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TECHNICAL PROGRAM

AT A GLANCE

	6-Oct	7-Oct	8-Oct
	Tuesday	Wednesday	Thursday
8:00-8:30	Registration		
8:30-9:00	Welcome	Paper	Plenary
9:00-9:30	Plenary	Paper	Li
9:30-10:00	Beard	Paper	Paper
10:00-10:30	Break	Break	Paper
10:30-11:00	Paper	Panel	Break
11:00-11:30	Paper	Panel	Paper
11:30-12:00	Paper	Panel	Paper
12:00-12:30	Lunch	Lunch	Paper
12:30-1:00	Lunch	Lunch	
1:00-1:30	Lunch	Lunch	
1:30-2:00	LateNews	LateNews	
2:00-2:30	LateNews	LateNews	
2:30-3:00	Break	Break	
3:00-3:30	Paper	Paper	
3:30-4:00	Paper	Paper	
4:00-4:30	Paper	Paper	
4:30-5:00	Paper	Paper	
	Break	Break	
	Reception (6:00-8:00)	Banquet (6:30-9:00) Speaker: Torrie	

TUESDAY

TuOT1 Ballroom D
Opening Session (Plenary Session)

08:30-09:00

Welcome and Introduction

TuPT1 Ballroom D
Plenary Session (Plenary Session)

09:00-10:00 TuPT1.1
*Coordination over Networks for Small Unmanned Air Systems**
Beard, Randy — Brigham Young University

TuAT1 Ballroom D
Cooperative Exploration and Monitoring (Regular Session)

10:30-11:00 TuAT1.1
Simultaneous Cooperative Exploration and Networking Based on Voronoi Diagrams, pp. 1-6.
Kim, Jonghoek — Georgia Tech.
Zhang, Fumin — Georgia Inst. of Tech.
Egerstedt, Magnus — Georgia Inst. of Tech.

11:00-11:30 TuAT1.2
Monitoring the Dispersion of a Contaminant Cloud in an Urban Region by a Swarm of UAV Sensors, pp. 7-12.
Sinha, Arpita — Indian Inst. of Tech. Bombay
Tsourdos, Antonios — Cranfield Univ.
White, Brian A. — Cranfield Univ.

11:30-12:00 TuAT1.3
Formations with Decentralized Centroidal Voronoi Tessellation Algorithm, pp. 13-18.
Adams, Joshua — Utah State Univ.
Sun, Wei — Beijing Inst. of Tech.
Chen, YangQuan — Utah State Univ.

TuBT1 Ballroom D
LateNews/Work-In-Progress Session 1 (Regular Session)

13:30-13:45 TuBT1.1
*Low Altitude Remote Sensing Program at the Idaho National Laboratory (INL)**.
Anderson, Matthew — Idaho National Lab.
Wadsworth, Derek — Idaho National Lab.

13:45-14:00 TuBT1.2
*Development and Implementation of a Robot-Based Freshman English Course**.
Gunderson, Robert — Montana State Univ.

14:00-14:15 TuBT1.3
*Activity Recognition and Anomaly Detection in a Dense Sensor Network**.
Hoff, William — Colorado School of Mines

14:15-14:30 TuBT1.4
*A Wireless Sensor Network Based Closed-Loop Integrated System for Continuous Plume Monitoring and Prediction**.
Han, Qi — Colorado School of Mines

14:30-14:45 TuBT1.5
*Force Estimation Schemes in Bilateral Teleoperation Systems Using Observers**.
Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Lee, Sang Chul — GIST

TuCT1 Ballroom D
Coordinated Navigation and Control (Regular Session)

15:00-15:30 TuCT1.1
Robotic Chain Formations, pp. 19-24.
Maxim, Paul M. — Univ. of Wyoming
Spears, William — Univ. of Wyoming
Spears, Diana — Univ. of Wyoming

15:30-16:00 TuCT1.2
Supporting Navigation in Multi-Robot Systems through Delay Tolerant Network Communication, pp. 25-30.
Ducatelle, Frederick — IDSIA
Förster, Alexander — SUPSI
Di Caro, Gianni — IDSIA
Gambardella, Luca Maria — IDSIA

16:00-16:30 TuCT1.3
Autonomous Mobile Radios for Enhancing Wireless Communications through Wireless Tethering in Tunnel-Like Environments, pp. 31-36.
Weiss, Manoja — Colorado School of Mines
Moore, Kevin L. — Colorado School of Mines

16:30-17:00 TuCT1.4
Control of a Nonholonomic Mobile Manipulator Using Neural-Network, pp. 37-42.
Lee, Taekyung — Gwangju Inst. of Science and Tech.
Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)

RECEPTION Table Mountain Inn

18:00-20:00

WEDNESDAY

WeAT1 Ballroom D
Swarms and Formation Control (Regular Session)

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Epidemic Synchronization in Robotic Swarms, pp. 43-49.
Schioeler, Henrik — Aalborg Univ.
Ngo, Trung Dung — Aalborg Univ.
Nielsen, Jens Dalsgaard — Aalborg Univ.

