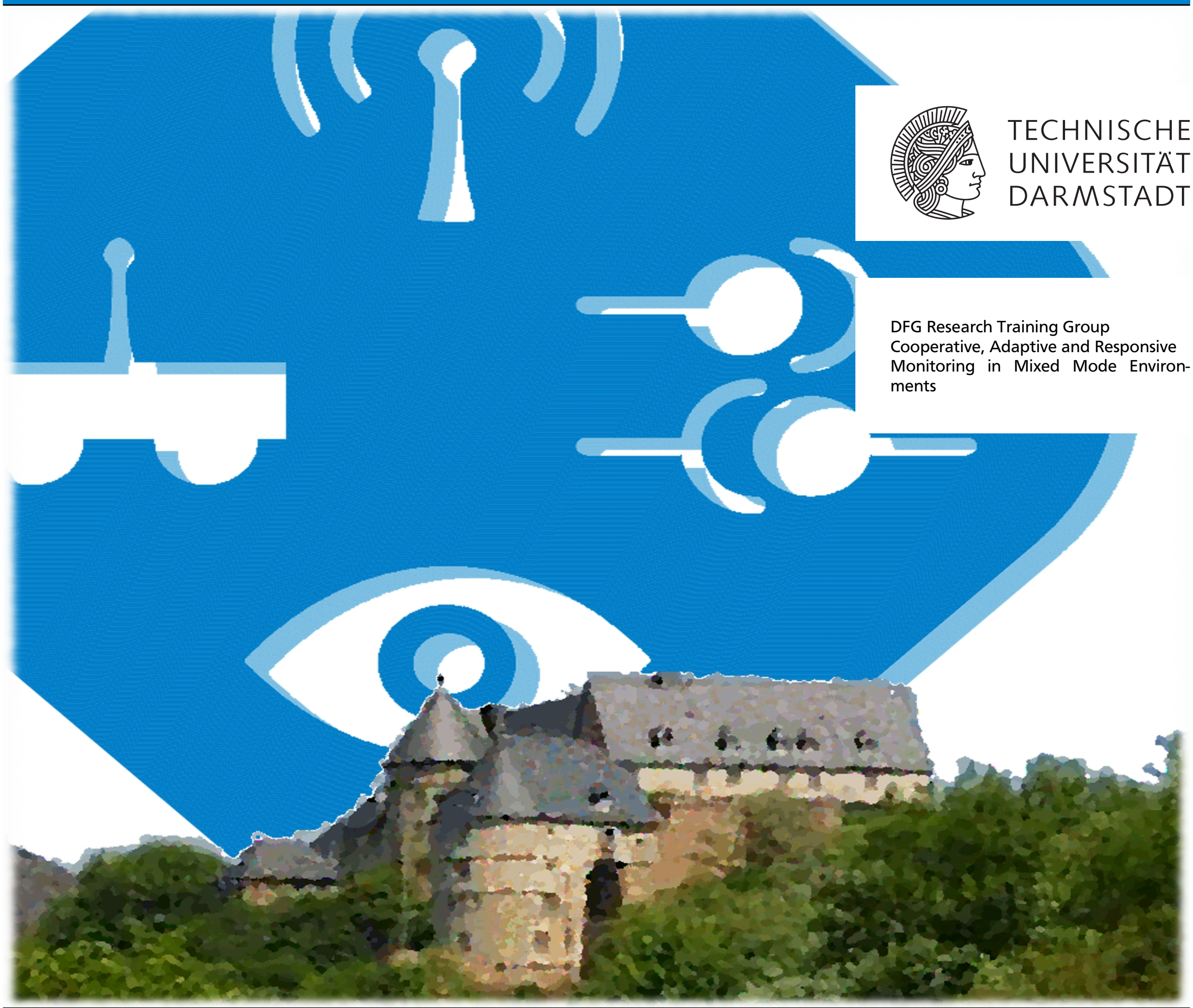
Summer School “Monitoring and Coordination Across Networked Autonomous Entities”

August 18-22, 2008
Castle Ebernburg



Summer School on "Monitoring and Coordination Across Networked Autonomous Entities"

Description:

Heterogeneous networks of sensors and unmanned vehicles open avenues for a class of novel applications. Tasks ranging from environmental monitoring to user support within emergency-response scenarios require fundamental, multi-disciplinary research, typically spanning Computer Science, Electrical Engineering and Mechanical Engineering topics.
The overall goal is to enable the transition towards a cooperative, adaptive and responsive monitoring using networked, autonomous entities. The solutions will comprise an array of devices ranging from inexpensive, tiny, low power sensor nodes, through unmanned autonomous vehicles, and all the way up to resource rich, powerful command stations. The heterogeneity in communication mechanisms, processing capabilities and inherent mobility of the different devices has been defined to be the *Mixed-Mode Environment*.

Goals:

This international summer school sets out to survey the state of the art in several highly important subareas of the above research domains. The lectures and tutorials will be held by renowned speakers from academia and industry.
The summer school will also provide a good opportunity to get to know other academic, industry and government researchers working in this field, to meet distinguished scholars, and to establish contacts that may lead to research collaborations in the future. This 5-day event will feature a number of different activities like lectures, hands-on tutorials, reading sessions and social events.
The summer school is organized by the Research Training Group Cooperative, Adaptive and Responsive Monitoring in Mixed Mode Environments, funded by the German Research Foundation, DFG, under grant GRK 1362 and endorsed by the EURON SIG on Cooperative Robotics.

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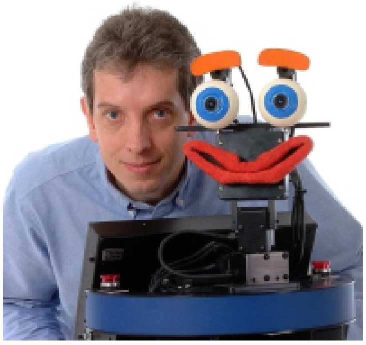
1 Contributions

1.1 Lecturers

1.1.1 Wolfram Burgard



Universität Freiburg

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Dr. Wolfram Burgard is professor for Computer Science at the University of Freiburg and head of the research lab for Autonomous Intelligent Systems. His areas of interest lie in artificial intelligence and mobile robots.

Prof. Burgard's research mainly focuses on the development of robust and adaptive techniques for state estimation and control. Over the past years, he and his group have developed a series of innovative probabilistic techniques for robot navigation and control. They cover different aspects such as localization, map-building, path-planning and exploration.

In his previous position from 1996 to 1999 at the University of Bonn he was head of the research lab for Autonomous Mobile Systems. In 1997 they deployed Rhino as the first interactive mobile tour-guide robot in the Deutsches Museum Bonn in Germany. During its deployment period of six days, Rhino was extremely successful and guided thousands of visitors through the crowded museum.

In 1998, he and his group went to Washington, DC, to install the mobile robot Minerva for a period of thirteen days in the Smithsonian Museum of American History. He has published over hundred papers and articles in robotic conferences and journals. In 2005, he published two books. Whereas the first one, entitled Principles of Robot Motion - Theory, Algorithms, and Implementations, is about sensor-based planning, stochastic planning, localization, mapping, and motion planning, the second one, entitled Probabilistic Robotics, covers robot perception and control in the face of uncertainty.

1.1.2 Friedemann Mattern

ETH Zurich

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Friedemann Mattern has been a full professor of computer science at ETH Zurich, Switzerland since 1999. He heads the computer science department's distributed systems research group and was the founding director of the Institute for Pervasive Computing.

Mattern obtained his Ph.D. from the University of Kaiserslautern, Germany. Before joining ETH Zurich, he was a faculty member of Saarland University in Saarbrucken and of TU Darmstadt, Germany. He also served as a visiting professor at a number of other universities in Austria and Germany.

Prof. Mattern initiated a number of successful international conferences (such as "Pervasive" or "Internet of Things"), is involved in various research projects in cooperation with industry, and published more than 150 research articles. His main research interests are distributed systems, ubiquitous computing, and the upcoming Internet of Things.

1.1.3 Natasha Neogi

University of Illinois at Urbana-Champaign

Webpage:
http://www.ae.uiuc.edu/people/faculty/neogi.html

Dr. Natasha Neogi is Assistant Professor at University of Illinois at Urbana-Champaign, USA. She is affiliated to the Aerospace Engineering Department.

Natasha Neogi obtained a Ph.D. title in Aeronautics and Astronautics from Massachusetts Institute of Technology, in June 2002 and M.Sc. title in Aeronautics and Astronautics from Massachusetts Institute of Technology in June 1999.

Professor Neogi's research interests cross several traditional engineering domains. Many of her research interests touch on issues of trust in critical infrastructure systems, such as the national airspace system. She is interested in expanding formal method techniques so they are practical and usable for non-experts. She is also exploring techniques for using HCI in improving security and reliability.

1.1.4 Lynne Parker

University of Tennessee

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Dr. Lynne E. Parker joined the faculty of the Department of Computer Science (now part of the new Department of Electrical Engineering and Computer Science) at The University of Tennessee-Knoxville in August 2002, founding the Distributed Intelligence Laboratory at that time. Besides her appointment as Professor in the EECS Department at UTK, she also holds an appointment as Adjunct Distinguished Research and Development Staff Member in the Computer Science and Mathematics Division at Oak Ridge National Laboratory, where she worked as a full time researcher for several years. Dr. Parker received her Ph.D. degree in computer science in 1994 from the Massachusetts Institute of Technology (MIT), performing her research on cooperative control algorithms for multi-robot systems in MIT's Artificial Intelligence Laboratory, with a minor in brain and cognitive science. She received her M.S. degree in computer science from The University of Tennessee-Knoxville, and her B.S. degree in computer science from Tennessee Technological University, with a minor in mathematics.
Dr. Parker is a leading international researcher in the field of cooperative multi-robot systems. She has published over 80 articles in the areas of mobile robot cooperation, human-robot cooperation, robotic learning, intelligent agent architectures, and robot navigation. These publications include five edited books on the topic of distributed robotics. She was awarded the 1999 DOE Office of Science Early Career Scientist Award, and the 2000 PECASE (Presidential Early Career Award for Scientists and Engineers) for her research in multi-robot systems. She also received a 2000 UT-Battelle Technical Achievement Award for Significant Research Accomplishments. In 2006, she was awarded the Angie Warren Perkins Award for scholorship, teaching, and contributions to campus intellectual life.

1.1.5 Andrew Redfern

Sentilla Corporation

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Andrew Redfern is Sr. Applications Engineer at Sentilla. Andrew leverages his real world experience with pervasive computing to develop new and innovative applications for customers worldwide.
Prior to Sentilla, Andrew worked as a Wireless Sensor Networks researcher in the Berkeley Manufacturing Institute (BMI) under the supervision of Prof. Paul Wright. At Berkeley, Andrew was the lead architect for the Fire Information and Rescue Equipment (FIRE) Project. Working closely with the Chicago Fire department, the team developed a first-responder tracking and communication system to assist firefighters with emergency building evacuation.
Andrew RedfernAndrew has worked on numerous other pervasive computing projects, including projects focusing on the developing systems to help conserve energy in the home and industrial environments through the use of self-powered wireless sensor networks and advanced control systems.
Andrew holds B.S. in Electrical Engineering and Computer Science from the University of California, Berkeley

1.1.6 Paolo Santi

University of Pisa

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Paolo Santi received the Laura Degree and Ph.D. degree in computer science from the University of Pisa in 1994 and 2000, respectively. He has been researcher at the Istituto di Informatica e Telematica del CNR in Pisa, Italy,since 2001.
During his career, he visited Georgia Institute of Technology in 2001, andCarnegie Mellon University in 2003. His research interests include fault-tolerant computing inmultiprocessor systems (during PhD studies), and, more recently, the investigation offundamental properties of wireless multihop networks such as connectivity, lifetime,capacity, mobility modeling, interference modeling, and cooperation issues. He has contributedmore than 40 papers and a book in the field of wireless ad hoc and sensornetworking.
Dr. Santi has been General Co-Chair of ACM VANET 2007, will serve as General Co-Chair of ACM VANET 20008, and hasbeen involved in the organizational committee of several conferences in the field. He has also beenmember of the technical program committee of major networking conferences, including ACMMobiHoc, ACM SenSys, IEEE Secon, IEEE ICDCS, IEEE Globecom, and IEEE DSN. Dr. Santi is Associate Editor of IEEE Transaction on Mobile Computing since2008, and he is a senior member of ACM and SIGMOBILE.

1.1.7 Dan Stilwell

Virginia Tech

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Daniel J. Stilwell is Associate Professor at Virginia Tech. He is affiliated to the research group Autonomous Systems and Controls Laboratory.
Dan Stilwell obtained a Ph.D. title in Electrical Engineering from Johns Hopkins University, in 1999, an M.S. title in Electrical Engineering from Virginia Tech in 1993, and a B.S. title in Computer Engineering from the University of Massachusetts in 1991.
His teaching interests include linear and nonlinear control systems and robotics. His research interests cover Control for cooperating dynamic systems, Autonomous underwater vehicles and Nonlinear control theory.

1.1.8 Craig Woolsey

Virginia Tech

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http://www.aoe.vt.edu/research/groups/nsl/
http://www.unmanned.vt.edu/

Craig Woolsey is an associate professor in Virginia Tech's Aerospace and Ocean Engineering department. He received a bachelors degree in mechanical engineering from Georgia Tech in 1995 and a Ph.D. in mechanical and aerospace engineering from Princeton University in 2001. Dr. Woolsey is a Senior Member of AIAA and IEEE.
In 2002, he was granted the National Science Foundation CAREER award and the Office of Naval Research Young Investigator Program Award. He was named a Virginia Tech College of Engineering Faculty Fellow in 2003. Dr. Woolsey's current research interests include nonlinear control theory, energy shaping control methods, and control of autonomous systems, such as autonomous marine and air vehicles.
For information concerning Dr. Woolsey's past and current research, visit the Nonlinear Systems Laboratory web site. Also, see the Virginia Center for Autonomous Systems (VaCAS) web site.

