PERFORMANCE METRICS
FOR
INTELLIGENT SYSTEMS WORKSHOP

National Institute of Standards and Technology, Gaithersburg, Maryland USA
August 21-23, 2006

Co-Located with the
IEEE International Workshop on Safety, Security, and Rescue Robotics

National Institute of Standards and Technology (NIST)

This year's workshop host was founded in 1901 as the first physical science research laboratory in the U.S. federal government. It currently is a non-regulatory federal agency within the U.S. Commerce Department's Technology Administration. NIST's mission is to promote innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

PERMIS-2006

In the sixth workshop in a series targeted at defining measures and methodologies of evaluating performance of intelligent systems, we will focus on applications of performance measures to practical problems in commercial, industrial, homeland security, and military applications. Topic areas include, but are not limited to:

Defining and measuring aspects of a system:
- **The level of autonomy**
- **Human-robot interaction**
- **Collaboration**

Evaluating components within intelligent system
- **Sensing and perception**
- **Knowledge representation, world models, ontologies**
- **Planning and control**
- **Learning and adaption**
- **Reasoning**

Infrastructural support for performance evaluation
- **Testbeds and competitions for intercomparisons**
- **Instrumentation and other measurement tools**
- **Simulation and modeling support**

Technology readiness measures for intelligent systems

Applied performance measures, e.g.,
- **Intelligent transportation systems**
- **Emergency response robots (search and rescue, bomb disposal)**
- **Homeland security systems**
- **De-mining robots**
- **Defense robotics**
- **Command and Control**
- **Hazardous environments (e.g., nuclear remediation)**
- **Industrial and manufacturing systems**
- **Space robotics**
- **Assistive devices**

SPONSORS

The dress code for this event is business casual.
Emergency responders should wear their insignias so that researchers and developers may strike up conversations.

PROGRAM COMMITTEE

General Chair:
Elena Messina, NIST Intelligent Systems Division, USA

Program Chair:
Raj Madhavan **(Oak Ridge National Laboratory/NIST, USA)**

S. Balakirsky (NIST, USA)
G. Berg-Cross (Engineering, Management and Integration, USA)
S. Carpin (International University Bremen, Germany)
M. Fields (US Army Research Laboratory, USA)
M. Foedisch (NIST, USA)
K. Fregene (Honeywell, USA)
J. Gorman (NIST, USA)
J. Gunderson (Gamma Two, Inc., USA)
Z. Kootbally (NIST, USA)
T. Kramer (NIST, USA)
M. Lewis (University of Pittsburgh, USA)
L. Reeker (NIST, USA)
S. Roumeliotis (University of Minnesota, USA)
C. Schlenoff (NIST, USA)
C. Scrapper (NIST, USA)
M. Shneier (NIST, USA)
Y. Wang (Technical University of Crete, Greece)
B. Weiss (NIST, USA)

PLENARY SPEAKER

PROF. HENRIK CHRISTENSEN

Georgia Tech.
USA

Evaluation of Robots for Human-Robot Interaction

Mon. 08:30

ABSTRACT

Robotics is gradually maturing as a discipline which also implies an increased need for comparative R&D. At the same time robots are more and more deployed to serve as assistants to humans be it for search and rescue or as part of normal daily chores in the home. To enable evaluation of progress in research it is essential that rigorous methodologies for evaluation and performance characterization are adopted. Often a number of objections are put forward as to why such rigorous experimental protocols are not well suited for robotics. Some of the typical objections will be presented and discussed in the presentation. To illustrate the value and strategy of experimental evaluation two example applications will be presented. Both applications are closely tied to robots that serve as assistants to people as part of daily operations. Experience from prior studies will also clearly illustrate the value of a careful design for evaluation and characterization of systems, which goes beyond the simple verification of theoretical models. Observations and lessons from an extensive set of studies will be summarized.

BIOGRAPHY

Henrik I Christensen is the Kuka Chair of Robotics and a Professor of Computing with the College of Computing, Georgia Institute of Technology. The appointment is part-time during 2006, which is a transition period from the earlier appointment at the Swedish Royal Institutute of Technology , which included leadership of the Center for Autonomous Systems. He does research on mobile robotics, autonomous systems, computer vision, and biologically inspired robot systems. The overall emphasis is on a holistic approach to design of systems, including mathematically well defined methods for design, analysis and implementation of systems. A fundamental idea is that methods should be evaluated in realistic settings which involves an interesting scenario and a full systems context. He is involved in a large number of national and international projects. Dr. Christensen is a co-founder of the company Intelligent Machines and serve as a scientific advisor to Evolution Robotics. Research cooperation involves research labs and companies on three continents. In addition he has been actively involved in a number of community efforts in particular as the founding coordinator of the EU network of excellence in Robotics - EURON (2000-2006). Dr. Christensen is a fellow of the International Foundation of Robotics Research and served as an IEEE RAS distinguished lecturer (2004-2006). He also serves on the board of trustees of the Swedish STINT foundation.

