





# MON-AM2

## Special Session I: Performance Metrics for Sustainable Manufacturing

Organizers: Kevin Lyons, Mahesh Mani & Ram Sriram

### Manufacturing Unit Process Life Cycle Inventories (Uplci)

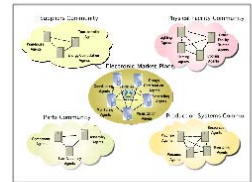
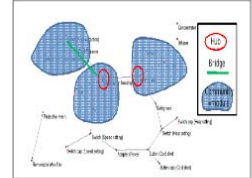
Professor Michael Overcash, Wichita State University  
 Professor Janey Twomey, Wichita State University  
 Professor Jacqueline Isaacs, Northeastern University

- Manufacturing plants represent the transition and use of materials (metals/polymers) and chemicals into a final product
- Uplci thus links the chemical lci world to the product manufacturing world
- Goal to encourage development of other uplci using similar format, so that additive property is achieved

### Conceptual Foundations of Energy Aware Manufacturing

Soundar Kumara  
 Department of Industrial Engineering, The Pennsylvania State University

- The importance of Energy Aware Manufacturing is discussed  
 The need for performance indices along with tasks that would be necessary to define performance indices is described  
 The three research components are outlined
1. Manufacturing Energy Computations is illustrated
  2. Manufacturing Energy Information Modeling using web services is described
  3. Manufacturing Energy Simulation Modeling based on Multi Agent Systems is discussed



### Discrete Event Simulation as Requirements Specification for Sustainable Design of Manufacturing Systems

Björn Johansson, Anders Skoogh,  
 Chalmers University of Technology, Sweden

Mahesh Mani, Swee Leong  
 Manufacturing System Integration Division, National Institute of Standards and Technology, USA

Designing manufacturing systems which lessen the impact on the environment is essential for a sustainable living. Discrete Event Simulation (DES) in combination with Lifecycle Assessment (LCA) data can be utilized to estimate how manufacturing systems will perform considering environmental measures.

- In the paper, we discuss how DES can be utilized to set requirements specifications on manufacturing systems in the early stages of the design phase.
- We present a case study of a paint shop model, that incorporates decisions on energy use, choice of machines, and environmental bottleneck detection. The results indicate the potential use of utilizing DES in combination with LCA data as requirements specification for designing sustainable manufacturing systems.



Figure 1. Schematic procedure for painting

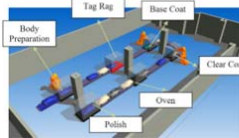
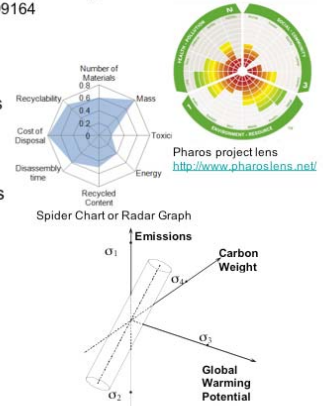


Figure 2. 3D-representation of the paint shop test model

### Towards a New Geometric Metric for Sustainability Assessment

Gaurav Ameta  
 School of Mechanical and Materials Engineering, Washington State University, Pullman, WA, 99164

- This paper puts forth a novel geometric metric for assessing sustainability of a product.
- The paper first reviews sustainability metrics and then focuses on the geometric metrics for evaluating sustainability aspects of a product.
- The purpose of the novel geometric metric is to present sustainability aspects of a product, for its entire life-cycle (material production, manufacturing, supply-chain, use and disposal), to design engineers in a readily comprehensible way.
- Based on the concept of areal coordinates, this paper constructs a preliminary geometric metric for sustainability assessment.



Pharos project lens  
<http://www.pharosians.net>



# MON-PM1

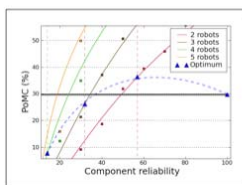
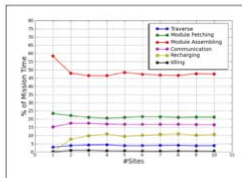
## Performance Assessment and Reliability of Unmanned Systems

Chairs: Hui-Min Huang & Coire Maranzano

### A Mission Taxonomy-Based Approach to Planetary Rover Cost-Reliability Tradeoffs

David Asikin, John M. Dolan  
The Robotics Institute, Carnegie Mellon University

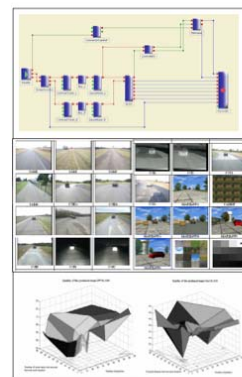
- Motivation of using taxonomy as a framework in analyzing the reliability of planetary robotic missions is discussed.
- Architecture of the planetary robotic mission taxonomy and the criteria used to generate it are introduced.
- Environment and robot model used for simulating one of the mission classes in the taxonomy are discussed.
- Optimization of the robot configuration and tradeoff analysis between robot team size – component reliability for Construction mission class are discussed.
- The stability of the simulation result is confirmed.