1.2 PhD Students

1.2.1 Energy-Efficient Schedule Based Routing Protocol for Application with Periodic Data Traffic

Keywords:
routing protocols
wireless sensor network
cros-layer design
environmental monitoring

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I am working on developing routing protocols for Wireless Sensor Networks (WSN). I have developed two energy-efficient data forwarding protocols for WSN; Energy Efficient Distributed Schedule Base protocol (EEDS), and a Generalized-EEDS (GEEDS). Both protocols are intended for applications with periodic data traffic such as environmental monitoring. They intend to increase the lifetime of the network by decreasing the energy consumption in sensor nodes. Energy consumption is minimized by optimally designing a distributed schedule for waking up sensor nodes. Cross-layer design methodology is implemented to develop the proposed protocols. based on the application, network and MAC layers are integrated to build a tree from all nodes towards the sink.
Performance evaluation shows that the developed protocols outperform the operation of some existing protocols in the context of network lifetime, throughput, total consumed energy, and information throughput[1]. based on this research, in addition to two published conference papers[1][2], other two journal papers are submitted and they are currently under review. I am now working on developing analytical formulation for the proposed protocols. Analytical formulation is useful to optimize the proposed protocols.
Meanwhile, I am now working within a team in a project to develop a WSN test bed for some environmental applications. this project is fundued by KAUST[1]. In this project we will use TELOS mote from Crossbow to build WSN to monitor enviroment in a specific region. We select real application from industry. We visit some local company such as ARAMCO[2], and we discuss with them their needs. We use TinyOS to build our protocols. In addition to design the protocols, my job is to write the codes using nesc language and then programming the TELOS motes . We start with SurgeTelos application, and then we will integrate our own routing protocol into SurgeTelos application.

[1] T. Alkhdour and U. Baroudi. An entropy-based throughput metric for fairly evaluating wsn routing protocols. *The proc. of the Fifteenth IEEE International Conference on Network Protocols, ICNP2007*, pages 342–343, 2007.

[2] T. Alkhdour and U. Baroudi. A generalized energy-aware data centric routing for wireless sensor network. *The Proc. of The 2007 IEEE International Conference on Signal Processing and Communications (ICSPC 2007)*, 2007.

[1] Webpage: `http://www.kaust.edu.sa/`
[2] Webpage: `http://www.saudiaramco.com/`

1.2.2 People detection in challenging real world scenes

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Localization of human victims is essential part of operation in any search and rescue scenario. In my work I develop computer vision algorithms which will enable autonomous robots to detect victims in difficult cluttered scenes, estimate their pose and track their position over time. We envision that our methods will enable not only search of the victims but also assessment of their state using pose estimation and motion cues.

In our recent work we have followed the local-feature based approach to object detection which has proven to be especially robust to significant occlusions and clutter. We have also demonstrated that our model can be extended to the setting where not only single images but a video stream is available. In such case we are able to include the temporal information by introducing the prior which jointly models poses of the people and their motions. Knowledge of the object pose allows us to extract object specific appearance model and use it to find a particular person in subsequent images even if it was occluded for significant period of time. Such object specific models could be used in search and rescue operations by first learning person specific models from surveillance videos and using this knowledge for confirmation or rejection of the hypothesis generated by autonomous vehicles performing search in the area.

Currently we are working on the extension of our detection method to arbitrary human articulations, which is a particularly difficult problem and is not solved by any of the state-of-the-art computer vision algorithms. The main challenge is to deal with extreme complexity of the pose space and variability in the people appearance. Again we would like to pursue approach in which we cope with pose space complexity by decomposing object into set of rigid components which are combined together using probabilistic spatial model. In our present work we are evaluating different methods for object-part detection and plan to integrate our method into victim detection system combined from unmanned aerial vehicle carrying the camera and ground station performing most of the computations.

1.2.3 Distributed self-Healing algorithms for mobile sensor networks

Keywords:

ad-hoc networks
sensor network
mission critical networks
distributed recovery
medical and emergency application

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My research of interest includes wireless sensor and actor networks, wireless ad-hoc networks, wireless networking, and radio resources management
Currently, I am focusing on wireless sensor and actor networks applications in monitoring applications as well as mission-based networks.
Methodology of my current research activities:
Considering a mission-based network such as swarm members, the nature of the problem imposes the ad-hoc paradigm for the communication among these robots. These robots will form an ad hoc infrastructure to facilitate performing tasks in a distributed manner. This ad hoc network structure has unique characteristics that should be taken into consideration when we design our complete system to perform a specific mission.
The literature is rich in algorithms and proposals that are designed to tackle the above requirements. However, most of these protocols are designed to be completely transparent to applications which impose sever restrictions on the exchanged information between the application and the network. The matter of fact is that the cooperation in the robotic environment is vital to the success of the whole mission . Appropriate access and routing protocols will be selected / developed to achieve the task requirements focusing on distributive and cooperative and energy saving approaches.

[1] T. Al-Khdour and U. Baroudi. An energy-efficient distributed schedule-based communication protocol for wireless sensor networks. *submitted to Springer's Journal on Wireless Networks*, June 2007.

[2] Prithwish Basu and Jason Redi. Movement control algorithms for realization of fault-tolerant ad hoc robot networks. *IEEE Network*, 18(4):36–44, 2004.

[3] S. M. Das, Y. C. Hu, C. S. George Lee, and Y.H. Lu. Supporting many-to-one communication in mobile multi-robot ad hoc sensing networks. *International Conference on Robotics & Automation, New Orleans*, pages 659–664, April 2004.

[4] Christine E. Jones, Krishna M. Sivalingam, Prathima Agrawal, and Jyh Cheng Chen. A survey of energy efficient network protocols for wireless networks. *Wirel. Netw.*, 7(4):343–358, 2001.

[5] B. S. Pimentel and M. F. M. Campos. Cooperative communication in ad hoc networked mobile robots. *Proc. of IEEE/RSJ int. Conference on Intelligent Robots and systems, Las Vegas, Nevada*, pages 2876–2881, Oct. 2003.

[6] A. Shanyour and U. Baroudi. Bypass aodv: Improving performance of ad hoc on-demand distance vector (aodv) routing protocol in wireless ad hoc networks. *submitted to IEEE transaction on Wireless Communications*, Feb. 2008.

1.2.4 QoS Routing in Ambient Intelligence Networks

Keywords:

routing
ad-hoc
wireless
quality-of-service
MAC
ambient intelligence

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My research interests cover the area of mobile wireless ad-hoc sensor networks, in particular, I'm working in the field of quality-of-service routing. For my studies, I focus on the ambient intelligence/pervasive computing domain, which aims to improve everyday life activities through the application of additional computing devices. In this domain, only very scarce energy, network, and platform resources are available due to size of network nodes. Thus, I'm concentrating on lightweight routing protocols with QoS support and low resource requirements to be deployed on mobile motes; currently I'm using MicaZ and Imote2 nodes for my research.

Starting with my diploma thesis, I'm in a team that works on a novel QoS mac layer, MacZ [1], for multi-hop wireless sensor networks including tick synchronization, medium slotting, and contention-based as well as contention-free medium access. Based on MacZ, we are researching upper layer protocols that yielded CatS, a first prototype of our communication stack, which offers reservations and QoS routing in wireless multi-hop networks.

We develop our protocols using a tailored model driven development approach based on SDL [2] that facilitates rapid prototyping on simulated and real hardware. Simulated deployments are created by coupling several specialized simulators (e.g. *ns*+SDL [4]) semantically at runtime using our PartsSim simulation framework [3]. This enables us to test protocols in simulated and real deployments with very high credibility.

[1] P. Becker, R. Gotzhein, and T. Kuhn. MacZ – A Quality-of-Service MAC Layer for Ad-hoc Networks. In *Proc. of 7th Conference on Hybrid Intelligent Systems*, Kaiserslautern, Germany, 2007.

[2] ITU-T Recommendation Z.100 (11/99). *Specification and Description Language (SDL)*. International Telecommunication Union (ITU), 1999.

[3] T. Kuhn and P. Becker. A Generic Framework for the Accurate Simulation of SDL Models. In *Proc. of 5th SAM (SDL And MSC) Workshop*, Kaiserslautern, Germany, 2006.

[4] T. Kuhn, A. Geraldy, R. Gotzhein, and F. Rothländer. *ns*+SDL - The Network Simulator for SDL Systems. *SDL 2005: Model Driven*, pages 103–116, 2005.

1.2.5 Optimal Trajectory Generation with applications to Robotics and Air Traffic Control Problems

Keywords:
optimal control theory
calculus of variations
robotics
free flight air traffic control.

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I'm a PhD student at the University Rey Juan Carlos (Madrid), Department of Statistics and Operations Research. I'm working on the problem of generating trajectories for a set of autonomous systems operating in the same space such as robots and aircrafts using Optimal Control Theory.

Firstly, I'm focused on the motion planning problem in cooperative robotic systems where there is a collection of robots sharing the same workspace and having the task of moving from an initial position to a goal position through a continuous free-collision path (see [1] for more information).

I'm also interested in Free Flight Air Traffic Control problems. According to [3], advances in navigation systems have made possible for an aircraft to design its own trajectory avoiding other aircrafts in the airspace. In other words, this is a method that doesn't depend on air traffic controllers and relies more on pilots.

The two problems are related to each other in the sense that both can be solved using Optimal Control Theory.

Given an object together with a set of constraints and an optimality criterion, the idea is to develop a general strategy that provides the trajectory satisfying the given set of constraints and optimizing the given criterion. I solve this optimal control problem using variational calculus (see [2] for further details).

[1] J. P. Desai. *Motion Planning and Control of Cooperative Robotic Systems*. PhD thesis, University of Pennsylvania Institute for Research in Cognitive Science, 1998.

[2] J. Gregory and C. Lin. *Constrained Optimization in the Calculus of Variations and Optimal Control Theory*. Chapman Hall, 1992.

[3] G.D. Sweriduck P.K. Menon and B. Shridhar. Optimal strategies for free flight air traffic conflict resolution. *Journal of Guidance, Control, and Dynamics*, 22:202–211, 1998.

1.2.6 Navigating multi-robot systems while taking network topology and link quality into account

Keywords:
multi-robot systems
robot communication
navigation strategies
probabilistic robotics
exploration

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Controlling a multi-robot system is a very demanding task. At the moment for telecontroled robots usualy one person or two persons are needed to control a robot. I am working in a reserach group that aims to enable an operator to control more than one robot at a time. We achieve this by creating tools and intelligent assistance systems to relieve the operator from basic control tasks, but keep him informed and in control of the behavior of the multi-robot systems all the time. The tasks for the multi-robot system I am currently interested in, all have in common that they are only solvable by keeping communication between robots in mind. Some examples for these tasks are:

- Exploring unknown environments with multi-robot systems, while do not loosing contact with the control station nor between the robots.
- Covering a known or unknown area with a multi-robot system, to provide an infrastructure (e.g. wifi connection via the robots) and using the robots as a mobile sensor network
- Reconnaissance of outdoor environments with a heterogeneous multi-robot system consisting of UGVs and UAVs, while providing real time data of the situation to the control station.

To control a multi-robot system communication between the robots and between the robots and the control station is crucial. To support this communication and to fulfil different task with the multi-robot system, navigation strategies which take the network topology and the link quality into account, are important.

To solve such tasks, I am evaluating and developing new navigation strategies. From a theoretical point of view, these are algorithms working on the network graphs, and from a more practical perspective, approaches like behavior-based robotics and swarm algorithms.

My current research deals with link-quality prediction based on propagation models and on-line collected data. This will be used to gain information about how network topology and link quality will change due to the movement of the robots. The information will then be used for decisions for the robot coordination and navigation.

In addition to the research topics mention above my research interests are in multi-robotic systems, robot navigation and human-machine interaction, and also in artificial neural networks, swarming, evolutionary algorithms and learning systems.

1.2.7 Cooperative Control for Autonomous Underwater Vehicles

Keywords:
autonomous underwater vehicles
cooperative control
nonlinear systems
formation control

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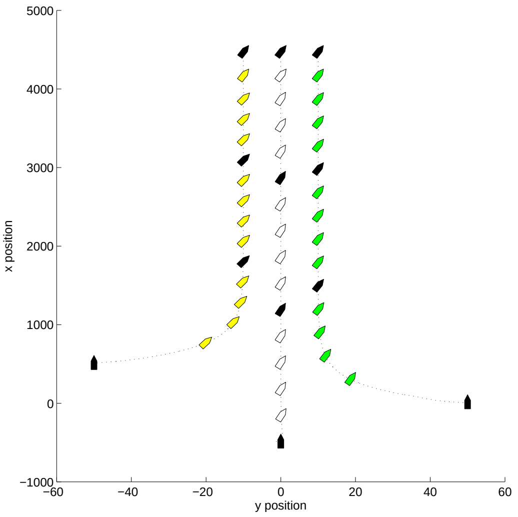
As a PhD student, I am working on a European project called FREE$_{sub}$NET. The focus of this project is the development of new standards for Intervention Autonomous Underwater Vehicles (I-AUVs). They are seen as the successors of the currently used Remotely Operated Vehicles (ROVs) in a number of tasks, but due to their autonomy they also increase the number of operations that can be done underwater (e.g. taking measurements under the ice of the polar regions, which becomes feasible since AUVs don't have a cable attached to control the vehicle).



Within this project, my focus is on obtaining control methods for groups of AUVs, thereby exploiting possible benefits of having multiple sensors (the AUVs), and making the control laws robust against communication errors, unknown disturbances (ocean currents), and modelling errors.

The figure shows three vessels converging to their desired path, and synchronising with each other to obtain their desired formation. The vessels are plotted at different time instances to show that indeed they adjust their along-path speed in order to get in line with each other. The novelty in this work [1] is that this is obtained in the presence of an unknown (and unmeasured) ocean current.

The topic of the summer school is very much in line with my research interests, since I will work with autonomous entities in a networked (formation using communication) setup. Although my focus will be on the area of underwater vehicles, the methodologies will (almost) be the same on land and in the air/ in space. Therefore I expect to be able to gain a lot of useful experience by attending the summer school, and establish contacts for possible research cooperation.

[1] M. Burger, A. Pavlov, E. Børhaug, and K.Y. Pettersen. Straight line path following for formations of underactuated surface vessels under influence of ocean currents. *submitted to the 47th IEEE Conference on Decision and Control*, 2008.

1.2.8 My Interest for Monitoring and Coordination Across Networked Autonomous Entities

Keywords:
multi-robot protocols
multi-robot architecture

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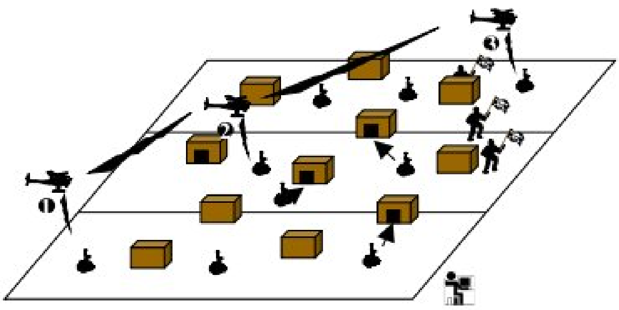
My name is Hung CAO, I'm a first year PhD student working under the direction of Prof. Rachid ALAMI[3], Associate Researcher Felix INGRAND and Prof. Simon LACROIX at the CNRS [4]. My research interest is in the multirobot cooperation, both in protocol and architecture aspect.