PLENARY SPEAKER

PROF. SHIGEO HIROSE

Tokyo Institute of Technology
Japan

Rescue and De-mining Robots

Tue. 08:30

ABSTRACT

In this plenary talk, I will explain about our activities on rescue and demining robots. As for the robots for rescue operation, I will first explain my previous efforts on snake-like robots with slender and actively bending bodies. I will then show several types of snake-like "Soryu" robots which consist of three crawler-driven segments and their connecting joints. The Soryu has been adapted with a specific driving mechanisms to move inside narrow and winding paths among debris and is designed to protect against dust and water. A newly introduced crawler belt made of thin metal with rubber knobs will also be explained. I will also present a debris-inserting inspection camera, we are developing with a snake-like expandable rod mechanism.

In general, I will introduce our development process for these and other devices. We believe that the most effective rescue tools will be the ones which are widely used in our daily life. Based on this belief, we also paid special attention to the development of ordinary-life-embedded rescue devices. For example, automobile jack-up devices which can be used for rescue operations will be shown. As for the demining robots, I will explain about my preliminary efforts to develop walking-demining robots, and their tool-detachable foot mechanisms. I will explain about our latest activities on a practical demining vehicle named "Gryphon." It has a weight balanced arm with metal and ground penetrating radar and a 3D camera. It can measure the uneven ground and can drive the sensors along the surface of the ground. I will show the result of the experiments in several places such as in Croatia.

BIOGRAPHY

Shigeo Hirose was born in Tokyo in 1947. He received the B. E. degree with first class honors in Mechanical Engineering from Yokohama National University in 1971, and his M. E. and Dr. E. degrees in Control Engineering from the Tokyo Institute of Technology in 1973 and 1976, respectively. He was Research Associate and Associate Professor of the same university, and since 1992 he has been a Professor of Tokyo Institute of Technology, Department of Mechanical and Aerospace Engineering. He is a Fellow of IEEE, JSME and RSJ. His research interest is in the creative design of robotic mechanisms and their control. He has been awarded more than 30 academic prizes including the "Medal with Purple Ribbon" from the Japanese government (2006), the first Pioneer in Robotics and Automation Award (1999), and the Best Conference Paper Award (1995) from the IEEE Robotics & Automation Society.

PLENARY SPEAKER

PROF. HUGH DURRANT-WHYTE

The University of Sydney Australia

Maximal Information Systems

Tue. 14:00

ABSTRACT

Information provides a quantitative metric for describing the value of individual systems components in autonomous systems tasks such as tracking, mapping and navigation, search and exploration; tasks in which the objective is information gain in some form. An information model is an abstraction of system capabilities in an anonymous form which allows a priori reasoning on the system itself. By construction, information measures have properties of composability and additivity and thus provides a natural means of modelling and describing large scale systems of systems.

This talk will begin by describing how information measures arise naturally in autonomous tracking, mapping and navigation, search and exploration tasks. It is then demonstrated that the performance of individual sensors and platforms can be modelled using these information measures and that system-level performance metrics can be computed. These ideas are illustrated in a series of tasks involving mixed air and ground autonomous systems. These include flight-tests of cooperative UAVs engaged in tracking and navigation tasks, mixed UAV, ground vehicles and human operatives, engaged in mapping and picture compilation operations, and operations involving multi-platform search in constrained environments. In each, it is shown how information provides both a performance metric and design objective underpinning large-scale systems of systems operation.

BIOGRAPHY

Hugh Durrant-Whyte received the B.Sc. in Nuclear Engineering from the University of London, U.K., in 1983, and the M.S.E. and Ph.D. degrees, both in Systems Engineering, from the University of Pennsylvania, U.S.A., in 1985 and 1986, respectively. From 1987 to 1995, he was a Senior Lecturer in Engineering Science, the University of Oxford, U.K. and a Fellow of Oriel College Oxford. From 1995 to 2002 he was Professor of Mechatronic Engineering at University of Sydney. In 2002 he was awarded an inaugural Australian Research Council (ARC) Federation Fellowship. He also now leads the ARC Centre of Excellence in Autonomous Systems. His research work focuses on autonomous vehicle navigation and decentralised data fusion methods. His work in applications includes automation in cargo handling, mining, defence, and marine systems. He has published over 300 technical papers and has won numerous awards and prizes for his work. He is a Fellow of the Academy of Technical Sciences, a Fellow of the IEEE and an IEEE Robotics Society Distinguished Lecturer.

PLENARY SPEAKER

DR. MARTIN BUEHLER

Boston Dynamics USA

Dynamic Legged Robots

Wed. 08:30

ABSTRACT

Mobility can be an important contributor to robot intelligence, for gathering information, implementing decisions, and interacting with the environment. While wheeled and tracked robots have a relatively easy time moving around, we have to invest some intelligence first into legged robot design and control in order to harvest their potentially much greater mobility.

This talk will describe several recent legged robots that walk, run, balance, climb, carry loads, resist kicks and negotiate rough terrain with new levels of dynamic mobility, robustness, and performance. In the process we will encounter interesting issues related to the system design, performance metrics, energy efficiency, and the experimental evaluation of these systems.