### Towards a systematic assessment of the functions of unmanned autonomous systems

R. Jaulmes, E. Moliné, L.Vielle  
DGA, Paris Expertise Center, France

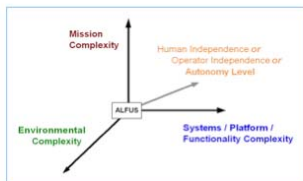
- A 4-phase generic methodology to evaluate any function of an autonomous system (UAV or UGV) is proposed.
- The method is illustrated on the evaluation of a beacon tracking algorithm for a UGV system, that was made within the TAROT study.
- The second chosen example is an evaluation of Simultaneous Localization And Mapping (SLAM) algorithms.
- Some of the relative metrics, gathered data and experimental results are presented for these two examples.
- The lessons learnt from these evaluations are described.



### Performance Measures Framework for Unmanned Systems (PerMFUS)

H. Huang  
Intelligent Systems Division, National Institute of Standards and Technology (NIST)

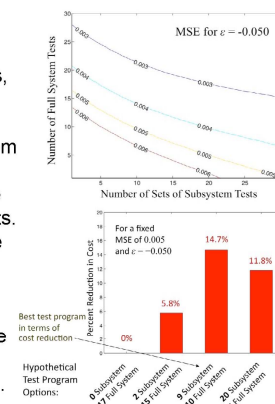
- Exploring a framework for capturing and organizing the performance metrics for Unmanned Systems (UMS)
- Based on the Autonomy Levels for Unmanned Systems (ALFUS) framework.
- Performance for UMS is to be characterizing per the missions that it is able to perform, the environments that the missions are to be performed in, the capabilities of the system itself, and the human interaction requirements.
- Axes depict increasing complexities. On Capability, low "levels" includes mobility mechanism types. High levels include collaboration methods.



### Optimum Combination of Full System and Subsystem Tests for Estimating the Reliability of a System

Coire J. Maranzano, James C. Spall  
The Johns Hopkins University Applied Physics Laboratory

This paper develops a method for finding an optimum test plan, which consists of a mixture of full system and subsystem tests, to estimate the reliability of a system. An optimum test plan is developed by trading off the number of full system and subsystem tests to minimize the mean-squared error (MSE) of the maximum likelihood estimate (MLE) of system reliability and testing costs. The MSE is decomposed into the variance of the MLE and a bias from incorrectly specifying the function that relates the subsystem reliabilities to the full system reliability. Optimum test plans involve trade offs between the MSE, the degree of modeling error, and the cost of doing tests.



# MON-PM2

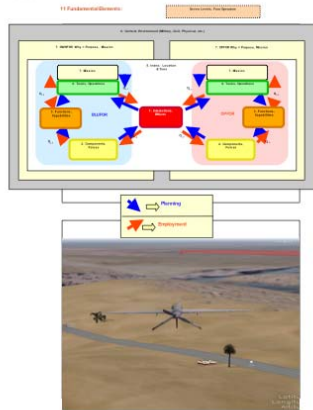
## Special Session II: Test and Evaluation of Unmanned and Autonomous Systems

Organizers: Mauricio Castillo-Effen & Nikita Visnevski

### Unmanned and Autonomous Systems Mission Based Test and Evaluation

Philipp A. Djang, Ph.D. and Frank Lopez  
Army Research Labs

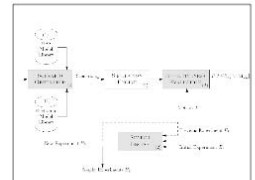
We propose to apply principles from the Army Evaluation Center's Mission Based Test and Evaluation (MBT&E) to Unmanned and Autonomous Systems (UAS) Test and Evaluation (T&E) in order to conduct rigorous, real-world testing based on anticipated military missions. In order to understand MBT&E, we introduce and describe its parent, the Mission and Means Framework. Finally, we describe a vignette that incorporates autonomous systems in the context of a mission to illustrate these principles.



