Maxwell

Magazine of the Electrotechnische Vereeniging

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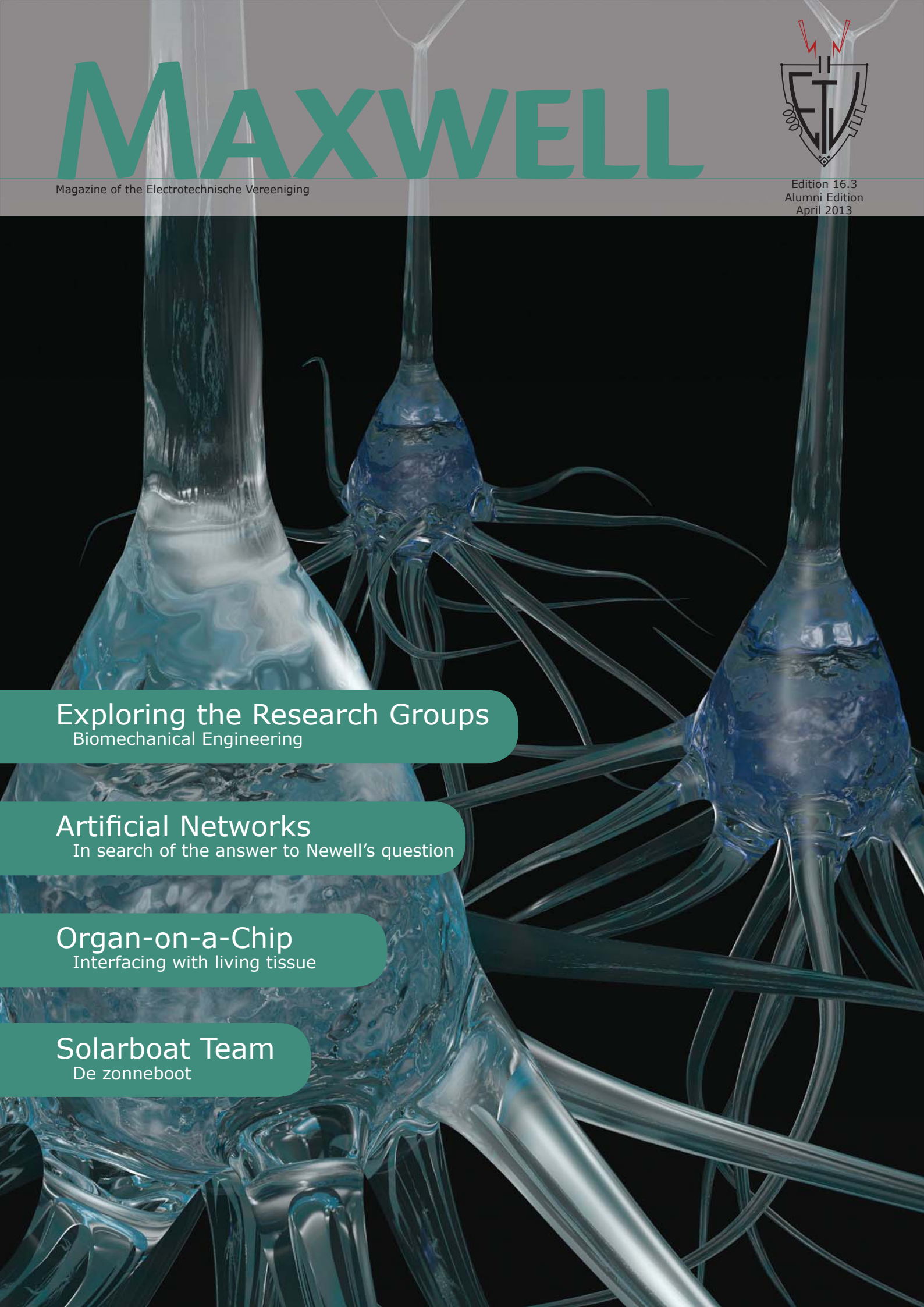

Exploring the Research Groups
Biomechanical Engineering

Artificial Networks
In search of the answer to Newell's question

Organ-on-a-Chip
Interfacing with living tissue

Solarboat Team
De zonneboot

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From the board
A whole new kind of busy

Dear reader,

This time I will admit that I started writing my column for the Maxwell to late, definitely to late. As many of the articles are already finished and everything else is being checked, I only just started working on this story to every one of you who receives the Maxwell. Everytime I wanted to start, I thought by myself: I can't write it yet. There are so many things that still have to happen until the real deadline, things that I want to include!

Well, deadline. Here you are.

While the third quarter of the year has passed, we have got to know a whole new kind of busy. A very pleasant one. The times we eat at home are lessening and the amount of free time we have is slimming as well. Obviously, after the exam weeks and after a short vacation which the board used to evaluate the current progress, we started off with a motivational drink in the /Pub. Many of our members are starting to enjoy it more and more as it is a time with very little stress – the start of a quarter, in this case also the semester – but everyone's mind is still swarming with the exams and most of the conversations are about that topic.

The agenda had hardly ever looked that messy, filled to the brim with activities for everyone. Meeting with committees, external events and many other things. The combined activities, for all the board members included meeting some of the EEMCS professors and going bowling with many of our first years. Saturday, we enjoyed a parents day which the ETV organises every year and where you can read about further in this edition. It was an inspiring day. Many mothers and fathers learned a lot about their child's education. The day after, both our board and our predecessors were invited by Lou van der Sluis, a honorary member of the ETV, for a diner at his home. It was most interesting to dine with all of them.

Next week: A general member meeting, at which we decided on a set of budget estimations. Later that evening, an awesome party that the 'FeeCie' organised together with two other associations that were from Leiden. With almost four hundred people present we had a real blast. In the weekend it was my honour to invite the other board members to my parents place for them to meet each other.

Before we knew it, it was time for three out of five board members – Rob, Pascal and myself – to take part in the Electrip. A four-day study tour which would take us to Groningen, Hamburg and Kopenhagen. The report of this is published further into the Maxwell so I won't go into further detail about it now. While the three of us were away, Menno and Erwin had the honour of representing the ETV at the last central Master graduation ceremony. Sadly enough, these events will no longer be organised for the graduates.

While our neighboring association, Christiaan Huygens was having their DIES week from the 4th to the 8th of March, we went to Utrecht to meet up with our daughter-associations from the other electrical engeneering studies in the Netherlands. We discussed our educational systems, travels and work on top of the city. It was most delightful seeing them again.

Someone else we also saw, was prof.ir. Boxma – A honorary member of our association. After a period of bad health he felt he could invite us over, even if it was merely for tea.

After meeting him, I hardly had the time to enjoy my weekend since our bus towards the snow would leave Saturday. With a group of fourteen people we got out of our ride at Avoriaz, france, and spend most of our time on the piste. If not so, we would all join up and have a good time in our of our rooms. Meanwhile the ETV members strengthened their bonds with a few of the faculty members by visiting the ELCA festival, a yearly music event by employees, and organising the 'Whiskey experience' where both students, employees and even a professor sat down and had their try on a lovely assortment of whiskies.

We ended that week, this week, by visiting the second bachelor graduation event of the year and the inauguration speech of our dean, Prof. Fastenau. Both of the events were, although far apart, very inspiring. I haven't had the pleasantry to be the focus of ether one yet, but why not both one day?

Well, there you have it. Thanks to our year as board members we when to a whole lot of new places and now it's time to set our feet back onto the ground once more. I wish everyone good luck with the exam period and hope to see you in the boardroom!

On behalf of the board,

Derk-Jan Hulsinga

Theme content

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... and more

Editorial

Dear reader,

It's friday evening, half past seven, and finally the last pieces of this Maxwell are coming together. A special edition at that, since this Maxwell will not only reach the regular list of ETV-members, but the alumni as well - which also means an extra thick, fourty-four page version of our magazine.

Of course more pages means more articles, so myself and all of the other editors have been quite busy last weeks coming up with interesting ideas for articles, either writing them or getting them to be written and finally putting them to the very paper I am writing on right now.

A keen eye may have already noticed that the table of contents, as well as the articles, have two different colors. This is, of course, no mistake, as it visually seperates some articles from the others. This time, the articles in orange are all about biomechanics, ranging from the minor report from one of our Bachelor students to organs on chips, there is more than enough information to get you up-to-date on recent developments in this very interesting research field.

Ofcourse you can't always be serious and focused, so there's some light reading too, as a column from one of the ETV's previous board members and an overview of recent activities will prove you.

Now, all that is left for me to do is taking a final look through all the digital pages, making sure that everything is in the right place and ready for printing, so I guess I'll just hurry up a bit so I can also start my weekend!

Jeroen Ouweneel

Newsflash
Updates from the EE field

Author: Jeroen Ouweneel

Intelligent self-repairing circuits

In the past, attempts have been made to make self-healing circuitry in various ways – but in most cases the research was more fundamental, such as the development of microcapsules containing liquid metal. Such techniques are able to fix broken wires, but not much more than that.

Engineers from the California Institute of Technology now have come up with a more elaborate design. Their vision was to create a chip which, not unlike the human immune system, can detect circuit malfunctions and intelligently construct a workaround to restore as much of the chips functionality as possible.

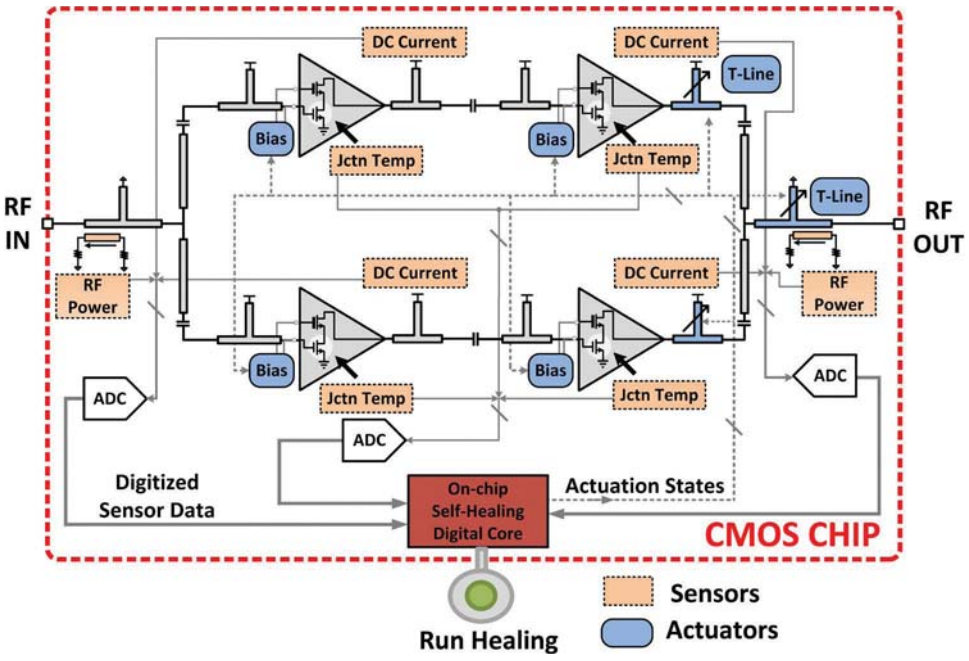
To achieve this, the chip (a power amplifier for millimeter-wave frequencies) is fitted with robust on-chip sensors that monitor temperature, current and voltage whose data is fed to an application-specific integrated circuit (ASIC). The ASIC then analyzes the chips performance, and if needed, adjusts certain actuators. These actuators are also on-chip, and determine which parts of the chip are used.

What's interesting is the operation of the ASIC. Rather than constructing an algorithm that knows exactly how to handle all possible malfunctions, it only 'knows' the desired output. Based on the aggregate response of the on-chip sensors, and due to general enough design of the chip, the ASIC figures out which parts of the chip to activate or not.

Tests have proved the workings of this chip and its self-repairing capabilities; even after intentionally destroying parts of the chip, it managed to re-establish its amplifying capabilities - for example increasing the aggregate yield of a damaged chip from not working at all to 80 percent of its original output.

A paper on this self-reparing chip has been recently been published on IEEE, so for further reading use the QR-code below.

Source: *www.caltech.edu*



Schematic of the self-healing chip design

QR code leading to the research paper

Weather forecast by cellular networks?

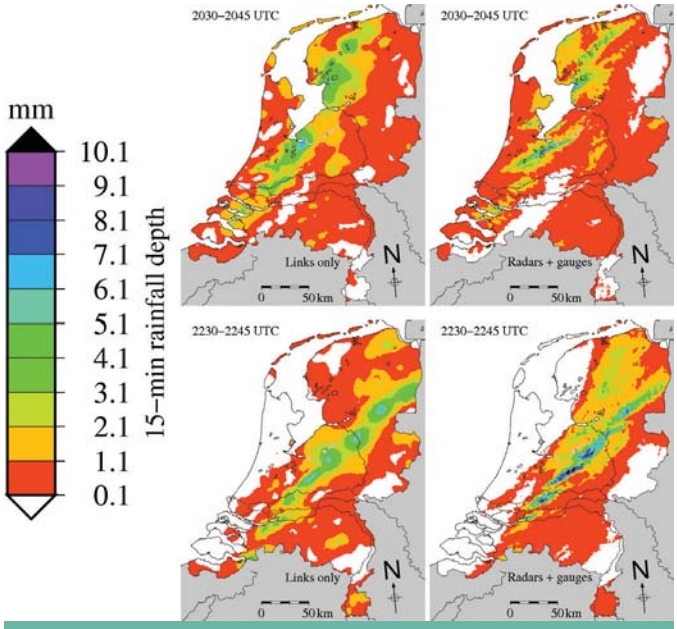
Nowadays, remote sensing of the environment (i.e. measuring rainfall in detail) is a powerful tool used not only for weather prediction, but also water recourse management. While useful in western countries, such information is much more critical on continents such as Africa, where water is scarcely available so optimizing its use guarantees maximum yield in industries such as agriculture.

Current techniques - mainly rain measuring stations - are expensive to set-up and maintain. In a joint research, however, the Dutch weather institute (KNMI) and the Wageningen University may have found a cheap solution to this problem, employing the readily available cellular networks.

The principle is quite straightforward: the signal strength between the transmitter of one and the receiver of another telephone pole - let's call them microwave links - is directly influenced by rainfall, as water droplets disrupt and scatter electromagnetic waves. Using this technique, the team was able to generate a quite accurate rainfall-map of the Netherlands, which is shown in the figure below. The images on the left show the data based on (no less than 2400!) microwave-links, while the image on the right shows the same situation based on regular radar and rainfall-meter measurements.

The measurements clearly show that globally, the results are quite representative and show the potential for this technique as real-time rainfall monitor.

Sources: *www.pnas.org*, *www.knmi.nl*



Rain measurements using cellular networks (left) and conventional measurements (right).

