Program
CADICS - NTU Workshop on Autonomy in Vehicular Systems

Visionen, Linköping university, Building B, Entrance 27

November 23 2009

The workshop has five sessions, each with three twenty minute presentations. The sessions end with a fifteen minutes discussion.

8.30-9.45: Session I, Chairman Lennart Ljung

8:30 – 8:50 Modeling, control and health monitoring for mobile robots

Speaker: Danwei Wang
School of Electrical and Electronic Engineering
Nanyang Technological University, Singapore,
Email: edwwang@ntu.edu.sg, Website: http://www.ntu.edu.sg/home/edwwang

Abstract: Outdoor mobile robots have potential applications in industries such as seaport container transportation, passengers’ transportation and entertainment etc. Autonomy of mobile robots requires integration of many enabling technologies such as localization, mobility, perception, path planning and obstacle avoidance, and health monitoring techniques. This presentation describes some of our mobile robot research activities. These research issues include developments of proper models of the mobile robot behaviors for the purposes of analysis, control, fault tolerant control, fault detection and isolation. The presentation will also describe solutions to problems such as convoying control, integrated positioning with high accuracy, estimation and compensation of side-slipping and skidding for precise motion, fault tolerant control in platooning formation, fault detection and isolation in vehicle steering system. Experimental results for these researches are shown to illustrate their effectiveness.

Biography: Danwei Wang received his Ph.D and MSE degrees from the University of Michigan, Ann Arbor in 1989 and 1985, respectively. He received his B.E degree from the South China University of Technology, China in 1982. Since 1989, he has been with the School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore. Currently, he is professor and head, Division of Control and Instrumentation, School of EEE, and deputy director of the Robotics Research Center, NTU. He has served as general chairman, technical chairman and various positions in international conferences, such as International Conference on Control, Automation, Robotics and Vision (CARCVs) and Asian Conference on Computer Vision (ACCV). He served as an associate editor of Conference Editorial Board, IEEE Control Systems Society, is an associate editor of the International Journal of Humanoid Robotics, and Chairman of IEEE Singapore Robotics and Automation Chapter. He was a recipient of Alexander von Humboldt fellowship, Germany. His research interests include robotics, control theory and applications. He has published more than 250 technical articles in the areas of iterative learning control, robust control and
adaptive control systems, manipulator and mobile robot dynamics, path planning, and control, as well as fault diagnosis and prognosis.

8:50 – 9:10 DyKnow: A Stream-Based Knowledge Processing Middleware Framework

Speaker: Fredrik Heintz
Department of Computer Science, Linköping university,
Email: frehe@ida.liu.se, Website: http://www.ida.liu.se/~frehe/

Abstract: To achieve complex missions in dynamic environments intelligent autonomous systems must create and maintain situational awareness. This requires a steady flow of information from sensors to high level reasoning components. However, while sensors tend to generate noisy and incomplete quantitative data, reasoning often requires crisp symbolic knowledge. The gap between sensing and reasoning is quite wide, and cannot in general be bridged in a single step. Instead, this task requires a more general approach to integrating and organizing multiple forms of information and knowledge processing on different levels of abstraction in a structured and principled manner.

DyKnow is a framework that provides such a systematic approach for organizing the knowledge processing within a distributed robotic architecture. DyKnow is stream-based since knowledge processing for autonomous systems is fundamentally incremental in nature.

In this talk, I will present how DyKnow can incrementally bridge the sense-reasoning gap in a UAV traffic monitoring application. I also discuss how the framework has been extended to allow sharing of information among UAVs in a DyKnow federation and thereby supporting multi-UAV surveillance missions. The system is implemented and has been tested both in simulation and in test flights.