### Modeling and Simulation for Unmanned and Autonomous System Test and Evaluation

Mauricio Castillo-Effen, Nikita Visnevski, Raj Subbu  
General Electric Global Research

- Relevance of T&E in robotics
- Clear differentiation and relationship between the concepts: M&S and T&E
- Main principles of the use of M&S in T&E of robots and autonomous systems
- Metrics from mission-based capability-driven T&E
- Test planning as a Design of Experiments problem
- Architecture for automated test planning
- Requirements imposed on simulation engine
- VR-Forces: A specific simulation engine chosen for test planning applied to Unmanned and Autonomous System Test & Evaluation (UAST)

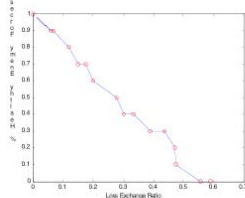


### Evolutionary Framework for Test of Autonomous Systems

Raj Subbu, Nikita Visnevski  
General Electric Global Research  
Niskayuna, NY 12309

Philipp Djang  
Army Research Lab  
White Sands Missile Range, NM 88002

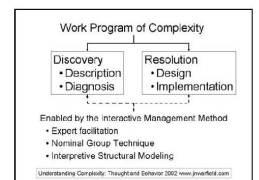
- DoD mission and challenge is to enable a high percentage of autonomous vehicles in the warfighter fleet by 2015.
- Autonomous systems of the future will need to be tested so their mission capabilities and robustness are predictable to the warfighter.
- Our goal is to develop an efficient intelligent test process that will enable the rapid introduction of autonomous systems on the battlefield.
- We propose a novel war game simulation-based multi-objective evolutionary test framework that combines the elements of testing an autonomous system's mission execution capabilities as a function of its innate capabilities and evolutionary computation.
- We present the evolutionary test framework, preliminary experimental results based on a limited scale war game, and ideas for developing this work into a deployable mission based test and evaluation framework.



### Metrics for Co-evolving Autonomous Systems

Jack Ring  
Educe LLC

- Nominates metrics for a whole system that produces and conveys knowledge regarding Unmanned Autonomous Systems capabilities and effects.
- Envisions a set of modular, distributed Autonomous Test and Evaluation Systems that maximize useful knowledge at minimum investment
- Envisions an Autonomous (Intelligent) Enterprise that generates customized Autonomous T&E Systems, wherever, whenever.
- Highlights four strategic capabilities for co-evolving the whole system.
- Cites proven practices and tools for achieving a unified capability.



## TUE-AM1

# The Role of Robotics Competitions in Advancing Intelligent Systems

Chairs: Stephen Balakirsky & Jason Gorman

### The Role of Robotics Competitions in Advancing Intelligent Systems: A Practitioner's Perspective

Intelligent Systems Division, National Institute of Standards and Technology (NIST)

- Competitions involving robots are becoming increasingly popular for stimulating interest and focusing efforts in engineering and science
- On one end of the spectrum, they attract young students to consider pursuing studies in science, technology and math, while at the other end, large "one time" government-funded competitions, such as the US Military's DARPA Grand Challenge serve as innovation stimulants
- In the middle, annual competitions with evolving challenges allow for continual and significant progress along a variety of technology trajectories
- This talk will discuss the role robotics competitions can play in measurement and evaluation of intelligent system capabilities and, how they can accelerate the pace of technological advancement



### History and Evolution of Robot Rescue Competitions

Adam Jacoff

Intelligent Systems Division, National Institute of Standards and Technology (NIST)

### Evaluating The RoboCup 2009 Virtual Robot Rescue Competition

Stephen Balakirsky<sup>1</sup>, Stefano Carpin<sup>2</sup>, Arnoud Visser<sup>3</sup>

- The format of the 2009 RoboCup Virtual Robot Rescue Competition is presented
- Details of the elemental tests and full search and rescue scenarios are presented
  - Autonomously generated map quality
  - Multi-vehicle tele-operation
  - Communication's system deployment
- The performance metrics utilized to evaluate the competition will be presented
  - Automatic scoring programs
  - Hand-generated scores
- Limitations and possible improvements are discussed



### RoboCupRescue Interleague Challenge 2009: Bridging the gap between Simulation and Reality

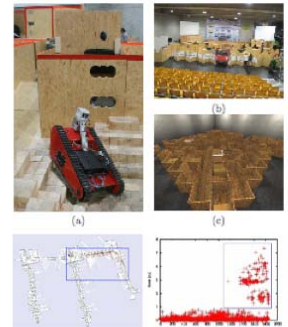
A. Kleiner\*, C. Scrapper\*\*, A. Jacoff\*\*\*

\* University of Freiburg

\*\* The MITRE Cooperation

\*\*\* National Institute of Standards and Technology (NIST)

- The Interleague Challenge has been initiated to evaluate real-world performance of algorithms developed in simulation, as well as to drive the development of a common interface to simplify the entry of newcomer teams to the robot league.
- This paper will discuss the development of emerging test methods used to evaluate robotic-mapping, the development of a common robotic platform, and the development of a novel map evaluation methodology deployed during the RoboCupRescue competition 2009.