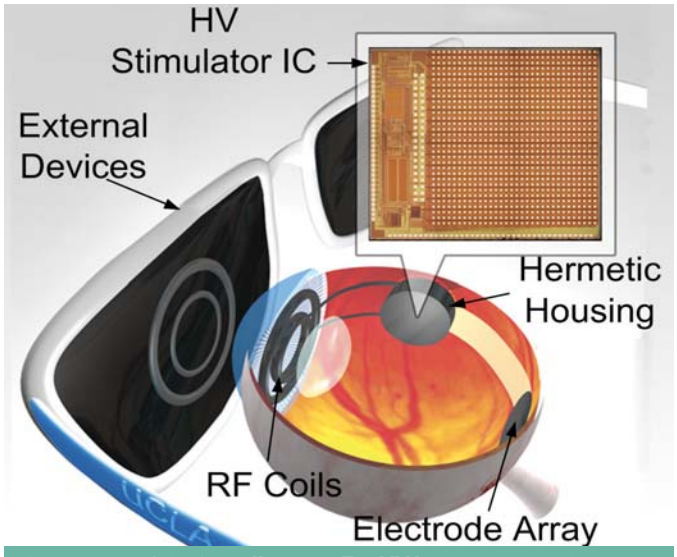
Bionic eye helps the blind

One of the common causes for blindness is non-functionality of the photoreceptors - the 'sensors' in the back of a human eye that convert incoming light into tiny electrochemical impulses. Second Sight, a company focused on implantable visual prosthetics, has now successfully developed a partly implanted, partly worn system that bypasses the photoreceptors altogether.

The system, called 'Argus II', consists of a pair of special glasses, which contains a miniature video camera, a small computer and an electrode array implanted into a patients eye (placed on the retina). The camera - obviously - captures whatever is in front of the patient. The video is then sent to the computer (or VPU: video processing unit), which processes the images into certain digital instructions and sends these back to the glasses via a cable.

The glasses also house a small wireless transmitter, which sends the digital instructions to a receiver in the in-eye implant. Finally, the implants' electrode array stimulates the remaining (working) retina cells. In medical trials, it has been proven that the Argus II can return some sight to blind patients. The current version uses 60 electrodes, but next versions focus on increasing this number. The final goal is to enable patients to read again. What's more, Second Sight has recently received FDA approval, which means the Argus II is beyond trial stage and may be marketed.

Source: *www.2-sight.eu*



An overview of the Argus II system. The VPU is worn seperately.

Biomedical Engineering
Minorverslag

Auteur: Reijer Leijsen

Mocht je alweer genoeg hebben van al die hachelijke elektro vakken en graag eens totaal wat anders doen, dan is de minor Biomedical Engineering zeker een aanrader. Niks geen drukke projecten, niks geen moeilijke vakken, en niks geen vroeg opstaan. Niet direct overtuigd? Laat u ompraten door de pracht en pralen van deze minor!

De eerste week

Zwaar en veeleisend was de eerste indruk. De inzichten in het volgeplempte rooster maakten het vooruitzicht niet bijster plezieriger. De eerste dag vol goede moed en veel enthousiasme aansjokkend, hoor je dan gelukkig toch prachtige en oorstrelende geluiden die zowat je hele wereld uit elkaar doen vallen; je sokken worden er spontaan wit van. De eerste week maar zo'n 6 contacturen, een ingepland uitje naar museum Boerhaave in Leiden (wat neerkwam op het pakken van een terrasje en spelen met de nieuwe slinky, gekocht in het museum) en voor de rest zelfstudie. Enige verplichting: drie opdrachten maken, die direct 2 EC waard zijn. Hoppa, eerste week al 2 EC verdiend, laat de rest van de minor maar komen!

Anders studeren dan gewend

De minor is opgedeeld in een paar vakken (de eerste periode) en een klein (4EC) en groot (12EC) project (beide 2e periode). De verscheidene vakken zijn goed georganiseerd, elke dag weliswaar contacturen en daarbovenop nog zo goed als elke dag opdrachten die je moet laten aftekenen, maar er is totaal geen noodzaak om 's avonds nog iets te doen. De opdrachten zijn meteen je voorbereiding voor het tentamen en voorbereiden van de colleges zijn eigenlijk ook niet nodig. Studeren voor de tentamens was dan ook behoorlijk vreemd. Normaliter gewend om tijdens de witte week en tentamen weken hele dagen in de UB door te brengen? Nu zit je hopeloos te tobben met het idee, wat gaan ze híér nou over vragen? Waar zijn de (oefen)sommen?

Veel op pad

Colleges zijn voor de zwakken, is wat ze gedacht moeten hebben. Er moet iets beters mogelijk zijn. Nog meer uitjes doen? Waarom ook niet! Lekker naar de snijzaal, op naar een paar menselijke kadavers, die al een jaar of 20 in en uit de vriezer gehaald worden, om met een zootje nieuwsgierige nietsnutten de boel eens goed te bestuderen. En ditmaal geen moeder die erbij staat om te zeggen "Alleen kijken en niks aanraken, jij bijdehante snotneus." Nee, binnen 3 minuten stond iedereen met darmen in hun handen en keken we nergens meer vreemd van op.

Een ander uitje, ook naar het AMC, was de rondleiding op de afdeling Radiotechnologie om alle beeldacquisitie methoden te laten zien: MRI, CT en ook conventionele röntgen. Dit werd uitgebreid tijdens de colleges behandeld, maar mocht alles nog niet duidelijk zijn, dan wordt dat hier wel. Mensen die na werktijden met alle liefde nog even vertellen wat zij daar zoal doen, en hoe de apparatuur praktisch gezien werkt.

Knippen, plakken, lijmen

Het eerste kleine project volgde je eerst allemaal gastcolleges van verscheidene mensen, allemaal gespecialiseerd in bepaalde technieken: vaatchirurgie, arthroscopy, trauma- of foetale chirurgie en nog meer. Uíterst enerverende colleges, werkelijk waar. Mensen die écht vol enthousiasme kunnen vertellen, nota bene over onderwerpen waar je haast niks van weet en toch uitermate interessant zijn. Na enkele van deze colleges maak je naar eigen inzicht groepen van 2 personen. Je wordt volledig vrij gelaten met alleen de instructie om een medisch instrument te ontwerpen, of een bestaand ontwerp te verbeteren. Ofwel: bedenk een medisch probleem wat stompzinnig wordt aangepakt, ga naar de doe-het-zelf-zaak, bouw iets leuks en presenteer het zo dat het iets lijkt wat nuttig zou kunnen zijn. Knippen, plakken, lijmen, dat was

Even langs museum Boerhaave te Leiden. Hmm... volgens mij zitten we verkeerd

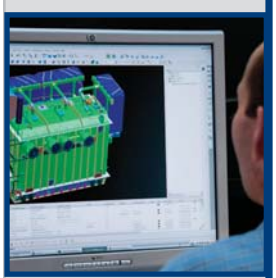
letterlijk de opdracht. Afspreken met de gastsprekers maakte dit projectje nog meeslepender. Bijvoorbeeld even langs bij het LUMC om daar een babbeltje te houden met een dienstdoende arts, en misschien wel iets medisch mee krijgen om thuis te onderzoeken of aan de muur te hangen, is toch wel uit de kunst.

Het grote project

Het grote project is maar liefst 12 EC, dat betekent zo'n miljoen studie-uren, ofwel 17 uur per dag 7 dagen in de week en dat zo'n 8 weken lang studeren. Of...? Bij dit project werd je ook erg vrij gelaten, maar onze groep (van 4 personen) gelukkig ook goed aangestuurd. Het viel dan ook reuze mee met het aantal uur dat hier uiteindelijk in gestoken moest worden. De eerste 3 weken zijn we maar een paar keer bijeengekomen, omdat we onszelf aan het inlezen waren in ons onderwerp, d.m.v. zo'n duizend papers door te spitten. Redelijk wat werk, maar dit kun je thuis doen op elk geschikt uur van de dag. 's Avonds bier drinken, en 's ochtends uitbrakken past perfect in dit rooster. Lumineus. Lekker een tijdje je geheel eigen onderzoekje doen, en uiteindelijk aan je medestudenten presenteren alsof het het beste onderzoek van de eeuw/van het millennium/sinds de geschiedenis van de mensheid is.

Samenvattend is Biomedical Engineering een minor zonder enige connectie met de bachelor elektrotechniek en (daardoor) zonder al te veel te bikkelen door te komen is. Voor de kunstenaars die nog geen idee hebben wat een weerstand of spoel is, is deze minor dan ook uitermate geschikt.

Onderzoek naar de houdkracht van botschroeven van verschillende biomaterialen gebruikt in orthopedische chirurgie



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Graduation project
Recharging the brain

By: R.C. van Dongen

Have you ever wondered why your grandpa is struggling to drink his Vlek graanjenever without spilling and why he is gazing at the floor and walks in a shuffling gait while retrieving the bottle from the kitchen? He might just drank one glass too much, but probably he is suffering from a neurodegenerative disorder. Since Parkinson's disease (PD) is effecting about 1% of all people over the age of 50 [1] and 3% of people over the age of 65 [2] this would be the best explanation for you grandpa's poor drinking skills.

In a very brief and basic summery, PD is caused by degeneration of an area in the brain called the substantia nigra. This, in turn, results in a shortage of the neurotransmitter dopamine. This neurotransmitter plays a crucial role in the parts in the brain that control and initiates movements. From an electrical engineering point of view you could compare the brain of a PD patient with an amplifier and feedback loop that has become unstable due to a faulty connection.

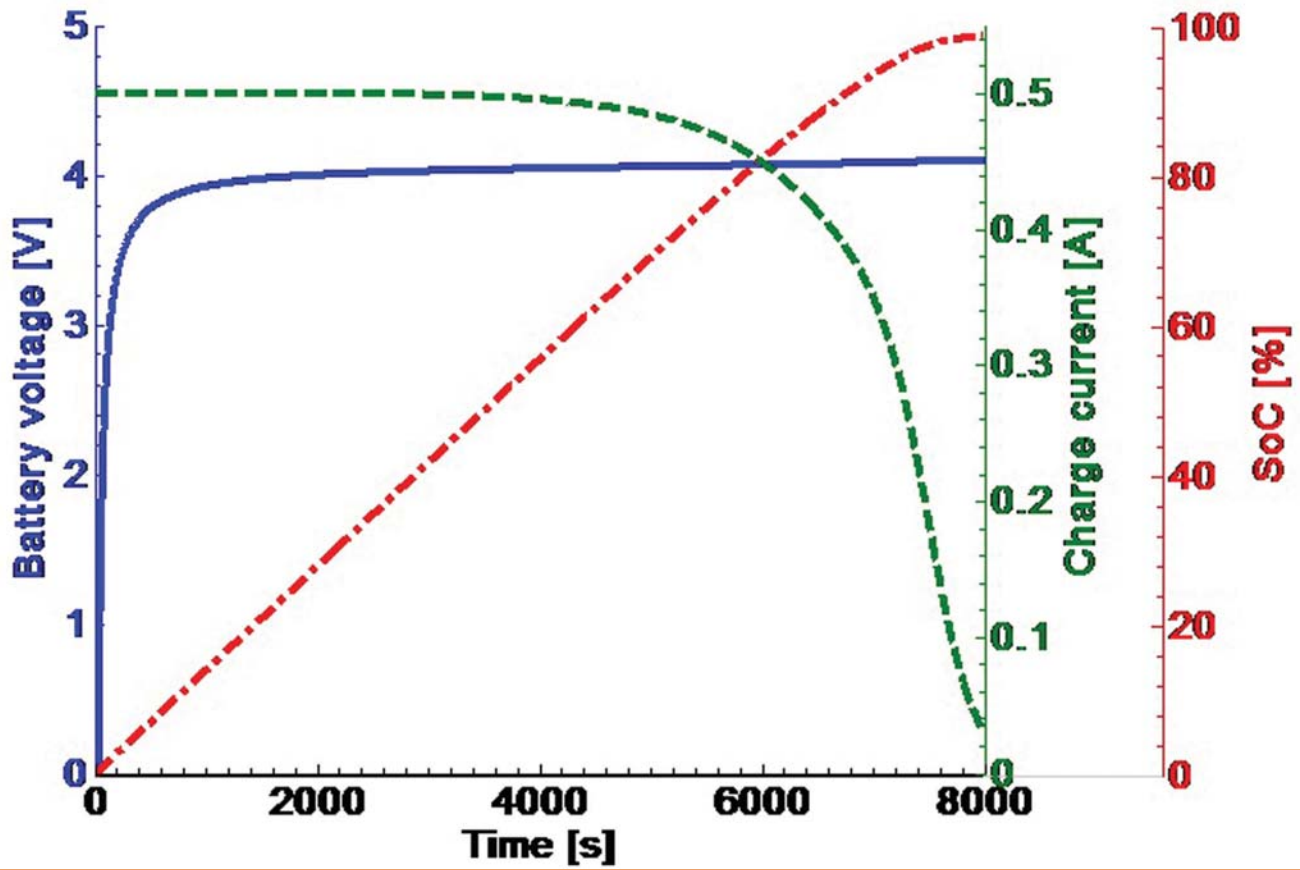

Figure 1: Hyperbolic tangent charge curve. Blue solid line indicates battery voltage rise over charge time. Green dashed line indicates charge current decay over charge time. Red dash-dotted line indicated rise of the battery State of Charge (SoC). Note that the charge current decays in a hyperbolic tangent manner as soon as the battery voltages is close to the final charge voltage.

For almost all PD patients the first method of treatment is by medication that increases the dopamine levels in the brain. Unfortunately these medications are slightly toxic to the remaining neurons in the substantia nigra. Further degeneration cannot be prevented so over time also the medication is no longer effective in relieving the symptoms

More radical treatments, like brain surgery, have been developed to improve the quality of life for severe PD patients. During these surgeries the surgeon is tinkering whit the wiring inside the brain to restore the balance between different areas. By damaging certain targets in the brain the motor feedback loop can be restored and the symptoms can be relieved.

Just as a poorly trained bomb technician, surgeons are terrified of clipping the wrong wire causing the patient to lose control off his limbs. Therefore electrical stimulation is often used today instead of just cutting away brain tissue. The big advantage of this is that the stimulation strength and pattern can be optimized for each patient and adapted over the course of the disease.

The drawback of electrical stimulation is that patients have to carry a pulse generator that can be implanted inside the body. Such implantable pulse generators (IPG) do exist today, but they are quite cruel and bulky devices. This is the point where it becomes interesting for electrical engineers like myself. A lot of work needs to be done to make today's devices last longer and make the installation and calibration easy and fast. The future IPG needs to be much smaller, smarter and more energy efficient in order to accomplish this.

