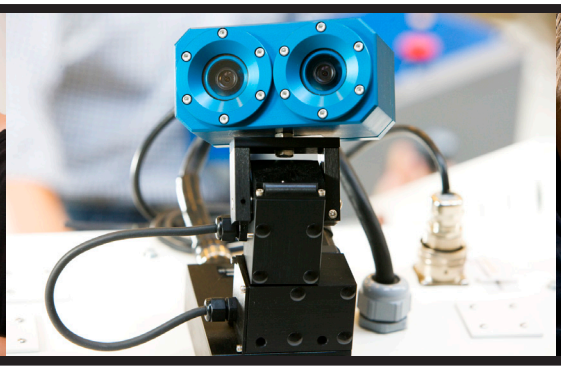
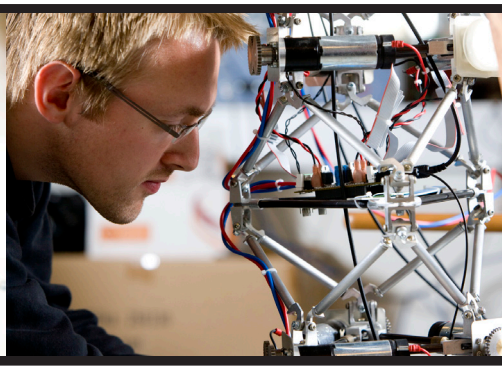
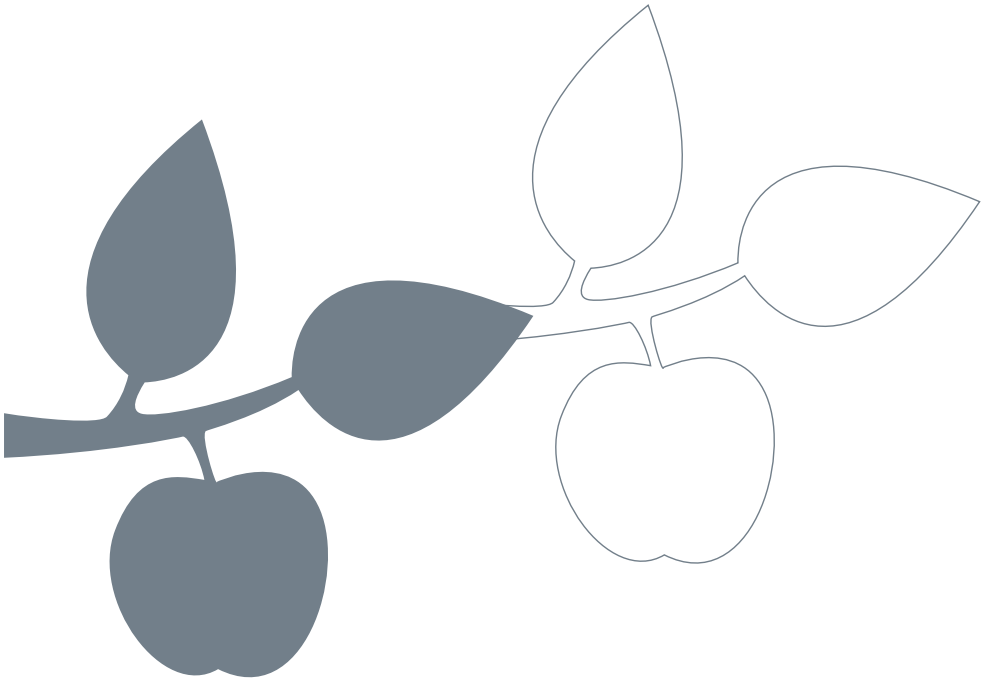




The Maersk Mc-Kinney Moller Institute

Faculty of Engineering

University of Southern Denmark



Foreword

The Maersk Mc-Kinney Moller Institute was established in 1997 as part of the Faculty of Science at University of Southern Denmark. In 1999 the Institute moved into new premises donated by A.P. Møller og Hustru Chastine Mc-Kinney Møllers Fond til almene Formaal (The Moller Foundation).

In 2006 the Institute merged with the then Ingeniørhøjskolen i Odense and a new faculty, The Faculty of Engineering, was estabilised. Due to the merger, the Institute activities are spread across two sites, and this situation will last until 2015, when a new building will be ready to accommodate the Faculty and its many departments.

The Maersk Mc-Kinney Moller Institute performs intensive research within the field of robotics and software engineering with the aim of developing robots that can optimise industrial as well as medical and other scientific disciplines and domains. Current research and innovation activities include:

- Cognitive and Applied Robotics
- Welfare and Innovation Activities
- Biologically-inspired Robotics
- Acoustics
- Embodied Artificial Intelligence (AI) and Neurorobotics
- Learning and Experience Technology
- Agricultural Robotics
- Power Electronics
- Energy Informatics
- Statistical Signal Processing
- Information and Knowledge Management

Collaboration initiatives are highly valued by the employees of The Maersk Mc-Kinney Moller Institute, not only across disciplines and sectors but also across national boundaries. Everybody strives to obtain the highest level of expertise and experience within their fields of education and research by using the latest methodologies and findings, and sharing knowledge and competencies with others.

On the pages overleaf, a selected number of our research experts describe in their own words the areas of interest that they are engaged in, thus providing this brochure with a unique mixture of information and enthusiasm, vocational pride, and knowledge.

Kasper Hallenborg
Director, Head of Department

What's Inside


3C95

Introduction

Beginning

The Maersk Mc-Kinney Moller Institute performs research and education within robotics. The Institute's many industry-related activities stem from a close cooperation with the former A.P. Moller-owned shipyard, Odense Staalskibsværft, which wished to introduce robots in its production halls. The Institute's current premises were built with a donation from A.P. Møller og Hustru Chastine Mc-Kinney Møllers Fond til almene Formaal (The Moller Foundation).

Building donated by The Moller Foundation

Industry

The Institute, which is one of the world's leading institutes in its field, is developing new technology that provides industrial robots with both intelligence and memory, so that they achieve an understanding of their surroundings and tasks at hand. Some of these robots are also easy to programme, even for non-programmers. The result is very adaptable colleague-like robots.

Easily-programmable robot

Welfare

Based on its expertise in industrial robotics, which includes a strong element of electronics and software, the Institute has taken on the challenge of the ageing society and now also specialises in developing robot technology to be used in the field of welfare, rehabilitation and surgery. To that end, our researchers and engineers collaborate with other professionals, such as physiotherapists and doctors.

Rehabilitation Robotics

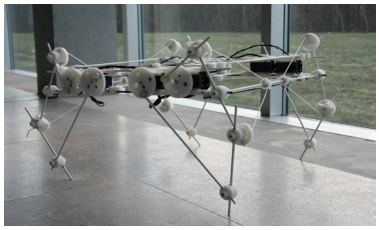
Introduction

Biorobotics

The Institute also performs basic research where completely new territory is uncovered. Biorobotics, for example, is an extreme form of bio-inspired robotics, with the aim of understanding how animals work rather than improving robot design. The research is divided into two areas:

The first concerns robust, modular, flexible robots that can move and survive in natural surroundings. This research is experimentally-based and strives to understand central aspects of locomotion through robot constructions.

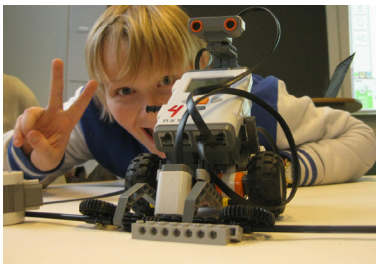
The second is on acoustic behaviour of animals such as lizards, frogs and bats. Although the main focus is biological, results useful for robot design often emerge.



Locomotion

Education

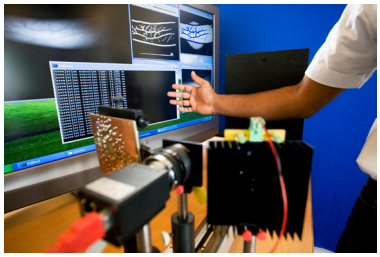
Modular and embedded robotics used in the context of education is another core research area of the Institute. Here, user-configurable robots are used by educators to teach a broad spectrum of subjects from biology to computational thinking and musical composition.



Education

Software

Software plays an important role in all of the Institute's activities, i.e. in terms of education, research and innovation.



Medical Robotics

Cognitive and Applied Robotics

The Cognitive and Applied Robotics (CARO) Group

Introduction

The Cognitive and Applied Robotics (CARO) Group addresses the modelling and execution of manipulation processes performed by robots. This involves a number of different scientific disciplines, namely computer vision, robot control, machine learning, and simulation, all aimed at establishing efficient action execution in various domains. The CARO Group is particularly interested in making use of prior-action knowledge to facilitate the establishment of robot solutions in new contexts and thus extend the application areas in which robots are used within industrial production, surgical and welfare robotics.

Computer Vision

The CARO Group addresses visual tasks, such as object recognition, pose estimation, and tracking, by means of rich and hierarchical representations. Functional motivations for the visual approach stem from the primate's visual system with the purpose of arriving at efficient algorithms that can be used in robot applications. The aim is to develop generic representations that allow for an efficient transfer of sensory motor experience across actions - especially by combining learning techniques and simulation.

Robot Control and Planning

Having robots perform complex tasks, such as assembly, requires accurate robot control and reaction to sensor feedback, which can be based on e.g. vision and force/torque measurements. When operating in complex and/or changing environments, robot paths need to be planned online to guarantee safe motions that do not collide with the environment.

Machine Learning

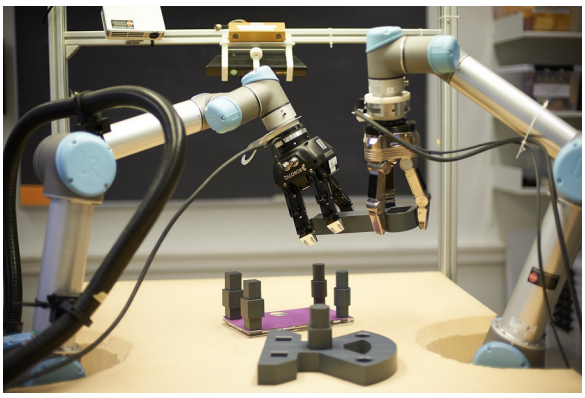
In the context of most robotic and vision tasks, parameters and models need to be learned. Here, the CARO Group makes use of a variety of machine-learning techniques such as Kernel Density Estimation and Random Forests as well as complex model-learning approaches in which action and perception interact to support each other.