<sup>1</sup>National Institute of Standards and Technology  
<sup>2</sup>University of California, Merced  
<sup>3</sup>Universiteit van Amsterdam

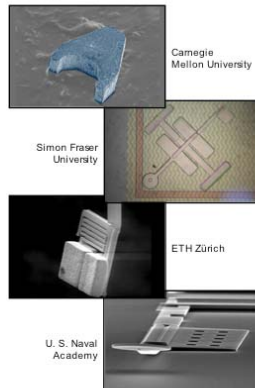
### Mobile Microrobot Characterization through Performance-Based Competitions

Jason J. Gorman<sup>a</sup>, Craig D. McGray<sup>b</sup>, and Richard A. Allen<sup>b</sup>

<sup>a</sup>Manufacturing Engineering Laboratory

<sup>b</sup>Electronics and Electrical Engineering Laboratory  
National Institute of Standards and Technology

- A mobile microrobot competition has been organized by NIST to:
  - Assess the state of the art
  - Identify the greatest technical challenges
  - Accelerate innovation in this field
- Results from the past three competitions held at RoboCup will be presented along with the demonstrated technologies
- Measuring the motion of microrobots and characterizing their performance remain challenging problems. Plans for integrating these measurements into future competitions are now being considered.





# TUE-AM2

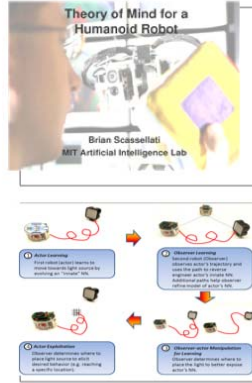
## Special Session III: Is an Agent Theory of Mind Valuable for Adaptive, Intelligent Systems?

### Organizer: Gary Berg-Cross

#### Is an Agent Theory of Mind (ToM) Valuable for Adaptive, Intelligent Systems?

Chair and Organizer: Gary Berg-Cross (Knowledge Strategies), Discussant: Alexei Samsonovich (GMU)

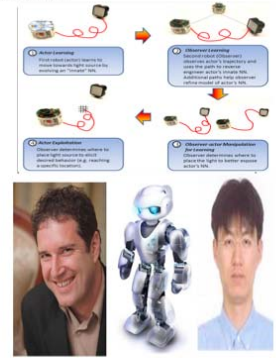
- Theory of Mind (ToM) propose a particular cognitive capacity by which a cognitive agent understands and predicts external behavior of others by attributing unobservable mental states, such as beliefs, desires and intentions.
- The session intends to explore the viability of the ToM concept for research and development and whether the ToM hypothesis is mature and relevant to the eventual goal of highly competent systems able to achieve goals in a relatively autonomous way.
- The session will address philosophical, research and robotic implementations and critiques central to the topic including:
  - Robotic theories of mind
  - Self-Reflecting Robots: Real Experiments with Small Societies of Minds
  - Neurodynamics of Cognition and Consciousness and Theory of Mind, Computational Tractability, and Mind Shaping



#### Robotic Theory of Mind

Kyung-Joong Kim      Hod Lipson  
 Dept. of Computer Engineering      Mechanical & Aerospace Engineering  
 Sejong University, Cornell University  
 South Korea      Ithaca, NY 14853, USA  
 kimkj@sejong.ac.kr      hod.lipson@cornell.edu

- Theory of mind (ToM) is a theory of cognitive function which proposes that we infer others' internal intention based on their behaviors.
- Issues include: Representation, discovery and exploitation of other's self models.
- We investigate robots representing other's self with artificial neural networks and an evolutionary learning mechanism to improve their ToM by continuous updates to weights in the network.
- Tests simulated physical robots and a novel prey-predator scenario to measure the performance of ToM learning.
- Experimental results showed that the proposed ToM approach can recover other's self models successfully.

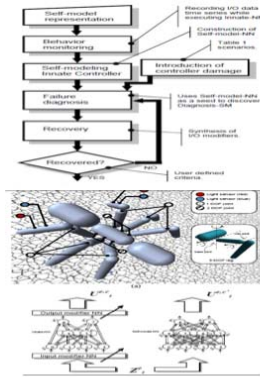


Resilient Robots

#### Resilient Behavior through Controller Self-Diagnosis, Adaptation and Recovery

Juan Cristobal Zagal      Hod Lipson  
 Computational Synthesis Laboratory      Mechanical & Aerospace Engineering  
 Cornell University  
 Ithaca, NY 14853, USA  
 jcz35@cornell.edu      hod.lipson@cornell.edu

