DaNES

DANISH NETWORK FOR INTELLIGENT EMBEDDED SYSTEMS

Modelling the future

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Modelling the Future

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EMBEDDED SYSTEMS are the future

Project Manager Kim Guldstrand Larsen,
Professor, Centre for Embedded Software Systems

The terms "software" and "computer" are usually associated with PCs and Macs that almost everyone uses every day. But in fact 99 percent of all computers today are hidden in our surroundings as intelligent embedded systems in for instance kitchen appliances, cars, wind turbines, climate control systems, satellites, stereo systems and so on and so forth. And the number and variety of embedded systems will only increase in the future. "IT in everything" is a popular saying – but we have only just seen the beginning.

Embedded systems hold an enormous potential for heightening our standard of living, for instance by ensuring more accurate medication when we are ill, by increasing road, train and airplane safety or by improving the functionality of the numerous appliances for everyday actions that we surround ourselves with, whether in terms of entertainment, cooking, communication – or something completely different. Embedded systems will play a significant role in all aspects of society in the future – no one can refute that. And that is why we all need to not just be prepared for the increased use of these systems – we need to be at the forefront of developing them and setting the standards for their construction and use.

Denmark is home to a large number of world-class researchers and companies working within embedded systems – but usually research and development take place within the individual research and/or departments at the universities or companies. When the DaNES (Danish Network for Intelligent Embedded Systems) collaboration was established in 2007, the aim was to further the transfer of knowledge, methods and tools from one industrial sector to others – to the benefit of all the participants and of Danish industry as a whole. We need to be at the forefront of this field in order to make it in the global market – and we need to have companies with the ability and courage to participate in co-European initiatives like the ARTEMIS (Advanced Research and Technology for EMbedded Intelligence and Systems) research programme to stay ahead and take part in setting the standards within the field.

With DaNES, it is our hope that all the participants have been brought one step closer to this. As you can read in this magazine, the project has occasioned a number of specific development projects within the participating companies, and each one has served to further either specific products or development processes within the companies. In addition, we as researchers have gained new insights into the needs of the industry and new inspiration and motivation as to which direction to take our research activities to mature our methods and tools.

Kim Guldstrand Larsen

Jan Madsen

Carsten Orth Gaarn Larsen

DIFFERENT SECTORS – same challenges

Satellites. Pig stables. Respirators. Robots. High-tech loudspeakers. Insulin pens. At first sight, it seems this diverse group of products have very little in common. But when you take a closer look, it turns out that they are all in some ways dependent on embedded platforms and software, enabling them to perform optimally in their given contexts. This means that helping the companies behind these products to improve the quality or performance of the embedded systems and/or the development of the systems, would enable the companies to bring forth better products more quickly – and thereby increase their competitiveness, not only on a Danish scale but also globally.

"Embedded systems are the very nerve centre of our society – probably to a larger degree than the man on the street is really aware of. Practically any kind of industry today can make use of embedded systems to improve their products or production system, but up until now, these systems have been developed within the individual companies with little or no collaboration or knowledge sharing among the companies. With a collaboration project like DaNES, we get the chance to solve some of the concrete problems that the companies are experiencing, and at the same time the researchers get new stimulating challenges," explains Project Manager of DaNES, Professor Kim Guldstrand Larsen.

"The basic idea of DaNES is that fundamentally, all the different sectors that work with or use embedded systems are facing the same challenges, for instance in terms of development time or the reliability of the products. And finding these common denominators will benefit us all. The companies will gain financially during the development process, and they will also be able to manage more numerous and more complex systems, and of course having common standards will be useful too. This is not just something we in DaNES believe; it is a current trend, especially on a European scale where a lot of ambitious objectives have been stated concerning precisely intelligent embedded systems, for instance about developing standards across different industrial sectors. And we are contributing to this through this Danish project," he says and adds: "Our researchers and companies within embedded systems are world-class, so we have great potential in Denmark for playing a key role. This is also underlined by the fact that we already have a number of companies participating in projects under the pan-European ARTEMIS research program."

And while the participants seem very diverse, the key to finding this common ground has been focusing on model-based development. "Working in DaNES has been both interesting and challenging," says Professor Jan Madsen of DTU Informatics, chairman of the steering committee and one of the key researchers in the project. "We are working with this underlying vision of a model-based approach to intelligent embedded systems, and our starting point was the team of very different companies, of which some see themselves as suppliers of intelligent embedded systems whereas others see themselves more as users of these systems. So one of our challenges has been to get all these different sectors to get a common understanding of the very term 'intelligent embedded systems' and also to make the universities see the different domains – computer science, electronics, control theory – merging to form a kind of holistic understanding, because all these elements are important when working with embedded systems," he explains.

The hard work has definitely been worth the effort – and may even be an advantage in the long run. "Having this variety, both in sectors and in geographical location, has been very important to our work. It means that we have been able to work on establishing a common understanding of the concept – we have been able to work as a national think tank, so to speak. This has not been a regional initiative, we have shown that we as a NATION need to join forces – and through DaNES, we have been able to bring together the key activities within the field," he emphasises.

Carsten Orth Gaarn-Larsen, Director of the Danish Advanced Technology Foundation that is funding the DaNES project, is also very happy about the results so far. "The unique thing about this project is that a number of seemingly mismatched partners have joined forces. Some work within satellite communications, some work within the pharmaceutical industry and some work with software solutions for stables. They have joined forces with a number of very strong embedded systems environments at the Danish universities, and they have given themselves an assignment to develop systems that are faster, better and, most importantly, cheaper," he says and finishes:

"This project is exactly what we in the Foundation are looking for: a project consortium who manage to take as their point of departure real, concrete challenges that are significant for the companies, and utilizing the most competent minds at our universities to work together to find these optimal solutions. And if these solutions are found, they can be generalised, and when that happens there is a very significant amount of money at stake."