Simulation

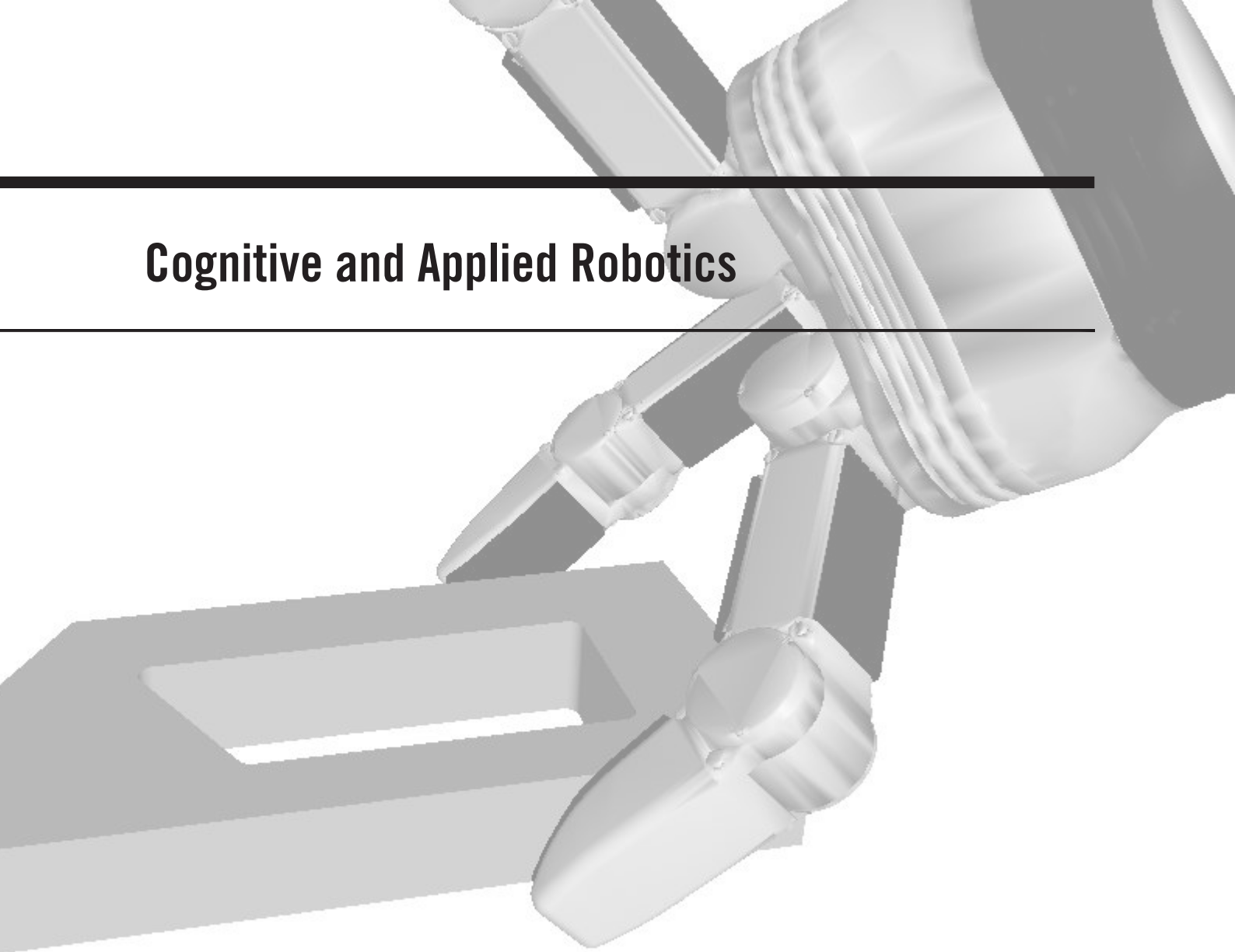
Humans are able quickly and reliably to predict the outcome of situations such as 'what happens when I drop this glass'. This ability is important since decisions such as 'don't drop it yet' are made based on such predictions. In the CARO Group, we exploit dynamic and kinematic simulation to equip robots with the same prediction and decision as humans. Physics simulation is a very generic tool which therefore allows us to investigate many different processes such as grasping or assembling parts. To this end, the CARO Group's research activities focus on extending current simulation engines in regard to accuracy and speed, and developing new methods of using simulation for predicting robot actions.

Cognitive Systems and Action Re-use

The CARO Group addresses problems in the context of cognitive robotics such as the development of action schema. The CARO Group is in particular interested in re-using sensory motor experience to solve new robotic problems quickly, it is often advantageous to re-use and adapt previous solutions to similar problems instead of learning new action parameterisations from scratch. To that end, the CARO Group is investigating how to store action knowledge, how to identify suitable actions given a new situation, and how to adapt action knowledge to these new situations.



Web site: http://caro.sdu.dk



Cognitive and Applied Robotics

Grants

The Cognitive and Applied Robotics (CARO) Group is currently involved in 6 national and 3 European projects:

The CARMEN project (2013-2018), supported by the Danish Council for Strategic Research (DSF), focuses on new and advanced methods for carrying out virtually the main phases of a robotics-based automation process.

The MADE platform for Future Production Systems (2014-2019) is a consortium also supported by DSF under the Strategic Platform for Innovation and Research (SPIR) programme. The CARO Group is in particular involved in the work packages 'Hyperflexible Automation' and 'Modular Manufacturing Systems'.

The Mini-Picker project (2014-2017) funded by the National Danish Advanced Technoloogy Foundation (HTF) focuses on developing an off-the-shelf bin picker, where the CARO Group is responsible for optimising robot motions and grasp planning.

The HTF project SAFE Perception (2014-2018) addresses the use of machine vision in an agricultural context.

In the EU project IntellAct (2011-2014), which was coordinated by the CARO group, a demonstrator was developed in a programming-by-demonstration setting within an industrial context.

The EU project ACAT (2013-2016) focuses on the automatic translation of instruction sheets designed for human workers into robot computer programs.

The SPIR project Patient@home (2012-2018) aims at developing technologies for reducing the time patients must stay in hospitals. For more information, see page 13 of this brochure.

The project ROSOR (2014-2017) establishes robot surgery research at the University of Southern Denmark.

The EU project Xperience (2011-2016) is about modelling structural bootstrapping processes in cognitive systems.

The total current project portfolio comprises an overall budget frame of approximately 5,500,000 €.

Robotics in Production

Automation using robotics is a key component in keeping a competitive industry in Denmark, and in Europe in general. In the last decades, many jobs in industry have been outsourced to other countries. The consequence may be that the knowledge of how to produce and how to create new innovative products may be outsourced as well. Besides, automating production is not only a question of economic savings, it is also a matter of ensuring product quality and relieving people of tasks that can be hazardous and exhausting and thus lead to chronic injuries.

Research within robotics in production can be divided into two lines: The first is about extending the capabilities of robots so that they can adapt to changing conditions and account for uncertainties in sensor systems etc. The second line is about accessibility, which means that robots should not be a tool only for experts and large companies, but a tool for everybody. A key part of making robots accessible is to reduce the cost of setting up new installations, which includes quick and simple programming and improved user acceptance by relaxing the constraints on the environment and sensors.

Cognitive and Applied Robotics

Welfare Robotics

An ageing society implies an increasing demand for various types of care support and therefore robots are expected to play an important role in tomorrow's high-level healthcare services to be provided to e.g. physically challenged people, since robots can assist patients and healthcare professionals when they need help to perform various tasks.

The Care-o-Bot is a research platform which is used to investigate a wide range of topics such as navigating and fetching items in home environments, and human-robot interaction. The research in this area is characterized by being highly interdisciplinary, addressing the areas covered by the CARO Group as well as many other areas such as Human-Robot-Interaction and Language.

Surgical Robotics

Patient safety and reducing medical errors have a high priority in today's health systems. Up-coming surgeons can no longer train in vivo, and within the field of laparoscopy there is an increased focus on new training strategies, including Virtual Reality (VR) simulator training. Robotic-assisted surgery allows for an increasing part of abdominal and retroperitoneal surgical procedures to be performed as minimal invasive techniques. Therefore, the demand for simulation-based surgery skills training increases. However, simulating realistic soft tissue interactions is technically difficult. Complex simulations (i.e. advanced operations) are not available and this limits the benefits obtained with the present available simulation programs for minimal invasive surgery (MIS). The CARO Group intends to develop - in close collaboration with Odense University Hospital (OUH) - automatic surgical procedures and improve patient-specific simulations of surgical tasks. As a hardware platform the Raven surgical robot (RSR) is used. RSR is a research robot used to simulate MIS. RSR gives researchers full access to movement, manipulation and kinematic data as well as control not available in commercial surgery robot systems such as the da Vinci robot that is used for surgery at OUH.

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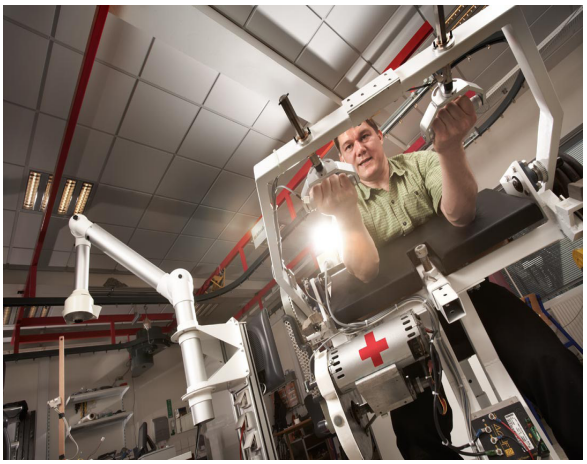
Welfare and Innovation Activities

Welfare Technology



Within the field of Welfare Technology, there is currently an increased focus on assistive and rehabilitation robotics. However, introducing robots in such an area requires that robots are easy and secure enough for therapists and patients to configure and operate.

Operating and especially configuring even a very simple robot used to be something that required technical skills, but through clever (modular) designs we can now let domain experts, rather than technical experts configure e.g. training exercises.

To this end technology-assisted training projects are paving the way for the development of technologies that can support e.g. patients suffering from back and muscles diseases through the patients' active participation in their own training and rehabilitation activities.

> "New Technology Means Hope"
>
> BrainTalk Communities 10/2006-8/2011

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Welfare and Innovation Activities

Patient@home: Innovative Welfare Technology for the 21st Century

Patient@home is the Danish Strategic Platform for Innovation and Research (SPIR) on welfare technologies. The platform is funded by the Danish Strategic Research Council, the Danish Council for Technology and Innovation, and the Region of Southern Denmark. The project runs from 2012 to 2018 and involves research and innovation partners from Denmark, USA, Japan, England, China, Finland, Norway, Spain, and Germany. More than 35 Danish companies are currently participating in the project.

Patient@home develops and tests new welfare technologies for the benefit of both patients and the public healthcare sector, focusing on minimizing hospital stays by using technology placed in the patient's home, such that (a) patients are enabled and motivated to take more responsibility for their own health, and (b) healthcare professionals can obtain data enabling more accurate determination of visits or other healthcare interventions.

It is envisaged that around 40 new products will be brought to market, all integrated within a single ontological framework to ensure ease of use, and using existing industry standards wherever possible.

Patient@home supports the development towards more patients treated, monitored, and rehabilitated at home.

Public-private innovation ensures relevance and impact of new welfare technology products and services. Processes are driven and results are generated in close collaboration with healthcare professionals, patients, private companies, and research institutions.

The mixing of company representatives and university researchers at all levels of project management will ensure that all project outcomes are based on the latest research and hospital requirements.