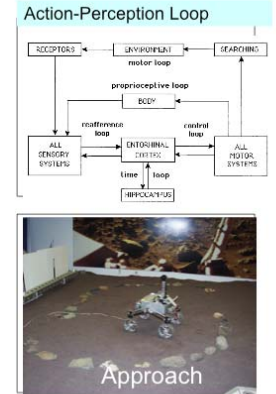
- Robot recovery behavior is investigated through a self-reflection-like process
- The robot employ 2controller: A primary "innate" reactive controller, and a secondary "reflective" controller that can observe, model and control the primary controller.
- A self-model derived observed sensorimotor time-series data data collected during normal operation of the robot is constructed by the reflective controller.
- This self-model can diagnoses the level of failure/damage introduced to the innate controller and we show that the reflective controller is able to recover performance.



#### Neurodynamics of Cognition and Consciousness

Robert Korzma      and      Walter J. Freeman  
 Department of Mathematical      Division of Neuroscience  
 Sciences  
 The University of Memphis      University of California at Berkeley

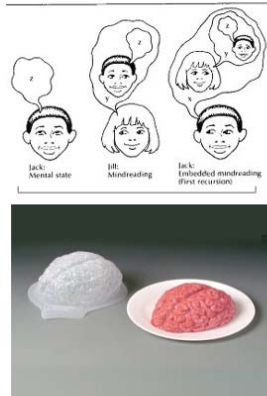
- Human cognition gathers seemingly homogeneous temporal sequences of perceptual experiences into meaningful, accessible and comprehensible chunks of fuzzy concepts
- A dynamical Theory-of-Mind (ToM) is presented to interpret experimental findings whereby meaningful knowledge is continuously created, processed, and dissipated in the form of sequences of oscillatory patterns of neural activity described through spatio-temporal phase transitions.
- The proposed approach has been implemented using intentional neurodynamics for mobile robot control in autonomous, robotic agents moving in a 2-dimensional environment.



#### Theory of Mind, Computational Tractability, and Mind Shaping

Dr. Tadeusz Zawidzki  
 Philosophy, Mind-Brain Institute, Mind-Brain-Evolution Cluster  
 George Washington University

- Theory of mind = attribution of mental states like beliefs and desires.
- Problem of holism = indefinite number of distinct, finite sets of mental states compatible with any finite behavioral evidence/consequences.
- Holism makes search for correct mental state attribution potentially intractable.
- Modularity can't help – any type of information is potentially relevant to "mind reading".
- Fast and frugal heuristics can't help – presuppose homogeneity, but good reasons to doubt social domain is sufficiently homogeneous.
- Mind shaping – automatic conformism, mimicry, normative sanctioning, pedagogy make human populations sufficiently homogeneous.



# TUE-PM1

## Ground Truth and Testbeds for Performance Testing

### Chairs: Tsai Hong & Barry Bodt

#### Data Collection Test-bed for the Evaluation of Range Imaging Sensors for ANSI/ITSDF B56.5 Safety Standard for Guided Industrial Vehicles

Will Shackelford, Roger Bostelman  
NIST

- ANSI/ITSDF B56.5 Safety Standard for Guided Industrial Vehicles
- Test-Bed Hardware
- Software Architecture
  - NML Packed Data Files
  - MOAST
  - Sensor Subsystem
  - Flash Lidar Display
  - Safety Laser Measurement Sensor
  - Camera/Positioning Navigation System/Spinning Laser Positioning System
- Test Results
- Changes to the Standard



#### Ground Truth Data Using 3D Imaging for US&R Robots

Nicholas A. Scott and Alan M. Lytle  
Construction Metrology and Automation Group, BFRL, NIST

- Two data collection events designed to capture ground truth data for US&R robotics research and standards development are discussed.
- Data sets were captured in 2006 and 2008 at the Disaster City training site in College Station, TX.
- Five training scenarios and two test methods captured.
- Anticipated uses:
  - Research in terrain characterization, mobility performance metrics, mapping algorithm evaluation, and developing virtual training and testing environments.
- Data available for public use.



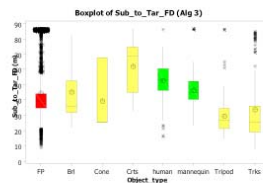
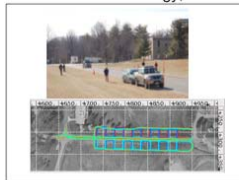
#### Performance Measurements for Evaluating Static and Dynamic Multiple Human Detection and Tracking Systems in Unstructured Environments

Barry Bodt, Richard Camden, Harry Scott, Adam Jacoff, Tsai Hong, Tommy Chang, Rick Norcross, Tony Downs, and Ann Virts  
Army Research Laboratory and National Institute of Standards and Technology.

