INTELLIGENT SYSTEMS GROUP (ISG)

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Background and Mission

The Intelligent Systems Group's mission is to carry out leading edge long-term research on intelligent systems technology. We concentrate on mobile and context-aware systems, data mining methods and secure programming. Our aim is to increase systematically our methodological understanding and to develop components for an intelligent environment that gives versatile services for its inhabitants.

We see behaviour modelling as one of the key challenges in developing intelligent environments. Models of user behaviour are needed to adapt the functionality of the intelligent environment to the situation at hand. Further, it is essential to be capable of modelling the behaviour of devices the intelligent environment controls, as it enables adaptation to environmental changes without reprogramming. In other words, a system learns and adapts automatically to perform behaviours fulfilling the requirements set to it.

The significance of developing this kind of calm technology is evident. The user does not have to command everything herself but the system can give commands on behalf of the user. In other words, the intelligent environment provided by calm technology enables people to do more by doing less. Our quality of life could thereby be improved, and for example by supporting the independent coping of the elderly, the expenses incurred by society would decrease.

We tackle the research challenge of the intelligent environment by increasing systematically our methodological understanding of the problem and applying the methods developed in realistic prototypes. We need to work on emergent intelligence by developing methods for self-organization and evolution of adaptive behaviours, and applying them with mobile robots and devices. We need to have a good understanding of signal analysis and sensor fusion, including structural and statistical pattern recognition. To acquire the knowledge embedded in the raw signal data, different data mining methods are required (softcomputing, clustering and visualization).

In the applied research, prototypes will be implemented for evaluating the developed learning methods. This work consists of specifying the applications, developing the software architectures, building the infrastructure, implementing the prototype systems, and testing them. We also target at robust software architectures that follow good information security practices.

The group co-operates with many international and domestic partners. In applied research, the group is active in European projects, and several joint projects funded by the National Technology Agency (Tekes) and industry. The group and its members are active in the scientific community. For example, Prof. Juha Röning served as Co-chair on the program committee of Intelligent Robots and Computer Vision XXII: Algorithms, Techniques, and Active Vision (25-29 October 2004, Philadelphia, Pennsylvania); and several members of the group were on the committees of international conferences. As recognition of profound work in the software vulnerability process Tiina Havana gave an invited talk at the "Cybersecurity, research, and disclosure" conference which was held at the Stanford Law School in Palo Alto, California, on 22nd November, 2003. The quality of research training in our group is high. Two recent master's theses (Kari Kangas and Heikki Pylkkö) have been awarded the title of the best thesis of the year and Ilmari Juutilainen received the Leo Törnqvist award for the best pro gradu thesis from the Finnish Statistical Society in 2003.

The activities of the ISG are led by professors Juha Röning (Director), Jukka Riekki and Tapio Seppänen.

Scientific Progress

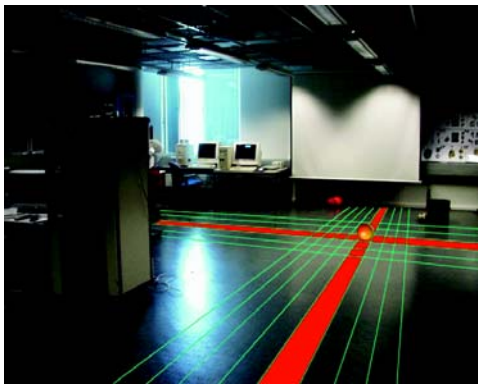
In 2003, the research on ISG concentrated on mobile and context-aware systems, data mining methods and secure programming. These were applied in context-aware mobile systems, intelligent service robots, steel plant and spot welding processes quality control, and analysis of biomedical ECG and EEG signals.

Context Aware Systems

The core of context aware systems research is realized in the Beacon (Behavioural Modeling in Context-Aware Systems) research project which is part of a research programme on Proactive Computing (PROACT) organised in co-operation with Tekes, the National Technology Agency of Finland and the French Ministry of Research. A proactive system adapts and adjusts to the user and his or her environment without requiring any conscious control.