Biography: Fredrik Heintz is a researcher at the Department of Computer and Information Sciences (IDA), Linköping University, Sweden. There he leads the Cognitive Robotics group in the Artificial Intelligence and Integrated Systems (AIICS) division. He received his PhD in computer science from Linköping University in 2009. His main research interest is high-level reasoning grounded through sensing. The research is applied in unmanned aerial vehicle and model-based diagnosis applications. He is a member of two multidisciplinary research excellence centers (MOVIII and CADICS) with research spanning from control theory and sensor fusion to visualization and artificial intelligence. He is also the secretary of the Swedish Artificial Intelligence Society and the contest director for the Nordic Collegiate Programming Contest which is part of ACMs International Collegiate Programming Contest.
9:10 – 9: 30 The Role of the Human in Mixed Multi Agent Collectives

**Speaker:** Seet Gim Lee, Gerald,
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Email : mglseet@ntu.edu.sg

**Abstract:** Researchers have dedicated much effort to the development of autonomous robotic system. The aim is to operate without any human assistance or intervention. In an unstructured and dynamic environment this is not readily achievable due to the high degree of complexity of perception. For many real-world applications, it would be desirable to have a human in the control loop for monitoring, detection of abnormalities, and to intervene as necessary. In many complex tasks, as typified by defence and hazardous applications, full autonomy may be undesirable. Such complex tasks require human attributes of judgment, reasoning and control to ensure desirable operations and outcome. Robots are generally not perceived to possess these human attributes.

It is possible for current-state-of robots to perform useful tasks and to provide appropriate assistance to the human, to correct his control input errors by supporting perception and cooperative task execution. Systems which facilitate cooperation between robots and human are becoming a reality and are attracting increasing attention from researchers. In the context of human-robot cooperation, one concern is in the design and development of flexible system architecture for incorporating their strengths based on their complementary capabilities and limitations.

**Biography:** Gerald is currently an Associate Professor with the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore. He lectures in mechatronics, engineering design and real-time systems, at undergraduate and graduate level. He holds a concurrent appointment as Director of the Robotics Research Centre, and as Head of the Division of Mechatronics and Design.

His main research interests are in mechatronics and field robotics, with specific interest in underwater mobile robotics and fluid power systems. He has authored, and co-authored over 90 peer refereed papers. He is a consultant to industry in these areas. Recently, his research interest has extended to include Unmanned Aerial Vehicles (UAV) and collaborative robotic systems.

**Coffee break**
10.15 -11.35: Session II, Chairman: Lars Nielsen

Helen Dannetun, Dean, Words of welcome

10:20 – 10:40 Collision avoidance on roads and in space

Speaker: Fredrik Gustafsson
Department of Electrical Engineering, Linköping university,
Email: fredrik@isy.liu.se, Website: http://www.control.isy.liu.se/~fredrik/

Abstract: Collision avoidance warnings and decisions are based on the current state, which is estimated from uncertain data. While sensor models and state estimation are routinely embedded in a stochastic framework, the consequence on decision theory is not that well explored. Probabilistic conflict measures will be described, and applications to road vehicles and unmanned aerial vehicles are presented.

Biograph: Fredrik Gustafsson is since 1999 professor at the Department of Electrical Engineering, Linköping University. His research interests are in stochastic signal processing, adaptive filtering and change detection, with applications to communication, vehicular, airborne, and audio systems. His work in the sensor fusion area involves design and implementation of nonlinear filtering algorithms for localization, navigation and tracking of all kind of platforms, including cars, aircraft, spacecraft, UAV’s, surface and underwater vessels, cell-phones and film cameras for augmented reality.

10:40- 11:00 Real Time Obstacle Detection and Map Building Using Multiple-Baseline Stereo

Speaker: Han Wang, EEE, NTU
School of Electrical and Electronic Engineering
Nanyang Technological University, Singapore, Email: ehwang@ntu.edu.sg

Abstract: The objective of this project is to navigate a mobile robot in an open (unknown) terrain using way points provided by GPS. The primary sensor used is trinocular stereo, developed in-house. It is able to detect obstacles at 25 meters range. Firstly, we detect the ground, and then objects above or below the ground is detected as obstacles. The obstacle map is passed to navigation module for path planning and map building. For long range detection, FOV is limited and our stereo could cover only 40 degrees. Therefore, 2 sets of stereo were used and fused together to provide larger FOV. A few innovations were implemented in this algorithm including the Disparity Gradient Limit for noise reduction during stereo reconstruction. We have also built an error model for the range error so that longer range objects have less confidence range estimation.
11:00 – 11:20 Cognitive systems for driver assistance and autonomous driving - an overview from the DIPLECS project