**Goal:**  
Toward evaluation of performance for CTA detection and tracking algorithms.

- Requirements:**
- Ensure accuracy and precision of the ground truth.
  - Establish time-stamp correspondences between ground-truth and detection.
  - Establish object/human correspondences between ground-truth and detection.
  - Define and compute metrics for performance measurements.

- The assessment of algorithms include:
- Detection and misclassification rates, and false positive frequency
  - Detection distance and persistence
  - Impact of study design factors



#### Mathematical Metrology for Evaluating a 6DOF Visual Servoing System

Mili Shah, Tommy Chang, Tsai Hong, Roger Eastman  
Loyola University Maryland and National Institute of Standards and Technology

**Goal:**  
Develop the best homogeneous matrix transformation to fit two streams of six degree of freedom (6DOF) data

- Challenges:**
- Synchronizing two streams of 6DOF data
  - Finding a common coordinate system for two streams of 6DOF data
  - Constructing an error metric that defines the accuracy between two streams of 6DOF data
  - Performing experiments to test the effectiveness of the best homogeneous matrix transformation







# WED-AM1

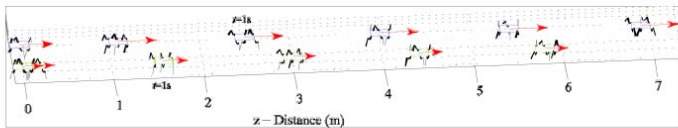
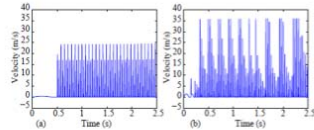
## Performance Measures for Mobile Robots

### Chairs: Alan Bowling & Rolf Lakaemper

#### Performance Measures of Agility for Mobile Robots

Alan Bowling and Shih-Chien Teng  
The University of Texas at Arlington

- Agility involves changing velocity, which requires acceleration
- This paper examines the effect of acceleration on a known performance measure applied to a legged robot



#### Measuring Rover Performance in Real-time for NASA Robotic Recon Operations

D. Schreckenghost<sup>1</sup>, T. Fong<sup>2</sup>, T. Milam<sup>1</sup>, H. Utz<sup>3</sup>  
<sup>1</sup> TRACLabs; <sup>2</sup> NASA Ames Research Center; <sup>3</sup> RIACS

- The use of real-time performance metrics for robotic reconnaissance operations during NASA's Human-Robot System field test is discussed.
- The real-time rover performance monitoring software is described.
- The performance metrics computed during the field test are defined.
- The use of these metrics during flight operations is described
  - Metrics for flight operations
  - Metrics for shift debrief
- The results of using these metrics in the field test are summarized.
- Conclusions for future operational use of performance metrics are presented.

#### Metrics for Flight Operations

Current Plan ID	Plan Timer	Name	Current Task	Status	Next % Task Done
001014.4	00:00:00.0	00:00:00.0	00:00:00.0	00:00:00.0	100

Current Plan ID	Plan Timer	Name	Current Task	Status	Next % Task Done
001014.4	00:00:00.0	00:00:00.0	00:00:00.0	00:00:00.0	100

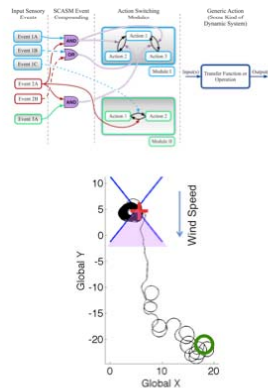
#### Metrics for Shift Debrief



#### A Biologically Inspired Sensory Driven Method for Tracking Wind-Borne Odors

Brian K. Taylor, Brandon L. Rutter, Roger D. Quinn  
Case Western Reserve University

- Sensory Coupled Action Switching Modules (SCASM)**, initially based on known neural circuits in stick insects, coordinates a system to generate an emergent behavior (e.g., stepping) using sensory feedback.
- SCASM has been implemented on legged locomotion systems and provides robust, low computational cost control.
- SCASM appears to be a general control concept. Here, it is generalized and applied to the problem of odor tracking. Results are quantified with basic performance metrics.



#### A Confidence Measure for Segment Based Maps

Rolf Lakaemper  
Temple University

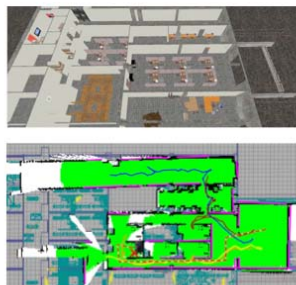
- Map confidence, or map quality based on regional consistency is an important measure to evaluate the quality of robot maps.
- We define a map-confidence measure that is tailored for segment based maps, without leaving the compact data representation by segments.
- The presented confidence measure is not based on comparison to ground truth data, but evaluates the map (ground truth free) based on consistency of segment clusters.
- Hierarchical clustering determines single features. Confidence measures the ambiguity in feature representation.



