

De Vonk

Periodical of  E.T.S.V. Scintilla

Main Article
Slow Wireless

Activities
Shooting with EE-Sports

Greenteam
What are you studying for?

Futuristic Technology,

That Really is my thing.

Author: TNO

TNO innovates with impact. By bringing together a wide range of disciplines in two areas of expertise and thereby tackling societal challenges within five current themes. Innovator Francesco Esposito works at TNO and is developing ground-breaking technology, which will be part of our everyday lives in a few years' time.



As an innovator on the Co-operative Mobility programme, Francesco is working on technology to enable self-driving cars to communicate with each other and with the infrastructure around them. "My main focus is the safety system, which ensures that the technology works in dangerous situations on the road. Another project I'm involved in, this time in Automotive, is the construction of a simulator to test self-driving cars. It's fantastic to be working on all this – we have so much to look forward to when it comes to self-driving cars. Some vehicles already have autonomous functions, but they're going to develop enormously over the next few years. So-called co-operative driving, especially, is really important for safety and traffic flows. That's the main thing we in Co-operative Mobility are working on. For most people this is very futuristic, but we're already developing the technology and we can see that it works."

certainly in Automotive. In so many technologies, hardly anyone else is as far advanced as TNO. Here I can keep building my own body of knowledge, and make myself useful by putting it into practice straight away", Francesco explains.

Future Project Manager

For TNO innovation means demonstrating how significant knowledge is for society. Working at TNO means working in teams on inspiring assignments for multinationals, SMEs and government. You contribute directly to innovation and the ongoing development and application of knowledge. The assignments range from contract research to consultancy, from policy studies to testing. Francesco tells: "You never run out of things to learn here. We work on big projects involving a lot of people, who have to collaborate effectively to make real progress. Even though I'm still relatively new here, I'm already encountering many aspects of project management. That's important to me, because it's the direction I want to move in. Right now, some colleagues and I are working on a bid for a major European tender procedure. For that I have to consult with our consortium partners and come up with solid proposals."

Futuristic Technology

"I studied electrical engineering at the university and I have a passion for cars. My thesis was about technology to repel intrusive or hostile drones. Futuristic technology – that really is my thing! After graduating, I chose TNO because I knew what brilliant things they do here,

The People of TNO

TNO employs around 3000 people with all kinds of backgrounds, qualities and interests. This multidisciplinary aspect is essential to be able to innovate.

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Presidential note.

Author: Guus Frijters

At the moment of writing this article almost everything hurts in my body, or at least, the most important parts. Why is this you ask? Well, that's in threefold. First of all, the Batavierenrace. Secondly, the StAf-tournament, and last but definitely not least, Scintilla-activities such as a Cantus, but I am still getting up early.

So, let's elaborate some more on the important parts of what happened to me. At the Batavierenrace I ran, as the tradition dictates, the last part of the run. From Enschede city centre to the Campus. 7,8 kilometres with lots of supporters and all the teams, and of course in a nice complementary outfit. The tiring run took place after a long day of keeping the team company during the full afternoon-team. So the day was already quite long when I stood there on the starting line, waiting for the signal that we could start. In that moment, I felt the thrill of joining in such a huge competition, but I also had flashes of all the batatraining I did with Scintilla where I noticed that my running skills are not as good as I had hoped. But then, the start-signal sounded and there we went, all the teams ran like their lives depended on it, which for me resulted in loads of muscle-ache and an average speed of 10,66 km/h.

Now we know the first part of my hurting, so we can continue with the second reason. As people can expect from an sportive and fit person like the president of the Electrical Engineering association, I also joined in with the StAf-tournament, with all the muscle-ache I still carried with me. But, through the pain and the rain, we fought hard against our larger committee, s.c.v.m.d.d.v.s.h.g. Arago, and got away with a hard and

important win. Which now means that we are second in our poule in the tournament, just below last year winners, Concept1, who are only in front of us because of their goal difference.

So with all this information we now know my physical pains and the great causes which were required to get it. But we still need the cause for the mental pains I suffer as a board member. At this moment, they are caused by the epic Scintilla-activities and the beer which is available at these activities. The early mornings combined with beer and muscle-ache do not really help with making you feel terrific. But another thing that plays a part here, is our new and fresh candidate-board. We are happy to have 6 enthusiastic and motivated people for next year, but it also means that it is now almost over for my board year, and this makes me feel a bit sad. But for now, I have the chance to teach a candidate some awesome specifics about the beauty of being a board member!

Op de Koningin, op Scintilla!



Guus Frijters



Scala's Summer Barbecue

On June 8th, Scala will be hosting its annual summer barbecue! If you want to have some nice cold drinks with some superbly cooked meat, sign up right now!

Electroshock Glow

After a very successful first edition, Electroshock is back! With a healthy new supply of the best beats accompanied by some great synths it will promise to be a great party. This edition will promise to be even more epic with its new venue 't Bôleke'. So be there on June 14th!

Masthead

De Vonk

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Editorial team

Mark van Holland, Jippe Rossen, Céline Steenge, Maarten Thoonen, Nahuel Manterola, Rik Engel, Wim Hoek, Gino van Spil, Marissa Jonker

Cover Artist

Robert Fennis

Board Representative

Wouter Pool

Print

Gildeprint, Enschede

Editorial office

E.T.S.V. Scintilla, University of Twente,
Postbus 217, 7500 AE Enschede,
☎ 0031 53 489 2810
vonk@scintilla.utwente.nl

Material

vonkkopij@scintilla.utwente.nl

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08 Main article

In this article a very narrow bandwidth scheme for wireless communication is discussed. This scheme allows for slow data rate transmissions with very low power usage.



18 Internship

Tobias tells about his internship at the Shenzhen Guohua Optoelectronic Technology Company in China. He tells about his stay there and the e-reader project he has been working on.

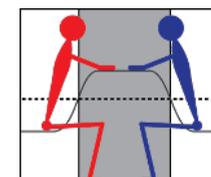
Education 12

Robert describes several parts of his master in Telecommunication Engineering, like the courses, internship and the master thesis.



Junction 28

This editions interview was held with Daphne Boere, the study advisor for EE. This is your chance to get to know her a bit better for when she comes back from maternity leave.



Editorial

Dear, sweet readers,

Proudly we present edition 35-2 of De Vonk! For this edition we have selected some great articles for you!

It has not always been easy for some members of De Vonk to finish this edition. We will remember the nights where Wouter distracted us with politics. Another famous shout we heard was "I think I broke the" from Gino. Luckily Jippe was there to fix the articles.

About the articles, you may recognize that there are babies in them! Two of them! Maybe, I am getting too much influence within De Vonk because the puzzle and recipes are also lovely. More cuteness can be found in the next Vonk, so be patient.

Furthermore, it is finally time to get yourself a cup a tea and get into great stories. We know that in the Scintilla Kamer a lot of topics appear like the activities, modules which are (not so) great and maybe even more! But we are giving you the chance to finally not be surrounded by people and just read De Vonk on your own. Of course you may also read it together with someone or someones, we actually do not really mind with who you read this.

Getting back to the problems some members of De Vonk face. You saw this nice cover? Well Jippe has been trying to fix it for at least 30 minutes now since Gino broke it but as you as can see, the cover is there! Let this inspire you to always finish your task even when it is broken.

Kisses,
Céline

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News

From the research groups

The Biomedical Signals and Systems (BSS) group has developed a portable gait lab called ForceShoes™ along with Xsens Technologies B.V. Stroke survivors suffer from loss of brain tissue leading to weakness of control on one side of the body. Using ForceShoes™ with stroke survivors can help clinicians understand level of recovery, compensatory mechanisms and use of the affected side. Several design iterations have been done to make it capable of measuring foot position, centre of mass and stability during walking for every step you take. This is enabled by on-board sensors that measure 3D forces and moments, acceleration, and orientation of the foot, offering several advantages over current systems such as motion capture and force plates, used in research labs.

There is one catch though. The ForceShoes™ are quite heavy, look odd and might draw some stares if you wear it outside. An alternative is to use pressure insoles.

Pressure insoles are like the insoles in your shoe, except that it is loaded with 1D resistive pressure sensors and

weights next to nothing. A linear regression model was built that could predict 3D forces and moments using only 1D pressure values during walking. To implement this idea, subjects were asked to walk a few metres with the ForceShoes™ fitted with pressure insoles. This information was used to build the predictive model. Once we know the 3D forces

Author: BSS
Mohamed Irfan
Mohamed Refai

BSS

and moments, we can find the trajectory of the centre of mass which tells us a lot about the stability during every step taken.

The study offers promising results. The correlation of the 3D forces/moments between the predictive model and measured values is above 85%. Subsequently, the accuracy of rightly classifying a step as stable or unstable by the pressure insoles is as high as 98%. The next steps involve optimizing the model for different walking speeds and reducing the number of pressure sensors. The project is a part of the NeuroCIMT project 7, funded by the Dutch National STW.



New to the world

Author: Stellae Scintillae



On the 90th day of the year, a little spark was born in this world. Scintilla hereby announces the birth of baby Lauren Doreen Boere on March 31st, 2017 16:45. This little girl weighted 2822 gram with a length of 47cm. She is doing fine and the mother and big sister are already in love with their own sunshine.

Congratulations Daphne and Ruben! Now is the time to enjoy Lauren's little feet and baby smell. It will not last forever, and we hope that you can enjoy this little bundle of love with the whole family. Don't forget to take many pictures, we do not want to miss a single precious moment!



