

WORKING PAPERS 2007

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ISE Working Paper 07-001

On The Time Series Support Vector Machine using Dynamic Time Warping Kernel for Brain Activity Classification

W. Chaovalitwongse and P. M. Pardalos

Abstract:

Most experiments in brain study have resulted in massive datasets, in a form of multi-dimensional time series data (e.g., EEGs, MRIs, PETs). These data contain both spatial and temporal properties of brain functions. Making sense of such massive data requires very efficient and sophisticated techniques that are capable of capturing both spatial and temporal properties simultaneously. Epilepsy will be a case point in our study. There is a growing interest in predicting epileptic seizures using intracranial electroencephalogram (EEG), which is a tool for evaluating the physiological state of the brain. Although recent research in seizure prediction has demonstrated the seizure predictability, the question of whether the brain's normal and pre-seizure (seizure pre-cursor) activities are distinctive or differentiable remains unanswered. As EEG data are in a form of multi-dimensional time series, we herein propose a new data mining technique used to classify normal and pre-seizure EEGs. Such a technique is based on a time series kernel, specifically dynamic time warping kernel, incorporated with support vector machines (SVMs). We then compare the classification performance achieved by the proposed technique with one achieved by a standard SVM. The experimental results indicate that the proposed technique is superior to a standard SVM and can improve the brain activity classification. This study suggests that it may be possible to design and develop efficient seizure warning algorithms for diagnostic and therapeutic purposes. This framework is also an initial proof of concept investigations, which is a necessary first step in differentiating the brain's normal and pre-seizure activities.

ISE Working Paper 07-002

Novel Optimization Models for Multidimensional Time Series Classifications:

Application to the Identification of Abnormal Brain Activity

W. Chaovalitwongse, Y. J. Fan and R. C. Sachdeo

Abstract:

The human brain is among the most complex systems known to man. Many theories of brain functions have been proposed over the last century. To empirically test those long-standing hypotheses about brain functions, one has to acquire and capture large enough number of neurons that will result into data avalanche with properties in space and time. In this study, novel optimization models for classification of spatio-temporal data (multidimensional time series) are developed and used as an advanced medical decision making tool. Epilepsy will be a case in point in this study. It is the second most common brain disorder after stroke, yet arguably the most devastating one because of unpredictable seizure occurrences. Most epilepsy studies use electroencephalograms (EEGs), acquired in multidimensional time series format as a gold-standard tool for capturing the electrical changes in the brain. The proposed optimization models are used in the development of a decision-making tool that can recognize seizure pre-cursors and identify seizure susceptibility (pre-seizure) periods. This study is a necessary first step to strike on the seizure prediction issue by developing a novel classification paradigm that can accurately and reliably differentiate pre-seizure from normal EEGs. The optimization models of the proposed paradigm are derived from the nearest neighbor rule and mathematical programming of support vector machines. The empirical results are very encouraging as the proposed classification paradigm achieved an average sensitivity and an average specificity over 80% in 10 patients. The proposed optimization models are very compact and scalable, and can be implemented as an online algorithm. The outcome of this study suggests that it is possible to construct a computerized algorithm used to detect seizure pre-cursors and warn of impending seizures through EEG classification.

ISE Working Paper 07-003

Novel Quadratic Programming Approach for Time Series Clustering with Biomedical Application

W. Chaovalitwongse

Abstract:

Fundamental problems in data mining fundamentally involve discrete decisions based on numerical analyses of data (e.g., class assignment, feature selection, data categorization, identifying outlier samples). These decision-making problems in data mining are combinatorial in nature and can naturally be formulated as discrete optimization problems. One of the most widely studied problems in data mining is clustering. In this paper, we propose a new optimization model for hierarchical clustering based on quadratic programming and later show that this model is compact and scalable. Application of this clustering technique in epilepsy, the second most common brain disorder, is a case point in

this study. In our empirical study, we will apply the proposed clustering technique to treatment problems in epilepsy through the brain dynamics analysis of electroencephalogram (EEG) recordings. This study is a proof of concept of our hypothesis that epilepsy brains tend to be more synchronized (clustered) during the period before a seizure than a normal period. The results of this study suggest that data mining research might be able to revolutionize current diagnosis and treatment of epilepsy as well as give a greater understanding of brain functions (as well as other complex systems) from a system perspective.

ISE Working Paper 07-004

A Path-Based Formulation Model with Column Generation Approach For Routing and Protection of Shared Risk Resource Group

Z. Liang, W. Chaovalitwongse, M. Cha, J. Yates, A. Shaikh and S. B. Moon

Abstract:

This paper describes a novel path-based formulation for always-on multicast streaming services in a core internet protocol (IP) network. This work is motivated by recent efforts to distribute broadcast TV contents over the telecommunication networks, known as IPTV services. In this multicast problem, there are two geographically diverse sources (for redundancy) and multiple destinations, where the goal of our optimization model is to find the minimal cost routing that can survive from catastrophic failures. In the IP network, routers, represented by nodes in a graph, are interconnected over a switched optical backbone through IP links, represented by edges in a graph. We propose a novel path-based mathematical model as well as develop a column generation approach to solve this problem. Using realistic networks, we evaluate the proposed solution approaches in terms of computational time and solution quality. Our empirical results show that the proposed approach is efficient and scalable and also assists the existing efforts toward this always-on multicast problem to become practical.