Numerous engineers of the ELCA Group at the 18th floor are working improving the IPG. Smart circuits are being developed

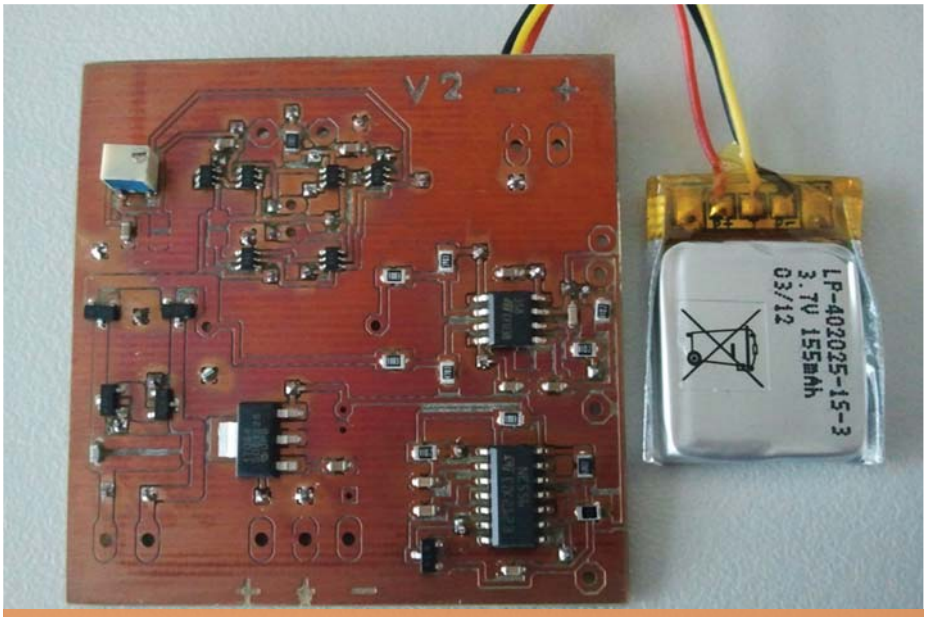

Figure 2: picture of prototype circuit and test battery.

that can detect when and how the brains need to be stimulated while at the same time more versatile and energy efficient output stages are under construction. Personally I had the privilege of doing my master research within the stimulating environment that ELCA is providing and contributing to the IPG of the future.

After a couple of months doing some background research and finishing other courses, I decided to focus on the battery that is powering the IPG and the circuits around it. Although the battery is consuming about half the volume of the IPGs currently available the focus has been on reducing power consumption of the stimulator instead of trying to reduce the battery volume in other manners. Due to my experience with batteries this would be an excellent topic to show my supervisor what I'm worth.

A quick comparison on the backside of a coaster will show you that non-rechargeable batteries, that are mostly used today, still can store more energy per volume than rechargeable batteries. However, rechargeable batteries can be recharged hundreds of times while non-rechargeable need to be disposed once the energy is drained.

Due to the rapid development of rechargeable batteries, the total amount of delivered energy of a non-rechargeable battery is equal to about five cycles of a rechargeable type with the same size. In other words, if we use a rechargeable battery that can be recharged daily or weekly for hundreds of times, we do not need such a big battery to power our IPG. The challenge now becomes to recharge the battery while it is inside the human body. Therefore I decided that this needed to be the focus of my graduation project.

Since we do not like the image of Matrix-like connections to your skull, wireless energy transfer would be the best option for our battery charger. Luckily, wireless energy transfer has also become a hot topic in automotive and consumer electronics so that I could use the techniques for inductive coupling that are already developed for my design. The problem now reduced to getting the energy from the inductive link to the battery in a way that is simple, guarantees battery safety and can be integrated with other parts of the IPG.

Before switching on the soldering iron I needed to decide which charge protocol I was going to use. After some simulations

it was clear that the classic Constant Current Constant Voltage (CCCV) was an easy and battery friendly protocol. To make the implementation even simpler this protocol was modified to follow a hyperbolic tangent charge curve [3]. By doing this, the control circuit requires only one differential amplifier to control the charge current instead of a current source, a voltage source and a control circuit that switches between these sources. Figure 1 shows the battery voltage, charge current and state of charge for this hyperbolic tangent protocol over a complete charge cycle.

To further improve the system efficiency, the charge curve has been implemented in a switched mode fashion. It is assumed that, as long as the switching frequency is high, this has no influence on the battery life. With the design now complete and the simulations showing promising results it is finally time to power op the soldering iron and put the circuit to the test.

After some troubleshooting the prototype circuit came to life and the result is shown in Figure 2. A small lithium battery can be charged wirelessly with this circuit with a descent efficiency of 87.4%. When this circuit is now combined with the efforts of other hard working engineers we can relief the motorsymptoms of your grandpa so he can still raise his glass with pride, for example, at another beautiful reception of the ETV.

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[1] M. Bear, B. Connors, and M. Paradiso, *Neuroscience, Exploring the Brain.* Lippincott Williams & Wilkins, 2007.

[2] S. Patel, C. Mancinelli, R. Hughes, A. Dalton, L. Shih, and P. Bonato, "*Optimizing deep brain stimulation settings using wearable sensing technology,*" *Neural Engineering*, 2009. NER '09. 4th International IEEE/EMBS Conference on, pp. 6 - 9, May 2009.

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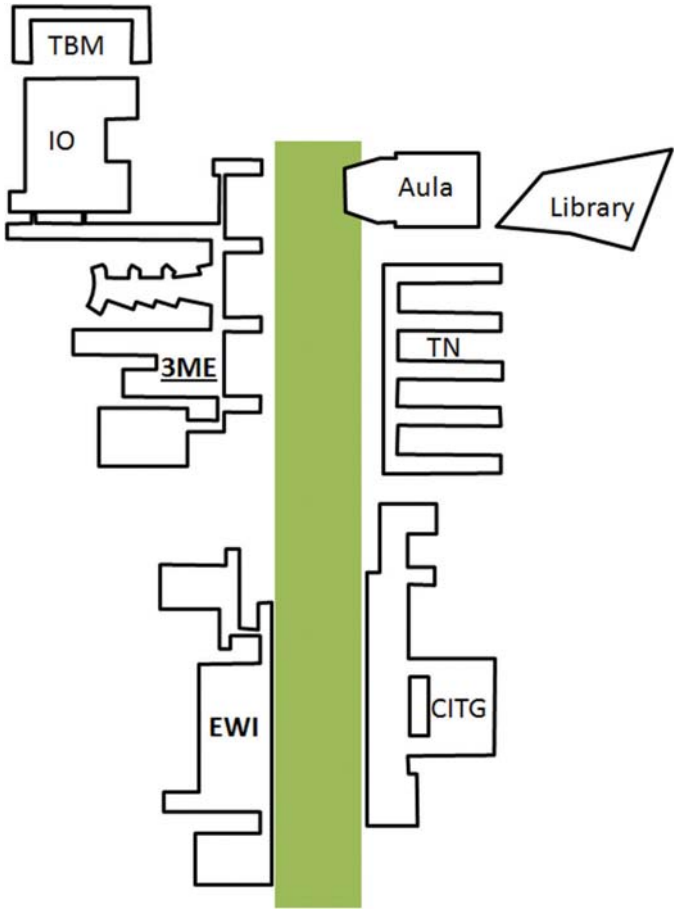
Exploring the research groups
Biomechanical Engineering

Author: Ester Stienstra

This edition we go to the faculty 3ME once again. We visit Prof. J Dankelman, who is the head of the department, as well as the head of the section medical instruments. In the Biomechanical Engineering(BmechE) department one of the main research themes is the interaction between humans and a mechanical system. The department consists of four groups being: Biomechatronics &biorobotics, Vision based robotics, Medical instruments, and Biomaterials technology. The common denominator of the research that is done in this department is the interaction of mechanical parts or systems with humans. This can be interaction on the level of biology, focusing on interaction with tissues or bones. But can also be on a behavioral level, where systems are developed to train someone, or to help people to perform better when doing everyday tasks. In this broad field it is always important to have knowledge from both sides of the story - the human and the machine - to be able to make the interaction meaningful.



Biomechatronics & biorobotics

In this section research is done on controlling the musculoskeletal system. Also interaction with the environment is important. In order to be able to make systems that are useful for humans knowledge of both the human system and the mechanical system is necessary. Apart from applications that are directly attached to your body also other applications are thought of. For instance a gas pedal or a steering wheel in a car that reacts differently depending on the environment. In this way you have to step harder on the gas if you want to accelerate when you are closely behind another car. But also robots for the fruits and vegetables industry are developed, here a human only serves as inspiration to look at for solving problems.

One of the project that the section is currently working on is a training system for patients with a muscle disease. First research needs to be done on how muscles, reflexes and the nervous system are influenced by diseases as Parkinson's or a stroke. The question here is how to see what has changed and how to know what a patient can and cannot do. Also the system should be able to change the task that is given to the patient while s/he is training. In this way the system will be able to make individual training possible, based on the needs and possibilities of someone.

Vision based robotics

The challenge in vision based robotics is to get as much information out of images as possible. Main questions are how to retrieve 3d information out of 2d images and how to identify objects. Most of the learning process is done by letting the robots learn themselves. This is done by presenting the same object multiple times in such a way that the robot will recognize the object. One application that is thought about is a personal assistant robot for elderly people. The population is aging and people are stay in their own homes longer. Such a robot should be able to identify products in the refrigerator, but also it should understand the difference between laying down and falling. Another big issue is the privacy of the person the robot is working with. The question that needs to be thought about is what to do with the images and when the safety of the person is more important than the privacy.

Medical instruments

One of the main fields of interest here is minimal invasive interventions. Research is done to improve instruments for keyhole surgery and needle and catheter interventions. One of the goals is to fit more functionality into the same instrument, for instance to make an instrument that can measure the forces that are present when interacting with tissue. But also optical fibers, for more visual support, or an extra joint for better control are options that are currently looked at. Besides better instruments, surgeons also need the training that is necessary to be able to use those tools. This training is done via virtual interfaces. But to be able to build such a training system developers have to figure out what a surgeon exactly does and feels during the procedure, while working with those new instruments. An example here is the epidural, in this procedure the needle goes through various layers of tissue, which all feel different. Besides knowing how it feels like if the needle goes through these layers, you also need to know how to feel if it is going in the right direction.

The group cooperates with a lot of medical institutes. Besides having conversations

Fig.1 : Steerable needle

Fig.2 : A surgeon practicing a knee operation

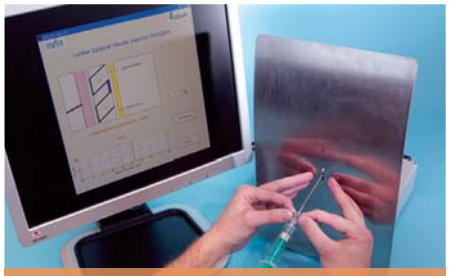


Fig.3 : Simulated epidural

with medical staff about their needs, researchers also observe procedures in the OR. One of the things that the researchers noticed is that there was no efficient planning around an operation. Following this observation a project called DORA was started. DORA stands for Digital Operating Room Assistant. During the project a system was developed that tracks all the instruments. Before the operation starts the system checks if everything is ready to be used, if this is not the case the system gives a warning, via the interface on an iPad using a color coding. If the system says something is wrong, the surgeon is not allowed to start. During the procedure the systems tracks which instruments are used, by knowing that it can figure out at which phase in the procedure the doctors are. In this way the system keeps track of the progress and is able to plan the next operation in a more effective way. At this moment the system with color codes is tested at the Reinier de Graaf Gasthuis, the hospital in Delft. The planning system is used in the specialized eye hospital in Rotterdam, to improve waiting times for patients.

Biomaterials technology

In this group research is done on materials that are used inside the human body. The question here is how you can change implants in such a way that the body reacts better on the materials. Through coatings or changes in the surface new properties are given to objects. Possibilities that are looked at are antibacterial coatings, dissolvability and porous surfaces. For antibacterial coatings the question is how a very thin coating can prevent bacteria

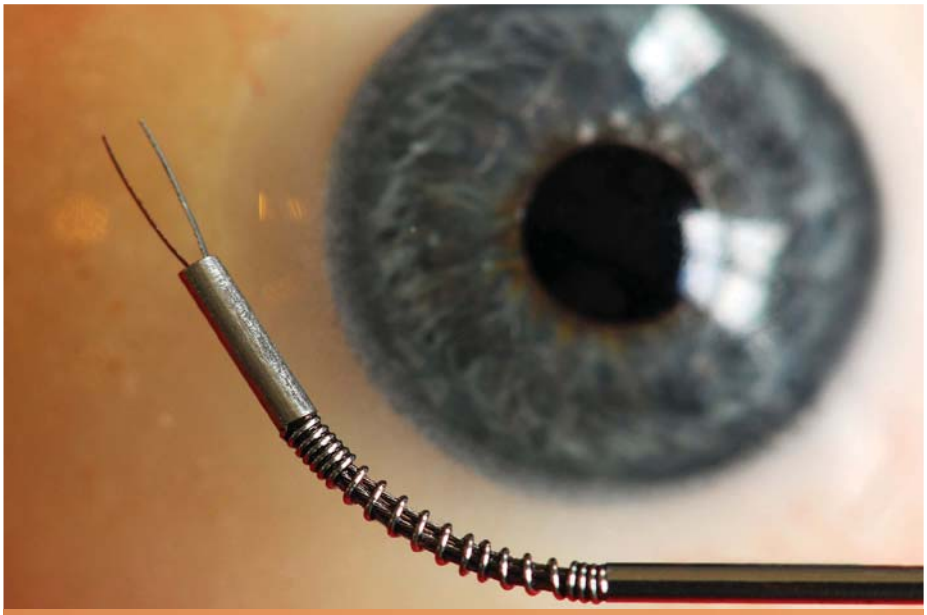


Fig.4 : flexible eye prosthesis

from attaching to the implant. When an implant would be more porous on the surface, it will be easier for a bone to form a good bond with the implant. This better bond will improve the quality of the implant for the patient. For permanent implants dissolvability is of course not a good property. This property can be useful though, for instance for stents that are inserted in blood vessels. Such a stent is used to re-open a vessel. When the vessel is opened again the stent is not necessary anymore. A lot of issues have to be solved before this property can be used. A question is how fast the process of dissolving will be, it should not be too fast, because then the stent has not done his job yet. You also have to be sure that there will be no big chucks coming of the stent and also no toxic chemicals, before you can put it into patients.