Parts of this article is based on the TV documentary "Teknik, der tænker" that aired on 10 February 2011 on DR2.

About DaNES

DaNES – Danish Network for Intelligent Embedded Systems – is an advanced-technology platform funded by the Danish Advanced Technology Foundation over the course of four years from 2007-2011. 9 partners participate in the project, of which 6 are industrial companies and 3 are universities. The work in DaNES has consisted of a number of case studies focusing on the challenges of the participating companies, as well as a number of joint seminars and workshops.

What are embedded systems?

Embedded systems are specialised computer systems designed to carry out a specific task (or set of tasks). They consist of a combination of hardware and software constituting an embedded computer that is hidden in the product and which the user therefore often does not perceive as a computer system. Embedded systems are found everywhere around us – in mobile phones, air conditioning systems, cars, microwave ovens, refrigerators, laundry machines etc. The appliances that are used range in size from the smallest chips to huge production machinery.

Model-based development

Developing a prototype just to discover that it does not function as intended is both expensive and frustrating. Any developer wants to avoid problems like that, and one way of preventing potential problems is to set up a mathematical model of the finished product and make calculations on whether it will perform according to plan – even before the company starts developing the actual hardware and software for the product. The method can also be used for testing: developers can set up a model, develop software on the basis of this model and subsequently test the software against the model in order to find out whether it performs according to the calculations. All with the purpose of increasing reliability and minimising the number of potential flaws and faults in the product.

ARTEMIS

ARTEMIS (Advanced Research and Technology for EMbedded Intelligence and Systems) is a pan-European research program established by the European Commission along with, among others, Philips, Siemens, Bosch, Airbus Industries and Daimler. €2.7 billion will be allotted to the field over the course of ten years. The aim of the ARTEMIS program is to build up competences and systems for a more efficient utilization of embedded systems, to the benefit of all industries. DaNES have been instrumental in getting Denmark to join this initiative.

PARTNERS

SKOV is an international market leader in the field of climate control and production monitoring for animal agricultural production. We develop, produce and market systems and components for ventilation systems, livestock house air cleaning and production control.

PAJ Systemteknik develops, manufactures and services devices for OEM-companies. The core competencies consist of delivering products that must observe strict operational and quality demands.
Both the development and the production - and the transition between-happens problem and risk-free for the customer whether the solution is a safety - critical component in trains, medical instruments that must not fail or advanced laboratory instruments.
The focus is on long term cooperations with customers by being single source supplier from development through to maintenance. Quality control is according to ISO 9001, ISO 13485 (Medico) and IRIS (Railway), while manufacturing according to IPC A Class 3 and ICE 61340-5-1 ensures customer satisfaction - every time. Consideration for the environment is ensured through ISO 14001-certification.

Prevas is an innovative IT company with a strong corporate culture that gives its customers a world's class competitive edge. Prevas has delivered profitable solutions for the future for over 20 years. At Prevas, we see the establishment of long-term relationships with customers and deep insight into our customers' operations as the basic requirements to being able to create customer benefits.
Successful products and processes are based on early and innovative use of IT. Prevas' strong corporate culture combined with our project methodology, quality assurance and delivery reliability have qualified us for many successful assignments from high-caliber companies.

Terma develops and markets high-tech solutions, systems, and products for civilian and military applications. The Terma headquarters are located in Lystrup near Aarhus, Denmark. The company is 100 per cent Danish owned. Terma's high-tech solutions and products are developed and designed for use in extreme mission critical environments and situations, where human lives and valuable material assets are at stake.
Terma's business areas cover:

- Aerostructures for aircraft
- Airborne Systems, including self-protection systems for aircraft, audio systems solutions, reconnaissance systems for Integrated Systems, including air traffic management systems, self-protection systems for ships, and command and control systems for navy, army, and air force applications
- Radar surveillance systems
- Solutions, services, and products for space applications

Novo Nordisk is a healthcare company and a world leader in diabetes care. In addition, Novo Nordisk has a leading position within areas such as haemostasis management, growth hormone therapy and hormone replacement therapy.
Novo Nordisk manufactures and markets pharmaceutical products and services that make a significant difference to patients, the medical profession and society.
With headquarters in Denmark, Novo Nordisk employs approximately 30,500 employees in 79 countries, and markets its products in 179 countries.

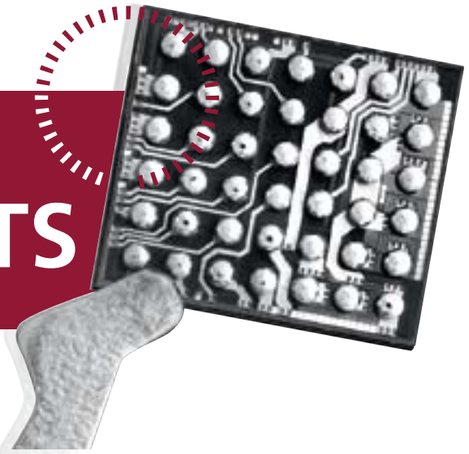
ICEpower today is a fast growing, scientifically based innovation house specializing in audio power conversion solutions. Over 80 percent of our 50 employees are directly involved in R&D. Based on our innovative technologies, represented in our strong IPR portfolio, we develop dedicated solutions for driving consumer and professional speakers, automotive audio, mobile/portable devices and home theatre systems.
The core brand promise of ICEpower is to deliver the industry's best audio performance, efficiency and power density in audio power conversion. After more than 13 years of scientific research, ICEpower has been able to achieve significant leaps in audio power conversion technology.