ISE Working Paper 07-005

Integer Linear Programs for Routing and Protection Problems in Optical Networks

M. Cha, Z. Liang, W. Chaovalitwongse, Y. Yates, A. Shaikh and S. B. Moon

Abstract:

This paper addresses the problem of provisioning for always-on multicast streaming services in a core IP network, in which routers are interconnected over a switched optical backbone. Our work is motivated by recent efforts to distribute broadcast TV contents over the telecommunication networks, known as IPTV services. We assume there are two geographically diverse sources (for redundancy) and multiple destinations, where the goal is to design routing strategy that is cost effective and also able to survive from catastrophic failures. Specifically, we consider robustness against single IP router or link failure, as well as multiple simultaneous failures due to shared fiber spans (SRLGs). Existing heuristic approaches to this \emph{NP-hard} problem in the literature are limited as they do not guarantee a feasible solution to be found nor the solution quality. The integer linear programming (ILP) model for this problem has been proposed in \cite{mee.gi06}, but the scalability issue of large-scale problems has not been addressed. In this paper, we develop efficient and scalable solution approaches that assist the existing efforts toward this problem to become practical. Our approaches are based on network decomposition technique, guarantee a solution, and outperform existing heuristic in terms of capital expense (CAPEX) savings. Using realistic networks, we evaluate the proposed solution approaches (in terms of computational time and CAPEX of designs) and compare it with that of existing approaches.

ISE Working Paper 07-006

Scheduling the Operations of an Integrated Production-Distribution Process

L. Lei, W. Chaovalitwongse and S. Bora

Abstract:

We consider a variation of the integrated scheduling problem where the operations of a capacitated facility and a fleet of heterogeneous vessels must be sequenced to minimize the operating cost during a multi-period production and distribution process. We prove the NP-hardness of the problem, analyze the problem properties, and propose a partial linear-programming relaxation based heuristic approach. We also derive an error bound of this heuristic for a special case of the problem. Finally, the empirical observations on the computational performance of the heuristic under general cases are reported.

ISE Working Paper 07-007

On the Quadratic Programming Approach for Uncapacitated Single Allocation p-Hub Median Problem

X. He, A. Chen, W. Chaovalitwongse, Z. Liang and H. Liu

Abstract:

Hub networks play an important role in many real life network systems such as transportation and telecommunication networks. Hub location problem is concerned with identifying appropriate hub locations in a network and connecting an efficient hub-and-spoke network that minimizes the flow-weighted costs across the network. This chapter is focused on the uncapacitated single allocation p -hub median problem (USA p HMP), which arises in many real world hub networks of logistics operations. There have been many approaches used to solve this problem. We herein focus on a quadratic programming approach, which has been proven very effective and efficient. This approach incorporates the use of the Reformulation-Linearization Techniques (RLTs) for 0-1 quadratic program. In this chapter, we give a brief review of the RLTs for 0-1 quadratic programs and compare the performance of several existing RLTs for USA p HMP. Toward the end, we discuss some properties, comments and possible developments of these RLTs in the real life USA p HMP.

ISE Working Paper 07-008**Reconstructing Sibling Relationships in Wild Populations**

T.Y. Berger-Wolf, S. Sheikh, B. DasGupta, M.V. Ashley,
I.C. Caballero and W. Chaovalitwongse

Abstract:

Reconstruction of sibling relationships from genetic data is an important component of many biological applications. Most current sibship reconstruction methods use statistical and heuristic techniques that rely on a priori knowledge about various parameter distributions. We present a deterministic algorithm that parsimoniously reconstructs sibling groups. We use Mendelian laws of inheritance to generate potential sibling groups. We then optimally select a minimum set of sibling groups necessary to explain the data. We validate our approach using both simulated and real biological data.

ISE Working Paper 07-009**On the K-Nearest Dynamic Time Warping Neighbor for
Abnormal Brain Activity Classification**

W. Chaovalitwongse, Y. J. Fan and R. Sachdeo

Abstract:

Epilepsy is one of the most common brain disorders but the dynamical transitions to neurological dysfunctions of epilepsy are not well understood in current neuroscience

research. Uncontrolled epilepsy poses a significant burden to society due to associated healthcare cost to treat and control the unpredictable and spontaneous occurrence of seizures. The objective of this study is to develop and present a novel classification technique used to classify normal and abnormal (epileptic) brain activities through quantitative analyses of electroencephalogram (EEG) recordings. Such technique is based on the integration of sophisticated approaches from data mining and signal processing research (i.e., chaos theory, k -nearest neighbor, and statistical time series analysis). The proposed technique can correctly classify normal and abnormal EEGs with the sensitivity 81.29% and the specificity of 72.86% on average across 10 patients. The experimental results suggest that the proposed technique can be used to develop an abnormal brain activity classification for detecting seizure pre-cursors. Success of this study demonstrates that the proposed technique can excavate hidden patterns/relationships in EEGs and give a greater understanding of brain functions from a system perspective, which will advance current diagnosis and treatment of epilepsy.

ISE Working Paper 07-010

Design and Analysis of Variable Micro-geometry Tooling for Machining using 3-D Process Simulations

Yigit Karpat, Tugrul Ozel, John Sockman and William Shaffer

Abstract:

Emerging machining techniques such as hard turning, hard milling and micro-mechanical machining, set high standards for tooling. These techniques, where the uncut chip thickness and the tool edge dimension are in the same order of magnitude, require cutting edges, which can withstand high mechanical and thermal induced stresses during machining. It has been known that sharp tools are not suitable for these kinds of operations, therefore, tool manufacturers introduced different types of tool edge preparations. A common approach is to provide uniform edge preparation. In this paper, variable edge micro-geometry designs are proposed. In 3-D tooling model, where the thickness of the chip varies from a maximum value, which is equal to the feed rate, to a minimum value on the tool's corner radius, the ideal tool edge preparation should possess a variable edge configuration which is different at the primary cutting edge than at the tool's corner radius. In variable edge design, the key parameter is the ratio of uncut chip thickness to edge radius. If this ratio can be calculated, for given cutting conditions a variable cutting edge can be designed or "engineered". In this study, the relationships between process inputs and outputs are established by analytical and 3-D finite element analysis based models. Analytical models which are mainly based on slip-line field analysis are utilized in identifying friction factors. Predicted temperatures and stress distributions on the tooling demonstrate the advantages of variable edge micro-geometry PCBN tooling in machining of steels.

