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SuRP-A01 Room D
Planning, Scheduling, and Coordination 1 (Regular Session)

Chair: Zhou, MengChu — New Jersey Inst. of Tech.
Co-Chair: Reveliotis, Spiridon — Georgia Inst. of Tech.

13:00-13:20 **SuRP-A01.1**

On Supervisory Control of a Class of Discrete Event Systems Modeled by Petri Nets, pp. 1-6

Zhou, MengChu — New Jersey Inst. of Tech.

This paper develops a deadlock prevention policy for Petri nets that can model concurrent manufacturing assembly processes in flexible manufacturing systems (FMS). They can be modeled by a class of nets, namely G-systems. They are supervised to have the non-blocking property of the behavior, i.e., from any reachable state, a desirable state can be always obtained under supervision. Their deadlock situations in terms of insufficiently marked siphons can be characterized. The proposed approach is to make these siphons satisfy controlled siphon property (cs-property) if the elementary siphons are properly supervised. Compared with the existing policies, the advantage of the method is that a much smaller number of supervisory monitors and arcs are added and iterative computing processes are avoided. Finally, an application of this technique to a G-system is presented.

13:20-13:40 **SuRP-A01.2**

Decentralized Supervisory Control of Petri Nets with Monitor Places, pp. 7-13

Basile, Francesco — Univ. di Salerno, Italy
Giua, Alessandro — Univ. of Cagliari, Italy
Seatzu, Carla — Univ. of Cagliari, Italy

In this paper we study the problem of determining a set of decentralized monitors for place/transition nets to enforce a global specification on the net behavior given in terms of Generalized Mutual Exclusion Constraints (GMECs). We generalize our previous results in this topic. In particular, the novel contribution here consists in removing the restrictive assumption that the weights of the GMECs must be positive, while we still assume that all transitions are controllable and observable, and the support of each decentralized GMEC is a singleton. The main feature of the proposed solution is that it guarantees fairness among places.

13:40-14:00 **SuRP-A01.3**

Minimization of Expected Cycle Time in Manufacturing Cells with Uncontrollable Behavior, pp. 14-19

Kobetski, Avenir — Chalmers Univ. of Tech.
Richardsson, Johan — Chalmers Univ. of Tech.
Akesson, Knut — Chalmers Univ. of Tech.
Fabian, Martin — Chalmers Univ. of Tech.

Finding optimal working sequences for flexible manufacturing systems (FMS) is a challenging task, especially if uncontrollable events, such as machine breakdowns, can occur in these systems. In this paper, we continue our previous work within the area of FMS scheduling by extending our methods to uncontrollable systems. For this sake, the ideas of probabilistic finite automata are combined with the modeling formalism of extended finite automata. Next, an A*-based scheduling algorithm, minimizing the expectation value of the FMS cycle time is designed.

14:00-14:20 **SuRP-A01.4**

Specification of Production Systems Using PPN and Sequential Operation Charts, pp. 20-25

Falkman, Petter — Chalmers Univ. of Tech.
Lennartson, Bengt — Chalmers Univ. of Tech.
Andersson, Kristin — Chalmers Univ. of Tech.

In this paper specification of discrete event systems, more specifically flexible production systems, is performed using two high level specification languages. The first language, called process algebra Petri net (PPN), is a mathematically well defined language that combines Petri nets and process algebra in order to achieve compact and concise specifications of complex systems. The second language, sequential operation charts (SOC), is a language specifically developed to meet expectations from industry concerning both programming style and information handling. SOC is based on the PPN language, but presents constructs that enable the language to be used not only for specifying process descriptions but also product and preparation related information. This makes it possible to use the SOC language all the way from the concept phase until final production. This paper has three aims. The first is to show the advantages of the PPN language compared to ordinary Petri nets. The second aim is to show how the SOC language is defined with respect to the PPN, language and the third aim finally is to show how SOCs can be used for the specification of a real industry case.

14:20-14:40 **SuRP-A01.5**

Improving On-Line Fault Diagnosis for Discrete Event Systems Using Time, pp. 26-32

Basile, Francesco — Univ. di Salerno
Chiacchio, Pasquale — Univ. di Salerno
De Tommasi, Gianmaria — Univ. degli Studi di Napoli

This paper presents an approach to fault diagnosis of discrete events systems modeled by Petri nets. Fault events are associated to a subset of unobservable transitions of the net. The approach is based on an extension of standard net marking, called generalized marking, which allows to efficiently estimate the explanations of the observed transitions.

The algorithm proposed in this paper uses the information on the timing structure of the net to accelerate the explanations estimate. In particular, it requires the solution of linear programming problems and the computation of a tree, called timed explanation tree, introduced to compute the firing time of the minimal unobservable explanations that include a given fault transition.

14:40-15:00 **SuRP-A01.6**

Generalization of Scheduling Information Acquired through User Manipulation for Self-Construction Production Scheduling System, pp. 33-38

Shibata, Tomoki — Waseda Univ.
Zhang, Xuerui — Waseda Univ.
Hai, Xue — Waseda Univ.
Shimizu, Yasuhiro — Waseda Univ.
Fujimura, Shigeru — Waseda Univ.

With the high speed innovation of information technology, many production scheduling systems (to support scheduling work) have been developed. However, a significant customization according to individual production environment is required, and then a large investment for development and maintenance is indispensable. Therefore now the direction to construct scheduling systems should be changed. The final objective of this research aims at developing a system which is built by itself extracting the scheduling technique automatically through the daily production scheduling work. By using the information extracted by the system, production scheduling operators can be supported to accelerate the production scheduling work easily and accurately without any restriction of scheduling works. In order to realize such a production scheduling system, the mechanism to extract scheduling information is needed. In this paper, using Gantt Chart Interface System that is developed to emulate the production scheduling work on papers through the analysis of operator's works, the method extracting and generalizing the relation information between operations from user manipulation is proposed. And the operator assistant function which uses the extracted information is proposed. Then by conducting experiment that uses the assistant function, the availability of the method of extracting and generalizing is shown.

SuRP-A02 — Room E

Automation / Assembly for Micro/Nano Technologies 1 (Regular Session)

Chair: Rakotondrabe, Micky — CNRS - ENSMM - Univ. de Franche-Comté
Co-Chair: Zhou, Rongliang — Rensselaer Pol. Inst.

13:00-13:20 — **SuRP-A02.1**

Modelling and Robust Position/Force Control of a Piezoelectric Microgripper, pp. 39-44

Rakotondrabe, Micky — CNRS - ENSMM - Univ. de Franche-Comté
Clévy, Cédric — CNRS - ENSMM - Univ. de Franche-Comté
Lutz, Philippe — CNRS - ENSMM - Univ. de Franche-Comté

This paper deals with the control of a piezoelectric microgripper based on two piezocantilevers. To avoid the destruction of the manipulated micro-object and to permit a high accurate positioning, the microgripper is controlled on position and on force. Each piezocantilever is separately modelled and controlled: while the one is controlled on position, the second is controlled on force. Because the models are subjected to uncertainties and the micromanipulation requires good performances, a H_infinity robust controller is designed for each system. The experiments end the paper and show that good performances are obtained.

13:20-13:40 — **SuRP-A02.2**

Active Thermal Management for Precision Positioning, pp. 45-50

Zhou, Rongliang — Rensselaer Pol. Inst.
Gressick, William — Rensselaer Pol. Inst.
Wen, John — Rensselaer Pol. Inst.

Precision positioning systems are inevitably subject to various thermal disturbances including heating from motors, friction between components, and ambient temperature fluctuations. Thermal disturbances cause unwanted thermal expansion and contraction; the resulting distortion of the components in the positioning system could lead to degraded positioning accuracy.

This paper explores the application of estimation and control techniques to address thermally-induced positioning error. A simplified planar system, motivated by linear stages used in semiconductor manufacturing, is considered as a case study. The goal is to estimate the displacements of the locations of interest at the top of the stage and control their positions within an acceptable error bound from the preset target positions. A linear time-invariant model is first identified from the numerical simulation of the system model. Kalman filter is applied for state estimator design and the optimal error covariance is used to guide the temperature sensor placement. It is found that the estimator performance does not significantly improve beyond a small number of well chosen temperature sensors. For the active heating control, an offset is introduced to allow for two-way (both positive and negative) control action. The linear-quadratic-Gaussian design is used for both actuator location selection as well as closed loop active heating control. It is found that the assumed boundary condition between different portions of the stage drastically affect the controllability of the locations of interest. Locations of interest far from the constrained points are well regulated, while those near the constrained points show limited improvement.

13:40-14:00 — **SuRP-A02.3**

CameraMan - Robot Cell with Flexible Vision Feedback for Automated Nanohandling Inside SEMs, pp. 51-56

Jasper, Daniel — Univ. of Oldenburg
Dahmen, Christian — Univ. of Oldenburg
Fatikow, Sergej — Univ. of Oldenburg

This paper presents a concept for a nanohandling robot cell with flexible visual feedback that can work inside an SEM's vacuum chamber and enable fully automated nanohandling and -assembly. Therefore, rail-based robots position miniature video microscopes to observe the process from different angles and with different magnifications. Image processing techniques can be used to recognize and track objects as well as three dimensional information can be obtained by stereo vision and by the microscope's focus. The mechanical feasibility and advantages of the CameraMan concept are analyzed with a prototypic implementation of a nanohandling robot cell. To control this highly non-linear system a self-learning controller is used, challenges for cooperatively controlling the multi-robot system are outlined and high-level automation is discussed.

14:00-14:20 — **SuRP-A02.4**

Automatic Nanorobotic Characterization of Anomalously Rolled-Up SiGe/Si Helical Nanobelts through Vision-Based Force Measurement, pp. 57-62

Kratochvil, Bradley — Swiss Federal Inst. of Tech.
Dong, Lixin — ETH Zurich

Zhang, Li — Paul Scherrer Inst.
Nelson, Bradley J. — ETH Zurich

We have described and demonstrated a rigid body tracking system suitable for use in a Scanning Electron Microscope under a variety of conditions. This system has demonstrated an ability to work with noisy images, sub-pixel resolution at a variety of magnifications and the ability to track moving targets at realtime (~10fps) frame rates. With this automated tracking system, the mechanical properties of anomalous, rolled-up, small pitch SiGe/Si/Cr helical nanobelts are experimentally investigated using nanorobotic manipulation in 3-D free space. Their ultra-high flexibility (0.003N/m) and exceptionally wide linear range (91% elongation from their unextended state) are far superior to either bottom-up synthesized nanocoils or top-down rolled-up ones. Additionally, the high degree of precision with which their diameter, chirality, helicity angle, and pitch can be controlled indicate their high suitability for batch fabrication and application as elastic elements in ultra-sensitive, large-range force/mass sensors for chemical sensing, bio-sensing, property characterization of nanomaterials, and elastic elements of nanoelectromechanical systems (NEMS).

14:20-14:40 **SuRP-A02.5**

Multi-Probe Micro Assembly, pp. 63-68

Wason, John — Rensselaer Pol. Inst.
Gressick, William — Rensselaer Pol. Inst.
Wen, John — Rensselaer Pol. Inst.
Gorman, Jason — National Inst. of Standards and Tech.
Dagalakis, Nicholas — National Inst. of Standards and Tech.

This paper describes the algorithm development and experimental results of a multi-probe micro-assembly system. The experimental testbed consists of two actuated probes, an actuated die stage, and vision feedback. The kinematics relationships for the probes, die stage, and part manipulation are derived and used for calibration and kinematics-based planning and control. Particular attention has been focused on the effect of adhesion forces in probe-part and part-stage contacts in order to achieve grasp stability and robust part manipulation. By combining pre-planned manipulation sequences and vision based manipulation, repeatable spatial (in contrast to planar) manipulation and insertion of a sub-millimeter part has been demonstrated. The insertion process only requires the operator to identify two features to initialize the calibration, and the remaining tasks involving part pick-up, manipulation, and insertion are all performed autonomously.

14:40-15:00 **SuRP-A02.6**

Feeding of Submillimeter-Sized Microparts Along a Saw-Tooth Surface Using Only Horizontal Vibration: Analysis of Convexities on the Surface of Microparts, pp. 69-76

Mitani, Atsushi — Sapporo City Univ.
Yoshimura, Toshiatsu — Ritsumeikan Univ.
Hirai, Shinichi — Ritsumeikan Univ.

We have previously showed that microparts can be fed along a saw-tooth surface using simple planar symmetric vibration. Microparts move forward because they adhere to the saw-tooth surface more backward than forward. We studied also the effects of saw-tooth pitch and vibration frequency on the movement of 2012-type capacitors (size:2.0 x 1.2 x 0.6 mm, weight 7.5 mg). In the present work, we studied the movement of smaller 0603-type capacitors (size:0.6 x 0.3 x 0.3 mm, weight:0.3 mg). We analysed the contact between a micropart and a saw-tooth surface based on measurements. A microscope was used for the measurements of a 0603-type capacitor surface to obtain precise surface profile model. Smaller capactors rotated on the saw-tooth surface when they were moving in one direction. We thus observed the movement of a smaller capacitors, and then examined the decrease of feeding velocity caused by rotation and swinging of the smaller capacitors.

SuRP-A03 — Room F

Semiconductor Manufacturing 1 (Regular Session)

Chair: Fowler, John — Arizona State University
Co-Chair: Morrison, James — Central Michigan Univ.

13:00-13:20 **SuRP-A03.1**

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Stochastic Modeling for Serial-Batching Workstations with Heterogeneous Machines, pp. 77-81

Ding, Shengwei — Univ. of California, Berkeley
Shanthikumar, J. George — Univ. of California, Berkeley
Akhavan-Tabatabaei, Raha — Intel Corp.

The bottleneck workstation in semiconductor manufacturing is lithography. Lithography is a complex manufacturing system (CMS) and consists of multiple products, serial-batching operations, re-entrant process flows, and parallel non-identical machines. Existing stochastic models for such a CMS focus on simple extensions of the classical queueing theory. These models fail to question the applicability of the theory but try to modify model inputs on the first moment (average) and the second moment (variation). The implementation of these models has been unsatisfactory. In this paper, we provide a stochastic model of such a CMS. We model the arrival process of CMS by Poisson Process and the service process by Markov Decision Process. We propose a geometric-distribution based probabilistic dispatching model. The model is verified using a lithography workstation in a high-volume wafer fabrication facility. This study provides a theoretic framework and promis-ing results for serial-batching operation modeling in semicon-ductor manufacturing and other industries as well.

13:20-13:40 **SuRP-A03.2**

A Finite Capacity Production Planning Approach for Semiconductor Manufacturing, pp. 82-87

Habla, Christoph — Univ. of Hagen
Moench, Lars — Univ. of Hagen
Driessel, Rene — Univ. of Hagen

In this paper, we suggest a production planning approach that takes the finite capacity of the manufacturing system into account. The approach is based on a reduced level of detail modeling of the process flows. We consider explicitly only bottleneck steps. A mixed integer programming (MIP) formulation is suggested to determine completion time targets for the bottleneck steps of the lots. A Lagrange relaxation technique is applied to solve the MIP approximately. We present some preliminary results of computational experiments that demonstrate

some promising features of the suggested approach with respect to solution quality and time needed for computation.

13:40-14:00 **SuRP-A03.3**

On the Throughput of Clustered Photolithography Tools: Wafer Advancement and Intrinsic Equipment Loss, pp. 88-93

Morrison, James — Central Michigan Univ.
Mutnuri, Maruthi Kumar — Central Michigan Univ.

For clustered photolithography tools we develop two analytic models characterizing the throughput. The models are essentially distinguished by the manner in which wafers advance through the tool and allow for many important features present in practical manufacturing systems. Such features include a diversity of lot populations (with different process times at each module) and disturbances to the ideal processing behavior such as delays to begin processing and delays incurred at specific modules. Our models thus allow us to quantify important classes of intrinsic equipment loss.

14:00-14:20 **SuRP-A03.4**

A Short-Term Forecast Method for Demand Quantities in Semiconductor Manufacturing, pp. 94-99

Habla, Christoph — Univ. of Hagen
Driessel, Rene — Univ. of Hagen
Moench, Lars — Univ. of Hagen
Ponsignon, Thomas — Infineon Tech. AG & Univ. of Hagen
Ehm, Hans — Infineon Tech. AG

In this paper, we study a forecast method for demand quantities in semiconductor manufacturing. We formulate and test a parameter-driven scheme to generate forecasts. We forecast demand quantities using the formula F = aX + bY where a and b are non-negative parameters to be estimated, X is a simple exponential smoothing forecast based on historical data, and Y are the firm orders that have been placed for the product for the current month. The parameters a, b, and the exponential smoothing parameters are chosen to optimize a statistical measure of forecast quality. We develop a spreadsheet model to address this problem. We suggest several forecast accuracy performance measures. We present the results of computational experiments on real-world data that clearly demonstrate that the suggested approach outperforms the current forecast approach.

14:20-14:40 **SuRP-A03.5**

Capacity Planning for Semiconductor Wafer Fab with Uncertain Demand and Capacity, pp. 100-105

Geng, Na — Shanghai Jiao Tong Univ.
Jiang, Zhibin — Shanghai Jiao Tong Univ.

Capacity planning, the determination of optimal tools' configuration based on the current information about future demand and capacity, is very hard due to the high uncertainties in both capacity and demand. To cope with this problem, this paper proposes a scenario-based stochastic programming model to facilitate tool procurement decision-making. The uncertainty of product demand is represented with a set of scenarios with associated occurrence possibilities. And the capacity variability is described with a set of scenarios on tools' utilization ratios. All of these make the tools procurement plan robust to uncertainties to specific context. The resulting robust tools deals well with the changes in demand and capacity with the maximal expected profits. For those companies of risk-aversion, this model is preferred.

14:40-15:00 **SuRP-A03.6**

Decision Paradigms in the Semiconductor Supply Chain: A Survey and Analysis, pp. 106-110

Sun, Yang — Arizona State University
Feller, Andrew — Arizona State University
Shunk, Dan — Arizona State University
Fowler, John — Arizona State University
Callarman, Tom — China Europe International Business School (CEIBS)
Duarte, Brett — Arizona State University/IBM

An online questionnaire was used to survey the current state of decision making paradigms for the semiconductor supply chain and to identify future trends and needs. A logistic regression analysis on the survey data clearly shows that decision makers tend to use optimization techniques in the front-end planning decisions, and to make them in a slow clockspeed fashion. As products move downstream in the supply chain, it is more likely that decision makers will use their tacit knowledge to make back-end configuration and allocation decisions quickly and frequently. Survey results also showed that executives want optimization methods to be used across the supply chain, creating a need to develop heuristic-based methods that will set the stage for optimizing final allocation decisions.

SuRP-A04 — Room JD's Terrace

Manufacturing Systems 1 (Regular Session)

Chair: Li, Jingshan — Univ. of Kentucky
Co-Chair: van der Stappen, Frank — Utrecht Univ.

13:00-13:20 **SuRP-A04.1**

Requirement of Three-Position Enabling Switches for Installing in Enabling Devices to Achieve Operational Safety of Robotics and Automation Applications, pp. 111-116

Fukui, Takao — IDEC Corp.
Nobuhiro, Masaki — IDEC Corp.
Sekino, Yoshio — IDEC Corp.
Maeda, Ikuo — IDEC Corp.
Matsumoto, Atsushi — IDEC Corp.
Fujita, Toshihiro — IDEC Corp.

Highly advanced production systems of robotics and automation applications involve many direct interactions between humans and machines. Ensuring an operators' safety, especially in a hazardous area, is of primary concern. As required by various international standards, including superior international standards such as ISO 12100, machine operation of human-attended operation must be controlled by using the enabling device. Three-position enabling switch is the integral component of enabling devices, and in 2006, IEC 60947-5-8 was newly published to set the requirements of three-position enabling switch. This report explains the requirement of the three-position enabling switches which play an important role in establishing the inherent safety in operating environment.

13:20-13:40 **SuRP-A04.2**

A Study of Industrial Logic Control Programming Using Library Components, pp. 117-122

Ljungkrantz, Oscar — Chalmers Univ. of Tech.
Akesson, Knut — Chalmers Univ. of Tech.

In this paper a study of logic control programming practices and use of library components at two European car manufacturers, is presented. The research provides results important to consider for researchers and PLC vendors when developing frameworks for control program generation, to cope with new requirements of flexible manufacturing systems. The main observations are: the programs, written mainly in Ladder Diagrams and Sequential Function Charts, frequently reuse pre-developed function blocks; it is important that the control programs can be understood and used for trouble-shooting by the operators; and finally, the code handles, besides automatic control, also safety and supervision, human machine interface, product data, communication etc., the code for automatic control is a minor part of the total code.

13:40-14:00 **SuRP-A04.3**

Assembly Line Balancing Problems Solved by Estimation of Distribution, pp. 123-127

Gu, Liya — LGIPM ENIM, France
Hennequin, Sophie — LGIPM ENIM, France
Sava, Alexandre — LGIPM ENIM, France
Xie, Xiaolan — Ec. des Mines de Saint Etienne

In this paper, we propose an algorithm based on an estimation of distribution (ED) to solve the assembly line balancing type II problem (SALBP-II). This problem aims to assign a set of assembly operations subject to precedence constraints to a given number of workstations of an assembly line in order to minimize the cycle time. We also prove that the optimal solution for determinist SALBP-II problem can maximize the reliability of the least reliable station in the line if the operation times are random and normally distributed with constant ratio of the variance and the mean. The ED algorithm is a population-based algorithm. The simulation results show that ED algorithm outperforms the simulated annealing (SA) algorithm especially for large-scaled problems.

14:00-14:20 **SuRP-A04.4**

Redundancy Based Controller Reconfiguration for Fault Recovery of Manufacturing Systems, pp. 128-133

Alcaraz, Mildreth — CINEVESTAV
Lopez-Mellado, Ernesto — CINEVESTAV
Ramirez, Antonio — CINEVESTAV

This work deals with fault recovery of discrete manufacturing systems modeled by Petri nets (PN). A technique for fault recovery that exploits the redundancies included in the PN model is proposed. This work presents two main contributions; the first one is a structural method for finding out the redundancies in the PN system model. Based on these redundancies, the second contribution is an algebraic technique used to reconfigure partially the controller when permanent faults occur in system components. This approach avoids the computation of a new controller every time a fault is detected.

14:20-14:40 **SuRP-A04.5**

Development and Implementation of NURBS Interpolator with Look-Ahead Technique, pp. 134-139

Lu, Yao — HKUST
Li, Zexiang — HKUST
Xu, Jijie — HKUST

With recent advances in high accuracy and high speed machining, the NURBS interpolator has shown significant effect on dealing with the free form curves and surfaces. The present study aims at developing the speed-controlled interpolator and the real-time hardware implementation. However, the system vibration at sharp corner is unavoidable. This paper proposes and implements a NURBS interpolation algorithm with look-ahead technique to generate smooth trajectory command under the corner error constraints. Experimental results indicate that the proposed NURBS interpolation algorithm is able to provide a satisfactory performance.

14:40-15:00 **SuRP-A04.6**

The Solution of 2-Dimensional Rectangular Cutting Stock Problem Considering Cutting Process, pp. 140-145

Shiomi, Yusuke — The Univ. of Tokyo
Sugi, Masao — The Univ. of Tokyo
Ota, Jun — The Univ. of Tokyo
Okubo, Tsuyoshi — NS Solutions Corp.
Yamamoto, Masashi — NS Solutions Corp.
Kojima, Hiroshi — NS Solutions Corp.
Inoue, Kazuyoshi — NS Solutions Corp.

The Cutting stock problem (CSP) is an important problem that affects the profit of the processing industries. The CSP that deals with a set of rectangular items is classified as the 2-Dimensional Rectangular Cutting Stock Problem (2DRCSP). Although the 2DRCSP has been researched widely in the field of mathematical programming, the solutions of these studies are not always suitable for the actual manufacturing. This is because most of the existing studies do not consider the cutting process in actual manufacturing. In this report, we formulate a solution for the 2DRCSP with the constraints of the cutting process being considered. As for the approach, we calculate smaller patterns of arrangement and perform all of arrangement by using them iteratively. In addition, we use the simulated annealing method to calculate their length.