The objective with context aware systems is to develop methods for learning behavioural models. Two kinds of models are needed: models for user behaviours and models enabling devices to adapt to their environment. Methods for learning models are needed to develop devices capable of adapting to different environments without reprogramming. Models of user behaviours are essential in proactive computing, as they are needed to adapt the functionality of the proactive system to the situation at hand. For example, a model might show that the elderly person walking in her apartment is probably heading towards the hallway. Using such a model, the proactive system could switch on the lights in the hallway. Methods for analysing sensor signals will be developed as well, as they produce the parameters used by the learning methods. The final goal is to enable the proactive system to adapt to environmental changes in real time.

The research on context-aware systems involves the development of proactive, context-aware environments. We are building a prototype of a smart living room in our laboratory. This living room will be a large proactive system. The technology and computation will be hidden as far as possible; the goal is to provide the user with a natural environment that offers advanced services. The hardware for the first version of the prototype has been installed during this year (2003). The implementation of the basic software and the development of the computational methods have been started. This environment will give us a great opportunity to demonstrate and validate our research results.



A pressure sensitive floor in the Robotics Laboratory.

Another environment utilized in the research of context aware systems has been built in the centre of Oulu, in a pedestrian precinct called Rotuaari. The Rotuaari project consists of developing a research environment, executing field trials in the research environment and developing the value network related to the context. The group maintains also test network infrastructure at Linnanmaa campus area. This is used also by others, for example MediaTeam.

Distributed software architecture is being developed for mobile context-aware systems. The architecture offers well defined and reusable interfaces for different resources like sensors, actuators, computing devices and user interfaces. The location and implementation of a software component is transparent for the rest of the system. The architecture was further developed. A common interface was developed for all robotics resources. Furthermore, methods to dynamically construct state machines for robot controllers were studied.

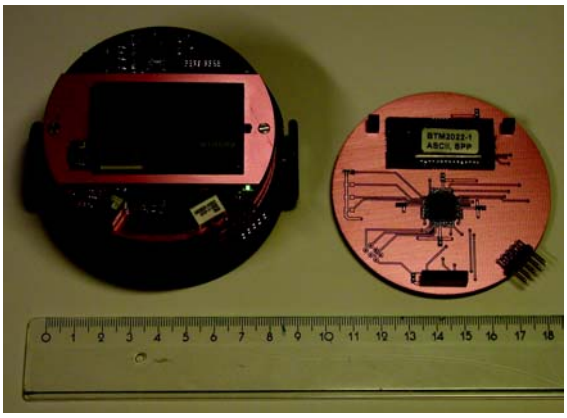
The architecture is being applied both to systems controlling mobile service robots and to ubiquitous systems serving mobile users. In 2003, development of a general agent-based architecture, Genie of the Net, for managing services on behalf of the user has progressed. This work has been done in co-operation with VTT Electronics.

For handling devices and services in our smart living room, we continued the development of a distributed CORBA architecture, called Property Service architecture. Through Property Service architecture, new devices are easy to append to the system. The focus is also on high reusability of existing code and software components as the same control algorithms can be used on various devices. A part of the architecture is work on dynamic state machines that are used for controlling multiple devices in cooperation. Easy to use tools like a graph editor were developed for the system to provide a possibility for a non-technical person to use the devices in the system.

As part of the future environment, we envisage home robots that can be used for different purposes, such as telepresence. In our research laboratory, we are developing a robot whose main purpose is to serve as a telepresence body, but which can also perform home aid functions. The goal is to develop new methods and devices that will improve the current telepresence equipment by providing a self-guiding, intuitive, and very easy-to-use user interface and by creating a realistic feeling of being present in the remote location. During the reporting period, work on speech recognition over a videoconference connection and robot sensor visualization via the video stream of the videoconference has been done. Our techniques al-

low the robot to be remotely controlled with generally available videoconference software applications such as Microsoft Netmeeting.

Evolutionary methods to evolve neural controllers for a mobile robot were studied. An approach called the Stochastic Evolutionary Neuron Migration Process (SENMP) was used to evolve neural control structures for mobile robots and to gain new insights into adaptation in neural networks. The neural structures were able to solve real problems in perception and control. The feasibility of the approach was demonstrated by evolving robust navigation behavior for a simulated and a real mobile robot.