09:00-09:30 WeAT1.2
On the Rendezvous Problem for Groups of Car-Like Mobile Robots, pp. 50-55.
Hess, Martin — Univ. of Wuerzburg
Schilling, Klaus — Univ. Wuerzburg

09:30-10:00 WeAT1.3
A Networked Telerobotic Observatory for Collaborative Remote Observation of Avian Activity and Range Change, pp. 56-61.
Faridani, Siamak — Univ. of California, Berkeley
Lee, Bryce — Univ. of California, Berkeley
Glasscock, Selma — Welder Wildlife Foundation
Rappole, John — Smithsonian National Zoological Park and Roger Tory Peterson Ins
Song, Dezhen — Texas A&M Univ.
Goldberg, Ken — Univ. of California, Berkeley

WeBT1 Ballroom D
Panel Session (Panel Session)

10:30-12:00 WeAT1.1
End-User Perspectives on Networked Robotics
Beer, Scott — Rajant Corporation
Dodd, ,Earl — IBM Corporation
Phip, Alex — GCS Holdings, Inc.
Wadsworth, Derek — Idaho National Laboratory

WeCT1 Ballroom D
LateNews/Work-In-Progress Session 2 (Regular Session)

13:30-13:45 WeCT1.1
*Bilateral Teleoperation Systems Design Using Genetic Algorithms**.
Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Kim, Byeong-yeon — GIST

13:45-14:00 WeCT1.2
*Prioritized Sensor Detection Via Dynamic Voronoi-Based Navigation**.
Cortez, Andres — Univ. of New Mexico
Fierro, Rafael — Univ. of New Mexico
Wood, John — Univ. of New Mexico

14:00-14:15 WeCT1.3
*Autonomous Vertical Autorotation for Safe Landing of Unmanned Helicopters**.
Valavanis, Kimon P. — Univ. of Denver

14:15-14:30 WeCT1.4
*Overview of US Army TARDEC Robotics Programs**.
Theisen, Bernard — US Army RDECOM TARDEC
Gerhart, Grant — US Army Tank Command

WeDT1 Ballroom D
Networked Sensing and Simulation (Regular Session)

15:00-15:30 WeDT1.1
Active Sensing by Unmanned Aircraft Systems in Realistic Communication Environments, pp. 62-67.
Frew, Eric W. — Univ. of Colorado, Boulder
Dixon, Cory — Univ. of Colorado
Elston, Jack — Univ. of Colorado
Stachura, Maciej — Univ. of Colorado at Boulder

15:30-16:00 WeDT1.2
Localizing Stationary Targets with Cooperative Unmanned Aerial Vehicles, pp. 68-73.
Pack, Daniel — US Air Force Acad.

16:00-16:30 WeDT1.3
A Simulation Study of Consensus Speed Over Scale-Free Networks, pp. 74-79.
Sun, Wei — Beijing Inst. of Tech.
Chen, YangQuan — Utah State Univ.

16:30-17:00 WeDT1.4
REALabs-BOT: A WebLab in Mobile Robotics Over High Speed Networks, pp. 80-85.
Cardozo, Eleri — Univ. of Campinas
Guimarães, Eliane — Information Tech. Center Renato Archer
Paolieri-Neto, Fernando — Information Tech. Center Renato Archer
Pinto, Victor — Information Tech. Center Renato Archer

WePT1 Table Mountain Inn
Banquet Presentation (Plenary Session)

19:30-20:30 WePT1.1
*Multiple Unmanned Vehicle Coordination and Cooperation for Mining Optimization**
Torrie, Mel — Autonomous Solutions, Inc.

THURSDAY

ThPT1 Ballroom D
Plenary Session (Plenary Session)

08:30-09:30 ThPT1.1
*Complex Dynamical Networks: Synchronization/Consensus and Beyond**.
Li, Changpin — Shanghai Univ.

ThAT1 Ballroom D
Tele-Robotics (Regular Session)

09:30-10:00 ThAT1.1
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Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Ryu, Jeha — Gwangju Inst. of Science and Tech. (GIST)

10:00-10:30 ThAT1.2
Towards a Predictive Mixed Reality User Interface for Mobile Robot Teleoperation, pp. 91-96.
Sauer, Markus — Univ. of Würzburg
Hess, Martin — Univ. of Wuerzburg
Schilling, Klaus — Univ. Wuerzburg

ThBT1 Ballroom D
Robotic MANETS (Regular Session)

11:00-11:30 ThBT1.1
Node Mobility Control and Capacity in Wireless Ad Hoc Networks, pp. 97-102.
Seol, Jae-Young — Yonsei Univ.
Kim, Seong-Lyun — Yonsei Univ.