SuRP-A05 — Garden Terrace

Information-Based Manufacturing 1 (Regular Session)

Chair: Banerjee, P. Pat — Univ. of Illinois at Chicago
Co-Chair: Cecil, J. — New Mexico State Univ.

13:00-13:20 **SuRP-A05.1**

GPU-Based Elastic-Object Deformation for Enhancement of Existing Haptic Applications, pp. 146-151

Luciano, Cristian J. — Univ. of Illinois at Chicago
Banerjee, P. Pat — Univ. of Illinois at Chicago

Lu, Yan — Siemens Corp. Res. Inc

Protecting manufacturing control systems from network-based attacks is becoming more important with increasing demand on vertical integration of plant floor and corporate networks. This paper discusses the differences between corporate networks and plant floor networks from a security perspective, and outlines some requirements for the plant floor network security. The challenges for the development of security solutions for automation and control systems are highlighted. Several on-going standardization activities are introduced. A conceptual reference framework for protecting industrial automation and control systems is proposed and features for detection and prevention of network-based attacks are disclosed. This paper ends with the discussion of possible solutions for the existing vulnerability examples.

SuRP-B01 — Room D

Planning, Scheduling, and Coordination 2 (Regular Session)

Chair: Jin, Tongdan — Teax A&M International Univ.
Co-Chair: Reveliotis, Spiridon — Georgia Inst. of Tech.

15:00-15:20 — **SuRP-B01.1**

An Hybrid Heuristic Using Genetic Algorithm and Simulated Annealing Algorithm to Solve Machine Loading Problem in FMS, pp. 182-187

M, Yogeshwaran — Monash Univ. Malaysia
S G, Ponnambalam — Monash Univ. Malaysia
Manoj Kumar, Tiwari — National Inst. of Foundry and Forge Tech. (NIFFT)

A machine loading problem in flexible manufacturing system (FMS) is discussed with bicriterion objectives of minimizing system unbalance and maximizing system throughput in the occurrence of technological constraints such as available machining time and tool slots. An efficient evolutionary algorithm by hybridizing the Genetic Algorithm (GA) and Simulated Annealing (SA) algorithm called GASA is proposed in this paper. The performance of the GASA is tested by using 10 sample dataset and the results are compared with the heuristics reported in the literature. Two machine selection heuristics are proposed and their influence on the quality of the solution is also studied. Extensive computational experiments have been carried out to evaluate the performance of the proposed evolutionary heuristics and the results are presented in tables and figures. The results clearly support the better performance of GASA over the algorithms reported in the literature.

15:20-15:40 — **SuRP-B01.2**

A Consolidated Approach to Minimize Semiconductor Production Loss Due to Unscheduled ATE Downtime, pp. 188-193

Jin, Tongdan — Texas A&M international Univ.
Belkhouche, Fethi — Texas A&M international Univ.

A production-loss based maintenance plan is proposed to minimize the cost due to unscheduled ATE (Automatic Test Equipment) downtime in the back-end process of semiconductor testing manufacturing. This paper suggests two methods, active redundancy and cold standby redundancy, to expedite the system repair time for returning the system back to production. This strategy is different from other reliability improvement methods such as corrective actions and preventive maintenance. By reducing the repair time, the system upper time actually increases and hence the production loss is minimized. The optimization is formulated to minimize the production loss considering the system deprecation, lost sales and idle labor when they are subject to maintenance budget and volume constraint. To solve this optimization problem, Genetic Algorithm is used to find the optimal solution. The illustrative example demonstrates that using redundant modules is a very effective way to minimize the semiconductor production loss due to unscheduled system downtime.

15:40-16:00 — **SuRP-B01.3**

State Estimation of Petri Nets by Transformation, pp. 194-199

Mahulea, Cristian — Univ. de Zaragoza
Recalde, Laura — Univ. de Zaragoza
Silva, Manuel — Univ. de Zaragoza
Cabasino, Maria Paola — Univ. of Cagliari, Italy
Giua, Alessandro — Univ. of Cagliari, Italy
Seatzu, Carla — Univ. of Cagliari, Italy

In this paper we propose four transformation rules to estimate the marking of a net, discrete or continuous, satisfying the following assumptions: the set of transitions is partitioned into observable and unobservable transitions; the net structure and the initial marking is known. For each rule we derive a set of linear algebraic constraints that characterize the set of markings of the original net that are consistent with the observed firing sequence.

16:00-16:20 — **SuRP-B01.4**

Correctness Verification of Generalized Algebraic Deadlock Avoidance Policies through Mathematical Programming, pp. 200-206

Reveliotis, Spiridon — Georgia Inst. of Tech.
Roszkowska, Elzbieta — Wroclaw Univ. of Tech.
Choi, Jin Young — Samsung Networks Inc.

Generalized algebraic deadlock avoidance policies (DAPs) for sequential resource allocation systems (RAS) have been recently proposed as an interesting extension of the class of algebraic DAPs, that maintains the analytical representation and computational simplicity of latter, while it guarantees completeness with respect to the maximally permissive DAP. The original work that introduced these policies also provided a design methodology for them, but this methodology is limited by the fact that it necessitates the deployment of the entire state space of the considered RAS. Hence, this paper seeks the development of alternative computational tools that can support the synthesis of correct generalized algebraic DAPs while controlling the underlying computational complexity. From a conceptual standpoint, the presented results are motivated by and extend similar past results for the synthesis of correct algebraic DAPs. However, when viewed from a more technical standpoint, the presented developments are complicated by the fact that generalized algebraic DAPs do not admit a convenient representation in the Petri net (PN) modeling framework, that has been the primary vehicle for the aforementioned past developments, and therefore, the relevant analysis must be pursued in an alternative, automaton-based representation of the RAS behavior and the applied policy logic. We believe that this translation of the past results in this new representational framework is a significant contribution in itself, since it enables a more profound understanding of the past developments, and at the same time, it renders them more accessible to the practitioner.

16:20-16:40 — **SuRP-B01.5**

PLC-Based Implementation of Process Observation and Fault Detection for Discrete Event Systems, pp. 207-212

Alenljung, Tord	Chalmers Univ. of Tech.
Sköldstam, Markus	Chalmers Univ. of Tech.
Lennartson, Bengt	Chalmers Univ. of Tech.
Akesson, Knut	Chalmers Univ. of Tech.

This paper demonstrates how PLC-code for process observation can be automatically generated from a discrete event process model expressed as either PLC-code or as extended finite automata (EFA). The generated code will also detect faults due to unexplainable sensor signal changes.

Extended finite automata are automata augmented with variables and transition conditions. These features make EFA suitable for modeling systems that interact with a PLC through binary signals. In order for the generated observer code to work, the EFA model must fulfill some requirements concerning determinism and observability. These requirements are here formalized.

Using the PLC-languages of the IEC 61131 standard for process modeling narrows the gap between the pragmatic industry and the formal academia. The cyclic execution model of a PLC is here replaced by execution at stochastic intervals.

16:40-17:00 **SuRP-B01.6**

Multi-Criteria Dynamic Scheduling Methodology for Controlling a Semiconductor Wafer Fabrication System, pp. 213-218

Zhang, Huai	Shanghai Jiao Tong Univ.
Jiang, Zhibin	Shanghai Jiao Tong Univ.
Hu, Hongtao	Shanghai Jiao Tong Univ.

Scheduling semiconductor wafer fabrication system (SWFS) is a very difficult problem. The assignment of wafer lots to machines is a complex problem that is often solved in real-time with simple dispatching rules. This paper proposes a multi-criteria dynamic scheduling methodology based on fuzzy logic and design of experiment (DOE). We adopt a fuzzy multi-criteria decision strategy to simultaneously take into account multiple aspects in every dispatching decision. Since most global dispatching rules only consider the static bottleneck to keep line balance, we also incorporate in the multi-criteria algorithm a specific heuristic rule that takes into account the dynamic bottleneck. Moreover, we also adopt DOE and multiple response optimization method to tune the weights associated to each decision criteria in the decision algorithm. A mini-fab model developed by Intel in collaboration with ASU is utilized to illustrate the proposed approach.

SuRP-B02 Room E

Automation in Life Sciences 1 (Regular Session)

Chair: Wen, John	Rensselaer Pol. Inst.
Co-Chair: Chao, Shih-hui	Arizona State University

15:00-15:20 **SuRP-B02.1**

IEEE CASE 2007 Invited Author Manuscript

Iterative Control Approach to High-Speed Force-Distance Curve Measurement Using AFM for Biological Applications, pp. 219-224

Kim, Kyongsoo	Iowa State Univ.
Lin, Zhiqun	Iowa State Univ.
Shrotriya, Pranav	Iowa State Univ.
Sundararajan, Sriram	Iowa State Univ.
Zou, Qingze	Iowa State Univ.

Abstract—Since its invention, atomic force microscopy (AFM) has been used in a wide variety of biological studies, from the topography imaging to the interactions of both subcell molecular (i.e., DNA and protein) and cell membranes. Particularly, the force-curve measurement using AFM has become a powerful tool to study the biophysical and/or biochemical properties of single bimolecular and single cell, at unprecedented spatial and force resolution. However, currently the temporal resolution of AFM force curve measurement is limited by its low operation speed. For example, studies such as the time-dependence of the unfolding force of a titin domain, and the time-dependence of the unbinding force of a single DNA strand, are still limited to the low-speed range when using force-curve measurement. Large temporal distortions also occur during the force-volume imaging of a live cell when mapping the force-curve distribution across the cell membrane, because of the large time lapse between the force-curve acquired at the first and the last sample point. In this article, a novel inversion-based iterative control technique is proposed to dramatically increase the speed of force-curve measurements. The experimental results are presented to show that by using the proposed control technique, the speed of force-curve measurements can be significantly increased (over 60 times) --- with no loss of spatial resolution. This control technique, demonstrated on a commercial AFM platform with a conventional cantilever, can be easily automated with guaranteed performance. To illustrate the great potential of the proposed control technique in studies such as the dynamics responses of biological samples, it is further applied to quantitively study the time-dependent elastic modulus of poly (dimethylsiloxane) (PDMS), a polymer whose surface stiffness is similar to many soft biological samples. The elastic modulus of PDMS were measured by using force-curves captured at push-in (load) rates spanning two-order differences, which clearly show the transition of the PDMS viscoelastic responses from rubbery (soft) towards glassy (stiff).

15:20-15:40 **SuRP-B02.2**

Fuzzy Filtering for an Intelligent Interpretation of Medical Data, pp. 225-230

Kumar, Mohit	Center for Life Science Automation
Stoll, Norbert	Univ. of Rostock
Kaber, David	North Carolina State Univ.
Thurow, Kerstin	Univ. of Rostock
Stoll, Regina	Univ. of Rostock

This study is concerned with an intelligent interpretation of medical data in the sense that involved complexities and uncertainties (arising in understanding the data behavior) are properly (i.e. mathematically) handled. The uncertainties in data interpretation may arise due to e.g. different behavior of individuals due to the different body conditions. We use a fuzzy model to filter out the uncertainties. The fuzzy model provides an interpretation of the data without the interpretation results being affected by the uncertainties. Such a fuzzy model (that could filter out the uncertainties) is identified using a robust identification algorithm. It was demonstrated through a real-world case study that the proposed approach of fuzzy filtering is suitable for dealing with the uncertainties involved in data interpretation. Fuzzy models, due to their capability of approximating nonlinear input-output mappings, could be exploited for the filtering of uncertainties. The efficient design of the

fuzzy filter is the bottleneck of the approach.

15:40-16:00 **SuRP-B02.3**

A Framework for the Modeling and Simulation of Health Care Systems, pp. 231-236

Augusto, Vincent — École Nationale Supérieure des Mines de Saint-Étienne
Xie, Xiaolan — École Nationale Supérieure des Mines de Saint-Étienne

To remedy lacks in modeling and analysis of health care _;ow, we present in this paper a new modeling methodology for addressing organization problems of health care systems. It is a patient-centered meta-model based on three views : (i) process (pathway of patients), (ii) resource (activity of involved resources), and (iii) organization (resources relations and specializations, structure of the system). These personalized view are a powerful communication tool. The resulting meta-model can be instanciated for a speci_;c system and immediatly simulated via templates, offering a fast-prototyping tool for health care systems.

16:00-16:20 **SuRP-B02.4**

Fuzzy Handling of Uncertainties in Modeling the Inhibition of Glycogen Synthase Kinase-3 by Paullones, pp. 237-242

Kumar, Mohit — Center for Life Science Automation
Thurow, Kerstin — Univ. of Rostock
Stoll, Norbert — Univ. of Rostock
Stoll, Regina — Univ. of Rostock

We consider the problem of modeling the biological activity of inhibitors (belonging to the paullone family) for Glycogen Synthase Kinase-3 (GSK-3). The development of a nonlinear model that establishes the quantitative structure-activity relationship (QSAR) involves an uncertainty regarding the optimal choice of molecular descriptors, structure of the model, number of free model parameters, and so on. This study advocates the use of a fuzzy filter, that mathematically takes into account the underlying uncertainties, for the handling of the uncertainties. The modeling performance is prevented from being adversely affected by the uncertainties with the help of a fuzzy filter. We demonstrate that a robustness of the modeling performance against uncertainties could be achieved using the proposed approach.

16:20-16:40 **SuRP-B02.5**

A Micropositioning System with Real-Time Feature Extraction Capability for Quantifying C. Elegans Locomotive Behavior, pp. 243-248

Wang, Wenhui — Univ. of Toronto
Sun, Yu — Univ. of Toronto
Dixon, Scott — Univ. of Toronto
Alexander, Mariam — Univ. of Toronto
Roy, Peter — Univ. of Toronto

Tracking C. elegans and extracting locomotive features of the nematode allow the investigation of how genes control behavioral phenotypes. Existing systems require large storage space for image data recording and significant time for off-line processing. This paper presents a visually servoed micropositioning system capable of extracting locomotive features on line at a full 30Hz. The employment of Gaussian Pyramid Level-2 images significantly reduces the image size by 16 folds and permits real-time feature extraction, without sacrificing accuracy due to the cubic smoothing spline fitting. Enabled by the capability of the micropositioning system in revealing subtle differences in locomotive behavior across strains, the relationship between C. elegans locomotive behavior and the number of muscle arms, for the first time, was investigated. A total of 128 worms of four C. elegans strains with different numbers of muscle arms were continuously tracked for 3 minutes per sample, and locomotive features were extracted on line. The potential impact of this research extends beyond revealing subtle phenotypic differences in C. elegans locomotive behavior across strains by demonstrating how automation techniques can be used to provide valuable tools for genetic investigations of C. elegans.

16:40-17:00 **SuRP-B02.6**

Computer Simulation of Dynamics of Human Leg, pp. 249-254

Nagarsheth, Hemant — S. V. National Inst. of Tech.
Surve, Sachin — S. V. National Inst. of Tech.
Patel, Mansi — Mahavir General Hospitals

Application of Robotics in the field of medical has gained a strong footing apart from manufacturing industries, sheep-shearing, agriculture, nuclear power industries, fire-fighting, mining, underseas applications, outerspace and other application. In the present work Dynamic equation of motions of a robot arm are considered using Lagrangian-Euler formulation and programs in C, C++ and MATLAB are developed. The program encompasses the Torque, Centrifugal and Coriolis and Gravity force applied to the leg of a human being which is compared to robot manipulator. For the purpose of analysis cases of a human being lifting weight is considered. The results obtained by the program are compared with those obtained by some of the researcher like Chia-Yu E. Wang, James E. Bobrow, and David J. Reinkensmeyer [20].

SuRP-B03 — Room F

Semiconductor Manufacturing 2 (Regular Session)

Chair: Chien, Chen-Fu — National Tsing Hua Univ.
Co-Chair: Schmidt, Kilian — Advanced Micro Devices

15:00-15:20 **SuRP-B03.1**

Calibration of Wafer Handling Robots: A Fixturing Approach, pp. 255-260

Zhang, Mike Tao — Spansion, Inc.
Goldberg, Ken — UC Berkeley

Semiconductor manufacturing industry requires highly accurate robot operation with short install/setup downtime. We develop a fast, low cost and easy-to-operate calibration system for wafer-handling robots. The system is defined by a fixture and a simple compensation algorithm. Given robot repeatability, endeffector uncertainties, and the tolerance requirements of wafer placement points, we derive fixture design and placement specifications based on a deterministic tolerance model. By employing the fixture-based calibration, we successfully relax the tolerance requirement of the endeffector by 20 times.

15:20-15:40 **SuRP-B03.2**

Improving Dispatch Rules for Cascading Tools, pp. 261-264

Grau, Gero — AMD Fab36 LLC & Co. KG

Weigang, Jörg — AMD Saxony LLC & Co. KG
Schmidt, Kilian — Advanced Micro Devices

Line balance and tool throughput are two important, yet conflicting goals. Especially for cascading tools supporting multiple layers in the line, there has to be a trade off between these two optimization criteria. Short cascades are optimal for line balancing, but this strategy leads to lower tool throughput. The size of the negative throughput impact is even stronger when tools require setup times for the switch from one cascade performing recipe A to another cascade performing recipe B. In the semiconductor industry, state-of-the-art dispatch rules are widely used as a tool to calculate optimal operational decisions. The paper presents an approach on how to combine the two criteria in a dispatch rule.

15:40-16:00 **SuRP-B03.3**

Wu, Jei-Zheng — National Tsing Hua Univ.
Chien, Chen-Fu — National Tsing Hua Univ.

Manufacturing strategy comprises decision- making problems in terms of manufacturing practices to achieve strategic manufacturing objectives with links to performance measurements. Manufacturing strategies involve many underlying sub-problems that can be framed in a wide spectrum of forms. This study aims to define the spectrum of problem-structuring for manufacturing strategies and then propose a decision analysis framework for modeling and analysis of related problems in different forms with respect to the spectrum. We use a realistic problem to validate the proposed framework and conclude with discussions of future research.

16:00-16:20 **SuRP-B03.4**

Cheng, Fan-Tien — National Cheng Kung Univ.
Huang, Hsien-Cheng — National Cheng Kung Univ.
Kao, Chi-An — National Cheng Kung Univ.

This work proposes a Dual-phase virtual metrology scheme. To consider both promptness and accuracy, this scheme generates dual-phase virtual metrology (VM) values. Phase I emphasizes promptness; that is to immediately calculate and output the Phase-I VM value (denoted VMI) of a workpiece (wafer or glass) once the entire process data of the workpiece are completely collected. Phase II intensifies accuracy; that is not to re-calculate and output the Phase-II VM values (denoted VMII) of all the workpieces in the cassette (also called FOUP in the semiconductor industry) until an actual metrology value (required for tuning or re-training purposes) of a workpiece in the same cassette is collected. Besides, in this scheme, the accompanying reliance index (RI) and global similarity index (GSI) of each VMI and VMII are also generated. The RI and GSI are applied to gauge the degree of reliance. If the reliance level of a VM value is lower than the threshold, this VM value may not be adopted. An illustrative example involving fifth-generation TFT-LCD CVD equipment is presented. Experimental results demonstrate that the proposed scheme is applicable to the wafer-to-wafer or glass-to-glass advanced process control for semiconductor or TFT-LCD factories.

16:20-16:40 **SuRP-B03.5**

Su, Yu-Chuan — Far East Univ.
Lin, Tung Ho — National Cheng Kung Univ.
Cheng, Fan-Tien — National Cheng Kung Univ.
Wu, Wei-Ming — National Cheng Kung Univ.

In the semiconductor industry, run-to-run (R2R) control is an important technique to improve process capability and further enhance the production yield. As the dimension of electronic device shrinks increasingly, wafer-to-wafer (W2W) advanced process control (APC) becomes essential for critical stages. W2W APC needs to obtain the metrology value of each wafer; however, it will be highly time and cost consuming for obtaining actual metrology value of each wafer by physical measurement. Recently, an efficient and cost-effective approach denoted virtual metrology (VM) was proposed to substitute the actual metrology. To implement VM in W2W APC, both conjecture-accuracy and real-time requirements need to be considered. In this paper, various VM algorithms of back-propagation neural network (BPNN), simple recurrent neural network (SRNN) and multiple regression (MR) are evaluated to see whether they can meet the accuracy and real-time requirements of W2W APC or not. The fifth-generation TFT-LCD CVD process is used to test and verify the requirements. Test results show that both one-hidden-layered BPNN and SRNN VM algorithms can achieve acceptable conjecture accuracy and meet the real-time requirements of semiconductor and TFT-LCD W2W APC applications.

16:40-17:00 **SuRP-B03.6**

Huang, Hsien-Cheng — National Cheng Kung Univ.
Su, Yu-Chuan — Far East Univ.
Cheng, Fan-Tien — National Cheng Kung Univ.
Jian, Jia-Mau — National Cheng Kung Univ.

Virtual metrology (VM) is a technology to predict metrology variables using information about the state of the process for every workpiece. An advanced dual-phase VM scheme possessing the properties of data preprocessing, dual-phase conjecturing, reliance-level evaluating, and similarity-level appraising was proposed by the author. This dual-phase VM scheme is applicable for all the typical VM applications. Among those applications, the one for workpiece-to-workpiece (W2W) advanced process control (APC) is the most critical. For easy implementation and deployment, a generic-virtual-metrology (GVM) framework shall be designed. The purpose of this paper is to develop the GVM framework. By applying this GVM framework, different VM functional modules can be easily implemented and applied for various kinds of VM applications, especially the W2W APC.

SuRP-B04 — Room JD's Terrace

Manufacturing Systems 2 (Regular Session)

Chair: Somes, Steven D. — Western Robotics Co.
Co-Chair: Wong, YS — National Univ. of Singapore

15:00-15:20 **SuRP-B04.1**

Cheong, Jae-Sook — Electronics and Telecommunications Res. Inst.
van der Stappen, Frank — Utrecht Univ.

Immobilization of objects is crucial to robot hand grasping and manufacturing processes, and has therefore been studied extensively. Relatively little consideration has been given to the computation of "all" grasps of three-dimensional objects, and grasps that are insensitive to misplacements of the fingers. This paper contributes in both directions. Like Nguyen~cite{n-cfcg-88} (for two-dimensional objects), we achieve insensitivity to misplacements by determining combinations of regions on the object boundary that yield a form-closure grasp, no matter where the fingers are placed in each of these regions. We call such a combination of regions "independent form-closure grasp regions". In this paper, we propose an efficient algorithm for computing "all" combinations of predefined face patches of a rectilinear polyhedron that form independent form-closure grasp regions with seven frictionless point fingers. This is the first efficient complete algorithm for computing independent form-closure grasp regions of a three-dimensional object.

Our approach is based on a decomposition of the original problem in six-dimensional (wrench space) into two problems in three-dimensional subspaces. These problems, in turn, can be transformed into two-color intersection problems in the plane, which can be tackled efficiently using concepts and techniques from the field of computational geometry. The resulting algorithm has the advantage that its running time depends largely on the number of independent form-closure grasp regions reported.

15:20-15:40 **SuRP-B04.2**

Overcoming Traditional Automation Limitations through Compliant Control and Contact Sensing, pp. 295-299

Somes, Steven D. — Western Robotics Co.
Buckmaster, David — Case Western Res. Univ.
Newman, Wyatt — Case Western Res. Univ.

Impediments to robot usage in manufacturing settings that arise from position-oriented control are identified. Process methods that leverage compliant robot control together with CAD model data and strategy based programming are shown to help overcome these impediments. The techniques are shown in the context of automating finish grinding of cast turbine blades.