The Mads Clausen Institute is part of the Faculty of Engineering at the University of Southern Denmark. The institute deals with innovation on a technology, design and business level, and organises a range of international and Danish higher education programmes. With the combination of research and education, and a close co-operation with industry, the Mads Clausen Institute is an exciting work place and study environment.

DTU Informatics carries out teaching and research within computer science and information processing, with a focus on application within engineering science. Relations to practical problems are essential.

CISS is an ICT competency centre based at Aalborg University and is accordingly anchored in a number of Denmark's leading research environments.
The researchers at CISS possess a wide range of competences within electronics and IT, and one of the purposes of the centre is to facilitate collaborations between research and industry – for the benefit of research, business and society.

DEVELOPING BETTER PRODUCTS - faster



At the Danish company Bang & Olufsen ICEpower, an innovation house under Bang & Olufsen, the collaboration with PhD student Anders Sejer Tranberg-Hansen from the Technical University of Denmark (DTU) has led to very promising results: introducing model-based development in the company's development processes shows potential for significantly faster development cycles and better products.

Photo: ICEpower

"I've been working on creating a framework which allows us to set up a model of a system and estimate its performance – before the actual system is even constructed. The specific system we've been looking at in relation to ICEpower is a set of audio processing algorithms for audio conversion to be used in mobile phones. The algorithms are to be run on a platform which was yet to be decided, and the company would like to know how to ensure that the algorithms are executed in the best possible way, and which platform would be best suited for that. Usually, choices like these are based on the engineers' prior experience, but now we are able to construct a model of the algorithm and of the platform that enables us to let the two interact and show how they will perform in a given situation within a relatively short time span. This allows a larger part of the design space to be explored, leading to better designs and thus better products. In short, we specify the system and get answers to how it will work," Anders Sejer Tranberg-Hansen explains.

Faster, better products

Professor Jan Madsen, DTU, is in no doubt as to the value of Anders Sejer Tranberg-Hansen's work. "This project has been very successful – the company has seen an improvement of productivity where they can construct parts of their systems seven times faster than usual," he says, and the PhD student agrees.

"The results have been very promising – we constructed models of the applications and analysed them, enabling us to see how they would work on different platforms. Our work showed that using these models will enable the company to implement such applications markedly faster, and the model also gives the engineers the answers to design questions faster, for instance in terms of what platform to use and how to configure it," he says.

Fits like a glove

And seeing how his research can be used in actual products has been a very rewarding experience for Anders Sejer Tranberg-Hansen. "It has been very interesting to be allowed to use the framework in parallel with the design flow at ICEpower and to see how this work has now resulted in a physical chip – and how our estimates come true when compared with how it actually works. There is often a wide gap between a research tool and its concrete application in real products but here, we have got a kind of proof of concept; we have shown that it works – that we can actually solve problems that companies experience. It fits like a glove," he says with a smile.

Building career on DaNES work

Anders Sejer Tranberg-Hansen will be finishing his PhD thesis in the near future and hopes to continue his career at ICEpower, who offered him a job. "I'd like to see the methods and tools I've been working with being more widely used and more widely available so that even more people can utilize them. I'd like to be able to contribute to the company's existing design methods and thereby continue my work, albeit from a more practical angle," he finishes.

Meanwhile, customers of B&O audio systems will soon be making use of his research – as part of the invisible embedded systems in their mobile phones.

SAFETY FIRST

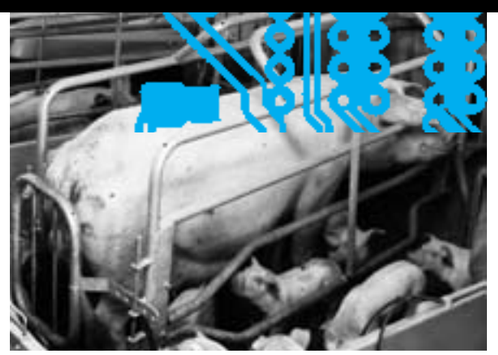


Photo: Skov

Safety-critical systems have been the focus of important parts of the work in DaNES. As the name implies, safety-critical systems function in contexts where their reliability is crucial and where, should errors occur or parts of the system break down, the system is capable of continuing to work until the breakage can be fixed.

One such system is the climate-control system for animal facilities developed by the company SKOV, which has been the focus for the company's case study under the DaNES project. In animal production, such as chicken or pig farms, having the right indoor climate is crucial to the well-being and even survival of the animals. SKOV's system consists of a number of sensors (CO2, temperature and humidity), ventilators, heaters, vents etc., and all of those are controlled by embedded software.

"Our PhD student Mehdi Gholami has been working with SKOV on how to enable their process control system to handle the situations that arise when errors occur. SKOV of course performs ongoing fault detection on their control systems, but Mehdi's approach uses model-based testing of the entire stable system – in the sense of the indoor climate as well as the climate-control system – and will not only be able to detect faults in the climate-control system but also faults outside the system, such as a broken window that draws in air," associate professor at CISS, Henrik Schiøler explains.

The new approach consists of constructing a model of the stable and climate-control system, including the various data from the sensors, and then comparing this to a model of how the stable system (for example temperature, humidity and airflow) should look, in order to give the animals optimal conditions. By comparing the two models, the control system will be able to discover differences and thus either remedy the imbalances or notify the farmer so he can send for a technician to make repairs.

"SKOV works with a climate system based on the idea of dividing a stable into zones," Henrik Schiøler explains. "This implies an increased level of component redundancy as a side effect, which can be utilized to handle errors allowing so-called 'graceful degradation'." This means that if a vent is broken in zone 1, a vent in another zone can be opened and thus draw air through the entire stable, including zone 1. The system will be able to keep working, only at a lower quality, until the technician arrives to do the necessary repairs.