Speaker: Michael Felsberg
Department of Electrical Engineering, Linköping university,
Email:mfe@isy.liu.se, Website: http://www.cvl.isy.liu.se/people/mfe

Abstract: The DIPLECS (Dynamic Interactive Perception-action LEarning in Cognitive Systems) project aims to design an Artificial Cognitive System capable of learning and adapting to respond in the everyday situations humans take for granted. The primary demonstration of its capability, will be the driving of a car. The system will learn by watching humans, how they act and react while driving, building models of their behaviour and predicting what a driver would do when presented with a specific driving scenario. The end goal of which is to provide a flexible cognitive system architecture demonstrated within the domain of a driver assistance system and an autonomous RC-car.

In order to achieve these goals, the DIPLECS architecture must allow for learning and adaptation in dynamic, real-time and real-world scenarios. Starting from a basic, rudimentary capability, it must constantly refine and improve its capability by observing a human driver, the car data and the surrounding environment. The architecture applies a hierarchical design principle, where adjacent levels are connected by feedback-loops. Learning occurs in two ways, either by analysing human-car-environment interaction or by (cognitive) bootstrapping of its own capabilities. We extend the established system architecture from the COSPAL project in order to establishes the fundament for implementing the three lower levels of the well-known ECOM model: tracking, regulating, and monitoring.

Lunch

13.15 - 14.30: Session III, Chairman: Patrick Doherty

13:15 – 13:35 Cooperative Distributed Control of Networked Systems

Speaker: Lihua Xie
School of Electrical and Electronic Engineering
Nanyang Technological University, Singapore
Email: elhxie@ntu.edu.sg
Website: http://www.ntu.edu.sg/home/elhxie

Abstract: Networked systems have attracted resurgent interest in recent years. Particular attention has been devoted to wireless sensor networks (WSNs), networked control, and networked multi-agent systems where the limited computing, communications and sensing resources, and the unreliability of networks have introduced many interesting problems for control researchers. In this talk, we shall give an overview of research on WSN and networked control in the Sensor Network Lab of NTU. The research issues to be discussed include data rate constrained estimation and control, control over unreliable networks, distributed consensus with limited data rate, and cooperative control. The applications in distributed target tracking, target tracking and interception, and multi-vehicle formation control will be demonstrated.

Biography: Lihua Xie is a professor and the Director, Centre for Intelligent Machines at EEE, NTU. His research interests include robust control and estimation, sensor networks, networked control systems, time delay systems, and control of disk drive systems. In these areas, he has published many papers and co-authored two patents and three books H-infinity Control and Filtering of Two-dimensional Systems (with C. Du); Optimal and Robust Estimation (with F.L. Lewis and D. Popa) and Control and Estimation of Systems with Input/Output Delays (with H. Zhang). He serves/served as an Associate Editor of IEEE Transactions on Automatic Control, Automatica, IEEE Transactions on Control Systems Technology, IEEE Transactions on Circuits and Systems. He was the General Chairman of the 9th International Conference on Control, Automation, Robotics and Vision, and is currently serving as the General Chair of the 7th IEEE International Conference on Control and Automation. Lihua Xie is a Fellow of IEEE.


Speaker: Lars Nielsen
Department of Electrical Engineering, Linköping university,
Email:lars@isy.liu.se, Website. http://www.vehicular.isy.liu.se/Staff/Employee/lars.html

Abstract: One scenario studied is a drive mission for a heavy diesel truck. With aid of an on board road slope database in combination with a GPS unit, information about the road geometry ahead is extracted. This look-ahead information is used in an optimization of the velocity trajectory with respect to a criterion formulation that
weighs trip time and fuel consumption. A dynamic programming algorithm is devised and used in a predictive control scheme by constantly feeding the conventional cruise controller with new set points. The algorithm is evaluated with a real truck on a highway, and the experimental results show that the fuel consumption is significantly reduced. These results are now extended in different directions, and in particular engineering machines, like wheel-loaders and dumpers, offer a set of new challenges.

