocation for Series-Parallel Systems Using a Column Generation Approach

Leila Zia and David W. Coit

Abstract:

Solution methods are described and demonstrated for the redundancy allocation problem based on the decomposition approach of column generation. This problem involves the maximization of system reliability by selecting components and redundancy levels as part of engineering design. It is a well-known nonlinear integer programming problem that has been studied in great detail using different solution approaches and problem formulations. Previously, when using mathematical programming approaches to solve the problem, either a restricted problem domain was considered or approximations or surrogate problems were used. Alternatively, metaheuristics have been used to solve the problem with impressive results. In this new approach, a linear master problem and multiple nonlinear subproblems are iteratively solved to obtain a final solution using column generations. The objective function is considered directly without any restrictions on the solution domain. This column generation approach is demonstrated on 33 well-known problems. The overall quality of the

solutions match or surpass existing methods, while only requiring a small fraction of the computational effort required by the metaheuristic approaches.

IE Working Paper 05-028

Queueing Analysis of a Server Node in Transaction Processing Middleware Systems

Wei Xiong and Tayfur Altiok

Abstract:

Quantitative performance modeling of complex information systems is of immense importance for designing enterprise e-business infrastructures and applications. In this paper, we present a traffic model of a server node in a typical Transaction Processing middleware system as well as a quantitative framework to model and analyze its performance. A multi-class open queueing network model is presented in which multi-class jobs are admitted to a number of server processes sharing hardware resources including the CPU and the disk. We have developed a viable approximation method, which decomposes the dependent components into their independent counterparts while preserving their relevant characteristics. We have conducted queueing-theoretic delay analyses and verified the approach using simulation. Results demonstrate the strength of our approach in predicting delays, elapsed times and other system performance measures.

IE Working Paper 05-029

TES Processes and ARIMA Models: A Comparison of Forecasting Performance

Abdullah S. Karaman and Tayfur Altiok

Abstract:

Forecasting is of prime importance for accuracy in decision-making. For data sets containing high autocorrelations, failure to account for temporal dependence will result in poor forecasting. TES (Transform-Expand-Sample) is a class of stochastic processes to model empirical autocorrelated time series and is frequently used in Monte Carlo simulation. Its merit is to capture simultaneously both the empirical distribution function and the autocorrelation function of a stochastic process. In addition, its analytical background makes it a viable tool to forecast future values of time series data. In this paper, we utilize phase-type random variables as the innovation density in the TES model fitting methodology, and we investigate the forecasting performance of TES processes compared

to traditional auto regressive integrated moving-average models. We find that TES models yield forecasts as accurate as time series models.

IE Working Paper 05-030

Component Criticality Importance Measures for the Power Industry

Jose F. Espiritu, David W. Coit and Upyukt Prakash

Abstract:

New reliability importance measures have been developed for the power industry to be applied for Electricity Transmission Systems (ETS). Reliability criticality measures are useful metrics to rank components regarding their impact on system performance. Criticality measures serve as useful tools to priority reliability improvement activities, identify weak-links in the system and many other uses. These proposed measures pertain to the outage rate of the system and component instead of the probability of failure or survival for a defined mission time. Outage rate is the best suited and appropriate output variable to evaluate the importance of the components in the electricity distribution system. The ETS is the component of the bulk transmission system to provide electricity to large municipalities, large industrial customers and the retail distribution system. The ETS is composed mainly of components such as lines, transformers, breakers and buses. All these components are interconnected with the aim of transporting electrical energy from the bulk transmission system to various load points. The new criticality measures are demonstrated on some commonly used electrical configurations, such as, breaker-and-a-half, breaker-and-a-third and the dual element spot network (DESN) for ETS.

IE Working Paper 05-031

Design and Development of Lightweight Sandwich Structures with Innovative Sheet Folded Cores

Basily B. Basily and Elsayed A. Elsayed

Abstract:

In this paper, use of folded patterns as core structures for paper-based flexible wall panels and floorboards building materials was investigated. Effect of changing the geometrical parameters/conditions of the Chevron and the Mating Surfaces Chevron (MSC) patterns on panel core structure performance were studied, aim is to achieve high compressive strength and equal bending stiffness in both the longitudinal and perpendicular directions of the laminated core. Three folded core configuration were considered namely; a 3:1 aspect ratio

Chevron pattern, a 1:1 aspect ratio MSC pattern with glued mating surfaces, and 1:1 aspect ratio MSC pattern without glued mating surfaces.