Slow Wireless

The Road to Robust Low-power Radio Links

Author: MHD Zaber Mahfouz, Arjan Meijerink, Ronan A. R. van der Zee, André B. J. Kokkeler and Mark J. Bentum



The Telecommunication Engineering group is involved in research projects (in collaboration with other groups, universities, and industry) as well as teaching activities (bachelor and master courses and assignments). The research is concentrated in two principle subject areas: **Electromagnetic Compatibility and Short Range Radio**. The latter research area is mainly focused on the physical layer of ad-hoc radio systems such as wireless sensor networks (WSNs).

Low-power consumption and interference robustness are two challenges faced by research as well as industry within WSNs. In this article, the “Slow Wireless” concept is presented along with its very narrowband (VNB) signaling scheme. The concept provides a promising low-power and interference-robust solution for low data rate WSN applications that operate in the 2.4-GHz ISM band. The potentials of the scheme as well as the possible research challenges are outlined throughout the article. The Slow Wireless project is a collaboration between the TE, ICD and CAES research groups.

Introduction

A wireless sensor network (WSN), in a typical architecture, is a wireless network in which tiny sensor nodes and/or actuators are deployed over an area of interest, sense their environment, and wirelessly transmit the sensing information on a periodic basis or on demand to a centralized base station “gateway” for further processing and/or action [1].

Eventually, based on the processing of the collected sensing information, the actuators will execute specific actions and, consequently, alter their environment in a systematic and desired manner.

The concept behind WSNs was first triggered as a military fantasy idea and then expanded enormously to result in a broad range of consumer and industrial applications. The research on WSNs has attracted a huge interest since the topic itself was given a boost by a project called “Smart Dust”. The project was developed at the University of California (Berkeley) and funded by the Defense Advanced Research Projects Agency known as DARPA [2]. It aimed at producing a sensing system based on tiny devices as well as presenting the challenges to the emerging technology of Smart Dust at the time. Recent years have witnessed a vast number of WSN applications, not only in the military arena (e.g. battlefield surveillance), but also both in consumer and industrial markets, such as inventory logistics, structural monitoring, warning systems

(e.g. fire detection), long-term in-home patient monitoring, and home/office automation (e.g. temperature control) [1, 3].

Many applications in WSNs require low-power nodes. And because the radio section in a typical node accounts for a considerable percentage of the total power consumption, research has focused (among others) on RF transceivers. Ultra-low-power radios have become a hot research topic in the past years, and therefore, many systems and schemes have been proposed. However, these systems are usually tested in laboratory conditions when there are no other interferers present. In practice the signal from a sensor node would be disturbed by other interfering signals (e.g. from Bluetooth and WLAN) sharing the same frequency band.

In this article, we present a very narrowband (VNB) scheme for WSNs that has a sufficiently low power consumption, but is still robust to interference. It is targeting low data rate applications operating in the 2.4-GHz ISM band. The

concept behind this scheme is called Slow Wireless.

Concept

The VNB scheme is based on the Slow Wireless concept of providing low instantaneous data rate communications (hundreds of bits/sec) by utilizing very narrowband signaling (order of kHz). The supporting idea behind this concept is that the majority of the WSN applications does not need high data rates. In fact, the majority of these applications is characterized by very low average data rates as the traffic generated by such WSN nodes is extremely low. Additionally, the dominant interference within the 2.4-GHz band is from Wi-Fi signals which have a wideband nature. Therefore, by following continuous transmission (very relaxed duty cycle) instead of heavy duty-cycling (i.e. tough sleeping schedules), we are able to follow the VNB scheme, and accordingly, only a small portion of the interference signal will enter the VNB receiver. Another advantage is the relaxation in the transmitter power and/or the receiver noise figure.

Low Data Rate WSNs

The majority of WSN applications is characterized by a low average data rate, i.e. the traffic generated by the sensor nodes is quite low. This is because the nodes in such applications usually sense slowly-changing variables in their environment. In [4], a survey on 64 well-documented WSN applications in the past decade was given and only 11% of

the reviewed applications were classified as “high-rate data collection”. On the other hand, more than half of the applications were classified as “low-rate data collection” and “on-demand data collection”, in both of which data are collected from the sensors either on a periodic basis or based on a request from a centralized base station. The nodes in most of those low-data-rate applications rely on simple sensors (e.g. temperature, infrared, etc.) which typically generate a scalar value of the objects they monitor every now and then. The low-data-rate applications in [4] were basically metering, monitoring and detection such as AC metering, environment monitoring and wildfire detection.

A comprehensive taxonomy of WSN applications was introduced in [5], in which a WSN application is defined to be a “low data stream” (LDS) application if the generated bit rate from each of its sensor nodes is less than 57.6 kbps. Another two categories for the bit rate were introduced in the survey paper; “high data stream” (HDS) and “medium data stream” (MDS), the definition for each of which is given in Table I.

Interference in the 2.4-GHz ISM Band

The industrial, scientific and medical (ISM) bands are usually used by WSNs for deployment because they are license-free. Radio technologies and standards utilized by WSN applications, such as Bluetooth and ZigBee, already operate in ISM bands which makes it another reason for why such bands are popular among WSNs. Particularly, the 2.4-

GHz range with the 80 MHz bandwidth available worldwide has attracted most of the license-free communication applications. Consequently it has become extremely crowded with the continuous emergence of radio technologies sharing this license-free band. Interference, as a result, caused not only between the coexisting different radio technologies but also in between devices using the same technology is quite serious. It degrades the overall utilization efficiency of the total band which has led to many publications since early 2000s in order to tackle the issue and propose mitigation mechanisms to alleviate the interference problem [6-10]. There are several license-free communication technologies that operate specifically in the 2.4-GHz band. Many of them are already established and standardized such as IEEE 802.11 (Wi-Fi), 802.15.1 (Bluetooth) and 802.15.4 (ZigBee). Emissions from non-communication appliances (e.g. microwave ovens, fluorescent lights, medical devices, etc.) also contribute undesirably to the overall interference in the ISM band, though the band itself was reserved for such industrial and medical applications in the first place. For instance, the severe effect of leaked radiations from a microwave oven could disturb the wireless devices nearby. According to [7], a ZigBee-based WSN receiver was severely disrupted when it was brought within 2 m of a 1100-watt microwave oven. The authors in [11] carried out interference measurements in a city hospital as well as in home and office environments. In hospitals, they observed that the radiological wards and rooms have low interference purposely due to thick walls whereas the measurements in the emergency ward indicates quite harsh environment since it includes many medical radiating devices. Table II summarizes the electromagnetic emissions within the 2.4-GHz ISM band from common communication technologies. The table gives the emission power, bandwidth (BW) and corresponding power spec-

TABLE I. Categories for data stream related applications [5]

Parameter	Bit Rate (kbps)		
	HDS	MDS	LDS
Range	> 115.2	57.6 – 115.2	< 57.6

tral density (PSD). According to Table II, WLAN access points (APs) usually transmit relatively high-power signals degrading the reliability of the RF links between the sensor nodes that would be deployed in the same coverage area of the APs. Moreover Wi-Fi APs have the highest value for emitted power spectral density, and what makes the interference situation much worse is that they are deployed almost everywhere in homes, offices, hospitals, factories and stations.

Potentials

As Table II indicates, the dominant emissions in the 2.4-GHz ISM band are the signals from Wi-Fi APs points which are featured as wideband interferers. Taking benefit of this very fact (i.e. wideband interference), the principal concept behind the VNB scheme is to use very narrowband (a bandwidth of few kHz at most) signals. For example, if we rescale the emitted PSD of a 20-MHz and 100-mW Wi-Fi signal to only 2 kHz, we end up into a value as small as -20 dBm. That is equivalent to a 40 dB gain against such existing interference. In other words, only a small portion of the interference power will enter the narrowband receiver. Hence, even when the total interference power is much larger than the desired signal power, reliable communication can be achieved if the bandwidth in use is sufficiently small. The obvious advantage is the relaxation of transmitted power at the transmitter. Additionally, a very narrowband receiver is going to be much more robust to strong interferers in crowded environments than its wideband counterparts. Moreover, the interference in

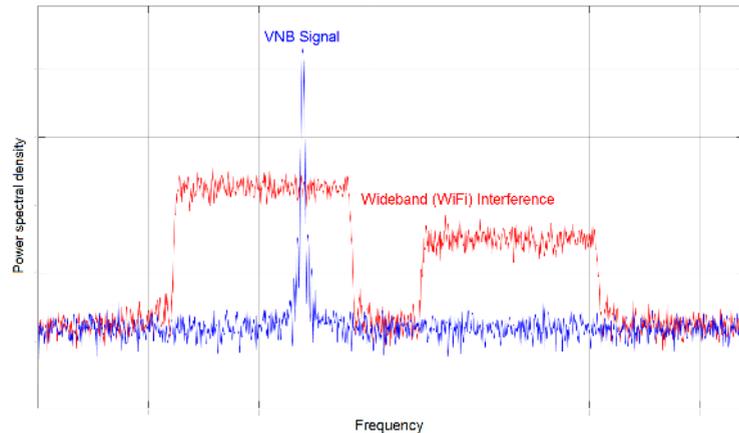


Figure showing the effect of rescaling the emitted PSD on interference levels.

such crowded environments dominates over the internal thermal noise of the receiver itself. Consequently, the noise figure of the receiver can be relaxed to a great deal. Given the previous example of a 2-kHz bandwidth receiver and a 60 dB attenuation on the Wi-Fi interfering signal, a 60 dB relaxation on the noise figure can be achieved.

Challenges

Although the VNB scheme gives a potential promise in combating interference that seems to have a wideband nature, it faces a few challenges that need to be addressed in order to have a complete physical-layer solution for ULP sensor nodes.