BIOGRAPHY

Martin Buehler received the M.Eng. and Ph.D. degrees in Electrical Engineering from Yale University in 1985 and 1990. His doctoral work focused on the design, control and analysis of juggling robots and the analysis of a hopping robot. After a Postdoc at MIT's leglab on dynamic legged locomotion, he joined McGill University, Montreal, in 1991 as an NSERC Junior Industrial Research Chair and a Scholar of the Canadian Institute for Advanced Research. He founded and headed the Ambulatory Robotics Lab, which produced one, four and six legged robots, including the ARL Monopods I and II, Scout I and II, CARL, PAW, RHex and AQUA, funded by major Canadian government, DARPA and industrial contracts and grants. In 2003 he received McGill's William Dawson Scholar Award. In the same year he moved on to become Director of Robotics at Boston Dynamics, Cambridge, USA. Dr. Buehler served as an Associate Editor of the IEEE Transactions on Robotics and Automation from 1998 - 2003, and is currently on the editorial boards of the International Journal of Robotics Research and the Journal of Field Robotics. He has supervised over 30 graduate students at McGill and has published over 100 papers on legged robot design and control, dynamic manipulation and motor control.d control, dynamic manipulation and motor control.

PLENARY SPEAKER

DR. JAMES ALBUS

NIST
USA

Building Brains for Thinking Machines

Wed. Banquet

ABSTRACT

In this talk, Dr. Albus will describe how research in computer science, control theory, and the neurosciences are converging towards intelligent systems that can mimic human performance in a broad range of applications. He will discuss current efforts to build machines that can perceive the environment, build an internal model of the external world, and use that model for decision-making, reasoning, planning, and real-time control of complex machines in uncertain, and potentially hostile, environments. He will suggest how system architectures designed for autonomous mobility systems are computationally similar in many respects to the human brain, and vice versa.

This work is part of a broad NIST program of research and engineering of intelligent systems to reduce costs and improve quality in manufacturing and construction, and to save lives of civilians on the highway and soldiers in combat. The research is conducted in collaboration with the Army Research Laboratory, DARPA, the Department of Transportation, and the U.S. manufacturing industry.

BIOGRAPHY

Dr. James S. Albus founded and led the Intelligent Systems Division at the National Institute of Standards and Technology for 20 years. He is currently a Senior NIST Fellow. Over a long and varied career Dr. Albus has made a number of scientific contributions. During the 1960's he designed electro-optical systems for more than 15 NASA spacecraft. During the 1970's, he developed a model of the cerebellum that after 30 years is still a leading theoretical model used by cerebellar neurophysiologists today. Based on that model, he invented the CMAC neural net, and co-invented the Real-time Control System (RCS). RCS is a reference model architecture for intelligent systems that has been used over the past 25 years for a number of systems including the NBS Automated Manufacturing Research Facility (AMRF), the NASA telerobotic servicer, a DARPA Multiple Autonomous Undersea Vehicle project, a nuclear Submarine Operational Automation System, a Post Office General Mail facility, a Bureau of Mines automated mining system, commercial open architecture machine tool controllers, and numerous advanced robotic projects, including the Army Research Lab Demo III Experimental Unmanned Ground vehicle. The latest version of the RCS architecture has been selected by the Army for the Autonomous Navigation Systems to be used on all Future Combat System ground vehicles, both manned and unmanned. He is also the inventor of the NIST RoboCrane. He is currently working with DARPA and other government agencies on a concept for a National Program for Understanding the Mind, a.k.a "Decade of the Mind."

Dr. Albus has received numerous awards for his work in control theory including the NIST Applied Research Award, the Department of Commerce Gold and Silver Medals, the Industrial Research IR-100 award, the Presidential Rank Meritorious Executive, the Jacob Rabinow award, the Japanese Industrial Robot Association R&D Award, and the Joseph F. Engelberger Award for robotics technology. In 1998, he was named a "Hero of Manufacturing" by Fortune magazine.

Dr. Albus is the author of more than 180 scientific papers, journal articles, book chapters, and official government studies on intelligent systems and robotics. He has lectured extensively throughout the world and authored or co-authored five books:

- Engineering of Mind: An Introduction to the Science of Intelligent Systems - Wiley, 2001
- Intelligent Systems: Architecture, Design, and Control - Wiley, 2002
  The RCS Handbook: Tools for Real-Time Control Systems Software Development - Wiley, 2001
- Brains, Behavior, and Robotics - Byte/McGraw-Hill, 1981
- Peoples' Capitalism: The Economics of the Robot Revolution - New World Books, 1976

He is a member of the editorial board of the Wiley Series on Intelligent Systems serves on the editorial boards of six journals related to intelligent systems and robotics.

Dr. Albus received a B.S. in Physics from Wheaton College (Illinois) in 1957, a M.S. in Electrical Engineering from Ohio State University in 1958, and a Ph.D. in Electrical Engineering from University of Maryland (College Park) in 1972.

FEATURED PRESENTATIONS

Army Initiatives for Autonomous Tactical UGVs: The Last 10 Years WEDNESDAY 14:00
Mr. Charles Shoemaker, Robotic Research LLC, USA (formerly with the Army Research Laboratory)

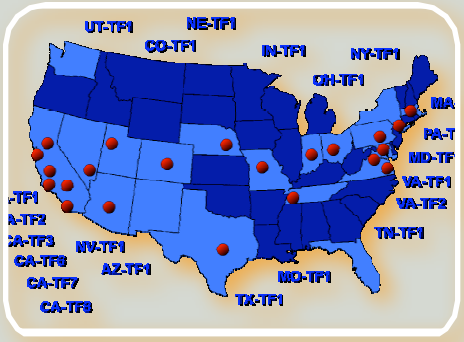
Winning the DARPA Grand Challenge WEDNESDAY 14:45
Dr. Michael Montemerlo, Stanford University's Stanley Team, USA