My work is supported by the project PEA ACTION[5] that aims to build a whole multirobot system in charge of surveillance and target tracking in a closed urban environment. The robot team is heterogeneous and is composed of 3 UAV[6] and 9 UGV [7].

This system design raises a certain number of challenges in multirobot cooperation (related to the team size, to the presence of an human operator, to the tasks specificities) that i am trying to resolve. The work has just started and the research direction is still open. However I have a rough idea about what could be my contribution. It consists in building a system for multiagent planning (extend the EUROPA planner), task allocation and task execution coordination. More precisely, it consists in proposing a multiagent planner and a efficient multiagent plan manipulation formalism (plan manipulation operators).

This summer school represents a precious chance for me to attend presentations given by very known people in the multirobot field like Prof. Parker and Prof. Santi. Discussions with them and other PhD students working on similar subjects could also be very useful.

[3] http://www.laas.fr/ rachid/
[4] Centre National de Recherche Scientifique
[5] http://action.onera.fr/
[6] Unmanned Aerial Vehicle
[7] Unmanned Ground Vehicle

1.2.9 Dynamic Robot Networks for Search and Rescue Operations

Keywords:

multi-robot teams
communication network
localization
cooperative search and rescue

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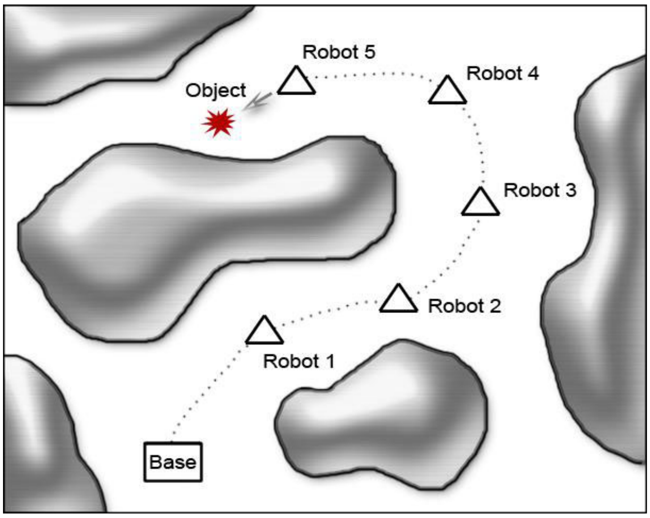

In our study [1] we focused on cooperative search by a team of mobile robots using dynamic (ad-hoc) network (communication topology). We implemented the algorithm on a set of custom designed mini-robots and compared its performance with the performance of non-cooperative search. It is observed that in the experiments performed cooperative search is faster than non-cooperative search. The focus here is on the importance of the wireless ad-hoc communication/networking in cooperative multi-robot systems . In our future researches we will extend this robotic search with relative position estimation based on RSSI(Received Signal Strength) and trilateration. Also we will measure the effects of different communication ranges on the search performance.

[1] Ömer Çayirpunar, Bülent Tavlý, and Veysel Gazi. Dynamic robot networks for search and rescue operations. In *Proceedings of the EURON/IARP International Workshop on Robotics for Risky Interventions and Surveillance of the Environment*, Benicassim, Spain, January 2008.

1.2.10 A distributed Java Virtual Machine as Programming Abstraction in Sensor Networks

Keywords:
distributed virtual machine
scalable source routing
sensor networks
ambient computing

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Sensor networks in today's research activities are seen mostly as a specialized solution that requires dedicated and explicit low-level programming. Thus many different programming abstractions exist to create software for sensor nodes. My main research interest is to combine well known features of high level programming languages with implicit network communication between sensor nodes. Particularly, I try to find answers to the following research questions. How can peer-to-peer routing algorithms serve a system that is distributed among small networked embedded systems? What performance does such a system provide especially if parts of the network are mobile and others are static? In which way programming of a distributed systems can be made easier and more intuitive by abstracting from explicit communication? Which new problems arise from applying concepts that were originally developed for powerful computers to small resources constrained devices? Other research interests include geo information systems, in particular routing and mapping of open free geo data and autonomous RC helicopter flight.

My current research activity is to develop a distributed virtual machine (DVM) for the Java language [2] under the BmBF project AmbiComp. It aims at providing a platform for ambient computing powered by networked 8-bit micro-controllers. Instances of the DVM leverage the Scalable Source Routing protocol [1] to build a fully decentralized global object space, an idea that originates from the field of cluster computing. Thus, the DVM is able to provide a single system illusion which promises to reduce the complexity of software development.

The properties of self-organisation in the DVM make it inherently suitable for swarm environments. Swarms impose exactly the requirements like mobility, communication and distributed processing AmbiComp's DVM tries to fit.

[1] Thomas Fuhrmann, Pengfei Di, Kendy Kutzner, and Curt Cramer. Pushing chord into the underlay: Scalable routing for hybrid manets. Interner Bericht 2006-12, Fakultät für Informatik, Universität Karlsruhe, June 21 2006.

[2] Bjoern Saballus, Johannes Eickhold, and Thomas Fuhrmann. Towards a distributed java vm in sensor networks using scalable source routing. In *6. Fachgespraech Sensornetzwerke der GI/ITG Fachgruppe "Kommunikation und Verteilte Systeme"*, pages 47–50, Aachen, Germany, 2007.

1.2.11 Adaptive Distributed Intelligent Observation Systems(ADIOS)

Keywords:
intelligent sensor networks
relevant communication
adaptivity
information needs
adaptive distributed intelligent observation systems

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September 2007 I started as a PhD student in September 2007 in a research group called the Centre of Intelligent Observation Systems (CIOS). I both work at the University of Amster- dam (UvA) and the Dutch Organization for Applied Scientific Research TNO. My research is called Adaptive Distributed Intelligent Observation Systems (ADIOS). A trend in observation systems for surveillance is to go from large single platform static systems to smaller, possibly mobile, systems with more adaptable complementary sensors. Approaches usually focus either on intelligent networks of relatively simple sensor capabilities and accompanying simple processing methods or on sophisticated smart sensors with ac- companying sophisticated detection, tracking and recognition algorithms connected through simple networks that are used to combine the information. Promising is the research being done on fusing measurements from sophisticated dissimilar and distributed sensors while tracking. This puts higher demands, however, on the bandwidth and latency of the network connecting them. Besides functions, like detecting unwanted behavior, tracking people in crowds or recognizing vehicles or faces, also adaptability to changing circumstances or changing information needs is desired. The requirement of optimal use of communication and processing resources and adaptability of the system calls for algorithms that are capable of selecting the most valuable measurements, originating from the local sensors, and /or adapting the processing of these measurements based on the current information needs of the system. The research focuses on investigating the applicability of various techniques and develop algorithms for a specific or limited set of specific applications. Currently I focus on networks of sensors which together keep track of an identical global state of the positions of the objects. Distributed detections of the same object can increase the quality of the position estimate. I developed a method which is able to locally determine the value of detections for the estimation of the position of the objects using information and utility theory. Only relevant detections which make up for the communication costs are communicated for updating the global state. This way the communication system can be used in an efficient way. The goal is to have the sensor network be more adaptive to different information needs of the network. Now it only focuses on position accuracy, but in the short future it should be able to switch between focusing on for example ambiguity and continuity of tracks.

This research relates to the topic of the summerschool in numerous ways. It aims on mak- ing heterogeneous, possibly mobile, sensor networks more cooperative, efficient and more adaptive to changing circumstances in the environment, in the goals of the network and the communication resources.

1.2.12 Connecting the world of sensors via Sensor Web Enablement

Keywords:

sensor
networks
virtualization
SWE

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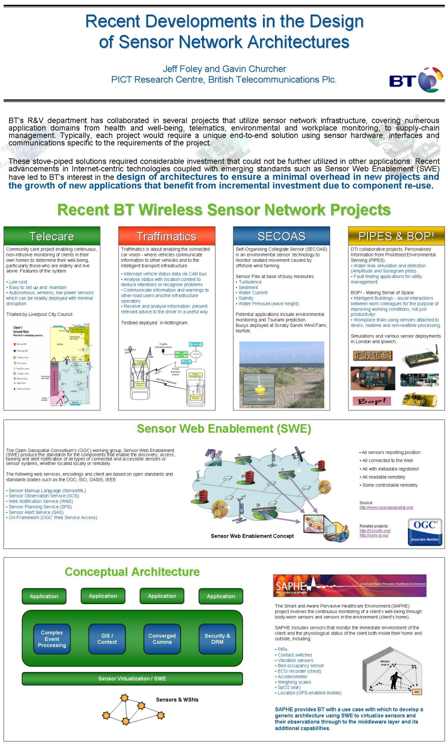

I'm a Researcher in BT's PICT Research Centre, based at Adastral Park, UK. For the last year, I've worked on the "Sensor Virtualization" Theme investigating how the Sensor Web Enablement (SWE) standards from the OGC could help streamline the creation of sensing / monitoring M2M applications. I also began an EngD at UCL entitled,"Data Fusion and Analysis in Sensor Networks and their Applications".

In 2005, I participated in the Eurescom P1555 - Sensor Telcos study with Dr. Chris Roadknight (BT), Telenor and Portugal Telecom. I have also contributed to several DTI sensor network projects, such as PIPES (Personalised Information from Prioritised Environmental Sensing) and BOP. More recently, during SenZations'07 (10-14 Sept) at Warsaw University of Technology, Poland, I presented, "Applications of Wireless Sensor Networks". I also presented a poster, "Recent Developments in the Design of Sensor Network Architectures" [2] during EuroSSC (Smart Sensing and Context) conference in Kendal, UK (23-25 Oct 2007). During a BT Workshop (Nov 2007) with 52North, who lead the development of a number of SWE specifications, SWE was applied to a BT health monitoring project, SAPHE (Smart and Aware Pervasive Healthcare Environment). This extended the functionality of the SWE specifications. E.g. mobile sensor features of interest (FoI) were required for the Body Sensor Network (BSN), in addition to the static sensors in the patient's home environment.

I presented, "BT Research's Sensor Network Projects and Experiences with SWE" at the 5th WiSIG (26 March 2008) at the National Physical Laboratory (NPL) in Teddington, UK. Finally, I co-authored a paper, "Experiences applying SWE to a practical Telecare application", [1] which details the installation and our experiences with SWE components, such as sensor observation service (SOS). The paper was presented at ISWPC (May 2008) in Santorini, Greece.

[1] G. Churcher and J. Foley. Experiences applying sensor web enablement to a practical telecare application. *International Symposium on Wireless Pervasive Computing (ISWPC) Santorini, Greece*, 2008.

[2] J. Foley and G. Churcher. Recent developments in the design of sensor network architectures. *Adjunct Proceedings Second European Conference on Smart Sensing and Context (EuroSSC) Kendal, England*, 2007.

1.2.13 Using Workflows as Programming Abstraction for Wireless Sensor and Actor Network Applications

Keywords:
programming abstractions
workflow
event detection
in-network actuation

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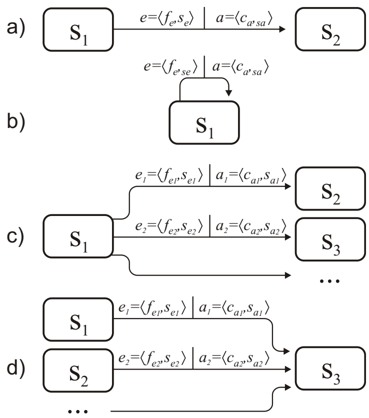
As initial challenges of Wireless Sensor and Actor Networks (WSANs) are overcome, their application possibilities evolve. There is general consensus that the existing node-level programming languages do not provide adequate abstractions to implement user applications. Different middleware approaches have been proposed to alleviate the development effort. These *macroprogramming* languages, however, mainly focus on data extraction and not on in-network actuation.

In [1], we have proposed the usage of *workflows* as a means to define the logic that orchestrates the network activity. With this abstraction, the loop of event-sensing, decision and acting can be closed, leading to a reduced need for unnecessary, slow and error-prone human intervention in the process. In this way, the whole WSAN loop can be shifted to the network. Intuitively, this approach presents a number of benefits, namely: a) faster reaction to the event, as the decision is taken closer to the point of interest; b) enhanced reliability, due to the smaller chance of losing messages in the loop sequence; and c) energy savings (i.e. extended network lifetime) for the reduced amount of messages exchanged between event sources, sinks and actuation nodes.



These benefits, however, don't come for free. For this purpose, an infrastructure must be devised which senses and generates the data that causes the state transitions in such workflow and executes its associated actions. We have already identified a minimal set of operator to compose workflows (see figure) and provided a simple execution algorithm in [1]. Our focus is now placed in defining an in-network event detection mechanism exploiting the hierarchically structure of a scoped sensor network [2]. We believe that this abstraction is of practical relevance to the WSAN practitioners while still holding promise to an in-network operation.

[1] Pablo Guerrero, Daniel Jacobi, and Alejandro Buchmann. Workflow Support for Wireless Sensor and Actor Networks. In *4th International Workshop on Data Management for Sensor Networks*, Vienna, Austria, September 2007.

[2] Jan Steffan, Ludger Fiege, Mariano Cilia, and Alejandro Buchmann. Scoping in Wireless Sensor Networks. In Nitya Narasimhan and Paddy Nixon, editors, *2nd International Workshop on Middleware for Pervasive and Ad-Hoc Computing (MPAC'04)*, Toronto, Canada, October 2004. ACM.

1.2.14 Networking Tiny Autonomous Sensors in Harsh Environments

Keywords:

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My research interests mainly lie in networked embedded systems, and particularly, wireless sensor networks. My current research focuses on robust routing mechanisms using low-power radios [1] [2]. To develop autonomous and robust network protocol that achieves sufficient connectivity among tiny sensor nodes, in spite of complicated loss conditions and technological limitations, is a very challenging task. The primary goal of such a protocol is reliable and low cost information delivery, often in terms of energy consumption per bit. Usually starting from an intuitive engineering idea, developed by mathematical modeling, a proposed protocol is then tested and refined interatively by real world evaluation, i.e. a full-scale deployment in the targeted application.
I consider the summer school's theme forms an interesting connection with my own area, and will provide inspirational ideas to extend my current research focused on monitoring of tiny sensors to more intelligent cooperation among heterogeneous devices.

[1] A. Dunkels, F. Österlind, and Z. He. An adaptive communication architecture for wireless sensor networks. In *Proceedings of the Fifth ACM Conference on Networked Embedded Sensor Systems (SenSys 2007)*, Sydney, Australia, November 2007.

[2] Z. He, A. Dunkels, T. Voigt, and N. Tsiftes. Rethinking link-level abstractions for sensor networks. In *The Second International Conference on Sensor Technologies and Applications (SENSORCOMM 2008)*, Cap Esterel, France, August 2008.