The main advantage of having very narrowband signals hides behind it a potential and serious challenge of how to deal with the frequency uncertainty of local oscillators at receivers as well as frequency synthesizers at transmitters. A local oscillator is responsible for

generating a sinusoidal signal for the purpose of down-converting the desired received signal from radio frequency to intermediate frequency (heterodyne) or baseband (homodyne), depending on the architectural approach. State of the art local oscillators have an accuracy ranging from 2 - 20 ppm. A crystal oscillator which has an accuracy of 0.35 ppm was reported in [12], but at the expense of a high power consumption of 303 mW. The down-converted signal then passes through a bandpass/low pass filter to suppress out-of-band noise and interference. The filter should have a bandwidth a bit larger than that of the received signal in order to accommodate for the aforementioned accuracy of the local oscillator. Therefore, in the case of 2-ppm LO accuracy and working on a carrier frequency of 2.4 GHz, a frequency deviation around 4800 Hz results in, which could be even greater than the bandwidth of desired signal itself. As a result the receiver should have a new design that is not only able to correctly demodulate the arbitrarily carrier-shifted signal, but also still benefit from the very small bandwidth feature to exhibit good sensitivity and stay immune to the wideband interference as well.

Communications in a multipath propagation environment experience random fluctuations in the amplitude of the

received signal known as fading. There are mainly two parameters describing the nature of a communication channel from fading perspective. They are coherence bandwidth and coherence time. The former indicates how much a channel of interest is time-dispersive and consequently how considerably flat it is in the frequency domain, whereas the latter determines to what extent the channel dynamically changes over time. Both parameters can be empirically obtained based on measurements conducted on the frequency channel in the sight of interest. According to the value of signal bandwidth compared to coherence bandwidth, channels are categorized into either flat or frequency-selective fading channels. Furthermore, in WSNs, from coherence time perspective, fading could be classified into either slow or fast fading depending on the relative motion between the sensor nodes and the base station as well as the movements of the objects around. Experimental results reported in [13] show that the coherence bandwidth of a propagation channel in indoor environments (e.g. office, gym, laboratory, etc.) in the 2.4-GHz ISM band is in orders of megahertz. Thereby due to the VNB signaling scheme, received signals are always subject to flat fading which considerably relaxes the design of channel equalizers. However, the coherence time for the same environmental conditions stated in [13] is as small as a few tens of milliseconds or even smaller. As a consequence, the fading becomes ultra-fast fading in which received data symbols, based on the VNB signaling scheme, can experience fading dips leading to phase fluctuations and an increase of the received signal bandwidth. This increase has to be accommodated by an increase of the receiver bandwidth, hence creating a trade-off between robustness to fading on one hand and receiver sensitivity and interference robustness on the other hand.

What TE Group Does! Acknowledgment

The TE group will be investigating the physical-layer aspects of the VNB radio link. As a first step, an initial framework for optimum design parameters from power consumption perspective will be made, assuming simple models for the channel and the interference. Later on, more realistic models suitable for the case of VNB signaling will be developed in order to describe their impact on the performance of such VNB radio link. The models, which to be validated through simulations and statistical measurements, will be used to upgrade the optimization framework taking into consideration conventional low-power oscillator circuits. These conventional oscillator circuits have an impact on the timing accuracy as well as the LO accuracy, which affects the results of optimization process itself. The obtained results will be used to develop an experimental platform in order to investigate the feasibility of the VNB scheme as a low-power and interference-robust node operating in interference-rich environments with harsh propagation conditions.

Conclusion

An initial concept of the VNB scheme as a solution for ultra-low power sensor nodes is presented in this article. The scheme is intended for low-data-rate WSNs operating in the crowded 2.4-GHz ISM band. It has the potentials of achieving low-sensitivity and interference-robust receivers. A couple of challenges have been addressed in the end of the article for the motivation of further research.

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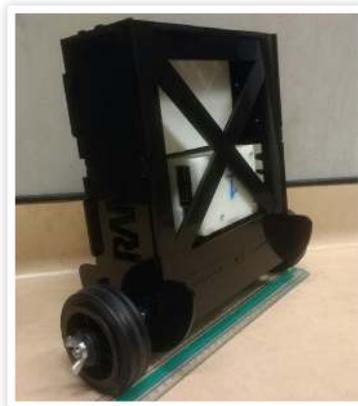
TABLE II. A comparison between different wireless technologies

Technology	Tx Power	BW	PSD
802.11g	20 dBm	20 MHz	7 dBm/MHz
802.15.1	4 dBm	1 MHz	4 dBm/MHz
802.15.4	0 dBm	2 MHz	-3 dBm/MHz

Module 6: Systems & Control

Author: Bas Keet

If you are a first-year student reading this, you might have heard about it. Some down sounding voices in the SK talking about that nasty module that is too difficult, doesn't explain everything well enough and just leaves you to fend for yourself. Or maybe you are already past your first year, which means you have probably already followed module six (at least) once. Then you might be familiar with the success rate and the extra resist that are organized during summer break. However, it is not all as bad as it seems. I have done this module three times now and finally passed it with quite a good grade (if I do say so myself). And I can tell you a lot has changed in these three years, a lot of which benefits the module.



So first let me explain what the module looks like. The module is just like any other and consists of three courses and a project. The courses are linear systems, control engineering and engineering system dynamics (ESD). Linear systems focusses on the math needed for the two other courses. Using transformations into different domains for both continuous and discrete signals to make life

"I am quite sure that most of the changes have made this module a bit easier on the nerves."

easier. Engineering system dynamics uses bondgraphs to better understand the dynamic behaviour of physical sys-

tems. With Control engineering, you learn to design a feed-back control of linear or linearized dynamic systems. Together these courses enable you to model, analyse, simulate and design dynamic behaviour of physical systems, even in non-electrical domains. Finally, the project stimulates the use of all the different courses to apply the gained knowledge on an actual physical system. If we don't consider the pilot year of the Twente Education Model (TOM in Dutch) the first time this module systems & control was taught was in 2014/2015. All exams were multiple choice with three exams for linear systems, two for ESD and two for control engineering. The module was still in its development stage. For example, the grading of the courses was changed up to three times during the module and there were no tutorial sessions for ESD. In 2015/2016 the amount of test was

severely increased in order to distribute the study load more evenly across the whole module. This meant 5 exams for linear systems, 5 multiple choice exams for ESD and three multiple choice exams for control engineering. This did not result in a much higher amount of people passing the module. It was still around 60 percent that passed with the

"In the first two years, the project meant constructing a hovercraft."

normal resits and regulations. Thus, like the previous year some additional resits were organised in the summer vacation. Which resulted in around 70 to 80 percent passing, still not very high.

During this year, Scintilla heard from a

few second-year students that the module was quite difficult. The main complaint was that no one knew what to expect from the ESD exams. This because no previous exams were available nor were there any exercises. Though the given lecture notes do contain some exercises, however those were only a few and not really a good representation of what is asked in the exam. Regarding the exam, you were not allowed to take the questions home nor were they available elsewhere. The taking home part was also not feasible since answers should be written on the question paper. A few older students that had already finished the course ESD organized a few tutorial sessions. These sessions were more like a minor course, a short summary of all the material that was handled during the lectures of ESD. These sessions consisted of a mini lecture and some exercises. Mainly the exercises were much appreciated by the people following this course. The tutorial sessions were a bit last minute but made the start for what would be actual tutorials in the next year.

"Some down sounding voices in the SK talking about that nasty module that is too difficult, doesn't explain everything well enough and just leaves you to fend for yourself."

Thus in 2016/2017 the schedule was also cramped with ESD tutorials. The number of exams was reduced to 2 for each course, containing both open and multiple choice questions. In my opinion these two changes made the course much better again. It greatly increased the understanding of ESD and due to the lower amount of test you had to

study more but you could internally compensate again in the exams. However, there is still room for improvement. This year the lectures of control engineering were not given in person but instead pre-recorded lectures were available to follow on blackboard. Though this was better than learning everything by self-study it lacks the ability of interaction and direct feedback. With the tutorials and question and answer sessions you do have the opportunity to ask away and get the answers you need.

"Thus in 2016/2017 the schedule was also cramped with ESD tutorials."

Another aspect that changed in 2016/2017 was the project. In the first two years, the project meant constructing a hovercraft. Then using knowledge and skill from the other courses make a model of the hovercraft and build a controller that could meet certain requirements. Because the hovercraft could be anything you could think of and build this meant very inaccurate models. This due to the fact that imperfections in the real design are difficult to model, like a fan being a few degrees off or the hovercraft keeling over a little bit. If the model is different from reality and your controller is based on this model, this means that the controller is likely not too practical on the real thing. This was also visible during demonstrations. Only one or two out of the ten plus groups got a semi-working hovercraft.

During this last year, a new project was introduced. This one is more centred around measuring and modelling. So, no building which is a shame, but way more reliable measurements, models and controllers. The project is now centred about a pre-built Segway. By measuring and testing all the parameters

that you would need to know could be derived. Since this year was the first time for this project there were still some things that needed some tuning. Some test setups were unreliable and the Segway's broke down sometimes. The part that people failed on however, was the report. So be warned, or rather advised to brush up on your report writing skills. Luckily there was a second chance to submit your report.

"The module is just like any other and consists of three courses and a project. The courses are linear systems, control engineering and engineering system dynamics (ESD)."

So there have been quite some changes to the module in these past years and I am quite sure that most of them have made this module a bit easier on the nerves. The changes in the types of lectures and tutorials offered helps to easier get a grip on all the subject. And though a new project is always inclined to bring some complications with it, I think this year went quite well. And the more experience and feedback the module and its coordinators get, the better it will become. But the module just has some tough subjects. This means that you also need to put some effort into it.

What are you studying for?

What are you studying for? This is a question I think about a lot, and can be answered at several levels. Why I chose to study EE is simple, though maybe unusual: I had a well-paying job as a software developer but became really interested in electronics through Arduino and so I decided I wanted to learn more.