ISE Working Paper 07-011

3-D FEA of Hard Turning: Investigation of PCBN Cutting Tool Micro-geometry Effects

Yigit Karpat and Tugrul Ozel

Abstract:

In this study, 3-D finite element modeling of precision hard turning has been used to investigate the effects of cutting edge micro-geometry on tool forces, temperatures and stresses in machining of AISI H13 steel using polycrystalline cubic boron nitride (PCBN) inserts with two distinct edge preparations. Hard turning experiments were conducted to investigate the effects of cutting edge geometry, feed rate and cutting speed on tool flank wear and resultant forces. During hard turning experiments, low-grade PCBN inserts with honed and chamfered edge preparations and through-hardened AISI H-13 steel bar were used. Three components of tool forces and flank wear of the inserts were measured. PCBN inserts with honed micro-geometry cutting edge resulted in lower tool flank wear in all cutting conditions. The feasibility of using finite element analysis to investigate the cutting tool micro-geometry effects in 3D hard turning is also explored.

ISE Working Paper 07-012

Port-of-entry Inspection: Sensor Deployment Policy Optimization

Elsayed A. Elsayed, Christina Schroepfer, Minge Xie, Hao Zhang and Yada Zhu

Abstract:

This paper considers the problem of container inspection at the port-of-entry. Containers are inspected through a specific sequence to detect the presence of nuclear materials, biological and chemical agents, and other illegal shipments. The threshold levels of sensors at the inspection stations affect the probabilities of incorrectly accepting or rejecting a container. In this paper we present several optimization approaches on how to select sensor threshold levels under considerations of misclassification errors, total cost of inspection, and budget constraint. Examples of the use of the approaches in different sensor arrangements are demonstrated.

ISE Working Paper 07-013

Semi-Markov Decision Processes: Nonstandard Criteria

M. Baykal-Gursoy and K. Gursoy

Abstract:

Considered are semi-Markov Decision Processes (SMDPs) with finite state and action spaces. We study two criteria; the expected average reward per unit time subject to a sample path constraint on the average cost per unit time, and the expected time-average variability. Under a certain condition, for communicating SMDPs, we construct (randomized) stationary policies that are ε -optimal for each criterion; the policy is optimal for the first criterion under the unichain assumption, the policy is optimal and pure for a specific variability function in the second criterion. For general multichain SMDPs, by using a state space decomposition approach, similar results are obtained.

ISE Working Paper 07-014

A Multi-Objective Evolutionary Algorithm for Determining Optimal Configurations of Multi-Task Production Systems

Heidi Taboada, Jose Espiritu, David Coit and Gregory Levitin

Abstract:

This paper proposes a new multiple objective evolutionary algorithm to determine optimal configurations of multi-state, multi-task production systems based on availability analysis. A multi-task production system is one in which different subsets of machines can be used to perform distinct functions or tasks. The performance of a manufacturing system is greatly influenced by its configuration. Availability can be used in the context of multi-task production systems to select a particular configuration that maximizes the probability of meeting a required demand for each specific task, or the expected productivity for each task. A particular configuration may not simultaneously maximize the probability of meeting demand for each of the individual tasks, and thus, the problem is treated as a multi-objective optimization problem. The solution to this problem is a set of promising solutions that provides a trade-off among the different objective functions considered.

ISE Working Paper 07-015

Applications of Folding Flat Sheets of Materials into 3-D Intricate Engineering Designs

Elsayed A. Elsayed and Basily B. Basily

Abstract:

Folding of flat sheets of material into intricate three-dimensional structures provides a new technology for production of cores and sandwich structures of high strength/weight and/or strength/volume ratios. Geometric patterns are generated by transforming flat sheets of materials (traditional or composite) by imposing a permanent fold at specific edges of tessellated sheets. This might result in new structures with improved mechanical properties and light weight. They are also developed at a cost significantly less than any existing manufacturing process. Folding technology for sheet material is unique and one of the most efficient shape and structural forming processes. Other production methods such as stretch-drawing, forging, pressing, casting and fabrication may appear to produce three-dimensional patterns that are cosmetically similar but the mechanical properties of the resultant patterns are significantly different. This is particularly so in the case of folding thin sheet materials where variations in sheet thickness and/or mechanical properties are unacceptable. In this paper we present new approaches for sheet folding and investigate the use of sheet folding theory and technology in generating 3-D intricate engineering designs. We describe the theory of generating different patterns by folding flat sheets of materials. We investigate the effect of the parameters of the pattern in terms of its material type and geometry on its performance measures of the folded patterns. We then describe the manufacturing process that transforms a flat sheet of material into the desired pattern. The advantages and limitations of the process are discussed in details.

ISE Working Paper 07-016

An Analytical Approach for Performance Analysis of J2EE Application Servers

Wei Xiong and Tayfur Altioek

Abstract:

With the advent of new technologies, there is an increasing demand for computer systems with stringent time 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 a 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.

ISE Working Paper 07-017

Multi-Period Inventory Models with

Multi-Dimensional Procurement Bidding

Pooya Farahvash and Tayfur Altıok

Abstract:

In this work, we consider a multi-period inventory model with raw material procurements done via a reverse auction. Bids are multi-dimensional and they consist of supplier information of price, shortage quantity and lead time. This work is an extension of our earlier work that has integrated single-period inventory models with multi-dimensional procurement auctions to multi-period settings. The new model is based on a hybrid approach combining stochastic dynamic programming and simulation.