At SKOV, they are very pleased with their participation in DaNES and not least their collaboration with CISS; a collaboration that goes beyond the DaNES activities. "We have been collaborating with universities and specifically CISS for years," says software manager Martin Riisgaard-Jensen and emphasises the importance of getting new eyes on the company's products and work processes. "Participating in projects like this gives us shortcuts to new solutions and inspiration to having our own world analysed. We work hard to achieve our results, but sometimes you need to take a step back and say, what exactly is the nature of our problems, what kind of project strategy should we follow? Having the opportunity to discuss such questions in a larger forum is very valuable," he finishes.

And at CISS, they do not underestimate the value of collaborating with SKOV. "Collaborating with SKOV gives us an opportunity to focus our research – it is very important to ensure that it has a basis in reality. SKOV makes a full-scale testing facility in the shape of a decommissioned poultry facility available to the university researchers . Having access to such a facility is of immense value," Henrik Schiøler emphasizes.

At the moment, PhD student Mehdi Gholami has tested the new methods on the simulation model he has constructed, and if things go according to plan, his work will soon be ready for further studies in the test stable.

GATEWAY to highly skilled manpower

Photo:
PAJ Systemteknik

At PAJ Systemteknik, an advanced-technology company in Sønderborg in Southern Denmark, industrial PhD Wei Guan is working to optimize the company's software development process through setting up a tool-chain which, among other things, gives engineers a number of 'software bricks' by which they can construct their products.

PAJ Systemteknik's work in DaNES concerns developing software for an embedded platform for use in one of PAJ Systemteknik's current products, an anaesthesia ventilator, but the hope is that the results will be useful for many other applications in the future.

"When we started this project, we had two goals: we wanted our software development process to be three times as fast as it was – and we wanted to heighten the quality of the software. And we hope to achieve this through the tool-chain that Wei Guan is currently working on," Poul Jessen explains.

Like LEGO bricks

Wei Guan elaborates: "The tool-chain contains several tools, grouped in two toolsets. One of these toolsets, called the component toolset, will enable the engineers to create a set of reusable software components that can be used like a set of LEGO bricks – when you set out to build a large toy, you have a large number of bricks, some of which may be constructed from other bricks. What we can do is pre-create these 'software bricks' and establish a repository of bricks that are thoroughly tested, giving us a set of trusted components. I can then use these bricks to build applications – when I set up the design, I know all the bricks are working perfectly, and all I need to do is configure them. Of course, we then need to perform tests on the overall design to eliminate design errors on that level, but it is our hope that with this tool-chain, the engineers will save a lot of time," he explains.

"The tool-chain will also contain tools generating testing suites that will help the engineers ensure that each component functions correctly, and tools that automatically, and very quickly, produce source code which it would earlier take an engineer days to write," Wei Guan continues. "The second set of tools in the tool-chain then facilitates the configuration process for the individual applications the engineers are constructing on the basis of the software bricks," he adds.

DaNES helped bring in the right competences

The tool-chain that Wei Guan is working on is targeted at the anaesthesia ventilator, but the plan is to be able to use the software bricks for other applications as well. "We will be able to construct a specific product by picking out the exact elements we need – that's what's so brilliant about this!" Poul Jessen says and adds that if it wasn't for DaNES, the project might not have been carried through at all.

"We've been working within platforms for years, but we haven't had the financial resources to carry through a development project like this. Through DaNES, we are now able to afford it, and we got the opportunity to bring in the exact competences we needed. It's important to remember that any time you bring in new employees, especially from for instance China or India, there's a kind of training period, and there's also a very large cultural gap. You need to take these things into account and make an effort to make them feel involved in the company and help them learn Danish and learn about our culture. But when they can contribute to the company through their skills, it is definitely worth it," Poul Jessen finishes.

NEW SOFTWARE DEVELOPMENT METHODS for device development

Photo: Novo Nordisk

Developing medical devices places very strict requirements on the company and developers. The products are subject to a range of approvals and requirements from the authorities to ensure the highest possible level of safety for the patients when using the products. This not only affects the products themselves and how embedded systems perform in the products, but also the development processes that lead to the products in question.

On this basis, Novo Nordisk has been participating in DaNES at two levels: in one project, a PhD student, Lise Tordrup Heeager from Aalborg University has been reviewing part of the software development process of one of Novo Nordisk's ongoing projects, and in a second project, researchers at CISS have been employing model-based development and test for testing and modelling sets of specifications for a new product, namely a new generation of insulin delivery devices containing embedded electronics and software.

Reviewing software development processes

"I've been working with the software group in the project with the purpose of reviewing their software development process during a period in which they have been implementing new processes such as Scrum and Lean software development," Lise Tordrup Heeager explains. "My work has consisted of 27 interviews as well as observing planning meetings and stand-up meetings. I started the work in 2009 and have done the second phase now in 2010 in order to see the development from one phase to another. And my work up until now indicates that it is beneficial to use agile processes for medical device software. In addition, it seems that using short two-week iterations in teams of 3-5 persons may have a positive impact on the overall development process and the interaction and cooperation among the developers in the teams," she elaborates.

Transferring knowledge and experience to other projects

The next step for the company will be the challenge of how to transfer the knowledge and experiences obtained in this project to a new development project. "Getting more focus on our development processes has been a very good thing," says senior project manager at Novo Nordisk, Michael Agerkvist Petersen. "It is one of the first times we've done this at Novo Nordisk, and it's very beneficial to be able to discuss these things with a third party. Those of our employees who have taken part in the interviews are of course excited to hear Lise's conclusions, and the developers in the new project are also very interested in hearing the results."