Open Problems of Robot Technologies for Disaster Response THURSDAY 08:30
Prof. Satoshi Tadokoro, Tohoku University and International Rescue Systems, Japan

EMERGENCY RESPONDER PANEL DISCUSSION

Responder Experiences in the Field: Where Can Robots Help? WEDNESDAY 16:00
CHAIR: G. Kemble Bennett, Ph.D., P.E., Vice Chancellor and Dean of Engineering, Texas A&M University, USA
PANEL: US&R responders from several FEMA teams

Due to the breadth and complexity of urban search and rescue (US&R) missions, and the diverse and evolving technologies present within robotic systems, the definition of performance requirements and associated test methods is an ambitious undertaking. Robot developers and emergency responders need to reach common understandings of the envisioned deployment scenarios, environmental conditions, and specific operational capabilities that are both desirable and possible for robots applied to US&R missions. Toward that end, NIST organizes events that bring emergency responders together with a broad variety of robots and the engineers that developed them to work within actual responder training facilities. These informal response robot evaluation exercises provide collaborative opportunities to experiment and practice, while refining stated requirements and performance objectives for robots intended for search and rescue tasks. This panel discussion will focus on responder perceptions regarding robot applicability, near-term opportunities for robots, and recent deployments that could have benefited from robotic technologies.



RELATED EVENT: RESPONSE ROBOT EXERCISE

MONDAY 16:00 - 18:00 FOR WORKSHOP VISITORS (SATURDAY-MONDAY FOR THOSE INVOLVED)

The third in a series of response robot exercises for FEMA US&R teams will be hosted at the Montgomery County Fire Rescue Training Academy in Rockville, Maryland (near NIST). This event will finalize the test methods targeted for the initial (Wave 1) set of standards as well as initiate experimentation with onboard payloads for chemical and radiological hazard detection. The three robot deployment categories selected by responders to be emphasized in Wave 1 are: ground peek robots that are small and throwable, wide-area ground survey robots that can traverse non-collapsed structures and provide remote situational awareness down-range, and aerial survey or loiter robots which in this case are rotary wing implementations. Robot developers take part in these multi-day exercises, which involve practicing operationally relevant US&R scenarios, to refine their understanding of responder requirements and deployment constraints. Buses from NIST will be provided so that attendees of SSRR and PERMIS can observe the final hours of this exercise.

BOMB SQUADS PRACTICE ROBOT DEPLOYMENTS

WEDNESDAY 17:00 - 18:30

Watch several civilian bomb squads deploy their robots in and around the test methods set up for all the other robot demos. See their operational methods and constraints. Discuss their needs.

Montgomery County, MD
Capt. Kevin Frazier

Fairfax County, VA
OFC Tom Eggers

Maryland State Police
Deputy Chief Jack Waldner

Michigan State Police
Lt. Shawn Stallworth

ROBOT DEMONSTRATIONS

DEMOS	RELATED EVENTS	LUNCH DEMOS	RECEPTION	BOMB SQUADS
	Monday afternoon there will be a tour of the FEMA MD-TF1 training facility to watch urban search and rescue robots perform test methods and operational scenarios.	Every day the cafeteria will be filled with robot exhibits and performance test methods to host robot demos.	Tuesday evening there will be an exhibitor's reception in the cafeteria for both conferences, featuring robot demonstrations, appetizers, and a cash bar.	Wednesday afternoon there will be a realistic training event for local bomb squads practicing robot deployments in and around test methods in the cafeteria

ROBOTS PRACTICING EXAMPLE ROBOT TEST METHODS

EXHIBITS, POSTERS, AND DEMOS

Throughout the workshop, all exhibits and posters will be set up in the NIST cafeteria, along with some example robot test methods. Robot demonstrations will take place in and around these test methods during:

- Lunch hours each day
- Exhibitor's reception (Tuesday 17:00 - 18:30)
- Bomb squad robots (Wednesday 17:00 - 18:30)
- Coffee breaks

See the cafeteria layout for more information about exhibit booths, example robot test methods, and where to sit during lunches for best viewing.

The booth layout will be updated based on final registrations and set-up.

Robots and Associated Techologies:

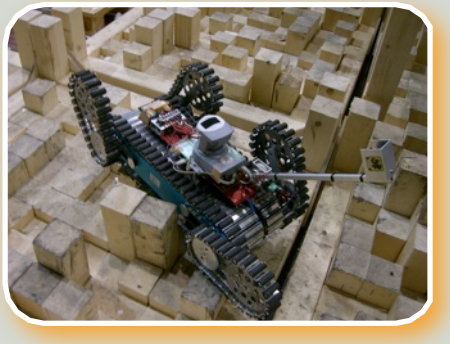
- **AirRobot (Germany)**
- **Applied Research Associates (USA)**
- **ARACAR (USA)**
- **Brno Univ. (Czech Republic)**
- **CRASAR (USA)**
- **Foster-Miller (USA)**
- **Fraunhofer AIS / Univ. of Osnabruck (Germany)**
- **Global Technical Systems (USA)**
- **HiBot (Japan)**
- **Idaho National Engineering Lab (USA)**
- **International Rescue System (Japan)**
- **Inuktun (Canada)**
- **iRobot (USA)**
- **Mesa Robotics (USA)**
- **NASA Goddard (USA)**
- **Non Lethal Solutions (USA)**
- **OmniTech (USA)**
- **Remington Technologies (USA)**
- **Remotec (USA)**
- **Skeyes Unlimited (USA)**
- **Telerob (Germany)**
- **Univ. of Electro-Communications (Japan)**
- **Univ. of Freiburg (Germany)**
- **Univ. of Massachusetts - Lowell (USA)**
- **Univ. of New South Wales (Australia)**
- **West Virginia High Tech Foundation (USA)**