11:30-12:00 ThBT1.2
Collaboration Layer for Robots in Mobile Ad-Hoc Networks, pp. 103-110.
Broberg, Jacob Honoré — Aalborg Univ.
Hede, Sřren Thorhauge — Aalborg Univ.
Mikkelsen, Simon — Aalborg Univ.
Pedersen, Jesper — Aalborg Univ.
Sřrensen, Christian Bräuner — Aalborg Univ.
Madsen, Per Printz — Aalborg Univ.
Ole Elenius Meilvang Borch — Aalborg Univ.

12:00-12:30 ThBT1.3
Integrating Teams of Mobile Robots in Wireless Ad-Hoc Networks, pp. 111-116.
Zeiger, Florian — Zentrum für Telematik
Sauer, Markus — Univ. of Würzburg
Stolz, Lothar — Univ. of Würzburg
Schilling, Klaus — Univ. Wuerzburg

BOOK OF ABSTRACTS

TuPT1 Ballroom D
Plenary Session (Plenary Session)

09:00-10:00 TuPT1.1
*Coordination over Networks for Small Unmanned Air Systems**
Beard, Randy Brigham Young University

The focus of this talk will be on coordinating the activities of small unmanned air systems (SUAS) over communication networks where the communication topology is not fully connected and may be changing. We will introduce the idea of input consensus and explore its use in several application domains including simultaneous rendezvous, perimeter monitoring, and coordinated ISR. Standard consensus algorithms achieve agreement between a team of agents, where the agreement value is the average of the initial condition of the agents. Therefore, the standard consensus algorithms do not accommodate changing environments or new measurements. The basic idea with input consensus is to come to agreement on the average of the inputs of each agent thereby allowing new measurements. We will also discuss our experiences with fielding multiple SUAS systems and some of the applications that we have pursued.

TuAT1 Ballroom D
Cooperative Exploration and Monitoring (Regular Session)

10:30-11:00 TuAT1.1
Simultaneous Cooperative Exploration and Networking Based on Voronoi Diagrams, pp. 1-6
Kim, Jonghoek Georgia Tech.
Zhang, Fumin Georgia Inst. of Tech.
Egerstedt, Magnus Georgia Inst. of Tech.

We develop a strategy that enables multiple intelligent vehicles to cooperatively explore complex territories. Every vehicle deploys communication devices and expands an information network while constructing a topological map based on Voronoi diagrams. As the information network weaved by each vehicle grows, intersections eventually happen so that the topological maps are shared. This allows for distributed vehicles to share information with other vehicles that have also deployed communication devices. Our exploration algorithms are provably complete under mild technical assumptions. A performance analysis of the algorithms shows that in a bounded workspace, the time spent to complete the exploration decreases as the number of vehicles increases. We further provide an analytical formula for this relationship. Time e±ciency of the algorithms is demonstrated in MATLAB simulation.

11:00-11:30 TuAT1.2
Monitoring the Dispersion of a Contaminant Cloud in an Urban Region by a Swarm of UAV Sensors, pp. 7-12
Sinha, Arpita Indian Inst. of Tech. Bombay
Tsourdos, Antonios Cranfield Univ.
White, Brian A. Cranfield Univ.

In this paper, we develop a mechanism to detect, model and track the shape of a contaminant cloud boundary using air borne sensor swarms. The cloud consists of a transparent gas of nuclear, biological or chemical contaminants and is spreading slowly in an urban environment. A group of UAVs, having the required sensors, are made to fly through the cloud to detect the boundary of the cloud. The shape of the cloud is modeled using splinegon. An observer is designed to track the movement of the cloud. The output of the observer is used in the path planning of the UAVs. The path planning is online, decentralized and considers obstacle avoidance and connectivity maintenance among the UAVs. Simulated experiments are carried out to test the proposed cloud tracking algorithm.

11:30-12:00 TuAT1.3
Formations with Decentralized Centroidal Voronoi Tessellation Algorithm, pp. 13-18
Adams, Joshua Utah State Univ.
Sun, Wei Beijing Inst. of Tech.
Chen, YangQuan Utah State Univ.

Centroidal Voronoi tessellations (CVTs) have recently attracted attention as a method for generating emergent behavior and swarm intelligence, for instance efficiently locating a source and creating evenly distributed formations. Previous research has focused on a centralized algorithm which depends on a base station computer to perform calculations and give the robotic agents direct movement commands. This research attempts to create an adaptive decentralized procedure for autonomous agents to create formations using CVTs. This decentralized approach will allow swarm systems a greater level of autonomy by removing the dependence on a centralized base station for calculating common agent tasks.

TuBT1 Ballroom D
LateNews/Work-In-Progress Session 1 (Regular Session)

13:30-13:45 TuBT1.1
*Low Altitude Remote Sensing Program at the Idaho National Laboratory (INL)**
Anderson, Matthew Idaho National Lab.
Wadsworth, Derek Idaho National Lab.