On a deeper and more interesting level, I ask myself: what is my ambition, the goal, the purpose of it all. Some don't have much ambition beyond passing exams and getting a job. Others strive for perfect grades, a cum laude degree, and are likely to join an honours programme. And then there is the group that includes me, that want to deeply understand things and apply their knowledge, who have their desk full of wires and breadboards at all times.

I want to make the case that deep understanding and practical experience are the only things that matter. My former employer even went so far as to say that in 10 years, no one will care about your degree, and you're solely defined by what you do.

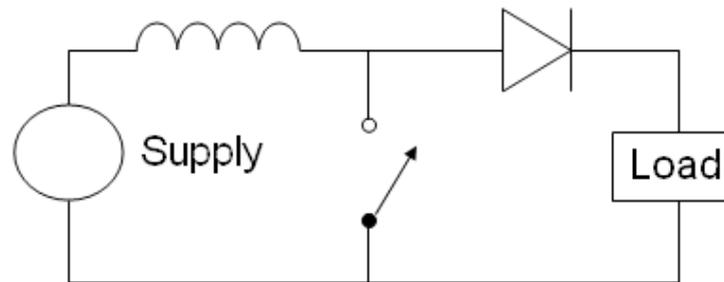
Good grades don't necessarily make good engineers. I know people on the verge of getting a negative BSA that I would hire instantly due to their insight, intuition and experience. I also know people with nines and tens that are sometimes surprisingly confused about things one step away from exam material.

I recently joined the Green Team Twente to work on the electronics of their hydrogen car, and I think it's one of the best ways to apply your knowledge and gain practical experience. It is also much closer to a real work environment than the carefully curated educational environment we live in. Let's take a look at the final project of Module 2 and contrast that with the boost converter I'm building for the Green Team Twente.

In Module 2 you learned about transfer functions and circuit analysis on carefully selected problems with nice solutions. You get exactly the information you need to build the final project, your



Author: Pepijn de Vos



Boost converter

solar inverter. Except maybe if - like me - you tried to analyse the transfer function of an LCL filter, only to find it's a 3rd order filter that does not come in the

"Good grades don't necessarily make good engineers."

nice "standard form" you're taught to solve. Well, better get used to it, because real-world problems seldom come in textbook questions with nice answers.

Boost converter

The boost converter you made in module two probably looks roughly like this. An inductor, a diode, and a MOSFET you drive with the PWM of your Arduino.

"This is an entire different game with new rules, and you're on your own without a rulebook. Good luck."

Now the Green Team Twente competes in a mileage challenge, where every percent of efficiency counts. It also operates at 48v and draws in excess of 100W peak power. This is an entire different game with new rules, and you're on your own without a rulebook. Good luck.

The large current means that in order to keep current ripple in check, you either need a bigger inductor (more resistance, more loss) or increase your PWM frequency beyond what your average Arduino can handle. Okay, so we need something with fast PWM.

But a MOSFET has a relatively large input capacitance, so now we're losing a lot of power in switching. Okay, so we need to use Gallium Nitride (GaN) transistors. (But due to the fast switching, parasitic inductance just became a pain in the neck)

And then there is this innocent-looking diode. Your average diode has a forward voltage drop of half a volt, which at a few amps of current is a few watts of loss right there. Even a fancier diode is no match for the milliohms of resistance in a GaN transistor. But using a transistor as an active diode is Module 2 H-bridge shoot-through current all over again. So in addition to being fast, our PWM con-

troller now also needs to have dead-time to avoid smoke.

And then they told me about the deadline

In the real world there is not always time to do "the right thing", sometimes it is really the case that "worse is better" (Google it). To finish the boost converter in time for the race - the renowned Shell Eco-Marathon 2017 in London - it is going to be a game of compromise, but it's really challenging and fun, so I'd recommend it to anyone passionate about applying their knowledge!

Interested?

The Green Team Twente will be looking for new team members for the academic year 17/18 soon! And of course you can always contact us about anything. Contact us at info@greenteamtwente.nl.



The hyper-efficient (> 850 km/L) hydrogen car of the Green Team Twente, racing at the international Shell Eco-marathon 2016, London. Over 250 teams from all around Europe compete in this competition.

Shooting with EE-sports

As a study association, Scintilla has organised a large amount of activities with a great variety. This year a sports committee was created to add even more variety. Now you might wonder, the typical Electrical Engineering student combined with sports? You mean those activities that make you tired, ugh... This could be noticed by looking at activities like the trainings for the Batavierenrace which were well received but not overly crowded. Luckily there is also a lot of variety in sports and it turns out there is a certain variety of sports the members of Scintilla are greatly interested in, namely: shooting.

On the 21st of March, the EE-sports committee went on a trip to the shooting range of the 'Schietvereniging Enschede en Lonneker'. This association was established as early as 1900 by a man with a most familiar name: van Heek. Besides the family's interest in textile the also had a large interest in the shooting sport. Fueled by their passion (and money) the association grew and switched locations numerous times during the past century, eventually settling upon a convenient location located right next to the Hengelosestraat.

Since it was this close to the the University, going to this location is easier done than said. The next step was to find people that would be interested. For most activities filling 20 slots would require a hefty amount of promotion. Fortunately, about 15 minutes after opening the registration, it could already be closed as all 20 places for a shooting event were taken. Actually, there were twice

as many people interested in this event such that it will be organised again in the near future. Needless to say, there was plenty of interest in this activity and for good reason!

After a short introductory talk by some of the enthusiastic volunteers at the association, the group was split in three and it was time to get shooting. The evening consisted out of three parts: shooting an air pistol, an air rifle and a low caliber gun. My group could follow these in the perfect order leading up to shooting a real gun. Discard everything you know about shooting guns from movies and other fiction, because it is much more than pulling the trigger. Shooting the air-powered guns afforded time to get accustomed to the guns and learn how to aim. It was at this point I started to realise why this is called a sport, besides the competitive aspect, it is also physically challenging to hold up a gun and keeping it completely still at



Author: Mattheijs van Minnen

the same time. This made aiming at the center of the target much more difficult than it may seem. After taking a few moments attempting to line up the sights with the center of the target, you would quickly squeeze the trigger and hope for the best, only to see you bullet hit some of the outer rings. Not exactly what you hoped for, but at least it hit the target. Luckily the air rifles were easy to operate and reload which allowed us to take many, many shots.

At last I got to shoot the actual gun, a .22 caliber pistol.

After a good two hours it was time for our group to venture into the cellars of the building and start putting our newly acquired skills to the test on the shooting range. In contrast to the air guns which you could operate yourself,

the real guns were mostly operated by the professionals (Dutch law makes it difficult for ordinary civilians to shoot actual guns). One of the association's volunteers brought a whole arsenal of weapons which we could hold (unloaded obviously) and also pull the trigger just to feel how the gun reacts. It turned out the volunteer that toured us around was actually an experienced shooter in this branch of the shooting sport. He explained to us how he used a special pistol to be able to shoot faster and more accurate. For this he had made the trigger more sensitive, we could also try this out. As soon as your finger would touch the trigger it would go off, kind of dangerous. Luckily the other pistols did not have this 'useful' function. The last pistol he showed us was a .45 revolver, a real hand cannon. We were told this would be too much for a first try, but he could certainly demonstrate how to operate the gun. One by one we could stand next to the man whilst he would shoot the gun. Remember when I gave the advice not to trust movies? We were given glasses and ear protection and these were totally necessary. Besides the large muzzle flash there was also an ultra



loud bang. Despite wearing the ear protection, the sound was still unpleasantly loud. After this everyone was even more enthusiastic to try it ourselves.

Before stepping onto the shooting range we got lectured on all the rules and things you should keep into account. I won't bore you with all the official regulations, but one important rule is to keep your hand on the grip and not

above it as the sheath of the gun shoots back during every shot. At last I got to shoot the actual gun. A .22 caliber pistol to be exact. A lower caliber means less power and less recoil which is nice for a first try. After putting on the protective gear I got handed the gun and as soon as I was ready, I could take the first shot out of five. After each shot a small moment to regroup and then another shot. Within a few seconds I had fired all the rounds and the target came back. Surprisingly all the shots had hit the target although not in the exact center. All in all not a bad result. After this we could go back upstairs and compare our scores.

We got plenty of time to brag about all the perfect shots we made whilst enjoying a cold beer. The shooting association has gotten their priorities straight with a nice bar in the same building as all the shooting ranges. Slowly all three groups came back to the bar and at the end of the night 2 prizes were handed out to the best shooting male and female. Afterwards we could had another drink and a nice talk with all the volunteers that had great stories about all their shooting adventures. At the end of the night we could go home and dream about this awesome sport activity.



Internship

Since I started studying, I always dreamt of going abroad. Already in my second year I asked the study advisor about possibilities to do part of my study abroad, to combine usefulness with fun. She explained that the internship is a perfect opportunity to do so, as you can spend three months (or more) in the country of your choice while getting credits for it. During my study, I already saw quite some of the western world (Canada and the USA during the study tour) so I decided I wanted to go somewhere totally different: China! I stayed there from September until December last year.

你好 (Nǐ hǎo)!

Begin

I did my internship at *Shenzhen Guohua Optoelectronic Technology Co., Ltd.* (*Guohua*), a company that has strong ties with the BIOS chair at the University of Twente since one of the founders did his PhD in Twente. After a long flight I was met by one of the employees (standing at the airport with my name

on a sign in his hands) who took me to my accommodation and helped me to arrange some necessities. Then he introduced me to some Chinese students working/studying at the company (see Figure 1), who spoke a little English. They helped me when I could not do something on my own and together we visited some places in/near Shenzhen.

After my first day of working, all the employees of the company went to a hotel near the company to have a 'big dinner'



Figure 1: Me and the Chinese students working at the company.