15:40-16:00 SuRP-B04.3

Towards Effective Multi-Platforming Design of Product Family Using Genetic Algorithm, pp. 300-305

Liu, Z — National Univ. of Singapore
Wong, Y. S. — National Univ. of Singapore
Lee, K. S. — National Univ. of Singapore

Platform-based product family design is recognized as an effective method to construct a product line that satisfies diverse performance requirements while aiming to keep design and production costs low. The success of the resulting product family often relies on properly resolving the tradeoff between increasing commonality across the family and performance loss compared to individual design. In this paper, a systematic approach is proposed to design the scale-based product family with multi-platforming configuration and it contributes in three aspects. Firstly, the effect of commonality on the related product life-cycle activities is evaluated in the platform decision to decide the expected degree of sharing for each design variable and thus generate the anticipated platform configuration. Secondly, unlike many existing methods that assume a given single-platform, the proposed method addresses the multi-platforming configuration across the family, and can generate alternative product family settings with different levels of commonality. Finally, the product family design is formulated as a multi-optimization problem and solved using a modified genetic algorithm. An industrial example of a planetary gear train for cordless drills is presented to demonstrate the proposed method.

16:00-16:20 **SuRP-B04.4**

The DOHELIX–Muscle: A Novel Technical Muscle for Bionic Robots and Actuating Drive Applications, pp. 306-311

Staab, Harald — Fraunhofer Inst. for Manufacturing Engineering and Automation
Sonnenburg, Arne — Fraunhofer Inst. for Manufacturing Engineering and Automation
Hieger, Christof — Fraunhofer Inst. for Manufacturing Engineering and Automation

In this paper a new concept of a technical muscle is presented. The proposed muscle is based on standard components and is scalable in many respects: size, weight, power, speed, price, and quality. It is composed of a turning shaft with small diameter and a high-strength and highly flexible plaited cord. The shaft may be driven by a small DC-motor, possibly in combination with a gearbox. This makes design, power supply, and control quite easy compared to other types of artificial muscles such as pneumatic, hydraulic, shape memory alloy, and electro-active polymer muscles. With appropriate measures in design it will be able to meet various application requirements such as wide temperature range and high IP rating. Moreover, with careful selection and dimensioning of components a very high degree of efficiency, a very high power to weight ratio, and high dependability may be achieved. The muscle is applicable as an actuating drive in industrial environments as well as for bionic robot mechanisms with biomimetic and undulatory motion. The name DOHELIX is an acronym for 'double helix', a shape resulting from contraction of the muscle.

16:20-16:40 **SuRP-B04.5**

Similarity-Based Retrieval of CAD Solid Models for Automated Reuse of Machining Process Plans, pp. 312-317

Marefat, Michael — Univ. of Arizona
Pitta, Chandan — Univ. of Arizona

It is a well known fact that most of the new designs are modified versions of previous designs. In an attempt to reuse as much as possible of the previous investments, engineers spend a lot of time searching for similarly shaped designs and modifying them to generate new designs. This process of searching and modifying similar designs is an extremely time consuming task when it is done manually. Addressing this need has resulted in systems for retrieval and reuse of CAD models. In this work we propose techniques and algorithms for automated retrieval of similar designs from a database of old designs. Features and the spatial relationships between the features form a signature, which can uniquely identify each part. Using this signature we develop an indexing scheme to store and speedily retrieve digital part/components searching.

16:40-17:00 **SuRP-B04.6**

Automated Feeding of Industrial Parts with Modular Blades: Design Software, Physical Experiments, and an Improved Algorithm, pp. 318-325

Goemans, Onno — Utrecht Univ.
Anderson, Marshall — University of California, Berkeley
Goldberg, Ken — University of California, Berkeley

van der Stappen, Frank — Utrecht Univ.

The ``blade", a three-parameter primitive for part feeding, and a complete (quasi-static) algorithm for its design (which runs in O(n^6) time) were introduced in [10]. Here, we present our implementation of the geometric blade design algorithm, a reconfigurable modular blade hardware design, and physical experiments: we report experiments with 14 blade configurations and 3 test parts. We then present an improved blade design algorithm which takes into account the part behaviors that are observed in the physical experiments, yet that are not considered by the quasi-static algorithm.

SuRP-B05 — Garden Terrace

System Modeling and Simulation 1 (Regular Session)

Chair: Beghi, Alessandro — Univ. di Padova
Co-Chair: Ha, Q P — Univ. of Tech. Sydney

15:00-15:20 **SuRP-B05.1**

Dynamic Coupling Simulation of a Power Transmission Line Inspection Robot with Its Flexible Moving Path When Overcoming Obstacles, pp. 326-331

Xiao, Xiaohui — Wuhan Univ.
Wu, Gongping — Wuhan Univ.
Li, Sanping — Northeast Univ. of Algriculture

The influence of the flexibility moving path- overhead transmission line - on the inspection robot's dynamic response performance is studied through coupling dynamic simulation. First, a rigid multi-body dynamic model of the robot and a flexible multi-body dynamic model of a span of transmission line were built with Lagrange equation and modal synthesis method, respectively. Then the two models were coupled in the grasping point under two typical postures of passing obstacles. The dynamic response simulation of each posture was carried out with three different spans of flexible overhead transmission line. The laws governing impacts of flexible job environment upon the robot's dynamic response performance are explored through simulation results comparison and analysis.

15:20-15:40 **SuRP-B05.2**

PSO-Based Cooperative Control of Multiple Mobile Robots in Parameter-Tuned Formations, pp. 332-337

Kwok, Ngai Ming — Univ. of Tech. Sydney
Ngo, Van Thuyen — Univ. of Tech. Sydney
Ha, Q P — Univ. of Tech. Sydney

This paper addresses the coordination of multiple mobile robots in navigation formations. Difficulties encountered in conventional leader-follower approaches, such as bounds on control commands and formation constraints are revealed. A generic control structure is then proposed, based on the leader-follower strategy and virtual robot tracking framework, to parameterize the formation configuration for cooperatively deploying the robots into desired patterns. In order to achieve both tracking accuracy and control feasibility, the design is further cast as a constrained optimization problem to obtain formation configuration parameters and controller parameters simultaneously. The particle swarm optimization (PSO) algorithm is used, owing to its computationally-efficient capability of handling multi-objective criteria. Satisfactory results obtained through simulation are included to illustrate the effectiveness of the proposed technique for a number of benchmark patterns.

15:40-16:00 **SuRP-B05.3**

Geometric Derived Information Spaces in Manipulation with Mechanical Contact, pp. 338-345

Murphey, Todd — Univ. of Colorado

This paper describes methods applicable to the modeling and control of mechanical contact, particularly those that experience uncertain stick/slip phenomena. Geometric kinematic reductions are used to show how to reduce a system's description from a second-order dynamic model with frictional disturbances coming from a function space to a first-order model with frictional disturbances coming from a space of finite automata over a finite set. As a result, modeling for purposes of control in the resulting derived information space is made more straight-forward by getting rid of some dependencies on low-level mechanics (in particular, the details of friction modeling).Moreover, the online estimation of the uncertain variables in the derived information space has reduced sensing requirements. Results are illustrated using an actuator array model.

16:00-16:20 **SuRP-B05.4**

Modeling and Identification for High-Speed Milling Machines, pp. 346-351

Yang, Jiangzhao — Shenzhen Graduate School, Harbin Inst. of Tech.
Zhang, Dongjun — Hong Kong Univ. of Science and Tech.
Li, Zexiang — Hong Kong Univ. of Science and Tech.

Accurate modeling and identification to the dynamics of the feed drive system is significant in designing a high performance milling machine. In this paper, mathematical model of the feed drive system, including electromagnetic and mechanical aspects, is concluded. Two different grey-box identification methods are discussed to estimate the model of a practical milling machine. It turns out that the sampled-data control system with a slower sample rate fits the system better than the faster one. Moreover, compared with the model estimated by partial continuous approach, the total discrete-time model achieves better results in the model validation.

16:20-16:40 **SuRP-B05.5**

DiagramDraw: A State Machine Diagram Designer for Flexible Automation, pp. 352-356

Zhou, MengChu — New Jersey Inst. of Tech. (NJIT)
Guo, Wenqi — New Jersey Inst. of Tech. (NJIT)
Wei, Dong — Siemens Corp. Res. Inc

To achieve ever-increasingly complex system functionality, modern machine control systems heavily count on software tools. Control software's primary purpose is to ensure correct execution of machine tasks in real time. DiagramDraw is proposed as a state machine modeling prototype. It is designed to help designers generate a state machine diagram and convert it to industrial sequence control programs for various industrial automation projects. The tool has been built on its early version that was designed to deal with some particular Siemens' industrial systems with a specific number of states. The new features and applications of DiagramDraw in control design automation are discussed in this paper. This developed tool can help designers produce a state machine and needed control programs

correctly and quickly.

16:40-17:00 **SuRP-B05.6**

Diagnosis and Treatment of Faults in Productive Systems Based on Bayesian Networks and Petri Net, pp. 357-362

Gomez Morales, Roy Andres — Univ. of Sao Paulo, Escola Pol.
Garcia Melo, Jose Isidro — Univ. del Valle
Miyagi, Paulo Eigi — Univ. of Sao Paulo, Escola Pol.

In this paper, we introduce a procedure for diagnosis and treatment of faults in productive systems, i.e., a supervision strategy that considers not only the normal behavior of system's components, but also abnormal (faulty) conditions of them. The present approach uses Bayesian networks for the diagnosis and decision-making purposes, and Petri net for the synthesis, modeling and control purposes. The integration of these techniques guarantees the specified functionality of the system. Special emphasis is laid on methodological issues and industrial systems, where a hierarchical structure can be adopted. It is presented, as a case study, the material entry system of a continuous pickling line process of a steel industry.

Monday, September 24, 2007

MoBPBP — Grand Ballroom DEF

Spansion™ Best Conference Paper Award Session (Regular Session)

Chair: Meldrum, Deirdre — Arizona State University
Co-Chair: Zhang, Mike Tao — Spansion, Inc.

09:30-09:50 **MoBPBP.1**

Autonomous Zebrafish Embryo Injection Using a Microrobotic System, pp. 363-368

Wang, Wenhui — Univ. of Toronto
Liu, Xinyu — Univ. of Toronto
Sun, Yu — Univ. of Toronto

As an important embodiment of biomanipulation, injection of foreign materials (e.g., DNA, RNAi, sperms, proteins, and drug compounds) into individual cells has significant implications in genetics, transgenics, assisted reproduction, and drug discovery. This paper presents a microrobotic system for fully automated zebrafish embryo injection, which overcomes the problems inherent in manual operation, such as human fatigue and large variations in success rates due to poor reproducibility. Based on computer vision and motion control, the microrobotic system performs injection at a speed of 15 zebrafish embryos (chorion unremoved) per minute, with a survival rate of 98% (350 embryos), a success rate of 99% (350 embryos), and a phenotypic rate of 98.5% (210 embryos). The sample preparation technique and microrobotic control method are applicable to other biological injection applications such as the injection of mouse oocytes/embryos and Drosophila embryos to enable high-throughput biological and pharmaceutical research.

09:50-10:10 **MoBPBP.2**

Dynamic Modelling of Wheel-Terrain Interaction of a UGV, pp. 369-374

Tran, T. H. — Univ. of Tech., Sydney
Kwok, Ngai Ming — Univ. of Tech., Sydney
Scheding, Steven — Univ. of Tech., Sydney
Ha, Q P — Univ. of Tech., Sydney

Understanding the vehicle-terrain interaction is essential for autonomous and safe operations of skid-steering unmanned ground vehicles (UGVs). This paper presents a comprehensive analysis of the dynamic processes involved in this interaction, using the vehicle kinetics and the theory of terramechanics to derive systematically shear displacement, reaction force, and load distribution for a wheel. The new model is then summarized in the form of an algorithm to allow for computation of characteristic performance of the interaction such as slip ratios, rolling resistance, and moment of turning resistance for a number of terrain types. Given the current state of the vehicle and terrain parameters, the model can be used to estimate its next states and to predict the vehicle running path. The development is illustrated by simulation and verified with experimental data.

10:10-10:30 **MoBPBP.3**

Automation and Yield of Micron-Scale Self-Assembly Processes, pp. 375-380

Saeedi, Ehsan — Univ. of Washington
Kim, Samuel — Univ. of Washington
Etzkorn, James — Univ. of Washington
Meldrum, Deirdre — Arizona State University
Parviz, Babak — Univ. of Washington

We present the use of self-assembly to integrate a large number of free-standing microcomponents onto unconventional substrates. The microcomponents are batch fabricated separately from different semiconductor materials in potentially incompatible microfabrication processes and integrated onto unconventional substrates such as glass and plastic. These substrates offer a number of unique attributes as compared with silicon such as transparency, flexibility, and lower cost. Here, we provide an overview of the self-assembly process, describe how microcomponents that can participate in the self-assembly process can be mass-produced, and discuss initial self-assembly experimental results. Our results indicate that even with a very simple set-up, self-assembly yields as high as 97 % for components as small as 100 m;m are achievable, making the self-assembly technique immediately comparable with (or better than) the state-of-the-art robotic pick-and-place systems. We discuss various parameters that affect the yield of the self-assembly process and a possible automation scheme.

10:30-10:50 **MoBPBP.4**

Enhancing the Throughput of Catalyst Screening Labs by Integration of a High Pressure Microplate Reactor, pp. 381-385

Allwardt, Arne — Univ. of Rostock
Wendler, Christian — Univ. of Rostock
Holzmüller-Laue, Silke — Univ. of Rostock
Stoll, Norbert — Univ. of Rostock

Thurow, Kerstin — Univ. of Rostock

In the future laboratories require particularly multivariate laboratory systems. The devices used in these systems are characterized by an increase of the reactions per time unit and the reduction of the reaction volumes with consideration of compact dimensions. They have to be variable integrable into laboratory robot systems in hard- and software. The multi-parallel high pressure reactor HPMR 50-384 enables the simultaneous execution of 384 reactions in a reaction module under reaction pressures up to 50 bar and temperatures in the range from 0 to 100°C. The mixing of the reagents is realized with magnetically propelled stir discs with a velocity up to 500 rpm. The reaction module is based on a commercial microplate made of polypropylene, MultiChem™ or glass. With a sealing mat, a support frame and a perforated plate such a microplate will be completed to a reaction module. By an injection system in the lid of the pressure tank the gas exchange in the reaction vessels can be ensured. The HPMR 50-384 enables an excellent gas exchange in the pressure tank and thus the handling of air sensitive compounds. The possibility of integration into a laboratory robot system or the connection to a LIMS makes the HPMR 50-384 to an all-purpose reaction system.

10:50-11:10 **MoBPBP.5**

Algorithm Advancements for the Measurement of Single Cell Oxygen Consumption Rates, pp. 386-391

Molter, Timothy — Univ. of Washington
McQuaide, Sarah — Univ. of Washington
Zhang, Meng — Univ. of Washington
Holl, Mark — Arizona State University
Burgess, Lloyd — Univ. of Washington
Lidstrom, Mary — Univ. of Washington
Meldrum, Deirdre — Arizona State University

Advancements in methods and algorithms for the measurement of oxygen consumption rates of single cells is presented. In this system a low density of randomly seeded eukaryotic cells are sealed in an array of microwells etched in glass (zero to three cells per microwell). The decrease in oxygen concentration inside each microwell in the array is measured yielding the oxygen consumption rates of the cells trapped in the array. While fundamentally simple in concept, the system requires advanced algorithms for data collection and image processing. The data collection technique enabling the oxygen sensors in each microwell has been modified to increase speed and sensor precision. Utilizing internal triggering and an integrate-on-chip mode rather than external triggering and an off-chip accumulation mode improves sensor precision by 45% and increases collection speed by a factor of seven. Furthermore, an optimized sensor locator algorithm has reduced the time to process image data for a single oxygen measurement point five-fold. A new measurement technique involving custom image-processing algorithms has also been developed revealing the microwell volumes to be 0.54 nL on average with a 6% maximum spread from the mean. To demonstrate the utility of the system, we present an experiment that successfully measured the oxygen consumption rates of 1, 2 or 3 cells in nine individual microwells simultaneously.

11:10-11:30 **MoBPBP.6**

On the Optimality of One-Unit Cycle Scheduling of Multi-Cluster Tools with Single-Blade Robots, pp. 392-397

Chan, Victor Wai-Kin — Rensselaer Pol. Inst.
Yi, Jingang — San Diego State Univ.
Ding, Shengwei — Univ. of California at Berkeley

In semiconductor manufacturing, finding an efficient way for scheduling a multi-cluster tool is crucial for productivity improvement and cost reduction. In this paper, we analyze optimal scheduling of multi-cluster tools under a general configuration with non-zero constant transfer robot traveling time. A resource-based method is developed to analyze optimal scheduling of single-cluster tools. Optimality conditions for obtaining minimum one-unit cycle time for multi-cluster tools are established. Under these conditions, it is shown that the optimal one-unit cycle can be achieved by first optimally scheduling each single-cluster tool separately and then combining the schedules to form the optimal schedule for the multi-cluster tool. A polynomial-time algorithm is presented to find the optimal one-unit cycle time and its corresponding schedules for a multi-cluster tool.

MoRP-A01 — Room D

Manufacturing Systems 3 (Regular Session)

Chair: van der Stappen, Frank — Utrecht Univ.
Co-Chair: Xiong, Caihua — Huazhong Univ. of Science and Tech.

12:30-12:50 **MoRP-A01.1**

Approximate Analysis of Re-Entrant Lines with Bernoulli Reliability Models, pp. 398-403

Li, Jingshan — Univ. of Kentucky
Wang, Chong — Univ. of Kentucky

Re-entrant lines are widely used in many manufacturing systems, such as semiconductor, electronics, etc. However, the performance analysis of re-entrant lines is largely unexplored due to its complexity. In this paper, we present iterative procedures to approximate the production rate of re-entrant lines with Bernoulli reliability of machines. The convergence of the algorithms, uniqueness of the solution, and monotonic properties, have been proved analytically. The accuracy of the procedures is investigated numerically. Finally, a case study of automotive ignition component line with re-entrant washing operations is introduced to illustrate the applicability of the method. The results of this study suggest a possible route for modeling and analysis of re-entrant systems.

12:50-13:10 **MoRP-A01.2**

Geometric Properties and Computation of Three-Finger Caging Grasps of Convex Polygons, pp. 404-411

Vahedi, Mostafa — Utrecht Univ.
van der Stappen, Frank — Utrecht Univ.

We study three-finger caging grasps of convex polygons. A grasp is said to cage a part when the fingers make it impossible for the part to move to a distant location ---and, hence, escape the grasp---without penetrating a finger. We present a collection of geometric properties of three-finger caging grasps of convex polygons, and establish a relation between caging grasps and immobilizing grasps. We use these results to derive an algorithm that computes a data structure in roughly $O(n^6)$ time for a given convex polygon with n edges and a specified distance between two so-called base fingers. The data structure allows us to efficiently solve two problems. (1) For a given placement of the base fingers and a placement for the third finger, we give an algorithm that determines in $O(\log n)$ time whether the resulting grasp cages

the polygon. (2) For a given placement of the base fingers on the polygon boundary we give an algorithm that outputs in *O(n+K)* time *all* placements of the third finger such that the three fingers together constitute a caging grasp of the polygon, in which *K* is proportional to the complexity of the output.

13:10-13:30 **MoRP-A01.3**

On the Error Elimination for Multi-Axis CNC Machining, pp. 412-417

Xiong, Caihua — Huazhong Univ. of Science and Tech.
Xiong, Youlun — Huazhong Univ. of Science and Tech.

The geometrical accuracy of a machined feature on a workpiece during machining processes is mainly affected by the kinematic chain errors of multi-axis CNC machines, locating precision of fixtures, and datum errors on the workpiece. It is necessary to find a way to minimize the feature errors on the workpiece. In this paper, the kinematic chain errors are transformed into the displacements of the workpiece. The relationship between the kinematic chain errors and the displacements of the position and orientation of the workpiece is developed. A mapping model between the displacements of workpieces and the datum errors, and adjustments of fixtures is established. An Error Elimination (EE) method of the machined feature is formulated. A case study is given to verify the EE method.

13:30-13:50 **MoRP-A01.4**

Study of the Dynamic Coupling Term in Parallel Force/Velocity Actuated Systems, pp. 418-423

Rabindran, Dinesh — University of Texas, Austin
Tesar, Delbert — University of Texas, Austin

Presented in this paper is an actuator concept, called a Parallel Force/Velocity Actuator (PFVA), that combines two fundamentally distinct actuators (one using low gear reduction or even direct drive, which we will call a Force Actuator (FA) and the other with a high reduction gear train that we will refer to as a Velocity Actuator (VA)). The objective of this work is to evaluate the effect of the relative scale factor, RSF, (ratio of gear reductions) between these inputs on their dynamic coupling. We conceptually describe a Parallel Force/Velocity Actuator (PFVA) based on a Dual-Input-Single-Output (DISO) epicyclic gear train. We then present an analytical formulation for the variation of the dynamic coupling term w.r.t. RSF. Conclusions from this formulation are illustrated through a numerical example involving a 1-DOF four-bar linkage. It is shown, both analytically and numerically, that as we increase the RSF, the two inputs to the PFVA are decoupled w.r.t. the inertia torques. This understanding can serve as an important design guideline for PFVAs. The paper also presents two limitations of this study and suggests future work based on these caveats.

13:50-14:10 **MoRP-A01.5**

A Hybrid Model with a Weighted Voting Scheme for Feature Selection in Machinery Condition Monitoring, pp. 424-429

Zhang, Kui — Univ. of Manchester
Ball, Andrew — Univ. of Manchester
Gu, Fengshou — Univ. of Manchester
Li, Yuhua — Univ. of Ulster

Feature selection method has become the focus of research in the area of engineering data processing where there exists a large amount of high-dimensional data from the high-frequency acquisition system. For high-dimensional data processing, engineers often resort to feature extraction methods and statistical theories to convert the original features into new features. However, the converted data always lose the engineering meaning of the original features and the choice and use of conversion methods are challenging. In this paper, a hybrid feature selection model is presented to select the most significant input features from all potentially relevant features. The algorithm combines a filter model with a wrapper model. In the filter model, four variable ranking methods are used to pre-rank the candidate features. These four methods including Pearson correlation coefficient, Relief algorithm, Fisher score and Class separability, measure features from various angles, which leads to different ranking results. Therefore, a weighted voting scheme is introduced to re-rank features based on the degree of significance of the four methods on the classification error rate of Radial Basis Function (RBF) classifier. In wrapper model, a Binary Search method and a Sequential Backward Search (SBS) method are utilized to minimize the number of relevant features when promising to keep the classification error rate of RBF classifier below a given threshold. To demonstrate the potential of applying the method to large-scale engineering data processing, a case study is conducted.

14:10-14:30 **MoRP-A01.6**

Modal Trajectory Generation for Adaptive Secondary Mirrors in Astronomical Adaptive Optics, pp. 430-435

Ruppel, Thomas — Univ. of Stuttgart
Lloyd-Hart, Michael — Univ. of Arizona
Zanotti, Daniela — Osservatorio Astrofisico di Arcetri
Sawodny, Oliver — Univ. of Stuttgart

The use of high speed adaptive secondary mirrors (AS) in cassegrain or gregorian telescopes shows high optical efficiency as well as the possibility to make Adaptive Optics (AO) available at all foci. After 4 years of extensive and successful use of a 336-actuator AS (MMT336) at the Multi Mirror Telescope (MMT), the need for faster control methods of the AS is arising. Recent wavefront sensors allow frame rates above 1kHz and the dynamically limiting part in the telescope's closed loop AO system is the AS. The development of two 672-actuator (LBT672) AS for the Large Binocular Telescope (LBT) underlines the need for accurate high speed control methods of AS systems with a large number of spatially distributed actuators in the near future. Currently, AS are controlled based on local position feedback for all actuators independently. Arising problems in this configuration are mode-dependent stiffness variations of the mirror shell, interacting actuators and the excitation of uncontrollable modal mirror modes in closed loop operation. Based on dynamic inversion of identified controllable modal eigenmodes of the deformable mirror shell we derive a feed-forward trajectory generator that excites only controllable modal mirror modes, compensates for the varying mirror stiffness, and the actuator interaction of the AS. Verified at the LBT672 prototype (P45), an experimental 45-actuator AS, we will show the benefits of modal feed-forward control including faster settling times and less overshoot for a setpoint change in closed loop operation.