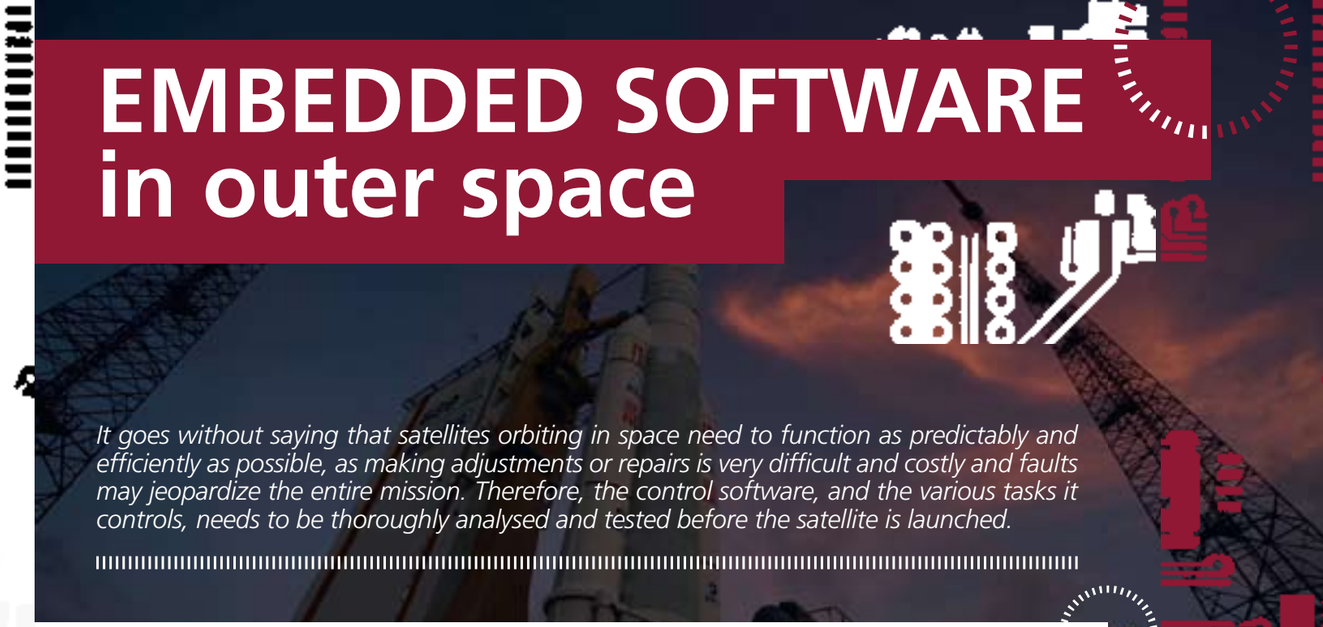
New methods are here to stay

In terms of model-based development, Michael Agerkvist Petersen hopes that the work in DaNES, and the methods and tools that the employees have gained familiarity with through the project will be increasingly implemented in the company's development processes. "The most important thing that Novo Nordisk has gained from DaNES in connection with this part of the project is an increased awareness of this kind of software development. Among other things, this has occasioned our initiating collaboration with universities in the shape of master's projects focusing on model-based development in the hope that with time we can adopt it as an integrated part of our development projects," he says.

Associate Professor at CISS, Arne Skou, agrees that the project has been beneficial for all involved. "Novo Nordisk offered us a set of very interesting, concrete problems that allowed us to develop our tools – both the UPPAAL tool, which is used for model-checking, and our tool for automatic test generation – even further, and the project has proven that active research can result in a commercially usable tool," he emphasises.

Read more about UPPAAL on page 15.

EMBEDDED SOFTWARE in outer space



It goes without saying that satellites orbiting in space need to function as predictably and efficiently as possible, as making adjustments or repairs is very difficult and costly and faults may jeopardize the entire mission. Therefore, the control software, and the various tasks it controls, needs to be thoroughly analysed and tested before the satellite is launched.

Photo: ESA

The Danish company Terma develops and markets high-tech solutions, systems and products for civilian and military applications. Among the business areas that Terma covers are services for space applications, and this field has been the focus of Terma's work within DaNES. Specifically, the case study has concerned software constructed for the ESA (European Space Agency) satellites Herschel and Planck that are currently part of ESA's scientific missions.

"What we did was perform a schedulability analysis on the satellite software – in other words, we exhaustively checked the timings of the tasks it needs to perform and whether it will be able to meet the deadlines," explains researcher Marius Mikučionis from Center for Embedded Software Systems at Aalborg University.

The traditional engineering methods used for schedulability analysis are very conservative and often give too pessimistic results; that is, they might show that the satellite software is not able to perform all necessary tasks within the set deadlines, even though an actual system simulation does not reveal such problems. This traditional type of analysis takes as its point of departure a scenario in which the worst possible things happen simultaneously, and as such will often ask the developers to improve their system by exposing only potential symptoms but not the actual fault or the scenario leading to the fault.