The Idaho National Laboratory's Low-Altitude Remote Sensing Program has developed small-unmanned aerial vehicle systems for the rapid, accurate, and safe collection of high resolution remote sensing data to address the needs of the region's and nation's resource managers. By performing the research needed to tackle challenging scientific problems in the area of UAV and sensor integration, INL has the capability to provide a platform to collect data needed by scientists in the areas of hydrologic monitoring and mapping, atmospheric chemistry data acquisition, and in helping to understand and monitor ecological processes. This has been accomplished through research in aerial particulate sampling, cooperative remote radiological sampling, and persistent surveillance including real-time mosaic and geo-referencing of video imagery, in addition to the collection of high-resolution still and hyperspectral imagery. Both fixed-wing and rotary airframes are used possessing capabilities spanning from remote controlled to fully autonomous operations.

13:45-14:00 TuBT1.2
*Development and Implementation of a Robot-Based Freshman English Course**
Gunderson, Robert Montana State Univ.

This talk will discuss the development and implementation of a robot-based freshman English course at Montana State University.

14:00-14:15 TuBT1.3
*Activity Recognition and Anomaly Detection in a Dense Sensor Network**
Hoff, William Colorado School of Mines

We describe a system composed of simple low cost infrared motion detector sensors connected to wireless motes to create a dense sensor network in a large building. Our system can automatically reconstruct the topology of the network and discover the general activities of people in the building. Our approach uses a combination of statistical techniques to recognize a hierarchy of motion features over a wide range of spatial and temporal scales. We augment the data from the sensors with additional contextual information such as time and day of week. This allows us to predict some activities and detect anomalous activities. This work has potential application to enhancing building security and improving energy efficiency in buildings.

14:15-14:30 TuBT1.4
*A Wireless Sensor Network Based Closed-Loop Integrated System for Continuous Plume Monitoring and Prediction**
Han, Qi Colorado School of Mines

The emerging wireless sensor networking technologies have the potential to keep track of contaminant plumes and predict future plumes behavior in real-time. As the wireless nodes are resource constrained, mass transport predictions may be used to increase the efficiency of the application-driven WSN protocols. A symbiotic relationship then exists between the wireless sensor network, which supplies data to calibrate the transport model in real-time, and the model, which optimizes the network monitoring performance. As current model calibration methods often require manual adjustment of

calibration parameters, real-time calibration procedures pose significant challenges. Based on insights from a previous intermediate-scale, proof-of-concept study, we are developing the models, tools, and protocols necessary for a closed-loop simulation. This talk briefly describes the setup of an experimental system in an aquifer test bed instrumented with wireless sensor nodes, and the development of fault detection techniques that reduces data uncertainty. If time permits, the talk will also touch upon planned future research that is relevant to the robotics community.

14:30-14:45 TuBT1.5

*Force Estimation Schemes in Bilateral Teleoperation Systems Using Observers**

Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Lee, Sang Chul — GIST

In these days, as the importance of the telesurgery is more remarked, the application of the haptic technology is essential to provide a better surgery environment. For use in the haptic technology and force coordination, we need measured reflected force from the end-effector of the manipulator. But the method using force sensors has some fundamental problems in terms of space, cost and infection. Thus, to overcome the limitations of using force sensors, we use a reaction force estimator that does not use any physical force sensor. In this research, we will present some experimental results using three estimation methods which can estimate the force without using force sensor. The experiment will be conducted by master/slave bilateral teleoperation manipulator. To guarantee the credibility, the experiment will be performed under the same condition. After comparing the performances among three estimation methods, we will discuss some ways to improve.

TuCT1 — Ballroom D
Coordinated Navigation and Control (Regular Session)

15:00-15:30 TuCT1.1

Robotic Chain Formations, pp. 19-24

Maxim, Paul M. — Univ. of Wyoming
Spears, William — Univ. of Wyoming
Spears, Diana — Univ. of Wyoming

One important task in cooperative robotics is the self-organization of robotic chain formations in unknown environments. Surveillance and reconnaissance in sewers, ducts, tunnels, caves or narrow passageways, in general, are some of the applications for this type of formation. Previously we have provided simulation results for a novel chain formation algorithm that addresses this task. This paper presents the results of the chain formation algorithm implementation on five robots.

15:30-16:00 TuCT1.2

Supporting Navigation in Multi-Robot Systems through Delay Tolerant Network Communication, pp. 25-30

Ducatelle, Frederick — IDSIA
Förster, Alexander — SUPSI
Di Caro, Gianni — IDSIA
Gambardella, Luca Maria — IDSIA

In this paper we study a problem of navigation in networked multi-robot systems. The robots are deployed in a confined area, where they move around and solve tasks. They communicate with each other through an infrared communication device, so that an ad hoc network is formed among them. Due to the limited range and line of sight nature of the infrared communication, this network has intermittent connectivity. The question we address is how a particular robot can use this network to find a target location that is indicated by another robot (e.g., the other robot has identified a task to be serviced by the searching robot). All other robots are involved in tasks of their own, and do not change their movements to help the searching robot find its destination. However, they do offer support by forwarding messages over the network. We propose a new algorithm based on routing in ad hoc and delay tolerant networks that can run on the network formed between the robots and provide navigation information to the searching robot. We evaluate the validity of our approach both in simulation and through an implementation on a group of 16 e-puck robots.