1.2.15 An Agent based Middleware Approach for Mixed Mode Environments

Keywords:
wireless sensor networks
middleware
multi-agent systems

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Mixed Mode Environments (MME) refer to networks composed of very different kinds of devices, which are distributed among various physical environments and communicate with each other using different communication technologies. The single nodes in the network can be sensors, actuators, robots, Unmanned Vehicles (UV), Human Interface Devices, Mission Control Stations, etc. All those devices have their specific capabilities and constraints. Many of these devices are manufactured by different companies and use different software and operating systems, if any. The physical environment can be indoor, outdoor, underground, underwater, etc. Those devices can communicate with each other by wire, radio, light, sound or other methods. For each of this communication methods many different communication technologies exist, which use different protocols, frequencies, encoding schemata, etc.

Nowadays application developers have to deal with the before mentioned heterogeneity when developing a new application for such a network. Each time a new kind of node appears the application has to be adjusted to deal with the new hardware. Middleware is a way to avoid this direct interaction of applications with the different hardware and software of the devices. So middleware has to abstract over all the different devices and communication technologies and to offer the applications uniform interfaces to interact with those.

Different middleware solutions already exist. Our aim is to enable interoperability among different nodes without the need of adjustments each time new hardware is introduced. The agent based approach offers an abstraction for the different hardware: it sees all the different nodes in the network as independent entities, we call them device agents. These device agents know their capabilities and constraints. Depending on its capabilities a device agent offers services to other agents and can also have tasks it tries to fulfill eventually using services of other agents. The complexity of agents running for example on a small sensor node and on an UV can vary considerably. Thus a sensor-agent might be only capable to measure the current temperature and to send it to someone who is interested in this data, whereas the UV-agent can move through the environment, collect the data from the sensor-agents, aggregate, evaluate the collected data and use the gathered information further in its decision making process.

[1] Arthur Herzog, Daniel Jacobi, and Alejandro Buchmann. A3ME - an Agent-based Middleware Approach for Mixed Mode Environments. In *UBICOMM 2008, Valencia, Spain*, to be published in September 2008.

1.2.16 Middleware for heterogeneous mixed mode Environments

Keywords:

wireless sensor networks
heterogeneity
middleware
network interoperability
disaster recovery

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Mixed mode Environments are composed out of many different devices. There are well known components like PC's, PDA's, notebooks and also special devices like wireless sensor networks (WSN) or unmanned ground and aerial vehicles (UGV/UAV). WSN's are built out of small systems with a microcontroller, a radio and other peripherals, like sensors; all this in a size much smaller than a pack of cigarettes. These sensor nodes are deployed in numbers of tens or hundreds to monitor a huge area. In contrast UxV's in general have significant computing power, comparable to a PDA or even a notebook and can move around, on the ground or flying in the air.

The scenario we are considering is a disaster recovery scenario at a chemical plant with different production lines and a deployed infrastructure to control and monitor the machinery and the environmental conditions all over the plant. After an incident, like a big fire or some explosions, a part of the existing equipment is destroyed and rescue personnel will arrive at the scenario. To get an overview of the situation and to get some more detailed information about the incident UxV's enter the area and a WSN may be deployed to monitor, e.g., concentrations of chemicals at specific locations. These devices can replace or co-exist with the pre-deployed infrastructure or bridge broken links to reconnect parts of the infrastructure. To gather information from all the deployed systems, firefighters or emergency rescue personnel can query information's with their handhelds or laptops. Firefighters or other personnel can even carry sensor nodes, to get sensor data from the vicinity of active personnel.

To be able to communicate with these different kinds of systems, not only the physical connectivity is important to integrate, e. g., a notebook and nodes from a wireless sensor network. A message has to traverse different kinds of wireless physical media, and routing schemes, different operating systems, using probably different programming languages. So to ease the development of applications for such a heterogeneous environment the development of a middleware that can be used on all of these systems is vital.

1.2.17 Aquatic Monitoring Network Using Cooperative Robots and Bouys

Keywords:
aquatic monitoring network
solar-powered
amphibian
robotics
novel design
environment protection

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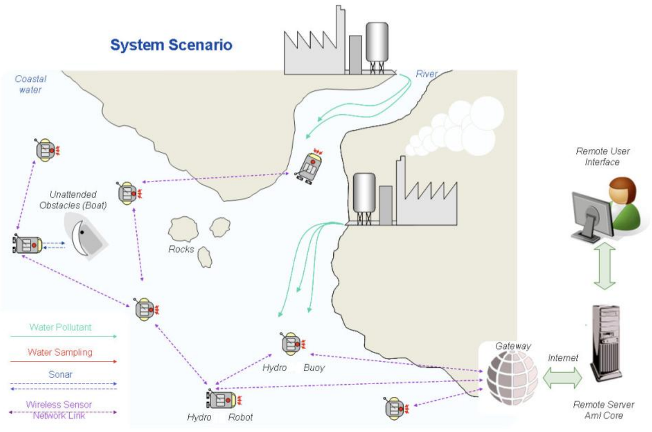
My research interests include underwater robotic robot cooperation, environmental monitoring and surveillance, underwater navigation, amphibian locomotion, wireless sensor network and so on.



The problem of monitoring environment to guarantee its integrity is recognized as one of the urgent issues to be addressed in the near future. Thanks to recent advancements in technology, the use of autonomous, inexpensive, dynamic sampling systems, potentially cooperating in a network, appears to be a feasible solution for such purpose.

Since 2007, I have been working in a research group trying to develop an aquatic monitoring network, primarily composed by robotic and stationary sensing nodes, which is promising substitution to the currently used buoyed devices, research stations and vessels through offering more widespread samplings, giving better synoptic views of water parameters, with less investment in human resources and facilities with respect to traditional methods.

Currently, we are working on a robotic platform designed to be a floating mobile sampling node for this aquatic monitoring network: the robot is solar-powered, amphibian and modularized. So far, we have developed the first prototype of the robotic platform to evaluate the novel design and the practicality of amphibian locomotion, field navigation, solar energy acquisition and other issues.

Therefore, the strong match between my work and the summer school topic "Monitoring and Coordination Across Networked Autonomous Entities" is obvious. I am particularly interested in the content of coordination (or cooperation) among heterogeneous platforms and the adaptive and responsive monitoring when facing complex target dispersion, since they are key issues to be solved in the next stage of our project.

1.2.18 Energy mangement on sensor nodes

Keywords:
energy management
MicaZ
Imote2
SDL
XEEMU
.

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My current work is based on sensor nodes like the MicaZ or the Imote2. The key challenge for my work on both nodes is the limited energy ressource. In [1], I showed a few meassurements on battery power and power consumption of the MicaZ node. As a surprise, the power consumption in receive mode was even higher than in transmit mode. Therefore new protocols coping this problem were developed in my workgroup. For our work, on specifying protocols, we use the high level specification language SDL. With this language we specify behavior and can directly generate code for the target plattform. To allow this transpilation additional hardware specific code for the target platform is needed.

Lately we've changed the sensor platform to the more powerful Imote2, since the memory of the MicaZ (4kB) was too small to add specialized protocols, new routing algorithms and an audio-communication system. Moreover this change allows us, to use our own transpiler ConTraST to transpile SDL to C++ code. Using our own transpiler allows us to make modifications, annotations to SDL and use this to generate new code.

In [2], a first approach on modelling and saving energy in SDL was presented. Most communication techniques, like the transceiver or the serial interface are, if enabled, in receive mode and prevent the device from sleeping and saving energy.

As appliance I participate in the new DFG-Project SPP-1305, which tries to couple control theory and communication. We want to do this by specialized protocols for communication and routing on the Imote2 platform. To get reliable and reproduceable results we couple our NS+SDL-simulator with the XScale simulator XEEMU and the control system simulator Matlab/Simulink. In all these projects my objective is to reduce power consumption and take remaining battery power into account to the features of the device.

[1] Marc Krämer and Alexander Geraly. Energy Measurements for MicaZ Node. In *5. GI/ITG KuVS Fachgespräch "Dahtlose Sensornetze"*, pages 61–68. Pedro José Marrón, 2006. Technischer Bericht.

[2] Marc Krämer and Alexander Geraly. Energieoptimiertes Scheduling für Mikrocontroller mit SDL. In *GI/ITG KuVS Fachgespräch "Systemsoftware und Energiewusste Systeme"*, pages 16–20. Prof. Dr. Frank Bellosa, 2007.

1.2.19 Wireless Network Architecture for Distant Diagnosis and Surveillance

Keywords:

wireless network architecture
condition monitoring
distributed diagnosis
autonomous systems
heterogeneous networks
windmill parks etc.

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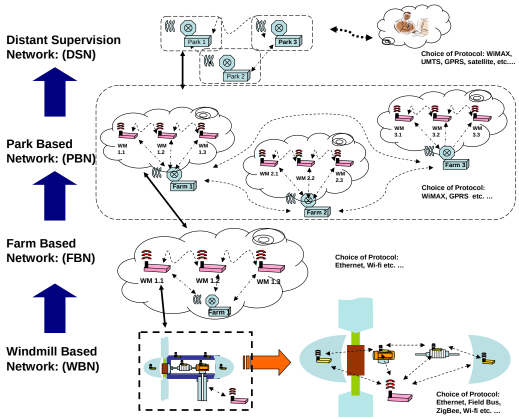

The aim of our project is to develop a distributed wireless network architecture for remote diagnosis and monitoring of critical systems at long distances [3]. A distant, distributed Windmill Energy Conversion System (WECS) is considered as a target application [4], which is grouped into small clusters of windmills communicating with each other for the purpose of cooperative, adaptive and responsive monitoring using networked, autonomous entities [2]. This includes diagnosis, control and FDI for optimal performance. A part of intelligent decision making would be available at each segment, communicating over wireless network. The distant operator/supervisor (static or mobile) will stay in contact by exchanging diagnostic and control information at long distance.

The coexistence of different wireless communication protocols will allow exchange of critical data in a heterogenous network with strict requirements on availability, robustness, reliability and performance. The quality of service (QoS) issues have to be solved for communication in a heterogenous environment [1]. The intelligence at each communication level is assigned based on the criticity of the information and the computational power available. Real time network scheduling and control for dynamic priority of data throughput, due to limited bandwidth, would enhance reliability of the communication network.

[1] A. Garibbo, M. Marchese, and M. Mongelli. Mapping the quality of service over heterogeneous networks: a proposal about architectures and bandwidth allocation. *IEEE International Conference on Communications, ICC '03, Marconi Selenia, Genova, Italy*, 3:1690– 1694, 2003.

[2] F. Salvadori, M. de Campos, R. de Figueiredo, C. Gehrke, C. Rech, P. S. Sausen, M.A. Spohn, and A. Oliveira. Monitoring and diagnosis in industrial systems using wireless sensor networks. *IEEE International Symposium on Intelligent Signal Processing, WISP 2007*, pages 1–6, 2007.

[3] V. Särkimäki, R. Tiainen, J. Ahola, and T. Lindh. Wireless technologies in condition monitoring and remote diagnosis of electric drives; requirements and applications. *European Conference on Power Electronics and Applications, Dresden, Germany*, 2005.

[4] Chen Wang, Liming Wang, Libao Shi, and Yixin Ni. A survey on wind power technologies in power systems. *IEEE Power Engineering Society General Meeting, FL, USA*, pages 1–6, 2007.

1.2.20 Simple Multi-degrees of Freedom Optoelectronic Control of an Wheelchair for Quadriplegic Patients

Keywords:
3D positioning
autonomous systems
control devices
microprocessor-based control
optoelectronic control
control of an wheelchair for quadriplegic patients

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Research interests

- Optoelectronic control devices for the positioning of an object in the 3D environment.
- Digital image processing.
- Microprocessor-based control of autonomous mobile robotic systems.
- Aplication of Field-programmable gate arrays in robotic systems.
- Aplication of Evolutional algorithms in robotic systems and image processing.

The control device consists of the digital camera and structured light source, for example diode laser module with Diffractive Optical Element. The robust algorithm is used for the analysis of the light spots positions. Multi-degrees-of-freedom information is computed for the control of the mobile robotic system and a sequence of multi-degrees-of-freedom information is analysed. Learning database and evolution algorithm are used as a support for the control algorithm.

Advantages are low cost, efficiency, visual feedback and inspiration by natural human behavior. Evaluating algorithm are implemented in Matlab and executive algorithms will be implemented in the Field Programmable Gate Array (FPGA) with the Very High Density Hardware Description Language (VHDL).

1.2.21 Deployment support for Real-Time communication in Wireless Sensor and Actuator Networks

Keywords:
wireless sensor and actuator networks
real-time communication
quality of service

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Future communication systems can be characterized as Mixed Mode Environments (MMEs), i.e., they consist of entities such as autonomous robots, heterogeneous sensor nodes that facilitate environment monitoring and control services, as well as all sorts of network nodes. Disaster recovery scenarios are one use case for such MMEs, which provide support to the traditional human based rescue chain. Coordinated cooperation of robots combined with data acquisition from various types of sensors demands for a reliable communication among all networked entities.

Due to the absence of network infrastructure it is foreseen that robots can directly support the instantaneous deployment of a communication infrastructure. Networked robots can either directly relay data packets and become part of the infrastructure or deploy wireless nodes at the most suitable positions to set up a multi-hop communication chain, connecting the sensors and other network entities to the mission control center. In the addressed scenarios certain communication services, which are based on the spontaneously deployed network infrastructure, require strict quality of service guarantees. For instance real-time sensing of data delivery. Moreover, applications in the emerging field of networked controlled system (NCS) or critical cyber-infrastructures require tight service bounds to ensure close loop stability for the control task of remote actuators. Recent advances in the area of ad hoc networks have shown, that holistic approaches, combining routing mechanisms with packet scheduling and coding in reservation based TDMA systems, can provide quality of service guarantees on the network level. However, these mechanisms suffer from their high complexity. Also, the robustness of the communication system in case of unreliable exchange of signalling messages has not been addressed properly yet. We propose to exploit the additional degree of freedom that can be introduced by mobile robots, which allow to change the network topology intentionally. As a result the reliability of the individual network links can be improved, thus facilitating a more stable network. Towards this end, we follow a cross-layer approach that jointly considers geographic and mobility aspects; we investigate mechanism for optimal node placement and /or robot movement. Also communication aspects spanning the physical layer, link layer, network layer and middleware aspects to provide the demanded service guarantees are to be researched.