It can be done

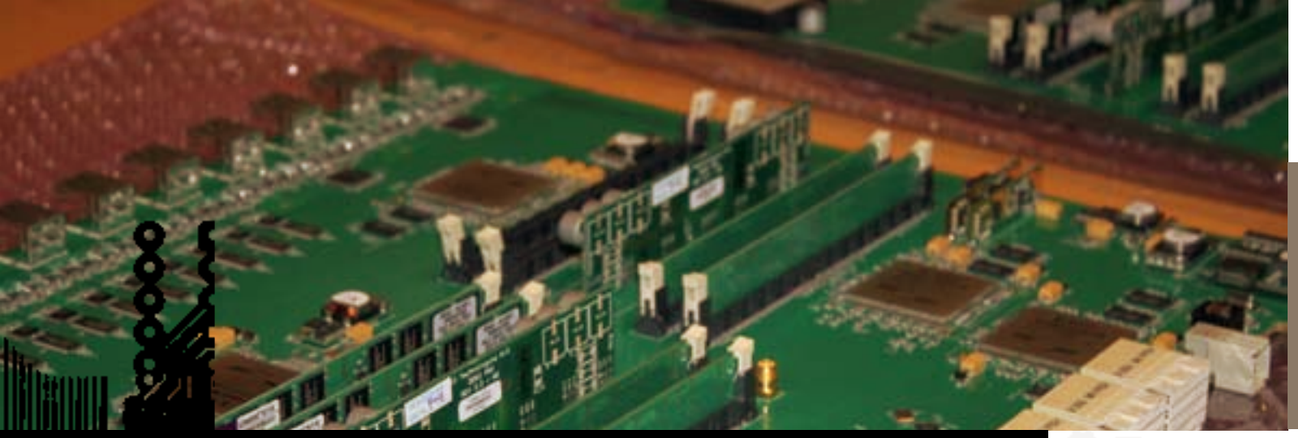
"In my experiment, I modelled the software system using a model-checker tool, UPPAAL. The result is an abstract model that is rich in details, which makes its behaviour more realistic than traditional models allow. The tool then automatically analysed the model and provided positive results, in that it showed that the satellite software will be able to perform all its tasks. In addition, it is able to simulate the entire scenario in case of persisting problems, allowing the developers to focus on solving the actual problems rather than a number of hypothetical ones," Marius Mikučionis explains.

At Terma, they are very happy about the results so far. "The result was an improved analysis in comparison with our usual method," says Senior Analyst at Terma Poul Hougaard. "It is difficult to create a model that mirrors reality completely, but we are now able to create a model that is more realistic than before, and hopefully this will help us focus our resources on the right elements that need improvement," he adds.

First step is taken

"The experiment has shown that this has great potential, but there's still a long way to go. The methods need maturing before they can be commercially applied, and then there's the official authorisation. There's a long development process ahead of us, but things look very promising so far – we've taken the first step," Poul Hougaard adds.

The researchers have got new paths to follow as well. "As researchers, we know that our technique offers a sound analysis and thus sound results, but our models don't always scale to real problems. What we found in this experiment was that we could actually use the model-checker for this kind of software. Moreover the model templates are generic and could be reused in analysing other systems as well. We've shown that our tool is applicable to a software system of this size – with more than 30 tasks, of which the most complicated consisted of 49 steps. This opens new doors for us as well," Marius Mikučionis finishes.



NEW KNOWLEDGE and new projects

The Danish IT company Prevas, who is celebrating its 25th anniversary this year, develops intelligent solutions for products and industrial systems. The company had no hesitation joining the DaNES project when one of their research collaborators invited them in.

Vice President Technology Rune Domsten explains the background for the company's participation in DaNES: "We have been working with embedded platforms for 12 years, and when Professor Jan Madsen from DTU Informatics at the Technical University of Denmark (DTU) invited us to join the project, we saw this as an opportunity to look at our product development processes. In our eyes collaboration with universities is a way of gaining insight into new ways of working with platforms – and this is exactly what we have gained," he says.

But the company's participation is not just a matter of getting new insight from the researchers or other companies – the company has made one of their current platforms available for studying, not just in DaNES but also for students at DTU. "We as a company need to be at the forefront of the market, and in order to gain such a position, we need to take part in new projects and collaboration with researchers. And of course we would also like the students to learn about platforms during their studies," Rune Domsten explains.

"Our role in the project has been minor compared with some of the other partners, so what we have gained most from is taking part in the joint activities such as seminars. These have given us the opportunity to learn about various approaches to platforms, for instance from universities we have not collaborated with before, such as SDU, and we have learned about new approaches to collaboration between universities and industrial partners – how this can be done – which has been highly valuable," he elaborates.

New doors have opened

In addition, the work in DaNES has led to other collaboration projects: there is currently a student project at DTU concerning a self-propelled robot based on one of Prevas' platforms, and the company is also participating in an industrial PhD project focusing on the design of the next generation of platform-based robots. "We would not have got the inspiration for setting these things in motion if it hadn't been for DaNES," Rune Domsten stresses.

But Prevas does not take part in DaNES just for their own sake – there is more at stake than what goes on in a single company.

"Intelligent embedded systems are THE largest value-adding element in new products. Therefore, we as a nation need to put extreme focus on constructing intelligence for products. If we don't, other countries will outmatch us," Rune Domsten stresses. "Through DaNES, we have achieved a wider understanding of platforms across the country and across the participating universities. And we have expanded our understanding of how to collaborate on it," he finishes with a smile.

Prevas

NASA interested in groundbreaking invention: self-repairing computer

In a research project in DaNES, a team of researchers from DTU Informatics have developed a biologically inspired computer capable of repairing itself. The computer is highly robust and thus very useful in safety-critical contexts and contexts in which repairs are hard or impossible to carry out, and this is what has caught the attention of NASA, who is currently looking into the possibility of incorporating the technology in future space applications.

The point of departure for the research team when they started their work three years ago was a wish to construct a highly reliable computer, but not in the typical way of using triple module redundancy (TMR). With TMR, the computer system is tripled so that if one component should fail, the two remaining will be able to detect it. One of them will then be able to take over and thus enable the computer to keep working. The team felt that it was possible to go one step further than this.

The result is a technology that goes under the name "eDNA" – electronic DNA, and constitutes a computer constructed of cells with a DNA-type coding which can identify defects and repair them without human intervention.

Electronic stem cells

"We have developed a computer that does not use one central CPU but rather a network of very small CPUs or 'cells'. All cells receive a DNA sequence, and depending on their location, they interpret this sequence and carry out their allotted tasks. If a cell malfunctions or dies, another cell will take over its role," explains Professor Jan Madsen, who is heading the DTU team.