16:00-16:30 TuCT1.3

Autonomous Mobile Radios for Enhancing Wireless Communications through Wireless Tethering in Tunnel-Like Environments, pp. 31-36

Weiss, Manoja — Colorado School of Mines
Moore, Kevin L. — Colorado School of Mines

An autonomous Mobile Radio (AMR) in a wireless network is a mobile robot with wireless communication capability whose mission is to achieve a network communications goal through control of its position. Wireless tethering is an AMR behavior for ensuring the quality of wireless links between an AMR and other nodes. We discuss the particular problem of autonomously penetrating a tunnel environment using wirelessly tethered AMRs. Using a realistic, experimentally-derived radio signal propagation model in an underground environment, we present a method of implementing tethering using a consensus variable protocol for motion control as well as a method of estimating the coverage range.

16:30-17:00 TuCT1.4

Control of a Nonholonomic Mobile Manipulator Using Neural-Network, pp. 37-42

Lee, Taekyung — Gwangju Inst. of Science and Tech.
Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)

In this paper, control method for mobile manipulator subjected to kinematic constraint is proposed. It makes difficult to control mobile manipulator that nonholonomic constraints on the mobile platform and the dynamic interaction. The neural network is used to estimate mobile manipulator dynamics with the dynamic interaction by on-line learning rule. The stability of the closed-loop system, the convergence of the neural network weightupdating process and boundeness of the neural network weight estimation error are guaranteed by Lyapunov theory.

WeAT1 — Ballroom D
Swarms and Formation Control (Regular Session)

08:30-09:00 WeAT1.1

Epidemic Synchronization in Robotic Swarms, pp. 43-49

Schioeler, Henrik — Aalborg Univ.
Ngo, Trung Dung — Aalborg Univ.
Nielsen, Jens Dalsgaard — Aalborg Univ.

Clock synchronization in swarms of networked mobile robots is studied in a probabilistic, epidemic framework. In this setting communication and synchonization is considered to be a randomized process, taking place at unplanned instants of geographical rendezvous between robots. In combination with a Markovian mobility model the synchronization process yields overall evolutionary dynamics for first and second conditional moments of synchronization error given geographical position. The established dynamics assume the shape of partial integro-differential equations and the swarm is subsequently studied as an infinite-dimensional optimal control problem. Illustrative numerical examples are given and commented.

09:00-09:30 WeAT1.2

On the Rendezvous Problem for Groups of Car-Like Mobile Robots, pp. 50-55

Hess, Martin — Univ. of Wuerzburg
Schilling, Klaus — Univ. Wuerzburg

This paper deals with the rendezvous for groups of car-like mobile robots. In the main part of this work we solve the rendezvous problem for bounded steering vehicles by applying discontinuous feedback control in combination with a specific switching logic. This logic commands certain vehicles to perform orientation adjusting maneuvers that drive the system out of undesired equilibria. The developed control system is demonstrated in several laboratory hardware experiments.

09:30-10:00 WeAT1.3

A Networked Telerobotic Observatory for Collaborative Remote Observation of Avian Activity and Range Change, pp. 56-61

Faridani, Siamak — Univ. of California, Berkeley

Lee, Bryce — Univ. of California, Berkeley
Glasscock, Selma — Welder Wildlife Foundation
Rappole, John — Smithsonian National Zoological Park and Roger Tory Peterson Ins
Song, Dezhen — Texas A&M Univ.
Goldberg, Ken — Univ. of California, Berkeley

The scientific field study of wildlife often requires vigilant observation of detailed animal behavior over extended periods. In remote and inhospitable locations, observation can be an arduous, expensive, and dangerous experience for field scientists. We are developing a new class of networked teleoperated robotic "observatories" that allows "citizen scientists" and professional scientists to remotely observe, record, and index animal activity and behaviors via the internet. This paper describes CONE-Welder, installed at the Rob & Bessie Welder Wildlife Foundation in Texas to gather photographic and quantitative data for a biological study of avian activity and hypothesized range change for selected subtropical bird species. Since the system was deployed on 12 May 2008, over 600 users ("players") have participated online. Players have requested over 2.2 million camera frames and captured over 29,000 photographs. Within these photos, citizen scientists have classified 74 unique species, including eight avian species previously unknown to have breeding populations within the region. The collected dataset quantifies seasonal presence of birds of particular interest, e.g., the Green Jay (*Cyanocorax incas*). This paper describes the system architecture, the game interface that provides incentives for player participation, and initial data collected. CONE-Welder is available online at: http://cone.berkeley.edu/

WeBT1 — Ballroom D
Panel Session (Panel Session)

10:30-12:00 — WeAT1.1
End-User Perspectives on Networked Robotics

Beer, Scott — Rajant Corporation
Dodd, ,Earl — IBM Corporation
Phip, Alex — GCS Holdings, Inc.
Wadsworth, Derek — Idaho National Laboratory