Biography: Dr. Nielsen was born in Sweden in 1955. He received his M.Sc. in engineering physics in 1979 and his Ph.D. degree in automatic control in 1985, both from Lund Institute of Technology. Since 1992 he is professor of Vehicular Systems holding the Sten Gustafsson chair at Linköping University. His main research interests are in automotive modeling, control, and diagnosis.

13:55 – 14:15 **Multiplexed Model Predictive Control**

**Speaker:** Keck Voon Ling  
School of Electrical and Electronic Engineering  
Nanyang Technological University, Singapore, Email: ekvling@ntu.edu.sg  
Website: [http://www.ntu.edu.sg/home/elhxie](http://www.ntu.edu.sg/home/elhxie)

**Abstract:** We propose a form of Model Predictive Control (MPC) in which the control variables are moved asynchronously. This contrast with most MIMO control schemes, which assume that all variables are updated simultaneously. MPC outperforms other control strategies through its ability to deal with constraints. This requires online optimisation, hence computational complexity can become an issue when applying MPC to complex systems with fast response times. The multiplexed MPC scheme described in this talk solves the MPC problem for each subsystem sequentially, and updates subsystem control as soon as the solution is available, thus distributing the control moves over a complete update cycle. The resulting computational speed-up allows faster response to disturbances, which may result in improved performance, despite finding sub-optimal solutions to the original problem.

**Biography:** Dr Keck-Voon LING's current research interests include Model Predictive Control (MPC), its embedded implementation on reconfigurable computing platforms and applications.

He is currently an Associate Professor at Nanyang Technological University (NTU), Singapore, and was the Deputy Head of the Control and Automation Division (2006-2008) at the School of Electrical and Electronic Engineering, NTU. He graduated from the National University of Singapore and Oxford University, UK in 1988 and 1992 respectively. He was awarded the Commonwealth Fellowship and was a visiting researcher at the Department of Engineering, University of Cambridge, in 2001 and 2006. He also holds a joint appointment as a senior scientist at the Singapore Institute of Manufacturing Technology (SIMTech). From 2006-2009, Dr Ling was a Programme Manager of the A*STAR Embedded and Hybrid Systems II (EHS-II) Research Programme.

**Coffee break**
15.00-16.15: Session IV, Chairman Fredrik Gustafsson

15:00 – 15:20 The use of Camera Information in Formulating and Solving Sensor Fusion Problems

Speaker: Thomas Schön
Department of Electrical Engineering, Linköping university
Email: schon@isy.liu.se, Website: http://www.control.isy.liu.se/~schon/

Abstract: The use of measurements from different, often complementary, sensors in order to obtain a better estimate of the system under study has recently become very popular within many scientific areas. This is often referred to as sensor fusion and the main topic of this talk is to discuss how this problem can be tackled, with special attention to problems including cameras among the sensors. This goal is to provide a brief overview of how sensor fusion problems can be approached and then illustrate this using several successful application examples. Furthermore, we will stress and exemplify the fact that there are typically several spin-off problems that needs to be solved before the actual fusion problem can be solved.

Biography: Thomas Schön was born in Sweden in 1977. He received the Ph. D. degree in Automatic Control in 2006, the M. Sc. degree in Applied Physics and Electrical Engineering in 2001 and the B.Sc. degree in Business Administration and Economics in 2001, all from Linköping University, Linköping, Sweden. He has held visiting positions at the University of Cambridge (UK) and the University of Newcastle (Australia). His research interests are mainly within the areas of sensor fusion, signal processing and system identification, with applications mainly to the automotive and aerospace industry. He is currently an Associate Professor with the division of Automatic Control at Linköping University, Sweden.