Fig.5 : Robot arm holding a tomato

Modelling neural networks
Searching the answer to Newell's question

Author: Wouter Kruijne, PhD-student of Martijn Meeter, Department of Cognitive Psyhology, Vrije Universiteit

In a 1991 lecture, Allen Newell stated that his 40-year scientific career in human cognition research had been driven by one particular question: *"The question for me is: 'how can the human mind occur in the physical universe?' We now know that the world is governed by physics. We now understand the way biology nestles comfortably within that. The issue is: how will the mind do that as well?."*

Newell's question is monumental, because it highlights an issue that is still prominent in brain research at present: the mapping from our physical brain to cognition is utterly unclear, which has resulted in a large gap between those studying the physical properties of the brain (neuroscientists) on one side, and those primarily concerned with the resulting cognition and behaviour (cognitive scientists) on the other. The answer to Newell's 'grand question' would lie in actually bridging this gap. However, as with any gap that needs to be bridged, there is no progress as long as both sides are too far apart.

Connecting the two views: neuroscience vs. cognitive science

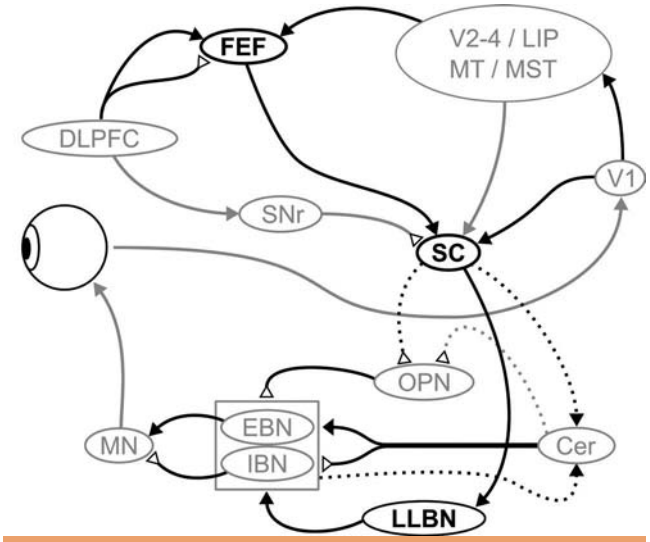
Neuroscientists describe the parts of the brain, where they are and what they do exactly during a task. Skeptics, a small but vocal community of mostly philosophers, pose that this doesn't bring us any closer to the answer to Newell's question: *"It belongs to understanding how the engine in your auto works that the functioning of its carburetor is to aerate the petrol; that's part of the story about how the engine's parts contribute to its running right. But why (...) does it matter where in the engine the carburetor is?"* (- Jerry Fodor, 1999)

Cognitive Scientists on the other hand, focus on the mind: they describe behaviour and propose theories of how processes and representations in the mind that cause us to do one thing or another. A problem is, however, that 'processes' and 'representations' are not clearly defined. A common pattern in the field is that two competing or contradicting theories exist, yet lack detail to sufficiently be proven or falsified. Debates on opposing theories tend to last for years to decades, as results from experiments are open to different interpretations and seem to spawn a new 'flavour' of each theory rather than supporting or rejecting it.

Connecting the two views

Computational neural modelling offers an approach to bridge the gap between these two. A neural model is generally a computer simulation in which a network of artificial neurons interact to produce a certain behaviour. Using data from neuroscience, we can constrain the behaviour of the nodes, the connections, and the large-scale architecture of the network (see for an example figure 1). From the eye to the back of the head, all the way trough the brain back to the eye muscles. Labelled boxes reflect separate brain structures, and their organization and connectivity is in agreement with how these areas are connected in the brain. The components themselves are internally composed of numerous model neurons. When we now want our model to produce behaviour as humans do, the model is faced with the same problems as our brain.

Such models have major benefits over cognitive theories: they are more detailed and less prone to subjective



Architecture of a model of the eye movement system. Each component reflets a brain structure, and the connections are in accordance with the brain. Each component is composed from numerous model neurons.

interpretation, they give insight into how the brains physical organization limits its possibilities, and they allow to make quantitative, detailed predictions of outcomes of future experiments. Indeed, models exist in which particular neurons or connections had to be 'invented', and years later these inventions were found in the brain as well.

This is the reason why I like neural modelling.

Modelling saccades

In my first project as a PhD-student, we constructed a neural model of the brain mechanisms that direct saccades (rapid eye movements that shift what you are looking at 3-5 times per second). To me, this project is a proof-of-concept of the above line of reasoning.

When you make a saccade to a target, say a particular tool in a lab, your eyes don't always go in a straight line to that target: they tend to curve whenever another interesting object, the distractor, is present at the same time. Interestingly, this curvature is usually away from the distractor, as if your eyes want to curve around it. When this phenomenon was discovered, the swift interpretation from cognitive scientists was that the distractor representation in the brain was inhibited strongly, and that this affected the motor plan of the saccade trajectory. It was as if the eye movement was an immediate reflection of the brain process (figure 2).

A decade of eye movement research yielded findings that supported this idea from a cognitive science perspective, but there was little neuroscientific evidence for it. In brains, there was no trace that (a) the presumed representations of trajectories exist, and that (b) any brain structure could actually apply such localized inhibition. When our computational model was constructed, we saw that the need for both could be banished by introducing one simple well-known finding from neurophysiology: neurons get tired after firing for a while.

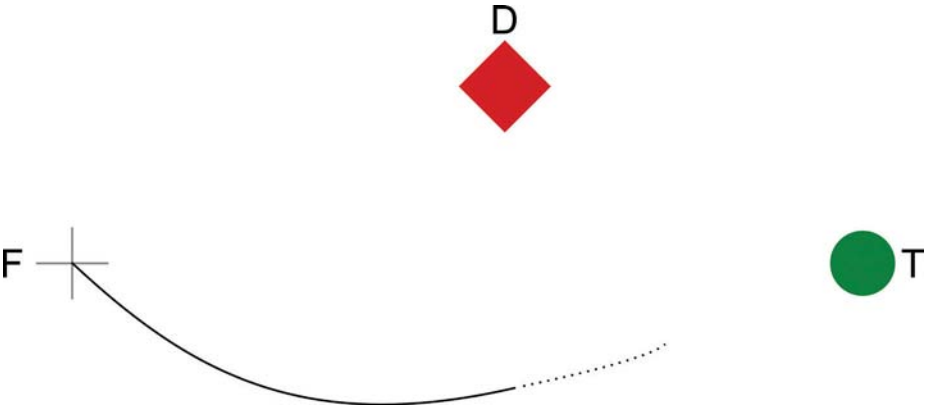


Figure 2: A saccade from fixation (F) to a green target (T) curves around a simultaneously presented distractor (D). It looks as if the 'distractor 'pushes' the saccade trajectory away.

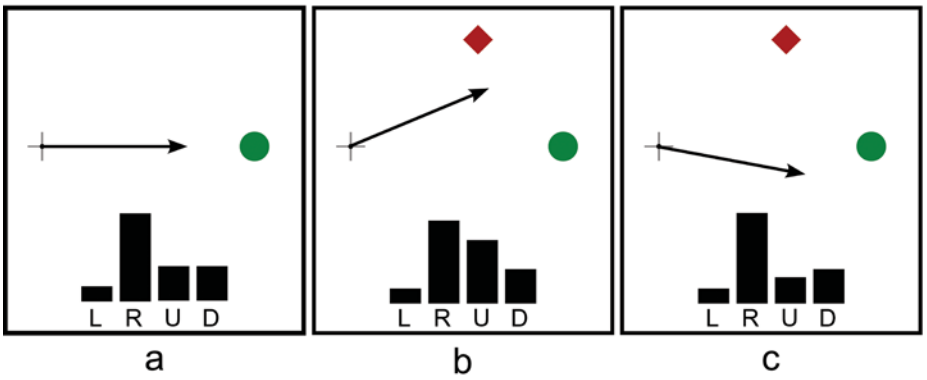


Figure 3: Our neuronal tiredness model. (a) Without a distractor, neurons to direct the eye (up, down,left, and right) fire to produce a saccade to the target (b) When a distractor is presented, it will initially activate the 'upwards' neurons before the saccade is triggerd. As a result (c), these neurons are tired once the saccade is triggered, resulting in deviation away.

Experiment reproduction and conclusions

We adapted our model so that activity evoked by the distractor actually causes neurons that encode movement in that direction to grow tired. As a result, saccades are pulled in the other direction, coded for by neurons that are not tired. From the outside, this results in saccades deviating away from the distractor (Fig 2) Then, we showed how findings that seemed to support an 'inhibition' theory, would fit in this scheme, by making our model reproduce the effects. Finally, we correctly predicted eye movement trajectories under an experimental condition that had never been tested before.

In the recent years, a wealth of new neuroscience techniques have been developed, which has resulted in new data that begs to be embedded in theories. Using neural models, we can ground theories from cognitive science in these neuroscientific data. Only then will we get closer to the answer to Newell's grand question: How can the human mind occur in the physical universe?

Organ-on-a-Chip
Interfacing with living tissue

Author: prof. dr. ir. Ronald Dekker

"A what on a chip?" is what most people ask with disbelief when they hear for the first time of the new and very exciting research area "Organ on a Chip." The topic has nothing to do with Science Fiction, but everything with a very surprising encounter between two completely different research fields: Micro-fabrication and Stem-Cell Biology! The final goal is to build simplified, but very well controlled models of human organs and diseases.

One of the principles of science is to translate a complex problem into a simple model. Once the simple model is fully understood, more complexity can be added. If you want to study the formation of rain for example, you can take a beaker and carefully control the: temperature, humidity, pressure and particle density. It is here that medical sciences so far have had a problem: the human body is an extremely complex system, with many factors interacting of some which are even not known. It is simply not possible to take for instance a lung out of a person to study what is going on in detail. Organ-on-a-Chip is a new research field which has the ambition to generate breakthrough solutions for exactly this problem.

Lung-on-a-chip

A beautiful example is the work done at the Wyss Institute in Harvard. They have developed a micro device consisting of a 10 μm thin membrane with micron-sized holes which has on one side lung epithelium, and on the other side blood vessel endothelium. The lung epithelium is exposed to air, while the blood vessel endothelium is exposed to a blood like medium. In this way only two cell types are involved while the membrane, as well as the air and the blood like medium, are exactly defined and controlled. Using the model they have traced bacteria entering the blood, and the resulting immune response to the bacterial infection, and studied the effect of ultra-fine dust particles on the lungs.

Fig. 1: Saeed Pakazad developed the Cytostretch device as part of his PhD project. Here he is plating cells on the device.

A breakthrough which has made Organ-on-a-Chip a reality, is the development of the Induced Pluripotent Stem-Cell (IPS) technology which received the Nobel Prize last year. So far, the source for human cells has always been a problem: highly specialized cells like heart muscle cells and neurons have lost the ability to divide, and thus in principle, cannot be cultured. However, with IPS technology it is possible to take a skin sample of an individual, reprogram the skin cells it into stem-cells, which can then be differentiated into one of the specialized cell types of the body. Since stem cells can be kept in culture indefinitely, this opens a route to an endless supply of cells with - very important - a specific genotype.

Heart-on-a-chip

In DIMES we have been working already for a number of years on an Organ-on-a-Chip model for the human heart, which can actually mimic the human heart during exercise. The primary goal of the model is to screen new drugs at a very early stage of their development for possible side-effects which can cause

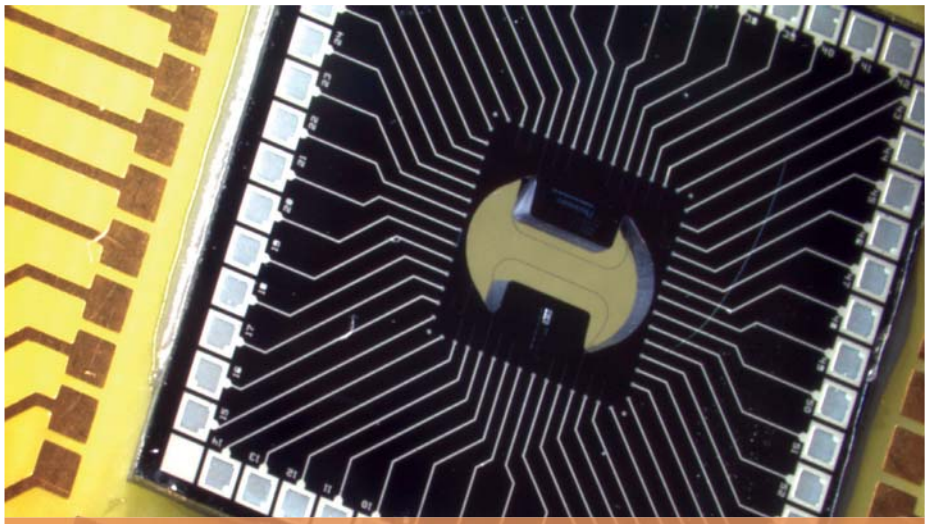


Fig.2: The Cytostretch device is used to measure the electrical activity of cells under stretch. It consist of an array of stretchable electrodes embedded in a silicone membrane.

Fig. 3: Heart muscle cells align to micron-sized grooves in the Cytostretch device

lethal arrhythmias. In the model a piece of human heart muscle tissue is grown on a thin stretchable membrane containing electrodes. The electrodes register the electrical activity of the cells while they are subjected to the drug compound. By stretching the membrane it is possible to simulate physical exercise which is an important factor in the occurrence of these arrhythmias. The project is done in close cooperation with the group of prof. Christine Mummery at the LUMC in Leiden which has a world renowned expertise in the differentiation of human stem cells into heart muscle cells.

The technology platform we developed – coined Cytostretch – has the unique property that it allows for electrical characterization of cells while they are mechanically stretched. It is the intention to use the Cytostretch platform also as a model for cardiac diseases like: heart failure, hypertrophic cardiomyopathy, and congenital cardiac arrhythmias. Also other diseases involving electrically active cells such as: muscular dystrophies, brain diseases, peripheral nerve cell diseases, and pain syndromes, can be studied with the Cytostretch platform.

Dutch Science Agenda

In 2011 the Royal Academy of Science in Holland (KNAW) formulated the Dutch Science Agenda: 49 research topics in different fields of science in which Holland could play an important role. Topic 32 was "Can we imitate organs on a chip?" The challenge was taken up by Dr. Anja van de Stolpe and prof. Jaap den Toonder. Together with a number of other Dutch top-scientists they received a KNAW grant to position Organ-on-a-Chip on the Dutch Research Roadmap. Their conclusion was that the concentration of unique expertise in micro-fluidics, stem cell technology, micro fabrication and biology, in a relatively small country as Holland puts us in an ideal position to become a key player in this field. In the mean time an extensive Dutch consortium has been formed, with collaboration in micro-fabrication and micro-fluidics between Philips Research/ TU Delft, Twente University, and TU Eindhoven, coupled to top biomedical/ clinical groups (LUMC, Erasmus, Utrecht, Amsterdam, Nijmegen).