WeCT1 — Ballroom D
LateNews/Work-In-Progress Session 2 (Regular Session)

13:30-13:45 — WeCT1.1
*Bilateral Teleoperation Systems Design Using Genetic Algorithms**

Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Kim, Byeong-yeon — GIST

This paper presents a synchronization scheme for bilateral teleoperation systems with time delay using genetic algorithms. In general, bilateral teleoperation systems have two main goals: stability and transparency. The system can be destabilized by time delay in the communication channel between the master and the slave. Also, transparency can be degraded by time delay. However, it is not straightforward to determine control gains to achieve these goals. In this work, a synchronization control of bilateral teleoperation systems with time delay using genetic algorithms and adaptive scheme is proposed. We use genetic algorithms to get optimal control gains for synchronization control law in free, soft contact and hard contact motion. Consequently, position and force tracking problem in free and contact motion is solved in a synchronized manner. Simulation and experimental results are presented to verify the effectiveness of proposed methods.

13:45-14:00 — WeCT1.2
*Prioritized Sensor Detection Via Dynamic Voronoi-Based Navigation**

Cortez, Andres — Univ. of New Mexico
Fierro, Rafael — Univ. of New Mexico
Wood, John — Univ. of New Mexico

This paper presents a decentralized coordination algorithm that allows a team of sensor-enabled robots to navigate a region populated with non-convex obstacles and take measurements within the region that contain the highest probability of having "good" information first. This approach is motivated by scenarios where prior knowledge of the search space is known or when time constraints are present that limit the amount of area that can be searched by a robot team. Practical applications include search and rescue, target detection, and hazardous contaminations. Our cooperative control algorithm combines Voronoi partitioning, a global optimization technique, and a modified navigation function to prioritize sensor detection. The issues we address such as non-convex obstacles as well as global search are not extensively addressed in the current literature. Simulation and experimental results of the control algorithm are given and validate the prioritized sensing behavior as well as the collision avoidance property.

14:00-14:15 — WeCT1.3
*Autonomous Vertical Autorotation for Safe Landing of Unmanned Helicopters**

Valavanis, Kimon P. — Univ. of Denver

This paper presents algorithms to enable autonomous Vertical Autorotation control for safe landing of unmanned helicopters.

14:15-14:30 — WeCT1.4
*Overview of US Army TARDEC Robotics Programs**

Theisen, Bernard — US Army RDECOM TARDEC
Gerhart, Grant — US Army Tank Command

The intelligent Ground Systems (IGD) robotics programs include the following technology focus areas: architecture development and demonstration, human robot interface, safe operations, platform mobility mechanisms, and support to the Warfighter. This presentation will describe some primary US Army robotics programs at TARDEC including convoy active safety technologies, autonomous platform demonstrator, near autonomous unmanned systems, robotics collaboration and vetronics technology integration. TARDEC supports the overall Army S&T program while simultaneously transitioning technologies from ARL, DARPA, TARDEC, etc. to the Robotic Systems Joint Program Office (RS-JPO). Some description will also be given of the Joint Center for Robotics (JCT) and its tri-service collaboration and outreach programs.

WeDT1 — Ballroom D
Networked Sensing and Simulation (Regular Session)

15:00-15:30 — WeDT1.1
Active Sensing by Unmanned Aircraft Systems in Realistic Communication Environments, pp. 62-67

Frew, Eric W. — Univ. of Colorado, Boulder
Dixon, Cory — Univ. of Colorado
Elston, Jack — Univ. of Colorado
Stachura, Maciej — Univ. of Colorado at Boulder

This paper describes an information-theoretic framework for active sensing by unmanned aircraft systems in realistic communication environments. The position dependency of wireless networked communication is modeled using the standard empirical radio model in combination with Shannon capacity or a packet erasure channel. The covariance of the extended information filter is used to model sensed information content. The two information-theoretic concepts are then combined into a single optimization metric. Decentralized control laws are developed for simplified network scenarios. Stochastic approximation and extremum seeking control techniques are used to estimate the gradient of the sampled objective function. Experimental flight results demonstrate the capabilities of the active sensing framework.

15:30-16:00 — WeDT1.2
Localizing Stationary Targets with Cooperative Unmanned Aerial Vehicles, pp. 68-73

Pack, Daniel — US Air Force Acad.

Unmanned aerial vehicles (UAVs) play an increasingly important role in a large number of military applications. Frequently deployed for intelligence collection (e.g., surveillance and reconnaissance), they are also useful for establishing long-range communication and providing tactical support. The focus of our research lies on the design and development of autonomous, cooperative UAVs using distributed control, sensing, and communication technologies. In this paper, we present several UAV technologies we developed that enable a team of UAVs to autonomously search, detect, and locate

stationary ground targets using airborne sensors. These enabling technologies include: (1) distributed, cooperative control of UAVs, (2) a novel out-of-order sigma-point Kalman _ltering method for local fusion of multiview sensor data collected by di_erent UAVs from varying perspectives, (3) a dynamic air-to-air and air-to-ground communication network, and (4) a UAV operating system to manage control, sensing, and communication activities. We illustrate the capabilities of this cooperative UAV system with test data acquired in ight demonstrations.