The new computer thus contains a number of 'stem cells', that is, cells that have not yet been assigned a specific task. Should one of the working computer cells fail for some reason, the network of CPUs will detect it, and the self-repairing process will find a stem cell which will then take the defect cell's place and enable the computer to continue carrying out its tasks – almost like the way that stem cells function in a human body, hence the name.

NASA hoping to incorporate the new technology

These 'stem cells' enable the self-repairing computer to tolerate far more defects before it stops working, and it will therefore be highly robust and well suited to the extreme environments that occur in outer space. And this is what has drawn the attention of NASA, who is currently studying the technology to see if it can be applied in their future work; a study that takes place in collaboration with PhD student Michael Reibel Boesen from DTU Informatics.

Specifically, the PhD student has been working on incorporating the new technology in a spectrometer which NASA uses when looking for extraterrestrial life. Satellites and the equipment they carry are subject to a number of very harsh conditions such as solar winds and cosmic radiation, not to mention the shakes and vibrations from the launch. As such, the demands on the computers is incredibly high, and the new self-repairing computer fits right into NASA's needs in this connection, and the results of Michael Reibel Boesen's work are so far looking very promising, and the research team is hoping that NASA is only the first of many to make use of the technology.

"We are living in a world where everyone wants robustness, not just within the medical field and at NASA's main facility, but also ordinary computer users. It is, of course, my dream – and my hope – that eDNA will come to be widely used by many people," Jan Madsen finished.

It doesn't stop here...

The activities in DaNES are far from limited to the case studies performed in connection with the participating companies. A large number of further research and collaboration activities holding great potential have taken place, which we will certainly hear more about in the years to come. Here, we present a number of these activities.

Millions for research within 'invisible' software

Two of the partners in DaNES, Centre for Embedded Software Systems (CISS) and the Technical University of Denmark have entered a groundbreaking collaboration with Chinese researchers. CISS will be heading the new collaboration that aims at making the many software-controlled appliances and systems that we see around us more reliable. The Danish National Research Foundation has allotted DKK 15 million for the research centre that is named IDEA4CPS.

The Danish part of the project will be led by Director of CISS, Professor Kim Guldstrand Larsen. He has great expectations to the new collaboration, which builds on Denmark's leading position within embedded software:

"When we combine the Danish competences within this field, we are among the foremost in the world. Now, the collaboration with very skilled Chinese researchers at the East China Normal University and the Institute of Software Chinese Academy of Science will enable us to take our work to new levels and into new territories," Kim Guldstrand Larsen explains.

The collaboration focuses on the theory and math behind the intelligent embedded software systems that are seen in an increasing number of contexts every day, without necessarily being aware of it. The software systems control mobile phones, ticket machines at the train station and automatic bars at the car park. In the homes of the future, they will also monitor and adjust temperature, heating and light, and they will enable the cars of the future to "communicate" with each other about road conditions and the optimal speed for safe driving.

"We are seeing a clear trend towards all these embedded systems in individual appliances having to communicating with each other in different ways in order to find out how best to solve a given task. The systems will be forming extensive self-organised networks known as cyber-physical systems. If we furnish our surroundings with even more of these kinds of IT systems, they cannot be allowed to fail. They will be the backbone of the society of the future, so we need to make sure that they are reliable, workable, efficient, fault-tolerant and resistant to hacker attacks," Kim Guldstrand Larsen elaborates.

The joint Danish-Chinese venture will serve to both strengthen the theoretical foundation and improve the practical methods that are used for modelling and analysing cyber-physical systems. Even though the collaboration focuses on basic research, the large grant from the Danish National Research Foundation is also given in the hope that in the long run, the research results will lead to an improved engineering practice and a significant improvement in the quality of the systems developed.

Special Interest Group on safety-critical systems formed

A number of the participants in DaNES, among them the Centre for Embedded Software Systems, DTU Informatics and companies PAJ Systemteknik and Novo Nordisk, have been the leading forces behind the formation of a Special Interest Group on safety-critical systems. The interest group is funded by the Danish innovation network for IT, InfinIT and has at this point held two seminars. The group is open to all interested companies, research institutions, universities, organisations etc.
Read more at: http://infinit.dk/dk/interessegrupper/sikkerhedskritiske_systemer/

Research tool now available for commercial use

One of the software tools that has played a major role in the work in DaNES is the model-checker tool UPPAAL that is developed in a collaboration between Uppsala University and CISS at Aalborg University. The tool has been matured during the course of the DaNES project, and this in combination with several companies showing their interest in the tool has led to UPPAAL being made available for commercial use through the newly-founded company UP4ALL.

"UPPAAL enables companies to verify that the embedded software in their products can perform all the necessary tasks within the given deadlines. The tool analyses and performs tests on a software model of the product – we like to say that 'if you can model it, you can verify it'," says Professor Kim Guldstrand Larsen, CISS, who is one of the originators of the UPPAAL tool. In other words, the company draws up a model of its product with all the tasks it needs to perform – for instance the various functionalities of a car – and UPPAAL can then generate test scenarios on the basis of this model and check whether the necessary tasks can be performed in time under various conditions.

Increasing demands on embedded software

"Many products nowadays contain software consisting of numerous interacting components. Every task a product needs to perform must react timely to the inputs it gets from various sensors. It needs to process the inputs and determine how to react to it. If all tasks had their own computer, this would not be a problem at all, but all the tasks use the same computer, and sometimes also the same sensors, so there is a constant competition for computer power. And in recent years, we have seen an increase in products where safety-critical functionalities get intertwined with what is called infotainment – for instance downloading maps from the internet while you are driving your car," he elaborates. This of course increases the demands on the embedded systems controlling and performing the various tasks – and thus also on developing and testing these systems. And in this connection, UPPAAL may have become commercially available at just the right time.