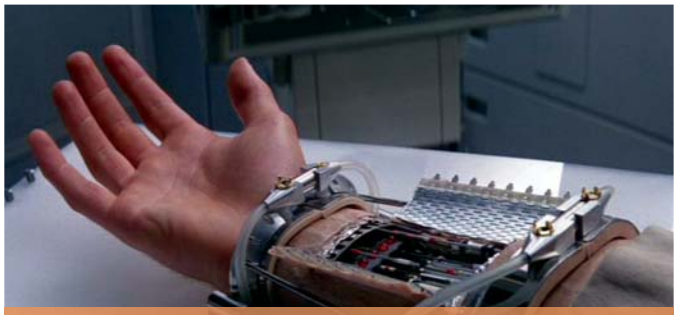
Although this is an emerging research field, it is clear that Organ-on-a-Chip will revolutionize the development of new (personalized) medicines, the understanding of organs and diseases, and the development of new therapies. Last but not least, Organ-on-a-Chip will greatly reduce the need for animal testing.

Want to see the Heart-on-a-chip in action? Scan the QR-code. Or go to: www.dos4ever.com/Maxwell/Maxwell.html

Biomechanics and electronics
Can change the lives of many

Creating fine motor skills in prosthetic fingers is challenging.

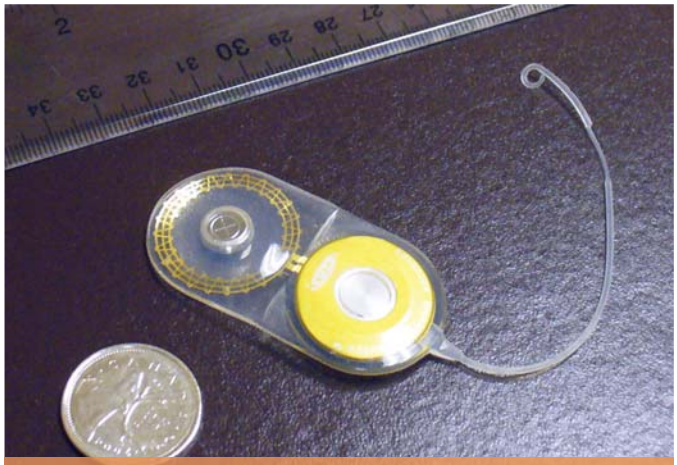
Vein scans can help when placing an IV.



Will we someday be able to make prosthetics as the ones in Star Wars?

There are serveral different prosthetic feet, some for walking...

some for running.



Cochlear implants can make the hearing impaired hear.

New advancements in bio electronics like this one can give an outcome for the blind.

Bio mechanics can change the tide on the battlefield with exoskeletons for infantry soldiers.

One of the first bio electronic devices, but a real lifesaver. The pacemaker.

Alliander zoekt naar innovatieve oplossingen om onze samenleving duurzamer en energiezuiniger te maken. Als jij je met 7.000 collega's wilt inzetten voor betrouwbare energiedistributie aan 3,3 miljoen klanten, krijg jij bij ons de ruimte om te groeien.

technisch trainees m/v

Nieuwe ideeën leiden tot nieuwe toepassingen in de bouw. Een voorbeeld van zo'n duurzame innovatie is de warmtepomp, waarbij omgevingswarmte wordt gebruikt om huizen te verwarmen. Zeer efficiënt, maar niet zonder uitdagingen. Je hebt geen gasnet meer nodig, maar belast het elektriciteitsnet zwaarder. Als trainee werk je mee aan dit soort duurzaamheids-vraagstukken.

Ben jij een ambitieuze starter met een achtergrond in bijvoorbeeld Elektrotechniek of Energietechniek? Dan investeren wij graag in jouw ontwikkeling met een technisch traineeship, toegesneden op jouw professionele en persoonlijke groei. Goed vooruitzicht? Ontdek onze traineeships op **alliander.com/trainee**. Of neem contact op via **starter@alliander.com**.

alliander iedereen energie

Column

It is Thursday evening, 8pm. I am writing this column sitting on the couch at home. Home these days happens to be in Gouda of all places. I'm a bit tired since I had to finish designing a chip for my PhD project before the deadline of the tape-out. My wife is sitting next to me, working.

On the same day of the week, same time, but then 5 years back, there is a 90% chance I would be in the E-kaffee, drinking one or two beers too much and for sure blaming the board that they didn't went out yet to get pizza for us.

How things change!

Anno 2013 the board doesn't need to go out anymore to get pizza: instead they can comfortably avoid any unnecessary social interactions and order pizza on justeat.nl.

And ok, I have to admit it: I also changed quite a bit… If you would have told the 5 year younger and 25 kilo heavier version of me that it was time to go home, for sure a "Don't be so 'burgerlijk'", followed by a loud "Goedemorgen!" would have been your answer, after which I would claim a seat in the car to join a party at a random social science association in Utrecht. Those times are long gone.

So, I certainly must feel sorry and bad about myself now, right? But the truth is: I don't care at all! The most remarkable is: back then and right now I am a perfectly happy man. Thinking about it, it is just amazing how fast things change and how easily one adapts to it.

Starting my PhD suddenly put me on the other side of the table: instead of attending classes and studying for exams, it is now me who is making students bored with circuit theory classes and stressing them with exams. In just a few months I went from complaining about difficult exams to complaining about failing students who don't study enough. But some things luckily stayed: I could keep myself busy with what I like most: electrical engineering!

For my PhD project I have the honor of building technology that does make a difference. Together with doctors we are on the way to cure Parkinson, Depression, Tinnitus, deafness and blindness (for those interested: it's called Neural Stimulation). And every day I cycle home I know we came one step closer to reaching our goal. I guess having the feeling that I am doing something that is useful for the society, is what makes me happy in the end.

And despite of what the government seems to be thinking these days, contributing to the ETV is just another example of that. The electrical engineering society is massively benefiting from all the activities the ETV is deploying. And being part of that by joining the board, organizing a Study Tour to North and South America or by making a yearbook: it has all been an incredibly rewarding experience.

It is tempting to think now about how different my life will be 5 years from now. I only hope that I can still say then that I have the feeling I am doing something useful for the society. But obviously I learned that anything can happen. Nothing stops me from becoming a Wall Street Broker trading in complicated derivative schemes and making millions per year[1]. One can only hope that such a thing will never happen….

[1] *www.zeitgeistmovingforward.com*

Marijn van Dongen, M.Sc.

Stageverslag
Minor in Japan

Auteur: Aimee Ferouge

Konichiwa ETV'ers,

Na drie jaar vakken volgen, lijnvolgende robots programmeren en de Drebbelweg onveilig maken met kleine terreinwagens, werd het tijd voor een minor. Een half jaar vrij te besteden aan een studie op een vakgebied naar keuze, op een locatie naar keuze. Deze vrijheden heb ik maximaal benut door een stage-minor te doen op het gebied van Industrial Engineering (afdeling Decision Science and Technology) in Tokyo, Japan.

Een hele tijd heb ik vrij luchtig tegen de hele expeditie aangekeken. Immers, de aanvragen voor de stageplek en de nodige beurzen waren goedgekeurd, de vliegtickets waren geboekt en de huisvesting geregeld. Pas een week voor vertrek, toen mijn kamer in Delft was leeggeruimd voor de onderhuurder en ik mijn afscheidsfeestje had gegeven, kwam het besef: wat wist ik eigenlijk van Japan? Gelukkig had ik op het feestje de nodige Lonely Planets, Japan-for-Dummies en mangastrips gekregen. Deze heb ik dan ook ijverig doorgeworsteld tijdens die 15 uur durende vlucht naar de andere kant van de wereld.

De stageplek

De precieze invulling van mijn stage werd me pas duidelijk na het ontmoetingsgesprek met mijn professor, Prof. Itoh. Hij was de afdelingsleider van Decision Science and Technology en bovendien groot fan van Europa (vooral Denemarken, waar hij twee jaar heeft gewoond). Hij vond het bovenal belangrijk dat ik een leuke tijd had in Japan en dat uitte zich onder andere in het feit dat ik me bij één van de vele projecten mocht aansluiten, afhankelijk van welke mij het meest interessant leek.

Dagje toeschouwer geweest bij een sumotoernooi

Uiteindelijk heb ik vijf maanden meegedraaid in een team van PhD studenten die onderzoek deden naar de managementsystemen van Japanse ziekenhuizen. Onder dit management vallen alle niet-medische aspecten zoals financiën, veiligheid, klanttevredenheid etc. In vergelijking met commerciële bedrijven, die erg zijn gebaat bij goed management, is die van ziekenhuizen (die non-profit zijn) niet erg professioneel en soms ontoereikend. Bovendien beschouwen ziekenhuizen elkaar vaak als concurrentie met een eigen visie en aanpakstrategie. Dit zorgt ervoor dat elk individueel ziekenhuis een eigen administratieve huishouding heeft en het dus lastig is om ziekenhuizen met elkaar te vergelijken (benchmarking). In mijn project heb ik me bezig gehouden met het ontwikkelen van een universeel managementsysteem, die door alle Japanse ziekenhuizen kan worden. Op deze manier kunnen hun prestaties worden geanalyseerd door researchers aan Tokyo Tech, krijgen de ziekenhuizen professionele feedback en worden ze vergeleken met andere ziekenhuizen. Zwakheden en kwaliteiten komen op deze manier sneller aan het licht.

Mijn taak was vooral gericht op het ontwerpen van de interface van het programma. Hiervoor heb ik een studie gedaan naar 'Usability Engineering', de theorie achter het ontwerpen van een product gericht op gebruiksvriendelijkheid. In mijn geval bijvoorbeeld had ik te maken met twee heel verschillende doelgroepen: enerzijds de administratieve medewerkers van de ziekenhuizen, die op een laagdrempelig niveau allerlei data moeten kunnen uploaden. Anderzijds waren er de researchers van Tokyo Tech, die een geavanceerd programma nodig hadden om allerlei analyses los te kunnen laten op de binnengekomen data.

Het resultaat van mijn periode binnen het team heeft geleid tot een eerste software prototype van mijn programma, de Amy-1 (vanwege de uitspraak van mijn naam). Ook heb ik een prototype gemaakt voor een digitale klanttevredenheidsenquete ter vervanging van de traditionele papieren enquetes die vaak linea recta in de prullenbak verdwijnen. De digitale enquete gaat per iPad en kan door patiënten in bed worden beantwoord.

Social life

Via het International Office in Tokyo kreeg ik een kamer toegewezen in de Komaba Dorm, op 5 minuten afstand van het populaire district Shibuya (bekend van het kruispunt). Met de andere internationale studenten ben ik menig avond in de vele izakaya's (Japanse tapasbars met hapjes en een all-you-can-drink beleid) of karaokebars beland. Via de Facebook group werden verschillende uitjes naar vuurwerkfestivals, expositie's of weekendtripjes geïnitieerd waar je je bij aan kon sluiten. Zo zijn we bijvoorbeeld met 20 man naar Dark Knight Rises geweest toen die in september eindelijk uitkwam, heb ik 10 matsuri's (vuurwerkfestivals) bijgewoond met shows die best 2 uur kunnen duren en heb ik veel barretjes en wijken leren kennen door mensen die al een tijdje in Tokyo zaten.

Naast het feit dat ik heel veel ben omgegaan met mijn dorm mates (en dus niet-Japanners) ben ik ook goede maatjes geworden met één van mijn labgenootjes. Met hem ben ik ook vaak op pad geweest, met als hoogtepunt het beklimmen van Mount Fuji (3776 meter). Daarnaast ben ik met het lab gaan BBQ'en en had ik een afscheidsfeestje in december, waar ik met hen en Prof. Itoh naar een karaokebar ben geweest. Anime zingen met 20 dronken Japanners was een hilarische en bizarre ervaring die ik niet snel meer zal vergeten.

Reizen

Mede dankzij de gastvrije houding van Prof. Itoh heb ik veel mogelijkheden gehad om te reizen. Met mijn moeder en opa ben ik in oktober twee weken naar het westen gegaan en heb daar Kyoto, Nara en Hiroshima bezocht. Met een vriendinnetje heb ik de hotsprings in Nikko bezocht en met mijn vriend zijn oude huis in Yokohama, waar hij vroeger heeft gewoond. Zoals je ziet, heb ik ondanks de grote afstand veel bezoek mogen ontvangen, wat die vijf maanden voorbij heeft doen vliegen.

Terugkijkend op mijn periode in Japan heb ik een fantastische tijd gehad en ben ik zeker van plan ooit eens terug te gaan. Dit natuurlijk wanneer ik later groot en rijk ben, want voor de arme student is Japan absoluut een rib uit je lijf. Mocht je meer willen weten over Tokyo of Japan dan kun je me altijd mailen op a.a.ferouge@student.tudelft.nl.

Sayonara!


Op de top van Mt. Fuji


In kimono naar een matsuri (vuurwerkfestival)


Kraanvogels bij vredesmonument (Hiroshima)

STeLA

Valerie Goemans

Na mijn bachelor had ik behoefte om te ontdekken hoe er in andere delen van de wereld wordt gedacht en samengewerkt. De interactie met internationale studenten op de TU is leuk, maar vaak ben je toch nog omsloten door een comfortabele Nederlandse bubbel. Om die bubbel te doorbreken reisde ik onder andere af naar Stanford om daar een week met 50 andere wetenschap- en techniekstudenten van over de hele wereld interactieve les te krijgen over leiderschap op een Forum van STeLA: de "Science and Technology Leadership Association".

STeLA is een organisatie die als doel heeft topstudenten vanuit de hele wereld bij elkaar te brengen en hen meer te leren over leiderschap. STeLA doet dit in een jaarlijks 9-daags Forum aan de hand van een thema, zoals natuurrampen (vorig jaar in Tokyo) of overpopulatie en urbanisatie (dit jaar in Delft). In de praktijk houdt het Forum in dat je in een groep met Chinezen, Japanners, Amerikanen en Europeanen workshops krijgt over leiderschapsmodellen, en uitdagende opdrachten gerelateerd aan het thema. Die opdrachten bieden een ideale mogelijkheid om te oefenen wat je hebt geleerd over leiderschap. De laatste drie dagen van het Forum staan in het teken van een groot groepsproject waarbij je echt op de proef wordt gesteld.

Toen ik aan het Forum meedeed in 2011 hoorde ik nog bij de eerste lichting Europeanen (het merendeel Nederlanders) die deelnamen. Bij terugkomst in Nederland besloten de meeste van de Nederlandse deelnemers – waaronder ik – dat we het bestuur van Europa op ons wilden nemen en STeLA ook bekend en groot wilden maken in Europa. In het jaar dat volgde hebben we bezoeken gebracht aan universiteiten in Aken, Zurich en London en contact opgenomen met universiteiten in Parijs. Het resultaat mocht er wezen: in het volgende forum in Tokyo hadden we ook deelnemers uit Parijs, London en Zurich. Inmiddels zit ik alweer in mijn tweede jaar bestuur en is de organisatie in volle gang voor het Forum in Delft, komende augustus. Het is flink wat werk, maar ik ben blij dat ik het mag doen. Alles wat ik heb geleerd en ben begonnen in het Forum– het samenwerken in een internationale setting, het oefenen van leiderschapskwaliteiten, en het opbouwen van een internationaal netwerk - ben ik nu aan het voortzetten in het bestuur. Na augustus komt mijn bestuurstijd bij STeLA toch echt tot zijn einde, maar daarvoor heb ik nog even tijd om ervan te genieten en te helpen met het neerzetten van een geweldig Forum in Delft!