(MoRP-B03) Room E

Supply Chain/Logistics/Transportation 1 (Regular Session)

Chair: Xie, Xiaolan — Ec. des Mines de Saint Etienne
Co-Chair: Schwartz, Jay — Arizona State University

12:30-12:50 **(MoRP-B03.1)**

Performance Design of Operating Robots in a Seaport Container-Handling System, pp. 692-697

Hoshino, Satoshi — Tokyo Inst. of Tech.
Ota, Jun — The Univ. of Tokyo

In order to provide a highly efficient container-handling system in a seaport terminal, for a given constraint, i.e., demand, we take into account the performance of operating robots, such as quay container cranes (QCCs), automated guided vehicles (AGVs), and rubber-tired gantry cranes (RTGCs) in addition to the number of robots, as design objectives. However, this is a combinatorial design problem. Therefore in this paper, we propose a design methodology with the use of a hybrid design process which had been proposed for designing the number of robots. By using this methodology, we design two objectives, that is, the number of robots and their performance for a given demand. Finally, we present the validity of the proposed methodology by comparing and evaluating construction costs of two systems, which are designed with the used of the proposed design methodology and a design methodology which does not take into account the robots performance. Also, we discuss the designed robots performance in terms of the system bottleneck.

12:50-13:10 **(MoRP-B03.2)**

Design of Multi-Commodity Distribution Network with Random Demands and Supply Lead-Times, pp. 698-703

Tanonkou, Guy Aimé — INRIA, Lorraine, France
Benyoucef, Lyes — INRIA, Lorraine, France
Xie, Xiaolan — Ec. des Mines de Saint Etienne

This paper deals with the stochastic multi-commodity distribution network design problem. The distribution network under consideration is composed of a single supplier serving a set of retailers through a set of distribution centers (DCs) to locate. The number and locations of DCs are not known a priori. They are chosen from a set of retailer locations. To manage its inventory, for each commodity, the Economic Order Quantity (EOQ) policy is used by each DC, and a safety stock is kept at the DC to ensure a given retailer service level. Each retailer faces independent random demands of different commodities, the supply lead-time from the supplier to each DC is random, and supply lead-times between DCs and retailers are neglected. The central issues of the problem are: which retailer locations should be selected as DCs and commodity-by-commodity how to assign retailers to DCs. The goal is to minimize the total location, shipment, and inventory costs, while ensuring a specified retailer service level. The introduction of inventory costs and safety stock costs leads to an NP-hard non-linear optimization problem. A Lagrangian relaxation approach is proposed, and computational experiments presented and analyzed showing its effectiveness.

13:10-13:30 **(MoRP-B03.3)**

A Decision Framework for Location Selection in Global Supply Chains, pp. 704-709

Viswanadham, Nukala — Indian School of Business
Sampath, Kameshwaran — Indian School of Business

The supply chain decision problems are becoming more complex with the globalization of businesses that spatially span across several international borders. One such strategic decision problem is the location selection problem, which determines an optimal location to build a new facility. This requires multicriteria evaluation of N alternate locations with respect to M location attributes. In this paper we develop a generic framework that can aid the decision maker in identifying and grouping the M attributes into an hierarchy for location selection in global supply chains. An hierarchical structuring is proposed with four fundamental criteria: product/process value chain, economic & political integration, resources & management, and connecting technologies. These are integral to many global business activities and the generic sub-criteria for the above are identified. This aids the decision maker to identify and group the M location attributes as a multilevel hierarchical tree. This structuring facilitates the use of analytic hierarchy process to synthesize the information about the M attributes along with the decision maker's preferences, to evaluate the locations. We illustrate the applicability of the framework using a stylized example of locating a Biotech R&D center in Asia.

13:30-13:50 **(MoRP-B03.4)**

Multi-Objective Control-Relevant Demand Modeling for Production and Inventory Control, pp. 710-715

Schwartz, Jay — Arizona State University
Rivera, Daniel E. — Arizona State University

The development of control-oriented decision policies for inventory management in supply chains has received considerable interest in recent years, and demand modeling to supply forecasts for these policies is an important component of an effective solution to this problem. Drawing from the problem of control-relevant identification, we present an approach for demand modeling based on data that relies on a control-relevant prefilter to tailor the emphasis of the fit to the intended purpose of the model, which is to provide forecast signals to tactical inventory management policies based on Model Predictive Control. Integrating the demand modeling and inventory control problems offers the opportunity to obtain reduced-order models that exhibit superior performance, with potentially lower user effort relative to traditional "open-loop" methods. Asystematic approach to generating these weights and prefilters is presented and the benefits resulting from their use are demonstrated on representative production/inventory system case studies. A multi-objective formulation is developed that allows the user to emphasize minimizing inventory variance, minimizing starts variance, or their combination.

13:50-14:10 **(MoRP-B03.5)**

A Combinatorial Procurement Auction for QoS-Aware Web Services Composition, pp. 716-721

Mohabey, Megha — Indian Inst. of Science
Narahari, Yadati — Indian Inst. of Science
Mallick, Sudeep — Infosys Tech. Ltd.
Suresh, P — Infosys Tech. Ltd.
Subrahmanya, S V — Infosys Tech. Ltd.

Business processes and application functionality are becoming available as internal web services inside enterprise boundaries as well as becoming available as commercial web services from enterprise solution vendors and web services marketplaces. Typically there are multiple web service providers offering services capable of fulfilling a particular functionality, although with different Quality of Service (QoS). Dynamic creation of business processes requires composing an appropriate set of web services that best suit the current need. This paper presents a novel combinatorial auction approach to QoS aware dynamic web services composition. Such an approach would enable not only stand-alone web services but also composite web services to be a part of a business process. The combinatorial auction leads to an integer programming formulation for the web services composition problem. An important feature of the model is the incorporation of service level agreements. We describe a software tool QWESC for QoS-aware web services composition based on the proposed approach.

14:10-14:30 **(MoRP-B03.6)**

Approximating State of DES Using Fuzzy Timed Petri Nets, pp. 722-728

Gonzalez-Castolo, Juan Carlos — CINEVESTAV
Lopez-Mellado, Ernesto — CINEVESTAV

This paper addresses state estimation of discrete event systems (DES) modeled by Fuzzy Timed Petri Nets (FTPN). A definition of FTPN in which fuzzy sets, associated to places, represent the ending time uncertainty of activities is presented; then the fuzzy state equation composed by a set of matrix expressions is developed, allowing computing the marking evolution of DES exhibiting cyclic behavior. A method for approximating the marking of strongly connected state machines is proposed.

MoRP-A03 — Room F

Semiconductor Manufacturing 3 (Regular Session)

Chair: Wu, Kan — Georgia Tech.
Co-Chair: Rose, Oliver — Dresden Univ. of Tech.

12:30-12:50 — **MoRP-A03.1**

Analysis of the Effects of Truncation on the EWMA Observer, pp. 472-477

Braun, Martin — Intel Corp.
Patel, Nital — Intel Corp.

For many years the Exponentially Weighted Moving Average (EWMA) observer has been used in practice for Advanced Process Control (APC) in the semiconductor industry. A common practice is to truncate the length of data used in creating an EWMA estimate of the system state. This practice enables easier maintenance of the installed controller, while running the risk of tighter robust stability margins. This paper provides a measure of when it may be safe to assume the stability results of a truncated EWMA are well predicted by those expressions for an infinite EWMA formulation. Additional stability criteria are provided for situations otherwise. A method for extending auto-tuning methods for use with truncated EWMA filters is also presented.

12:50-13:10 — **MoRP-A03.2**

Forecasting Final/Class Yield Based on Fabrication Process E-Test and Sort Data, pp. 478-483

YIP, Wai-Kuan — Intel Tech. Sdn Bhd
Law, KG — Intel Tech. Sdn Bhd
Lee, Wen-Jau — Intel Malaysia

This paper presents an application of data mining using Gradient Boosting Trees to predict class test yield performance at high volume manufacturing (HVM) based on e-test and sort ancestry parameters. The paper also presents a framework for the predictive capability system and highlights some of the techniques and implementation details. Modeling at wafer level was found to give the best accuracy and the analytic model provides wafer level yield accuracy at 97% within +/-2% accuracy level for Intel chipset products. Certain functional bins that correlate to e-test and sort can also be modeled for identification of possible high fallouts. In addition, the modeling process also produced pareto analysis reports that lists dominant influencers and the dependency plots, enabling Assembly and Test (ATM) engineers to feedback to upstream operation engineers. The overall predictive capability has set a new standard for proactive yield monitoring and excursion management at Intel ATM factories and it is useful to various functions including the yield engineering, product engineering, manufacturing and planning.

13:10-13:30 — **MoRP-A03.3**

Semiconductor System with Multiple Closed-Loops Constrains, pp. 484-488

Na, Li — Tsinghua University

In semiconductor Assembly and Test factory, the carts which are used as transports and fixtures are always cycling in the system and they are enablers for the semiconductor production. The limited cart resource, especially when the several different kinds of carts are needed to perform the operation, affect the system performance quite significantly. In this paper, a production line with three machines and two WIP buffers, two types of carts, two loop and two cart buffers are addressed, all the processing times by these machines are assumed to be exponential. Markov models for this two-loop closed line with finite buffers were derived to explore the relationship between the system performance and system structure and parameters, such as the cart numbers. Based on numerical examples, some valuable insights on how to management these systems effectively were proposed.

13:30-13:50 — **MoRP-A03.4**

Line Planning in a Hierarchical Production Planning Approach, pp. 489-494

Quadt, Daniel — Infineon Tech. AG
Chua, Koon Min — Infineon Tech. (Advanced Logic)

We discuss the line planning problem as it appears in a large semiconductor back-end. The line planning is a short-term planning phase in a hierarchical production planning approach. We highlight its major objectives and constraints as well as outline a manual solution procedure. The solution procedure consists of the phases package planning and device planning. Due to an ongoing increase in the complexity and size of the line planning problem, the manual solution procedure reaches its limitations. This is especially the case for the more detailed device planning. Hence, we present a prototype of a mathematical mixed integer program (MIP) model formulation as a starting point for a more automated optimization approach.

13:50-14:10 — **MoRP-A03.5**

Lot Dispatching and Scheduling Integrating OHT Traffic Information in the 300mm Wafer Fab, pp. 495-500

Huang, How Wei — National Taiwan Univ.
Fu, Li-Chen — National Taiwan Univ.
Lu, Ching-Hu — National Taiwan Univ.

In this paper, we focus on the lot dispatching and vehicle dispatching problems in a 300mm wafer fab. We propose a two phase lot dispatching and vehicle dispatching integrated algorithm. The first phase is the offline optimization phase and the second phase is the online dispatching phase. In the offline optimization phase, we focus on the lot dispatching problem. We propose a scheduler which can search for appropriate weights of several rules and combines them into one mixed rule. Genetic algorithm(GA) is used to find the optimal combination of these heuristic rules. And the mixed rule is used in online dispatching phase. In the online dispatching phase, we focus on

the vehicle dispatching problem. We take the real time traffic information into consideration and we apply Markov decision model to estimate the cost of traversing a congested edge. Compared with the traditional shortest path method that searches for the shortest distance path, in our traffic model we search for the path with least expected travel time.

14:10-14:30 **MoRP-A03.6**

Compatibility of Queueing Theory, Manufacturing Systems and SEMI Standards, pp. 501-506

Wu, Kan — Georgia Tech.
McGinnis, Leon — Georgia Tech.
Zwart, Bert — Georgia Tech.

Queueing theory is a powerful method to evaluate the performance of a manufacturing system. However, when applying it to a real system, both practical and theoretical issues arise.

The practical issues are how to determine the values for queuing models from the data available in real manufacturing systems. We explore this issue by comparing the data needed by queueing models with SEMI standards definitions.

The theoretical issues are the selection of a specific queuing model and its proper use. In order to illustrate this, we design a specific situation for the applications of an M/M/1/Unreliable Machine queue, and compare the performances of two other approaches with it. The results show that, depending on the approach chosen, the approximation error for cycle time can be over 30% at lower utilization levels.

MoRP-A04 — Room JD's Terrace

Service/Home Automation 1 (Regular Session)

Chair: Nugent, Chris — Univ. of Ulster
Co-Chair: Xie, Xiaolan — Ec. des Mines de Saint Etienne

12:30-12:50 **MoRP-A04.1**

Simulated Annealing Algorithm for Daily Nursing Care Scheduling Problem, pp. 507-512

Cheng, Mingang — The Univ. of Tokyo
Ozaku itoh, Hiromi — Knowledge Science Lab. ATR
Kuwahara, Noriaki — ATR Knowledge Science Lab.
Kogure, Kiyoshi — Advanced Telecommunications Res. Inst. International
Ota, Jun — The Univ. of Tokyo

Nursing, with the primary mission to provide quality services to patients, is accompanied by a serial of activities like patients assessment, outcomes identification for patients. In general, there has been less attention on ensuring that nurses provide nursing cares in a timely and accurate fashion. Consequently, in this paper, considering the similarity to the traditional job shop scheduling problems, we will model the daily nursing care scheduling problems and propose an efficient scheduling method based on simulated annealing algorithm. By the comparison of several nursing care plans obtained by the dispatching-rule based methods (which have been recognized to be the implementation of human thoughts), the proposed method is evaluated to be applicable to the nursing care scheduling problems (providing comprehensive, coordinated and cost effective nursing cares to patients).

12:50-13:10 **MoRP-A04.2**

HomeRuleML – a Model for the Exchange of Decision Support Rules within Smart Environments, pp. 513-520

Hallberg, Josef — Luleí Univ. of Tech.
Nugent, Chris — Univ. of Ulster
Davies, Richard John — Univ. of Ulster
Synnes, KÍre — Luleí Univ. of Tech.
Donnelly, Mark P — Univ. of Ulster
Finlay, Dewar — Univ. of Ulster
Mulvenna, Maurice — Univ. of Ulster

The demands for smart environments, which can help to facilitate as well as monitor independent living are increasing. With this comes a desire for decision support rules to process data recorded from such environments. However, testing and evaluating rules can be both time-consuming and indeed stressful for the inhabitants. Within this paper we propose a model, referred to as HomeRuleML, for representing decision support rules for smart environments. The motivating factor behind such a proposal is to provide a widely and freely accessible set of rules which can be openly used and exchanged within the research domain and beyond. This model has the potential to decrease the time required for deployment, and inevitability improve the inhabitants' quality of life. In the paper we explain in detail the structure of adopting this approach and also provide an indication of the typical types of software tools required for its use.

13:10-13:30 **MoRP-A04.3**

Operating Room Planning with Random Surgery Times, pp. 521-526

Lamiri, Mehdi — Ec. Nationale Supérieure des Mines de Saint-Etienne
Dreo, Johann — Ec. Nationale Supérieure des Mines de Saint-Etienne
Xie, Xiaolan — Ec. Nationale Supérieure des Mines de Saint-Etienne

This paper addresses the elective surgery planning under uncertainties related to surgery times and emergency surgery demands. Surgery times as well operating rooms' capacities used by emergency surgery are assumed to be random variables. The planning problem consists of assigning elective patients to operating rooms (ORs) over a planning horizon in order to minimize patients' related costs and expected ORs' overtime costs. The planning problem is first formulated as a stochastic mathematical program. Then, a solution approach combining Monte Carlo simulation and column generation has been proposed. Computation experiments show that the solution approach results in near-optimal solutions in a reasonable computation time.

13:30-13:50 **MoRP-A04.4**

Multiple-Angle Hand Gesture Recognition by Fusing SVM Classifiers, pp. 527-530

Chen, Yen-Ting — Mechanical and Systems Res. Lab. Tech.
Tseng, Kuo-Tsung — Industrial Tech. Res. Inst.

This article presents a robotic visual system that allows effective recognition of multiple-angle hand gestures in finger guessing games. Three support vector machine (SVM) classifiers were trained for the construction of the hand gesture recognition system. The classified

outputs were fused by proposed plans to improve system performance. Our experimental results show that the system presented by this article can effectively recognize hand gestures, at over 93%, of different angles, sizes, and different skin colors.

13:50-14:10 **MoRP-A04.5**

Quantitative Evaluation of Human Supporting Production System "Attentive Workbench", pp. 531-535

SUGI, Masao	The Univ. of Tokyo
Matsumura, Ippei	The Univ. of Tokyo
Tamura, Yusuke	The Univ. of Tokyo
Ota, Jun	The Univ. of Tokyo
Arai, Tamio	The Univ. of Tokyo

We have proposed "attentive workbench (AWB)," an assembly cell that supports the production activities of human workers. Attentive Workbench is composed of an augmented desk interface and self-moving trays with the Sawyer planar motors. In this paper, real assembly experiments using the implemented AWB system are carried out. The merit of the proposed system is evaluated quantitatively in the view of necessary time for product assembly.

14:10-14:30 **MoRP-A04.6**

Efficient Navigation Algorithm Using 1D Panoramic Images, pp. 536-541

Yoon, Sukjune	Mechatronics and Manufacturing Tech. Center, Samsung Elec.
Han, Woosup	Mechatronics and Manufacturing Tech. Center, Samsung Elec.
Shim, Youngbo	Mechatronics and Manufacturing Tech. Center, Samsung Elec.
Min, Seung Ki	Mechatronics and Manufacturing Tech. Center, Samsung Elec.
Roh, Kyungshik	Mechatronics and Manufacturing Tech. Center, Samsung Elec.

We propose a practical and efficient navigation method of the indoor mobile robot using 1D panoramic images. Mobile robot navigation, one of the most importation components in the robotic application, was carried out using the omni-directional camera that can capture 360°; images around a robot. Therefore, this camera has many advantages in the indoor navigation. In this paper, position of the robot can be estimated by 1D panoramic image correlations. This 1D image is the circular horizontal line in the omni-directional image. The proposed method can estimate the position of the robot without any previous position information in the short time i.e. kidnap problem can be coped with. The path of a robot is generated based on the node map that includes 1D panoramic images and the node information at the captured points. For the feasibility test of the proposed algorithms, we applied them to the mobile robot, iMARO-III. In this test, iMARO-III has succeeded in real world operation without any interaction with operator.

MoRP-A05 — Garden Terrace

Machine Vision in Automation 1 (Regular Session)

Chair: Li, Shigang — Iwate Univ.
Co-Chair: Li, Jingshan — Univ. of Kentucky

12:30-12:50 **MoRP-A05.1**

Automated Feature Selection Methodology for Reconfigurable Automated Visual Inspection Systems, pp. 542-547

Garcia, Hugo	Arizona State University
Jesus Rene, Villalobos	Arizona State University

The lack of flexibility of the current Automated Visual Inspection (AVI) systems to accommodate new products is one of the main problems faced by the users of these systems. In this paper, the authors propose a framework that will facilitate the design of highly reconfigurable AVI systems. We focus on two issues: the general description of a framework for the development of reconfigurable systems and the description of a method for feature selection that will make the automation of this process easier.

12:50-13:10 **MoRP-A05.2**

Intelligent Kite Aerial Platform for Site Photography, pp. 548-553

Murray, John Christopher	Univ. of Wales, Aberystwyth
Labrosse, Frederic	Univ. of Wales, Aberystwyth
Neal, Mark	Univ. of Wales, Aberystwyth

In this paper we present a semi-autonomous intelligent kite aerial photography platform (iKAPP). We detail the hardware and software aspects of the system and show how such a platform can be used to provide a portable, low cost, high quality solution to current aerial photography methods. In addition, we show how this system can be used to acquire high quality images which can be tiled together in order to create a high resolution detailed image of a large area. We use the system to acquire images of local sites of interest that have previously been photographed using other techniques and compare and present our results in this paper.

13:10-13:30 **MoRP-A05.3**

Automated Classification of Macrophage Membrane Integrity Using a Fluorescent Live/Dead Stain, pp. 554-559

McVittie, Patrick	Univ. of Washington
Sun, Clement	Univ. of Washington
Molter, Timothy	Univ. of Washington
McQuaide, Sarah	Univ. of Washington
Lidstrom, Mary	Univ. of Washington
Holl, Mark	Arizona State University
Meldrum, Deirdre	Arizona State University

The analysis of cell function comprises an examination of gene expression, protein synthesis, and metabolic activity. In order to measure these parameters in single cells a means for signal transduction and amplification is required. Fluorescent molecules have been demonstrated to provide a powerful tool for this detection need when performing living cell analysis. The development of an image analysis tool is the first step in automating multi-parameter cell function analysis where the objective is to ascertain cell membrane integrity and by extension, to obtain an estimate of cell health. A live/dead fluorescent stain was used to make this distinction. Two image analysis algorithms were implemented from the literature and one new method was developed. Three methods were tried: threshold segmentation, matched filtering, and an original method named morphological subtraction. The threshold technique produced the greatest overall accuracy in reducing spurious counts, closely followed by the morphological subtraction and then the matched filter. However, the original

morphological subtraction method may be more appropriate in single cell studies because it overestimates live cells, aiding in the identification of unsuitable data.

13:30-13:50 **MoRP-A05.4**

Modeling the Variation of the Intrinsic Parameters of an Automatic Zoom Camera System Using Moving Least-Squares, pp. 560-565

Sarkis, Michel — Munich Univ. of Tech.
Senft, Christian Thomas — Munich Univ. of Tech.
Diepold, Klaus — Tech. Univ. München

The accuracy of machine vision systems is highly depending on the correct estimates of the camera intrinsic parameters. This accuracy is needed in numerous applications like telepresence and robot navigation. In this work, a novel technique is proposed based on the moving least-squares approach, to model the variation of the camera internal parameters as a function of focus and zoom. Compared to a previous technique using a global least-squares regression scheme with bivariate polynomial functions, the new method results in a huge reduction of the mean estimation error. In addition, validation tests show that the estimated values of the interpolated data are enhanced substantially even with a small number of easured focus and zoom settings. Consequently, fewer measurement points are needed to obtain an accurate model of the internal parameters of a zoom camera system.

13:50-14:10 **MoRP-A05.5**

Qualitative Localization by Full-View Spherical Image, pp. 566-571

Li, Shigang — Iwate Univ.
Isago, Takumi — Iwate Univ.

The content of a full-view spherical image is independent of the camera rotation. In this paper we propose a method of qualitative localization of a robot by full-view spherical images. First, a robot is guided by humans and memorizes the rout scenes by capturing a spherical image sequence from a spherical image sensor; then the robot localizes itself by matching the current spherical image with the stored ones in terms of the similarity of the feature vectors computed from the histograms of spherical images. The advantage of the proposed full-view image approach over the lower hemispherical images from conventional catadioptric omnidirectional camera is shown by real-world experiments of both indoor and outdoor environment.

14:10-14:30 **MoRP-A05.6**

Object Localization in Range Data for Robotic Bin Picking, pp. 572-577

Boehnke, Kay — Univ. Pol. Timisoara

This paper describes an approach to solve the bin picking problem. In many industrial processes, product parts, which have to be assembled, are delivered scrambled in boxes. Usually these parts have to be picked out of the box manually to feed them into an automated process. Using an industrial robot for this task is very difficult. This problem is not solved in general up to now. Our flexible approach uses knowledge about the form of the objects to find them in range data. We compare the 2.5D-appearance of simulated object poses with the real range data in two different steps, and find the best matching pose of the object. This approach can handle many different kinds of objects and takes features of range sensors into consideration to improve the accuracy and robustness of the object localization.

MoRP-A06 — Las Palmas B

Sensors, Instrumentation, and Measurement 1 (Regular Session)

Chair: Ding, Yu — Texas A&M Univ.
Co-Chair: Bukkapatnam, Satish — Oklahoma State Univ.

12:30-12:50 **MoRP-A06.1**

Intruder Activity Analysis under Unreliable Sensor Networks, pp. 578-584

Yoo, Tae-Sic — Idaho National Lab.
Garcia, Humberto — Idaho National Lab.