Author: Tobias Feijten



to celebrate International Teachers Day. This also involved a lot of alcohol, as the custom in China is to drink (Bottoms up (or ganbei!)) with someone or with the whole table. The next day, everybody had a huge headache (although I seemed to suffer less than the Chinese). These 'big dinners' happened a couple of times more during the internship, and in the end I hosted one of them to thank everybody.

Assignment

Ok, let's get through the boring stuff... Of course I went to China to do some useful stuff for the company. At Guohua, they are researching display technologies like electrowetting and electrofluidic. The aim is to get these technologies ready for use in products. To get funding and financing, they already made some products not based on this, but in the smart home and mobile sectors. For government funding, they also made some proof-of-concept products.

A new product they want to develop is a small and cheap e-reader, which could be distributed all over China (their



Figure 2: The device for which I developed a text reading application.

dream is for every Chinese child to have one). For this product, I first did some research on the requirements for the hardware to run an e-reading software product. After this, I developed a proof-of-concept text-reading application in C for one of their existing products which uses an e-paper display, see Figure 2.

One of the struggles I had during this development, was that the text, before it could be shown on the display, had to be rotated for 90 degrees. This is not a trivial task in C, as it is a quite limited programming language. I ended up using an open-source image manipulation library for this task, something the Chinese never imagined to do (they just do everything themselves or copy code fragments from the internet, without understanding how it works). Another struggle I had was communicating with the Chinese people (my colleagues), as some speak a little English but most don't. Without any means for communicating with them, it's very hard to find out how their product works. This meant I had to find many things out myself. However, in the end they were very happy with the work I delivered and they even asked me to come work there after graduation!

Holiday

During my internship, I had one week of holiday during which all of China had a holiday as well. I took this opportunity to visit JelmerG who was doing his internship simultaneously in Beijing. My transportation to Beijing was a slow sleeper train, which took about 30 hours. Together we visited the Olympic park and the Beihai park in Beijing. But the pinnacle of this visit was going to an unrestored section of the Great Wall of China, Jiankou, see Figure 3. We had a really hard time finding the right way and had to climb up a very steep hill.



Figure 3: The Great Wall of China, unrestored section.

But, when we reached the Wall and had a great view over the valleys around, it was totally worth it. It felt like standing on top of the world! My return journey to Shenzhen was by fast train, it took only 8,5 hours to go back.

Because of visa issues, I also had to leave the country during the internship. Because Shenzhen is at the border with Hong Kong (I went there by metro...), I decided to go there to re-enter the country. Because it would be the only chance I would get to visit Hong Kong during



Figure 4: Hong Kong

this internship, I asked for some days off to do some sightseeing, see Figure 4. I visited some parks, temples and did a lot of hiking. One of the places I visited was the longest roofed escalator of the world.

After my internship, I travelled around China for a while. I visited some places in the Guangdong and Guangxi provinces: Nanling National Forest Park (beautiful hike along a river with waterfalls), Kaiping (impressive watchtowers built by Chinese merchants after they came back from their travels with a lot of money), Longji Rice terraces (astounding views of hills with terraced rice fields, see Figure 5, named very creatively like Moon and Seven Stars or Five Dragons and Nine Tigers) and Yangshuo (biking region with amazing karst mountains). Since these visits were in the low season, I did not meet many travellers at most places. However, at Yangshuo I met quite some European travellers which was very nice.



Figure 5: Longji rice terraces.

After Yangshuo the time had come to cross the country (my flight home would leave from Beijing) to get to Beijing once again. Here I visited the summer palace, forbidden city, another part of the Great Wall and a temple. After eating the famous Beijing duck, my time in China was over and I had to go back. It was a fantastic experience and I would recommend anyone thinking about going abroad to expand your borders and take the leap! If you have any questions for me, about China or about my internship, please contact me!

tobiasf@scintilla.utwente.nl

RoboTeam Twente

Author: Boi Okken

The RoboTeam Twente is one of the two new student teams this year. It was set up to create a robotic football team, and to be the first University of Twente team to compete in the international robot football league, Robocup.



The competition

Robocup was founded in 1997 as an international competition to promote robotics and artificial intelligence research. The original goal of the project is to create a fully autonomous humanoid football team that can win a game against the most recent world cup winners (of human football), by the middle of the 21st century.

Next to being very approachable for the less technically inclined person (I mean, who doesn't know football right!), it is also a very significant challenge in all kinds of engineering disciplines.

The competition itself is held all over the world, just to name a few: Mexico, China, the US, Australia, Brazil, France and the Netherlands. After the first Robocup in Nagoya, Japan in 1997, it finally returns to this location again in 2017, and that is where we will represent the University of Twente.

The competition is split up into multiple different leagues. Some leagues use standard humanoid robots, whilst in some other leagues all electronics and mechanics have to be made by teams themselves, there is even some leagues with no robots at all! Some leagues are focused on tasks at home, others for

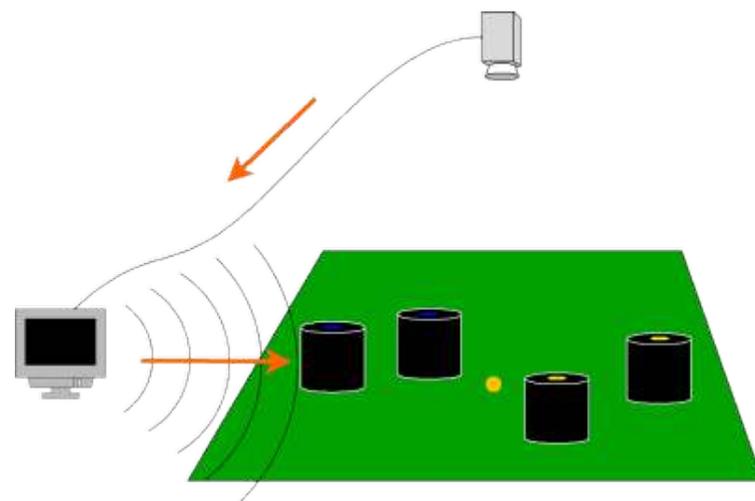
search and rescue, but most are still focused on the original goal of playing soccer. The most famous of the leagues for people in the Netherlands is probably the Middle Size league, because a team from Eindhoven is already competing in it (and doing quite well!). In our first year we will focus on the small sized league.

Small sized league

In the small sized league, two teams of each 6 robots will compete against each other. The robots are fairly limited in size, only around 18 cm in diameter, quite a bit smaller than the middle sized league. Another big difference with the

middle sized league, is that the robots themselves do not have to use a camera, and do not need to come up with a game plan themselves. Instead of finding out where they are on the field, and seeing what they have to do, a computer on the sideline of the field is used. This computer also takes inputs from two cameras hanging above the field. Each of the robots has a specific pattern of coloured dots to identify it. Using all this information, the computer thinks up a strategy, and commands the robots to execute this.

As said before, these robots aren't standard robots you can buy in a store, so everything has to be custom designed. Due to the size constraint, a lot of



system engineering is put into fitting everything together. There is a lot of cooperation between the mechanical engineers and electrical engineers to fit everything together.

Mechanical

On the mechanical side, there are 4 main components to the robot. The first is the chassis, which does exactly what you think it does. It keeps the robot from falling apart. Second are the wheels. We use custom designed omni-wheels. These are wheels that can not only rotate like normal wheels, but also 'glide' in the direction of its axis. This will make it possible for the robot to very quickly move in all directions. The third component is the kicker, which is of course necessary for the robot to shoot. There are two types of 'kicking'. Just a normal straight kick, and a 'chip', which shoots the ball in an arc to pass a ball over the top of an opponent. The last component is the dribbler. This is a drum that rotates, so that if a ball is caught, it will give a backspin to the ball. This way the ball 'sticks' to the robot, so that it can move freely without fear of losing the ball.

Electronics

On the electrical side of things, the robot of course has to move. So connected to the omni-wheels are EC-45 flat brushless motors made by Maxon Motor. In the small sized league you are limited to using brushless motors, since no other type of motor can deliver as much power for its size. These motors of course need a special controller, which is build using an FPGA, which does all the signal conditioning and control loops for all 4 motors. The drivers are made with discrete components and gate drive ICs. Of course the robots have to be commanded from the sideline, so some form of communication is necessary. This is done with a base station, which

used 2.4Ghz to send commands to all the robots. Every robot has a 2.4Ghz transceiver on board, and next to just receiving commands and position data from the cameras, it also transmits back data such as battery voltage and whether the robot has the ball or not.

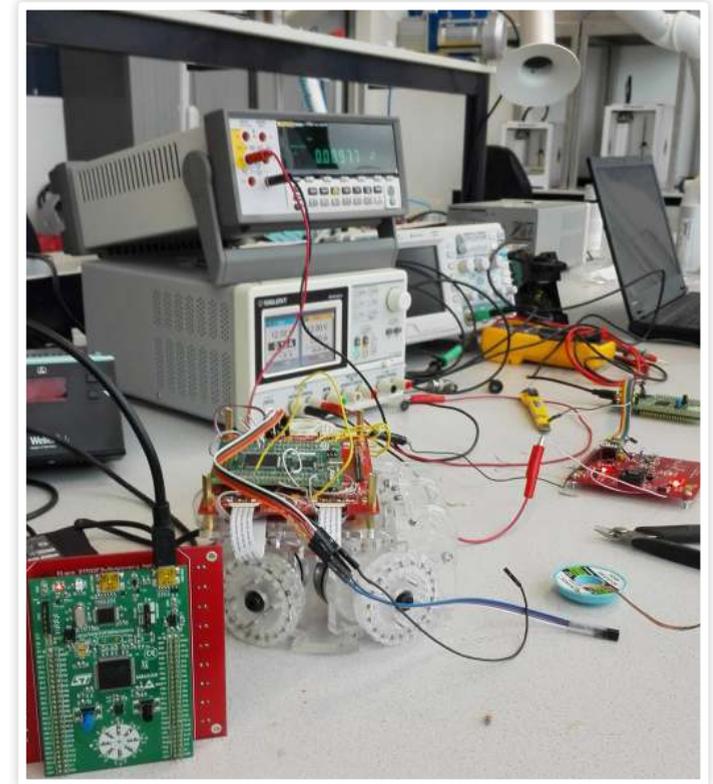
To brains of each robot is the cortex ARM-M4 main processor. This fairly big processor handles the communication with the base-station, but also does the control loops for movement. The FPGA just does velocity control loops on the motor, and the CPU does the velocity and position control loops of the robot as a whole. Next to the camera data from the video cameras above the field, it uses an onboard IMU from Xsens for extra precision and lower response time as well.