Hylke de Visser

Het STeLA Forum in Tokyo heeft me meer geleerd dan ik had verwacht. In het jaar voor het Forum was ik bezig met een traject waarmee ik meer van mezelf te weten kwam. Dit leidde me onder andere naar de STeLA Europe events. Toen ik bij de reflectie van een spel op een van de events een eye-opener had over hoe je denkt als je er niet bewust mee bezig was, was ik geboeid. Ik wilde er meer van weten, leren hoe je het toe kan passen in teamverband, en ik meldde me aan voor het STeLA Forum in Tokyo.

Iedereen die deelneemt aan het Forum heeft daar zo zijn of haar redenen voor – een set van doelen, om maar zo te zeggen – en je wordt gedurende het hele Forum gestimuleerd om hier actief mee bezig te gaan en je doelen voor ogen te houden. Je werkt in een groepje en door middel van reflecties en feedback help je elkaar te groeien. Zo haal je uit het Forum waar je voor kwam. Natuurlijk faalt dit gaandeweg af en toe keihard en vooral als er een beetje tijdsdruk komt kijken bij de opdrachten merk je al snel dat je al je doelen over boord gooit en niet meer let op wat je hebt geleerd. Dit leren door vallen en opstaan maakt het Forum moeilijker en intensiever, maar persoonlijk vond ik het een prettige manier. Iedereen is daar met hetzelfde bezig en doordat je het met elkaar deelt en elkaar steunt creëert het een stimulerende sfeer.

Met de kennis en ervaring die ik heb opgedaan in Tokyo ben ik veel beter in staat om in een team de rest te helpen om te doen wat ze leuk vinden en waar ze goed in zijn, waardoor er een veel beter resultaat behaald wordt. Het belangrijkste is dat ik heb geleerd dat het uit je comfort zone treden grote frustraties kan opleveren en erg onprettig kan zijn, maar dat de groei die je daardoor kan door maken het de moeite zeker waard maakt.

Het Forum in Delft is van 23 augustus t/m 31 augustus. De deadline voor het aanmelden is 30 april. Heb je nog vragen? Mail recruit-eu@stelaform.org of ga naar stelaforum.org

SCIENCE AND TECHNOLOGY LEADERSHIP ASSOCIATION

ETV parentsday
Inviting our parents into EE

Author: Tobias Roest

Saturday morning, February 16th. I get up quite early for the weekend. Today is the parents day at the ETV. Ten O'clock sharp, my parents pick me up to go to EWI, where coffee and tea awaits us. After this, we were asked to go to lecture hall Ampère, where the day will officially begin.

Derk-Jan Hulsinga, the president of the assosiaion opened the day with a presentation about the role of the ETV in the life of EE students, as well as a short explanation of Delft being a city with a large university. Prof. ir. L. van der Sluis, a honorary member of the ETV, followed with an example lecture to show our parents what their children do every day. As I expected from Van der Sluis, the lecture was fun and at the same time it gave a good example of the study Electrical Engineering. My parents, who have no engineering background whatsoever, were very pleased with such a clear story that was understandable for them.

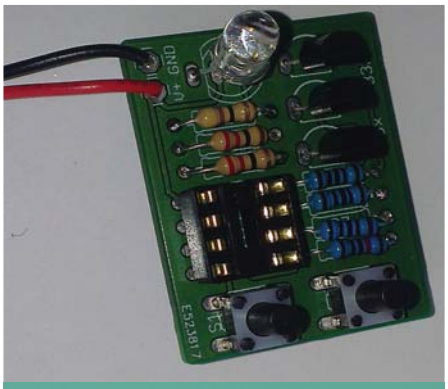
At this time, we were a bit ahead of schedule, which meant that there was more time for the lunch. The bread was on a central table, but the spreads were divided across the tables, which was fun, because there was a lot of interaction between the students and their respective parents.

The opening of the day

Once we were done with the lunch, the rather large group was split up in smaller ones for the rest of the program. The group that me and my parents were in, first went to the faculty CiTG for the practical assignment, which was to assemble a 'mood light kit'. The parents had to calculate some resistor values for an RGB LED, after which they got these resistors. These made the kit complete, and, supervised by their children, the parents soldered the components to a PCB.

The time had arrived for a tour through EWI. In groups of around 6 students and their respective parents, we first went to DIMES, the Delft Institute of Microsystems and Nano-electronics. Here, a short presentation and a tour of the facilities were given. Especially the tour was quite impressive, I did not know EWI had such an amazingly facilitated clean room.

My favorite part of the tour through EWI had arrived. We went downstairs to the 'Studieverzameling'. Hundreds, maybe even thousands of old devices are stored here. Some non-electronic, as typewriters, but most of the devices are indeed electronic. There are dozens of different radio models from some of the earliest, until quite recent ones. Computers are not left out of course. With old Apple computers, laptops weighing 13 kg and even a ZEBRA computer. It's like a museum, and my favorite part of the entire faculty. My parents were quite enthusiastic as well, as there were a lot of devices from their time.


the result of our pratical assignment

After DIMES and the 'Studieverzameling', we went to the High Voltage laboratory. Here we were given an explanation of the research that is done here and the facilities available. It is quite an impressive laboratory, with a really big equipment.

Because we were a bit behind schedule, we had quite a short visit to the rooftop, but my mother did not mind the shortness because she is afraid of heights. After this we went to the /Pub, the faculty pub in the basement. Here we had a beer, after which my parents had to go back for diner. The day was quite long, but very enjoyable, and my parents were quite pleased. Now they finally know what I am up to, here in Delft. It was a great success!

No Return

13/5 - 17/5

Electrip 2013
Een reisje door Europa

Door: Derk-Jan Hulsinga

Op het moment van schrijven slaat het asfalt voor ons de brug terug naar Nederland en sluit ik zelf mijn tweede trip af. Eerste keer als deelnemer, nu ook als organisatie. De Electrip is een bijna jaarlijkse mini-studiereis die een groep van achttien ETV'ers in busjes de route laat testen die de commissie in de afgelopen periode voor hun heeft uitgestippeld.

Het is niets vreemds dat er vroeg opgestaan en laat geslapen word. Er word op bizarre tijden gereden om in een korte tijd op geschikte locaties interessante bedrijven te bezoeken en om mooie steden te zien. Gecombineerd met veel geel goud en zwarte motor olie drijft het programma de leden tot het gaatje te gaan.


De verzameling ouderwetse gehoorapparaten van Oticon word door deelnemers bewonderd

Dit jaar heeft de commissie drie landen laten afvinken, waarbij begonnen werd in ons eigen kikkerlandje. De hoogspanningsverbinding tussen Groningen en Noorwegen zelf was onzichtbaar, maar het voorbereidingsproces minstens zo intrigerend. Installaties van meerdere fahraden en vele henries zoemden op 55 Hz om AC om te zetten naar DC en andersom. Met een vermogen van maarliefst 700 MW werd op deze locatie energie getransporteerd, afhankelijk van waar de stroom goedkoper is.


Een deel van de NordNet opstelling

In Duitsland werden we warm onthaald door een set Duitse studenten die ons met enige twijfel wel een feestje wisten te wijzen. Uiteindelijk waren we totaal in de wolken met twee prachtige bezoeken aan de luchtvaartbedrijven. Bij airbus werden we ontvangen door een oude rot van het vak. Een brit die zijn verhalen net zo goed had kunnen beginnen met anekdotes uit de tweede wereld oorlog waar hij zelf in voorkwam. Het proces, zoals hij vertelde, was op twee manieren intrigerend. Naast een uitgebreide uitleg over welke manier de vliegtuigen vergelijkbaar ontworpen zijn zodat componenten universeel gemaakt kunnen worden, genoot hij zelf nog altijd aanzienlijk van de uitleg hoe de assemblage lijn op zich al een staaltje prachtige techniek was. Bij Lufthansa werden we door een oud werkplaats manager weer met twee voeten op de grond gezet en meegenomen op een rondleiding die door het vliegtuig zelf heen leek te gaan – in zo veel detail werden er onderdelen getoond.

Kopenhagen bracht ons een bezoek aan het onderzoekscentrum van Oticon, wat vanuit de visie van een van de mensen die het bedrijf groot heeft gemaakt totaal lost staand was van de rest van het bedrijf. De locatie Eriksholm was werkelijk slechts een onderzoekscentrum. Gesplitst van alle economische plichten en ontwerp beperkingen waren ze totaal vrij om te onderzoeken wat ze maar willen. Het einde van de dag werd besteed in Kopenhagen en werd gekenmerkt door prachtige gebouwen en enkele gezellige kroegjes welke uiteraard werden bezocht. Als wat minder serieus bezoek is als laatste de eerste Carlsburg brouwerij bezocht. Met een stevige paardenlucht en een combinatie van gerestaureerde oude architectuur en een moderne bar viel en prima te genieten van een dynamisch aanbot van biertjes.

Kortom zijn de vier dagen electrip een mooie ervaring. Elk bezoek word in pak afgelegd, vermoeid of niet geeft de groep hier een goed beeld mee af. Voor mij is het feest nu over maar ik wens alle ooit deelnemers alvast heel veel plezier!

ETV Social Activities

An overview of last quarters' socail events

During the Mexican drink there Coronas, mustaches and lots of sombreros

...and some sleeping Mexicans

The 'Barbies and Brouwvakkers' theme party was a succes

Bowling at the 'Karrenwiel'

Tasting some nice whiskys in the /Pub

Lots of strikes, spares and splits were thrown

Network automation
The digitisation of the energy supply

Author: Alliander

Electronics offer unprecedented opportunities. Network managers long struggled with the question of how electronics could be used in sub-stations to automate their operations. After all, the electromagnetic fields that arise from mid- and high-voltage systems interfere with electronics. That struggle ended when manufacturers like ABB and Siemens discovered that good grounding made it possible to combine electronics and high voltages. This paved the way for new automated functions in the network and laid the foundation for intelligent networks and smart meters.

SASensor: the ingenuity of a simple interface

The introduction of the new Station Automation Sensor (SASensor) in Liander's midvoltage networks has made thousands of control and monitoring cabinets redundant. The communication between operations and the network now goes through a small cabinet that stands out because it contains surprisingly little. In the past, the control and monitoring systems for the mid-voltage network were housed in a large number of cabinets and racks. Now, however, the revolutionary SASensor includes these functions (data storage, quality control and remote fault tracing) in the 'simplest' and smallest possible interface. All the software elements that were once in the interface have been eliminated from the SASensor. All intelligence has been placed in a central computer that is connected with the SASensor via a glass fibre cable.

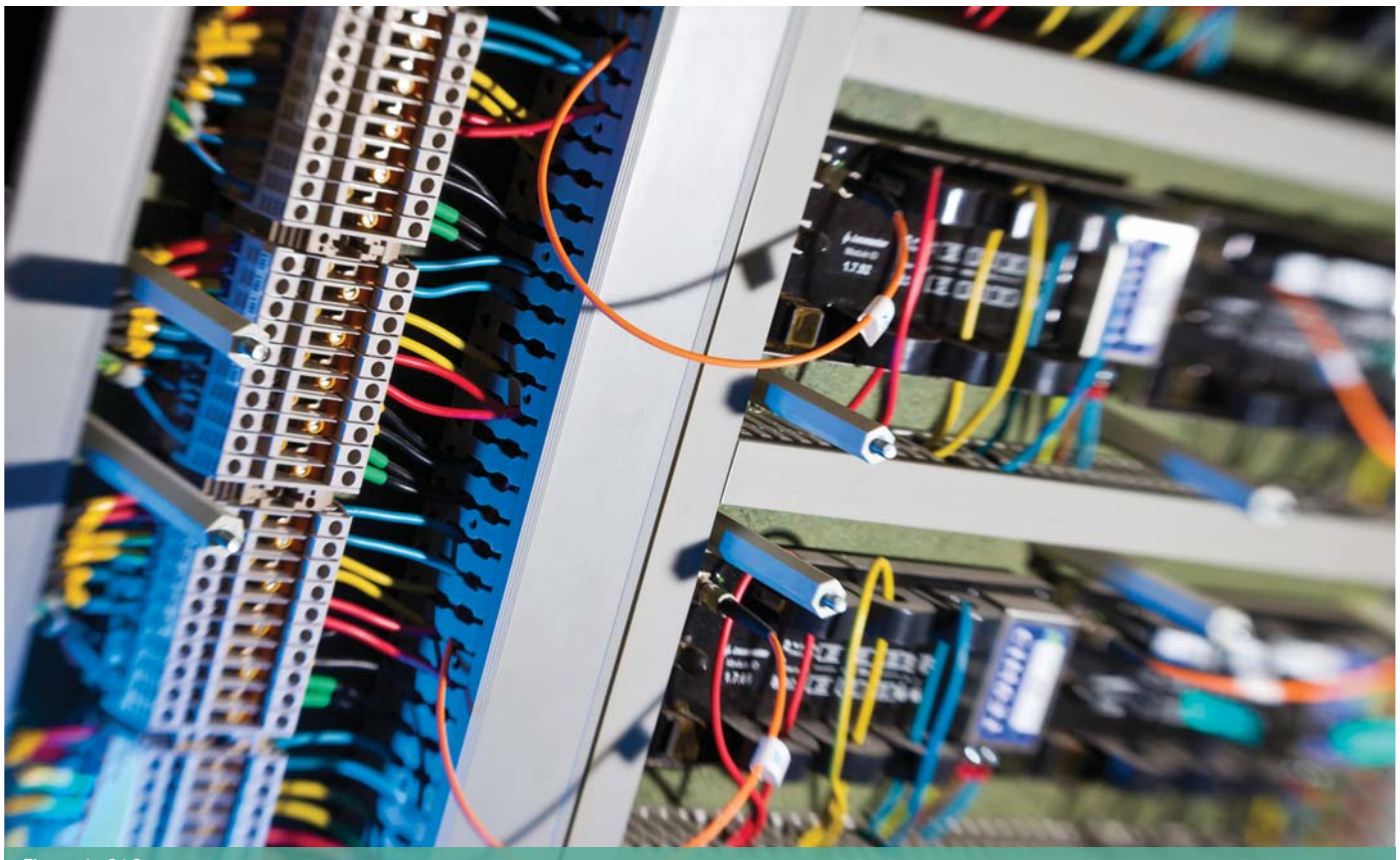


Figure 1: SASensor

Thanks to its simplicity, the sensor itself is relatively insensitive to ageing and should, in principle, have a useful life of about 30 years. The software and the central computer have a much shorter life expectancy, but can be easily replaced. In this way the SASensor is effectively blazing a trail for the intelligent networks. One great advantage of this simple box is that operational staff now often see a fault even before the first complaints come in, and technicians can generally resolve the problem within 30 minutes.