Sensors:

- **Advanced Scientific Concepts (USA)**
- **Canesta (USA)**
- **CSEM (Switzerland)**
- **Envision Product Design CMOS X-ray (USA)**
- **Hokuyo (Japan)**
- **Multispectral Solutions (USA)**
- **RIKEN/Univ. of Tokyo (Japan)**
- **XRF Corporation (USA)**

VISUAL ACUITY

STEP-FIELD DASH



DIRECTED PERCEPTION

ZIG-ZAG DASH

MANIPULATOR DEXTERITY

CONFINED SPACE DASH

CACHE PACKAGING

STAIRS, RAMPS, ETC.

EXAMPLE ROBOT TEST METHODS

The Department of Homeland Security, through the Science and Technology Directorate Standards Program, is developing performance standards for robots applied to urban search and rescue. NIST is leading this effort with collaboration from subject matter experts within FEMA US&R Task Forces and other response organizations, along with robot manufacturers and robot researchers intent on this application domain. The resulting standard test methods are being developed within the Homeland Security Applications Committee of ASTM International.

The various ASTM working groups developing these standard test methods will be meeting at NIST on Monday morning. All workshop attendees are welcome to participate in these meetings and to join the ASTM working groups.

August

21

MONDAY

PROGRAM

WITH COMBINED EVENTS

SSRR

08:15	Opening Remarks in Green Auditorium			
08:30	Plenary Presentation in Green Auditorium: *Evaluation of Robots for Human-Robot Interaction* [Henrik Christensen]			
09:30	Coffee Break			
10:00	ASTM Working Group: SENSORS		Status of test methods will be presented along with images and video of robots practicing.	
	All conference attendees are welcome to attend these open meetings and join the working groups. Responders are expected there to guide discussions.	ASTM Working Group: HUMAN-ROBOT INTERACTION		
11:30			ASTM Working Group: COMMUNICATIONS	ASTM Working Group: MOBILITY
13:00	Lunch in Cafeteria			
14:00	Responders and robot developers involved in the response robot exercise at the MD-TF1 training academy take bus to site to continue practice robot deployments and test methods			
16:00	All interested conference attendees take bus (10 min.) to MD-TF1 training academy to watch response robot exercise: • Robots practicing operational scenarios • Robots practicing test methods • Radiation sensor integrations			
18:00	Bus to Hotels			

WATCH RESPONDERS DEPLOY ROBOTS AT A FIRE RESCUE TRAINING FACILITY

PERMIS

PROGRAM

WITH COMBINED EVENTS

August 21

MONDAY

08:15	**Opening Remarks in Green Auditorium**
08:30	**Plenary Presentation in Green Auditorium:** ***Evaluation of Robots for Human-Robot Interaction*** **[Henrik Christensen]**
09:30	**Coffee Break**
10:00	**MON-AM1 Autonomy and Intelligence** (Chairs: G. Berg-Cross and J. Gunderson) • Improving Knowledge for Intelligent Agents: Exploring Parallels in Ontological Analysis and Epigenetic Robotics [G. Berg-Cross] (Invited) • Intellectual Performance Using Dynamical Expert Knowledge in Seismic Environment [V. Stefanuk] • Reification: What is it, and Why Should I Care? [J. Gunderson, L. Gunderson] • Characteristics of the Autonomy Levels for Unmanned Systems (ALFUS) Framework [H. Huang]
11:30	**MON-AM2 Performance Metrics** (Chairs: D. Gage and S. Balakirsky) • Meaningful Metrics and Evaluation of Embodied, Situated, and Taskable Systems [D. Gage] (Invited) • Fault-Tolerance Based Metrics for Evaluating System Performance in Multi-Robot Teams [B. Kannan, L. Parker] • Image Classification and Retrieval Using Elastic Shape Metrics [S. Joshi, A. Srivastava] • Performance Metrics for Operational Mars Rovers [E. Tunstel] • Traversability Metrics for Urban Search and Rescue Robots on Rough Terrain [V. Molino, R. Madhavan, E. Messina, A. Downs, A. Jacoff, S. Balakirsky]
13:00	**Lunch in Cafeteria**
14:00	**MON-PM1 Performance Evaluation** (Chairs: M. Lewis and R. Schrag) • Performance Evaluation of Integrated Vehicle-Based Safety Systems [J. Ference, S. Szabo, W. Najm] • A Performance Evaluation Laboratory for Threat Detection Technologies [R. Schrag] • USARSim: Providing a Framework for Multi-robot Performance Evaluation [S. Balakirsky, C. Scrapper, S. Carpin, M. Lewis] • Performance Evaluation of a Terrain Traversability Learning Algorithm in the DARPA LAGR Program [M. Shneier, W. Shackleford, T. Hong, T. Chang] • Quantitative Assessments of USARSim Accuracy [S. Carpin, T. Stoyanov, Y. Nevatia, M. Lewis, J. Wang] • Feedback and Weighting Mechanisms for Improved Learning in the Adaptive Simultaneous Perturbation Algorithm [J. Spall]
16:00	**All interested conference attendees take bus (10 min.) to MD-TF1 training academy to watch response robot exercise:** • Robots practicing operational scenarios • Robots practicing test methods • Radiation sensor integrations WATCH RESPONDERS DEPLOY ROBOTS AT A FIRE RESCUE TRAINING FACILITY
18:00	**Bus to Hotels**