The technological development in Patient@home is supported by new research focusing on clinical evidence, user involvement, and health economics. Through coordination of parallel and interdisciplinary research and innovation activities, Patient@home will: (1) enable optimization of Danish healthcare procedures; (2) enable increased patient participation and responsibility of life; (3) provide Danish industry and partners with access to state-of-the-art knowledge, laboratories, and real-life test facilities; (4) strengthen research and education at the universities involved in the project; (5) promote interdisciplinary and collaborative research; (6) promote interaction between front-line researchers and relevant businesses; (7) produce prototypes and new products; and (8) disseminate results through publications, trade-fair demonstrations and representation at relevant conferences and workshops.

patient@home

www.patientathome.dk

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Biology-inspi

Centre for BioRobotics

Many animals have versatile and robust sensory skills or useful and interesting behaviour that researchers would like to be able to exploit in robotic systems. Basic research in biorobotics investigates the mechanisms that enable animals to perform as they do, by building working models of the mechanisms that may be responsible for their abilities. These models are normally robots, and the fundamental thrust of the research may be described as "doing biology with robots".

A second, alternative, way of transferring good ideas from Nature to robotics is bio-inspired robotics. Here, there is less attention paid to modelling the inspirational animal(s) - the biology - and more to replicating the desired properties or skills of the animals using engineering methods.

Biorobotics and biologically-inspired robotics research takes place within the new Centre for BioRobotics, established by University of Southern Denmark (SDU) late in 2013. The new Centre is funded by a 5-year grant from SDU and is a cross-faculty collaborative venture between The Maersk Mc-Kinney Moller Institute and the Department of Biology (SDU).

The scientific goal of the Centre for BioRobotics is to tackle questions arising from the acoustic behaviours of animals which cannot be addressed completely by biology or technology alone, while also exploring applications of insights from biology in the robotics and technological domain and vice versa. Practically, the intention is to strengthen existing synergy and use it to create new opportunities for seeking external funding.

The Centre's programme comprises work on the hearing system of lizards, the coordination of calling behaviour among large groups of frogs, and the echo-locating behaviours of bats, as well as bio-inspired embodied artificial intelligence and neurobotics including research and development on the neural control of insect locomotion using legged robotic platforms.

Core research in the Centre consists of three themes:

- Embodied Sensorimotor Behaviour Theme (Lizards)
- Embodied Communication and Acoustic Stigmergy (Frogs)
- Embodied Acoustic Scene Analysis (Bats)

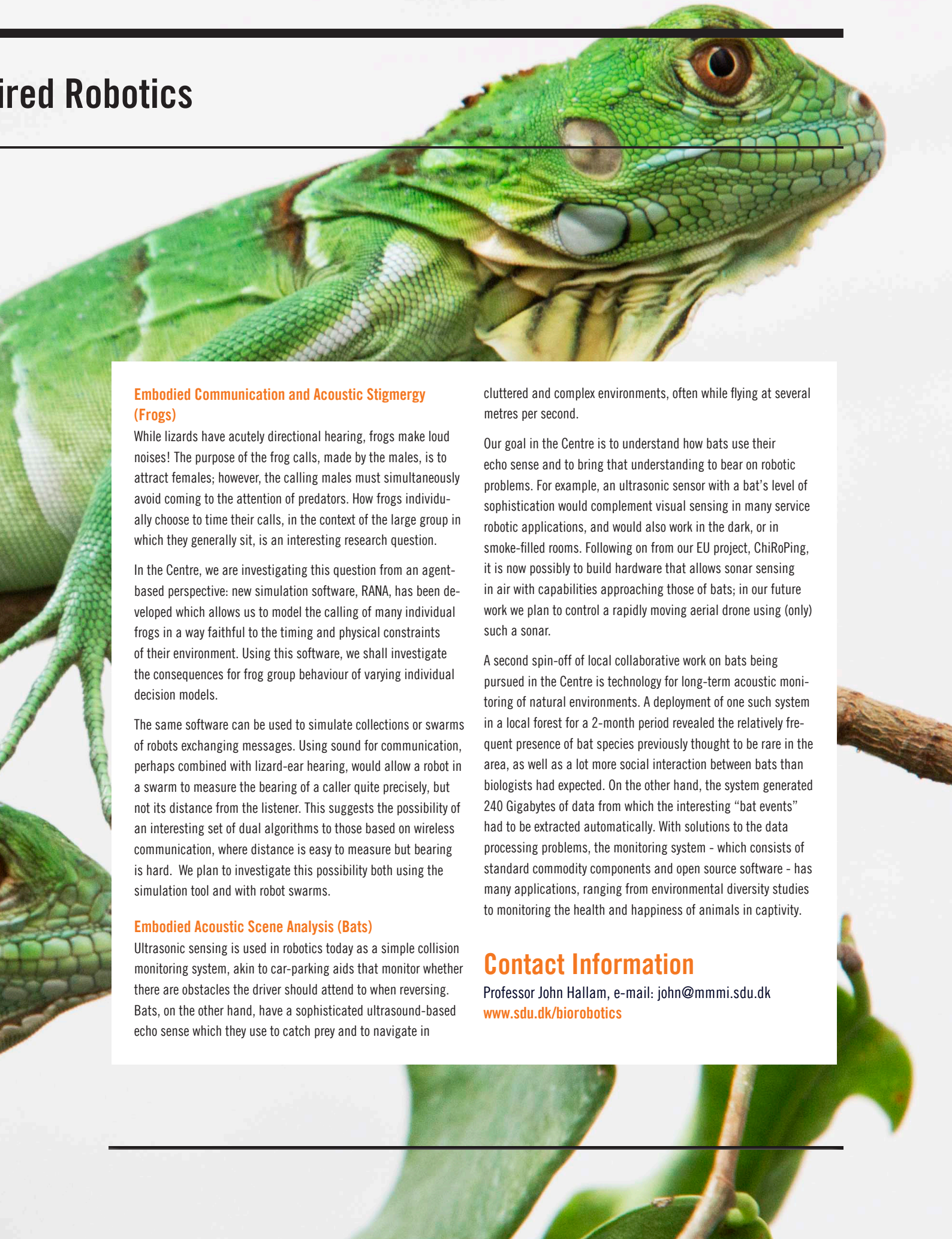
Lizards have one of the most directionally hearing systems of all vertebrates, which they achieve by the trick of having a wide tube connecting their middle ears together. This allows as much sound to reach the inside of the eardrum from the opposite side of the head (through the tube) as from the outside. Mixing these two sound paths results in interference that converts a very small amplitude difference between the two sides of the head into a large amplitude difference in eardrum vibration.

A lizard robot, built in collaboration with the Department of Biology, allows us to explore the properties of this system in a real environment. The ear anatomy is modelled by a set of simple digital filters and the eardrum vibration signals generated by the model are used to control the robot behaviour, for instance to cause it to turn toward the side of the eardrum that vibrates more strongly.

Embodied Sensorimotor Behaviour Theme (Lizards)

Work in the Centre focusses on extending this lizard model to include aspects of the lizard's neural processing of sound, and to deploy the model in a number of simple application systems - for instance, in a wheelchair that comes when you whistle, or a camera that looks at the person speaking. The ear model will also be integrated on the neurobotic walking robot referred to below, as one of its sensory input streams.

ired Robotics



Embodied Communication and Acoustic Stigmergy (Frogs)

While lizards have acutely directional hearing, frogs make loud noises! The purpose of the frog calls, made by the males, is to attract females; however, the calling males must simultaneously avoid coming to the attention of predators. How frogs individually choose to time their calls, in the context of the large group in which they generally sit, is an interesting research question.

In the Centre, we are investigating this question from an agent-based perspective: new simulation software, RANA, has been developed which allows us to model the calling of many individual frogs in a way faithful to the timing and physical constraints of their environment. Using this software, we shall investigate the consequences for frog group behaviour of varying individual decision models.

The same software can be used to simulate collections or swarms of robots exchanging messages. Using sound for communication, perhaps combined with lizard-ear hearing, would allow a robot in a swarm to measure the bearing of a caller quite precisely, but not its distance from the listener. This suggests the possibility of an interesting set of dual algorithms to those based on wireless communication, where distance is easy to measure but bearing is hard. We plan to investigate this possibility both using the simulation tool and with robot swarms.

Embodied Acoustic Scene Analysis (Bats)

Ultrasonic sensing is used in robotics today as a simple collision monitoring system, akin to car-parking aids that monitor whether there are obstacles the driver should attend to when reversing. Bats, on the other hand, have a sophisticated ultrasound-based echo sense which they use to catch prey and to navigate in cluttered and complex environments, often while flying at several metres per second.

Our goal in the Centre is to understand how bats use their echo sense and to bring that understanding to bear on robotic problems. For example, an ultrasonic sensor with a bat's level of sophistication would complement visual sensing in many service robotic applications, and would also work in the dark, or in smoke-filled rooms. Following on from our EU project, ChiRoPing, it is now possibly to build hardware that allows sonar sensing in air with capabilities approaching those of bats; in our future work we plan to control a rapidly moving aerial drone using (only) such a sonar.

A second spin-off of local collaborative work on bats being pursued in the Centre is technology for long-term acoustic monitoring of natural environments. A deployment of one such system in a local forest for a 2-month period revealed the relatively frequent presence of bat species previously thought to be rare in the area, as well as a lot more social interaction between bats than biologists had expected. On the other hand, the system generated 240 Gigabytes of data from which the interesting "bat events" had to be extracted automatically. With solutions to the data processing problems, the monitoring system - which consists of standard commodity components and open source software - has many applications, ranging from environmental diversity studies to monitoring the health and happiness of animals in captivity.

Contact Information

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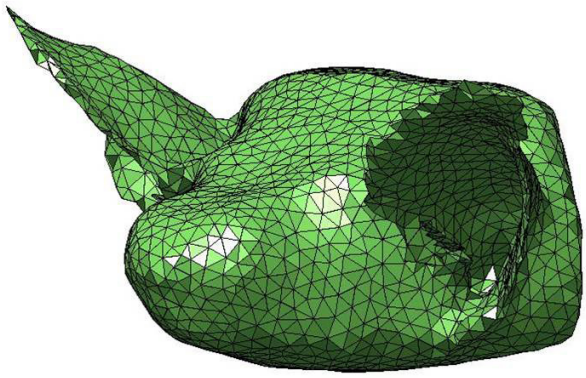
Acoustics



Introduction

The Acoustics Group is involved in research and development projects with several external and internal partners, and in self-defined research projects of more fundamental character. The core competences of the Group are a solid expertise in mathematical and numerical modelling as well as a deep knowledge of acoustic transducers and transducer systems. Furthermore, the Group collaborates closely with other departments at the University of Southern Denmark in order to facilitate research in cross-disciplinary areas such as medical acoustics.

Acoustics in Welfare Technology

Assessing peoples hearing ability is important when deciding whether or not to treat for a hearing disorder and when evaluating the effect of such treatment. Often the hearing ability is measured with a speech-in-noise test, in which the patient tries to identify words or short sentences in a noisy environment. Investigations into this matter involves constructing tests and test procedures that are sensitive enough to reveal complicated hearing disorders, but yet robust enough to obtain good repeatability of test results.