1.2.22 Cooperative Control of Heterogeneous Dynamic Systems

Keywords:

cooperative control
heterogeneous
underactuated
and nonholonomic systems
passivity
robotics

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Cooperative control of multi-vehicle systems is a rapidly evolving field of research combining different fields, such as graph theory, control theory and robotics. The main goal is to solve a global task based on local knowledge by information sharing and distributed computing. As the information flow between the agents plays a crucial role in the system regarding the stability of the solutions of the task etc. (see [2]), the network topology, i.e. the spatial distribution of the agents, is of a primer interest. Depending on the distribution of the agents in the environment or on the environment itself some may not be able to communicate with each other, i.e. no information is exchanged. Therefore, we would like to control the network topology (in the sense of a loose formation control) such that joint connectivity is guaranteed at all times in order to be able to share information and achieve the global task.

Since each agent is regarded as a mobile node, a mathematical description of its dynamics is needed, resulting in a nonlinear ODE model for the dynamics of the whole group. Hence, an effective nonlinear control scheme is required to achieve group coordination. The problems achieving this goal are manifold and may not all be considered in one work, but considering different robotic vehicles as agents in the group gives rise to some specific problems, namely: (I) Much has been said about the cooperation of homogeneous systems in literature, but only some approaches exist regarding heterogeneous dynamics of the agents; (II) Typical autonomous robots, e.g. cars, ships, helicopters, are underactuated systems, i.e. they have less controls than degrees of freedom, many of the existing methods fail for those systems; (III) Willing to apply the control algorithms to real systems they need to be computationally efficient and robust to communication problems.

Hence, we focus on a methodology based controller synthesis able to overcome these problems. As a starting point we take a passivity based approach, as in [1], and try to expand it to underactuated systems. The resulting controllers should be quite robust to communication challenges and should narrow the information exchange down to a minimum required.

[1] Murat Arcak. Passivity as a design tool for group coordination. *IEEE Transactions on Automatic Control*, 52(8):1380–1390, 2007.

[2] J. Alexander Fax and Richard M. Murray. Information flow and cooperative control of vehicle formations. *IEEE Transactions on Automatic Control*, 49(9):1465–1476, 2004.

1.2.23 Coordination in Mixed-Mode Environments

Keywords:

distributed systems
byzantine fault-tolerance
atomic broadcast
state-machine replication

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Mixed Mode Environments (MME) are characterized by the heterogeneity of their components in terms of resources, capabilities, and connectivity. The challenge is to provide dependable coordination among a wide range of different machines reaching from simple sensor nodes to autonomous vehicles. Large distributed systems such as MMEs provide means for enhancing the resilience of services through replication. We propose a composite protocol for state machine replication called Collision-Resistant Fast Paxos (CoReFP) that allows for deciding on the quickest outcome of the two protocols Classic Paxos (CP) [2] and Fast Paxos (FP) [3].

To evaluate the latency of our protocol, we describe the communication patterns of CP and FP: In CP, only the leader proposes commands. The clients ask the leader to propose commands on their behalf. A command is chosen if $\lceil \frac{n+1}{2} \rceil$ acceptors (out of n) have voted for that command. In FP, every client proposes commands directly, bypassing the leader. A command is chosen if $\lceil \frac{3n+1}{4} \rceil$ acceptors have voted for that command. In both protocols, some nonfaulty learner must eventually learn every command chosen. As all-to-all communication has been found inappropriate in heterogeneous networks [1], instead of having the acceptors directly send their votes to the learners, the votes are aggregated by the leader into a single message that is forwarded to all learners. In comparison to LANs, replication in MMEs incurs the cost of high link latency and variance. Thus, optimizing for response time becomes a challenging issue. On one hand, a high link latency requires reducing the number of communication steps, suggesting the use of FP to save one step. On the other hand, a high link variance suggests that outlier nodes in the critical path significantly increase response time. Thus, in order to reduce the likelihood of outlier nodes being critical, the set of nodes witnessing the decisions taken by the leader must be small, preferring the use of CP to that of FP.

In summary, both FP and CP have their merits and complement each other in a MME setting. This suggests that combining CP and FP into a single protocol CoReFP allows obtaining a solution satisfying the requirements imposed by a heterogeneous environment.

[1] I. Keidar and A. Shraer. How to choose a timing model? In *Proc. of DSN*, pages 389–398, 2007.

[2] L. Lamport. The part-time parliament. *ACM Trans. Computer Systems*, (2):133–169, 1998.

[3] L. Lamport. Fast paxos. *Distributed Computing*, 19(2), 2006.

1.2.24 Cooperative Mission Planning for a Group of Autonomous Unmanned Vehicles

Keywords:
unmanned vehicles
mission planning
distributed control
probabilistic reasoning

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The interest in unmanned autonomous vehicles has grown significantly during the last few years. Especially groups of aerial vehicles (UAVs) can be used for many tasks which include surveillance, exploration and mapping as well as search and rescue missions. They compete with networks of stationary sensors on the one side and manned vehicles on the other.

The Institute of Flight Systems and Automatic Control has developed a wheeled car and a quad-rotor aircraft as UV demonstrators, which offer great possibilities for further research. While manual control or simple waypoint navigation can be considered as solved, there still exist many challenges on the way to a fully autonomously operating vehicle like a reliable obstacle detection and avoidance, cooperative mission planning and intelligent distributed control mechanisms, which are able to deal with high uncertainties in localization and perception and unforeseen communication failures. Operating UAVs in public airspace makes further demands on sense and avoid capabilities and requires knowledge about air traffic control structures.

In my recent work I developed a general approach for scheduling linear and nonlinear measurements in wireless sensor networks which optimizes the information gain while considering energy and communication constraints in the presence of uncertainty. These concepts can partly be adapted to groups of vehicles to make them capable to find an optimal trajectory and configuration given one or several high-order mission objectives. As efficiency is always a topic, it is crucial to combine methods from control theory, probabilistic reasoning, machine learning and distributed intelligence to reach a high degree of autonomy and reliability while simultaneously optimize the energy and time consumption. Additionally, even if a fully autonomous operation may be desirable from an engineer's point of view, imperfect sensor readings and acceptance of unmanned flying robots in the public, make it necessary to integrate a human operator, who is able to monitor the vehicles' state and react on unexpected situations, especially in urban areas.

As a prerequisite, a flexible and reliable communication framework is needed for sharing information about the environment and coordination of the individual plans. For this reason our working group uses a combination of small radio devices based on the ZigBee standard for the reliable transfer of small data snippets for monitoring and control purposes and a conventional 802.11 wireless network for transmitting high-volume data, e.g. video signals.

Last but not least the adaptation of the developed methods for cooperative control of multi-agent systems to future air traffic management concepts in manned aviation could be a interesting field of investigation.

1.2.25 Simulation and Analytic Evaluation of Fault Tolerance Measures of Distributed Systems

supervised be Prof. Dr.-Ing. Oliver Theel and Prof. Dr. Ernt-Rüdiger Olderog

Keywords:
fault tolerance
simulation
multiobjective optimization
probabilistic model checking
wireless sensor network

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During my master thesis I implemented a simulator for self-stabilizing distributed algorithms called *SiSSDA* to determine fault tolerance measures. My supervisors and I presented the results at the 41^{st} Annual Simulation Symposium (AnSS41) in Ottawa, Canada [2]. This work was relevant in reference to support theoretical methods [1] presented by my supervisors earlier. After graduating with a diploma in computer science I was employed as research assistant at the transregional DFG-funded project *Automatic Verification and Analysis of Complex Systems* (AVACS) where I investigated coupling the probabilistic model checker *PRISM* with a multi-objective optimizer to derive *Pareto fronts* which show optimal tradeoffs between contradicting objectives.

The object of my current research is *unmasking fault tolerance*. During my research I experiment with distributed systems to find a possibility for scaling them between *masking* and *nonmasking fault tolerance*. As I just started my work I am highly interested in acquiring more expertise in the field of distributed systems, especially wireless sensor networks (WSNs). This class of distributed systems in particular are in the focus of the practical part of my work as they cover a large field of application, are widely accepted in literature and comfortably comparable to abstract models. Hence, I am eager to gain a deeper insight in their fundamentals, their behavior and the correct art of monitoring. WSNs are a designated model to exemplify the methods I develop and further background will be precious for the development of my thesis.

I am certain that I will benefit from this summer school as it covers my interests perfectly.

[1] Abhishek Dhama, Oliver Theel, and Timo Warns. Reliability and availability analysis of self-stabilizing systems. In *SSS '06: Proceedings of the Eighth International Symposium an Stabilization, Safety, and Security of Distributed Systems*, pages 244–261, Dallas, Texas, USA, 2006.

[2] Nils Müllner, Abhishek Dhama, and Oliver Theel. Derivation of Fault Tolerance Measures of Self-Stabilizing Algorithms by Simulation. In *AnSS '08: Proceedings of the 41st annual symposium on Simulation*, Ottawa, Ontario, Canada, April 2008. IEEE Computer Society Press.

1.2.26 Towards a FIPA Compliant Multiagent Based Middleware for Wireless Sensor Networks

Keywords:
FIPA
multiagent systems
middleware
Wireless Sensor Networks
Proximate Environment Monitoring

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Wireless Sensor Networks (WSNs) are composed of tiny nodes that have sensing, processing, and wireless communication capabilities. Their use is increasing in many spheres of human activity including, but not limited to, environmental monitoring, health-care, natural habitat monitoring, agriculture, military, pervasive computing, ambient intelligence etc. As is true of any new technology, their rapid acceptability is also occasionally marred by technical difficulties arising due to the specific requirements posed by different application scenarios. For instance, in industrial setups like underground mines, it is very difficult to ensure the connectivity of the deployed WSN due to the geometry of these underground structures. This difficulty in wireless communication underground, coupled with inherent problems of node failures due to running on low battery power, results in partitions in the deployed WSN. Additionally, in almost all industrial setups, it is one of the basic worker safety issues to ensure a safe working environment for the workers. Therefore, enabling the workers in such industrial setups to know different environmental parameters such as temperature, humidity, concentration of different gases etc. around their workplace is of paramount importance. We refer to this requirement as Proximate Environment Monitoring (PEM).

There are several other requirements in underground mining as well as other industrial scenarios that we are considering for our proposed solution which is based on Multiagent paradigm. There have been some useful contributions like Agilla [2] in this regard but theses solutions lack not only on the reliability of agent-to-agent communication but also on the standards compliance front. Our solution supports mobile base stations that could be carried by the miners in an underground mine. We would like to mention here that agents are a form of distributed code processes that can communicate using different paradigms. They communicate through asynchronous message passing in our proposed middleware architecture which is very closely aligned to the Foundation for Intelligent, Physical Agents (FIPA) standards [1]. This standards compliance feature would help in promoting interoperability between different agent based systems for WSNs. Consequently, the messages that agents exchange, in our middleware solution, follow the FIPA specified Agent Communication Language (ACL) standard.

[1] FIPA. Abstract architecture specifications at http://www.fipa.org. December 2002.

[2] C.L. Fok. Agilla: A mobile agent middleware for wireless sensor networks at http://mobilab.wustl.edu/projects/agilla/.

1.2.27 Automation of Transportation Tasks in Hospitals: Key Technical Issues To Be Solved

Keywords:

Mobile Robots
hospital logistics
asset tracking

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Hospitals have to deal with a heavy load of traffic on a daily basis in order to maintain the level of the basic patient care they have to provide. A complex flow of goods with varying sizes, weights and importances has to be coordinated inside the hospital, which has been traditionally carried by human porters. Due to several factors, including the increasing numbers of patients and running costs ,and decreasing number of available skilled personell makes the situation neither feasible nor sustainable (The analysis of the situation had been given in[1]) It is evident that at least a portion of these supporting services has to be automated which will consequently enable the staff to spend more of their time with directly patient related tasks, rather than, i.e. carrying specimens.

The PhD project that I am involved in deals with identifying the key technical issues that hinders the automation of transportation tasks in hospitals, from a product design perspective. One aspect of the project is to propose a design solution for transporting small sized cargos with autonomous robots. Transportation being their main function, these robots should also provide surveillence, remote presence, asset tracking and monitoring. In order to optimally solve the above mentioned logistic problem, these robots should act cooperatively, not only with each other, but also with other entities in the hospital; which brings up the other aspect of the project.

Hospitals are among the foremost technology adapting public institutes, due to the critical nature of the services they provide. Most of the modern hospitals already employ technologies such as patient/personell tracking systems, automatic doors and gates, or closed circuit camera networks; to assure effectivity of their operations. Furthermore, new or renovated hospitals put even more emphasis on the networkability of such systems and the 'smartness' of the buildings. The project aims to first identify the already existing networked entities or propose such technologies, and then exploit their potential to successfully integrate such a robotic courier team.

The expected outcome of the project is a blueprint of an automated and optimized hospital transportation system which adresses several issues around the fields of autonomous robotics, logistics, automation, human robot interaction and mechatronic product design.

[1] Ozkil A., Dawids S., Fan Z., and Sorensen T. Design of a robotic automation system for transportation of goods in hospitals. In *Computational Intelligence in Robotics and Automation, 2007. CIRA 2007. International Symposium on*, volume 20, page 392/397, 2007.

1.2.28 A Framework for End-User-Requirements-Driven Design and Developement of Wireless Sensor Networks

Keywords:
sensor networks
deployment
usability
framework
components

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During my undergraduate studies I was interested in a wide variety of topics in the domain of computer science. I was especially interested in the deployment of cognitive models to improve the usability and safety of technical systems. Lately, my focus shifted towards networked and distributed systems. In my PhD thesis I am focusing on methods to simplify the deployment of sensor networks.
Despite large research interest in sensor networks, their adoption outside of the scientific community is still limited. In the past years a wide variety of specific algorithms and technical means have been proposed to solve particular aspects of sensor networks [1]. The required knowledge is far beyond what can be expected from the envisioned end-users, who are assumed to be experts in their field, like biology or geology, but who cannot be expected to be especially skilled in computer science [2]. This is particulary severe, because a wrong decision made at the design phase can severely affect the performance and reliability of the network.
In order to make the deployment of sensor networks easier and more reliable for unacquainted end-users, a methodology is required to synthesize a possible structure for an applicable sensor network based solely on the requirements and constraints of the intended task. Such a framework eases the decisions to be made during the design of a sensor network and allows the less acquainted end-users to successfully deploy a sensor network for solving the specific problem. With my research I want to investigate how parts of the design decisions during the deployment of a sensor network can be automated. The ultimate goal is to offer the end-user a tool to automatically generate a useful selection out of the available hardware and software components at “the push of a single button.” As a groundwork the requirements of different deployment scenarios as well as common building blocks of sensor networks and their implication on the requirements have to be identified. Finally, with exemplary applications to a suite of real world problems, the usefullness of the framework will be demonstrated.

[1] Ian F. Akyildiz and Ismail H. Kasimoglu. Wireless sensor and actor networks: Research challenges. *Ad Hoc Networks Journal*, 2(4):351–367, October 2004.