As described in the mechanics, the robot has two kickers on board to shoot the ball. The shooting is done with two

solenoids. These solenoids need a high voltage, so that a lot of energy can be released at once into the magnets. This is done with a high voltage flyback converter, which boosts the 12V board voltage up to 380V.

If working in a multidisciplinary team, learning lots of new things, meeting new friends and travelling to faraway places sound like a lot of fun to you as well, feel free to contact us at info@roboteamtwente.nl. You can always contact us if you'd just like to know more about the Robocup, or about what we do. You can also contact me personally as well for a private tour of what we do, just send me an email at b.okken@roboteamtwente.nl and i'd be happy to tell you all about it!

If you are feeling really generous, you can also support our crowdfunding campaign at www.steunutwente.nl.





Prom

Sjaarscie bounce
dodgeball

Parents day

Stellea pole dancing

Sjaarscie glowgolf

Sjaarscie Dutch
game night

Firstyear excursion
AME



Rioting with the Mobile Unit

Why brawling with trained professionals in riot gear is totally unfair and a lot of fun

Author: Friso van de Boom

Let me start off by saying that I don't consider myself a violent person, nor a stereotypical adrenaline junkie. Nevertheless, I thought having a fight with the mobile unit would be quite thrilling, and I was very enthusiastic to join members of Scintilla and Newton to participate in a training day for the Dutch riot police. We were supposed to role-play as protestors, hooligans or rioters, and the police had to deal with us using the appropriate amount of force. Even though it is a training exercise, the batons are very real, and resisting arrest definitely falls under the category 'crusin' for a bruisin'.

I'm not sure why, but this sounded very exciting to me.

This excitement dwindled while I was setting my alarm the night before, as we had to leave at 6:00 with the bus to Ossendrecht. Here, the police academy has a massive training ground with a real fake city center, train station, bus stop and much more. Luckily, we were able to get some sleep on the way there and,

"Even though it is a training exercise, the batons are very real."

upon arriving, were greeted with a cup of coffee. The briefing started and informed us about the referees which could pause or stop the fight for any reason, as well as the actors, who would be on our

side. These actors set the tone for the rioters, and would often rile up the group. Our first scenario was to block a railway using a group of around 30 protestors. So, we sat down on the rails in a large circle with our backs towards each

other and our arms hooked together and started chanting our political opinions. Soon, two officers arrived to assess the situation and to try and persuade us to move our protest to somewhere that is not in front of a train. Their at-



tempts obviously failed. Two officers on horseback arrived at the scene, but did nothing more than trying to intimidate us by having their horses tower over the group.

This tactic also proved pretty ineffective, and after a while the mobile unit ar-

"I don't consider myself a violent person, nor a stereotypical adrenaline junkie."

rived and quickly surrounded us. While our stand-up spokesperson was negotiating with the commanding officer, we were looking up at the policemen (and women) behind their riot shield, but without helmet. The negotiations came to a swift halt as our negotiator, who was wearing a kilt, decided to moon the police officer. I don't imagine he gets to do that often in his everyday life.

As he was promptly dragged away the officer decided it was time to clear up the mess ASAP. He pointed at a rioter who was immediately jumped by three policemen, pulling him away from the crowd while hitting anyone who tried to hold onto him. This left us only one method of defense; lean back and round-house kick anything that comes near, while trying to fend off the truncheon hits to the kneecap.

Although this worked relatively well, we were still losing protestors every minute, and after a while it was my turn to be arrested. However, I was not planning on giving up just yet and, as luck would have it, I found the opportunity to snag a baton and started swinging it everywhere in a desperate attempt to get my damage per second up. This lasted for maybe two seconds before a policeman grabbed my hand which received hits from every direction until I dropped my newly acquired weapon. I tried to use the distraction to make a run for it, but was soon on my face on the ground with two policemen on my back. Since they now had twisted both arms behind my back, I decided my arrest was inevitable and surrendered.

"The negotiations came to a swift halt as our negotiator, who was wearing a kilt, decided to moon the police officer."

The next assignment took place in the center of a small city. We were protesting in front of the town hall, which escalated into a full riot. The police tried breaking us up and fending us out of the town. We fought back by building barri-



ades using pellets and throwing blocks at the police line. The main group was standing in the street face to face with

"Everybody was cheering as the referees ended the exercise and declared that we had conquered the town."

the line, whilst a couple other rioters used the back alleys to flank. We were able to defend the alleyways as there were a number of chokepoints where we could outnumber the officers.

Gas grenades were also being deployed to separate the main group. I saw my opportunity and kicked the grenade back to the line. As it flew away in slow motion, I felt like a complete badass. However, this was over quickly as the line charged forward and I received a baton hit to my thigh as I tried to run away. This replaced running with hobbling for the rest of my day. Nevertheless, we were eventually able to drive the police back until they decided to retreat.

Multiple vans pushed through the crowd to retrieve the policemen, but we had them with their back against the wall. So, while they were rushing to get inside the vans, they were absolutely bombarded from multiple directions. Everybody was cheering as the referees ended the exercise and declared that we had conquered the town. Time for lunch.

We continued that afternoon and after a full day of exercises, we returned to the bus and started the journey back to Enschede. Everybody was sharing stories about their adventures and bragging about the stuff they had done. We arrived on campus right before dinner time, and decided we would definitely be doing this again as soon as possible.

The atmosphere in Eindhoven is great!

Author: Rutger van Anrooij



I would like to begin with a small story of how I enjoy studying and living in Eindhoven. Every day of the week there is something to do at Thor or at another study association. Being a Board member of Thor for a year also made me realize that I do not have enough time to pursue all my interests. You cannot be everywhere at once. You have to divide your precious time in parts that are necessary e.g. studying, doing a part time job and fun, social and sport activities. I will not bother you further with all the details, but dividing your time is hard. Sometimes you can put all pieces of the puzzle together, but mostly you cannot. I would like to tell you a small story when all the pieces of the puzzle did fit together.

There was a Monday, it was not a regular Monday, it was in fact the opening of our celebration week for the birthday of Thor. The week started with eating some pie and a speech of our beloved President. During this week a lot of activities take place. Our activity committee for example organizes a week full of thrill

with your fellow students. Every year there are different weapons and this year the kills would be made with inflatable swords. It also was somewhat different than normal, because they made a special application which could keep score of all the different kills and could handout new targets. After some kills I got the hang of it and as a Board member you are always at the University, so you have lots of opportunities to kill your targets. Having eaten some pie and having fought some battles I returned to the Board room to do some work. It was hard to work and not spend time enjoying this week. So I was relieved that I could enjoy a nice cold beer in Het Walhalla at half past four. I felt great looking forward to this special week, but I was also a bit nervous for one of our last activities. First it was time to go home and have a good meal, which

was a prerequisite for what was to come in the evening. Rick, my fellow Board member, had the same idea and, because

“Having eaten some pie and having fought some battles I returned to the Board room to do some work.”

my student room was closest to our next adventure, we had diner at my place. We were in a bit of a hurry, because we were somewhat late and Rick also had three very important items that were needed for the next activity.

Arriving just at the start of the cantus we were joyful and relieved that we could

start the cantus on time. Rick and me both drank a glass Ad Fundum a bit exhausted but also with pleasure. This cantus was very fun. The Procantor brought us beautiful songs to sing and the Questor had to punish a lot of Thor members for misbehaving. Some even dared to show up an hour late. These gentlemen were kindly asked to keep

“These gentlemen where kindly asked to keep up with the rest of the corona by drinking a liter Ad Fundum.”

up with the rest of the corona by drinking a liter Ad Fundum. After drinking a liter they could also join the corona. This cantus was, for me, the best in recent past and still is up to this date.

After the cantus I still had some energy left for a party. I heard there was a party from another study association. I was under the assumption that all my fellow Board members were joining me as well. I was the first one of us to arrive at the party and I was still under the assumption that they were going to join me. After an hour they still had not arrived and I did not really care anymore. I met an old friend from my home town who studies in Eindhoven like me and I also talked to some new people and some board members of the other study associations. In short it was a great party. This Monday was one of the greatest of this year and I hope more will follow. I would like to invite everybody to have a look at Eindhoven sometime and even visit Thor or Het Walhalla as well.

I will be at the Cantus Scintillae and I hope it will be as great as or even greater than the cantus in my story.

With kind and joyful regards,

Rutger van Anrooij
Secretary of the 60th Board of Thor
Geen gedonder!



Junction

Born in St. Peterburg, having studied there and coming as a post-doc to Enschede, Alexey tells what he has done and how he was as a student.