Another project (see picture in the right-hand column) involves the calibration and evaluation of devices and methods of measuring a person's vocal capacity, which is an important tool for diagnosis of speech and singing problems/disorders, and for evaluating the effect on speech of different treatment schemes for diseases such as cancer of the voice box (larynx).

Numerical Acoustics

Research in this area spans from applying numerical methods such as the Boundary Element Method as a calculation tool for other research topics, such as investigation of directional hearing of bats (see picture in the left-hand coumn) that is related to the Institute's research in BioRobotics, to more fundamental research of expanding the numerical methods in order to be able to deal with a larger frequency range.

A particular research topic is the implementation of viscous and thermal losses in acoustic Boundary Element calculations. An accurate modelling of losses is of increasing interest being important for the behaviour of small devices and transducers, which are under development in many industries such as the hearing-aid and cell-phone companies.

A research project in calculating the potential of using bubble curtains for reducing underwater noise from ramming piles into the seabed is about to finish. A bubble curtain is produced by surrounding the pile with an air-water mixture produced by injecting air into the water through pressurised hoses with small perforations.

Array Acoustics

Recent developments in data acquisition systems have made it possible to acquire and handle many signals simultaneously. As the first step in abatement of noise is to identify the source, systems for noise-source identification are of much interest – in particular in the transport industry. Beamforming (see picture opposite page) and acoustic holography are among the techniques that comprise many microphones in array. Research is directed towards increasing the performance of array systems in terms of robustness and resolution (ability to identify and separate noise sources).

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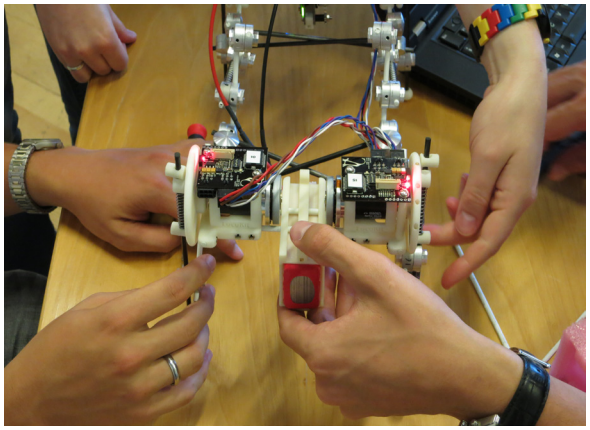
Embodied AI and Neurorobotics



LocoKit

The LocoKit construction kit is a toolkit for scientists who are interested in investigating locomotion and movement in robots. This research area needs a combination of multidisciplinary approaches from both biology, biomechanics, neuroscience, robotics, and embodied intelligence.

LocoKit is a robot construction kit optimised for building lightweight, dynamic robots and comes with a complete construction package including mechanics, electronics, and software.

The aim of LocoKit is to make it easier to build legged robots that mimic locomotion in animals, thus enabling scientists without a scientific background in robotics to use LocoKit in their research. Furthermore, LocoKit provides a great platform for teaching and studying embodied artificial intelligence.

In our day-to-day activities at the Institute, LocoKit is often used as part of the education programme in Artificial Intelligence on our MSc in Engineering (Robot Systems) programme, and in our MSc project work, thus securing an ongoing development of the LocoKit.

Neurorobotics

How can one equip artiifical agents with brain-like mechanisms and appropriate biomechanics so that they can match the level of performance of living creatues?

To tackle this challenging problem, Neurorobotics investigates and develops advanced modular neural mechanisms.

The mechanisms, consisting of neural motor control and high-level neural circuits with dynamic memory and learning, are used to generate complex adaptive behaviours of embodied autonomous robots in complex environments. Here, different types of robots, like a dynamic quadruped robot built from LocoKit, the dynamic planar biped robot RunBot, and the bio-inspired hexapod robot AMOS, are employed as our experimental platforms.

By doing so, we try also to achieve general, flexible, adaptable, and scalable solutions for real-world robotic systems as well as gain a better understanding of dynamical interactions on different levels and time scales of neural activities, learning, and memory in embodied neural sensori-motor functions.

The vision of the Embodied Artificial Intelligence (AI) and Neurorobotics Lab

- Develop modular bio-inspired robots and their modular neural mechanisms towards embodied autonomous locomotion systems with adaptivity, energy efficiency, and versatility
- Understand complex dynamical interactions between physical and computational components in embodied neural closed-loop systems

Embodied AI and Neurorobotics

Embedded Computer Systems

Embedded computer systems are used pervasively in modern technology, from climate control systems to cars, and are key to the functioning of any robotic system.

Programming embedded systems is, however, difficult due to the inherent complexity of dealing with the parallelism and distributedness of the physical world. Moreover, errors in embedded programmes can have disastrous consequences for the system being controlled. We use model-driven software development as a means to overcome this complexity while providing correctness guarantees. Models are used as an abstraction to describe the concepts of the domain, typically in the form of a domain-specific language. Real-world, safety-critical systems such as airplanes and nuclear power plants are already being programmed using techniques from model-driven software development. Our research goal is to further push the adoption of these principles in domains being investigated at The Maersk Mc-Kinney Moller Institute.

Modular Robotics

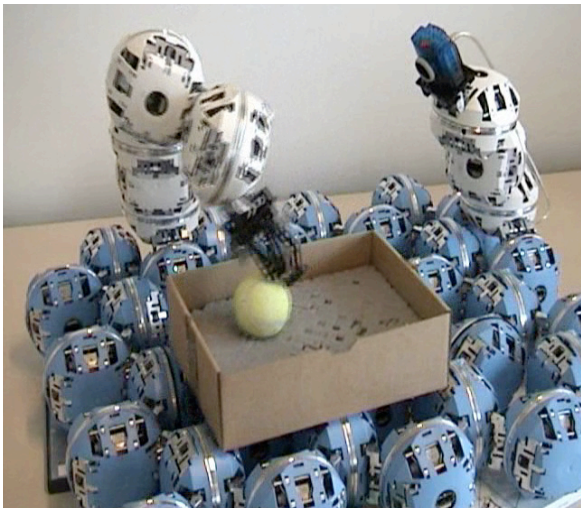
Modular robotics is an approach to the design, construction and operation of robotic devices aiming to achieve flexibility and reliability by using a reconfigurable assembly of simple subsystems.

Robots built from modular components can potentially overcome the limitations of traditional, fixed morphology systems because they are able to rearrange modules automatically, a process known as self-reconfiguration, and are able to replace unserviceable modules without disrupting the system's operations significantly.

Programming reconfigurable robots is, however, complicated by the need to adapt the behaviour of each of the individual modules to the overall physical shape of the robot and the difficulty of handling partial hardware failures in a robust manner.

To facilitate programming of modular robots, we are investigating several different domain-specific programming language designs to help the user express the overall intention of what the robot should do. These designs include role-based behaviour descriptions, geometric awareness for generalising over the specific kinematics of the modular robot, distributed and robust execution for describing fault-tolerant execution sequences across the structure of a robot, reversibility as an error-recovery mechanism, and lastly a dynamic distributed scope as a unified abstraction for the various components of the language. We believe these language design principles to be generally useful for programming distributed robotic systems.

This research is based on the results of the HYDRA (EU FP5; 2001-2004) and Morphing Production Lines (Danish Research Council; 2007-2010) projects, and uses the ATRON self-reconfigurable robot as experimental platform.



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Learning and Experience Technology

Research - Selected Projects - Modular Systems

The research area of Learning and Experience Technology focuses on the design of interactive systems and digitally-supported learning processes. The key question here is: how can interactive systems support effective and playful learning processes? This question involves two aspects: (1) the Learning Process that focuses on the learner's active participation and reflection. (2) the Technological Aspect that focuses on the interactive features of technology as well the art of enabling new forms of participation.

Our research is based on real-life experiments in the class room and design projects in our Social Technology Lab. Besides developing new technology, we also develop methodology for testing educational systems and developing new knowledge on use of interactive technology for learning.

Testing NAO-robots in Schools

In this research, we use the humanoid robot, NAO, in primary and secondary schools. The pupils program the robot's behaviour in a high-level language. Our research questions are: how does a programmable humanoid enrich teaching and how do we prepare the teachers? Twenty school classes are using the robot for creative programming. In one case, the robot presented lyrics and made corresponding gestures. So far, we have experienced that the robot enriches the learning processes by combining the auditory, visual and kinaesthetic modalities. More information is available at: http://academy.insero.dk/fremtek/

Playful and Reflective Game

How do we transform digital natives into reflective designers? In this research, we explore how to transform digital natives into reflective designers of tomorrow's digital games. Our target group is engineering students. We have developed design activities which made the students' games more playful, interesting and technically advanced. The design activities are related to game tests and include formal game elements, game balancing, reward structure, game-fill, juiciness, feedback and polish. More information is available at http://op.tek.sdu.dk.

Modular systems are inspired by the results of our research in User-configurable Modular Robotics as well as the theory and methods of Constructionism as described by Seymour Papert. Constructionism is an approach to education centred on having learners construct physical artefacts that can be shared with others as a way to construct meaning. With our research, we wish to investigate how to create modular interactive systems that provide an easy interface to somewhat complex paradigms (such as learning robots, technological sensor and actuator tools, musical compositions, spelling, grammar, mathematics etc.), and which are flexible enough to allow the users to experiment within a given paradigm creating many different kinds of emergent behaviours.

I-BLOCKS

Our research in this field also involves Embodied AI, Modular Design, and Interaction Design and has resulted in the development of several generations of user-centred, user-configurable modular robotic systems, e.g. the I-BLOCKS that allow a user to configure a system of technological modules, which means that the user can define the physical manifestation and the system behaviour while constructing. In other words, the user physically programs a technological device by assembling a structure of modules.