Commercial demand

"DaNES has played a significant role in maturing and adapting the UPPAAL tool for use in companies. During the course of the project, the tool has been used in different contexts for testing and analysing real-time aspects of embedded systems. At the same time, word about the tool has spread, and we got a number of enquiries from major companies as to whether they could purchase a license for the tool. This led to the evolution into setting up the commercial company UP4ALL," Kim Guldstrand Larsen explains.

A large number of companies have already shown an interest in the tool, ranging from major international companies over consultants offering test services, who want to use the tool in their work for clients, to smaller companies who want to incorporate the UPPAAL engine in order to improve their own test tools. At the same time, the tool is still being used for academic purposes – both research and education – at universities all over the world.

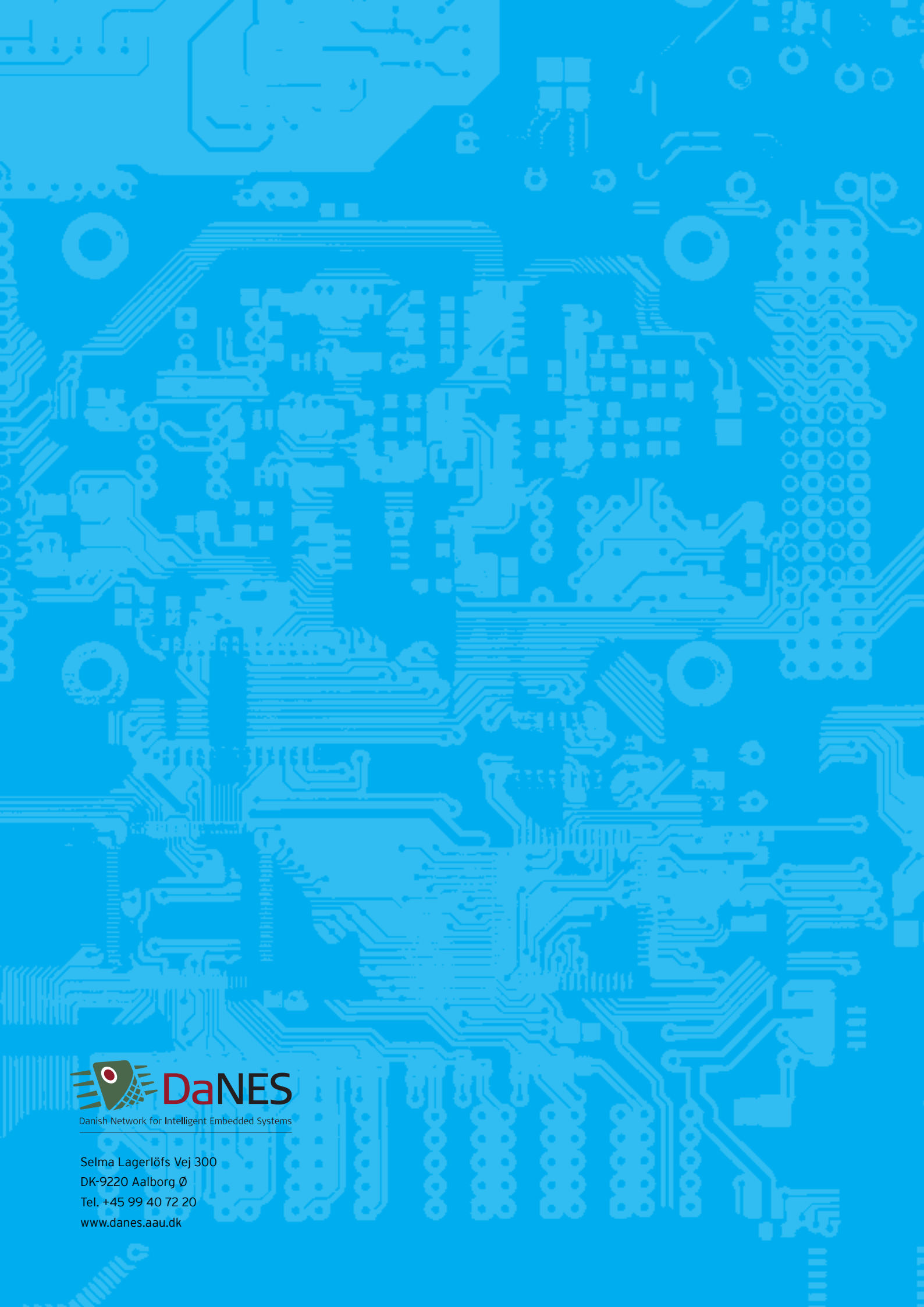
"We will of course keep developing the UPPAAL tool for both uses. We have now got a commercial product that is applicable and is being used, but there is still potential for improving and adapting elements of it in order to make it even more useful in the companies' development processes. We are hoping that different collaboration projects with companies, for instance within the ARTEMIS programme (see p. 5), will provide us with feedback that we can use for this purpose. And we will also continually work on developing the tool academically, for instance through research and student projects," he finishes.

UP4ALL

UPPAAL is used for design verification and testing of real-time embedded systems, as exemplified in the article Embedded software in outer space on page 11. Read more about UPPAAL and UP4ALL on www.uppaal.com

Danish companies in pan-European projects

A number of the partners behind DaNES, including Kim Guldstrand Larsen and Arne Skou, CISS, and Jan Madsen, DTU, established the Danish D-Artemis initiative whose aim was to disseminate knowledge about the possibilities for Danish companies to take part in pan-European research and development projects under the ARTEMIS initiative (see page 5). The results have been very positive as the number of participating companies has surpassed all expectations: of 57 initiated projects, 17 have participation from Danish companies.



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