[2] Phil Buonadonna, David Gay, Joseph M. Hellerstein, Wei Hong, and Samuel Madden. TASK: Sensor network in a box. In *Proceedings of the Second European Workshop on Sensor Networks*, 2005.

1.2.29 Solving Complex Tasks with Teams of Strongly Heterogeneous Autonomous Systems

Keywords:

heterogeneous teams
task allocation
multi-robot systems

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Autonomous mobile systems (AMS) are characterized by abilities to perceive the physical world and their own state by means of sensors ("sense"), planning abilities using embedded computers ("plan") and physical interaction abilities as locomotion or manipulation ("act"). Despite tremendous progress in single AMS or homogeneous teams of AMS the level of autonomy and the complexity of tasks to be solved autonomously and efficiently is limited. This holds even stronger for teams of AMS with strongly heterogeneous sense/plan/act abilities and possibly including humans as team members. As prerequisite for cooperation the heterogeneous AMS are assumed to be aware of each other and to cooperate towards one or several common goals. Whereas bio-inspired swarm algorithms may be suitable for navigation of homogeneous AMS [2], more abstract methods like market-based approaches [1] may be better suited for strongly heterogeneous teams.

The challenge is to determine an efficient and flexible way, how the required use of sense, plan and act abilities for a given task can be distributed among the cooperating, heterogeneous AMS which may include humans as team members. This distribution may vary with different scenarios. For example, if in the cooperation of a human mission manager or expert with a team of AMS a task can be fulfilled sufficiently reliable by the robots, it is enough to inform the operator about the current status, if he asks for it. This could be for example the task to move a robot to a specified point on a known map, if the robot is able to locate itself on this map. Some other tasks can be done by the robots autonomously only unreliable, so that it is necessary for the operator to monitor this tasks most of the time. An example in a search and rescue scenario is the identification of a victim in a camera image. Some other tasks cannot be fulfilled by robots without the help of a human, they should have highest priority for the operator. An example is a robot that got stuck in difficult or dangerous terrain. If the operator has full access to all of the robot's sensor readings (from cameras, distance sensors, accelerometer, etc.) he can interpret them in a way, the robot is not able to do, and help the robot to get out of this situation.

[1] Brian P. Gerkey and Maja J. Mataric. Sold!: Auction methods for multirobot coordination. *IEEE Transactions on Robotics and Automation*, 18(5), October 2002.

[2] C. Ronald Kube and Hong Zhang. Collective robotics: From social insects to robots. *Adaptive Behavior*, 2(2):189–218, 1993.

1.2.30 Data Aggregation techniques for WSNs

Keywords:
data aggregation
forwarding and routing techniques
network coding
MAC and network layer
analysis of protocols
WS&AN

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Giorgio Quer is a PhD student in Information Engineering. He is a member of the Signet research group, supervised by prof. Michele Zorzi. The group is focused on wireless networks.
His research interests include MAC and routing protocols for Ad Hoc and Wireless Sensor Networks (WSNs). He has developed forwarding techniques for low power and delay tolerant WSNs, using Data Centric routing under a Publish/Subscribe middleware, suitable for environmental monitoring, presented in [3].
His current research is focused on energy effcient Data Aggregation techniques [2] for WSNs. He is also interested in Network Coding [1] and its application for Data Dissemination and Data Gathering in heterogeneous networks (e.g. next generation Wireless Sensor and Actuator Networks (WS&ANs) and the Future Internet). He is actively involved in a project on inter-Vehicular Networks, which aims at developing an integrated framework where vehicles as well as public transportation can share useful information in a distributed manner.
The research methodology is based on an established experience in MAC and routing protocols, as well as on a solid mathematical background and a teamwork attitude inside the Signet laboratory. New research problems, both theoretical and rising from application requirements, are first mathematically analyzed, for a general understanding of the problem. Successively theoretical solution is provided. Then simulation tools are used to confirm the analysis results. Finally the developed techniques are tested within the WSNs testbed of the Signet laboratory. This well established way allows a complete understanding of the problems examined, from a theoretical as well as from a realistic point of view, analyzing the performance also under non-ideal facets of the real world.

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[2] E. Fasolo, M. Rossi, J. Widmer, and M. Zorzi. In-network Aggregation Techniques for Wireless Sensor Networks: A Survey. *IEEE Wireless Communication Magazine*, Apr. 2007.

[3] Giorgio Quer, Mauro Stramazzotti, Carlos Pomalaza-Ráez, and Zach Shelby. Sparse Forwarding for WSNs Publish-Subscribe. In *5th European Conference on Wireless Sensor Networks, January 31th, February 1st-2nd, Bologna, Italy*, 2008.

1.2.31 Novel Robust Locomotion Systems and Strategies for Bipeds

Keywords:
locomotion
compliant legs
walking robots
running robots

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Walking is still looked upon as the best way of movement in unstructured and unknown areas. In order to improve the walking capabilities of robots, engineers and researchers all over the world make use of the various studies conducted on animals and humans. Indeed, the orientation towards more biologically inspired walking principles enables the development of more powerful robots. Conventionally built bipedal robots demonstrate a variety of different walking movements. These walking capabilities are accomplished, however, by means of powerful, rigid rotary electric actuators. The legs consist of rigid kinematic chains with six or seven revolute joints, each actuated by one motor. Besides, it is made use of numerous sensors, such as positioning sensors for feedback control or accelerometers in the upper body and contact sensors in the feet. Passive dynamic walkers, robots that show a perfectly stable gait when walking down a gentle slope without any control or actuation, demonstrate more human-like movements. Based on this successful and highly energy-efficient approach, prototypes of underactuated robots were built in order to realize also walking on even terrain [3, 1]. These machines, however, do not walk nearly as efficient as humans do: (1) Ankle joints are not necessary; (2) complete extension of the knees during the stance phase is required, thus limiting the walking pattern to one speed and step frequency; uphill or omnidirectional walking are not possible. Consequently, the passive dynamic walking concept is only limitedly transferrable. Therefore, there is strongly the need to build robots that are more similar to the human motion apparatus. In order to facilitate the longtime realization of walking and running of two-legged robots with human-like efficiency in the same kinematic leg design, the walking stability of three-segmented legs are being investigated. The aim is to continue work on the Jena Walker II model, a bipedal model with passive elastic 3-segmented legs and two DC motors driving the hip joints [2, 4]. On our way to realize fast walking and running robots that are similar to the human locomotion system, we will also need to raise the autonomy stepwise. Furthermore, automatic selection of gait patterns depending on the terrain and effective strategies for the motion planning and the walking stabilization in specific situations are favorable.

[1] S. Collins, A. Ruina, R. Tedrake, and M. Wisse. Efficient bipedal robots based on passive-dynamic walkers. *Science*, 307(5712):1082–1085, 2005.

[2] F. Lida, Y. Minekawa, J. Rummel, and A. Seyfarth. Toward a human like walking robot with compliant legs. *AMAM*, pages 177–184, 2005.

[3] T. McGeer. Passive dynamic walking. *International Journal of Robotics Research*, 9(2):62–82, 1990.

[4] A. Seyfarth, R. Tausch, M. Stelzer, F. Lida, A. Karguth, and O. v. Stryk. Towards bipedal running as a natural result of optimizing walking speed for passively compliant three-segmented legs. *CLAWAR*, pages 396–401, 2006.

1.2.32 Extending a Networked Robot System with Tiny Devices and Everyday Objects

Keywords:
PEIS
middleware
wireless sensor network
mote
networked robot system

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My Phd thesis project, called ”Ecology for Assisted Ambient Living”, is part of a larger project “PEIS-Ecology”[2] running in the Mobile Robotics Lab at AASS at Örebro University. This project is dedicated for the elderly care. The goal of the PEIS-Ecology project is to allow the coexistence and cooperation of many robotic devices (PEIS or Physically Embedded Intelligent System) in a domestic environment. PEIS should range from full mobile robots to tiny embedded devices (e.g., sensor network motes) and simple tagged every day objects (e.g., a cup with an RFID tag). These vision infer the necessity of integrating highly capable robots and mote like tiny memory constraint devices.

Using a middleware is typical to deal this issue. However, the middleware for robots are very different than that of the sensor network motes. Thus, in order to integrate standard robots, embedded devices, and possibly other entities (e.g., home appliances), one would have to use different middleware models and implementations, and then combine those middlewares in some way. In our opinion, this is a major obstacle to the building of a truly integrated, distributed, heterogeneous robot ecology. We have developed PEIS-Middleware for coexisting robots and tiny embedded devices seamlessly in the PEIS-Ecology[1]. I have been responsible for the tiny version of the PEIS-Kernel, tiny peis-kernel, for tiny embedded devices and to integrate them to the rest of the ecology.

As the continuation of my work, we are working for introducing dumb/proxied objects, (in PEIS ecology perspective), which cannot run the middleware on board and are not capable to communicate themselves with rest of the ecology such as RFID-tags and XBee communication module. This part of work has been submitted in an International Conference. The proposed modle is called the *Concept of Proxied Objects*.

These two works can be named together as "Extending a Networked Robot Systems with Tiny Devices and Everyday Objects“, which is the title of my on going licentiate thesis.

[1] M. Bordignon, J. Rashid, M. Broxvall, and A. Saffiotti. Seamless integration of robots and tiny embedded devices in a peis-ecology. In *Proc of the IEEE/RSJ Int Conf on Intelligent Robots and Systems (IROS)*, San Diego, CA, 2007. Online at http://www.aass.oru.se/~asaffio/.

[2] PEIS ecology homepage. www.aass.oru.se/~peis.

1.2.33 The Heterogeneous TWiNS.KOM Sensor Network Testbed

Keywords:

heterogeneous sensor networks
sensor network testbed
deployment support network

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While sensor network simulators often rely on statistical models for radio link characteristics and sensor readings, they mostly disregard unexpected events, such as burst interference or erroneous sensor readings. To verify an application's operation under real-world constraints, sensor network testbeds are hence essential.
Existing testbeds can be characterized by different metrics, the most prominent ones being heterogeneity, mobility, and deployment support. MoteLab [2] is a prominent example for a static homogeneous indoor testbed with deployment support, while the outdoor ZebraNet [1] deployment provides heterogeneity in sensing and radio protocols, at the cost of limited reproducibility of the results due to the non-deterministic movements of the sensors.
However, these experiment setups were either specifically tailored to a single field of use (ZebraNet), or are limited in other regards, reducing their applicability in generic scenarios. Our approach of addressing these limitations is to compose TWiNS.KOM (**T**estbed for a **Wi**reless **N**etwork of **S**ensors), consisting of twenty sensor *Tubicles*, as shown in the figure. Tubicles integrate three different platforms, introducing heterogeneity in terms of computational capabilities, employed radio standards and sensor devices. TWiNS.KOM additionally features mobility, portability, debugging and sophisticated deployment support to enhance the user's experience with the platform.

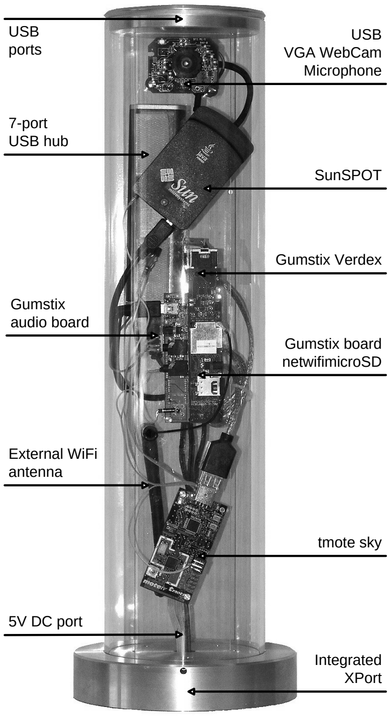

Figure 1.1: The Tubicle

Our research is inline with the topics of this summer school by providing a versatile heterogeneous sensor network testbed for the Mixed-Mode Environment.

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[2] Geoffrey Werner-Allen, Patrick Swieskowski, and Matt Welsh. MoteLab: A Wireless Sensor Network Testbed. In *Proceedings of the 4th International Symposium on Information Processing in Sensor Networks*, 2005.

1.2.34 Optimal Control of Multi-Vehicle Systems Under Connectivity Constraints Using Linearized Models

Keywords:

multi-vehicle system
linearized mixed-integer optimal control
multi-vehicle communication
cooperative mobile system
connectivity constraints on locomotion

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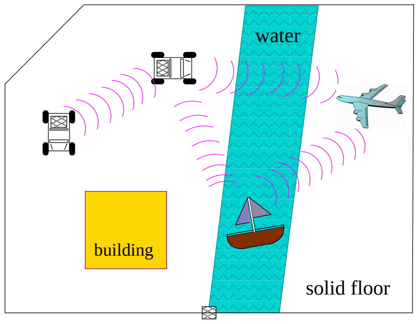

We are investigating a general modeling and trajectory optimization framework for heterogeneous multi-vehicle systems. It enables to consider the individual vehicles' motion dynamics with individual, physical motion constraints as well as connectivity constraints for wireless communication (cf. [2]). For instance, this is decisive for the quality of cooperative monitoring and surveillance missions with multiple vehicles. Here, the influence of communication (i.e. connectivity) constraints on the optimal cooperative control of individual motion dynamics for multi-vehicle systems is investigated. In this context, structured physical environments are considered that allow the vehicles to locomote in a regular manner according to their individual type of ground, water or aerial locomotion.

A general formulation as nonlinear hybrid optimal control problem (HOCP) [1] is used that considers very general motion and sensor abilities. The problems here are primarily characterized by a tight coupling of continuous differential equations (i.e. locomotion properties) and discrete structures (i.e. waypoint sequencing, network topology). From the numerical point of view, this leads to a high-dimensional nonlinear optimization problem that is possibly dominated by a combinatorial characteristic.

Transformation techniques are applied to reduce this computational burden towards a future online application.Hereby the general problem is transcribed to a mixed-integer linear problem (MILP) which can be solved much more efficiently. Complex scenarios can be reduced to fast solvable MILPs, without losing the basic physical structure of the system.

This centralized, MILP-based approach will is applicable for different purposes, like evaluating the degree of optimality of heuristic, distributed control schemes. MILP formulations are an appropriate method to compute good bounds or initial solution estimates for numerical methods tackling the general HOCP formulation. Also, mixed-integer linear models itself may be developed further towards online application in a model-predictive control method for multi-vehicle systems in uncertain environments.

[1] M.Glocker, C. Reinl, and O. von Stryk. Optimal task allocation and dynamic trajectory planning for multi-vehicle systems using nonlinear hybrid optimal control. In *Proc. 1st IFAC-Symposium on Multivehicle Systems*, pages 38–43, Salvador, Brazil, October 2-3 2006.