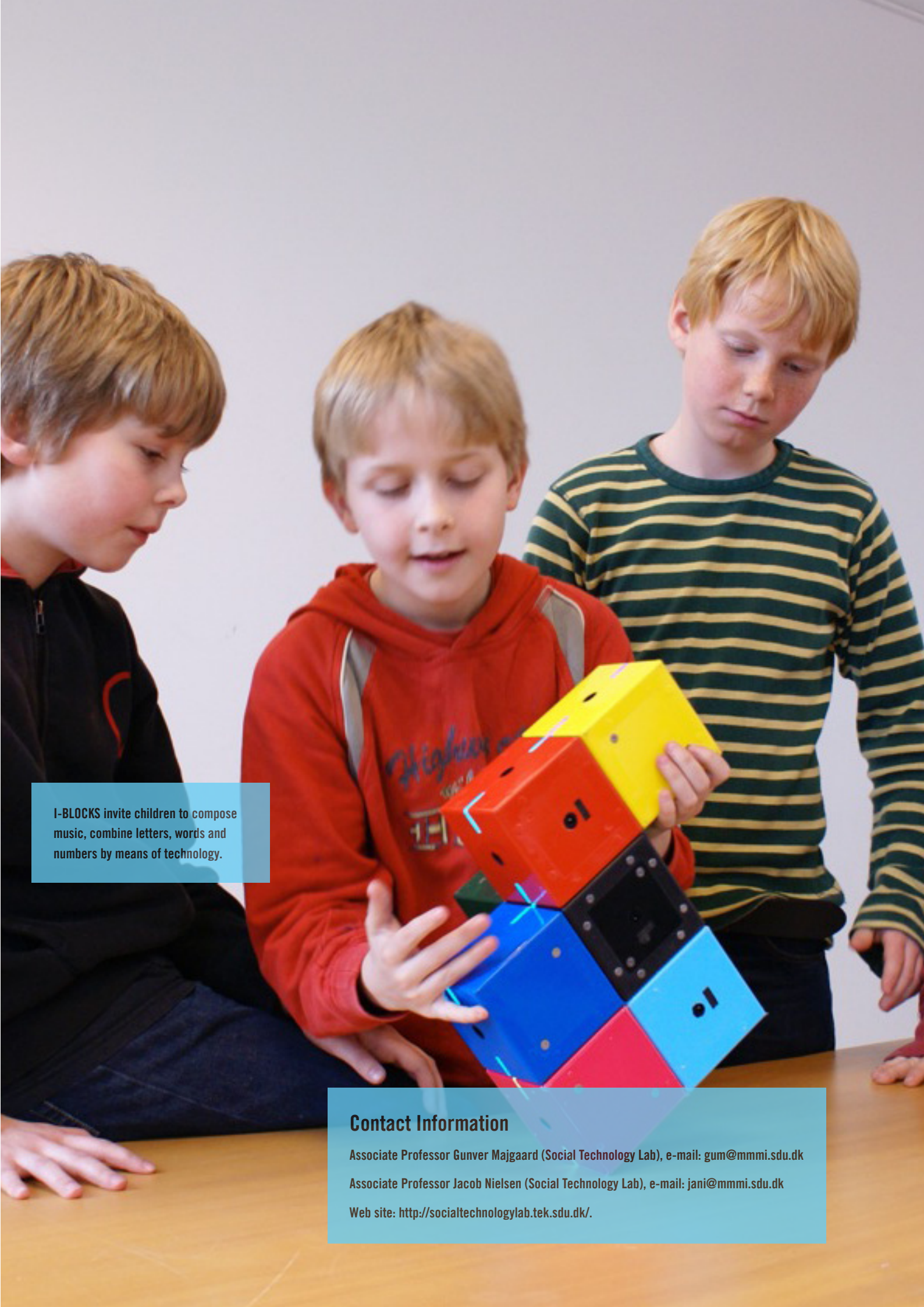
Vision and Motivation

We hope to be able to continue our investigation of modularizing technologies in order to obtain greater flexibility for the users: in general, by moving the Lego or IKEA principles into the engineering world, and thereby making complex (learning) paradigms available and accessible to non-experts, allowing users of all kinds to play and experiment with (construct and deconstruct) the different elements within each paradigm.

Within our schooling systems modular technological devices or even modular visual programming tools will be able to aid pupils and students in experimenting with complex systems, through hands-on, experimental approaches. Such devices have already been shown to allow the pupils access to work with music, numbers, letters, words, electronics and robotics, and have the potential to be used in even more areas.

Examples of Use

Modular technologies also have the potential to drastically speed up prototyping processes, so within areas like technology and engineering design we already see modular electronics such as the Arduino platform, Raspberry Pi, beagleboard etc. It is, however, still possible to lower the floor even further here, making more intelligent prototyping modules, that will allow designers to integrate physical shape, user interface and behaviour more easily.



I-BLOCKS invite children to compose music, combine letters, words and numbers by means of technology.

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Agricultural Robotics

Research Area

The agricultural sector is central to Denmark as well as the EU, but it is currently under pressure to reduce environmental impact while maintaining a high level of efficiency.

A way of achieving this goal is a reduction of pesticide (herbicide) usage, for example by mechanical weeding or precision spraying.

Such techniques are, however, difficult to deploy efficiently using conventional agricultural technology, whereas agricultural robotics provides a promising technology for significantly reducing the use of pesticides by employing mechanical weeding or precision spraying.

This is substantiated by the fact that recent advances in robot cognition, navigation and perception have brought autonomous agricultural robots that operate in dynamic, real-world environments closer to market.

Selected Projects

SAFE - Safer Autonomous Farming Equipment (2014–2017) - is a project funded by the Danish National Advanced Technology Foundation. The vision is to develop safety systems that permit agricultural machines to handle autonomously all significant physical hazards in the field.

GrassBots (2013-2015) is a project funded by ICT-AGRI and Region Midt. It deals with grassland-harvesting operations for biogas and biorefinery plants. SDU contributes with adaptation of the FroboMind Software platform* to perform user-supervised autonomous grass cutting and bailing by two collaborating agricultural robots. SDU also develops a computer-vision-based sensor for obstacle detection.

Kongskilde Crop Robotti (2013) is an autonomous agricultural platform built in collaboration with Kongskilde. SDU contributed with the design of the mechanical platform and the FroboMind software platform*) for autonomous navigation and implement control. The platform is a belt-driven module, attachable with different forms of working implements, e.g. for precision weeding.

*) FroboMind is an application-oriented open software platform for multi-purpose field robotics.

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Agricultural Robotics

Research Profile

The research team's competencies cover a wide range of research areas relevant to agricultural robotics. We have demonstrated design and implementation of mechanical systems capable of performing agricultural tasks in varying conditions as well as design and implementation of a generic software platform for field robotics based on ROS (Robot Operating System).

Regarding operation, we have demonstrated the design and implementation of advanced vision algorithms for the agricultural domain including use in realistic field experiments. Moreover, we have significant experience in modular and distributed robotics as well as the use of model-driven software development of automated program generation in the robotics domain.

Since Agricultural Robotics is a highly interdisciplinary science area, inputs from other sources are very important, for instance from study programmes like Integrated Design and Mechanical Engineering at the Department of Technology and Innovation, University of Southern Denmark.

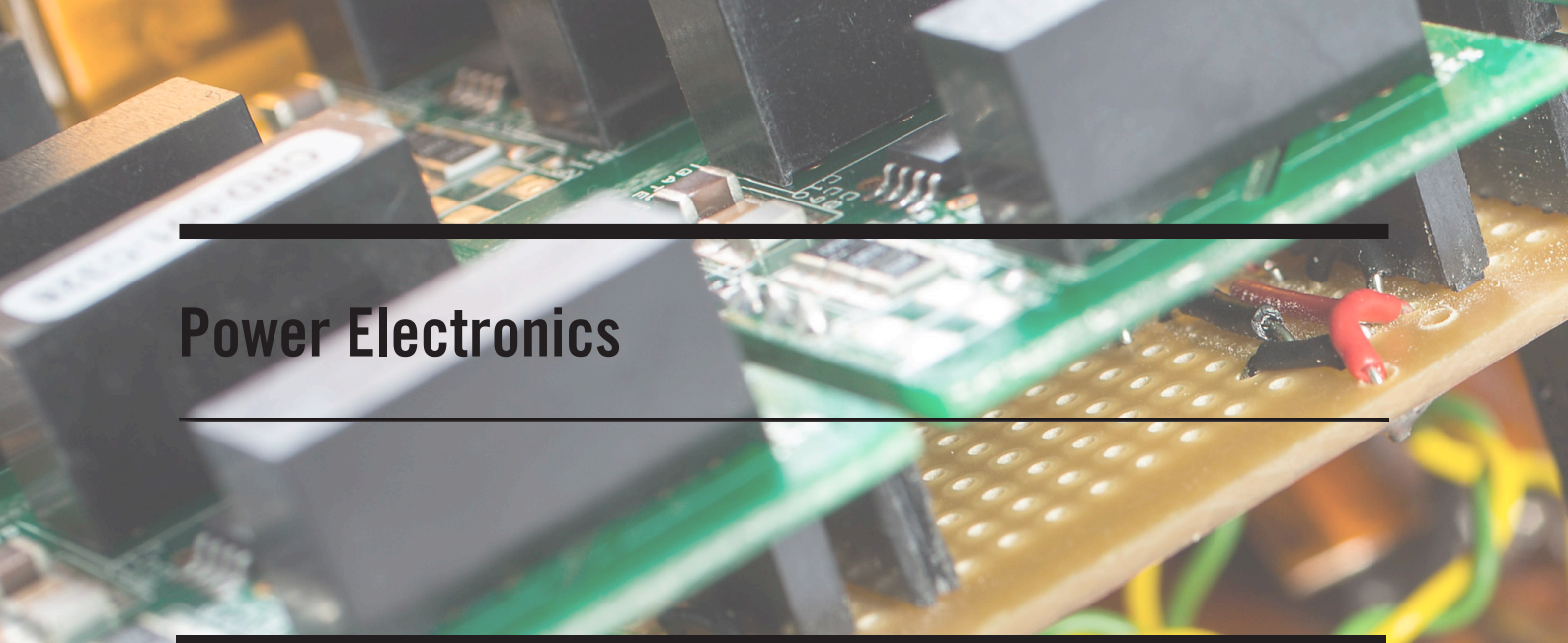
Collaboration

All research activities are performed in collaboration with a number of public research institutions and industrial partners related to the agricultural domain. Key partners are the three Danish companies, Kongskilde Industries A/S, Claas Agrosystems A/S, and Conpleks Innovation ApS.

Kongskilde Industries is an international company that produces agricultural machinery and has a significant interest in the development of automated agricultural machinery, including agricultural robots.

Claas Agrosystems is part of the Germany-based CLAAS Group and develops software solutions and systems including GPS control systems, camera systems, sensor-based measuring of harvest area, telemetric solutions and management software. All solutions support the concept of "Precision Farming".

Conpleks Innovation is an SME that develops software for the control of agricultural robots and has a significant interest in automated approaches for developing safety-critical software for different agricultural robots.



Power Electronics

Research Focus and Objectives

Power Electronics is a technology for efficient control and conversion of electrical energy. Power Electronics is used extensively in all parts of a modern society such as in harvesting, storing and distributing renewable energy, and powering satellites, air crafts, electrical vehicles, robots, pumps, data centres, home appliances and electronics. Power Electronics is, therefore, a key element in achieving a sustainable future.

Ultra-high efficiency DC-DC converter with 99% efficiency

Our research in DC-DC converters focuses on achieving the highest possible conversion efficiency. Reducing losses will increase available output power leading to more sellable power in solar applications or longer ranges in electrical vehicles. In terms of higher power levels, lower losses also reduce size and cost of the converter itself. Achieving the highest conversion efficiency requires a total optimisation of the complete converter design including all steps from selection of converter topology, optimisation of magnetic design, selection of power devices, design of EMI-filters to the detailed circuit-board layout. Measured efficiency is therefore a good metric of the level of design optimisation achieved in a given application and thus also becomes a very useful research objective in Power Electronics.

Advanced digital control of DC-DC converters

Our research is focused on achieving maximum bandwidth in digital controllers for DC-DC converters. Although having significant advantages such as increased immunity to noise and environmental changes and offering possibilities of designing advanced, flexible and adaptive controllers, digital controllers also have inherently lower bandwidth due to sampling and processing delays. Since controller bandwidth is directly related to the converter dynamic performance, our research objective is to regain as much of the lost bandwidth as possible while exploiting the potential benefits of digital controllers. Embedded system technologies such as Field-Programmable Gate Array (FPGA) are used to implement the digital controllers in order to take advantage of the parallel execution and the flexibility that FPGAs offers.