#### Evaluation of Robocup Maps

Ben Balaguer<sup>1</sup>, Stefano Carpin<sup>1</sup>, Stephen Balakirsky<sup>2</sup>, Arnoud Visser<sup>3</sup>  
University of California Merced<sup>1</sup>, NIST<sup>2</sup>, University of Amsterdam<sup>3</sup>

- The evolution of map scoring methods in the Robocup Virtual Rescue competition is presented
- Maps are scored based on metric quality, skeleton quality, attribution & grouping, and utility
- Examples from Robocup competitions are provided
- Steps towards a fully automated scoring procedure are presented







# WED-PM1

## Issues in Designing Intelligent Systems

### Chairs: Danil Prokhorov & Satyandra Gupta

#### Performance measurement and its role in advancement for intelligent systems: discussion points

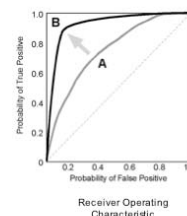
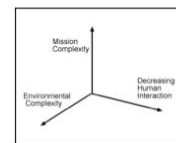
Danil Prokhorov and Yasuo Uehara  
Toyota Research Institute NA, Ann Arbor, MI

- Focus on autonomous UAV, UGV and home robots.
- From performance measurement to performance test.
- Specifics and examples of performance test for autonomous IS.
- Common issues of testing autonomous IS:
  - Testing vs. humans
  - Using quantifiable performance metrics
  - Recognizing importance of high-fidelity simulators.

#### Collective Intelligence: Toward Classifying Systems of Systems

Alan J. Ramsbotham, Jr.  
Orion Enterprises, Inc.

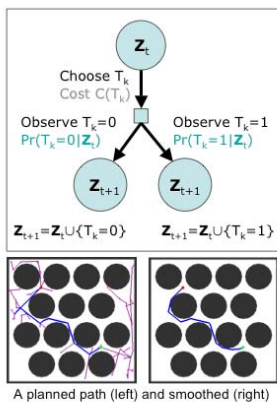
- Characteristics of future intelligent systems of systems are presented and discussed:
  - Ad hoc (indeterminate in terms of configuration and task).
  - Multiple mobile (or at least transportable) agents.
  - Functions associated with intelligent behavior dynamically distributed.
- Examples of different broad classes of systems are presented and possible extensions of existing conceptual frameworks are postulated.
- Practical challenges to predicting performance are discussed:
  - Mission Uncertainty.
  - Inadequacy of current metrics.
  - Complexity.
  - Laws of Nature and the Myth of Information Assurance.



#### A Decision-Theoretic Formalism for Belief-Optimal Reasoning

Kris Hauser  
School of Informatics and Computing, Indiana University

- Benchmarking pitfalls: poor sampling of problem space, overfitting.
- How else can intelligent systems be optimized?
- Represent problem space using probabilistic prior knowledge
- Formalism for systems with physical and "mental" uncertainty, bounded rationality, priced information
- Formulated as a Markov Decision Process in belief space
- Belief-optimal policy solves problem optimally given prior knowledge
- Illustrated on several toy problems and a path optimization problem encountered in motion planning



#### Evaluation of Automatically Generated Reactive Planning Logic for Unmanned Surface Vehicles

M. Schwartz, P. Svec, A. Thakur, S. K. Gupta  
Energetics Technology Center, University of Maryland College Park

- Unmanned Surface Vehicles often need to utilize high speed reactive planning to carry out certain mission tasks
- We have developed a mission planning system which utilizes machine learning techniques and virtual environment to automatically synthesize a reactive planning logic for various tasks
- We have specifically used the system to develop a reactive planning logic for blocking the advancement of an intruder boat toward a valuable target
- We have developed an approach for evaluating an automatically developed decision tree representing the blocking planning logic



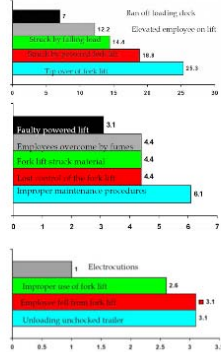
# WED-PM2

## Special Session VI: Performance Measurements Towards Improved Forklift Safety Organizer: Roger Bostelman

### Fork Lift Awareness

Mark Austin  
Occupational Safety and Health Administration

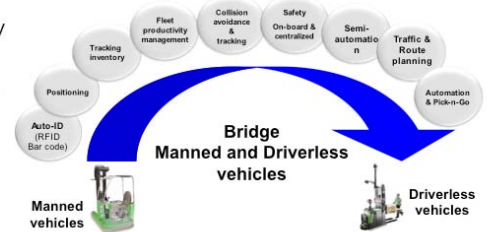
- In this presentation, we discuss the Occupational Safety and Health Administrations' statistics on fork lift accidents and injuries caused by these accidents. Fork lift benefits and the operating environments where these manned machines work are considered. Methods used to reduce fork lift accidents as well as reported cases of lost time at work due to fork lift accidents will be discussed, along with the percentage of lift truck accident causes.