[2] C. Reinl and O. von Stryk. Optimal control of multi-vehicle systems under communication constraints using mixed-integer linear programming. In *Proc. of the 1st Intl. Conference on Robot Communication and Coordination (RoboComm)*, Athens, Greece, 2007. ICST.

1.2.35 Conditional Random Fields for Detection of Visual Object Classes

Keywords:

object detection
conditional random fields

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Object detection is one of the key tasks in computer vision and an essential part of unmanned vehicles. On the way to scene interpretation object detection and segmentation of given scenes seem to be fundamental. One promising model stores global statistics of objects of a given class and a classifier is carried forward to unseen images to infer hypothesis of present object instances. In the presence of occlusion these global object descriptors fail to reliably infer the correct hypotheses. On the other hand, part based object detection was originally designed to handle flexible objects like humans and animals but they also achieved promising results for occlusion scenarios. Modelling the object as a composition of different parts showed to be benefitial since the presence of one object part determines the location of other parts and therefore the location of the entire instance.

Conditional Random Fields (CRFs) [1] gained increasing attention as they can be designed to model these dependencies directly. Especially segmenting a given image is well covered by CRFs as fixed image regions are linked to pairwise connected nodes of the model. In my work, I am focussing on CRFs to increase the discriminative nature of these models and thereby achieve better detection results. Furthermore, I am aiming at providing a reliable scene interpretation in order to be able to detect victims with unmanned vehicles. In this setting, I am facing the challenges of multiscale, multiview and heavily occluded object instances. Especially detecting victims after any desaster is very challenging since only parts of victims might be visible and humans could appear in any arbitrary pose.

[1] John Lafferty, Andrew McCallum, and Fernando Pereira. Conditional random fields: Probabilistic models for segmenting and labeling sequence data. In *Proc. 18th International Conf. on Machine Learning*, pages 282–289. Morgan Kaufmann, San Francisco, CA, 2001.

1.2.36 Fault Diagnosis in Mixed-Mode Systems Subject to Transient and Intermittent Faults

Keywords:

fault diagnosis
distributed systems
transient faults

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Systems in the Mixed-Mode-Environment (MME) are characterized by a high level of interoperation between different distributed entities, which results in a higher degree of interdependencies. In this context, it becomes fundamental for each distributed entity to obtain a view of the operational status of the system, in terms of existing usable physical resources and associated functionalities. This is particularly useful in scenarios where a large number of nodes can fail quickly and it is necessary to build a notion of the portion of the system that is correct. Disasters are a typical example scenario where it is useful to build a notion of the perimeter of the disaster and of the functional entities that can support rescue operations. Fault diagnosis and resource location need to be done online, i.e., during system operations. They are thus inherently distributed. This in turn raises the problem of obtaining a distributed agreement among all participants in order to enable global reconfiguration actions.

The determination of faulty MME entities in a distributed manner must take into consideration that embedded networks are particularly subject to transient faults. The reasons are multiple. Since the communication medium is often broadcast-based, shared and unreliable, message loss can induce nodes of the distributed system to incorrectly deem other nodes as faulty. Furthermore, the small geometry and low energy consumption of many embedded devices, as for example sensor nodes, result in a higher rate of soft errors. In both cases, resources appear as faulty but are in fact correct.

My research is both on the algorithmic and stochastic aspects of the problem. From a distributed algorithm viewpoint, one wants to build fault location protocols that are provably correct. In fact, resource management becomes a critical functionality in disaster scenarios. From a stochastic viewpoint, it is necessary to define probabilistic analysis that allow to fix a correct tradeoff of the filtering given a time to failure and time to recovery of the different nodes.

1.2.37 Application-Aware Tunable Data Transport in Heterogeneous Wireless Sensor Networks (HWSN)

Keywords:
Heterogeneous Wireless Sensor Networks
Data Transport
Reliability
QoS

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Heterogeneous Wireless Sensor Networks (HWSNs) cover the range from static and structured to highly dynamic and unstructured environments. We expect these environments to consist of a myriad of networked nodes including, e.g., static sensor nodes, highly mobile sensor nodes, and centralized servers (sinks). Applications require sensor information (simple or aggregated) to be delivered over networks with varying degree of heterogeneity (best-effort v/s real-time v/s delay-tolerant) and with different QoS constraints. The heterogeneity and reliability semantics provided by different protocols are fixed, i.e., either they provide delay critical (DC) or delay tolerant (DTol) service with no reliability or some probabilistic reliability. As protocols are tailored for specific environment and conditions one cannot switch between these semantics. However the realistic deployment scenarios exhibits both the DC and DTol data along with switching reliability guarantees as well as a wide range of operating conditions. Thus necessitating a framework and set of protocols which dynamically adjust themselves to the evolving physical and network world.

We aim at taking advantage of tunable framework that allows for a trade-off between multidimensional constraints induced by wireless communications, mobility, the type of data (DC v/s DTol), and various other factors (e.g., limited energy). In our approach we radically depart from existing frameworks/protocols and propose to investigate the adaptation for subparts of the network to efficiently reach equilibrium states despite the fact that individual network entities are no longer operational or collaborating.

We classified and compared the WSN transport protocols [2] to have insights of data delivery patterns and showed that existing transport protocols are specific to application scenarios and always show a tradeoff between reliability and efficiency. For DC applications we first modeled the reliability of data transport using reliability block diagrams (RBD) [1]. Such a modeling goes a long way in providing insights into the better design of transport protocols. As a future work we extend the framework for DTol applications.

[1] F. K. Shaikh, A. Khelil, and N. Suri. On modeling the reliability of data transport in wireless sensor networks. In *PDP*, pages 395–402, 2007.

[2] F. K. Shaikh, A. Khelil, and N. Suri. A comparative study for data transport protocols for wsn. In *WOWMOM*, 2008.

1.2.38 Dynamic map building for optimal trajectory planning by using multiple UVs

Keywords:
UVs
swarming
mapping
exploration
high-level controlling

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For unmanned vehicles no matter of which kind they are, it is a well known problem to conduct there missions in an unknown or even changing environment, e.g. a catastrophe scenario after a hurricane or an earthquake. Even if there has been a map of the region before the disaster, it is likely that it is more or less useless at the moment, when the unmanned vehicles are used to explore the region. Besides missing or new objects, additional challenges an unmanned vehicle has to cope with are moving obstacles like other vehicles or persons.

To be able to navigate efficiently through a disaster area, an autonomous robot has to have a good knowledge of its environment. A good starting point is a map dated before the disaster but it is much more important to update this map while operating in the area.

The aim of this research is to get to an updated map of a disaster scenario much faster by using multiple heterogeneous UVs exploring the area from all sides and sharing their experiences with all other vehicles in the swarm. One approach could be to have every robot equipped with a single camera, sending the data to a ground station, where all pictures are used to calculate a virtual 3D representation of the environment (distributed photogrammetry). A little swarm of heterogenous robots will be build to implement the algorithms and evaluate them in real scenarios.

1.2.39 Multirobot Coordination and Cooperation Methods

Keywords:
cooperation
coordination
multi-robot
MRROC++

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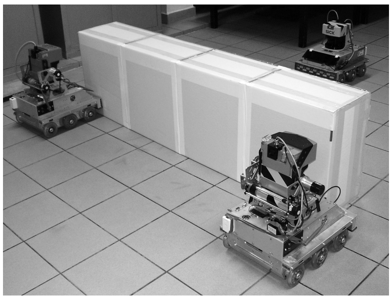

The focus of my research is in the cooperation and coordination in multirobot systems, including both manipulators and mobile robots. I have been developing a common benchmarking task – box-pushing, where two mobile robots were cooperating using implicit communication (stigmergy) [1]. This task has been specified using state-transition functions and formal methods of MRROC++ [2]. I am also interested in the methods of integrating robot programming frameworks, expecially MRROC++ and Player, in order to build common environment for both manipulators and mobile robots programming. I am evaluating developed algorithms and control methods using both real robots (our custom Electron mobile platform and IRp6 industrial manipulator) and simulation (Gazebo).

In my current research I investigate methods of multirobot tasks specification using Petri nets, which seems very promising concept for parallel execution of robot behaviours. The motivation of this work is to create tools for programming multirobot systems for elderly care. Such systems have to integrate both human-robot interaction modules (ie. speech and gesture recognition) and effector devices (including servovision and force control). The system composed of multiple robots will be cheaper and more expandable than single, probably very complex, devices. The solution have to integrate as much autonomy as possible in order to guarantee robustness and reliability. At the other hand the formal specification methods are required to assure the system is safe for use by the humans.

[1] P. Trojanek, C. Zieliński, and W. Szynkiewicz. Definition and composition of individual robot behaviours in cooperative box pushing. In *Proceedings of the 13th IEEE IFAC International Conference on Methods and Models in Automation and Robotics (on CD)*. Technical University of Szczecin, 29–30 August 2007.

[2] C. Zieliński. Transition-function based approach to structuring robot control software. In K. Kozłowski, editor, *Robot Motion and Control: Recent Developments, Lecture Notes in Control and Information Sciences, Vol.335*, pages 265–286. Springer Verlag, 2006.

1.2.40 Dynamic robot networks for pathfinding and pathplanning using A* search algorithm

Keywords:

multi-robot teams
communication network
A* search algorithm
path planning
localization

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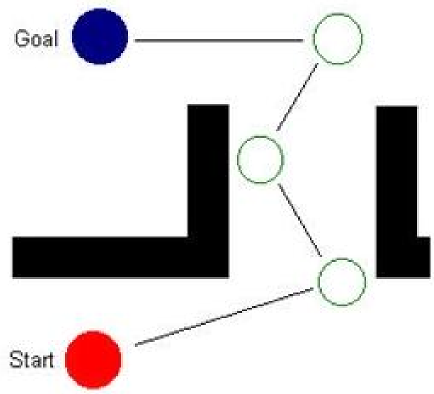

One of the goals of autonomous robotics is a robots gathering information about its environment in order to be able to move in an intelligent manner. In our project we focused on localization and pathfinding of mobile robots using dynamic (ad-hoc) network (communication topology). We implemented the algorithm on a set of custom designed mini-robots with vision based localization but it is not reliable enough for us. This is because in open area it will not work and we are planning to localize using dynamic network of robots. In vision based pathfinding we use A* search algorithm for finding the shortest path and in the same time obstacle avoidance of mobile robots. A* search algorithm is a graph search algorithm that finds the least-cost path from a given start node to one goal node. The focus here is on the importance of the wireless ad-hoc communication/networking in localization of mobile robots and nodes which will be used in A* search algorithm. In our future researches we will combine and extend this robotic search with relative position estimation based on RSSI(Received Signal Strength) and vision based localization.

1.2.41 Leveraging Quality of Information in Context-aware Systems

Keywords:

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Context-aware systems are concerned with the acquisition of context from different sensors, context interpretation, and adapting application behavior based on the recognized context. However, the underlying sensors have inherent limitations with respect to the quality of the context information they produce. Such limitations are due to the capabilities of the sensors themselves (like clock rate of a GPS receiver), their operational environment (like atmospheric effects on GPS signal) and how timely and reliably the sensor values are fed into the application (e.g. Zigbee provides wireless transport at low data rates and over a few meter ranges). The effects of these uncertainties are further amplified as the context is disseminated within communication networks (such as wireless sensor networks) or if context-specific operations like aggregation and reasoning are applied.

Therefore, it is crucial to ensure the quality of information for context-aware systems in real-world settings, especially for mission-critical applications. In a fire fighting scenario for example, a context-aware system can aid in collecting the information about the boundaries of flame as well as smoke zones and their ambient temperatures or toxicity levels . Clearly, the system is useless if this information has uncertainty and/or is outdated.

Through my research, I try to investigate mechanisms to provide support of quality of context information within context-aware systems. In particular, I emphasize on the research challenges that are related to the communication and networking aspects within heterogeneous context-aware systems. On one side, I give focus on modeling quality of information to enable applications to adapt not only to the context itself, but also to the quality of the context. On the other side, I focus on expanding the information base for context-aware systems by integrating human-related (non-technical) aspects such as social context and physiological state of the user. Social relations, for example, can be regarded as valuable context information that, when captured, make the context-aware application behave in a more natural and convenient way. For an everyday example outside the emergency response domain, think of a context-aware virtual communication assistant that enables you to receive an incoming call from your wife during the lunch break, but forwarding your colleagues call to your voice mail. An ultimate goal for my thesis will be to acquire such high-level contexts by utilizing heterogeneous sensors (wireless vs. wired, software vs. hardware) and applying reasoning and interpretation techniques (semantics, social analysis). Extent of quality of context improvement is to be evaluated as well

2 Schedule and Events

2.1 Overview

	Su, 17th	Mo, 18th	Tu, 19th	We, 20th	Th, 21st	Fr, 22nd
8.00 - 9.00		Breakfast				
9.00 - 9.15		Opening Address	Talk: N. Neogi, Integrating UAVs into Civilan Airspace	Reading Groups: a) P. Santi, Topology Control b) L. Parker, Dynamic Task Allocation in Heterogeneous Multi-Robot Teams	Talk: C. Woolsey, Using Flight Vehicles for Control Volume Sampling	Talk: C. Woolsey, Energy Shaping for Mechanical Systems
9.15 - 10.30		Talk: L. Parker, Performance Evaluation and Benchmarking in Multi-Robot Teams				
10.30 - 11.00		-break-				
11.00 - 12.30		Talk: N. Neogi, Fault Detection and Diagnosis Techniques for Networked UAVs	Talk: A. Redfern, Pervasive Computing in the Every Day World	Talk: D. Stilwell, Control and Estimation Over Networks, Part 1	Talk: W. Burgard, Coordinated Multi-Robot Exploration	Talk : F. Mattern, Towards the Internet of Things
12.30 - 14.00		Lunch				
14.00 - 15.30		Tutorial: P. Santi, Topology Control in Wireless Multi-hop Networks, Part 1	Tutorial: L. Parker, Dynamic Task Allocation in Heterogeneous Multi-Robot Teams	Social Event: Multi-Sensorial Experience" (Bus)	Tutorial : A. Redfern, Pervasive Computing Application Development, Part 1	Talk: D. Stilwell, Control and Estimation Over Networks, Part 2
15.30 - 16.00		-break-			-break-	Conclusions
16.00 - 17.30		Tutorial: P. Santi, Topology Control in Wireless Multi-hop Networks, Part 2	Students' Session: Presentations (later:) Sports Event		Tutorial: A. Redfern, Pervasive Computing Application Development, Part 2	
17.30 - 18.00		-break-			-break-	
18.00 -19.00		Dinner			Talk: F. Mattern, Wonderful Future	
19.00 - 19.30		Social Event: Wine-tasting	Students' Session: Posters and Demos	Social Event: Rittermahl		
19.30 - 20.00	Talk about the Castle				Barbecue	
20.00 - 22.30	Come together				Last evening party	
22.30 - ...			Nightguard			

2.2 Talks

Monday, August 18th

- 09:00 **Lynne Parker: Performance Evaluation and Benchmarking in Multi-Robot Teams**
  A common challenge when comparing and contrasting alternative multi-robot solutions is the selection of appropriate metrics and application domains that enable the generation of meaningful comparisons. Many metrics are application-specific, and, while useful for a narrow application domain, are difficult to generalize across other domains. Ideally, we would like to be able to identify more general metrics that can provide some predictive performance when applying a multi-robot solution to a new task, or in a new domain. Perhaps the use of benchmarks can help standardize the comparisons of robotic solutions. For example, one benchmark popularly used in the multi-robot domain is robotic soccer, where the measure of effectiveness of the robotic solution is the win-loss record of the robot team. However, a single benchmark is unlikely to adequately evaluate robot systems along all the characteristics of interest. This talk will explore these issues of performance evaluation and benchmarking in the context of multi-robot teams. We will discuss many techniques used to date, along with new developments that may be needed to provide better evaluation capabilities for multi-robot systems.