ISE Working Paper 07-018

Modelling and Simulation of Micro-Milling Process

T. Ozel, X. Liu and A. Dhanorker

Abstract:

Micro-milling is a direct operation to manufacture net-shaped small parts offering alternative to other micromanufacturing processes. It is a flexible method of fabricating three-dimensional (3-D) features including micro molds/dies and fully functional metal devices specifically with recently developed miniature machine tools. Increasing popularity of micro-milling has sparked the interest of researchers to study the micro-milling processes to improve the quality, reliability and productivity. In this paper, experimental and modeling studies on micro-milling of AL 2024-T6 aluminum and AISI 4340 steel are presented. Micro-milling experiments are conducted using 0.635 mm diameter end mill at spindle speeds up to 80,000 rpm. Experimental studies include dynamic force measurements to understand the influence of feed rate and spindle speed on the forces and surfaces generated. The finite element modeling of micro-milling based on large plastic deformations is also conducted to predict chip formation and temperature fields without considering process dynamics. Size effects and minimum chip thickness related to edge radius and chip load on the workpiece deformations are also investigated.

ISE Working Paper 07-019

Identification of Constitutive Material Model Parameters For High-Strain Rate Metal Cutting Conditions Using Evolutionary Computational Algorithms

Abstract:

Advances in plasticity based analytical modeling and finite element methods (FEM) based numerical modeling of metal cutting have resulted in capabilities of predicting the physical phenomena in metal cutting such as forces, temperature and stresses generated. However, accuracy and reliability of these predictions rely on a work material constitutive model describing the flow stress, at which work material starts to plastically deform. This paper presents a methodology to determine deformation behavior of work materials in high-strain rate metal cutting conditions and utilizing evolutionary computational methods in identifying constitutive model parameters. The Johnson-Cook (JC) constitutive model and cooperative particle swarm optimization (CPSO) method are combined to investigate the effects of high-strain rate dependency, thermal softening and strain rate-temperature coupling on the material flow stress. The methodology is applied in predicting Johnson-Cook constitutive model parameters, and the results are compared with the other solutions. Evolutionary computational algorithms have outperformed the classical data fitting solutions. This methodology can also be extended to other constitutive material models.

ISE Working Paper 07-020

Neural Network Process Modeling for Turning of Steel Parts using Conventional and Wiper Inserts

Tugrul Ozel, A. Esteves Correia and J. Paulo Davim

Abstract:

In this paper, the effects of tool corner design on the surface finish and productivity in turning of steel parts are presented. Surface finishing has been investigated in finish turning of AISI 1045 steel using conventional and wiper (multi-radii) design inserts. Multiple linear regression models and neural network models are developed for predicting surface roughness, mean force and cutting power. Experimental results indicate that lower surface roughness values are attainable with wiper tools. Neural network based predictions of surface roughness are carried out and compared with a non-training experimental data. These results show that neural network models are suitable to predict surface roughness patterns for a range of cutting conditions in turning with conventional and wiper inserts.

ISE Working Paper 07-021

Laser Micro-Machining of Spherical and Elliptical 3-D Objects Using Hold Area Modulation Method

Wen-Hui Lee and Tugrul Ozel

Abstract:

Laser micromachining has the capability to fabricate very small and basic 2.5 D geometric features on a range of materials in the form of laser ablation or irradiation. Short pulsed lasers that can achieve wide range of wavelengths in the form of harmonics of infrared laser beam at 1064 nm wavelength have been a very effective micro-machining tool used for hole drilling, cutting, scribing, trimming, and marking. A review of laser processing of materials is given in this paper.

Direct laser ablation can be performed by controlling laser beam properties such as laser energy, intensity, pulse duration and wavelength in micro-machining 3-D geometric features. However, this method requires additional capabilities for a typical laser beam generating and delivery system. When the laser beam properties cannot be altered, Hole Area Modulation (HAM) method becomes alternative solution by controlling the density of the holes and the step size in a mask to improve the accuracy of the 3-D geometric feature.

In this paper, we perform modeling, planning and simulation of laser micromachining with hold area modulation method to produce spherical and elliptical objects 3-D geometrical features that are typical for aspheric and or refractive micro-lenses. A computational methodology is developed to design a mask with varying density and diameter of the holds. The masks are created using micro-drilling and utilized in laser micromachining of 3-D objects on polycarbonate polymer substrates.

ISE Working Paper 07-022

Stochastic Decomposition: Markov Modulated Arrival and Service, and Retrial Queues

Melike Baykal-Gursoy and Zhe Duan

Abstract:

In this paper, we study M/M/infinite queue with two state Markov-modulated arrival and service processes. We obtain the stationary distribution of the number of customers in the system explicitly and present its expected value and its variance. Then, we investigate the stochastic decomposition result for the M/M/1/1 retrial queue with infinite capacity in the

retrial orbit. We demonstrate the form of the density function for both cases via some numerical examples.