Experimental study of the mechanical properties of the folded structures was focused on flexural rigidity derived from three point bending tests, and the structure load bearing capacity derived from static compression test, with a main objective of developing a panel with folded core structure of a specific pattern and geometry that provides high compressive strength and equal flexural rigidity in both longitudinal and perpendicular directions of the folded structure.

Test results indicated that panel with core structure of 1:1 aspect ratio MSC folded pattern with glued mating surfaces provided sandwich structure of equal flexural rigidity in both the longitudinal and perpendicular directions and higher compressive strength, where, the applications for such high performance lightweight structure produced at much reduced cost are numerous.

IE Working Paper 05-032

Vision-based Online Process Control in Manufacturing Applications

Yuan Cheng and Mohsen A. Jafari

Abstract:

Applications such as layered manufacturing, or in general, solid free-form fabrication, pose a major challenge on online process control. For these parts to be functional, it is imperative that their mechanical and structural properties are strictly kept within respective tolerances. To that end, no internal or external defects, especially voids, can be tolerated. Since these parts are made layer by layer, it is then necessary to inspect top surface and boundary of each layer before the next layer is deposited. Two issues are of major concern here: (1) Inspection must be non-destructive, that is, layer surface and boundary must not be touched by the inspecting instruments, (2) the time window for inspection and any corrective measures should not exceed the maximum time limits necessary for two adjacent layers to properly bind together. Here, we present a closed loop online process control model where the process feedbacks are obtained from a 3D imaging system, and where the process dynamics model takes into account the correlation and dependency between adjacent layers. To ensure that the feedback is performed within the tolerable time windows, our 3D image processing parametric model takes advantage of physical characteristic of layer surface, and uses Gaussian function as a shape descriptor of image units. We obtain 2-D profiles from representative signature(s), and then sweep along road path defined in the CAD model. The idea of reconstructing representative signature comprises some accuracy, but compared with classical shape-from-shading method, the proposed approach is computationally more efficient. The 3D quality measures (such as volume or depth of voids) are then fed to process dynamics model, which computes the necessary compensation on the deposition flow rate for the next layer. We examine three process dynamics models to

find out that a fuzzy model, which takes into account correlation between adjacent layers and includes locally linear sub-models for underfills and overfills is the most appropriate.

IE Working Paper 05-033

Optimization of Open-water Disposal Sites using NLP

Haleh Valian, Trevor Williams and Mohsen A. Jafari

Abstract:

Dredging disposal in areas with environmental constraints requires that decisions about the placement of dredging material be made with little margin for error. A nonlinear programming model has been developed to assist in the management of open water dredged material disposal sites. The model has been developed based on conditions at the near-shore open water disposal site near the mouth of the Columbia River. The optimization model considers available capacity of cells within the disposal area to produce a plan that minimizes mounding within the site. Initial testing of the optimization model indicates that it produces reasonable dumping plans. Ultimately, the optimal dumping plans will be simulated for various stages of the dredging disposal cycle.

IE Working Paper 05-034

An Analytical Approach for Performance Analysis of J2EE Application Servers

Wei Xiong and Tayfur Altiok

Abstract:

With the advent of new technologies, there is an increasing demand for computer systems with stringent timing constraints. The goal of our research is to compute client response times in J2EE applications in an efficient and accurate manner. For this purpose, we have described a framework to identify critical components of an application server based on architectural analysis. A traffic model is constructed and studied as a queueing network to approximate the performance of the server node. Performance measures such as elapsed times, response times, and CPU/disk utilization are obtained. Numerical examples are provided to show accuracy of the proposed approximation in various load scenarios.

IE Working Paper 05-035

Queues with Deterministic Reneging Times

Wei Xiong, Tayfur Altiok and David Jagerman

Abstract:

We consider single-server and multi-server queues with deterministic reneging times motivated by the timeout mechanisms used in application servers. A Volterra integral equation is developed using the level crossing analysis for the M/G/1 queue with reneging. An analytical solution is given for the M/Hyper-Exponential/1 queue with deterministic reneging times and a numerical approach is presented for the M/G/1 queue with deterministic reneging times. We further present an approximation method for the expected waiting time in the M/G/n queue with deterministic reneging times. Approximations are verified via simulation and numerical results reveal that predictions are highly accurate with errors, in general, below 5%.