Fault localisation

The quicker the fault in the electricity network is found, the faster the repair technician can reach the affected location. Sounds straightforward and, thanks to the SASensor, it is. Using the SASensor's measurements, a fault can be located within a radius of 0.5 to 1 kilometre.

This means that operational staff can quickly see which disconnected parts of the network can be reconnected and how the power supply can be re-routed to minimise any inconvenience caused by the power outage. The large-scale introduction of the SASensor in the network began in 2011 and will be completed in 2018. The SASensor will reduce the maintenance costs and investments in the network, while further increasing its reliability.

Investment

Liander will take seven years to roll out the SASensor system. Apart from the investment, Liander will also provide test facilities as well as input for developing and perfecting the SASensor.

The sensor makes it possible to remotely operate the 10kV switches in the sub-stations and thus proactively monitor the quality of the power voltage.

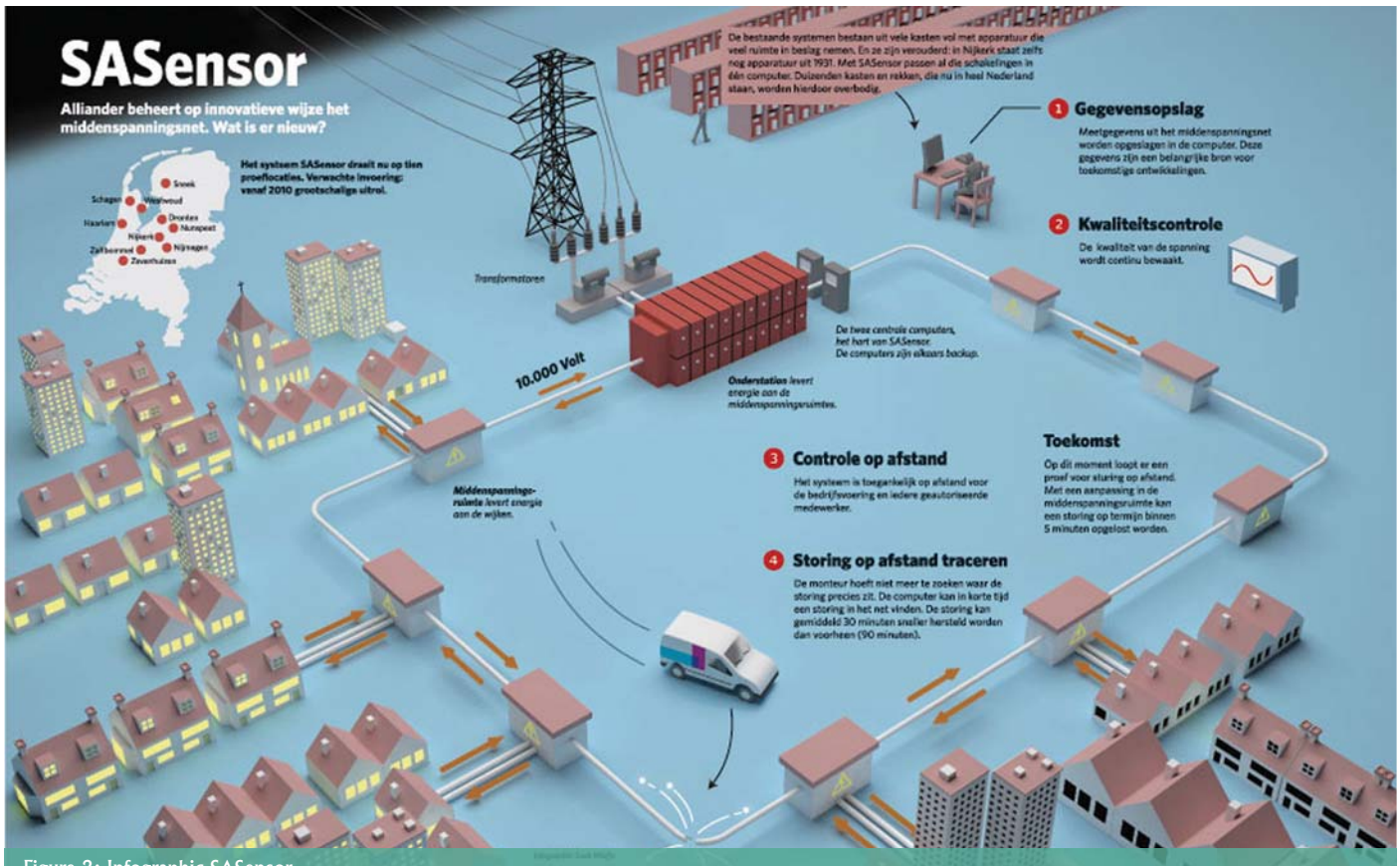


Figure 2: Infographic SASensor

Dream team
De zonneboot

Erik Jansen

Eén van de mooiste dingen van het werken in een dreamteam is de samenwerking tussen de verschillende studies en disciplines. Het zonnebootteam van de TU Delft bouwt sinds 2006 elke twee jaar een nieuwe zonneboot, waarmee over de Friese Elfstedenroute wordt meegestreden naar de wereldtitel voor zonneboten.

In de internationale competitie is in 2006 en 2008 een eerste plek behaald. In 2010 werd het team derde en in 2012 vijfde. De concurrentie wordt sterker. Momenteel wordt er hard gewerkt om het tij te keren en weer voor de eerste plaats te gaan.

Het team is daarom op zoek naar studenten die graag de nieuwste versie van de zonneboot willen ontwikkelen in collegejaar 2013-2014, om in juli 2014 te vliegen over de Friese wateren.

Want vliegen doet het team sinds 2010. De laatste twee boten waren draagvleugelboten. De draagvleugels onder de romp tillen de romp vanaf 12km/h uit het water, waardoor de weerstand op hoge snelheid halveert. Op deze manier wordt veel energie bespaard, waardoor met een lager vermogen een hogere snelheid bereikt kan worden.

Uiteraard zit er veel elektrotechniek binnen het zonnebootproject. Uit de zonnepanelen komt elektrische energie. Verder beschikt de boot over een accu als buffer. Gedurende de hele week van de race mag deze niet extern opgeladen worden. Momenteel wordt gebruik gemaakt van een zelfgemaakte accu, samengesteld uit li-ion batterijcellen met een hoge energiedichtheid. Er is veel tijd besteed aan een efficiënte samenstelling van de batterij en het monitoringssysteem.

Figuur 1: Rustmoment tijdens de Frisian Solar Challenge

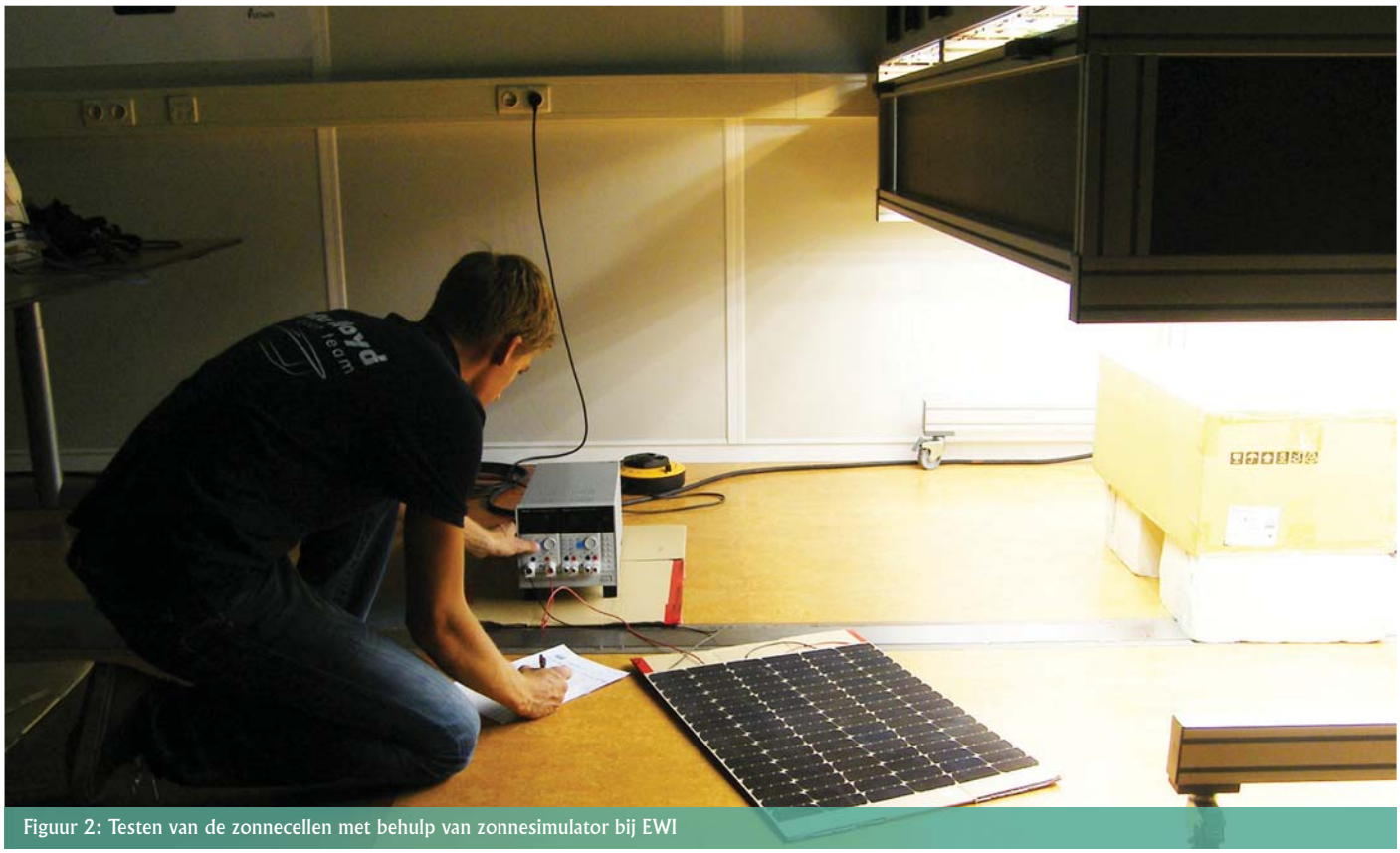
In het tussenjaar, tussen twee fulltime raceteams in, wordt op dit moment verder gewerkt aan een monitoringssysteem. Alle gegevens uit de boot moeten tegelijk worden gemeten, weergegeven op een beeldscherm en opgeslagen. Verder moet de hele strategie op deze gegevens gebaseerd worden. Zo is het de bedoeling dat het team beter te weten krijgt wat de meest efficiënte snelheid is. Hoe snel kan de finish bereikt worden met de huidige zonintensiteit en de staat van de accu? Op dit gebied worden grote stappen gezet.

Verder zijn de eerder genoemde draagvleugels instelbaar van invalshoek. Op deze manier kan er op verschillende snelheden zo efficiënt mogelijk gevaren worden. Momenteel beschikt de boot over een knop, waarmee de draagvleugelstanden discreet zijn in te stellen. De bedoeling is dat er op termijn een snelheidsafhankelijke aansturing van de draagvleugels komt. Hoe deze ingesteld moeten worden, is een lastig vraagstuk. Daarom wordt hier samengewerkt tussen de verschillende studies die de TU te bieden heeft. De draagvleugels zullen onder een maritiemer of een lucht- en ruimtevaart student vallen. De voorstuwing is de taak van een werktuigbouwer. Elektrotechniek is een verbindende factor binnen de boot. Er moeten veel dingen gemeten worden, er moet een goede regeling zijn en er moeten dingen worden aangestuurd.

Naast samenwerking met mensen van verschillende studies, wordt er binnen een studententeam veel samengewerkt met externe bedrijven. Deel uitmaken van een studententeam als deze opent vaak deuren. Zo is er door de afgelopen zonnebootteams veel elektrisch testwerk verricht in samenwerking met een bedrijf. Dit maakt de mogelijkheden veel groter.

Kortom, er kan nog veel ontwikkeld worden aan de nieuwe zonneboot. Lijkt het jou een interessante uitdaging om je vast te bijten in één van de vraagstukken van de zonneboot? Kom gerust eens langs, of neem contact op via onze website:

www.deltalloydsolarboat.nl



Figuur 2: Testen van de zonnecellen met behulp van zonnesimulator bij EWI

VDL Enabling Technologies Group

25 april lunchlezing “Hoogspanning in de high-tech industrie”

Kracht door samenwerking

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Model-based radar classification
To distinguish between a human & a duck

Author: Stephan Groot

As part of acquiring my master degree in Telecommunications I developed – in close cooperation with Thales Nederland - a method to automatically detect human movement. With the developed algorithm large areas – such as railways, secure sites like prisons and nuclear reactors – can be easily secured, removing any reliability on human detection.

Let's start at the beginning: what are the pros and cons of wanting to automatically detect humans using radar anyway?

\+ Real-time detection: from the raw radar data human presence is detected without human interference. Currently, many security systems consist of a large amount (often hundreds) of Closed Circuit TV (CCTV) cameras, monitored by human operators. The operators are usually unable to watch all the imagery, due to the large number of monitors. Furthermore, the human operator is subject to boredom and fatigue. As a consequence, surveillance video is often used for post-analysis, rather than real time detection.

\+ Capabilities of radar: typically, many security applications avoid the placement of cameras, because these are easily subject to vandalism. A radar has the advantage it can function at a distance from potential targets and therefore can be placed out of range for humans. Besides that, radar functions during day and night, as well as in virtually all weather conditions. Last, the CW radars used in this research are low-cast, meaning it's economical to cover large areas.

\- No visual image: no visual image of the target is obtained using radars, which is one of the big plusses of using cameras. Because radar and cameras complement each other in terms of(dis)advantages, it is often very convenient to use both sensor types for human detection, This is often referred to as sensor fusion.