Advanced high-frequency magnetic components

Advanced high-frequency magnetic components are a key element in achieving high conversion efficiency in power converters. Our research is therefore focused on reducing losses and sizes of magnetic components. To achieve this objective, we conduct research into improving methods for analysing, simulating, designing, manufacturing, and testing magnetic components.

Three-phase Power Factor Correction rectifiers

A Power Factor Correction (PFC) rectifier is a front-end switch- mode converter that regulates the input current of an electronic load (DC-DC converter) to achieve unity power factor, thereby improving grid-power quality. However, PFC rectifiers add significant costs and losses. Hence, our research is focused on reducing losses in PFC rectifiers. Bi-directional PFCs will become a key component in realising future SMART grid systems.

Electromagnetic Interference in DC-DC converters

While achieving very high conversion efficiency and small size, the high switching frequency in modern power converters is also responsible for the majority of the electromagnetic noise generation and emission in electronic systems. The filters required to attenuate this noise to comply with required emission standards can be both large and expensive. Thereflore, we conduct research into improving analysis and prediction of converter noise levels and to design optimum Electromagnetic Interference (EMI) filters.

Power Electronics

Grants and Projects

The Power Electronics group is currently involved in the following projects:

IEPE (Intelligent and Efficient Power Electronis) is a strategic research centre between industry and universities. The overall goal is to produce cheaper and more reliable power electronic systems, which will accelerate the transition to sustainable energy solutions. The project is supported by The Danish National Advanced Technology Foundation.

E-Motion (Cross-border electromobility - development and deployment of new technologies enabling sustainable electric mobility (eMOTION)) is an Interreg 4a project in the Schleswig-K.E.R.N. and Southern Denmark region. Focus is on enhancing regional know- ledge and business development options within the electromobility sector.

Green PET (Green Power Electronics Test Lab)'s main purpose is to support Danish companies in developing energy-efficient products by having access to world-class test facilities combined with technological support. Green Power Electronics Test Lab's facilities will continuously be developed in a close relationship with participating universities and companies and thereby create an international research and educational environment within Power Electronics.

EMoCrane aims at developing and testing an energy-efficient, modular and battery-driven electro-hydraulic unit to power mobile cranes. The project is upported by the Danish Energy Agency's EUDP programme.

Partners and Collaboration

Danfoss Power Electronics, Grundfos, Banke Accessory Drives, KK Wind Solutions, Vestas, Servodan, DELTA, Lodam, OJ Electronics, Danfoss Power Systems, Aalborg University, Technical University of Denmark, Christian Albrechts Universität zu Kiel, Fachhochschule Kiel, Fachhochschule Flensburg, Udviklingsråd Sønderjylland, CLEAN.

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Centre for Energy Informatics

Introduction

The Centre for Energy Informatics is an interdisciplinary research and innovation centre and part of The Maersk Mc-Kinney Moller Institute. The Centre was established in 2013 and brings together software engineers, computer scientists, applied physicists, electrical engineers, and social scientists in the application of information technology.

Mission

The Centre's mission is to contribute to the green transition of the energy system by focusing on innovative IT-based solutions for energy-efficiency improvements of buildings and industrial processes, and the integration of fluctuating renewable energy production sources in the intelligent electricity system of the future.

Research Areas

At present, the Centre's research activities are aimed at developing IT-based solutions to increase the intelligent use of energy within the following four interconnected areas:

Smart Buildings – Development of IT-based solutions to improve the energy-efficiency of existing buildings and to ensure compliance with the rules on energy performance of buildings certified according to energy efficiency and sustainability standards like ENERGY Star, LEED and Green Globes. Specific solutions address automated monitoring, evaluation, and diagnostics of building energy performance; intelligent building control considering relevant factors including occupant behaviour, weather conditions, operation of building systems, building typology and thermodynamics; integration of buildings and the electricity grid with the view of providing demand response services during operation, demand peaks and shortages.

Smart Cities and Communities – Investigation of synergies between demand patterns and supply availability of energy flows in cities and communities to improve energy efficiency, increase integration of renewable sources, and provide resilience towards system faults caused by extreme situations such as hurricanes and flooding. A specific focus area is the development of a citywide coordination and control infrastructure to optimise real-time energy demand and supply.

Smart Industries – Development of IT-based solutions to improve the energy efficiency and predictability of energy-intensive industrial processes, without compromising process and product quality. The solutions are based on advanced mathematical and artificial intelligence models of the industrial processes that correlate process parameters, production tasks, product quality, and energy consumption. Exact control of the energy consumption enables close integration with the energy networks sustaining the energy flow of the processes.

Smart Energy Networks – Development of IT-based solutions to coordinate the supply and demand of environmentally-sustainable energy networks, including electricity, gas, district heating and cooling, as well as storage such as geothermal heat. A specific focus area is the development of intelligent energy management systems to coordinate demand, supply, and storage, both at the intersection points of production and consumption.

www.sdu.dk/energyinformatics

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Centre for Energy Informatics

Research Projects

COORDICY

This project will provide the theoretical and technological means for benchmarking, diagnosing, and controlling building operations, considering relevant factors such as occupant behaviour, weather conditions, construction typologies, thermal properties, building systems and controls, and their complex interactions. COORDICY will achieve its objective by developing a holistic IT-based approach to coordinate the actual energy performance of the building systems in order to meet the original intent of the building design, without compromising the comfort of the occupants. Diagnostics of energy-performance gaps revealed during benchmarking will be used in building energy-performance simulation systems to determine the optimal trade-offs of alternative combinations of energy retrofits, and to advance the intelligence of building control systems. COORDICY will hereby enable public and commercial buildings to play a central role in a future sustainable energy system. Total budget: DKK 42,580,574. Funding agency: Innovation Fund Denmark.

Smart Grid Ready Energy-Cost-Efficient Light Control for Greenhouses

This project will enable commercial greenhouses to become prosumers by developing the next generation of energy-cost-efficient supplemental lighting systems that utilise the physiological flexibility of crops to provide balancing services in the Danish Smart Grid anno 2020. Total budget: DKK 20,617,718. Funding agencies: GUDP and EUDP.

Green Growing

This project has two aims. One is to spread knowledge already available about energy savings in the greenhouse growing industry. The second aim is to create new knowledge that can reduce energy costs in commercial greenhouses. Total budget: DKK 30,479,655. Funding agency: Interreg IVB North Sea Region Programme.

EnovHeat

This project puts emhasis on energy efficient heat pumps that will play a crucial role in the future sustainable energy system. The overall goal of the present project is to develop the scientific and technological foundation for high-efficiency heat pumps using magnetocaloric technology. Due to the special characteristics of active magnetocaloric regenerators, the optimal operation of such heat pumps in a practical system requires special consideration. The project will develop a fully functioning prototype for operational test. Total budget: DKK 22,400,000. Funding agency: The Danish Council for Strategic Research (Programme Commission on Sustainable Energy and Environment).

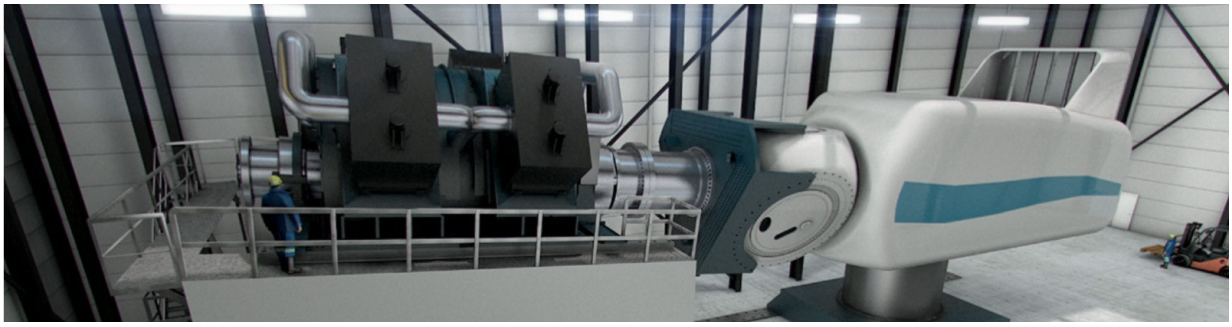
Demand-Response Capacity Management in Commercial Buildings

This project will demonstrate how Smart Grid technology can enable operators of commercial buildings to provide flexibility services to existing flexibility markets and to distribution system operators. Total budget: DKK 8,763,000. Funding agency: EUDP.

Project Key Words:

Actuation, Fault Diagnostics, Modelling,Occupancy, Retrofits, Simulation, Sensoring

Statistical Signal Processing



Introduction

Statistical signal processing is an area of applied mathematics concerning reliable estimation, detection and classification of signals which are subject to random fluctuations. πSeG addresses applications that require extraction of a signal or parameter of interest from degraded measurements to developing highly sensitive signal estimation, detection, or tracking algorithms which can exploit small but persistent differences between signals, interferences, and noise. Conversely, these approaches can be used to develop algorithms to identify a channel or system producing a signal in additive noise and interference, even when the channel input is unknown but has known statistical properties.

The focus of πSeG is mainly on two applications, 'Fault Detection and Prediction in Offshore Wind Turbines' and 'Tracking of Micro-Robots in Minimally Invasive Medicine'.

https://piseg.sdu.dk

Fault Detection and Prediction in Offshore Wind Turbines

Installation of offshore wind turbines for exploitation of the huge wind energy resources in marine environments represents the most important opportunity for further development of this technology. However, the reliability of the entire system will play a central role in the design, construction and installation of competitive wind turbines, given that for 20 years of turbine life-time, the operation and maintenance (O&M) cost of e.g. a 750kW turbine might account for about 25%-30% of the overall energy generation cost or 75%-90% of the investment cost.

Together with major industrial partners our research group develop novel statistical fault detection and prediction methods to foresee abnormalities (system instability and emerging errors) at a very early stage during test operations to prevent the occurrence of system errors and unnecessary downtime. πSeG has access to two databases: 1) SCADA and CMS database of each wind turbine produced (active or inactive) by Siemens Wind Power in the span of more than 20 years; 2) Medium voltage interface points of offshore wind farms with more than 800 operational turbines across Europe run by the Danish wind power operator DONG Energy. In addition, our group has access to the world-leading high-performance HALT and the functional test bench built by Lindoe Offshore Renewables Center for full-scale testing of complete wind turbine nacelles.

The aim of our group is to detect and identify mechanical and electrical faults in offshore wind turbines at system and component levels that can be mapped to addressing the problem of Big Data analyses with time-varying dependencies and sparsity using statistical signal processing methods.

This project is in collaboration with the leading suppliers of renewable energy solutions (Siemens Wind Power and Vestas), world-leading wind turbine test facilities (Lindoe Offshore Renewables Center (LORC)) and the Danish wind-power developer and operator Dong Energy.