15:20 – 15:40 Embedded Computing Techniques for Vision Based Sensing

Speaker: Thambipillai Srikanthan
School of Computer Engineering
Nanyang Technological University Email: ASTSRIKAN@ntu.edu.sg

Abstract: As pressure continues to achieve higher levels of device integration while reducing cost, size, complexity and power consumption, the need to devise architecture-centric efficient algorithms has become very crucial. This talk will focus on his R&D efforts in the development of architecture-centric algorithms for vision based sensing. Through first-hand experiences of developing solutions for use-inspired research, the talk will first outline the motivations for creating IP for vision enabled sensing through algorithm innovation. Our experience in the development of architecture-centric algorithms will be discussed to illustrate the potential of this approach to exploit inherent parallelism and to reduce the overall
computational complexity for real-time performance. In particular, a delicate balance between performance, power consumption, form factor and cost in embedded systems will be emphasized. Embedded computing techniques for vision based sensing will be discussed based on our on-going R&D projects at the Center for High Performance Embedded Systems (CHiPES), NTU, Singapore. This talk will also address the inter play between design methodologies and architecture-centric algorithm development towards realizing real-time embedded computing solutions.

**Biography:** Dr Srikanthan joined Nanyang Technological University (NTU), Singapore in June 1991. At present, he holds a full professor and joint appointment as Director of a 100 strong Centre for High Performance Embedded Systems (CHiPES). He founded CHiPES in 1998 and elevated it to a university level research Centre in February 2000. He has also served as founding Director of the Intelligent Devices and Systems (iDeAS) cluster for 2 years (2005-2007).

His research interests include design methodologies for complex embedded systems, architectural translations of compute intensive algorithms, computer arithmetic and high-speed techniques for image processing and dynamic routing. He has published more than 250 technical papers including 60 journals in IEEE Transactions, IEE Proceedings and other reputed international journals. His services as a key consultant to embedded systems industry, both locally and internationally are continually being sought for.

He contributed to all aspects of the curriculum development and operation of the undergraduate and post graduate programs. In particular, he proposed and developed a Master of Science course in Embedded Systems Engineering, based on his expertise in this emerging field of Computer Engineering. He was nominated for the ‘Best Teacher’ award for six consecutive years and won this award in 2002. He was awarded the Public Administration Medal (Bronze) on 2006 National Day in recognition of his contributions to education in Singapore.

15:40 – 16:00 **Rendering and interacting with large scale volumetric data for medical applications**

**Speaker:** Anders Ynnerman  
Department of Science and Technology, Linköping university  
Email: andyn@itn.liu.se, Website: http://webstaff.itn.liu.se/~andyn/ITN/Home.html

**Abstract:** The latest radiology modalities are capable of producing several thousand high resolution images per examination. These images are used to construct volumes of data. This talk will present some recent results from the Center of Medical Image Science (CMIV) and the Norrköping Visualization and Interaction Studio (NVIS), both at Linköping University in Sweden. The first part of the talk will address the issue of data reduction and multi resolution representations for Level-of-Detail selection using the knowledge encoded in transfer functions. Knowledge encoding can also be used to obtain fuzzy classification of unsegmented data and it will be demonstrated how classification can be used to improve transfer function design and enhance features of interest. The second part of the talk will present methods for haptic (force feedback) interaction with volumetric data. New methods for the design and implementation of haptic modes for
medical data will be presented and haptic feedback for time resolved volumes will be demonstrated. Throughout the presentation medical examples of volume rendering will be shown such as full body virtual autopsies using the presented methods.

**Biography:** Professor Anders Ynnerman received a Ph.D. in physics from Gothenburg University. During the early 90s he was doing research at Oxford University, UK, and Vanderbilt University, USA. In 1996 he started the Swedish National Graduate School in Scientific Computing, which he directed until 1999. From 1997 to 2002 he directed the Swedish National Supercomputer Centre and from 2002 to 2006 he directed the Swedish National Infrastructure for Computing (SNIC). Ynnerman is representing Sweden and the Nordic region in several international collaborations and policy bodies.