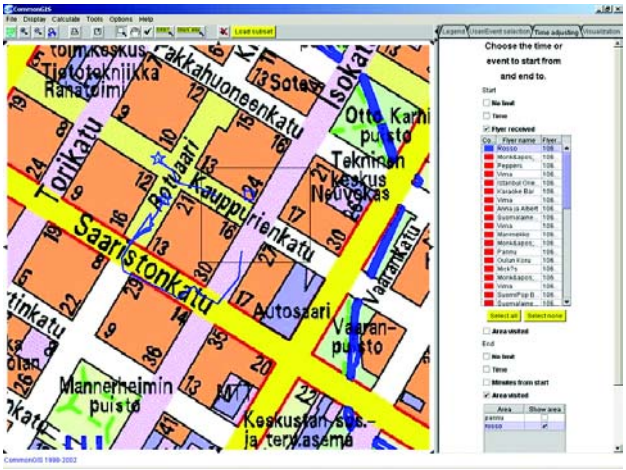


The prototype of the miniature mobile robot that is being developed in the Computer Engineering Laboratory. Left: The robot (lithium-ion battery module at the top). Right: Detached Bluetooth module.

In the context-aware research, the group participates in the CAPNET (Context-Aware Pervasive Networking) program. The purpose is to create context-aware mobile technologies for ubiquitous computing. Two other research groups, MediaTeam, and the Human Computer Interaction group from the Department of Information Processing Science, participate in the program, also. The Intelligent Systems Group's work focuses on developing an architecture which enables smooth utilization of context-aware applications. Also, the user's context and routines are identified from different kinds of sensory data, mainly location information through wireless LAN and other information from different kinds of mobile devices.

The focus of the CAPNET program is on context-aware mobile technologies for ubiquitous computing. These are technologies, which allow communication anytime and anywhere, with any kind of terminal device, automatically taking into account the characteristics of the network and the terminal. The ISG participates in the CAPNET program by studying context-awareness and developing software architectures. Context-awareness research concentrates on identifying the user's routines, utilizing location information acquired through WLAN, and a pressure sensitive floor on the premises of the Tietotalo Robotics Laboratory.

The Rotuaari project (Context-aware mobile multimedia services) is aimed at developing and testing technologies and earnings models for context-aware mobile multimedia services of the future. This project involves co-operation with MediaTeam, the INTERACT group from the Faculty of Science, the Department of Marketing from the Faculty of Economics and Business Administration, and the Educational Technology research unit from the Faculty of Education. Other research parties include Linköping University (Sweden) and Oulu Polytechnic. The ISG's role lies in developing visual data mining methods for user data collected in several field trials for mobile applications, in building models for the conditions and processes of security related communication, and in vulnerability assessment.



The data collected within the Rotuaari field trials can be visualized with setting different limitations to the data. Here, the stars describe the places where the user has received a flyer to his mobile device. The path from receiving the flyer to ending up in the neigbourhood of the restaurant responsible of the flyer is plotted. Furthermore, other constraints can be set (time, minutes from the start, no limit), and the data from several users can be shown simultaneously.

Research with the pressure sensitive floor focused on improving the methods used for segmenting footstep profiles from EMFi-data. Accurate detection of good footstep patterns from raw EMFi-data is vital for the purposes of person identification and tracking. A segmental semi-Markov model based pattern matching algorithm was applied for this task. First a segmental semi-Markov model of a footstep pattern was constructed, where each state in the model corresponds to a linear segment in a piecewise linear approximation fitted to the example footstep pattern. Then a Viterbi-like algorithm was used to detect occurrences of patterns similar to the model in the EMFi-data.

This methodology introduced the important aspect of shape variability to the footstep detection procedure. The extent of the allowed shape variability was easily set in the model creation by adjusting the model's state duration distributions and segmental observation distributions. This was a very useful feature due to fact that, because of certain characteristics of the EMFi-floor, the footstep patterns vary quite a lot, depending, for example, on the walking style of a person. The first version of the system was made to work off-line, and the tests made proved it worked very well on EMFi-data.

The identification of segmented footsteps from the pressure-sensitive floor was studied. At the early stage, identification methods included discrete Hidden Markov Models (HMM). After that, Learning Vector Quantization (LVQ) was applied to single footstep classification, and showed more accurate results (65% total accuracy of eleven testees). To improve identification accuracy and reliability, a reject-optional LVQ-based classifier, which uses identification information of several consecutive footsteps, was also development. This method showed about 90% recognition rate of eleven walkers.

A real-time version is currently being implemented. At the first stage, it will include methods for segmenting the raw footstep pressure signal for person tracking and identification. Signal segmentation will be based on a segmental semi-Markov Models, and identification on VQ.