This paper addresses the problem of counting intruder activities within a monitored domain by a sensor network. The deployed sensors are unreliable. We characterize imperfect sensors with misdetection and false-alarm probabilities. We model intruder activities with Markov Chains. A set of Hidden Markov Models (HMM) models the imperfect sensors and intruder activities to be monitored. A novel sequential change detection/isolation algorithm is developed to detect and isolate a change from an HMM representing no intruder activity to another HMM representing some intruder activities. Procedures for estimating the entry time and the trace of intruder activities are developed. A domain monitoring example is given to illustrate the presented concepts and computational procedures.

12:50-13:10 **MoRP-A06.2**

Container Integrity and Condition Monitoring Using RF Vibration Sensor Tags, pp. 585-590

Bukkapatnam, Satish — Oklahoma State Univ.

Global supply chain operations use hundreds of thousands of container trucks to transport valuable packages and items within and across continents. The recent developments in wireless sensing, including in the so-called RFID sensor tags, offer significant potential for continuous long-range integrity monitoring of containers at various phases of their shipment. In particular, the vibration patterns of a container and its contents can reveal significant information related to its operating environment and integrity during transport, handling and storage. The present work investigates the sensitivity of the patterns of container vibrations gathered as signals from wireless sensor networks to the following four major factors that define the operating condition of a container:terrain type, speed of the vehicle, weight dimensions of the container items. Quantitative relationships are established between the vibration patterns and the salient factors through a series of experiments involving the use of a scaled model of a container truck and a wireless (T-mote) sensor that captures vibrations at 200Hz sampling rates. The idea is to classify the operating conditions by analyzing the complex dynamics underlying vibration signals. Using nonlinear analysis, we find that the system exhibits nonlinear dynamics. The Lyapunov exponents are in the range of 0.01-0.02 for dynamics underlying signals from Stage 1 experiments and 0.005 for those from Stage 2 experiments. The statistical and nonlinear dynamic features together are successfully mapped using a neural network to classify between the different operating conditions. The neural networks were able to identify the correct operating conditions from the vibration sensor features about 90% of the times. In real life, the research results can be applied to accurately capture the environmental and operating conditions during container transport. This will help proactively address possible serious integrity losses.

13:10-13:30 **MoRP-A06.3**

Optimal Transmission Power in Self-Sustainable Sensor Networks for Pipeline Monitoring, pp. 591-596

Ok, Changsoo — Pennsylvania State Univ.
Thadakamalla, Hari — Pennsylvania State Univ.
Raghavan, Usha — Pennsylvania State Univ.
Kumara, Soundar — The Pennsylvania State Univ.
Kim, Sang-gook — Massachusetts Inst. of Tech.
Zhang, Xiang — Univ. of California at Berkeley
Bukkapatnam, Satish — Oklahoma State Univ.

In this paper, we present a self-sustainable sensor network model for integrity monitoring of pipeline infrastructures. Sensor nodes consist of energy harvesting modules which help them to be always alive and hence monitor the pipeline continuously. These nodes report in a multi-hop fashion to more expensive sink nodes that can broadcast to the base station. The main objective of the paper is to compute the minimal number of sinks required to keep the network connected and satisfy the required constraints. Firstly, we present an algorithm (CON_NET) for determining if a network is connected. We propose a modified bisection algorithm to compute the maximum sampling rate for a given number of sinks nodes. Further, we propose an algorithm for computing the minimal number of sink nodes required. We illustrate the use of algorithms by providing design guidelines for a sensor network on a linear pipeline structure.

13:30-13:50 **MoRP-A06.4**

A Fast RANSAC--Based Registration Algorithm for Accurate Localization in Unknown Environments Using LIDAR Measurements, pp. 597-602

Fontanelli, Daniele — Univ. of Pisa
Ricciato, Luigi — UCLA
Soatto, Stefano — UCLA

The problem of accurate localization using only measurements from a LIDAR sensor is analyzed in this paper. The sensor is rigidly fixed on a generic moving platform, which moves on a plane. Practical on--line applications of localization algorithms impose constraints on the execution time, problem that is addressed in this paper and compared with other existing solutions.

Due to the nature of the sensor adopted, the localization algorithm is based on a fast and accurate {em registration} algorithm, which is able to deal with noisy measurements, outliers and dynamic environments. The proposed solution relies on the RANSAC algorithm in combination with a Huber kernel in order to cope with typical nuisances in LIDAR measurements. The robust registration is successively used in combination with an Extended Kalman Filter to track the trajectory of the LIDAR over time, hence to solve the localization problem.

Simulations and experimental results are reported to show the feasibility of the proposed approach.

13:50-14:10 **MoRP-A06.5**

A New Approach to Accelerometer-Based Head Tracking for Augmented Reality & Other Applications, pp. 603-608

Keir, Matthew — Univ. of Canterbury
Hann, Christopher Eric — Univ. of Canterbury
Chase, Geoff — Univ. of Canterbury
Chen, XiaoQi — Univ. of Canterbury

This work seeks to improve dynamic accuracy of viewpoint tracking for Augmented Reality. Using an inverted pendulum to model the head, dynamic orientation sensing in a vertical plane is achieved using only a dual axis accelerometer. A unique solution is presented as conventional approaches to solve the model equations fail to produce stable results due to ill conditioning. Accuracy is limited by the noise and model error. However, dynamic tracking with better than 1 degree accuracy is achieved analytically and experimentally.

14:10-14:30 **MoRP-A06.6**

A General Telematics Framework for Autonomous Service Robots, pp. 609-614

Sampath Kumar, Veera Ragavan — Monash Univ. Malaysia
Velappa, Ganapathy — Monash Univ. Malaysia

Many environment and task specific methods and systems for building Service Robots exist. However vast strides in the evolution of Smart Device Technologies and Telematics create the need for a Telematic Framework that is generic, scalable, modular and dynamic. This Framework though generic in nature can be applied quite successfully to specific problems like Robot Navigation and Sensor Fusion as discussed here. The fundamental design aspects and implementation issues encountered during the development are discussed. Experiments were conducted and the results of the deployment of three major peripheral modules of the Telematics Framework namely the GSM/GPRS based Communication Module, GIS based Decision Support Module and Smart Client Integration Modules (for GPS sensor) are reported in this paper.

MoRP-B01 — Room D

Automation in Life Sciences 2 (Regular Session)

Chair: Wen, John — Rensselaer Pol. Inst.
Co-Chair: Kaber, David — North Carolina State Univ.

15:00-15:20 **MoRP-B01.1**

IEEE CASE 2007 Invited Author Manuscript

Human-Automation Interaction Strategies for Life Science Applications: Implications and Future Research, pp. 615-620

Kaber, David — North Carolina State Univ.
Stoll, Norbert — Univ. of Rostock
Thurow, Kerstin — Univ. of Rostock

Abstract— The objective of this research was to identify current and future approaches to the design of highly automated systems for life science processes involving humans in control loops in applications such as high-throughput compound screening and high-performance analytical chemistry. (In some advanced applications, screening of biochemical reactions and analytics are performed together.) The identified approaches were classified according to existing theories of human-centered automation, which provided a basis for projecting human performance implications, including error recovery capability. We provide background on the life sciences domain and established theories of types and levels of automation in complex human-machine systems. We describe specific forms of robotic and automated

technologies used in life science applications and the general design of high-throughput screening and analytical systems to accommodate particular process configurations. Some example classifications of life science automation (LSA) schemes are presented by referring to a taxonomy of levels of automation from the literature. Finally, we identify the need for future empirical research on human performance consequences of LSA and remedial measures, including enhanced supervisory control interface design.

15:20-15:40 **MoRP-B01.2**

Characterization of Program Controlled CO2 Laser-Cut PDMS Channels for Lab-On-A-Chip Applications, pp. 621-627

Holle, Andrew W. — Arizona State University
Chao, Shih-hui — Arizona State University
Holl, Mark — Arizona State University
Houkal, Jeffrey M. — Arizona State University
Meldrum, Deirdre — Arizona State University

PDMS (polydimethylsiloxane) is an important material for lab-on-a-chip, an emerging technology to automate biological and chemical operations in microfluidic devices. Laser manufacturing of materials suitable for use in laminate-based construction of lab-on-a-chip devices is an important step in the development of automated assembly line procedures. This study investigates the effect of laser cutting parameters on channel topography when a carbon dioxide laser is used to create trenches in PDMS. We present cross-sectional micrographs of the laser-ablated channels that reveal a modified Gaussian contour, with smooth, circular arcs at the bottom of the channel. We define geometric parameters that describe the contours, including cut depth and maximum cut width. Relationships between laser power, pulses per inch, and laser traverse speed and ablation profile patterns are established. A strong linear relationship (R^2=0.9951) between cut depth and laser power is demonstrated. Analysis of the radii of circular arcs at the bottom of the channel and at the surface of the PDMS was performed. As laser power density is increased (increase in laser power or pulses per inch) the PDMS surface radii and channel floor radius decrease.

15:40-16:00 **MoRP-B01.3**

Real-Time and Long-Time Quantification of Behavior of Laboratory Mice Scratching, pp. 628-633

Ishii, Idaku — Hiroshima Univ.
Nie, Yuman — Hiroshima Univ.
Yamamoto, Kenkichi — Hiroshima Univ.
Orito, Kensuke — Azabu Univ.
Matsuda, Hiroshi — Tokyo Univ. of Agriculture and Tech.

A novel real-time motion analysis system was developed for detecting the scratching behavior of laboratory mice in long-time experiments, which enables automated behavior quantification for new drug development in diseases such as atopic dermatitis and so on. This system can detect quick movements of laboratory mice, such as scratching, by introducing a specially designed high-speed vision system that can calculate the frame-to-frame difference at a frame rate of 240 fps (frames per second). Quantification algorithm was also implemented for distinguishing scratching behavior from other behaviors. In fact, we evaluated the effectiveness of our system by demonstrating the experimental results of scratching behavior detection during long-time observation of several ICR mice.

16:00-16:20 **MoRP-B01.4**

Automatic Mixing of Bio-Samples Using Micro-Channel and Centrifugation, pp. 634-639

Yuan, Liang — Ohio State Univ.
Zheng, Yuan F. — Ohio State Univ.

Automatic mixing of bio-samples using micro-channel and centrifugation is considered. Existing methods for mixing bio-samples for life science applications use micro-well, micro-stirrer, and PCR which are ineffective when used with highly viscous materials at the microliter or nanoliter level.Our method mixes viscous bio-samples in micro-capsules using micro-channels and centrifugation which minimizes contact with mixing tools. First, the design of the micro-capsule along with the micro-channels is presented. Secondly, a hydrodynamic model describing the flow of the material in the micro-channel is presented, and the mean velocity and the traveling time through the micro-channel are analyzed. Thirdly, the relationship between centrifugation speed and time is given to achieve high-throughput and programmability of the new method. Finally, experimental and theoretical results are compared.

16:20-16:40 **MoRP-B01.5**

Development of Whole Human Genome Micro-Array Automated Hybridization Platform, pp. 640-645

Jiang, Jinq-Yu — Tech. Res. Institute, Taiwan
Lin, Kuo-Hsiung — Tech. Res. Institute, Taiwan
Chen, Chia-Chun — Tech. Res. Institute, Taiwan
Huang, Jie-Len — Tech. Res. Institute, Taiwan
Huang, Chun-Hung — Tech. Res. Institute, Taiwan
Su, Hung-Ju — Tech. Res. Institute, Taiwan

A micro-array based automated hybridization platform, ITRI HybOne, has been developed for whole human genome expression profiling test. According to the user-defined protocol, operator can set the heating temperature, washing temperature, heating hours and washing hours before starting the profiling test. Operator inputs target samples and micro-arrays to ITRI HybOne and push Cycle-Start button to start. After hours of automation process, the micro-arrays are ready for profile scanning. The prototype platform has a throughput rate of 12-sets of hybridization per lot.

16:40-17:00 **MoRP-B01.6**

Prototyping and Usability Testing of Supervisory Control Interfaces for Life Science Automation, pp. 646-651

Green, Rebecca — North Carolina State Univ.
Kim, Sang-Hwan — North Carolina State Univ.
Kaber, David — North Carolina State Univ.
Stoll, Norbert — Univ. of Rostock

The objectives of this study were to (1) prototype enhanced human-machine interfaces for supervisory control of high-throughput biological screening (HTS) operations, (2) conduct usability evaluations of the prototypes and make comparisons with existing interface technologies, and (3) demonstrate the plausibility of using computational cognitive models for such evaluations through comparison with the human test results. Task completion times were recorded during human performance and cognitive model trials with the HTS interfaces in two

scenarios. GOMSL (Goals, Operators, Methods, and Selection rules Language) models were constructed based on a combination of cognitive task analyses. Usability tests revealed improvements in task performance with new prototypes. The cognitive models also proved predictive of actual human performance and were considered a valid basis for assessing the usability of two HTS task interfaces.

MoRP-B02 Room E

Supply Chain/Logistics/Transportation 2 (Regular Session)

Chair: Narahari, Yadati — Indian Inst. of Science
Co-Chair: Goldberg, Ken — UC Berkeley

15:00-15:20 **MoRP-B02.1**

On Bundling and Pricing of the Service with the Product, pp. 652-657

Sampath, Kameshwaran — Indian School of Business
Viswanadham, Nukala — Indian School of Business
Desai, Vijay — Columbia Univ.

Integration of service with product is considered as one of the innovative supply chain initiatives of the next decade. In this paper we consider the problem of product-service bundling and pricing. The product and service are two different, but related markets. We consider a complex durable product, which is economically attractive to maintain and service, than to replace. We show that a manufacturing firm that intends to bundle its service with the product, should take into account the other players in the service market as well as the product market. The problem of bundling and pricing are considered for two product market structures: monopoly and duopoly. In the monopoly case, the decision framework is an optimization problem, whereas for the duopoly, the strategic interactions of the two firms are modeled as a two stage non cooperative game. These decision frameworks enable the manufacturing firms to decide upon the product-service bundling and pricing.

15:20-15:40 **MoRP-B02.2**

A Decomposition Method with Cut Generation for Simultaneous Production Scheduling and Routing for Multiple AGVs, pp. 658-663

Nishi, Tatsushi — Osaka Univ.
Hiranaka, Yuichiro — Osaka Univ.
Inuiguchi, Masahiro — Osaka Univ.
Grossmann, Ignacio E. — Carnegie-Mellon Univ.

Conventional methods for simutaneous production scheduling and routing problem have hierarchical decomposition scheme where production scheduling problem and routing problem are separately solved due to computational complexity. We propose a novel decomposition method with cut generation. The entire problem is decomposed into a upper level subproblem for production scheduling and task assignment problem and a lower level subproblem for collision-free routing of multiple AGVs. The novel idea of the proposed method is the upper level subproblem is solved by using Lagrangian relaxation technique incorporating cuts generated from a solution of the lower level subproblem. The algorithm solves successively the upper level problem and the lower level problem until a near-optimal solution for original problem is derived. The effectiveness of the proposed method is investigated from numerical experiments.

15:40-16:00 **MoRP-B02.3**

A Shapley Value Analysis to Coordinate the Formation of Procurement Networks, pp. 664-669

Tallichetty, Chandrashekar — Indian Inst. of Science
Narahari, Yadati — Indian Inst. of Science

Complex economic activity often involves inter-relationships at several levels of production, often referred to as supply chains or procurement networks. In this paper we address the problem of forming procurement networks for items with value adding stages that are linearly arranged. Formation of such procurement networks involves a bottom-up assembly of complex production, assembly, and exchange relationships through supplier selection and contracting decisions. Recent research in supply chain management has emphasized that such decisions need to take into account the fact that suppliers and buyers are intelligent and rational agents who act strategically.In this paper, we view the problem of Procurement Network Formation (PNF) for multiple units of a single item as a cooperative game where agents cooperate to form a surplus maximizing procurement network and then share the surplus in a fair manner. We study the implications of using the Shapley value as a solution concept for forming such procurement networks.We also present a protocol, based on the extensive form game realization of the Shapley value, for forming these networks.

16:00-16:20 **MoRP-B02.4**

Coherent Modeling and Effective Coordination for Building Emergency Evacuation, pp. 670-677

Xiong, Bo — Univ. of Connecticut
Luh, Peter — Univ. of Connecticut

Building evacuation planning has long been recognized as an important issue to reduce egress time and improve occupant survivability in case of emergencies. This paper presents coherent modeling and effective coordination of egress and HVAC systems for offline building evacuation planning, with the goal to evaluate what is the best that can be done assuming that everyone follows egress instructions. Key characteristics of the egress and HVAC systems are abstracted to establish two linear state-space models, and their interdependencies are innovatively formulated as linear inequality constraints. To solve the problem, our key idea is to let each establish a local representation of the global problem by combining its own detail model with an aggregate model of the other system. For model aggregation, an approach is developed based on wavelet transformations that systematically and coherently link states and decisions across different scales and over distinct time periods. With the other's aggregate model, each system solves its own problem by using dynamic programming within the surrogate optimization framework. To make incremental solution improvement, multiplier consistency is then leveraged. Numerical results demonstrate that a reasonable solution is obtained when time is limited, while allowing incremental improvement when more time is available.

16:20-16:40 **MoRP-B02.5**

Automated Tracking of Pallets in Warehouses: Beacon Layout and Asymmetric Ultrasound Observation Models, pp. 678-685

Fogel, Menasheh — Univ. of California, Berkeley
Burkhart, Nathan — Univ. of California, Berkeley
Ren, Hongliang — The Chinese Univ. of Hong Kong
Schiff, Jeremy — UC Berkeley
Meng, Max — The Chinese Univ. of Hong Kong

Goldberg, Ken — UC Berkeley

We consider the use of wireless sensor networks to automatically track "perceptive pallets" of materials in warehouses for the purpose of monitoring volumetric and spatial constraints. A combination of radio frequency and ultrasound chirping produces position estimates that are noisy and prone to error. To address this, we measure and characterize the ultrasound response from standard "Cricket" wireless sensor motes and beacons. We develop a non-parametric particle filtering approach to estimate trajectories of moving motes and introduce two asymmetric observation models that incorporate measured cardioid-shaped response patterns of ultrasound. We use simulation to study the effects of mote placement: position error as a function of ceiling height and beacon density, and then perform physical experiments to evaluate the effectiveness of asymmetric vs. symmetric observation models for pallet tracking. Experiments suggest that asymmetric observation models can improve position estimates by as much as 11%.

16:40-17:00 **MoRP-B02.6**

Automatic Feasibility Verification of Object Configurations: A New Approach Based on Feature Interaction Matrices, pp. 686-691

Yang, Fan — Univ. of Arizona
Marefat, Michael — Univ. of Arizona

A new approach based on qualitative feature interaction matrices (FIMs) to determine the feasibility of contact states between a pair of spatial polyhedra is presented. Determining feasibility of contact state descriptions can potentially be used in automatic generation of assembly strategy. Feature Interaction Matrices are exploited in this paper to model and characterize contact states. A hypothetical contact description in FIM is geometrically feasible if there exists a configuration such that the kinematic constraints imposed by all elements of the FIM are satisfied and the two polyhedra do not penetrate each other. In this paper, an optimization method is used to determine whether kinematic constraints are satisfied. A Spatial reasoning technique is developed to perform penetration checks.

(MoRP-A02) Room F

Planning, Scheduling, and Coordination 3 (Regular Session)

Chair: Shi, Leyuan — Univ. of Wisconsin-Madison
Co-Chair: Lennartson, Bengt — Chalmers Univ. of Tech.

15:00-15:20 **(MoRP-A02.1)**

Compressor Scheduling in Oil Fields: A Piecewise-Linear Formulation, pp. 436-441

Camponogara, Eduardo — Federal Univ. of Santa Catarina
de Castro, Melissa Pereira — Federal Univ. of Santa Catarina
Plucenio, Agustinho — Federal Univ. of Santa Catarina

The scheduling of compressors to gas-lifted oil wells has received little attention despite its theoretical and practical relevance. The problem consists of deciding which compressors (facilities) should be installed and how they should service the wells (clients). A compressor is modeled by a performance curve relating output rate and pressure, while a well demands lift-gas at a given rate and pressure. The compressor scheduling problem can be thought of as a generalized facility location problem and formulated as a mixed-integer nonlinear program. This paper develops a piecewise-linear reformulation, states simplifying conditions, and starts an analysis of the convex hull of integer solutions by proposing valid inequalities. The paper ends by reporting computational results and suggesting directions for future research.

15:20-15:40 **(MoRP-A02.2)**

Timed Petri Net Modeling and Simulation of a High-Throughput Biological Screening Process, pp. 442-447

Vanijjirattikhan, Rangsarit — North Carolina State Univ.
Kaber, David — North Carolina State Univ.
Chow, Mo-Yuen — North Carolina State Univ.
Stoll, Norbert — Univ. of Rostock

Petri nets are a popular tool for process modeling, formal analysis and design of discrete event systems. This paper introduces the use of timed Petri nets to model a high-throughput screening (HTS) process, specifically automation used for testing biological compounds for drug derivative discovery. This paper also illustrates of the use of a general hybrid simulation tool such as Simulink to implement timed Petri nets. A mathematical description of how we implemented the design of the timed Petri net model is provided. A simulator of the Petri net model in Simulink is implemented and verified. The resulting model can be used to estimate the operation time of the target HTS process and for process planning. The demonstrated approach to Petri net modeling and simulation development may be applicable to other domains involving highly automated processes with time delays dictating product quality.

15:40-16:00 **(MoRP-A02.3)**

Resource-Task Assignment Process with Rejections and Reassignments, pp. 448-453

Pi, Liang — Univ. of Wisconsin-Madison
Shi, Leyuan — Univ. of Wisconsin-Madison

We present a simple model for the resource-task assignment process with rejections and reassignments, where the assignment rejection probabilities are considered explicitly. Particularly, we assume that each resource can serve at most one task, and provide several approaches for solving the problem. For many application fields, the assignment rejection probabilities can be obtained from the historical data, the model and solution approaches provided in this paper may help to make better assignment decisions.

16:00-16:20 **(MoRP-A02.4)**

Local Monitor Implementation for Decentralized Intrusion Detection in Secure Multi-Agent Systems, pp. 454-459

Fagiolini, Adriano — Univ. of Pisa
Valenti, Gianni — Univ. of Pisa
Pallottino, Lucia — Univ. di Pisa
Dini, Gianluca — Univ. of Pisa
Bicchi, Antonio — Univ. of Pisa

This paper focuses on the detection of misbehaving agents within a group of mobile robots. A novel approach to automatically synthesize a decentralized Intrusion Detection System (IDS) as well as an efficient implementation of local monitors are presented. In our scenario,

agents perform possibly different independent tasks, but cooperate to guarantee the entire system's safety. Indeed, agents plan their next actions by following a set of logic rules which is shared among them. Such rules are decentralized, i.e. they depend only on configurations of neighboring agents. However, some agents may not be acting according to this cooperation protocol, due to spontaneous failure or tampering. To detect such misbehaviors, we propose a solution where each agent runs a local monitor that uses only locally available information. In this paper, we present an implementation of such monitors by which events occurred to a target–agent can be estimated for any combination of neighborhood and observable space. Validity of the proposed implementation is shown through simulation.

16:20-16:40 **(MoRP-A02.5)**

Petri Net Based Supervisory Control Reconfiguration of Project Management Systems, pp. 460-465

Darabi, Houshang — Univ. of Illinois at Chicago
Haji, Maryam — Univ. of Illinois at Chicago

This paper shows the application of Petri net based supervisory control reconfiguration techniques in project planning and control. Given a project set of tasks and their resource information, we first construct a Petri net supervisory controller that enforces the project task precedence relationships and resource constraints. We then show how the actual progress of the project tasks and resources information could be handled by reconfiguring the developed supervisory controller. The reconfiguration solutions are used to control the project when the project actual progress and planned progress are different. An example illustrates the stated models.

16:40-17:00 **(MoRP-A02.6)**

Dynamic Local Focusing Approach for Production Scheduling Problems, pp. 466-471

Gu, Ping — Waseda Univ.
Lou, Yajie — Waseda Univ.
Zhang, Xuerui — Waseda Univ.
Fujimura, Shigeru — Waseda Univ.