August

22

TUESDAY

PROGRAM

WITH COMBINED EVENTS

SSRR

08:15	**Opening Remarks in Green Auditorium**
08:30	**Plenary Presentation in Green Auditorium:** ***Development of Rescue and Demining Robots*** **[Shigeo Hirose]**
09:30	**Coffee Break**
10:00	**TUE-AM1 Implementations from the Tokyo Institute of Technology** (Chair: Satoshi Tadokoro) • Improved Driving Mechanism for Connected Crawler Vehicle "Souryu-IV" for In-Rubble Searching [M. Arai, Y. Tanaka, S. Hirose, S. Tsukui, H. Kuwahara] • Development of "Souryu-V" with Mono Tread Crawlers and Elastic-Rods Joint [Y. Tanaka, M. Arai, S. Hirose, S. Tsukui] • Connected Two Units Crawlers for Automatic Multiple Configurations as Search and Rescue Robot [K. Tadakuma] • Development of the Rescue Probe in Tight Space, "Slime Scope II" [T. Aoki, S. Hirose] • Development of "FALCON", A Three Wheeled Personal Vehicle for Uneven Terrain [S. Hirose, K. Kuramitsu, Y. Ota, T. Aoki]
11:30	**TUE-AM2 Robot Prototypes** (Chair: Daniele Nardi) • The Redback: A Low-Cost Advanced Mobility Robot [R. Sheh] • Robot Prototyping for Rough Terrain Applications and High Mobility with VolksBot RT [T. Wisspeintner, A. Bose, P. Plöger] • SALAMANDER: A Firefighting Robot [A. Gross] • AMOEBA-I: An Improved Link-type Shape Shifting Modular Robot for Search and Rescue Operation [B. Li, S. Ma, J. Liu, Y. Wang] • Design & Implementation of a Mobile Robotic Vehicle with a 5 dof Robotic Manipulator [J. Iqbal, K. Yousuf, A. N. Malik]
13:00	**Lunch and Robot Demonstrations in Cafeteria and Courtyard**
14:00	**Plenary Presentation in Green Auditorium:** ***Maximal Information Systems*** **[Hugh Durrant-Whyte]**
15:00	**Coffee Break**
15:30	**TUE-PM1 Robot Exercises and Deployment Experiences** (Chair: Adam Jacoff) • DHS/NIST Response Robot Evaluation Exercises [E. Messina, A. Jacoff] • Use of Micro Air Vehicles at Hurricane Katrina [R. Murphy, C. Griffin, S. Stover, K. Pratt] • Field Studies of Safety Security Rescue Technologies through Training and Response Activities [R. Murphy, J. Burke, S. Stover] • RACART: the Robot Assisted Crisis Assessment and Response Team Concept [J. Blitch]
17:00	**Exhibitors Reception in the Cafeteria and Courtyard** • Robot demonstrations • Example robot test methods • Posters APPETIZERS, DRINKS, AND ROBOT DEMOS
18:30	**Bus to Hotels**

PERMIS

PROGRAM

WITH COMBINED EVENTS

August 22

TUESDAY

08:15	**Opening Remarks in Green Auditorium**
08:30	**Plenary Presentation in Green Auditorium:** ***Development of Rescue and Demining Robots*** **[Shigeo Hirose]**
09:30	**Coffee Break**
10:00	**TUE-AM1 DARPA ASSIST Special Session** (Chairs: C. Schlenoff and M. Linegang) • Overview of the First Advanced Technology Evaluations for ASSIST [C. Schlenoff, B. Weiss, M. Steves, A. Virts, M. Shneier, M. Linegang] • A Two-Stage Approach to People and Vehicle Detection With HOG-Based SVM [F. Han, Y. Shan, R. Cekander, H. Sawhney, R. Kumar] • Performance Metrics and Evaluation Issues for Continuous Activity Recognition [D. Minnen, T. Westeyn, T. Starner, J. Ward, P. Lukowicz] • An Improved Stereo-based Visual Odometry System [Z. Zhu, T. Oskiper, O. Naroditsky, S. Samarasekera, H. Sawhney, R. Kumar] • Technology Evaluations and Performance Metrics for Soldier-Worn Sensors for ASSIST [B. Weiss, C. Schlenoff, M. Shneier, A. Virts] • Utility Assessments of Soldier-Worn Sensor Systems for ASSIST [M. Steves] • Using an Ontology to Support Evaluation of Soldier-Worn Sensor Systems for ASSIST [R. Washington, C. Manteuffel, C. White] • Evaluating Intelligent Systems for Complex Socio-technical Problems: Seeking Wicked Methods [M. Linegang, J. Freeman]
13:00	**Lunch and Robot Demonstrations in Cafeteria and Courtyard**
14:00	**Plenary Presentation in Green Auditorium:** ***Maximal Information Systems*** **[Hugh Durrant-Whyte]**
15:00	**Coffee Break**
15:30	**TUE-PM1 Performance Analysis** (Chairs: B. Brendle and A. Jones) • Memetics and Intelligent Systems [R. Finkelstein] (Invited) • An Information-based Cyber Infrastructure to Support Performance Analysis in Complex Systems [M-S. Li, A. Deshmukh, A. Jones] • Three-Dimensional Data Registration Based On Human Perception [B. Brendle] • Performance Analysis of Symbolic Road Recognition for On-road Driving [M. Foedisch, C. Schlenoff, R. Madhavan] • Control of Nonlinear Stochastic Systems [V. Aksakalli, D. Ursu]
17:00	**Exhibitors Reception in the Cafeteria and Courtyard** • Robot demonstrations • Example robot test methods • Posters
18:30	**Bus to Hotels**