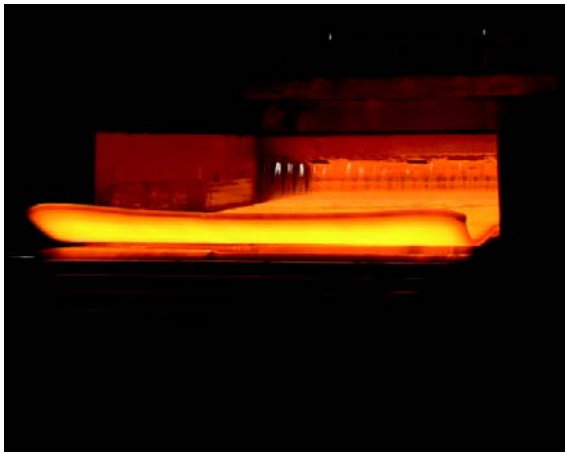
Data Mining

Quality Control

New data mining methods were developed for steel plant quality control and spot welding processes. The two-year VALTA project in co-operation with Rautaruukki Steel in Raahe contains three application areas: furnace control study, predicting the scaling of the steel strips and the modeling of strength properties of steel plates. The steel plant quality control study has continued during the second year of the project.

In the furnace control study, the development of an intelligent furnace control system has continued. The development of architecture for the intelligent management of data and prediction models was accomplished. The development of software for the utilization of dynamic neural networks for optimizing the heating process has progressed and the software is ready for implementation in the production line. It is impossible to measure the temperature of slabs in the furnace, and a reliable prediction model will be used for optimizing the heating.

The research on the reasons for the steel strip scale



Rolling in progress.

defects continued. The preprocessing of the data proved to be a very complex task. The localization of the thermomechanical treatments made during the rolling to the final strip is difficult, because the length of the strip grows from ten meters to hundreds of meters and the speed of the strip varies during the rolling. Despite of deficiencies in the data, software for localization was developed. After the localization of treatments, the prediction of the scale defects was tried using neural networks, but the scale defects proved to be very difficult to predict. However, some reasons affecting the scale defects were found, and also the software for localization is now utilized in Rautaruukki.

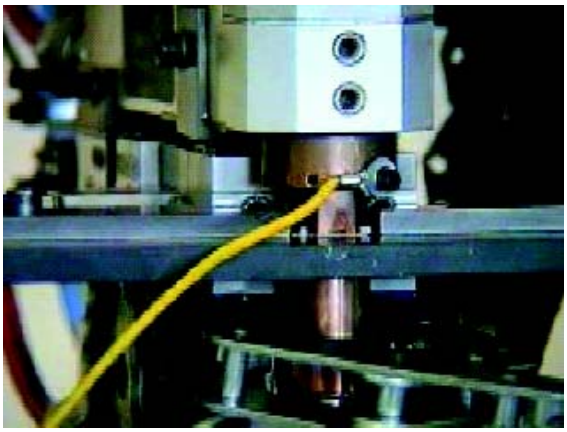
In the study of the strength properties of steel plates, heteroscedastic regression models have been used for the joint modeling of the mean and dispersion. Tensile strength and yield strength have been modeled separately. A planning model with a simple user interface has been developed, and the planning model is already in everyday use in Rautaruukki. The variance of strength depends heavily on the production method. Taking account of the variance heterogeneity with a predictive model is a novel approach and offers clear advantages compared to the classical approach of predicting only the mean.

We have also co-operated with Steel Dynamics Inc. from the United States. Methods for data preprocessing have been developed and the reasons for disqualification have been analyzed from the perspective of the whole production process.

SIOUX (Intelligent system for dynamic online quality control of spot welding processes for cross-sectoral applications) is a two-year EU-project developing a real time quality control system of resistance spot welding joints. The aim of the system is to replace time and cost intensive destructive tests by using soft computing methods for quality estimation. The benefit is that the approach does not require any addi-

tional sensors, like for example ultrasound based methods, as it uses on-line process data combined with knowledge gathered from previous experiments.