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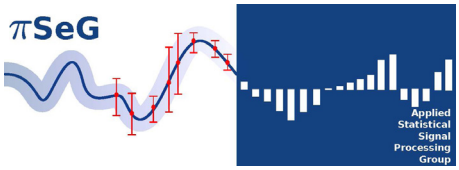

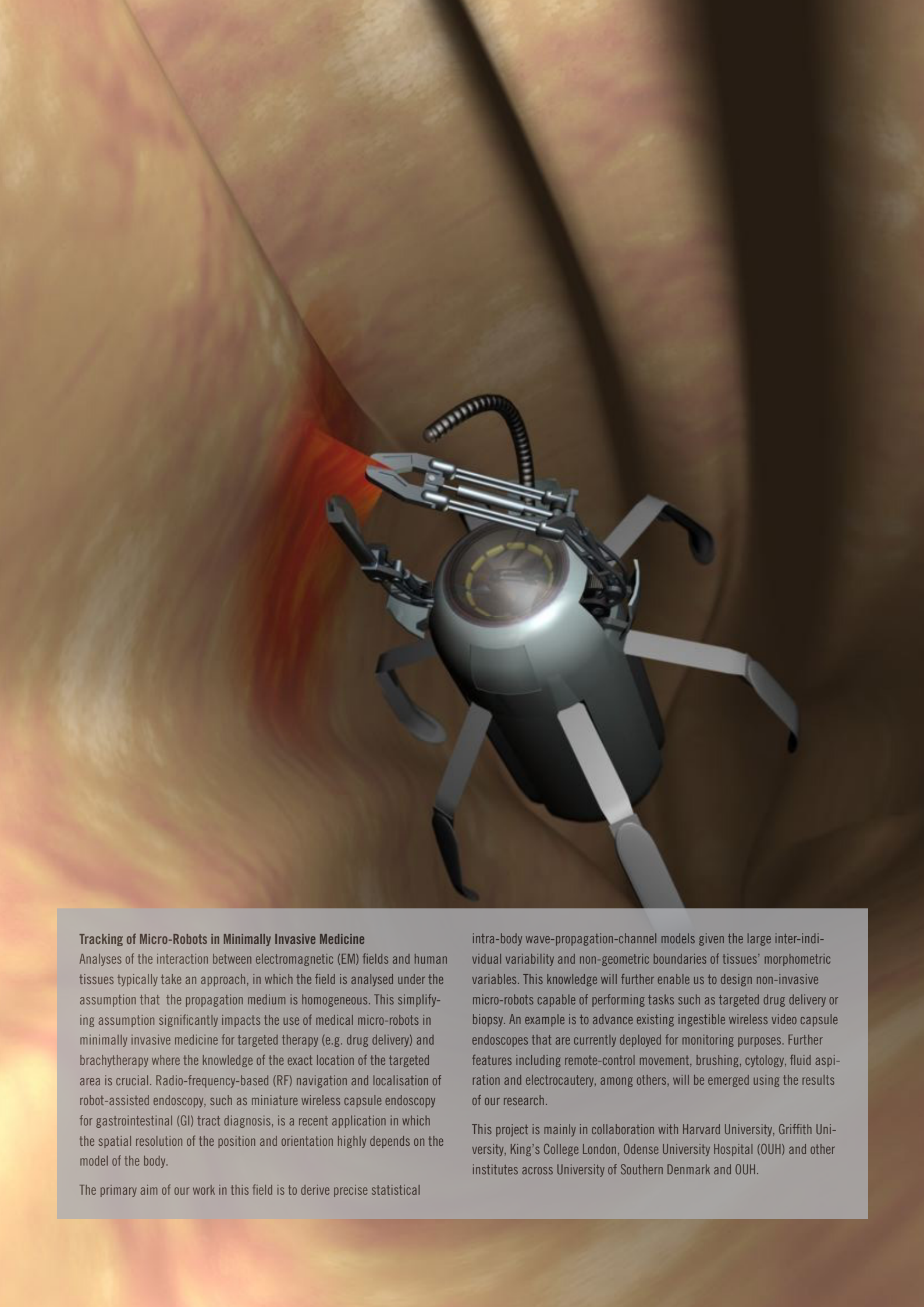

Tracking of Micro-Robots in Minimally Invasive Medicine

Analyses of the interaction between electromagnetic (EM) fields and human tissues typically take an approach, in which the field is analysed under the assumption that the propagation medium is homogeneous. This simplifying assumption significantly impacts the use of medical micro-robots in minimally invasive medicine for targeted therapy (e.g. drug delivery) and brachytherapy where the knowledge of the exact location of the targeted area is crucial. Radio-frequency-based (RF) navigation and localisation of robot-assisted endoscopy, such as miniature wireless capsule endoscopy for gastrointestinal (GI) tract diagnosis, is a recent application in which the spatial resolution of the position and orientation highly depends on the model of the body.

The primary aim of our work in this field is to derive precise statistical intra-body wave-propagation-channel models given the large inter-individual variability and non-geometric boundaries of tissues' morphometric variables. This knowledge will further enable us to design non-invasive micro-robots capable of performing tasks such as targeted drug delivery or biopsy. An example is to advance existing ingestible wireless video capsule endoscopes that are currently deployed for monitoring purposes. Further features including remote-control movement, brushing, cytology, fluid aspiration and electrocautery, among others, will be emerged using the results of our research.

This project is mainly in collaboration with Harvard University, Griffith University, King's College London, Odense University Hospital (OUH) and other institutes across University of Southern Denmark and OUH.

Information and Knowledge Management

Research Area

The Information and Knowledge Management (IKM) Lab focuses on development of novel IKM tools and techniques in relation to solving advanced IKM problems and to support advanced IKM processes (including big data aspects).

IKM Lab works with various aspects in relation to collecting, monitoring, structuring, mining, interpreting, analysing, and visualising information.

The overall goal is to develop human-centred software tools that enable humans to make better decisions faster by (semi) automating various data, information, and knowledge management tasks. IKM Lab is primarily engaged in two overall application areas: Health Informatics and Security Informatics. The goal is that developed prototypes evolve into real products at a later stage.

Health Informatics

Within Health Informatics, the primary focus is on advanced IKM solutions for clinical decision support and patient empowerment in close collaboration with Odense University Hospital (OUH) and other hospitals.

IKM Lab has interest in design, development, and deployment of tools and techniques for structuring, mining, analysing, and visualising medical data including identification of patients with high risk conditions, early warning of degradation in patient condition, decision support for medical staff, patient overview of their own medical condition, patient motivation for rehabilitation, information sharing in patient social networks, and discovering medical relationships between treatment, care, rehabilitation, etc.

The IKM Lab manager is also the principal investigator and project manager for the Patient@home project, see page 13 for more information.

Ongoing activities (all part of the Patient@home project):

- Identification of high risk patients: deterioration detection of acute patients. More information is available at http://www.en.patientathome.dk/projects/identification-of-high-risk-patients.aspx.
- DiabeticLink: Self-management portal for Danish diabetes patients. More information is available at http://www.en.patientathome.dk/projects/diabeticlink.aspx.
- Osteoporosis risk prediction.
- Self-management portal for heart patients. More information is available at http://www.en.patientathome.dk/projects/use-of-patient-centered-tools-to-combat-heart-failure.aspx.

Security Informatics

Within security informatics, the primary focus is on advanced IKM solutions for criminal network investigation.

IKM Lab has interest in design, development, and deployment of tools and techniques for collection, monitoring, structuring, interpreting, mining, analyzing, and visualizing of (open source) information. Social network analysis and mining techniques play a key role in this work.

Ongoing activities:

- Analysis of complex (heterogeneous) networks – including techniques for prediction of simple and compound links.
- Collection and monitoring of social media data – including data from YouTube, Facebook, and Twitter.
- Visualisation of complex networks – including techniques for temporal, clustering, and composite features.

Other Application Areas

In the past, IKM Lab has also focused on other application areas such as development of IKM tools and techniques for software engineering, planning, innovation, and learning processes.

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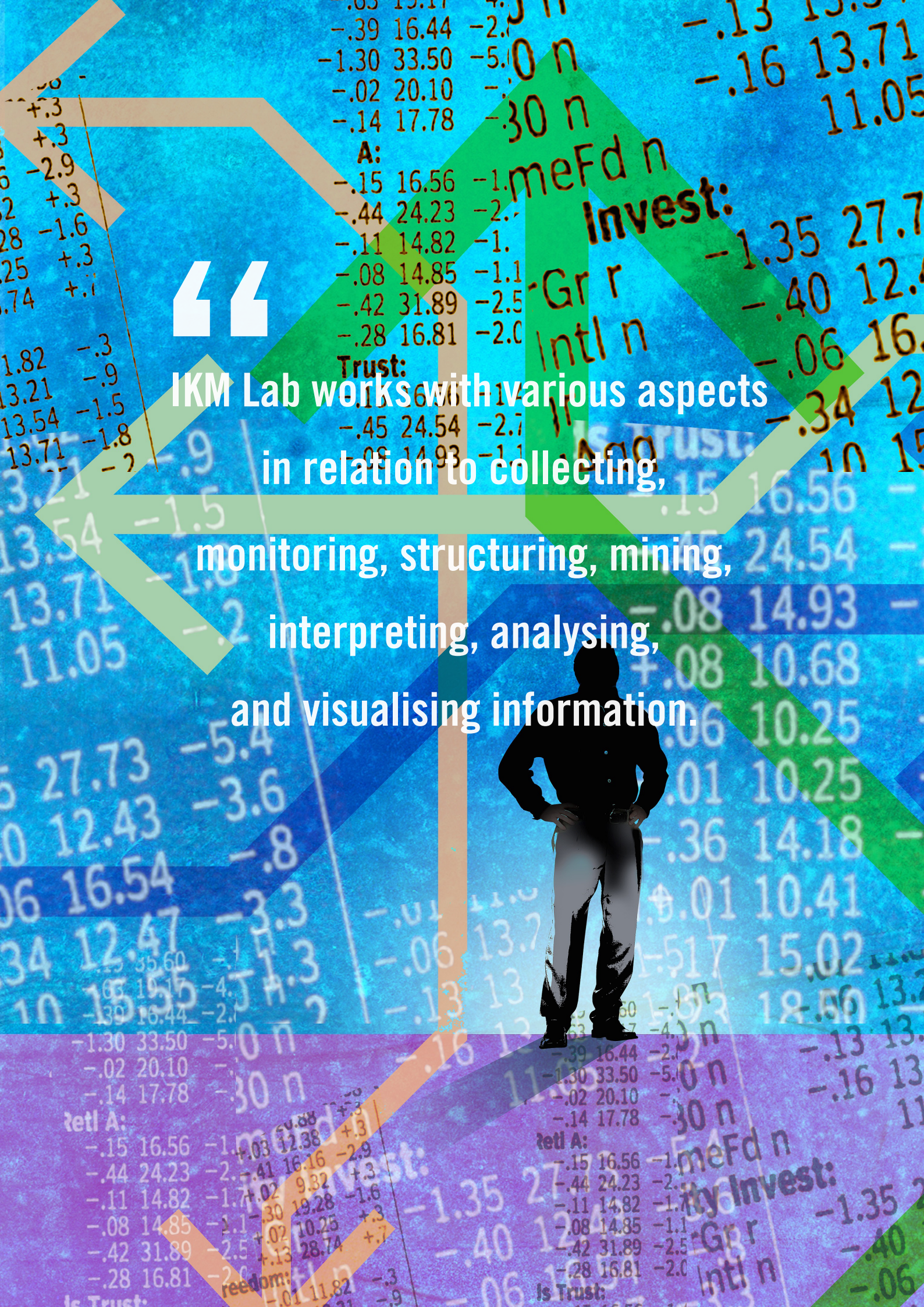
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IKM Lab works with various aspects
in relation to collecting,
monitoring, structuring, mining,
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and visualising information.