I was born in St. Petersburg, Russia. There I grew up and studied, and I also did my PhD there. In 1997 I came to Enschede as a postdoc, to work on my first project. After 20 years I can still remember: that project was on the deposition of layers of germanium-silicon. Next, I was involved in an EU project on making novel sensor devices, after which I got a permanent position as a university teacher. That happened in November 2001. I worked a number of years as an assistant professor, doing research, tutoring AIOs (people studying to be research assistants) and doing a bit of teaching. At a certain moment I was the leader of six projects, and after a while I became an associate professor. Nowadays I teach three courses: the master course 'material science and technology' and the master course 'technology' for the NT master, and the bachelor module field and waves, which is a module both EE and AT students follow, but at different times. So with these three courses, all quarters of the year are filled.

What kind of student were you?

I think I was a reasonably normal student. I worked hard during my studies and usually got good grades, mostly an 8 or a 9 when translated to the Dutch grading system (in Russia the highest mark is 5). Of course, sometimes also worse grades. I always did a lot of research, also during my studies. I worked

for a research group and did a lot of experiments. I was a good student, I think. During my time as a student, I also already helped with research that led to a scientific article.

Did you do an internship?

In Russia you didn't do an internship at a company, but you did do an internship with a research group within the university. So I already started doing real research in my 5th year of studying. The total study was six years in my university, and it still is. But I already did research from the beginning of the 5th year, or maybe even since the 4th year.

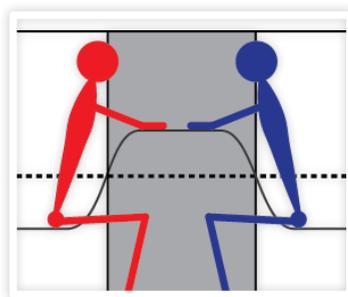
How did you end up in the Netherlands?

I was just looking for a job, so I wrote and sent many application letters. And one of them ended up being accepted. So I just sent lots of letters, and sometimes you get lucky and get a good reaction, and get invited.

What do you think of TEM?

It's not easy for the students. During all the modules, students really have to work intensively. It certainly has its merits, but it also depends on the student. Students really have to take everything seriously. If they don't work hard enough, they fall behind and take longer to finish their studies, or even have to leave the university. But I do think it is a good model. It results in a lot of pressure on the students, but that is a good thing.

Author: Maarten Thoonen



Real life is also hard. The only way to learn things well is to do them yourself. You can't just memorize everything. You have to put time and effort into things to learn them, and that is not easy.

What do you think is the best module at this time?

I don't really know about all the modules, I for example know that module 7, which is taught by my research group, is much appreciated by students. I myself teach in the fields and waves module (and I like that!), which is module 4 for EE and module 7 for AT, but I don't know much about the other modules.

What would you change in TEM?

I think sometimes students really don't get enough lectures. When a subject is genuinely hard to understand, it is hard to figure it out yourself. So maybe some extra explaining and some extra lectures wouldn't be a bad idea for some modules. But other modules are quite good in that regard. It is a hard question. The more you explain, the more it becomes school-like. There has to be a certain balance between a classroom approach

and working independently. There are still things to improve there.

What are your hobbies?

I have little free time, but I enjoy strolling through nature. Other than that, travelling and going on holidays. Preferably somewhere with lots of nature. The more nature the better.

What keeps you awake at night?

Luckily, I still sleep reasonably well, and don't lay awake that often. There are no real issues that keep me awake at night, luckily.

What is your home situation?

I have a wife and two children. They are both grown up now, my daughter is 26 and has already finished her studies. She works for a company in Amsterdam. She is married, and I am a grandpa. My grandson is two years old now. My son just got 18, and thus is still studying.

What would you like to do in the future?

Even more strolling through nature. I genuinely enjoy my job, and have a number of ideas, and I try to put my ideas in to practice as well as possible. I also like teaching, and see it also as a part of my personal development. It improves my own understanding if I am able to better explain concepts to students. So all in all, just keep following the path I am on now.

Do you have a piece of advice for the students?

Take everything seriously, and work hard. You also have to do that in real life. I would advise students make use of all the opportunities students have here as well as possible. So learning certain things, writing reports, writing

scientific articles, modelling, using all the facilities as effectively as possible, to learn as much as possible. That is your

advantage, the amount of facilities that is available to you.



Alexey Y. Kovalgin

Age

51

Favorite food

Lasagna

Favorite Drink

Wine

Favorite Color

green or yellow, also blue, never really thought about it.

Skitilla

It's the first thing you look forward to after the start of a new year. You can't concentrate in class for an entire month, because in your head you're already carving through the snow. This was no different this year, when Scintilla organized a trip to Ramsau im Zillertal, Austria.

We departed on February 17. Our bus drivers, Geert and Harry, brought us to Tirol with minimal delay and enthusiasm. This was a pleasant difference with last year, where we got stuck and had to make a detour due to the weather. Once we arrived in Ramsau, Shing, Wouter and Friso were already waiting for us with breakfast, which we devoured like animals. After storing our belongings in our house, we immediately went skiing in the areas closest to us. Being a transition day, most people were either going home or just arriving, which meant we had the whole slope to ourselves to try and remember how skiing works. After a tiring day, we returned to our home, where we had dinner. After dinner, any party plans for that evening were cancel-

led due to sleep deprivation, and everyone was fast asleep at 10 o'clock.

The location

Ramsau im Zillertal is a very small village in the Ziller valley. This valley contained seven large ski resorts, for all of which we had a pass. Busses and trains were available to take us to any of these resorts, but since they were so big I only had time to see four. Most resorts offered a wide variety of difficulty. The Zillertal Arena had quite some blue pistes, but also had a very black one called the Harakiri. This slope has a decline of 78%, and is the steepest in Europe. Another resort, the Hintertux Glacier, was built



Author: Nahuel Manterola



right on a glacier. It lies at an altitude of 3250 meters, which means the pistes can be used all year. It also means it's way too cold to be there on a normal day, so we only visited the glacier on a very hot day. Fun fact: every large ascension had two cabin lifts in parallel. This is because the glacier is slowly sliding downwards, and every now and then the poles of one of the lifts needs to be moved up again. This means that when one of the lifts is under maintenance, the other lift can be used.

"The leg didn't like this one bit, and asked for an emergency helicopter"

The rest of the week we had quite some adventures. I have learned not to take pistes labelled 'Winterwanderweg', since these aren't guaranteed to keep going downwards, but rather go upwards again on the account of being a hiking trail. Stuck in the middle of nowhere, we made the decision to ski straight



downwards into the woods, since you could see something that looked like a piste deep down below. This decision proved to be an interesting one, and had us hiking downwards through a forest for an hour. A less fortunate adventure started when Pascal's right ski decided not to let go of the shoe in an accident. The leg didn't like this one bit, and asked for an emergency helicopter, which arrived shortly after.

The accommodation

The house we stayed in was a beautiful wooden building which probably out-



dates the invention of the wheel. The bedrooms were cosy and had great beds. They varied in warmth between scor-

"The rooms varied in warmth between scorching hot and ice cold."

ching hot and ice cold, depending on whether the main (wood-powered) heating system passed through the room. A cooking roster determined which team would cook one of Shing's brilliant recipes. Although carefully written down,



the notes didn't stop Sven from adding two full jars of sambal to the food, resulting in a water shortage and several burned tongues. The people responsible for cooking initially had to start two hours beforehand, since the wood-powered stoves didn't feel like providing enough heat to cook anything. Luckily Daan came prepared with two huge gas burners, which made cooking a lot easier. I won't bother to tell you about the misty and icy days, as there weren't many and I'd like to forget about them. All-in all we had a great week. I would like to thank the committee once again for the great planning and organization, and I hope to see you all on next year's trip.

Solarteam

The different phases in the process of building a solar car

Author: Jan Lenssen

My name is Jan Lenssen and I am one of the electrical engineers at Solar Team Twente. I was asked to write something about my experience in the team, to illustrate what we do and what challenges we face during the design process. The last few months we have been busy designing the new systems for our new solar car. Last month our focus was primarily on building and testing the mock-up in February (a couple of weeks ago). The mock-up of our car is an aluminium frame to which all the new components are attached. The mock-up period is one of the significant phases we have in the project. Each of the phases requires a different approach and makes working in the team a dynamic and broad experience.



The design phase(s)

Due to the mock-up phase in February, the production of the first parts had to start a lot earlier than I initially expected. It also showed a big difference in the way of working between the different disciplines within the team. While a lot of design choices had already been made by the mechanical and structural subteams, the electrical engineers were still choosing between different concepts. This has several reasons, but one of the most significant is that the production time of the electrical components is relatively short. This means we can spend more time on improving our designs, making them more efficient. It is important, however, to not forget that all components have to work together in the end.

The offset in phases became apparent the most at the end of the aerodynamic design phase. We ended up with the final shape of the car and had to make

sure all other components and systems fit within it. While the mechanics and structural components were already converging towards their final designs, I suddenly had to take the weight and exact shape of my projects into account. This did not completely come as a surprise, I knew weight was an important factor, but I never suspected having to negotiate for more space for my PCB.

“I never suspected having to negotiate for more space for my PCB.”

We had multiple options such as changing the location of the system, changing the rib structure of the car, or making the PCB smaller. Everyone involved in the discussions had the same goal, making the car as efficient as possible,

but with the pressure of deadlines, it was often tempting to just let the other team members do the extra work. I was never told that there would not be enough space for my PCB, why should I have to fix it? Of course, on the other hand, I could have thought of the available space myself. It was never going to be infinite. I learned that different design aspects are more obvious to different disciplines. The size of the PCB and its components never really was an issue in the projects I did before.

The right way to solve these kind of problems was by looking at all the realistic options and weighing their difficulty and the time these solutions would take. I managed to set some upper limits for the size of my PCB, at that point I hadn't placed a single component yet, and the structural design was changed a little to make sure this upper limit would fit.