Since 1999 he is holding a chair in scientific visualization at Linköping University and in 2000 he founded the Norrköping Visualization and Interaction Studio (NVIS). NVIS currently constitutes one of the main focal points for research and education in computer graphics and visualization in the Nordic region. Ynnerman’s current research interest lies in the area of visualization of large scale and complex data sets with a focus on volume rendering and multi-modal interaction.

16.30-17.30: Session V, Chairman, Anders Ynnerman
16:30 – 16:50 **UAV Flight Dynamics & Control Research in NTU**

**Speaker:** Yongki Go Tiauw Hiong  
School of Mechanical and Aerospace Engineering  
Nanyang Technological University  
Email: yongkigo@ntu.edu.sg  
Website: [http://www.ntu.edu.sg/mae/admin/divisions/ae/ykg.asp](http://www.ntu.edu.sg/mae/admin/divisions/ae/ykg.asp)

**Abstract:** This talk will cover research on flight dynamics and control aspects of UAV performed by the Flight Mechanics & Control research group within the School of Mechanical and Aerospace Engineering, NTU. The focus will be on the unconventional UAV development and work related to unconventional UAV maneuvers. The projects discussed include versatile small UAV development, optimization of transition maneuvers for convertible UAV type, and formation flight control of multiple UAVs.

**Biography:** Yongki Go Tiauw Hiong obtained his Master’s and Doctoral degrees from Massachusetts Institute of Technology (MIT), USA, both in Aeronautics and Astronautics in 1994 and 1999, respectively. After finishing his doctoral program, he worked at MIT’s Man-Vehicle Laboratory and Center for Transportation and Logistics as a Postdoctoral Associate and later on as a Research Engineer. His work at MIT includes dynamics and control of aircraft wing rock, spacecraft attitude control using geomagnetic field, simulator motion effects on airline pilot training, and environmental impact of aviation. Since December 2005, he has been an assistant professor at the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore. His current research activities include unmanned aerial vehicle system, unconventional flight dynamics and control, and formation flight control.

16:50 – 17:10 **Unmanned Aerial Vehicle Research Activities in AIICS**

**Speaker:** Patrick Doherty  
Department of Computer Science, Linköping university  
Email: pdy@ida.liu.se, Website: [http://www.ida.liu.se/~patdo/patdosite1/index.html](http://www.ida.liu.se/~patdo/patdosite1/index.html)

**Abstract:** For roughly a decade now, the Artificial Intelligence and Integrated Computer Systems Division (AIICS) at the Computer and Information Sciences Division has been involved in unmanned aerial vehicle research. Topics range from traditional control and development of autopilot flight boards, to software architectures for autonomous systems, to artificial intelligence technologies such as path and task planners, knowledge representation and reasoning systems, and to techniques which support cooperation among such vehicles. This broad multi-disciplinary endeavor has had a large pay-off in terms of developing fully functional autonomous UAV systems and in terms of laying scientific foundations for such systems. In this talk, I will provide an overview of some of the systems we have developed and some of the real-world scenarios we are interested in. Emphasis will be placed on those activities we believe can lead to strong and long term collaboration with NTU in the development of cutting edge technologies for UAV systems. This talk will also serve as a complement to a scheduled visit to our UAV lab where we will demonstrate some of the work described in this talk.
Biography: Patrick Doherty is a Professor of Computer Science at the Department of Computer and Information Sciences (IDA), Linkoping University, Sweden. He heads the Artificial Intelligence and Integrated Computer Systems Division at IDA. He serves as director of LinkLab, a research center for future aviation systems, which is a collaborative endeavor between Linkoping University and Saab Aero Systems. He is an ECCAI fellow and currently an ECCAI board member. He has previously served as president of SAIS, the Swedish Artificial Intelligence Society. He is also an associate editor for the Artificial Intelligence Journal. His main areas of interest are knowledge representation, automated planning, intelligent autonomous systems and multi-agent systems. A major area of application is with Unmanned Aircraft Systems. His research group has won several international competitions pertaining to micro-air vehicles and to automated planning. He has over a hundred refereed publications in his areas of expertise. He is also CEO of a new start-up company UAS Technologies Sweden which markets Micro-Aerial Vehicles (MAVs).