- 11:00 **Natasha Neogi: Fault Detection and Diagnosis Techniques for Networked UAVs**
  The seminar outlines a software oriented approach for the real-time detection of faults and byzantine behaviour in multi-modal hybrid systems. Online model generation of continuous variables enables the detection of multiple faults, while managing computational complexity. As an example, the aileron control loop and propulsive system of a UAV using a Piccolo Plus autopilot are examined. A theoretical upper bound for the detection threshold for the “stuck aileron” fault is derived. This enables the dynamic selection of the optimal threshold, in terms of false alarms, over a range of maneuvers in an online manner. The development of several independent models for the calculation of the propulsion system residual that use diverse and redundant data sources, allows for the diagnosis of several distinct faults via multiple thresholds on a single residual in a concurrent fashion. A conflict detection and positioning algorithm for a network of UAVs is outlined, in the presence of byzantine agents, and bounds for k-quality consensus are developed.

- 14:00 **Paolo Santi: Tutorial: Topology Control in Wireless Multi-hop Networks**
  Forthcoming wireless multi-hop networks such as wireless sensor networks will allow network nodes to control the communication topology by choosing their transmit power and, consequently, transmission range. Informally speaking, topology control (TC) is the art of coordinating nodes’ decisions regarding their transmission range in order to generate a network with the desired features. Building an optimized network topology helps surpass the prevalent scalability and capacity problems.

  In this tutorial, we first make the case for TC for what concerns both energy consumption and network capacity. We then introduce the several TC techniques presented in the literature, ranging from the simplest form of TC (optimally setting a common transmission range), to more complex topology optimization problems aimed at reducing nodes’ energy consumption. Special care will be devoted to describe fully distributed TC approaches. Finally, we will consider more recent TC approaches, in which the optimization goal is no longer energy, but reducing wireless interference between nodes.

Tuesday, August 19th

- 09:00 **Natasha Neogi: Integrating UAVs into Civilian Airspace: Security of Networked Autonomous Agents**
  A review and analysis of uninhabited aerial vehicle (UAV) accident data has been conducted to identify important human factors issues related to their use. Classification of accident data into primal causative factors, denoted by categories such as human factors, maintenance, aircraft integrity, as well as unknown factors, can be used as a first pass for analysis. Each category can be further elaborated upon by examining the accidents in detail, and creating a set of likely subdivisions, for example, accidents caused due to human factors related issues can be related to display design, procedural errors, skill-based errors etc. A critical issue lies in the vast array of differences in the currently fielded platforms. Since UAVs span a range of sizes and weights, from microvehicles to fully functional combat fighter aircraft, the related accidents and incidents are inextricably intertwined with their functional missions and payloads. Furthermore, failure modes and path-to-failure are also conditioned upon these key factors. Nonetheless, many of these accident failure modes can be anticipated by a throrough analysis of user interfaces employed and procedures implemented for their use. This creates a basis for the qualities inherently necessary for certifiable UAV platforms to enable their integration into civilian airspace.

- 11:00 **Andrew Redfern: Pervasive Computing in the Every Day World**
  Firefighting is an extremely demanding occupation set in a chaotic environment where lives and buildings are at stake. Firefighters must make quick decisions with little information and divide their attention between many events, making it difficult to efficiently and effectively complete critical tasks such as building search and rescue. The Fire Information and Rescue Equipment (FIRE) project at UC Berkeley addresses these challenges by applying and designing new technologies, such as wireless sensor networks (WSNs) and small head-mounted displays (HMDs), to firefighting. In this talk, I will highlight three core components of FIRE: (1)SmokeNet, (2)FireEye, and (3)eICS. The design of each of these components will be discussed and I will demonstrate how user interviews, observations of firefighter tactics and prototypes have help to refine these three main subsystems of FIRE. FIRE is just one example of pervasive computing, in addition to the FIRE system I will introduce a few other pervasive computing applications including some industrial monitoring systems, interactive toys, and another application of people tracking.

- 14:00 **Lynne Parker: Dynamic Task Allocation in Heterogeneous Multi-Robot Teams**
  In a heterogeneous team of robots, the morphological and/or behavioral capabilities of the team members can vary significantly from robot to robot. These differences lead to very different abilities of robots to perform the tasks within an application. A key challenge in these problems is to determine the proper allocation of tasks to robots, to attempt to optimize some criteria of performance. Unfortunately, this problem is similar to the set-covering problem, which is an NP-hard problem. Thus, researchers have developed a variety of alternative approximation approaches to task allocation to address this problem. In this tutorial, we will define the general multi-robot task allocation problem (MRTA), and discuss some alternative techniques for addressing this problem. Approaches to be discussed include behavior-based approaches, such as ALLIANCE and BLE, as well as market-based approaches, such as M+, MURDOCH, TraderBots, and Hoplites. The intent of this tutorial is to outline the general strategies that have been proposed, along with comparisons of alternatives.

Wednesday, August 20th

- 09:00 **Reading Groups**
  - Paolo Santi: Topology Control in Wireless Multi-hop Networks
    The goal of this reading group is to let the participants gain a view of state-of-the-art implementations of TC techniques. In particular, the participants will gain a deeper understanding of the notable technological challenges that must be solved in order to apply even very simple TC techniques into a real wireless multi-hop network.
  - Lynne Parker: Dynamic Task Allocation in Heterogeneous Multi-Robot Teams
    The objective of this reading group is for the participants to gain a deeper understanding of techniques for dynamic task allocation in heterogeneous multi-robot teams. We will discuss papers on dynamic task allocation, as introduced in the corresponding tutorial session. We will compare and contrast the approaches, and discuss the advantages and disadvantages of the alternative techniques. We will examine some hypothetical case studies to motivate the need for alternative approaches.
- 11:00 **Dan Stilwell: Control and Estimation Over Networks: Part 1**
  Graph-theoretic tools have proven useful for analysis and design of systems that operate over networks. In this talk, we introduce several basic graph-theoretic concepts and discuss how they apply to analysis of control and estimation problems over networks. We specifically address the case of time-varying network topologies and consider the case of both deterministic and stochastic switching between topologies. Network analysis concepts are illustrated via analysis of oscillator synchronization, consensus algorithms, and data fusion algorithms.

Thursday, August 21st

- 09:00 **Craig Woolsey: Using Flight Vehicles for Control Volume Sampling**
  Unmanned air vehicles (UAVs) and autonomous underwater vehicles (AUVs) are often used to assess phenomena that occur within a sample volume by measuring the flux of related quantities or properties across the volume's boundary. This presentation will describe example applications in this class of sampling tasks and related work on vehicle control and coordination for autonomous underwater gliders and UAVs.
- 11:00 **Wolfram Burgard: Coordinated Multi-Robot Exploration**
  In this presentation we consider the problem of exploring an unknown environment by a team of robots. As in single-robot exploration the goal is to minimize the overall exploration time. The key problem to be solved therefore is to choose appropriate target points for the individual robots so that they simultaneously explore different regions of their environment. We present an approach for the coordination of multiple robots which simultaneously takes into account the costs of reaching a target point and the utility of target points. The utility of target points is given by the size of the unexplored area that a robot can cover with its sensors upon reaching a target position. Whenever a target point is assigned to a specific robot, the utility of the unexplored area visible from this target position is reduced for the other robots. This way, a team of multiple robots assigns different target points to the individual robots. The technique has been implemented and tested extensively in real-world experiments and simulation runs. We will present experimental results which demonstrate that our coordination technique significantly reduces the exploration time compared to previous approaches. We also will describe different extensions of this approach towards limited communication and limited bandwidth of

the communication channel. Additionally, we will describe how to utilize high-level information about the type of places to improve the exploration process.

- 14:00 **Andrew Redfern: Hands-on Introduction to Pervasive Computing Application Development**
  Building embedded application has been traditionally difficult because different toolsets must be used for various aspects of the system. Sentilla has solved this problem by developing a system that enables a developer to build pervasive computing applications using Java. In this lab, the participants will be introduced to the Sentilla technology with a demonstration of how Java enables rapid sensor network development. Examples of design wins include logistics, transportation, security, health care, agriculture and green technology. After introducing the technology there will be hands-on lab in which the participants will be introduced to the fundamentals of building pervasive computing applications. The tutorial will cover tools, debugging techniques and architecture schemes for building applications using Java on a resource constrained device. Basic sensor implementation will be demonstrated through simple acceleration and temperature measurements, and a more advanced sensor implementaiton will follow if time permits. After completing this course the participants will have a rudimentary understanding of the Sentilla technology and how they might be able to apply it in their field.

- 19:30 **Friedemann Mattern: Wonderful Future - Early Predictions of (Information) Technology**
  As is well known, making predictions is a bit tricky. A hundred years ago, a man took a cautious view of our time and predicted something wonderful: the mobile phone. This would allow not only monarchs and chancellors to run their businesses from a distance, but also the happy time for love would begin – because the couples would always know what the partner would be doing. The past technology forecasts promised still many other fantastic things – teaching machines replace teachers, color fax machines and screen phones to be found in every home, and household robots doing the dishes and serving coffee. Only the Web, E-commerce, search engines, SMS, game consoles, blogs, Ebay, camera phones, . . . that is, all the blessings of the information age which did not exist 15 years ago, whose name had not even been invented, but without which we could barely live today, would virtually seem not having being predicted by anyone! Or did the unrecognized prophets of the digital age exist?

Friday, August 22nd

- 09:00 **Craig Woolsey: Energy Shaping for Mechanical Systems**
  The operating envelope for an autonomous vehicle can often be expanded through clever control design that respects and exploits the vehicle's natural, nonlinear dynamics. Energy-based control design can provide controllers which are energy efficient, robust to model uncertainty, and perform well over a large operating envelope. This presentation will discuss methods for controlling mechanical systems using feedback that reshapes the system's total energy and its dynamic structure.

- 11:00 **Friedemann Mattern: Towards the Internet of Things**
  The term "Internet of Things" has come to describe a number of technologies that enable the Internet to reach out into the real world of physical objects. In fact, the trend of information and communication technology seems to be clear: The ongoing miniaturization of electronic devices enables processors and sensors being embedded into more and more everyday things - not only electrical devices, but also very mundane things such as key chains or even clothes.

Many of these devices will then be interwoven and connected together by wireless networks.
A world full of smart things that may communicate with each other and that interact with global services sounds fascinating, giving rise to many new applications and business opportunities. But how realistic are the promises? To approach this question, we will first elaborate the vision of the "Internet of Things" and summarize its enabling technologies. We take a broad view and identify long-term trends which, by extrapolation, give us some hints on what to expect in the future. We then discuss the main challenges and analyze what progress is necessary to overcome current technological hurdles.
In our talk we will also present several applications and prototypes of cooperating real-world objects that have been realized at ETH Zurich, and we shall briefly discuss the social and economic consequences and challenges of a future world pervaded by invisible computers.

- 14:00 **Dan Stilwell: Control and Estimation Over Networks: Part 2**
  In this talk, we discuss control and data fusion architectures for mobile sensor networks that are based on either information states or full-state observers. We describe a general architecture and show that no Kalman separation principal exists. Thus we conclude, in general, that data fusion and control algorithms are coupled. By stating the problem in general, we are able to recognize specific cases for which there exists no coupling, and we explore two cases in detail. At Virginia Tech, we are using this general framework for developing data fusion and control algorithms that enable a team of autonomous underwater vehicles to cooperatively find an acoustic target. We use this example throughout the talk for motivation and illustration.

2.3 Social Events

Introduction to Castle Ebernburg

Sunday evening
In the first evening there will be a short talk to introduce the castle where the summer school takes place and to give some historical overview. There will also be a saga explaining the name "Ebernburg", which can be translated as "boar's castle".

Wine Tasting

Monday evening
A local vintner will provide some of his wine and local food specialties for a nice evening, with stories about growing, tasting and enjoying wine.

Sports Event

Tuesday afternoon
In the sport event we would like to prove the human abilities for distributed cooperation and sensing of fast moving objects. Besides sensing, we will also test various algorithms for controlling body attached actuators like arms and legs, following the human in the loop methodology. Additionally, we expect to get insights into team performance depending on different approaches for topology control, distributed scene interpretation and communication. For the evaluation we focus on two realistic benchmark scenarios, namely volleyball and soccer. Due to the robot heterogeneity, a middleware concept (referee) will provide a common world model (rules) and will accordingly exclude misbehaving nodes.

Nightguard

Tuesday night
For about 1.5 hours a traditional nightguard of Ebernburg will show historic sites in the city and speak about the history this old town. At the end the group is lead to a medieval tavern to discuss the tour having a cool drink.

Multi-Sensorial Experience

Wednesday afternoon
A strongly bio-inspired multi-sensorial experience in monitoring, coordination and control of networked heterogeneous sensors and actuators will be offered which is as well entertaining and relaxing.

Rittermahl: The Great Feast at the Knights Board

Wednesday evening

As the main social event we will organize a dinner in the style of the late middle age near castle Kauzenburg.

While the lord of the castle, drummers, minstrels and fanfare players organize a medieval spectacle, the guests can eat for 2.5 hours a lusty meal, where kind maids and squires urge you to follow table manners from ancient times. You dine with dagger and fingers.

Barbecue at the Castle

Thursday evening

It is planned to have a Barbecue on Thursday evening as the last joint evening of the summer school at the castle. It will take place in the courtyard of the castle.

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Title:
Summer School “Monitoring and Coordination Across Networked Autonomous Entities”
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DFG Research Training Group “Cooperative, Adaptive and Responsive Monitoring in Mixed Mode Environments”
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