16:00-16:30 WeDT1.3
A Simulation Study of Consensus Speed Over Scale-Free Networks, pp. 74-79
Sun, Wei — Beijing Inst. of Tech.
Chen, YangQuan — Utah State Univ.

Scale-free network and consensus among multiple agents have both drawn quite much attention. To investigate the consensus speed over scale-free networks is the main topic in this paper. Given a set of different values for the power-law distribution parameter gamma, and a set of different values for the minimum degree (d_{min}) for the nodes, the algebraic connectivity (lambda_2) of the network topology is studied, as well as the time (t_c) (or iteration (k_c), for discrete algorithm) taken to reach consensus. The results exhibit that lambda_2 decreases while gamma increases. The lambda_2 increases monotonically as d_{min} grows, and they fit very well in a linear relationship. t_c (or k_c) decreases as gamma reduces and d_{min} increases. Via observing the behavior of the largest eigenvalue (lambda_n) of the Laplacian of the network topology, we draw the conclusion that the robustness over time delays declines while the robustness over node-failures and edge-failures increases.

16:30-17:00 WeDT1.4
REALabs-BOT: A WebLab in Mobile Robotics Over High Speed Networks, pp. 80-85
Cardozo, Eleri — Univ. of Campinas
Guimarães, Eliane — Information Tech. Center Renato Archer
Paolieri-Neto, Fernando — Information Tech. Center Renato Archer
Pinto, Victor — Information Tech. Center Renato Archer

This paper presents the architecture and implementation of REALabs-BOT, a WebLab in mobile robotics. REALabs-BOT was designed to run over high speed networks. As such, mobile robotics experiments run on the user's computer and control the robots over the network and in real time. The proposal of the WebLab is to let the student to develop his/her robotic algorithm in Java or Javascript, to tune and evaluate the algorithmin a simulated environment, and finally to run exactly the same algorithm to drive the real robots. REALabs-BOT maintains a repository of robotic experiments for demonstration purposes and as starting point for new experiments. The WebLab also supports secure interaction from multiple users located at different sites.

WePT1 Table Mountain Inn
Banquet Presentation (Plenary Session)

19:30-20:30 WePT1.1
*Multiple Unmanned Vehicle Coordination and Cooperation for Mining Optimization**
Torrie, Mel — Autonomous Solutions, Inc.

Autonomous Solutions Inc. has spent the last four years working on automating and optimizing open pit mining operations with unmanned trucks and dozers. Durability testing has proven the productivity improvements are real and significant. These improvements and how they are realized will be presented.

ThPT1 Ballroom D
Plenary Session (Plenary Session)

08:30-09:30 ThPT1.1
*Complex Dynamical Networks: Synchronization/Consensus and Beyond**
Li, Changpin — Shanghai Univ.

Complex dynamical networks have been booming in the past ten years. They are now permeating in various fields of sciences, from physics science to biological science, even to social sciences. From the mathematical point of view, a network is a graph composed of nodes or vertices and their connections or edges. Presently, the regular network, random graph, small_;world network and scale_;free network are studied widely. The last two networks provide researchers a powerful tool to analyze many real networks, such as the actor and movie networks, World Wide Web, internet, biological systems, etc. The nature of complex networks lies in their complexity, including topological structure, dynamical evolution, node diversity and meta_;complication. In this seminar, I will first recall the brief history of complex networks research and introduce some basic definitions. Then, I will also show some hot topics in the research field of complex networks, such as synchronization, consensus, and applications. Finally, I will browse some of the recent research results from my group and share some perspectives on the future research efforts in complex dynamical networks.

ThAT1 Ballroom D
Tele-Robotics (Regular Session)

09:30-10:00 ThAT1.1
Exponential Synchronization of Bilateral Teleoperation Systems with Delayed Force-Feedbacks, pp. 86-90
Ahn, Hyo-Sung — Gwangju Inst. of Science and Tech. (GIST)
Ryu, Jeha — Gwangju Inst. of Science and Tech. (GIST)

This paper addresses a synchronization scheme of multi-input and multi-output (MIMO) teleoperation systems when there exists a time delay during signal transfer between the master and slave devices. Without any passivity assumption, exponentially convergence will be ensured. Through a numerical simulation, the validity of the proposed methods will be illustrated.