We are building a dynamic database containing measurements from welding tests and developing data mining methods for analyzing the measurement data to achieve better welding quality. During the last period the database has been set up and now covers an extensive data set of welding experiments. Methods for estimating the welding spot quality using Bayesian networks and self organizing maps have been developed and the results have been reported in conference publications. Furthermore, methods for identifying a newly set-up welding process from a set of existing welding processes have been developed. The results can greatly shorten the time required for setting up the new process and increase the quality of the products.



A spot welding machine producing electrical switches.

The system is an application example of one of our research topics - a smart archive. A smart archive is a system combining expertise in databases and data mining methods. The goal is to implement and bring this know-how to processes that produce large amounts of data and demand adaptive, continuous and largely autonomous supervision.

Biomedical ECG and EEG Signals

Research into ECG signals has been conducted. The main goal in the project is to study heart rate variability of patients and healthy people in order to develop methods for automatic diagnosis and prognosis for clinical use. The medical part of the research is performed in the Oulu University Hospital and Merikoski Rehabilitation and Research Centre, while our group is responsible for signal analysis algorithms. The work is highly international, including universities from Europe and the USA. Scientific results were achieved mainly in the study of heart rate variability of patients with a severe heart condition or healthy subjects under physical stress. Four journal papers and three conference papers were published from our results, while one journal paper is at a finalizing stage.

Research on the methods for automatic assessment of the depth of anesthesia and physical reaction to pain was continued. A new multi-sensor approach to this is being developed. One PhD student had a four-month visit to Professor Nitish Thakor's laboratory at the John Hopkings University in the USA. A manuscript of a journal paper is under final revision with the achieved results of utilizing EEG and EOG simultaneously for anesthesia level estimation. Another journal paper is under preparation that describes the results achieved from ECG signal analysis. The work is performed in cooperation with the Oulu University Hospital and the Lappeenranta University Hospital, while our team is responsible for algorithm and software development.

Research of muscle symphatetic nervous activity (MSNA) was continued. The aim is to study the basic relations between heart rate, blood pressure, breathing and MSNA signals. Equipment is used that only ten other research groups in the world possess. One journal paper is undergoing final revisions.

Blood oxygen level dependent functional MRI (BOLD fMRI) was utilized in order to investigate the effects that hyperventilation has on an animal brain. EEG was measured simultaneously. The set of time series signals offered by the EEG and fMRI enables us to see the changes in the electrical behavior of the cortex and the oxygen level changes in brain tissue simultaneously. One journal paper was accepted related to this research.

Secure Programming

Inside the Intelligent Systems Group, the Oulu University Secure Programming Group (OUSPG) has kept its focus on implementation level security issues and software security testing. Software implementation may introduce potential for unanticipated and undesired program behaviour, e.g. an intruder can exploit the vulnerability to compromise the computer system. The group has researched different approaches to testing implementations of protocols using black-box (i.e. functional) testing methods (PROTOS). During the year 2003 the focus of the testing was on voice over internet protocols.

Regarding the vulnerability process work, Tiina Havana finished her Master's thesis on the theme "Communication in the software vulnerability process" in May 2003. Based on the thesis work and a conference presentation given at the FIRST 2003 conference, she received an invitation to speak at the "Cybersecurity, research, and disclosure" conference which was held at the Stanford Law School in Palo Alto, California,

on 22nd November, 2003. At the conference she gave a presentation with the title "Checklist for designing a vulnerability disclosure policy".

During the year 2003, the vulnerability work has been executed also in the Rotuaari project and the work in Rotuaari will continue. Besides being the pedestrian precinct in the centre of Oulu, Rotuaari is the name of a research project at the University of Oulu. The Rotuaari project aims at the development and empirical evaluation of future context-aware mobile multimedia services and underlying business models in a real end user environment with user and business driven research. Rotuaari consists of developing a research environment, executing field trials in the research environment and developing the value network related to the context. The research in the Rotuaari project is conducted by seven work packages from four faculties at the University of Oulu. OUSPG executes vulnerability analysis on selected hardware and software products that are brought to the Rotuaari setting, and handles incident response when needed. OUSPG has also executed case study research on information security communication with qualitative interviews in the Rotuaari context. The purpose of the communication study was to evaluate the attitudes, perceptions and knowledge on information security of various participant groups in order to develop effective and purposeful communication channels for information security issues.

During the latter part of 2003, funding was sought for a new project to proceed on the PROTOS theme. The project is entitled "Vulnerability management of the information infrastructure from the protocol dependence point of view", and its purpose is to develop a visual model for understanding dependencies related to protocols. Work on the project commences in 2004.