Although decomposition procedure is a common approach to handle computational complexity caused by large scale production scheduling problems, in order to extend the applicability of the decomposition approach, the overall problem should be decomposed on which criterion is always a problem. Also how to improve decomposition approach's computational efficiency and resultant effectiveness is still a challenging task in this field. With the purpose of improving decomposition approach's efficiency and decreasing computational complexity for job shop scheduling problems, a new dynamic local focusing approach which has a machine-based divided criterion focused on the longest active chain is proposed in this paper. Disliking the used decomposition procedure, the proposed one does not decompose a job shop into cells at the very beginning. It dynamically classifies the machines, which process operations on the identified longest active chain of the whole problem as one focused cell (decomposed sub-problem). The schedule is improved by redefining, adjusting and solving the focused cell schedule which is updated iteratively with the entire schedule's longest active chain in this dynamic procedure. The proposed approach is tested on make-span minimum benchmark job shop scheduling problems. Test results show that the algorithm is capable of efficiently generating good schedules.

MoRP-B04 — Room JD's Terrace

Service/Home Automation 2 (Regular Session)

Chair: Dong, Lixin — ETH Zurich
Co-Chair: Yi, Jingang — San Diego State Univ.

15:00-15:20 **MoRP-B04.1**

Human-Robot Interface by Using Frame Like Knowledge Base, pp. 729-734

Aramaki, Shigeto — Fukuoka Univ.
Nagai, Tatsuichirou — Fukuoka Univ.
Kawamura, Masato — Fukuoka Univ.
Hatada, Yasutaka — Fukuoka Univ.
Tsuruoka, Tomoaki — Fukuoka Univ.

We have developed human-robot interface by using frame like knowledge base. The concept of object oriented programming, the case grammar, and the Conceptual Dependency theory (CD theory) is introduced into this knowledge base in order that the total system can be easily and naturally composed. In this system, a robot can interact with humans in the voice and the finger pointing. Furthermore, termination condition of a robot task can be easily realized by using CD theory, and the robustness of robot tasks is improved. We carried out the work experiment by using actual humanoid robot and the effectiveness was confirmed.

15:20-15:40 **MoRP-B04.2**

Robot Drawing Techniques for Contoured Surface Using an Automated Sketching Platform, pp. 735-740

Lam, Josh H.M. — The Chinese Univ. of Hong Kong
Lo, Ka Wah — The Chinese Univ. of Hong Kong
Yam, Yeung — The Chinese Univ. of Hong Kong

This paper presents techniques for robot drawing on a contoured (2.5D) surface and their implementation using a 3-DOF robotic sketching platform. The related algorithms include pen tip trajectory generation from given digital image and point projection on a contoured surface. The trajectory generation is conducted with existing digital image operations which include erosion, filling, boundary extraction, skeleton estimation and line segment sequencing. Further translating the pen tip coordinates based on model geometry, automated robot drawing can be practically achieved. The work includes discussion and analysis of the drawing mechanism of the sketching platform, as well as experiments conducted to show the performance of automated drawing on flat and contoured surfaces. This paper also proposes improvements to enhance the compatibility of the robotic sketching platform to eventually achieve 3D surface drawing.

15:40-16:00 **MoRP-B04.3**

Creating Robust Activity Maps Using Wireless Sensor Network in a Smart Home, pp. 741-746

Lu, Ching-Hu — National Taiwan Univ.
Ho, Yu-Chen — National Taiwan Univ.
Fu, Li-Chen — National Taiwan Univ.

This paper presents a practical application called "activity map" to serve as guidance to show ambient intelligence-related contextual information gathered from both humans and their surrounding environments. The activity map utilizes results inferred from a location-aware

activity recognition approach to statistically show a resident's possibly interleaved activities along with corresponding location-related contexts. With observations from a variety of multi-modal and non-intrusive wireless sensors, the approach utilizes a Bayesian Network fusion engine with inputs from a set of the most informative features extracted from the sensors and applies joint inference to improve the accuracy and consistency of activity and location estimates. Additionally, each feature has to reckon its corresponding reliability factor to control its contribution in case of possible device failure, therefore making the system more tolerant to inevitable disturbance commonly encountered in a cluttered home environment. This mechanism can cope with some inherent sensor limitations and noise interference, thus improving overall robustness and performance. All experiments were conducted in an instrumented living lab and their results demonstrate the effectiveness of the system.

16:00-16:20 **MoRP-B04.4**

HomeTL: A Visual Formalism, Based on Temporal Logic, for the Design of Home Based Care, pp. 747-752

Rugnone, Alberto — Univ. of Florence
Nugent, Chris — Univ. of Ulster
Donnelly, Mark P — Univ. of Ulster
Craig, David — Queen's Univ. of Belfast
Vicario, Enrico — Univ. of Florence
Paggetti, Cristiano — I+ S.r.l.
Tamburini, Tamb — No affiliation

The demands of introducing a more practical means of managing and monitoring technology within the home environment to support independent living are increasing. Efforts have been made recently to address these concerns, however, they may be considered to be lacking in mathematical rigour or have not benefited from incorporating the needs and expectations of the healthcare professionals. In this paper, we present a prototype solution, referred to as HomeTL, which allows healthcare professionals to establish the conditions/rules within which technology in the home should operate. The HomeTL concept is based on previous work in the area of visual notation and linear temporal logic. A visual editor for HomeTL has been developed and is presented in this paper. Following a description of the methodology and the prototype developed, results from a usability study, conducted on three computer scientists specializing in the area of healthcare management, are presented. The initial results based on this survey are positive and show that the topic deserves further investigation.

16:20-16:40 **MoRP-B04.5**

Motion Control of a Robotic Puppet through a Hybrid Motion Capture Device, pp. 753-758

Nguyen, Kim Doang — Nanyang Tech. Univ.
Chen, I-Ming — Nanyang Tech. Univ.
Yeo, Song Huat — Nanyang Tech. Univ.
Duh, Been-Lirn — Nanyang Tech. Univ.

In this paper we explore the motion control of a robotic puppet through motion capture data. A motion mapping technique is investigated to map the human motion into marionette motion, and from that calculate the rotation of the servo motors to achieve desired marionette motions. A software was developed to capture human motions utilizing a bend-twist sensor system, and use the motion data to control the robotic marionette by either offline control method or online control method (real-time). We also propose the idea of integrating human into the system to close the control loop. Experimental results show that our motion mapping enables puppet to follow the actor motions with good correspondence.

16:40-17:00 **MoRP-B04.6**

Multi-User Preference Model and Service Provision in a Smart Home Environment, pp. 759-764

Lin, Zhi-Hau — National Taiwan Univ.
Fu, Li-Chen — National Taiwan Univ.

An important issue to be addressed in a smart home environment is how to provide appropriate services according to the preference of inhabitants. In this paper, we aim at developing a system to learn a multi-user reference model that represents relationships among users as well as dependency between services and sensor observations. Thus, the service can be inferred based on the learnt model. To achieve this, we propose a three-layer model in our work. At the first layer, raw data from sensors are interpreted as context information after noise removal. The second layer is dynamic Bayesian networks which model the observation sequences including inhabitants' location and electrical appliance information. At the highest layer, we integrate second layer's, environment information and the relations between inhabitants to provide the service to inhabitants. Therefore, the system can infer appropriate services to inhabitants at right time and right place, and let them feel comfortable. In experiments, we show our model can provide reliable and appreciate services to inhabitants in a smart home environment.

MoRP-B06 — Las Palmas B

System Modeling and Simulation 2 (Regular Session)

Chair: Sawodny, Oliver — Univ. of Stuttgart
Co-Chair: Holl, Mark — Arizona State University

15:00-15:20 **MoRP-B06.1**

Properties of Frequency Weighted Balanced Truncation Techniques, pp. 765-770

Sahlan, Shafishuhaza — Univ. of Western Australia
Ghafoor, Abdul — The Univ. of Western Australia
Sreeram, Victor — Univ. of Western Australia

In this paper, we derive interesting conditions under which the frequency weighted balanced truncation techniques: Enns' technique, Lin and Chiu's technique, Wang et al's technique as well as Varga and Anderson's technique are equivalent.

15:20-15:40 **MoRP-B06.2**

Decision Making Based on Fuzzy Logic for Products Subcontracting Taking into Account Maintenance Actions, pp. 771-776

Fernandez Gomez, Ricardo Arturo — ENIM
Hennequin, Sophie — ENIM
Rezg, Nidhal — Univ. of Metz

This paper deals with the decision making of subcontracting the production of parts taking into account maintenance actions. Indeed, when deciding to use subcontracting for the manufacturing of products, the industry usually focuses on its production capacity and forgets to take into account the effects of its maintenance actions. Then, the purpose of this paper is to present a method where the closeness to the next maintenance action as well as the production capacity is taken into account to make the subcontracting decision. This method is based on fuzzy logic as it simplifies the decision making when having to analyze the effects of the amount of parts to deliver, its deadline and the closeness of the next preventive maintenance action. Numerical results are given for a simple manufacturing system which consists of a single machine which undergoes a block-type preventive maintenance periodically and is completely repaired at each random failure. These numerical results show the efficiency of our proposed method based on fuzzy logic compared with classical logic.

15:40-16:00 **MoRP-B06.3**

Calibration Using Generalized Error Matrices of a Long Reach Articulated Carrier, pp. 777-782

Chalfoun, Joe — Commissariat ŕ l'Energie Atomique
Bidard, Catherine — Commissariat ŕ l'Energie Atomique
Keller, Delphine — Lab. Robotique et Mesorobotique
Perrot, Yann — Commissariat ŕ l'Energie Atomique

This work concerns the development of advanced robotic systems for nuclear application. The manipulator will be used for light intervention in spent fuel management facilities. The robot must meet severe specifications: small diameter, long reach within a minimum range of 6 m, high dexterity to move in constrained environment and lots of degrees of freedom (DOF) for obstacle avoidance. In order to meet these requirements, The Interactive Robotics Unit of CEA LIST has developed a very challenging robotic carrier (called P.A.C.) This long reach multi-link carrier has 11 DOF and weighs less than 30 kg. The gravity effect in the manipulator is largely compensated by a special mechanical structure (the parallelogram) that helps reducing the size of the rotation actuators used to operate the robot. Also, a glass fiber epoxy equilibrium spring is used to compensate the gravity effect over the elevation actuators. A field test is made to measure the robot's repeatability and accuracy by using a laser tracker to measure the end effector's position. Due to its size and weight, this large robot manipulator holds lots of elastic and geometric deformations. Thus it possesses a very low accuracy. A calibration method of the robot using generalized error matrices is applied to reduce the positioning error of the system. These matrices are a polynomial function of the system geometry and joint variables. The method is first tested by simulation to examine its viability on large manipulators. After encouraging simulation results, the calibration of the PAC is tested on experimental data. Results show that the adopted polynomial model, with the new identified parameters, is capable of correcting and reducing the system errors of long reach manipulators.

16:00-16:20 **MoRP-B06.4**

DC Machine Control with Time Delay and a PID Controller, pp. 783-787

Kirkpatrick, Kevin — Univ. of Missouri-Kansas City
Chaudhry, Ghulam — Univ. of Missouri-Kansas City

The feedback control system of a DC machine utilizes communication with time delay.A PID Controller is also added to the system. The effects of the tuning of PID controller on the DC machine and associated communication system with time-delay are analyzed.

16:20-16:40 **MoRP-B06.5**

Mechanical Design of "Omni-Ball": Spherical Wheel for Holonomic Omnidirectional Motion, pp. 788-794

Tadakuma, Kenjiro — Massachusetts Inst. of Tech.
Tadakuma, Riichiro — Harvard Univ.

In this paper, mechanical design of a novel spherical wheel shape for a omni-directional mobile robot is presented. The wheel is used in a omnidirectional mobile robot realizing high step-climbing capability with its hemispherical wheel. Conventional Omniwheels can realize omnidirectional motion, however they have a poor step overcoming ability due to the sub-wheel small size. The proposed desing solves this drawback by means of a 4 wheeled design. "Omni-Ball" is formed by two passive rotational hemispherical wheels and one active rotational axis. An actual prototype model has been developed to illustrate the concept and to perform preliminary motion experiments, through which the basic performance of the Omnidirectional vechicle with this proposed Omni-Ball mechanism was confirmed. An prototype has been developed to illustrate the concept. Motion experiments, with a test vehicle are also presented.

16:40-17:00 **MoRP-B06.6**

A Type-2 Fuzzy Planner with Semi Qualitative World Model for Robocup Domain, pp. 795-799

Kavaklioglu, Can — Istanbul Bilgi Univ.
Kaynak, Okyay — Bogazici Univ.

The inherent uncertainty present in robotics in general and Robocup in particular demands the use of probabilistic methods. With its fuzzy constructs, Fuzzy Logic has been used as a solution for the current problems of robotics including uncertainty. Extending the use of Fuzzy Logic with Type-2 systems and high level world models should present new solutions to the robotics domain.

MoRP-C05 — Garden Terrace

Information-Based Manufacturing 2 (Regular Session)

Chair: Cecil, J. — New Mexico State Univ.
Co-Chair: Holl, Mark — Arizona State University

15:00-15:20 **MoRP-C05.1**

Expression and Verification of Task Management in Collaborative Design, pp. 800-805

An, Yisheng — Xian Jiaotong Univ.
Li, Renhou — Xian Jiaotong Univ.
Mamat, Anwar — Univ. of Nebraska-Lincoln

Focusing on how to enhance the concurrency and smoothness of collaborative design systems, and to ensure the quality and reliability of task management, the expression and verification of task management and an object fuzzy Petri nets (OFPN) are proposed based on the fuzzy set theory. The task dependency could be verified by analyzing the reachable graph of the OFPN's structure net and the certainty of task being decomposed and executed could be verified by applying the fuzzy inference algorithms. An example shows that the task management expression and its verification method based on OFPN are valid, and can be used to promote the task management in collaborative design systems.

15:20-15:40 **MoRP-C05.2**

An Advanced Collaborative Framework for Micro Assembly, pp. 806-811

Boettner, Scott — New Mexico State Univ.
Cecil, J. — New Mexico State Univ.
Jiao, Yunfang — New Mexico State Univ.

Manual assembly is very difficult and time-consuming task in micro field. In this paper, a Virtual Reality (VR) environment is developed to help the MDA of an advanced work cell. The use of two cameras provides 3D image feedback signals from the work cell. An Enterprise (Engineering) Modeling Language (eEML) is used to present a simulation steps in VR.

15:40-16:00 **MoRP-C05.3**

A Semantic Web Based Framework for Bio Cell Manipulation, pp. 812-817

Yang, Ruiguo — New Mexico State Univ.
Cecil, J. — New Mexico State Univ.
Zhang, Lunwei — Shandong Univ. of Science and Tech.

Bio cell manipulation is becoming an important area of interest. The current manipulation activities are mostly empirically driven approaches. There is a need to develop an integrated cell manipulation framework. Meanwhile, as the development of information technology (IT) and World Wide Web (WWW), it would be useful to create a 'semantic' web which would enable the computers explicitly and software tools implicitly to understand the requests provided by users. The paper presents a semantic web based integrated framework for bio cell manipulation. The design of the overall approach is described using engineering Enterprise Modeling Language (eEML). With the identified life cycle for bio cell manipulation, a 3-world model for bio cell manipulation (3WMBM) is delineated with the necessary hardware units and software modules.

16:00-16:20 **MoRP-C05.4**

A Quantitative Knife-Edge Testing Method for Local Deformation Evaluation in Optical Aspheric Fabrication, pp. 818-822

Cheng, Haobo — Beijing Inst. of Tech.
Yam, Yeung — The Chinese Univ. of Hong Kong
Tong, Hang — The Chinese Univ. of Hong Kong

This paper presents a shadow measuring method applicable to quantitatively assessing the local deformation of aspherical mirrors. The method calls for placing an image capture setup behind the traditional knife-edge testing device to record the resultant shadow maps. Local deformation of the surface of the work-piece under testing are then extracted from illumination level changes of the shadow maps via Fourier transformation. The shape of the work-piece can be constructed from the extracted deformation data. Experimental studies showed that performance achieved with the present method agrees well with that using Zygo interferometer for a polished aspherical surface on low frequency deformation. The proposed approach serves to expand the usefulness of the knife-edge method into quantitative testing, enabling its applications to the manufacturing of aspherical mirrors.

MoRP-D05 — Garden Terrace

Machine Vision in Automation 2 (Regular Session)

Chair: Casanova Alcalde, Victor Hugo — Univ. of Brasilia
Co-Chair: Ding, Shengwei — Univ. of California at Berkeley

16:20-16:40 **MoRP-D05.1**

A High-Speed 3D Shape Measurement System Using a Multi-Sided Mirror, pp. 823-828

Yamamoto, Kenkichi — Hiroshima Univ.
Fujii, Hiroaki — Hiroshima Univ.
Ishii, Idaku — Hiroshima Univ.

In this paper, the authors propose a new concept for high spatial resolution 3D shape measurement based on the light-section method by setting a multi-sided mirror between an image sensor and measured object. The authors developed a prototype system for 3D measurement based on a high-speed vision hardware, which can process a 1024x1024 pixel image at 1000 fps, and evaluated its effectiveness by showing the experimental results for a printed circuit board.

16:40-17:00 **MoRP-D05.2**

Window-Matching Techniques with Kalman Filtering for an Improved Object Visual Tracking, pp. 829-834

Vidal, Flávio B. — Univ. of Brasilia
Casanova Alcalde, Victor Hugo — Univ. of Brasilia

This paper describes the development and application of an algorithm for object visual tracking from a sequence of images. The algorithm is based on window-matching techniques using the sum of squared differences (SSD) as a distance-similarity measure, but adding stochastic filtering. The algorithm is then applied for tracking: a vehicle on an urban environment; two people meeting and walking together; a ball on a ping-pong game. It is concluded that incorporating the Kalman filtering greatly improves the tracking performance.

Tuesday, September 25, 2007

TuRP-A01 — Room D

Automation in Life Sciences 3 (Regular Session)

Chair: Yang, Yongmo — Arizona State Univ.
Co-Chair: Frenger, Paul — A Working Hypothesis, Inc.

10:00-10:20 **TuRP-A01.1**

Information Measures for Biometric Identification Via 2D Discrete Wavelet Transform, pp. 835-840

Ye, Zhengmao — Southern Univ.
Mohamadian, Habib — Southern Univ.
Ye, Yongmao — Liaoning TV Station

Biometric identification is crucial to information assurance and national security. With the rapid development of artificial intelligence technologies, various approaches have been successfully applied to the biometric identification, like the neural network, fuzzy logic, principal component analysis, independent component analysis and wavelet transform (1D and 2D). A typical fingerprint image usually appears as an arbitrary picture with a unique pattern whose reoccurring data are reflected within each individual print. The 2D discrete wavelet transform can be used to digitally compress fingerprints and reconstruct original images via components of the approximation, horizontal detail, vertical detail and diagonal detail from the input image transformation. At the same time, some quantitative measures are needed in order to evaluate the quality of the wavelet transform. In this research, several measures are proposed to evaluate information flow of the 2D discrete wavelet transform. The gray level energy, discrete entropy and relative entropy are used to measure the outcomes of the biometric fingerprint identification via the 2D discrete wavelet transform.

10:20-10:40 **TuRP-A01.2**

Laboratory Information Management Systems – an Approach As an Integration Platform within Flexible Laboratory Automation for Application in Life Sciences, pp. 841-845

Göde, Bernd — Univ. of Rostock
Holzmüller-Laue, Silke — Univ. of Rostock
Rimane, Kristina — Univ. of Rostock
Chow, Mo-Yuen — North Carolina State Univ.
Stoll, Norbert — Univ. of Rostock

Pharmaceutical and biotechnological research claims high throughput of experimental assays running on automated laboratory systems. Complex and flexible laboratory automation requires adaptive laboratory information management systems (LIMS) and a suitable LIMS systems integration. Therefore, the direct, automated, and bi-directional communication between LIMS and laboratory components (sensors, analytical instruments, robot process control systems, cell handling systems, etc.) is key to secure and efficient control of the thereby generated data. The heterogeneous laboratory environment requires a flexible open framework that permits an appropriate syntax and semantic conversion for exchanging the data. After a detailed analysis of different laboratory processes in life science automation, loose system coupling based on a service-oriented approach is suggested for vertical and horizontal systems integration in LIMS. Thus, the involved systems benefit from data consistency and usability. Independence and robustness of the systems is ensured. Extended functionalities (such as integrated process tracking with embedded data visualizations in LIMS) as well as the fulfillment of comprehensive collaborative tasks become possible. This article presents a general concept for this kind of framework by describing an example of a process mapping in the field of drug discovery within LIMS.

10:40-11:00 **TuRP-A01.3**

Design Considerations for a Minimally Invasive High-Throughput Automation System for Radiation Biodosimetry, pp. 846-852

Salerno, Alessio — Columbia Univ.
Zhang, Jian — Columbia Univ.
Bhatla, Anubha — Columbia Univ.
Lyulko, Oleksandra V. — Columbia Univ.
Nie, Jing — Columbia Univ.
Dutta, Aparajita — Columbia Univ.
Garty, Guy — Columbia Univ.
Simaan, Nabil — Columbia Univ.
Randers-Pehrson, Gerhard — Columbia Univ.
Yao, Y. Lawrence — Columbia Univ.
Brenner, David J. — Columbia Univ.

Design aspects of a minimally invasive high-throughput automation system for radiation biodosimetry are reported. The system, currently under development, relies on robotic devices and advanced high-speed automated image acquisition to perform mass triage following a radiological event. A design concept of the automation system is proposed based on the use of an input stage, a centrifuge module, a cell harvesting system, a liquid handling module, an imaging system and a service robot. The biological assays are described along with an analysis of the throughput requirements. The special requirements imposed by bioassay automation, system throughput and minimal invasiveness lead to the design of a custom-made multipurpose gripper and a cell harvesting module. Results on the embodiment design of these modules are provided. A prototype of the automation system is included.

11:00-11:20 **TuRP-A01.4**

A Compact Separation Column for Hazardous Chemicals, pp. 853-856

Yang, Yongmo — Arizona State Univ.
Chae, Junseok — Arizona State Univ.

This paper reports a miniaturized Reverse-Phase High Performance Liquid Chromatography (HPLC) column for chemically hazardous molecules. The mini-column is designed to generate a phase delay for mixed sample molecules by the reverse-phase separation mechanism. The reverse-phase separation is performed by silica-based nano-pore beads (C-18) as stationary phase and a mixture of methanol and DI water as mobile phase.The C-18 beads are packed inside the compact chamber enclosed by a custom built PDMS (Polydimethylsiloxane) housing, equipped with microfluidic channels, inlet/outlet ports, and connectors. The mobile phase and target analytes are controlled by a syringe pump capable of manipulating two different flow rates using LabVIEW interface.The mini-column successfully separates two sample chemical molecules: Acetaminophen and Aspirin. The intensity ratio of two molecules decreases 35% from two different samples collecting at 3 and 8 min.

11:20-11:40 **TuRP-A01.5**

GRANNIE 2: A Ubiquitous, Protean Robotic Guardian Angel, pp. 857-862

Frenger, Paul — A Working Hypothesis, Inc.

GRANNIE 2 is the latest iteration of the author's artificial intelligence-enhanced robot control system. Early versions provided a biologically inspired, object oriented, open systems, multiprocessor network to support android or simian robots. Later extensions assisted with research into human growth and development, simulated hormone action and drug responses, and served as a user-friendly interface for medical devices for patients. The current system is being developed as an intelligent agent to monitor persons via communications networks and assist with their activities of daily living, via any available machine-controllable resources.