ISE Working Paper 07-023

Recent Developed Evolutionary Algorithms for the Multi-Objective Optimization of Design Allocation Problems

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

Abstract:

This paper presents an overview of a collection of recent developed evolutionary algorithms for solving different types of allocation problems under the algorithms are: MOEA-DAP, MOMS-GA and the Multi-multiple objective evolutionary algorithm for solving design allocation problems. MOEA-DAP considers binary-state reliability. In contrast, MOMS-GA, which is a natural extension of MOEA-DAP, works under the assumption that both the system and its components, experience more than two possible states of performance. The last algorithm presented in the paper is the Multi-Task Multi-State MOEA, which is a multiple objective algorithm designed to determine optimal configurations of multi-state, multi-task, production systems based on availability analysis. These three algorithms are novel approaches that offer distinct advantages to current existing MOEAs,

ISE Working Paper 07-024

Component Replacement Models for Electricity Transmission and Distribution Systems

Jose F. Espiritu, David W. Coit and Naruemon Wattanapongsakorn

Abstract:

Two different methods are proposed to optimize the operations of the electricity transmission and distribution systems. In the first method new criticality importance measures are developed in order to determine the relative importance of each individual component within the system. The second method is a combined dynamic programming and integer programming replacement analysis method to obtain optimal system-level component replacement schedules with the objective of minimizing the total Net Present Value of unmet demand, maintenance and purchase costs over a finite horizon planning.

ISE Working Paper 07-025

Management of Medical Staff in Case of Emergency Evacuation Preparedness and Response

M. A. Jafari, J. Hammond, D. Golmohammadi and K. Seyed

Abstract:

In this paper, the crucial role of resource management in an emergency situation is addressed and analyzed. We propose a methodology to allocate hospitals limited human resources (medical staff) to the sections of the hospital, which need to be evacuated of its patients. In this regard, we first show that the assumptions of unlimited resource capacity and lack of interaction between these resources may lead to invalid results and plans. We then present an analytical methodology to model the dispatching of the limited human resources to aid patients to transfer to a safe location. We also formulate a procedure to estimate the evacuation time. Within a reasonable degree of accuracy this estimation methodology can be used instead of a full-blown simulation, which often takes long time to develop and test. The rationale for this research is our recent experience with a local hospital.

ISE Working Paper 07-026

Quasi-Renewal Time-Delay Fault Removal Software Reliability Modeling

Seheon Hwang and Hoang Pham

Abstract:

This paper presents a generalized NHPP software reliability model considering quasi-renewal time-delay fault removal. The quasi-renewal process is employed to estimate the time-delay due to identifying and prioritizing the detected faults before actual code change in the software reliability assessment. Model formulation based on the quasi-renewal time-delay assumption is provided and the generalized mean value function (MVF) for the proposed model is derived by using the method of steps. The general solution of the MVFs for the proposed model is also obtained for some specific existing models. The numerical examples, based on a software failure data set, show that the consideration of quasi-renewal time-delay fault removal assumption improves the descriptive properties of the model, which means that the length of time delay is getting decreased since testers and programmers adapt themselves to the working environment as testing and debugging activities are in progress.

ISE Working Paper 07-027

Multi-Objective Optimization for Turning Processes Using Neural Network Modeling and Dynamic- Neighborhood Particle Swarm Optimization

Yigit Karpat and Tugrul Ozel

Abstract:

In this paper, we introduce a procedure to formulate and solve optimization problems for multiple and conflicting objectives that may exist in turning processes. Advanced turning processes, such as hard turning, demand the use of advanced tools with specially prepared cutting edges. It is also evident from a large number of experimental works that the tool geometry and selected machining parameters have complex relations with the tool life and the roughness and integrity of the finished surfaces. The non-linear relations between the machining parameters including tool geometry and the performance measure of interest can be obtained by neural networks using experimental data. The neural network models can be used in defining objective functions. In this study, Dynamic-Neighborhood Particle Swarm Optimization (DN-PSO) methodology is used to handle multi-objective optimization problems existing in turning process planning. The objective is to obtain a group of optimal process parameters for each of three different case studies presented in this paper. The case studies considered in this study are; minimizing surface roughness values and maximizing the productivity, maximizing tool life and material removal rate, and minimizing machining induced stresses on the surface and minimizing surface roughness. The optimum cutting conditions for each case study can be selected from calculated Pareto-optimal fronts by the user according to production planning requirements. The results indicate that the proposed methodology which makes use of dynamic-neighborhood particle swarm approach for solving the multi-objective optimization problems with conflicting objectives is both effective and efficient, and can be utilized in solving complex turning optimization problems and adds intelligence in production planning process.

ISE Working Paper 07-028

Mechanics of High Speed Cutting with Curvilinear Edge Tools

Yigit Karpat and Tugrul Ozel

Abstract:

High-speed cutting is advantageous due to the reduced forces and power, increased energy savings and overall improved productivity for discrete-part metal manufacturing. However, tool edge geometry and combined cutting conditions highly affects the performance of high speed cutting. In this study, mechanics of high-speed cutting with curvilinear (round and oval-like) edge preparation tools in the presence of dead metal zone has been presented to investigate the effects of edge geometry and cutting conditions on the friction and resultant tool temperatures. An analytical slip-line field model is utilized to study the cutting mechanics and friction at the tool-chip and tool-workpiece interfaces in the presence of the dead metal zone in machining with negative rake curvilinear PCBN tools. Inserts with six different edge designs, including a chamfered edge, are tested with a set of orthogonal cutting experiments on AISI 4340 steel. Friction conditions in each different edge design are identified by utilizing the forces and chip geometries measured. Finite Element simulations are conducted using the friction conditions identified and process predictions are compared with experiments. Analyses of temperature, strain and stress fields are utilized in understanding the mechanics of machining with curvilinear tools.

ISE Working Paper 07-029

Process Simulations for 3-D Turning using Uniform and Variable Micro-Geometry PcBN Tools

Yigit Karpat and Tugrul Ozel

Abstract:

In this paper, uniform and variable edge micro-geometry design inserts are utilized and tested for 3-D turning process. In 3-D tool engagement with workpiece, thickness of the chip varies from a maximum equal to the feed rate (at primary cutting edge) to a minimum on the tool's corner radius (at trailing cutting edge). The ideal tool edge preparation should possess a variable configuration, which has larger edge radius at the primary cutting edge than at the trailing cutting edge. Here the key parameter is the ratio of uncut chip thickness to edge radius. If a proper ratio is chosen, for given cutting conditions a variable cutting edge along the corner radius can be designed or "engineered". In this study, finite element modeling (FEM) based 3-D process simulations are utilized to predict forces and temperatures on various uniform and variable edge micro-geometry tools. Predicted forces are compared with experiments. The temperature distributions on the tool demonstrate the advantages of variable edge micro-geometry design.