Spin-off Enterprises

Lizard Technology

Lizard Technology ApS was established in 2009 as a result of a collaborative PhD project between the Maersk Mc-Kinney Moller Institute and the Institute of Biology, University of Southern Denmark.

The overall purpose of the company was to identify, develop and commercialise new leading edge audio and sound technologies, and platforms, in close cooperation with universities, research institutions, industry and public and private investors within two areas:

First, Active Sound Localization (ASL) is a unique and intelligent sensor and pointing technology applicable within a wide range of areas such as sensor systems, surveillance systems and medico/disability support aid systems. ASL is based on many years of research on hearing characteristics and dynamics of lizards, frogs and insects. The key component of the ASL technology is a mathematical model based on understanding the structure of the lizard ear, the directionality of which can then be realised by a simple electronic circuit.

Second, Virtual Spatial Sound Presentation (VSS), a leading-edge 3-dimentional sound and voice change technology - called artificial colouring of sound - can be applied within areas such as virtual training systems, surveillance systems, teleconference systems, mobile phones/PDAs, computer games and maybe even hearing aids.

Mobile Industrial Robots

MiR (Mobile Industrial Robots) was established in 2013 by senior robotics researchers from The Maersk Mc-Kinney Moller Institute having a strong desire to develop a smart and simple approach to in-house transportation.

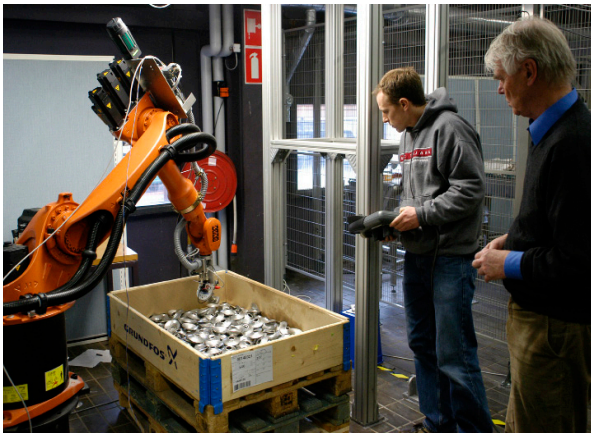
The product result is a robust and safe automate system that is easy to handle. It is operable via a smart phone, an iPad or a PC and moves freely in environments with people and obstacles, ensuring a natural coexistence with humans.

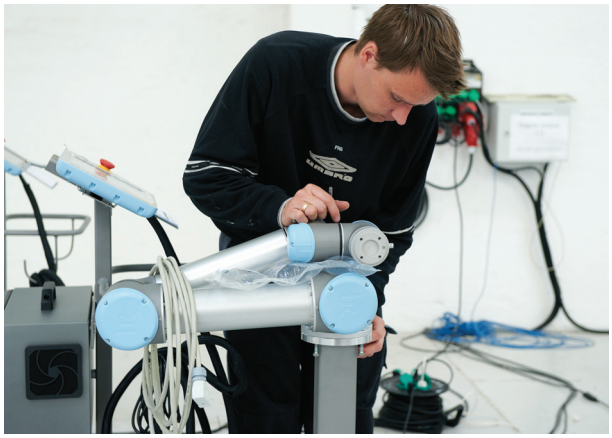
The target groups are industry, manufacturing companies and hospitals.

The depicted MiR100 is for smaller transport tasks in industry and healthcare. It requires no structural changes to buildings, wires in the floor or sensors in the ceiling. The design allows agile driving through doorways as well as in and out of elevators.

www.mobile-industrial-robots.com

Spin-off Enterprises





Scape Technologies

The SCAPE Bin-Picker system enables robot arms to locate and pick up individual items randomly piled in a container. Bin-picking robots are applicable in many production and manufacturing areas, e.g. in the automobile and aerospace industries.

Scape Technologies works closely with integration companies to provide state-of-the-art bin-picking robots for flexible feeding systems. They increase the productivity of manufacturers and reduce manual repetitive work, which includes physically demanding and monotonous tasks, detrimental to the workers' health.

Scape Technologies was founded in 2004 after many years of research and development at The Maersk Mc-Kinney Moller Institute. The result of these efforts is SCAPE, an acronym for Smart Classifier and Pose Estimator. SCAPE is the core of the Scape Technologies' bin-picking product, the SCAPE Bin-Picker. Shortly after the company was established, a partnership between the leading Danish pump manufacturer, Grundfos A/S, and Scape Technologies came about to develop and commercialise the SCAPE Bin-Picker. An on-going project funded by The Danish National Advanced Technology Foundation has further developed the technology, and the first commercial bin-picking projects based on the new standards are now being realized.

Scape Technologies A/S is located in Odense and has still close ties to the University of Southern Denmark.

www.scapetechnologies.com

Universal Robots

Universal Robots has developed a highly specialized, flexible, low-cost robot arm that can be used in almost any industry, where traditional robots are too large, expensive, noisy or inflexible.

Since the robots weigh only 18 kilos, they are easy to move around and the user-friendly software makes the re-programming of the robots a very straightforward process. The idea was to develop a robot that would add value as quickly as possible. Therefore, it can be used in the production process from day one - no need for a cumbersome setup or installation.

The idea of creating a light and relatively inexpensive robot that is easy to install and program arose in 2003. Kristian Kassow, one of the founders of the company, was working on an analysis of the requirements for robots in the food industry. At the same time, Esben H. Østergaard and Kasper Støy, also founders of the company, were working in their PhD projects on modular robots at The Maersk Mc-Kinney Molelr Institute. Together, they discovered that the robotics market was characterised by heavy, expensive and unwieldy robots and decided, with help from an investor, Syddansk Innovation, to establish the company Universal Robots with the ambition of making robot technology available to all.

Universal Robots A/S is located in Odense and has still close ties to the University of Southern Denmark.

www.universal-robots.dk

Overview of Study Programmes

Master's Degree Programmes

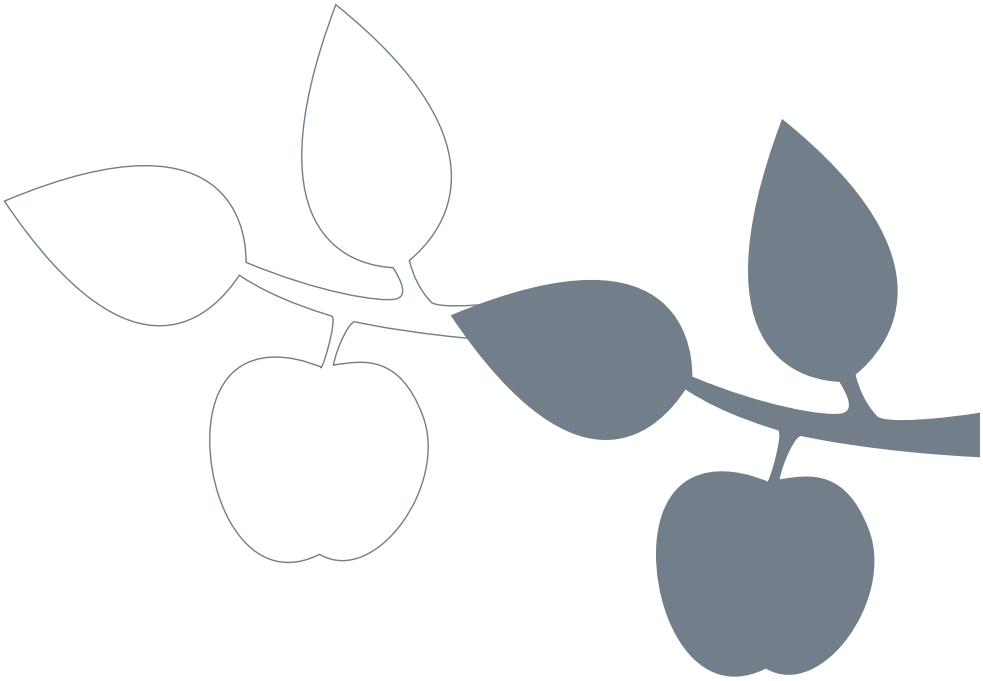
- Master of Science (MSc) in Engineering (Electronics) - starts February 2016
- Master of Science (MSc) in Engineering (Energy Technology)
- Master of Science (MSc) in Engineering (Learning and Experience Technology)
- Master of Science (MSc) in Engineering (Physics and Technology)
- Master of Science (MSc) in Engineering (Robot Systems)
- Master of Science (MSc) in Engineering (Software Engineering)
- Master of Science (MSc) in Engineering (Welfare Technology)

Bachelor's Degree Programmes

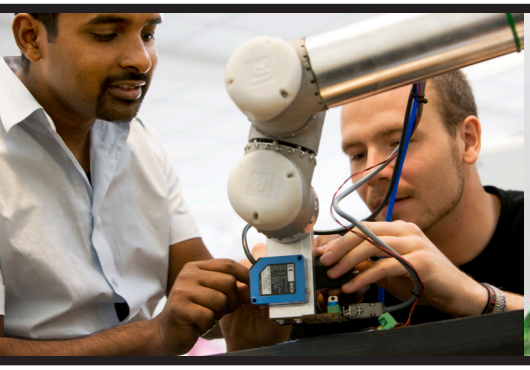
- Bachelor of Engineering (BEng) in Information and Communication Technology
- Bachelor of Engineering (BEng) in Electrical Power Engineering
- Bachelor of Engineering (BEng) in Electronics and Computer Engineering
- Bachelor of Science (BSc) in Engineering (Energy Technology)
- Bachelor of Science (BSc) in Engineering (Learning and Experience Technology)
- Bachelor of Science (BSc) in Engineering (Physics and Technology)
- Bachelor of Science (BSc) in Engineering (Robot Systems)
- Bachelor of Science (BSc) in Engineering (Software Engineering)
- Bachelor of Science (BSc) in Engineering (Welfare Technology)

Diploma

- Diploma of Electrical Power Engineering



ADDRESS: The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark. **EDITORS:** Editor-in-chief KASPER HALLENBORG, deputy editor VIBEKE NIELSEN. **CONTRIBUTORS:** Staff members of The Maersk Mc-Kinney Moller Institute. **PUBLISHED:** March 2015. **WEB SITE:** www.sdu.dk/mmmi. **E-MAIL:** secretary@mmmi.sdu.dk. **TELEPHONE:** +45 6550 3541. **FAX:** +45 6615 7697. Pictures used by kind permission of the photographers - further information is available by contacting VIBEKE NIELSEN.



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