11:40-12:00 **TuRP-A01.6**

Usability of a Mobile Self-Help Tool for People with Diabetes: The Easy Health Diary, pp. 863-868

Arsand, Eirik — Univ. Hospital of North Norway
Hartvigsen, Gunnar — Univ. of Tromso
Varmedal, Ragnhild — Univ. Hospital of North Norway

Changes in diet and lifestyle are leading to a dramatic worldwide increase in chronic diseases, including Type 2 diabetes. The demand for health-related support is thus growing, and many self-help tools are available. However, few of these are easy to use and to integrate with users' daily routines and necessary medical or fitness equipment in a way that motivates long-term use. Our research group is working with the Easy Health Diary, a self-help tool for people with Type 2 diabetes. The tool is based on Smartphones, and its functionality applies to each of the three cornerstones of diabetes management: physical activity, nutrition and healthy blood glucose values. The target user group is typically aged 50 or more, so it is especially important that a self-help tool should have low technical thresholds and a highly usable design. Such tools may also support applications to help the general population meet today's vast health challenges. A prototype has been designed and tested on 32 people: 12 users with Type 2 diabetes and 20 individuals without diabetes. All informants had a generally positive reaction to the prototype and the user group was more positive than the reference group. The informants emphasized the importance of making the tool extremely easy to use and integrated with the everyday routines of the users.

TuRP-A02 — Room E

Planning, Scheduling, and Coordination 4 (Regular Session)

Chair: Chow, Mo-Yuen — North Carolina State Univ.
Co-Chair: Wen, John — Rensselaer Pol. Inst.

10:00-10:20 **TuRP-A02.1**

Diagnosability Analysis and Sensor Selection in Discrete Event Systems with Permanent Failures, pp. 869-874

Pan, JiangJing — Concordia Univ.
Hashtrudi Zad, Shahin — Concordia Univ.

In this paper, the problems of failure diagnosability and sensor selection for failure detection and isolation in discrete-event systems are studied. The system could operate in normal condition, or in a set of faulty conditions each corresponding to a combination of failure modes of the system. A polynomial algorithm is proposed that verifies diagnosability by examining the distinguishability of two conditions at a time. Furthermore, a polynomial procedure is presented that first finds minimal sensor sets for distinguishing one condition from another (minimal distinguishers), and then combines these sensor sets to obtain a minimal sensor set for failure detection and isolation. It is shown that taking advantage of the structure of the system, as done in the algorithms proposed in this paper, reduces the time and space complexity of testing diagnosability and sensor selection. A benefit of using minimal distinguishers is that their computation (thus, the computations for sensor selection) may be speeded up using heuristics and expert knowledge.

10:20-10:40 **TuRP-A02.2**

A Successive Lagrangian Relaxation Method for Solving Flowshop Scheduling Problems with Total Weighted Tardiness, pp. 875-880

Nishi, Tatsushi — Osaka Univ.
Hiranaka, Yuichiro — Osaka Univ.
Inuiguchi, Masahiro — Osaka Univ.

Lagrangian relaxation technique has been used for solving a wide variety of scheduling problems to obtain near optimal solutions. The approach has been successfully applied to jobshop scheduling problems by relaxing the capacity constraints on machines by using Lagrange multipliers. The relaxed problem can be decomposed into independent job-level subproblems which can be solved by dynamic programming. By extending the technique, in this paper, we propose a successive Lagrangian relaxation method for solving flowshop scheduling problems with total weighted tardiness. In the proposed method, the quality of lower bound is improved by successively solving the Lagrangian dual problem embedding cuts into the Lagrangian relaxation problem. The state space reduction for dynamic programming is also incorporated. The effectiveness of the proposed method is demonstrated from numerical experiments.

10:40-11:00 **TuRP-A02.3**

Multi-Robot Localization and Mapping Strategy: Utilizing Behavior Based Dynamic Tree Structure and Observer-Explorer Routine, pp. 881-886

Leung, Kevin Ka Kei — Univ. of California, Davis
Gallagher, Garratt — Univ. of California, Davis

In this paper, we propose a simultaneous localization and map-building (SLAM) strategy to explore unknown environment. Multiple robots are deployed in unknown area and required to localize each other accurately while exploring. Instead of relying on active obstacle detector, we propose a method of exploration which uses only tactile sensors and inter-robot distance measurements. To avoid dead-reckoning and odometry errors, an observer-explorer based routine is adopted. A dynamic spanning tree structure is implemented for multi-robot coordination. Parent(observer) nodes monitor the distances of their children(explorer) nodes. In order to promote completeness of the map, the reconfigurable spanning tree structure favors unexplored area implicitly. An online behavior-based finite state machine drives the configuration of the structure. Our exploration scheme allows the differentiation between robots and obstacles or boundaries. When an obstacle or boundary is detected, it is recorded on a map that is shared with all other robots. The proposed strategy is simulated and results are presented.

11:00-11:20 **TuRP-A02.4**

Resource Allocation for a Life Science Automation Line: A Petri Nets Approach, pp. 887-892

Hong, Tao — North Carolina State Univ.
Chow, Mo-Yuen — North Carolina State Univ.

Abstract—High-Throughput Screening (HTS) processes have been increasingly used in the life sciences area for diverse bio-chemical experiments. This paper investigates the resource allocation issue of scheduling HTS processes under multiple constraints including operation constraints, resource constraints, starvation constraints and multi-experiment constraints. We first use timed transition Petri nets (PN) to model the HTS processes. We then illustrate the transition variant property of the PN model, and propose an efficient best-first (E-BF) algorithm combined with PN execution to find the schedule. Finally we apply the E-BF algorithm to three typical HTS experimental processes under different resource constraints and compare the E-BF algorithm with a traditional best-first (BF) algorithm as case studies.

The results show that the E-BF algorithm can be used to allocate resources for HTS processes properly and can easily be more efficient than the BF algorithm when applied to transition variant PN.

11:20-11:40 **TuRP-A02.5**

On Line Identification of Discrete Event Systems Via Petri Nets: An Application to Monitor Specification, pp. 893-898

Dotoli, Mariagrazia — Pol. di Bari
Fanti, Maria Pia — Pol. di Bari
Mangini, Agostino Marcello — Pol. di Bari

The paper proves some properties of a previously proposed identification algorithm that builds on line the Petri net model of Discrete Event Systems (DES). The procedure uses the real time observation of the DES events and the corresponding available output vectors that partially provide the place markings. The paper shows how the considered identification method allows us to define a supervisory controller via monitor places enforcing generalized mutual exclusion constraints. To show the efficiency of the proposed approach, a communication gateway case study is presented.

11:40-12:00 **TuRP-A02.6**

Coverage of a Planar Point Set with Multiple Constrained Robots, pp. 899-904

Chakraborty, Nilanjan — Rensselaer Pol. Inst.
Akella, Srinivas — Rensselaer Pol. Inst.
Wen, John — Rensselaer Pol. Inst.

An important problem that arises in many applications is: Given k robots with known {em processing footprint} to {em process} a set of N points in the plane, find trajectories for each robot satisfying the geometric, kinematic, and dynamic constraints such that the time required to cover the points (processing time plus travel time) is minimized. This problem is a hybrid discrete-continuous optimization problem and is hard to solve optimally even for k = 1. One approach is to treat this as a two stage problem where the first stage is to find the best possible path satisfying the geometric constraints and then convert it into a trajectory satisfying the differential constraints. In this paper, we consider an industrial microelectronics manufacturing system of k (= 2) robots, with square footprints, that are constrained to translate along a line while satisfying proximity constraints. The points lie on a planar base plate that can translate along the plane normal to the direction of motion of the robots. We solve the geometric problem of path generation for the robots using a two step approach that yields a suboptimal solution: 1) Minimize the number of k-tuples subject to geometric constraints. 2) Solve a Traveling Salesman Problem (TSP) in the k-tuple space with an appropriately defined metric to minimize the total travel cost.We show that for k = 2, step 1 can be converted to a maximum cardinality matching problem on a graph and solved optimally in polynomial time. The matching algorithm takes O(N^3) time in general and is too slow for large datasets. Therefore, we also provide a greedy algorithm for step 1 that takes O(Nlog N) time. We provide computational results comparing the two approaches and show that the greedy algorithm is very close to the optimal solution for large datasets. We also provide local search based heuristics to improve the TSP tour in the pair space and give preliminary implementation results showing an improvement of 1 % to 2 % in the resultant tour.

TuRP-A03 — Room F

Sensors, Instrumentation, and Measurement 2 (Regular Session)

Chair: Mattikalli, Raju — The Boeing Company
Co-Chair: Yi, Jingang — San Diego State Univ.

10:00-10:20 **TuRP-A03.1**

Distributed Energy-Adaptive Routing for Wireless Sensor Networks, pp. 905-910

Ok, Changsoo — Pennsylvania State Univ.
Mitra, Pransenjit — Pennsylvania State Univ.
Lee, Seokcheon — Purdue Univ.
Kumara, Soundar — Pennsylvania State Univ.

Most routing algorithms for sensor networks focus on finding energy efficient paths to prolong the lifetime of sensor networks. As a result, the power of sensors on efficient paths depletes quickly, and consequently sensor networks become incapable of monitoring events from some parts of their target areas. In many sensor network applications, the events that must be tracked occur at random locations and have non-deterministic generation patterns. Therefore, ideally, routing algorithms should consider not only energy efficiency, but also the amount of energy remaining in each sensor, thus avoiding non-functioning sensors due to early power depletion. This paper introduces a new metric, Energy Cost, devised to consider a balance of sensors' remaining energies, as well as energy efficiency. This metric gives rise to the design of the Distributed Energy Adaptive Routing (DEAR) algorithm devised to balance the data traffic of sensor networks in a decentralized manner and consequently prolong the lifetime of the networks. DEAR is scalable in the number of sensors and also robust to the variations in the dynamics of event generation. We demonstrate the effectiveness of the proposed algorithm by comparing three existing routing algorithms: Direct Communication Approach, Minimum Transmission Energy, and Self-Organized Routing and find that energy balance should be considered to extend lifetime of sensor network and increase robustness of sensor network for diverse event generation patterns.

10:20-10:40 **TuRP-A03.2**

Optimal Sensor Selection and Placement for Perimeter Defense, pp. 911-918

Mattikalli, Raju — The Boeing Company
Fresnedo, Roman — The Boeing Company
Frank, Paul — The Boeing Company
Locke, Summer — The Boeing Company
Thunemann, Paul — The Boeing Company

This paper describes analytical methods for selecting and positioning sensors on terrain to detect, classify and locate events of interest. Our choice of sensors and their time-invariant locations is based on obtaining measured data that is most informative about the event. We adopt a novel system-based approach—minimize not simply the uncertainty of the sensor system's output, but rather minimize the risk of poor performance that arises from decisions made based on it. Our decision function combines the information provided by the sensors and is constructed by minimizing the system's posterior loss; it is therefore an optimal decision function. The sensor positioning problem presents several challenges for optimization methods arising from the intricate nature of sensor occlusion from terrain and the introduction of discrete variables such as the minimum number of sensors. This renders the optimal sensor positioning problem highly nonlinear, nonsmooth, and

multi-modal. We will discuss several techniques, including metaheuristic methods in combination with "grid refinement" techniques, response-model-based methods, and novel modifications to problem objectives to handle the above optimization challenges.

10:40-11:00 **TuRP-A03.3**

Robust Calibration for Localization in Clustered Wireless Sensor Networks, pp. 919-924

Cho, Jung Jin — Texas A&M Univ.
Ding, Yu — Texas A&M Univ.
Chen, Yong — Univ. of Iowa
Tang, Jiong — Univ. of Connecticut

This paper presents a robust calibration procedure for a clustered wireless sensor network. The calibration problem is often formulated as a parameter estimation problem using a linear calibration model. For reducing or eliminating unwanted influences of measurement corruptions or outliers on parameter estimation, a robust regression estimator is a natural choice. In order to solve a robust estimation problem more efficiently, we utilize cluster structure in a network configuration and decompose a large network into smaller subsystems that can be solved much faster. To this end, we present two algorithms for a robust calibration procedure. Two examples are presented to illustrate how the proposed methods enable robust calibration in a sensor network.

11:00-11:20 **TuRP-A03.4**

Inertia Identification of Mechatronic Servo Systems with Infinitesimal Motions, pp. 925-932

Andoh, Fukashi — YASKAWA Electric Corp.

An algorithm to identify the inertia of mechatronic servo systems with infinitesimal motions is proposed. The proposed algorithm utilizes a position control with sinusoidal position reference input, and identifies total inertia of the motor and a mechanical load attached to the motor based on the amplitude of motor position at steady state.The proposed algorithm is suitable for the off-line inertia identification used in the preparatory period of mechatronic servo systems with limited strokes. Inertia is identified for two mechatronic servo systems in simulations and experiments, and the effectiveness of the proposed algorithm on mechatronic servo systems with limited strokes is demonstrated.

11:20-11:40 **TuRP-A03.5**

Metal Transfer Characterization with an Active Contour Algorithm in MIG/MAG Welding Movies, pp. 933-938

Planckaert, Jean-Pierre — CRAN

In this paper, we present a discrete contour model used to follow the dynamical behaviour of a molten metal bridge in short arc welding. Good results are achieved on experimental movies as bridge edges are well detected. This approach enables the estimation of the relevant variables in the establishment of a model of MIG/MAG welding in short arc mode.

11:40-12:00 **TuRP-A03.6**

A Rationale for the Use of Optical Mice Chips for Economic and Accurate Vehicle Tracking, pp. 939-944

Jackson, Joshua — Univ. of Alabama at Birmingham
Callahan, Dale — Univ. of Alabama at Birmingham
Marstrander, Jon — Univ. of Alabama at Birmingham

Accurate vehicle localization is a frequent requirement of tracking applications. Unfortunately cost is often the limiting factor in the selection of tolerable error limits. This paper provides a rationale for using optical navigation chips out of optical computer mice for economic and accurate vehicle tracking. Supporting evidence is provided in the form of a comparative analysis of several tracking technologies. The technologies analyzed include varieties of GPS, accelerometers, laser rangefinders, and optical mouse sensors. The comparative analysis presented in this paper uses a model based on cost, accuracy, speed, and range.

TuRP-A05 — Garden Terrace

System Modeling and Simulation 3 (Regular Session)

Chair: Beghi, Alessandro — Univ. di Padova
Co-Chair: Ding, Han — Shanghai Jiao Tong Univ.

10:00-10:20 **TuRP-A05.1**

Von Mises Stress and Level Set Method Based Structural Topology Optimization with Multi-Phase Materials, pp. 945-949

zhuang, ChunGang — Shanghai Jiao Tong Univ.
Xiong, Zhenhua — Shanghai Jiao Tong Univ.
Zhu, Xiangyang — Shanghai Jiao Tong Univ.
Ding, Han — Shanghai Jiao Tong Univ.

Abstract—This paper presents a topology optimization method based on Von Mises stress and the level set method for the multiple materials design. Since the level set method can naturally handle topological changes during the interface propagation, the level set model based material implicit representation has been applied to structural topology optimization. However, the level set method can not generate new holes during the optimization process and the final result depends on the initial topological guess. In this paper, the new holes are generated according to the distribution of Von Mises stress of material region to suppress the dependence of the initialization. We establish the replacement strategy of multiple materials to make the objective function minimum. And then, the shape optimization is implemented by the propagating of the level set method with the descent gradient direction. Numerical examples demonstrate the validity of the proposed method.

10:20-10:40 **TuRP-A05.2**

Two-Degree-Of-Freedom Based Cross-Coupled Control for High-Accuracy Tracking Systems, pp. 950-955

Yang, Jiangzhao — Shenzhen Graduate School, Harbin Inst. of Tech.
Li, Zexiang — HKUST
Xu, Jijie — HKUST

Recent work recognizes that cross-coupled control (CCC) can significantly improve the accuracy of contour tracking in biaxial systems. However, it's complicated to apply CCC to arbitrary contour because of additional requirements to calculation and switching the cross-coupled gains. In addition, since most of CCC are based on the PID controlled loops of the individual axes, performances are conserved in some sense. In this paper, we propose a structure for arbitrary contours by efficiently determining the cross-coupling gains for CCC with the two-degree-of-freedom~(2DOF) controlled to the single axes. Furthermore, an approach for stability analysis of the CCC is posed.

Experimental results for a two-axial motion system indicate that the proposed structure eliminates the contouring error significantly.

10:40-11:00 **TuRP-A05.3**

An Importance Sampling Based Approach for Reliability Analysis, pp. 956-961

Wu, Teresa — Arizona State University
Li, Fan — Arizona State University

In this paper, an importance sampling based approach for reliability analysis is proposed. The fundamental of this approach is to bias the realization of random variables around the most probable point (MPP) such that the number of simulations can be reduced significantly. Compared to the basic Monte Carlo simulation (MCS), the proposed approach requires less computational effort since it only evaluates the system performance functions at the reduced probability space. Two comparison experiments are conducted at the end of the paper. One is used to demonstrate the proposed method improves the efficiency comparing with basic MCS without losing accuracy. The second one is used to illustrate the proposed method generates more accurate results than that of FORM (first order reliability method).

11:00-11:20 **TuRP-A05.4**

A Simulation Environment for the Design of Advanced Chiller Control Systems, pp. 962-967

Michele, Albieri — Rhoss S.P.A.
Beghi, Alessandro — Univ. di Padova
Cristian, Bodo — Univ. di Padova
Cecchinato, Luca — Univ. di Padova

In this paper we address the problem of designing advanced control systems for increasing the performances of one of the key elements of an HVAC system, the chiller unit. In particular, we present a simulation environment based on Matlab/Simulink that has been validated on a state-of-the-art experimental facility and used to design an adaptive controller for single scroll compressor, packaged air-cooled water chillers, that allows to substantially increase the energy performance of the system, as well as to achieve excellent regulation performances in process applications.

11:20-11:40 **TuRP-A05.5**

Fuzzy Arithmetic-Based Stability Analysis and Design of Fuzzy Controller, pp. 968-973

Bogdan, Stjepan — Univ. of Zagreb
Kovacic, Zdenko — Univ. of Zagreb
Fazinic, Ivana — Univ. of Zagreb
Draganjac, Ivica — Univ. of Zagreb

Initially introduced as a model-free control design method, in today practice fuzzy control is dominantly used as yet another nonlinear control technique based either on a linear or nonlinear model of a process. This paper addresses the stability assessment of a fuzzy logic control system based only on the partial knowledge of a controlled process. Lyapunov stability conditions are derived and analyzed by using fuzzy numbers and fuzzy arithmetic. The experimental results obtained for a non-stable second-order system confirmed that this approach could be successfully implemented. Some questions, addressed in the paper, remained open for further investigation.

11:40-12:00 **TuRP-A05.6**

Automated Modeling of Rotorcraft Dynamics with Special Reference to Autosim, pp. 974-979

Tomas-Rodriguez, Maria — Imperial Coll.
Sharp, Robin — Imperial Coll.

Some of the more challenging aspects of modeling the mechanical dynamics of rotorcraft systems are addressed in this paper. The generic model here presented contains an articulated rigid-bladed rotor and fuselage. Special attention is given to the building of the main rotor model containing flap, lag and feather blade degrees of freedom for each of the equispaced blades. A full descriptive AutoSim model is built, some simulations results are generated and they are processed for comparison with theoretical findings from the literature. Such comparisons show that the results are accurate.It is concluded that contemporary multibody analysis tools are applicable with advantage to the modeling of complex mechanical-dynamic systems like helicopters.

TuRP-C04 — Room JD's Terrace

Construction Automation (Regular Session)

Chair: Viswanadham, Nukala — Indian School of Business
Co-Chair: Avi, Wiezel — Arizona State Univ.

10:00-10:20 **TuRP-C04.1**

A CBR-Based Decision Support System for Construction Supply Chain Risk Management, pp. 980-985

Mishra, Vinit Kumar — Indian School of Business
Viswanadham, Nukala — Indian School of Business

Risk Management is an essential process of construction project planning. When a risk event occurs during project execution, the required actions are taken by project managers using their own experience and knowledge. While knowledge and experience gained in past projects is very useful in identifying and managing risks in a new project, such information resides primarily in Project Managers' minds and is seldom documented in a reusable form of information. A decision support system with a case-base of previously taken actions and a record of previous risk management plans can assist managers in risk management of construction supply chains in a new project. This paper suggests the framework of a Decision Support System adopting Case-Based Reasoning approach; which can support decision makers in preventive as well as interceptive construction supply chain risk management.

10:20-10:40 **TuRP-C04.2**

Proposed Methodology for Dynamic Schedule Compression, pp. 986-991

Lee, Jaesung — Univ. of Florida
Ellis, Ralph — Univ. of Florida
Pyeon, Jae-Ho — San Jose State Univ.

Despite aggressive efforts of project managers to maintain a project schedule or to recover from a lapsed schedule, delays and cost overruns have become routine phenomenon at many construction projects. This research proposes a proactive schedule compression method to reduce the expected project completion time by removing latent lazy time caused by constraints that impose non-value-added

effects on project. An additional objective of this research is to develop a systematic environmental model, the Dynamic Schedule Compression Model (DSCM), to improve performance against latency and complexities of design and construction projects in schedule compression. Developing and implementing the DSCM model will result in the following research outcomes: optimizing schedule compression concepts and methods to minimize waste and maximize project performance; detecting and eliminating latent lazy time that project has potentially; managing latency caused by schedule compression; understanding of schedule compression frameworks; and developing system dynamics-based schedule compression model.

10:40-11:00 **TuRP-C04.3**

Application of IFC Product Data Model in Computer-Integrated Building Prefabrication, pp. 992-996

Li, Shutao — Forschungszentrum Karlsruhe
Isele, Jörg — Forschungszentrum Karlsruhe
Bretthauer, Georg — Forschungszentrum Karlsruhe

Computer-integrated prefabrication (CIP) of wall elements for individually planned houses improves the quality, while reducing the time consumption and costs of architecture, engineering, and construction. It will, however, only be successful, if the information exchange between planning (architect) and manufacturing (machine) can be automated in an effective and efficient manner. A continuous information flow requires a neutral data model. The most notable and widely accepted product data model for buildings is the IFC model which enables applications to efficiently share and exchange project information. This paper presents an approach pursued by the Forschungszentrum Karlsruhe in Germany, to applying the IFC product data model in computer-integrated prefabrication. Not only the geometrical information of walls is of special interest, but also additional parameters such as materials, wall construction and relation to other walls and openings as well as installations from the area of HVAC (Heating, Ventilation, and Air Conditioning) could be extracted and manipulated. Entire information flow from the planning stage to the computer-integrated manufacturing process will be described. The mechanisms, including all steps necessary to prepare the building model for prefabrication with floor-to-ceiling AAC (Autoclaved Aerated Concrete) wall elements, will be outlined. Finally, the performance and validation of the mechanisms developed will be reported.

TuRP-D04 — Room JD's Terrace

Manufacturing Systems 4 (Regular Session)

Chair: Li, Jingshan — Univ. of Kentucky
Co-Chair: Na, Xiaodong — Univ. of Kentucky

11:00-11:20 **TuRP-D04.1**

An Application of Real-Time Operating System in High Speed and High Precision Motion Control Systems, pp. 997-1001

Pu, Donglin — Shanghai Jiao Tong Univ.
Sheng, Xinjun — Shanghai Jiao Tong Univ.
Zhang, Weijun — Shanghai Jiao Tong Univ.
Ding, Han — Shanghai Jiao Tong Univ.

This paper addresses the development and applications of the control system based on the real-time operating system (RTOS) RTX which constructs an open architecture control system with real-time performance, flexibility and low cost. In this paper, the RTX-based control system is considered from RTOS evaluation, system-level design, to experiments and applications. A novel software structure consisting of Windows, Labview or Matlab, and RTX is presented, which makes the trade-off between real-time tasks running and data processing or displaying. Finally, the control system is successfully applied in two direct-drive high speed and high precision motion platforms.

11:20-11:40 **TuRP-D04.2**

Discrete-Model Identification for Nonlinear Laser Welding Process, pp. 1002-1007

Na, Xiaodong — Univ. of Kentucky
Zhang, Yuming — Univ. of Kentucky
Walcott, Bruce — Univ. of Kentucky

This paper introduces the identification results of a discrete-time model of a laser welding process whose input is the reciprocal of the welding speed and output is the width of the weld pool. To model this nonlinear process, a Hammerstein model is used. A series of step response experiments have been conducted to obtain the experimental data. A method has been proposed to identify the discrete Hammerstein model in two steps. MATLAB programs are utilized with Least Square method for parameters identification. Experimental results confirmed that the proposed identification method for the nonlinear dynamic discrete-time as described by a Hammerstein model is effective to approximate the laser welding process.