ISE Working Paper 07-030

Analytical and Thermal Modeling of High-Speed Machining with Chamfered Tools

Abstract:

High speed machining offers several advantages such as increased flexibility and productivity for discrete-part manufacturing. However, excessive heat generation and resulting high temperatures on the tool and workpiece surfaces in high speed machining leads to a shorter tool life and poor part quality especially if the tool edge geometry and cutting conditions were not selected properly. In this study, analytical and thermal modeling of high-speed machining with chamfered tools in the presence of dead metal zone has been presented to investigate the effects of cutting conditions, heat generation and resultant temperature distributions at the tool and in the workpiece. An analytical slip-line field model is utilized to investigate the process mechanics and friction at the tool-chip and tool-workpiece interfaces in the presence of the dead metal zone in machining with a negative rake chamfered PCBN tool. In order to identify friction conditions, a set of orthogonal cutting tests is performed on AISI 4340 steel and chip geometries and cutting forces are measured. Thermal modeling of machining with chamfered tools based on moving band heat source theory, which utilizes the identified friction conditions and stress distributions on the tool-chip and tool-workpiece interfaces, is also formulated and temperature distributions at the tool, cutting zone and in the workpiece are obtained. These temperature distributions are compared with the results obtained from Finite Element simulations. The comparison of temperature fields indicates that the proposed model provide reasonable solutions to understand the mechanics of machining with chamfered tools. Models presented here can be further utilized to optimize the tool geometry and cutting conditions for increasing benefits that high speed machining offers.

ISE Working Paper 07-031

**Numerical Modelling of 3-D Hard Turning using
Arbitrary Eulerian Lagrangian Finite Element Method**

P. J. Arrazola and Tugrul Ozel

Abstract:

In this paper, 3-D Finite Element Method (FEM) based numerical modeling of precision hard turning has been studied to investigate the effects of chamfered edge geometry on tool forces, temperatures and stresses in machining of AISI 52100 steel using log-grade polycrystalline cubic boron nitride (PCBN) inserts. An Arbitrary Lagrangian Eulerian (ALE) based numerical modeling is employed for 3-D precision hard turning. The Johnson-Cook plasticity 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

chamfer geometry of the cutting edge is carefully modeled with adaptive meshing simulation capability. In process simulations, feed rate and cutting speed were kept constant and analysis was focused on forces, temperatures and tool stresses. Results revealed good agreements between FEM results and those reported in literature about experimental ones.

ISE Working Paper 07-032

Pulsed Laser Assisted Micromilling for Die/Mold Manufacturing

Tugrul Ozel and Frank Pfefferkorn

Abstract:

Laser assisted machining is an alternative to conventional machining of hard and/or difficult-to-process materials which involves pre-heating of a focused area with a laser beam over the surface of the workpiece to cause localized thermal softening along the path of the cutting action. The main advantage that laser assisted machining has over conventional machining is the increased material removal rate and productivity. Laser assisted micromilling is a scaled down derivative of laser assisted machining, assuming that the process effectiveness potentially exists at the meso/micro scale. It is well known that continuous-wave (c.w.) lasers generate a wide and deep heat affected zone, and can cause microstructure alterations, potentially making laser assistance counter-productive at the meso/micro scale. The novel use of a pulsed laser in assisting micromilling enables processing of die/mold metal alloys that are typically hard and/or difficult-to-process in micro scale, while reducing the heat affected zone. A fairly innovative technique is introduced by thermally softening only the focused microscale area of the work material with induced heat from a pulsed laser, and material removal is performed immediately with micro mechanical end milling. The focus of this paper is to present a fundamental understanding of the pulsed laser assisted micromilling (PLAM), in particular, to investigate the influence of pulsing on microscale localized thermal softening by coupling with the finite element simulation of the micromilling process. Experiments and Finite element method-based process simulations for micromilling of AISI 4340 steel with and without laser assistance are conducted to study the influence of the pulsed laser thermal softening on the reduction in cutting forces and its influence on the temperature rise in the cutting tool.

ISE Working Paper 07-033

Micromilling Process Planning and Modeling for Micromold Manufacturing

Atul Dhanorker, Xinyu Liu and Tugrul Ozel

Abstract:

In this paper, a model-based micro-end milling process planning guideline for machining micro mold cavities was proposed. The goal is to facilitate proper selections of the process parameters. Specifically, the axial depth of cut, the feed per tooth are critical in achieving performance objectives in terms of cutting forces, surface accuracy, tool life, etc. To this end, the finite element modeling was used to provide a comprehensive understanding of the underlying science base for the micro-machining (e.g., chip formation mechanisms, minimum chip thickness effect, material deformation flows, stress, strain and temperature distributions). Further, a mechanistic time-domain simulation model was utilized to provide predictive capability in practical machining performance, such as cutting forces, tool vibrations, surface accuracy, and surface roughness. The generalized process planning strategy consists of two steps: roughing and finishing. In roughing, the objective is to control the cutting force within a predefined threshold to prevent premature tool breakage and to maximize the material removal rate. In finishing, the primary objective is to control the form error within the tolerance and to obtain satisfactory surface roughness. The proposed process planning strategy was applied for micro-milling of a mold cavity in AL2024-T6.