10:00-10:30 ThAT1.2
Towards a Predictive Mixed Reality User Interface for Mobile Robot Teleoperation, pp. 91-96
Sauer, Markus — Univ. of Würzburg
Hess, Martin — Univ. of Wuerzburg
Schilling, Klaus — Univ. Wuerzburg

Lack of situation awareness significantly decreases the performance in missions where a mobile robot is operated by a human from remote. The user interface is a key influencing element for situation awareness of the human operator. The information from the remote site is limited to what the robot’s sensors can provide. In addition, this information is in general only delivered with a certain - maybe varying - communication delay. Predictive displays provide a promising approach to cope with these problems. In order to increase the situation awareness for the human operator in teleoperation scenarios predictive user interfaces can be used to achieve an artificial excoentric view. This work presents an approach how a predictive mixed reality user interface can be realized with the help of motion control theory. The human operator commands a virtual robot projected into the camera image delivered to the human operator from the physical robot. Hereby a trajectory for the real physical robot is generated, which is executed by the physical robot after a certain time. Combined with mixed reality technologies an artificial, exocentric view of the mobile robot is achieved which leads to a short time predictive user interface for mobile-robot teleoperation.

ThBT1 Ballroom D
Robotic MANETS (Regular Session)

11:00-11:30 ThBT1.1
Node Mobility Control and Capacity in Wireless Ad Hoc Networks, pp. 97-102
Seol, Jae-Young — Yonsei Univ.
Kim, Seong-Lyun — Yonsei Univ.

The end-to-end throughput of stationary random wireless networks is

scaled by Ł(p 1 n log n). This throughput scale can be changed into Ł(1) by making the °ows to be local °ow patterns. By exploiting the controllable mobility of mobile nodes in order to reduce the path length, it is possible to achieve the constant scale end-to-end capacity regardless of the node density. Since the shortened path length contributes the decrease of the number of hop counts the number of relaying packets, this reduces the tra±c delay and improves the energy e±ciency at the same time. The mobility control for the constant throughput scale can be formulated as a optimization problem, and we propose a simple heuristic mobility control algorithm based on the analysis and the problem formulation. Extensive simulation results show that the proposed mobility control algorithm improve the end-to-end capacity.

11:30-12:00 ThBT1.2

Collaboration Layer for Robots in Mobile Ad-Hoc Networks, pp. 103-110

Broberg, Jacob Honoré	Aalborg Univ.
Hede, Sřren Thorhauge	Aalborg Univ.
Mikkelsen, Simon	Aalborg Univ.
Pedersen, Jesper	Aalborg Univ.
Sřrensen, Christian Bräuner	Aalborg Univ.
Madsen, Per Printz	Aalborg Univ.
Ole Elenius Meilvang Borch	Aalborg Univ.

In many applications multiple robots in Mobile Ad-hoc Networks are required to collaborate in order to solve a task. This paper shows by proof of concept that a Collaboration Layer can be modelled and designed to handle the collaborative communication, which enables robots in small to medium size networks to solve tasks collaboratively. In this proposal the Collaboration Layer is modelled to handle service and position discovery, group management, and synchronisation among robots, but the layer is also designed to be extendable. Based on this model of the Collaboration Layer, generic services are provided to the application running on the robot. The services are generic because they can be used by many different applications, independent of the task to be solved. Likewise, specific services are requested from the underlying Virtual Machine, such as broadcast, multicast, and reliable unicast. A prototype of the Collaboration Layer has been developed to run in a simulated environment and tested in an evaluation scenario. In the scenario five robots solve the tasks of vacuum cleaning and entrance guarding, which involves the ability to discover potential co-workers, form groups, shift from one group to another, and communicate among group members. The successful outcome of the evaluation scenario indicates that a generic Collaboration Layer may be realisable.

12:00-12:30 ThBT1.3

Integrating Teams of Mobile Robots in Wireless Ad-Hoc Networks, pp. 111-116

Zeiger, Florian	Zentrum für Telematik
Sauer, Markus	Univ. of Würzburg
Stolz, Lothar	Univ. of Würzburg
Schilling, Klaus	Univ. Wuerzburg

Modern applications of mobile robot teams or robot teleoperation often demand wireless any-to-any communication in combination with highly dynamical network topologies to accomplish more and more complex tasks. These communication systems should also not rely on any pre-existing infrastructure, have low costs, and should allow for a seamless integration into existing communication networks. The well tested technology IEEE 802.11 wireless LAN offers all these possibilities. Especially the capability of realizing ad-hoc networks offers a high potential for WLAN to be used in the area of networked robots. Mesh networks and mobile ad-hoc networks are able to provide mechanisms for realizing stable communication links for networked robots. This work gives a brief overview on mesh networks and ad-hoc networks and further shows the behavior of different ad-hoc routing protocols (AODV, OLSR, DSR, BATMAN) in typical scenarios for remote operation of mobile robots. Also the differences between the application scenarios of mobile robot teams and in pure telecommunication environments are explained. The presented results are not only based on simulations. The ad-hoc routing protocols are compared in test scenarios with real mobile robot hardware experiments and the analysis is done according to well established methods and valid metrics well known from literature. Hints for the setup and parameter tuning of selected ad-hoc routing protocols are given to enable a better teleoperation of mobile robots and to improve the communication inside teams of mobile robots and humans. Finally a first approach is presented how to increase the system performance also on the application layer.