APPETIZERS, DRINKS, AND ROBOT DEMOS

August

23

WEDNESDAY

PROGRAM

WITH COMBINED EVENTS

SSRR

08:15	**Opening Remarks in Green Auditorium**
08:30	**Plenary Presentation in Green Auditorium:** ***Developing Dynamic Legged Robots*** **[Martin Buehler]**
09:30	**Coffee Break**
10:00	**WED-AM1 Human Robot Interaction** (Chair: Fumitoshi Matsuno) • Camera Placement and Multi-Camera Fusion for Remote Robot Operation [B. Keyes, R. Casey, H. Yanco, B. Maxwell, Y. Georgiev] • Analysis of Human-Robot Interaction for Urban Search and Rescue [H. Yanco, M. Baker, R. Casey, B. Keyes, P. Thoren, J. Drury, D. Few, C. Nielsen, D. Bruemmer] • ARGOS – User Interface for Multiple Mobile Robot Teleoperation [L. Zalud] • Vibrotactile Feedback for Enhanced Control of Urban Search and Rescue Robots [J. Sibert, J. Cooper, C. Covington, A. Stefanovski, D. Thompson, R. Lindeman] • Comparing Situation Awareness for Two UAV Human Interface Approaches [J. Drury, J. Richer, N. Rackliffe, M. Goodrich]
11:30	**WED-AM2 Localization, Mapping and Planning** (Chair: Andreas Birk) • 3D Laser Scanner for Tele-exploration Robotic Systems [K. Pervolz, H. Surmann, S. May] • 6D SLAM - Mapping Outdoor Environments [A. Nuchter, K. Lingemann, J. Hertzberg, H. Surmann] • Robot Mapping for Rescue Robots [N. Adluru, L. Latecki, R. Lakaemper, R. Madhavan] • Multi-Objective Autonomous Exploration in a Rescue Environment [D. Calisi, A. Farinelli, L. Iocchi, D. Nardi, F. Pucci]
13:00	**Lunch and Robot Demonstrations in Cafeteria and Courtyard**
14:00	**Featured Presentations in Green Auditorium:** • ***Army Autonomous Tactical UGVs*** **[Chuck Shoemaker]** • ***Winning the DARPA Grand Challenge*** **[Mike Montemerlo]**
15:30	**Coffee Break**
16:00	**Emergency Responder Panel Discussion in Green Auditorium:** • Chair: G. Kemble Bennett • US&R Responders from Several FEMA Task Forces
17:00	**Local bomb squads deploy their robots in/around cafeteria** • Robots practice training on test methods • Operator interfaces and personal protective equipment • Methods of deployment
18:30	**Bus to Hotels**
19:00	**Banquet for all attendees and responders at the Hilton Hotel (Gaithersburg)** • Drinks then Dinner at 20:00 • ***Building Brains for Thinking Machines*** **[James Albus]**

WATCH BOMB SQUAD ROBOTS DEPLOY IN/AROUND TEST METHODS

PERMIS

PROGRAM

WITH COMBINED EVENTS

August 23

WEDNESDAY

08:15	**Opening Remarks in Green Auditorium**
08:30	**Plenary Presentation in Green Auditorium:** ***Developing Dynamic Legged Robots*** **[Martin Buehler]**
09:30	**Coffee Break**
10:00	**WED-AM1 Autonomous Systems Evaluation: Testbeds & Tools** (A. Freedy and D. Sparrow) • Challenges in Autonomous System Development [J. Connelly, W. Hong, R. Mahoney, Jr., D. Sparrow] (Invited) • Long Term Study of a Portable Field Robot in Urban Terrain [C. Lundberg, H. Christensen, R. Reinhold] • A Standardized Testing-Ground for Artificial Potential-Field based Motion Planning for Robot Collectives [L-F. Lee, V. Krovi] • A Testbed for Heterogeneous Autonomous Collaborative Agents [S. Asundi, A. Waldrum, N. Fitz-Coy] • Endurance Testing for Safety, Security, and Rescue Robots [J. Kramer, R. Murphy] • A Complete Simulation Environment for Measuring and Assessing Human-Robot Team Performance [A. Freedy, E. Freedy, J. DeVisser, G. Weltman, M. Kalphat, D. Palmer, N. Coyeman] • Development of an Evaluation Method for Acceptable Usability [B. Stanton, B. Antonishek, J.Scholtz] • Measuring Up as an Intelligent Robot - On the Use of High-Fidelity Simulations for Human-Robot Interaction Research [A. Green, H. Huttenrauch, E. Topp] • On-orbit Servicing: A Brief Survey [A. Tatsch, N. Fitz-Coy, S. Gladun]
13:00	**Lunch and Robot Demonstrations in Cafeteria and Courtyard**
14:00	**Featured Presentations in Green Auditorium:** • ***Army Autonomous Tactical UGVs*** **[Chuck Shoemaker]** • ***Winning the DARPA Grand Challenge*** **[Mike Montemerlo]**
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16:00	**Emergency Responder Panel Discussion in Green Auditorium:** • **Chair: G. Kemble Bennett** • **US&R Responders from Several FEMA Task Forces**
17:00	**Local bomb squads deploy their robots in/around cafeteria** • **Robots practice training on test methods** • **Operator interfaces and personal protective equipment** • **Methods of deployment**
18:30	**Bus to Hotels**
19:00	**Banquet for all attendees and responders at the Hilton Hotel (Gaithersburg)** • **Drinks then Dinner at 20:00** • ***Building Brains for Thinking Machines*** **[James Albus]**