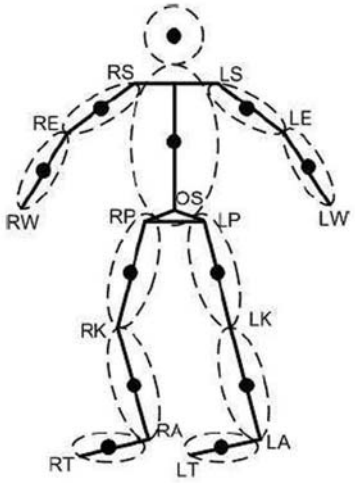
So, what do I exactly want to achieve with this research, besides from graduating? The ultimate objective was to detect human motion using radars. Since this is a rather broad objective, I am going to give you some statements, which earlier research has learned us. However, I'm going to save you from a boring literature study, and just boldly put the most important conclusions:

1. You are probably all familiar with the Doppler effect (the well-known change in frequency caused by the difference in velocity between source and observer noticed when a police car approaches you), but you might not be aware of the so-called micro-Doppler effect. The micro-Doppler basically describes an object as the superposition of different targets, each moving with their own velocity, and hence each inducing their own micro-Doppler shift. You can divide a human body in a discrete number of body parts, each following a different periodic movement and each with a different velocity. This means that each body part induces a time-varying micro-Doppler frequency. In figure 1 is schematically shown how the body is modeled.

2. From point 1 follows that for detecting human motion, human movement gives us much information. Therefore we use human motion for the detection. Three hypothesis are assumed:

- H_0: null-hypothesis: all the other motions you can think of, i.e. animals, cars, bicycles and also no motion at all
- H_1: walking humans
- H_2: running humans

3. A spectrogram is a way of processing a Continuous Wave (CW)-radar signal into a time-varying representation of the spectrum, which captures the micro-Doppler effect. Again, I'll spare you the details, but



Modeled human body

you might sense some serious FFT'ing is going on!

Given these statements the research question was to see whether the information in the spectrogram could be exploited to detect human motion by using a particle filer.

But how?

In order to estimate the state of a system (i.e. in our case this means answering the question what form of (human) motion are we dealing with?) from measurements (in our case the measured spectrogram) two models are required:

- **The system model: because** we're talking about a dynamic system (i.e. the behavior changes over time) we need a model that describes the evolution of the state over time.
- **The measurement model:** gives a relation between the noisy measurements (i.e. the radar signals transferred to a spectrogram and the state.

So far the theoretical background of state estimation problems. In order to actually come to a solution to the problem, the following steps need to be followed:

Formulate the problem

Before you can solve your state estimation problem, it makes to first properly define the problem. This is done by drafting a so-called state vector xk, in which you put all the parameters you want to estimate. In our case the state vector looks like:

$$\mathbf{x}_k = \begin{bmatrix} m \\ v_{\text{rel}} \\ h \\ \varphi_{\text{gc}} \end{bmatrix}$$

- **m** is a discrete variable out of the set {0,1,2} which corresponds to the earlier explained hypotheses. A quite important one, since this is actually the key variable we want to estimate!
- $\mathbf{v}_{rel}$ which estimates the relative velocity of the human motion (relative in the sense that the average velocity is normalized against the height of the person)
- The height **h** of the person
- Since walking and running are periodic movements, φ_{gc} indicates the phase in one of these periods.

Determine the system model

In our case we model the system model as follows:

$$\mathbf{x}_{k+1} = \mathbf{x}_k + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{\Delta t}{T_C} \end{bmatrix} + \mathbf{v}_k$$

This probably requires some explanation. First of all, why are all but one equal to zero? This is because we assume that the mode, the velocity and the height of the person do not change over time. Of course this is trivial for the height of the person. But what if a human accelerates? Or what if a person decides to stop walking, or go running? These changes are modeled through the process noise vector vk. The probability of changing states is model as a Markov process, where the probability of state change is 1%. The noise on the velocity is modeled as the familiar **aΔt**, where the acceleration a is modeled as **a** zero-mean Gaussian distribution.

Determine the measurement model

The modeling of the measurement model is a complex process, and comprises in itself several steps. Just a reminder, the goal of this step is to model the relation between variables in the state vector xk and the traces of an estimated spectrogram at a given time.

1. Estimation of kinematic positions: the first step in the measurement model is to actually model the human motion. What you need to know is that models are used, which give the positions of a discrete number of points on the human body as function of the relative velocity and the phase. Also, these models describe the size of the human body by modeling the human body parts as ellipsoids with the size as function of the total height of the person. Please note that all the inputs of these models are equal to the variables we put in the state vector, how convenient!

2. Radar Equipment Model: from the motion models we end up with two inputs for the radar equipment model: the kinematic positions of 17 points on the human body and the size of 14 body parts. To model the received radar signal, we superposition the returned signal of these 14 body parts:

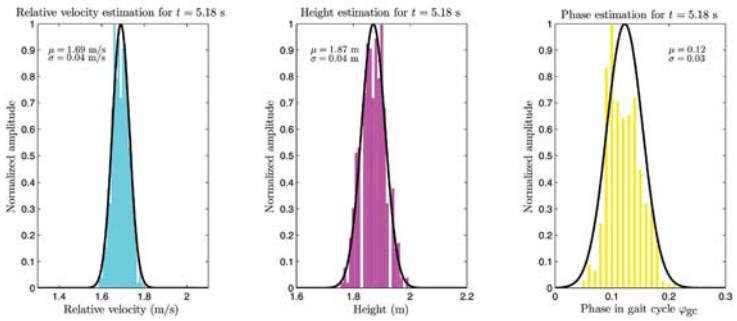


Figure 3. Parameter estimation for measurements with a walking human

$$r(n) = \sum_{i=1}^{14} A_i(n) e^{\frac{j4\pi A_i(n)}{\lambda}}$$

with

$$A_i(n) = C \frac{P_{EIRP} \lambda^2 \sigma_i(n)}{4\pi^3 R_i^4(n)}$$

Almost all these parameters are dependent on the radar you use, except the Radar Cross Section σ, which depends on the size of the individual body parts.

3. Spectrum Estimation: final step is to translate the received radar signal to the estimated trace in the spectrogram. This is simply done by windowing the signal, and performing a FFT.

Choose a suitable filter solution

State estimation problems can be solved by a certain number of filters. Choosing a suitable filter depends on the nature of the system and measurement model of your system. For most filters it is required that these models are either Gaussian or linear, or both. I'll spare you an elaborate discussion of the many filter types, but instead present you with the filter of our choice: the particle filter. In a particle filter you try to estimate the state of a system, by simply trying many times what the state is, each time with different inputs. By comparing for each try the estimated spectrum with the actual measurement you can come up with a distribution of how good your estimation is.

Does it work?

Measurements of a walking human, a running human and a duck were performed in order to test the correct working of the algorithm on measured data. All classifications were performed correctly. In the top part of Figure 2, the measured spectrogram of a walking person is given. The walking person has a length of 1.85 m. Looking at the velocity of the torso, the average walking velocity can be extracted from the spectrogram and is assumed to be constant at 1.55 m/s. The bottom part of Figure 2 shows the classification result. From this figure can be seen that the part of the spectrogram, which contains the motion of the walking human (up to about 5.5 s), is classified correctly as human walking. When the person stops moving, the algorithm classifies this part also correctly as the null-hypothesis. The estimation results of the motion parameters at t = 5.18 s are given in Figure 3.

Similar results are obtained from measurements with a running person. A good check to see that the filter is actually picking up human motion, is to check how the filter classifies non-human motion.

Since a duck is bipedal like humans, a walking duck shows some similarities to human walking and proves to be a good test. In Figure 4 the measured spectrogram of a duck is shown. After 4.5 s the duck stops moving and hence no motion occurs anymore. This allows the same spectrogram to be used for testing whether no motion is classified correctly. In the bottom part of Fig. 10 the classification results are indicated. You can see that both the movement of the duck and the part containing no motion are classified correctly.

Doing your internship at Thales Nederland

Got reading about this research you enthusiastic about radars, or do you want to know more about the many other cool internships Thales offers? Browse to radar.ewi.tudelft.nl to learn more about the possibilities to do your master thesis at the Microwave Sensing, Signals and Systems group. Check out www.thales-group.com/nl for an up-to-date overview of open position at the Thales locations in Delft, Huizen en Hengelo.

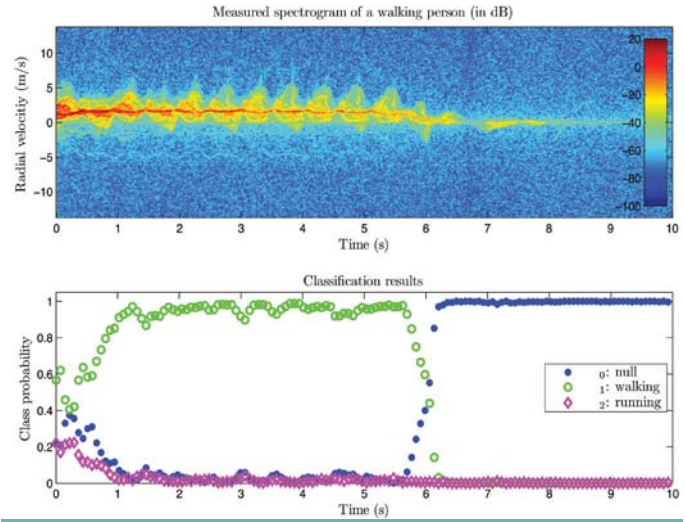


Figure 2. Measured spectogram for a walking human and its classification results

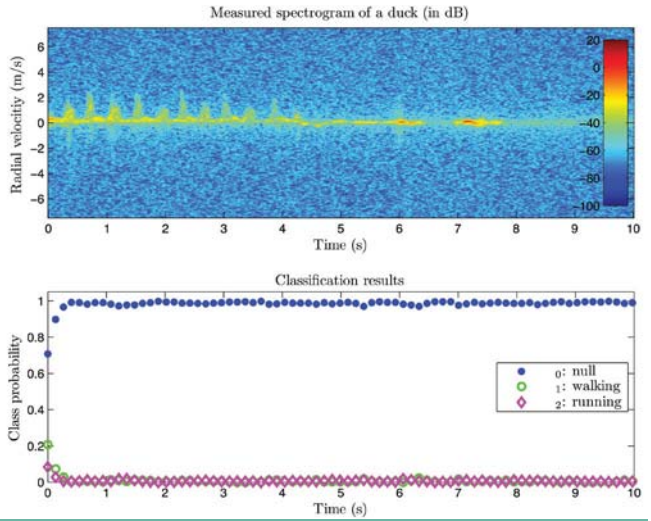


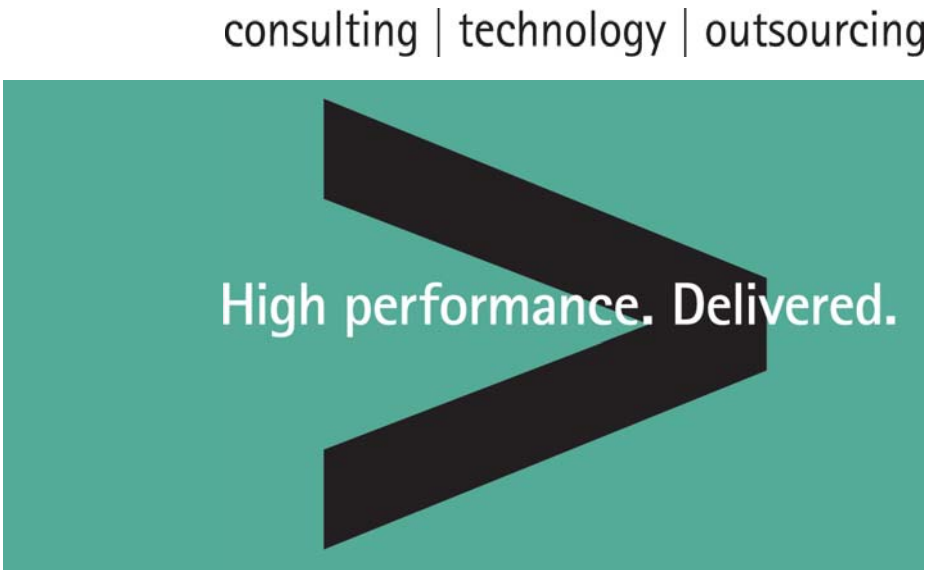
Figure 4. Measured spectrogram of a duck and its classification results

Life after studying EE
My career at Accenture

Author: Stephan Groot

At some point during your student life there comes a moment you have to think about your life after the TU Delft. Of course, the same applied to me. After graduating in November '11, I started working for the Communications, Media and High-Tech (CMT) practice of Accenture. Interested to know what it's like to work as a technology consultant for Accenture? Read along!

When you start at Accenture, you first attend the New Hire Days. These days provide you with an excellent introduction of the company and all its internal processes. Maybe even more important, the New Hire Days give you a chance to build your first network of people within Accenture.



My first project was at a large cable operator. This operator was working hard on introducing a digital solution on the Dutch market, that allowed its customers to watch TV and order movies from their tablets, smart phones and PCs. Our responsibility was to test the speed and stability of the digital TV solution from different perspectives: from the end-user (i.e. using the new TV and tablet screens) and from the cable operator (e.g. loading new content). We were able to significantly speed up the testing time by automation of the different tests we executed. Equally important was the fact that we also provided good recommendations to make the solution even more faster and stable.

After this project I remained working for the same client, but then as an architect in several projects. I worked on the architecture of different digital telecom solutions, such as a digital TV platform for East-European countries and a Voice over IP service for Business Customers. As an architect you first translate the business requirements into technical requirements. Subsequently you determine through which component the functionality can be fulfilled, and you define how these components interact with each other. Last important step is to define the use cases – this explains how external parties interact with the systems, and explains how the business scenarios are executed.

Since Accenture is a large, global company – more than 240.000 people in 120 countries (2700 in NL), it's important to have a place within Accenture you can call your "home". For me, this is the CMT group, aligned to Technology. The CMT group is relatively small, which means everyone knows each other well. Because everyone is on different projects, there are regular meetings to keep everyone posted – these meetings always consist of a business part, followed by a more relaxing activity.

Last, let's not forget that Accenture is a great company to work for! Accenture offers a career with international opportunities, challenging work, great colleagues and interesting projects. For me, this is why I really like working for Accenture!

Do you want to have more information about working for Accenture in general, and working for the CMT group in particular, do not hesitate to contact me at stephan.groot@accenture.com

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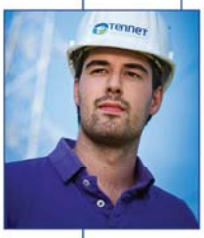

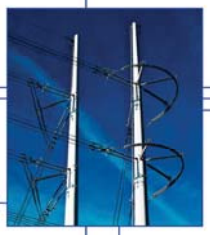

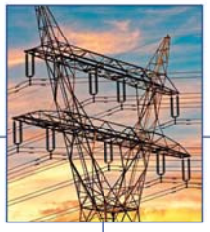

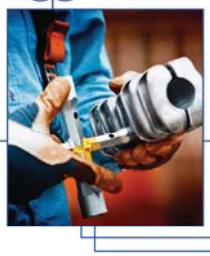

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