The second major research area in OUSPG is finding methods for managing the complexity of systems. The increasing complexity of networks has made security assessment difficult. The more complicated a system is, the more likely vulnerabilities are. Merging different kinds of networks, such as telephone and IP networks creates new threats, which have not been thought of when the networks were originally designed.

The purpose of the Frontier project was to develop a systematic methodology to identify information security related vulnerabilities in a complex multi-modal network scenario. A way of looking at the 'big picture' of overall vulnerability was sought. Methodology development was supported by prototyping activity which tied the theory into practical setting; this was used as a testbed for the effectiveness of the developed methodology. The practical research allowed us to set our hands dirty and provided an understanding of the ways traditional vulnerabilities manifest themselves in a more complicated context. Thus supporting the in-depth understanding of complicated network scenarios were found to be important.

A method for analyzing complex distributed systems by inferring and visualizing causal relationships between different events was developed during the final year of the project. Initial results in applying the method to the problem-field of the project were encouraging and the method will be developed further in a follow-up project, FRONTIER-COMPAT.

Exploitation of Results

The results of our research were applied to real-world problems in many projects, often in collaboration with industrial and other partners. Some examples of exploitation are described below.

The Intelligent Systems Group utilizes a robotics laboratory and the pressure-sensitive floor (EMFi material) installed in our laboratory as part of a smart living room. Other equipment include a home theatre, two degree-of-freedom active cameras, four mobile robots and one manipulator, a WLAN network, and various mobile devices (PDAs, a tablet PC, Symbian mobile phones). WLAN positioning covers a large part of the campus (including the laboratory), and a home automation network is being installed. Our aim is to gradually build a versatile infrastructure that offers various generic services for pervasive applications. Naturally, this kind of environment enables realistic experiments that lead to a better understanding of such applications.

The group's expertise in robotics was applied in developing a mobile robot for domestic help. A teleoperated robot serves as the remote eyes of the elderly and those who take care of them. During the reporting period, the main task was to develop teleoperation capabilities for the robot. A voice controlled service robot was successfully demonstrated. The purpose of the robot is to assist elderly people in their homes and provide a communication link to the health care personnel. A design project was launched with the University of Lapland to further develop the appearance of the robot, and make it suitable for various applications and research studies regarding human-robot interaction.

The development in robotics has continued in the area of mechanical and miniaturization research. Qutie is an interactive mobile robot designed in co-operation with the University of Lapland. The development of the Qutie robot has continued, as the robot has gained

a new neck mechanism with 4 DOF. The robot has now also a new better frame for carrying a greater load.

The development of a miniature mobile robot is a part of the BEACON project. The aim of the robot project is to provide a small sized mobile agent with powerful audio-video processing capabilities and sophisticated on-board sensors for proactive computing applications. The robot will be easily manufactured and replicated because of its modular design. The robot is used in real and miniaturized environments to study how group of mobile agents can be utilized in proactive computing applications such as environment monitoring, guarding, and distributed information gathering and processing. In addition, robots provide a way of simulating actions taken by humans in real and miniaturized worlds, and, at the same time, collecting real environmental information with on-board sensors for later analysis and discovery of decision making processes.

The miniature robots use the latest CMOS-camera technology and a powerful DSP processor for video and audio processing. The communication link between the robots and the host computer is established using blue-tooth technology. The additional modules are: the central control module, lithium ion battery module, infrared proximity sensor module, and infrared based positioning module. Each module is an independent system and has its own micro processor. The inter module communication is established using serial buses.

During 2003 significant practical penetration for developed theories and procedures was achieved in the software industry and security community. In the PROTOS project, OUSPG is researching different approaches to testing implementations of protocols using black-box (i.e. functional) testing methods. The goal is to support the pro-active elimination of faults with information security implications. During the 2003, the focus of the testing was on voice over internet protocols. Protocol test suites were developed for the Session Initiation Protocol (SIP) and the call signalling of the H.323 teleconferencing protocol suite. Vulnerability management for the SIP test suite was handled by the CERT Coordination Center (*http://www.cert.org/advisories/CA-2003-06.html*). The H.323 test suite and advisory were published in cooperation with the British National Infrastructure Security Co-ordination Centre (NISCC) (*http://www.uniras.gov.uk/vuls/2004/006489/h323.htm*). As a result of PROTOS research, a spin-off company, Codenomicon Ltd., was founded in 2001 to develop commercial software testing products (*http://www.codenomicon.com*).