### AGV Forklifts - Current and Future Safety Systems

Benny Forsman  
Kollmorgen Corp.

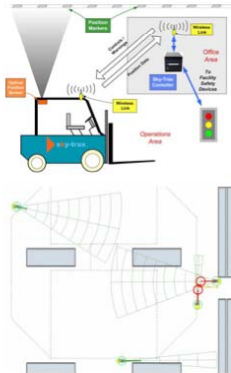
- This presentation will focus on current and future technical solutions that direct or in-direct will reduce the number of forklift related incidents. New components, new system solutions – but also new processes enabled by the new systems – will have the potential to eliminate many of the situations leading to injuries or fatalities.
- We will discuss the safety systems in AGV applications, but also the more important question of how these safe systems and practices can be used for manned forklifts and mixed fleets.



### Where AGV's and Forklifts Roam: Preserving Operational Safety in a Shared Workspace

Richard H. Ungerbuehler  
Sky-Trax Incorporated

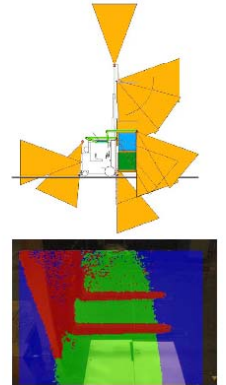
- Operational safety can be assured in facilities where industrial utility vehicles are used to transport goods only when safe practices are clearly established and carefully monitored. For example, forklift trucks, pallet jacks, buggies and carts can safely share operational space if safety is designed into the operation and vehicle operators follow safety rules and remain alert.
- In facilities where autonomous vehicles are used, a different set of safety requirements is needed. Autonomous vehicle control systems must assure that inter-vehicular collisions are prevented, and the vehicles must be equipped with safety devices, such as laser bumpers, to prevent collisions with people or equipment.



### Performance Measurements Towards Improved Manufacturing Vehicle Safety

Roger Bostelman, Will Shackelford  
NIST Intelligent Systems Division

- In this paper, we describe the current 2D (two dimensional) sensor configurations used for industrial vehicles and ideal sensor configurations for mounting 3D imagers on manufacturing vehicles in an attempt to make them safer. In a search for the ideal sensor configuration, three experiments were performed using an advanced 3D imager and a color camera. The experiments were intended to be useful to the standards community and manned and unmanned forklift and automated guided vehicle industries. The imager that was used was a 3D Flash LIDAR (Light Detection and Ranging) camera with 7 m range and rapid detection. It was selected because it shows promise for use on forklifts and other industrial vehicles. Experiments included: 1) detection of standard sized obstacles, 2) detection of obstacles while highly reflective surfaces are also within detection range, and 3) detection of forklift tines above the floor. We briefly describe these experiments and reference their detailed reports.



### Group Discussion

“Recommendations for Next Generation Forklifts to Become Safer”  
led by: Roger Bostelman

- This group discussion will follow the session papers with a focus on directing how the next generation of forklifts can become or be made safer. Ideas to start the discussion are:
  - Better safety devices and alerts to improve driver and pedestrian awareness,
  - Better driver skills, training
  - Improved standards
  - Current or advanced technology, for example:
    - Sensors, algorithms and/or other:
      - that improve situation awareness for both the forklift driver and/or pedestrians,
      - that are integrated into the vehicle controls,
      - that can retrofit to existing forklifts,
      - performance measurements to ensure safety and reliability.
  - Etc.
- The outcome of this discussion may be put towards a white paper on the topic.

Reported Loading Dock Accidents



Courtesy:  
[http://www.rtebite.com/ahr/traest/traxess\\_nst/ContentEntries/Dock+Accident+Articles/OpenDocument](http://www.rtebite.com/ahr/traest/traxess_nst/ContentEntries/Dock+Accident+Articles/OpenDocument)

Eighteen percent of forklift accidents occur when a walking employee or other pedestrian is struck by a lift, according to Construction-injuries.com

Courtesy:  
<http://forklift-safety-training.blogspot.com/2006/06/pedestrian-accidents.html>