ISE Working Paper 07-034**Waiting Time Approximation in Single-Class
Queueing Systems with Multiple Types of Interruptions:
Modeling Vessel Entrances at Waterways**

Ozgecan S. Uluscu and Tayfur Altioek

Abstract:

We consider a single-server queue subject to multiple types of operation-independent interruptions motivated by operations and vessel queueing at entrances of waterways. A case in point is the Istanbul Strait. We are using waiting-time arguments and service completion time analysis to obtain the expected waiting time of a customer (vessel) in the aforementioned queue with single-class of customers and k non-simultaneous and possibly simultaneous service interruptions.

ISE Working Paper 07-035**Transit Vessel Scheduling
in the Istanbul Strait**

Ozgecan S. Uluscu, Tayfur Altiok, Ilhan Or, Birnur Ozbas, Alper O. Almaz and Tuba Yilmaz

Abstract:

Managing the transit vessel traffic in the Istanbul Strait is a highly complex operation since vessels, weather and water conditions, and a set of regulations affect its operation significantly. At the present time, the VTS operators manage the traffic based on some fundamental rules. After discussions with the operators, in this report, we present a mathematical formulation of the scheduling process currently in place and validate it by comparing its results with scheduling decisions made by the operators in some days of 2005. The results are highly promising. The proposed algorithm can be slightly altered to be used in traffic scheduling in other waterways as well.

ISE Working Paper 07-036

**Reliability-Redundancy Allocation
Using a Column Generation Approach**

Leila Zia and David W. Coit

Abstract:

A new column generation decomposition algorithm is described and demonstrated to determine efficient solutions for the reliability-redundancy allocation problem. The problem is a well-known nonlinear mixed integer-programming problem, which involves the maximization of system reliability by simultaneously selecting component reliability levels and redundancy levels as part of systems engineering design. The solution method is a decomposition approach based on the formulation of a restricted linear master problem and generation of possible better solutions through a set of subproblems. Numerical results are presented and compared to previously studied examples. The overall quality of the solutions matches or surpasses most of the existing methods with less computation time.

ISE Working Paper 07-037

**Quantitative Complexity Analysis in Multi-Channel
Intracranial EEG Recordings from Epilepsy Brains**

C. C. Liu, P. M. Pardalos, W. Chaovaitwongse, D. S. Shiau,
G. A. Ghacibeh, W. Suharitdamrong and J. C. Sackellares

Abstract:

Epilepsy is a brain disorder characterized clinically by temporary but recurrent disturbances of brain function that may or may not be associated with destruction or loss of consciousness and abnormal behavior. Human brain is composed of more than 10 to the power 10 interconnected neurons, each of which receives electrical impulses known as action potentials from others neurons via synapses and sends electrical impulses via a sing output line to a similar (the axon) number of neurons. When neuronal networks are active, they produced a change in voltage potential, which can be captured by an electroencephalogram (EEG). The EEG recordings represent the time series that match up to neurological activity as a function of time. By analyzing the EEG recordings, we sought to evaluate the degree of underlining dynamical complexity prior to progression of seizure onset. By utilizing the dynamical measurements, it is possible to classify the state of the brain according to the dynamical properties underlining the EEG recordings. The results from two patients with temporal lobe epilepsy (TLE), the degree of complexity start converging to lower value during the epileptic seizures was observed from epileptic regions as well as non-epileptic regions. The dynamical measurements appear to reflect the changes of underling dynamical structure. We suggest that the nonlinear dynamical analysis can provide a useful mechanism for detecting relative changes in brain dynamics, which cannot be detected by conventional linear analysis.

ISE Working Paper 07-038**Graph-Based Data Mining Techniques to Study
Brain Connectivity in Epilepsy Patients**

W. Chaovalitwongse, C. C. Liu, W. Suharitdamrong and M. L. Anderson

Abstract:

The human brain is one of the most complex biological systems. Neuroscientists seek to understand and empirically test the theories of human brain function through detailed analysis of neuronal excitability and synaptic transmission. In this study, we propose a network analysis framework to study the evolution of epileptic seizures. We apply a signal processing approach, derived from information theory, to investigate the synchronization of neuronal activities, which can be captured by electroencephalogram (EEG) recordings. Two network-theoretic approaches are proposed to globally model the synchronization the brain network. We observe some unique patterns related to the development of epileptic seizures, which can be used to illuminate the brain function governed by the epileptogenic process during the period before a seizure. The proposed framework can provide global structural patterns in the brain network and may be used in the simulation study of dynamical systems (like the brain) to predict oncoming events (like seizures). To analyze long-term EEG recordings in the future, we give a discussion on how the Markov-Chain Monte Carlo (MCMC) methodology can be applied to estimate the clique parameters. This MCMC

framework fits very well with this work as the epileptic evolution is considered to be a system with unobservable state variables and nonlinearities.

ISE Working Paper 07-039

Mechanism-Based Clustering of Genome-Wide mRNA Levels: Roles of Transcription and Transcript-Degradation Rates

S. Ji, W. Chaovalitwongse, N. Fefferman, W. Yoo and J. E. Perez-Ortin

Abstract:

DNA array techniques invented over a decade ago enable biologists to measure tens of thousands of mRNA levels in cells simultaneously as functions of environmental perturbations. In a few cases the same technique has been employed to measure not only genome-wide transcript levels (TL) but also transcription rates (TR) simultaneously. Since TL is determined by the balance between two opposing processes, i.e., transcription and transcript degradation, simple theoretical considerations indicate that it would be impossible to determine TR based on TL data alone. This conclusion is supported by the finding that TL and TR do not always vary in parallel. In fact, the genome-wide measurements of TL and TR in budding yeast undergoing glucose-galactose shift indicate that TL can decrease even though TR increases and TL can increase despite the fact that TR decrease. These counter-intuitive findings cannot be accounted for unless transcript-degradation rates (TD) are also taken into account. One of the main objectives of this contribution is to derive a mathematical equation relating TL to TR and TD. Based on this equation, it was predicted that there would be 9 different mechanisms by which TL can be altered in cells. The TL and TR data measured in budding yeast demonstrate that all of the 9 predicted mechanisms are found to be activated in budding yeast during glucose-galactose shift, except Mechanisms 5 (decreasing TL with no change in TR) and 9 (no change in TL nor in TR). It was also shown that the opposite changes in the mRNA levels of glycolytic and respiratory genes observed between 5 and 360 minutes following the glucose-galactose shift could be quantitatively accounted for in terms of what is referred to as the transcript-degradation/transcription (D/T) ratios calculated here for the first time. These results suggest that the predicted 9 mechanisms of glucose-galactose shift may be used to cluster the genome-wide measurements to understand the biological functional unit of each gene.

ISE Working Paper 07-040

On Approximating Four Covering/Packing Problems With Applications to Bioinformatics

M. V. Ashley, T. Y. Berger-Wolf, P. Berman,
W. Chaovalitwongse, B. DasGupta and M.-Y. Kao

Abstract:

In this paper, we consider approximability issues of several set covering type problems, which have important applications in computational biology. The problems considered in this paper are the full sibling reconstruction problem under two parsimonious assumptions, the maximum profit coverage problem and the 2-coverage problem. We provide approximation algorithms and inapproximability results for various values of parameters of interest for the problems. Our theoretical results on full siblings reconstruction problems answers open questions about the computational complexities of these methods posed in [5] and our results on the maximum profit coverage problem completely characterizes the computational complexity of the problem posed in [20]. In spite of the provable inapproximabilities, we conclude by showing that an implementation of a version of the combinatorial heuristic for the full sibling reconstruction reported in [5] performs empirically well on two new biological datasets.

ISE Working Paper 07-041

Novel Optimization Model and Solution Approach for Sibling Relationship Reconstruction from Microsatellite Data

W. Chaovalitwongse, T. Y. Berger-Wolf, B. DasGupta,
M. V. Ashley, C.-A. Chou, S. Sheikh and I. C. Caballero

Abstract:

Research studies in population-based genetic (allelic) association like sibling relationship reconstruction have offered a great opportunity to study the processes governing the macro-evolutionary patterns of trait evolution. This may result into the revolutionary of knowledge in the mechanisms of pathogenesis and the immune response, and the evolutionary consequences of medical and public health interventions. This paper presents an optimization framework for sibling reconstruction from single generation microsatellite genetic data. Our framework is based on the parsimony assumption and the combinatorial concepts of the Mendel's inheritance laws. We develop a novel optimization model for sibling reconstruction. This mathematical model is a large-scale MIP, shown to be a generalization of the set covering problem. Therefore, we propose a new heuristic approach to solve this large-scale optimization problem. We will test our approach on both real biological and simulated data and compare our results with other state-of-the-art sibling reconstruction methods. The empirical results show that our approaches are very efficient and outperform other methods while providing the best known solutions in the literature on two real datasets. The result of this study suggests that our framework can be employed as an analytical tool for biologists to study complex evolutionary processes.

ISE Working Paper 07-042

On the Network Flow Based Model for Aircraft Maintenance Routing Problem

Z. Liang, W. Chaovalitwongse, H. C. Huang and E. L. Johnson

Abstract:

The aircraft maintenance industry is currently a over \$40 billion market and is expected to grow rapidly in the next few years. Everyday thousands aircrafts undergo maintenance, repair and overhaul in America. The aircraft maintenance problem is to schedule the aircrafts routing so that enough maintenance opportunities are provided for each aircraft. In this paper, we present a new maintenance network model for the aircraft maintenance routing problem (ARM). The computational results show that the new model provides a very good LP bound for the IP solution. We also compare our model with the flight string model in Barnhart et al. 1998. The comparison results show our model can generate competitive solution to the flight string model for all 4 test case problems.

ISE Working Paper 07-043

**Cooperative Clustering Approach to Battle Space
Reconstruction from Wide Area Search Munition Data**

Z. Liang, W. Chaovalitwongse, D. E. Jeffcoat,
D. A. Grundel and J. K. O'Niel

Abstract:

Wide Area Search Munitions (WASMs) are unmanned aerial vehicles with an array of onboard sensors, a warhead or other kill mechanism, and autonomous flight capabilities. WASMs have played many important roles in the modern battle field including reconnaissance, search, battle damage assessment, or communications relay. The ATR (automatic target recognition) system in WASM is used to identify potential targets and broadcast this information to other WASMs. However, target identification is subject to errors. For example, two WASMs might detect the same target, but associate with that target two separate target tracks. Conversely, two WASMs might detect separate targets, but assign the same target ID to both targets. We call this problem as the object misidentification (OMI) problem. To solve the OMI problem for a set of points in 4-dimensional space (time, longitude, latitude and altitude), we propose a novel cooperative clustering technique (CCT) to identify the individual route of each target (detected point). Our technique differs from the traditional nearest neighbor (NN) clustering technique in that CCT groups a set of points by a path rather than connecting and grouping points by a tree. The key idea of CCT is to solve a path optimization problem using the NN rule. In order to evaluate the proposed CCT, Distributed Interactive, Simulation (DIS) is used to generate test data. A DIS is a real time simulation in which entities can exchange information on a network. Based on seven simulated scenarios, the computational results show that our methods provide very good clustering results in a timely fashion. On average, CCT can accurately reconstruct the real battle space with 98.58% fidelity in less than ten seconds.