In addition to the core research, OUSPG also maintains a test network infrastructure for research groups such as OUSPG, ISG and MediaTeam. Test networks are required for the safety of both our own research and innocent bystanders, and one was constructed for internal use in the laboratory. The network provides a fully functional infrastructure with services such as storage, backups, DNS and mail.

The infrastructure started life as an isolated test network for OUSPG use, but during the year 2003 the project was expanded to provide basic infrastructure to others in need. There are three separate networks: a core network for basic services, a combined playground and a wireless access network panOULU, and an Internet-connected network with connectivity independent of the main university network.

Future Goals

We will continue to strengthen our long term research and researcher training. We will also continuously seek opportunities for the exploitation of our research results by collaborating with partners from industry and other research institutions in national and international research programs and projects. The group is a founding member of the European Robotic Network of Excellence (EURON). The group is a contract member of EURON II which was approved for the EU's 6th framework as a Network of Excellence.

Personnel

professors & doctors	5
graduate students	15
others	34
total	**54**
person years	33

External Funding

Source	**EUR**
Academy of Finland	13 000
Ministry of Education	167 000
Tekes	260 000
domestic private	243 500
EU + other international	354 000
total	**1 037 500**

Selected Publications

Hautala A, Mäkikallio TH, Seppänen T, Huikuri HV & Tulppo MP (2003) Short-term correlation properties of R-R interval dynamics at different exercise intensity levels. Clinical Physiology and Functional Imaging 23(4):215-223.

Juutilainen I & Röning J (2003) Heteroscedastic linear models for analysing process data. WSEAS Transactions on Mathematics 2(3):179-187.

Korpipää P, Koskinen M, Peltola J, Mäkelä S-M & Seppänen T (2003) A Bayesian approach to sensor-based mobile device context recognition. Personal and Ubiquitous Computing.

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Mäkiranta M, Ruohonen J, Suominen K, Sonkajärvi E, Salomäki T, Kiviniemi V, Seppänen T, Alahuhta S, Jäntti V & Tervonen O (2004) BOLD-contrast functional MRI signal changes related to intermittent rhythmic delta activity in EEG during voluntary hyperventilation - Simultaneous EEG and fMRI study. NeuroImage.

Mäntyjärvi J & Seppänen T (2003) Adapting applications in mobile terminals using fuzzy context information. Interacting with Computers - Special Issue on Human-Computer Interaction with Mobile Devices 15:512-538.

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Junno H, Laurinen P, Tuovinen L & Röning J (2004) Studying the quality of resistance spot welding joints using self-organising maps. Fourth International ICSC Symposium on Engineering of Intelligent Systems (EIS 2004), February 29 - March 2, Madeira, Portugal.

Juutilainen I, Röning J & Myllykoski L (2003) Modelling the strength of steel plates using regression analysis and neural networks. International Conference on Computational Intelligence for Modelling Control and Automation (CIMCA2003), February 12-14, Vienna, Austria.

Laurinen P, Junno H, Tuovinen L & Röning J (2004) Studying the quality of resistance spot welding joints using Bayesian networks. Artificial Intelligence and Applications (AIA 2004), February 16-18, Innsbruck, Austria.

Pirttikangas S, Riekki J, Kaartinen J & Röning J (2003) Context-recognition and data mining methods for a health club application. 12th Int. Conf. Intelligent and Adaptive Systems and Software Engineering (IASSE 2003), July 9-11, San Francisco, CA, USA, 79-84.

Pirttikangas S, Suutala J, Riekki J & Röning J (2003) Learning vector quantization in footstep identification, 3rd IASTED International Conference on Artificial Intelligence and Applications (AIA 2003), September 8-10, Benalmadena, Spain, 413-417.

Tikanmäki A, Riekki J &Röning J (2003) Qutie - an interactive mobile robot. The 11th International Conference on Advanced Robotics (ICAR'03), June 30 - July 3, Coimbra, Portugal.

Vallius T & Röning J (2003) Easy-to-use telepresence and home aid robot, The 11th International Conference on Advanced Robotics (ICAR'03), June 30 - July 3, Coimbra, Portugal.