WATCH BOMB SQUAD ROBOTS IN/AROUND TEST METHODS

August 24

THURSDAY

PROGRAM

WITH COMBINED EVENTS

SSRR

08:15	Opening Remarks in Lecture Room
08:30	***Open Problems of RT for Disaster Response: Roadmap in Japan [Satoshi Tadokoro, Shiro Fujita, Hideo Tanaka]***
09:30	**Coffee Break and Robot Demonstrations in Cafeteria and Courtyard**
10:00	**THU-AM1 Robot Behaviors** (Chair: Daniele Nardi) • Visual Odometry for Tracked Vehicles [C. Dornhege, A. Kleiner] • The IUB Rugbot: An Intelligent, Rugged Mobile Robot for Search and Rescue Operations [A. Birk, K. Pathak, S. Schwertfeger, W. Chonnaparamutt] • Autonomous Rescue Operations on the IUB Rugbot [A. Birk, S. Markov, I. Delchev, K. Pathak] • Automatic Step Climbing by Wheeled Robot HANZO with Variable Structure Functionality using 3D Range Sensor [N. Shiroma, Y. Fujino, F. Matsuno]
11:30	**THU-AM2 Collapse/Rubble Characterization** (Chair: Robin Murphy) • Issues in Debris Field Characterization and USAR Robot Interaction [R. Scott, R. Richardson] • Digital GAREKI Modeling for Exploring Knowledge of Disaster-Collapsed Houses [M. Onosato, H. Masuda, H. Takeuchi, K. Ito, F. Tanaka, T. Watasue] • US&R Data Characterization Sets [A. Lytle, G. Cheok, K. Saidi, A. Jacoff, E. Messina]
13:00	**Lunch and Robot Demonstrations in Cafeteria and Courtyard**
14:00	**THU-PM1 Potential Robot Swarms and Networks** (Chair: Robin Murphy) • Low Cost Micro Exploration Robots for Search and Rescue in Rough Terrain [S. Dubowsky, J. S. Plante, P. Boston] • Throw-able Search and Rescue Robot with Tetrahedral Shape [K. Tadakuma, J. Berengueres] • Robot-Sensor Networks for Search and Rescue [J. Reich, E. Sklar] • Networked Aerial-Ground Robot System with Distributed Task Allocation for Disaster Management [I. Maza, A. Viguria, A. Ollero] • Genetic Algorithm for Combinatorial Search Problems [G. Giardini, T. Kalmar-Nagy]
15:30	**Coffee Break and Robot Demonstrations in Cafeteria and Courtyard**
16:00	**THU-PM2 Assorted Sensors** (Chair: Fumitoshi Matsuno) • Development of Image Stabilization System using Camera Posture Information [R. Miyauchi, N. Shiroma, F. Matsuno] • The Use of an Inertial Measurement Unit to assist in Dynamic Stability during Mobile Robot Exploration [A. Nagendran, R. Scott, R. Richardson] • Smart Lift/Shore Agents for Adaptive Shoring of Collapse Structures: A Feasibility Study [R. Murphy, T. Vestgaarden, H. Huang, S. Saigal] • Evaluation of Canesta's Range Sensor Technology for US&R and Robot Navigation [J. Craighead, B. Day, R. Murphy]
17:30	**Farewell Demonstrations and a Toast to Next Year!**
18:00	Bus to Hotels

POSTERS SESSIONS

Technical posters will be set up among the exhibit booths at demonstration times and lunches. The authors will be available for discussions at those times, and their papers will be included in the proceedings.

- **Expedients for Marsupial Operations of USAR Robots**
  [A. Ferworn, G. Hough, R. Manca]
- **Using Common Sensation Sensor to Operate Pet Robots at Littered Floor**
  [K. Kawamura, T. Takahashi]
- **A Haptic Object Probe with Urban Search and Rescue Applications**
  [P. Odiase, R. Scott, R. Richardson]
- **Vision-based Victim Detection**
  [C. Castillo, C. Chang]
- **Dynamic Mobile Robots for Emergency Surveillance and Situational Awareness**
  [L. Ray, J. Joslin, J. Murphy, J. Barlow, D. Brande, D. Balkcom]
- **Game-Theory based Multi-Robot Searching Approach**
  [Y. Meng, K. Cao]
- **“REAL” Real-Time X-Ray**
  [J. Pursley, W. Movalson]

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