TuRP-B01 — Room D

RFID Application (Regular Session)

Chair: Floerkemeier, Christian — ETH Zurich
Co-Chair: Panos, Ryan — California Pol. State Univ.

13:00-13:20 **TuRP-B01.1**

Open-Source Demo System to Support Automated Identification and Tracking Workshops, pp. 1008-1013

Laakso, Mikko — Helsinki Univ. of Tech.
Kajosaari, Risto — Helsinki Univ. of Tech.
Holmström, Jan — Helsinki Univ. of Tech.
Främling, Kary — Helsinki Univ. of Tech.

Currently only larger companies get most benefit from advanced tracking. A research project aims to provide a lighter option suitable also for smaller companies. Primary goal is free, open-source software package offering affordable item-centric tracking and tracing solutions. One way to find new potential solutions and applications is through a series of workshops, where the idea is to give the audience a hands-on experience of the tracking system usage and the current solutions available. For this purpose, we have created a framework for the development of tracking-based business and implemented an open-source tracking software demo. The paper gives an overview of our proposed framework, guidelines how to conduct a successful workshop and instructions how to use our workshop demo system.

13:20-13:40 **TuRP-B01.2**

RFID-Enabled Target Tracking and Following with a Mobile Robot Using Direction Finding Antennas, pp. 1014-1019

Kim, Myungsik — JAIST

Chong, Nak Young — JAIST
Ahn, Hyo-Sung — Electronics and Telecommunications Res. Inst. (ETRI)
Yu, Wonpil — Electronics and Telecommunications Res. Inst. (ETRI)

A stand-alone direction finding RFID reader is developed for mobile robot applications employing a dual directional antenna. By adding search and localization capabilities to the current state of RFID technology, the robot is able to acquire and dock to a static target in a real environment without requiring a map or landmarks. Furthermore, we demonstrate RFID-enabled tracking and following of a target moving unpredictably with a mobile robot. The RFID reader keeps the robot aware of the direction of arrival (DOA) of the signal of interest toward which the dual directional antenna faces the target transponder. The simulation results show that the proposed RFID system can track in real time the movement of the target transponder. To verify the effectiveness of the system in a real environment, we perform a variety of experiments in a hallway including target tracking and following with a mobile robot.

13:40-14:00 **TuRP-B01.3**

Inventory Management with an RFID-Equipped Mobile Robot, pp. 1020-1026

Ehrenberg, Isaac — Massachusetts Inst. of Tech.
Floerkemeier, Christian — ETH Zurich
Sarma, Sanjay — Massachusetts Inst. of Tech.

The use of RFID technology has increased in libraries where it is the centerpiece of emerging automated self-checkout, return, and theft detection systems. In this paper, we present LibBot, a robot equipped with an RFID reader, that automates the otherwise manual shelf-reading process and finds misplaced books autonomously. Our experiments with a single library shelf show that our robot-assisted approach to inventory management can not only detect misplaced books reliably, but also correctly determine the order of the books on the shelves and even localize each book with an accuracy of a few centimeters. Our work also shows to what extent RFID challenges such as metal shelves and thin books with RFID tags in close proximity affect the location accuracy.

14:00-14:20 **TuRP-B01.4**

Improving the Remote Control of a Mobile Robot Using Positioning and Ubiquitous Techniques, pp. 1027-1033

Luimula, Mika — Central Ostrobothnia Univ. of Applied Sciences
Sääskilahti, Kirsti — Univ. of Oulu
Partala, Timo — Univ. of Oulu
Pieskä, Sakari — Central Ostrobothnia Univ. of Applied Sciences
Alaspää, Juha — Central Ostrobothnia Univ. of Applied Sciences
Lof, Andries — Central Ostrobothnia Univ. of Applied Sciences

In the current paper, we describe a remotely controlled robotic system and an experimental comparison of three techniques for displaying information about the position and movements of a remote robot to the user. The developed system was based on a mobile robot (Evolution Robotics' ER-1) with remote controlling features over internet and Locawe, which is a platform for developing location-aware systems. The experimental techniques displayed the position of the robot on an indoor floor plan augmented with 1) a video view from a camera attached to a robot 2) displaying nearby obstacles (identified using RFID technology) on the floor plan, and 3) both features. 10 subjects controlled the mobile robot through predetermined routes in an indoor environment as quickly as possible avoiding collisions. The results showed that all three developed techniques were successful. The technique without a camera view was the fastest, and number of steering motions made was smallest using this technique, but it also had the highest need for physical human interventions. The technique with both additional features was subjectively preferred by the users.

14:20-14:40 **TuRP-B01.5**

The Benefits of Automatic Data Collection in the Fresh Produce Supply Chain, pp. 1034-1038

Panos, Ryan — California Pol. State Univ.
Freed, Tali — California Pol. State Univ.

The potential for RFID based systems to improve the safety and efficiency of a supply chain with rapidly decaying products and strict health standards is creating pressure to adopt RFID in several agricultural industries. A handful of fresh produce industry leaders currently participate in mandated pilot projects, while the industry as a whole is still intimidated by the perceived cost of RFID. Therefore in this study we attempt to validate the correlation between performance and automated data collection, paving the way to economic justification of investment in data collection technologies, such as barcode and RFID.

The majority of product in this industry is identified and tracked using pallet barcode labels at the more progressive facilities, or facility-specific manual identification methods at the less advanced facilities. Most fresh produce facilities in the US have minimal information systems capabilities, and most of their logistics operations are documented on paper only.

Thus the form of Automated Data Collection (ADC) used in the more advanced facilities is Barcode-based. This study compares facilities that use ADC with those that do not. Significant advantages of using ADC are found in many areas, especially in product spoilage, administrative labor and space utilization.

TuRP-B02 — Room E

Supply Chain/Logistics/Transportation 3 (Regular Session)

Chair: Shi, Leyuan — Univ. of Wisconsin-Madison
Co-Chair: Narahari, Yadati — Indian Inst. of Science

13:00-13:20 **TuRP-B02.1**

Optimal Supply Location Selection and Routing for Emergency Material Delivery, pp. 1039-1044

Han, Yunjun — Tsinghua Univ.
Guan, Xiaohong — Tsinghua Univ.
Shi, Leyuan — Univ. of Wisconsin-Madison

Supplying emergent materials for a disaster area in time plays a vital role in emergency response. Supply location selection and routing problem including warehouse selection and fleets scheduling and routing to guarantee to meet the demand in the required time window considered in this paper is a new and difficult problem and is proved to be NP-Hard. The salient feature of this problem lies in the incorporation of the location selection into the problem. Moreover, every supply source can send a commodity to any customer such that

the supply system makes full use of the commodities among different warehouses. The jam caused by heavy traffic is also considered in our problem. Clearly this problem is closer to the requirements in a practical emergency response system and is solved with ILOG CPLEX for a small and medium scale problem. The numerical testing results show that our problem formulation is valid and is difficult to solve. It is also shown that the total transportation cost increases as the demand deadlines become tighter and the number of commodities is larger. The computational times generally become intolerable for problems with more than 60 nodes.

13:20-13:40 **TuRP-B02.2**

Towards an Automated Multiagent Taxi-Dispatch System, pp. 1045-1050

Seow, Kiam Tian — Nanyang Tech. Univ.
Dang, Nam Hai — Nanyang Tech. Univ.
Lee, Der-Horng — National Univ. of Singapore

This paper presents the study of a novel approach towards an automated taxi dispatch system that handles current bookings in a distributed fashion. Existing systems in use by taxi operators in Singapore attempt to increase customer satisfaction locally, by sequentially dispatching nearby taxis to service customers. The proposed dispatch system attempts to increase customer satisfaction more globally, by concurrently dispatching multiple taxis to the same number of customers in the same geographical region, and vis-`a-vis human driver satisfaction. To realize the system, we propose a multiagent architecture, populated with software collaborative agents that can actively negotiate on behalf of taxi drivers in groups of size N for available customer bookings. The operational efficiency of the existing and proposed dispatch systems was evaluated through computer simulations on MITSIMLab, an existing simulation-based laboratory originally developed for evaluating traffic management system designs at the operational level. The empirical results, obtained for a 1000-strong taxi fleet over a discrete range of N, show that the proposed system can dispatch taxis with up to 33.1% and 26.3% reduction in customer waiting time and empty taxi cruising time, respectively.

13:40-14:00 **TuRP-B02.3**

A Semi Markov Decision Approach to E-Mail Management in a Knowledge Work Environment, pp. 1051-1056

Yadati Narasimha, Chetan — TUDelft
Kamath, Manjunath — Oklahoma State Univ.
Sharda, Ramesh — Oklahoma State Univ.

Growing dependence on knowledge workers has made it not only desirable but also imperative that research be dedicated to modeling and improving the performance of this new kind of 'worker'. The degree to which the capacities of this new breed of workers are used to increase the cooperative effectiveness of the enterprise depends on understanding how well the enabling technologies can mesh with organizational priorities and outcomes. With growing acceptance of e-mail as the de facto medium of communication, managing a knowledge worker's time between email processing and his regular duties has emerged as a challenge to enterprises. In this paper we propose to use a variant of MDP known as the Semi Markov Decision Process to model and generate strategies to effectively handle a knowledge worker's time between e-mail processing and his other regular duties.

14:00-14:20 **TuRP-B02.4**

Multi-Agent Systems Based Intelligent Maintenance Management for a Component-Handling Platform, pp. 1057-1062

Vermaak, Herman — Central Univ. of Tech. Free State
Kinyua, Johnson — Central Univ. of Tech. Free State

Throughout history it has been proved that tendencies on the manufacturing floor are a reflection of the changes in the customers' demands. Manufacturing systems of the next generation will have to incorporate more flexibility and intelligence, evolving towards reconfigurable manufacturing systems. The concept of 'intelligence' becomes increasingly relevant because of the need to maintain effective and efficient manufacturing operations with minimum downtime under conditions of uncertainty. This paper discusses the development of an Intelligent Maintenance Management System making use of Multi-Agent Systems.

TuRP-B03 — Room F

Semiconductor Manufacturing 4 (Regular Session)

Chair: Chien, Chen-Fu — National Tsing Hua Univ.
Co-Chair: McGinnis, Leon — Georgia Tech.

13:00-13:20 **TuRP-B03.1**

Throughput Analysis of Linear Cluster Tools, pp. 1063-1068

Yi, Jingang — San Diego State Univ.
Ding, Shengwei — Univ. of California at Berkeley
Zhang, Mike Tao — Spansion, Inc.
van der Meulen, Peter — BlueShift Tech. Inc.

In this paper, we analyze steady-state throughput and scheduling of linear cluster tools with single-blade robots in semiconductor manufacturing. We extend the existing research results in throughput and scheduling analysis for regular cluster tools to linear cluster tools. We analyze the tool's throughput for typical single and separate input/output configurations. We also consider a general distribution of the parallel process modules. We present a few examples of linear cluster tools to illustrate the proposed decomposition method and algorithms. The numerical and experimental results demonstrate that the proposed approach provides a powerful method to analyze the throughput and robot schedules of newly developed linear cluster tools.

13:20-13:40 **TuRP-B03.2**

Queue Time and X-Factor Characteristics for Semiconductor Manufacturing with Small Lot Sizes, pp. 1069-1074

Schmidt, Kilian — Advanced Micro Devices
Rose, Oliver — Dresden Univ. of Tech.

Small lot size is widely regarded as a promising means to achieve shorter cycle times in semiconductor manufacturing. The dominant contributor to cycle time is queue time. In this paper, we quantify how the queue time changes with lot size reductions by means of queuing theory and single-operation simulation. This includes an analysis of the factors shaping this queue time change and how their influence changes for different availability characteristics. Additionally, the x-factor changes resulting from the changes in queue time and raw process time are outlined.

13:40-14:00 **TuRP-B03.3**

SysML-Based Simulation Framework for Semiconductor Manufacturing, pp. 1075-1080

Kwon, Kysang — Georgia Inst. of Tech.
McGinnis, Leon — Georgia Inst. of Tech.

The speed of change, high complexity and risk in the semiconductor industry increases the importance of decision making in manufacturing. In particular, a growing need for faster and better decisions on factory design and operation demands more complexity and higher fidelity in factory simulation models. Two requirements to realize such models economically are reuse of existing simulation model information and integrating a wide range of factory, product and process information from numerous data sources to create specific instance simulation models. In this paper, we describe how a new systems modeling language, SysML, can support creating complex semiconductor factory simulation models that satisfy these two requirements. In particular, we show how to deal with very large complex instance models in terms of information integration across a range of information and engineering tools. As a demonstration, we show how the factory layout, or geometric model, can be integrated with a SysML instance model to achieve bidirectional data exchange.

14:00-14:20 **TuRP-B03.4**

Analytical Model for Optimal Inspection Frequency with Consideration of Setup Inspections, pp. 1081-1086

Berger, Kfir — Ben-Gurion Univ. of the Negev
Bar-Gera, Hillel — Ben-Gurion Univ. of the Negev
Kalir, Adar — Intel Corp.
Rabinowitz, Gad — Ben-Gurion Univ. of the Negev

Inspections are an essential component of the production process in semiconductor fabrication facilities. Inspection frequency influences the process yield as well as the production cost. It is therefore important to identify the optimal frequency by considering both aspects together. Several methods have been proposed in the literature for identifying optimal inspection frequencies. These methods assume that inspections occur only according to a single static rule of a constant predetermined frequency. In reality, inspections may occur due to other reasons, for example after every setup change, and are not necessarily static.

In this paper we discuss the effect of setup inspections on the decisions about regular inspections. We show how to modify the basic model for inspection costs and excursion costs in view of setup inspections. We further show how to determine the optimal frequency in this case using our proposed model. We then discuss the potential benefits from using a dynamic inspection rule, that makes inspection decisions with consideration of the expected number of batches until the next setup change.

TuRP-E04 Room JD's Terrace

Automation / Assembly for Micro/Nano Technologies 2 (Regular Session)

Chair: Touri, Rouzbeh — Univ. of Illinois
Co-Chair: Zimmermann, Jan — Univ. Stuttgart

13:00-13:20 **TuRP-E04.1**

A MEMS Stage for 3-Axis Nanopositioning, pp. 1087-1092

Liu, Xinyu — Univ. of Toronto
Kim, Keekyoung — Univ. of Toronto
Sun, Yu — Univ. of Toronto

Applications in micro and nanotechnologies require millimeter-sized devices that are capable of 3-axis positioning with motion ranges of micrometers and resolutions of nanometers. This paper reports on the design, fabrication, and testing of a MEMS-based 3-axis positioning stage. In-plane and out-of-plane electrostatic actuators (comb-drive and parallel-plate) are employed for driving the stage to move independently along the XYZ directions, by +/-12.5um in the X and Y directions at an actuation voltage of 30V and by 3.5um in the Z direction at 14.8V. The structures are designed to achieve highly decoupled motions by effectively suppressing cross axis motion coupling. Open-loop positioning repeatability is determined to be better than 17.3nm along all three axes.

13:20-13:40 **TuRP-E04.2**

Modeling for Simulation and Control of a X-Y High Precision Positioning Table, pp. 1093-1098

Zimmermann, Jan — Univ. of Stuttgart
Sawodny, Oliver — Univ. of Stuttgart

The production of micro-scale objects with nano-scale properties demands for appropriate measurement and test equipment for quality control. This work is motivated by an experimental setup to proof nano-positioning capabilities with 200mm traveling range. This paper is about the modeling of an x-y high precision positioning table, with double-H-configuration and driven by direct linear DC motors, using the Lagrange method. Furthermore the elasto-plastic friction model was extended, based on system parameters and former experiments with nano-positioning guides. The influence of the normal force on the friction force is essential for creating a connection between the macroscopic and microscopic models. A simplified model for control purposes was derived and applied to a PI-state regulator with additional feedforward of the system dynamics. Simulation results show the effectiveness of the approach.

13:40-14:00 **TuRP-E04.3**

High Yield Automated MEMS Assembly, pp. 1099-1104

Popa, Dan — Univ. of Texas at Arlington
Murthy, Rakesh — Univ. of Texas at Arlington
Das, Aditya — Univ. of Texas at Arlington
Stephanou, Harry — Univ. of Texas at Arlington
Lee, W.-H. — Univ. of Texas at Arlington

Heterogeneous assembly of 2˝D or 3D MEMS components is an alternate micromanufacturing route to monolithic integration or other stochastic, self-assembly approaches. This approach is deterministic (directed) and involves using microgrippers mounted on precision robots to pick-and-place microparts. In this context, the use of engineered compliance has been recently proposed as a very practical way to account for positional tolerances of the robot end-effectors and the manufacturing tolerances in the microparts. In this paper, we examine the most important tradeoffs in compliant MEMS assembly and conclude that the use of automation at these scales is qualitatively different than automation at larger scales. Whereas at the meso and macro scales, automation is often undertaken after, and often benchmarked against manual assembly, deterministic automation at the MEMS scale is a more holistic approach. This means that the designs of the assembly cell, part and end-effectors should be done simultaneously, by doing so, we obtain an easier route to completed assemblies than

through teleoperation or through the use of closed-loop feedback. To support our findings, we use several examples of micropart design and experimental results with µł, a microrobotic workcell configured for high yield MEMS assembly.

TuRP-E05 Garden Terrace
Sensors, Instrumentation, and Measurement 3 (Regular Session)

Chair: Tilbury, Dawn — Univ. of Michigan
Co-Chair: Bukkapatnam, Satish — Oklahoma State Univ.

13:00-13:20 **TuRP-E05.1**

Hardware-In-The-Loop for Manufacturing Automation Control: Current Status and Identified Needs, pp. 1105-1110

Gu, Fangming — General Motors
Harrison, William — Univ. of Michigan
Yuan, Chengyin — General Motors Res. & Development Center
Tilbury, Dawn — Univ. of Michigan

In the past simulation and prototyping coexisted as disjointed iterative steps with limited benefits. As technology has advanced and processes have become more complex, the traditional isolated simulation and prototyping approaches can't satisfy dynamic, global competition requirements. Because of this there is a need for a mixture of simulation and physical implementation, which is called Hardware-in-the-Loop (HIL). This paper will explore the most active fields and research achievements within HIL including component compatibility testing, controller verification, and software. This assessment is used to highlight regions within HIL research that would benefit manufacturing automation control.

13:20-13:40 **TuRP-E05.2**

Enhancement of Manipulator Interactivity through Compliant Skin and Extended Kalman Filtering, pp. 1111-1116

Rajruangrabin, Jartuwat — Automation Robotics Res. Inst. Univ. of Texas at Arlington
Popa, Dan — Automation Robotics Res. Inst. Univ. of Texas at Arlington

In this paper we discuss control algorithms for real-time interaction between humans and robot manipulators sharing a common workspace. Unlike traditional robotic manipulators, we assume that the interaction between human and robot is not restricted to the wrist/end-effector of the robot, but that it can happen anywhere along the kinematic chain. Interaction forces are measured in some directions, and estimated in others via an Extended Kalman Filter. Sensory measurements used are traditional shaft encoders and also 1 dimensional force sensors via robotic "skin" placed on the robot links. We present simulation results with a CRS A465 showing the performance of our algorithms that compare the impedance response in the presence and absence of force measurements. We also show planned experimental validation on an actual robot using "Quickskin", a piezo-electric skin patch prototype in our lab.

13:40-14:00 **TuRP-E05.3**

Few D.O.F. Walking Robot with Outer-Wheels, pp. 1117-1124

Tadakuma, Riichiro — Harvard Univ.
Tadakuma, Kenjiro — Massachusetts Inst. of Tech.
Howe, Robert D. — Harvard Univ.

This paper describes the design and prototype testing of a few D.O.F. walking robot. This new design has hybrid wheeled-legged mechanism composed of an outer frame with novel omni-directional wheels, "Omni-Balls", and inner legs that provide thrust. Compared to previous hybrid designs, this walking robot has high stability on rough terrain because the wheels are located outside of the legs. In addition, the design permits the use of simplified leg designs with only one or two actuated degrees of freedom. We present performance results from prototype tests and consider implications for enhanced designs.

TuRP-F05 Garden Terrace
Planning, Scheduling, and Coordination 5 (Regular Session)

Chair: Zu, Di — Shenyang Inst.
Co-Chair: Ruiz Beltrán, Elvia — CINVESTAV

14:00-14:20 **TuRP-F05.1**

Trajectory Generation in Relative Velocity Coordinates Using Mixed Integer Linear Programming with IHDR Guidance, pp. 1125-1130

Zu, Di — Shenyang Inst. of Automation,Chinese Acad. of Sciences (CAS)
Han, Jianda — Shenyang Inst. of Automation,Chinese Acad. of Sciences (CAS)
Tan, Dalong — Shenyang Inst. of Automation,Chinese Acad. of Sciences (CAS)

Mixed-integer linear programming (MILP) for trajectory generation of mobile robot suffers from nonlinear constraints due to complex obstacle contours and dynamic environment. In this paper, firstly, we introduce a relative velocity coordinates MILP (RVCs-MILP) for solving the nonlinear constraints problem in the trajectory generation of the target pursuit and multiple-obstacle avoidance (TPMOA). The computational load of the RVCs-MILP does not increase with the complexity of obstacle contour but only relates to the number of the obstacles. It can be applied in real time when the number of the obstacles is small. For the large numbers of obstacles avoidance, further, we propose an IHDR based online learning mechanism. It sets up a "scenario-action mapping" knowledge base by continuously offline training and online updating. For a trajectory generation task, it will search a best match path of the current state in the knowledge base according to the external environments and the state of the robot in real time. Simulations are presented in comparison with the evolution algorithms (EA) and IHDR. The former shows significant improvement in a number of aspects. The latter confirms the validation of the proposed IHDR methods.

14:20-14:40 **TuRP-F05.2**

Offline and Online Evolutionary Bi-Directional RRT Algorithms for Efficient Re-Planning in Dynamic Environments, pp. 1131-1136

Martin, Sean — Johns Hopkins Univ. APL
Wright, Steve — Johns Hopkins Univ. APL
Sheppard, John — The Johns Hopkins Univ.

This paper explores the use of evolutionary algorithms (EAs) to formulate additional biases for a probabilistic motion planner known as the Rapidly Exploring Random Tree (RRT) algorithm in environments with changing obstacle locations. An offline EA is utilized to produce a bias in an obstacle filled environment prior to rearranging the obstacles. It is demonstrated that the offline EA finds a bias reflecting the

original environment and improves the RRT's efficiency during re-planning in environments with a small number of rearrangements. The Rapidly Exploring Evolutionary Tree (RET) algorithm is introduced as a hybrid RRT algorithm employing an online EA. It is demonstrated that the RET can improve the RRT's performance during re-planning in environments with many rearranged obstacles by exploiting characteristics of a balanced spatial kd-tree.

14:40-15:00 **TuRP-F05.3**

A Structural Characterization of Diagnosable Petri Net Models, pp. 1137-1142

Ruiz Beltrán, Elvia	CINVESTAV
Ramirez, Antonio	CINVESTAV
Lopez-Mellado, Ernesto	CINVESTAV
Arámburo Lizárraga, Jesús	CINVESTAV

This paper is concerned with the diagnosability property of Discrete Event Systems (DES) modeled by live and safe Interpreted Petri Nets (IPN). The IPN are used to model both, the normal and faulty behavior of the system. Based on this model, the notion of input-output diagnosability is introduced and a polynomial algorithm to characterize diagnosable IPN is proposed. The novel features of the approach herein presented are: a) the notion of relative distance between any pair of transitions; b) the use of the net siphons and T-semiflows to determine the relative distance between any pair of transitions; c) a characterization of diagnosable IPN based on the relative distance concept. Moreover, the approach herein presented characterizes a broader class of IPN exhibiting the diagnosability property and presents a better deepening of the structures needed to characterize diagnosable IPN.