A cattle grid in Australia

The mock-up phase

After all mechanical designs were produced, it was time to test them on our mock-up. This testing phase has cost many people a lot of time. Not only did we need a testing supervisor, a driver for the mock-up, a driver for the support vehicle, and our data acquisition, the mock-up had to be serviced as well. This meant that teams worked in shifts, with a test crew during the day and a service crew in the evening. The last group made sure

the tests the next day could start without problems.

As an electrical engineer, my tasks were making sure the battery pack was charged for use and the electrical systems were installed properly. I also got to be test driver for one day, which sounds more exciting than it really is, although it was still fun to do. The driver of our car basically has to act like a machine, only following orders and not doing anything without specific instructions. All this is to make sure the car is always driving in accordance with our strategy and unexpected problems due



Cleaning our workspace at the airport for the mock-up and production

to miscommunications are minimized. During the mock-up phase safety was even more of a concern as well, as all components were new and untested.

We finished the testing phase by driving over a cattle grid multiple times. This is the worst load case for our car in Australia and the route contains a lot of cattle grids. As you can see on the picture, the spacing between the steel bars can be quite large. The car has to withstand the forces when driving across the grid with more than 90 kilometres an hour.

The production phase

At the time of writing this article, the production phase has just started. This means that, from now on, our team will be divided into multiple production groups and a group that will stay and still work mostly at the office. The production groups will return just before the summer. The electrical engineers are part of the group staying in Enschede. We will continue working on our designs at the office and in our workshop at the airport. During the production phase, the first prototypes of the new electrical system will be produced. The production phase for me is a bit more of a mix of production, testing, and finalizing my designs.

The production of the most visible parts of our car, the carbon fibre rib structure and outer shell, will take place at different locations within the country. This is a process that takes a couple of months, which is why it will be a lot quieter in our office. At the beginning of summer, all mechanical components will be added to the then finished body of the car, after which we can show it to the public during our car reveal near the end of June. This is also the moment that most of the electronics has to be finished, as shortly after our presentation the next phase, the testing phase, will begin.

Datasheet

Since students need to have varied meals in order to function properly, De Vonk decided that the magazine needed a cooking column. Since I was the first one to yell: "I ate something yesterday which was really delicious!", I got the honour to come up with various recipes every Vonk! So here are the first 3 recipes. Go to the supermarket, get to the stove and cook!

Old but gold French Toast

Everyone knows that moment when the bread is too old to eat but well, we are students, and so we still eat those last slices. What we can do is we could change the taste! We won't do that with a grilled cheese sandwich because that is what we do all the time. This time, make French toast! It may be tough in the beginning, but don't give up too soon!

Ingredients:

- 2 eggs
- 250 ml milk

- 1 tbsp cinnamon
- 2 tbsp brown sugar
- 70 gr butter
- 10 slices old (white) bread without crust

What to do:

1. Take a deep plate and beat the eggs in it.
2. Stir with a whisk or fork the milk, cinnamon and sugar through the egg mixture (until the sugar is completely dissolved).
3. Get the slices of bread through the egg mixture. Make sure the bread is well soaked. (the big trick is to

Author: Céline Steenge



- have them soaked as much but to not let them fall apart) Stack the bread slices together and pour the remaining egg mixture over the bread stack (leaving the pile for 5 minutes for the best French toast).
4. Heat in the meantime the butter in a frying pan. Once the butter is fully heated, remove the pan from the heat source.
 5. Depending on the size of the pan, put one or two slices of bread in the frying pan. Press them briefly (about 3 seconds) firmly with a fork, then turn it right around.
 6. Place the frying pan back on the heat source.
 7. Bake the bread 1 minute on each side. Turn the toast a few times in the meantime.
 8. Ready to serve

Variations:

- Pour cinnamon, icing sugar, honey, jam and/or syrup on your French toast.
- Pour vanilla custard on the French toast and finish off with raspberries.

Source: <http://www.wentelteefjes.net/>



Can't resist (Patatas a la riojana)

Loving this Spanish dish. It uses the Dutch potatoes, but still it is a lot different from what we are used to. The chorizo gives is the special taste and it is meat so why not!



Ingredients (4 persons):

- 1 kg potatoes
- 400 gr chorizo
- 1 large onion
- 2 garlic cloves
- 2 pimientos choricero or 1 tbsp choricero pepper paste
- 2 red bell peppers
- 750 ml tom 1 l vegetable stock
- 1 bay leaf
- 2 springs of thyme

What to do:

1. Peel the potatoes, wash them and cut them into equal pieces.
2. When using dried pimientos choricero: cut the pimientos choricero in half, remove the seeds and let it soak for 10 minutes in warm water. Scrape the pulp with the help of a spoon or knife.
3. Cut the chorizo into slices and set aside.
4. Heat the oil in a large pan and fry

the onion and garlic cloves until the onion is translucent.

5. Add the paprika and choricero pulp. Stir well for 2 minutes and add the chorizo.
6. Bake for 2 minutes until everything starts to get a beautiful red colour, then add the potatoes and stir well and cook another 2 minutes so the potatoes adopt the red colour and flavour of the choricero and chorizo.
7. Pour in the vegetable stock until everything is just covered and put the bay leaf and thyme in the pan. Leave on a high heat to boil.
8. Turn off the heat again when boiling and simmer until the potatoes are done.
9. Spread over deep bowls and sprinkle with chopped parsley.

Variations:

- Add some beans and/or corn for your daily 200 gr of vegetables ;).

Source: <http://bijzonderspaans.nl/5669/patatas-a-la-riojana-2/>



Mom's input (Arretjes-cake)

At birthdays, we only got a small piece of this delicious Dutch cake and when reading the ingredients, you will understand why. This one is for the chocolate lovers, the guys who want to win a girls heart or for who needs to treat their roommates.

Ingredients:

- 125 gr butter
- 200 gr oatmeal cookies
- 400 gr brown sugar
- 2 eggs
- 4 tbsp cocoa

What to do:

1. Mix the eggs with the brown sugar
2. Melt the butter
3. Break the cookies
4. Mix the eggs, sugar, cookies and cocoa
5. Add the melted butter and mix even more
6. Leave the cake in the refrigerator for a couple of hours till the cake is solid enough to cut
7. Get diabetes and get fat

Variations:

- Add some melted pure chocolate or even some Maltesers!

These were the recipes of this edition. When you feel like sharing your recipes, please mail them to vonk@scintilla.ut-wente.nl!

Afterlife

I had a good time at the University of Twente. I look back at an intensive and interesting part of my life. During my master thesis in 2009 I did not have any time to look for a job. After a well-deserved holiday in Egypt I started looking. It was actually easy to find a job but it was really hard to find a job that I really wanted. So I took my time and had a lot of interviews over a period of about 5 months.

During this time I started to find out which things I liked and which things were really not interesting. At the end I ended up finding my first job at the “Bedrijvendagen” at the University of Twente. I became biomedical engineer at the hospital in Enschede (Medisch Spectrum Twente). Not a bad start since I specialized in Biomedical Engineering. I remember being happy to finally stop studying and going to work instead. Earning money and not worrying about the next exam was very satisfying. I performed risk analyses on medical equipment and this was a really good experience. I attended a lot of surgeries and learned a lot about how hospitals work. I also realized quickly what it means to work at a non-profit organization.

One of the main issues I had to deal with was the lacking attention of medical specialists. Their time schedules were already full, but they had to make time for me too. After 1,5 years I lost interest and was on the lookout for something new. It only took a little time and I could choose between two jobs in Enschede and Almelo respectively. The job in Almelo was found by a recruiter and the job in Enschede was sent to me by a former colleague through LinkedIn. At that moment I realized that engineers in the Enschede area really do not have to

worry about finding a job.

“At that moment I realized that engineers in the Enschede area really do not have to worry about finding a job”

I chose to work as application engineer at Xsens in Enschede. I focused on application support for about 2 years. During this time I more and more realized that I enjoy working with customers and I really enjoy acquiring new customer and projects. So after two years I told my boss that I wanted to move away from support to a technical sales job. I was appointed to Asia and travelled to China, Japan and South-Korea for business development through our distributors in those areas. I really enjoyed this job and was successful. In 2012 I got married so this year I will be celebrating a 5 year anniversary already.

Towards the end of 2014 I realized that my job at Xsens did not provide me with enough inspiration anymore and I did not see enough growth opportunities within the company. I missed

Author: Bernard Gerdes



the technical challenges. For example, I disliked the fact that I had practically no influence on the technical developments on the product portfolio.

In 2013 my daughter Lara was born. My whole life was up-side down but in a good way. All of a sudden my free time was limited and I had to plan everything. I can really say that being a dad is the best thing that ever happened to me. It is more inspiring than any job can ever be. A child is like a mirror, copying every small thing that you do.

“I can really say that being a dad is the best thing that ever happened to me”

Even though I was not even looking for a job yet, I was contacted by a recruiter at the end of 2014. He sent me a job description for a Sales and Application Manager at Tecnotion in Almelo. At that time I just bought my own house in Buurse and I really did not have any time to worry about a new job. However, I was pretty inspired by the job description so I told the recruiter I was interested. This also points out where a recruiter can really make a difference.

Since I was far too busy looking for a new job, I would have never seen the job at Tecnotion myself. I am contacted by recruiters quite often, even though I am really not interested for a change. In a lot of cases I get copy paste e-mails which state that they think I would really fit the job. Then I see that my colleague next to me gets the exact same e-mail. I think the hit-rate is quite low and they just contact every person they can find. Even though, in some cases, there is absolutely no match.

The job at Tecnotion is largely the same as what I did at Xsens, only with a (very) different product. I would describe my job as a technical account manager. However, at Tecnotion the sales person is also involved in product development when it comes to customized customer specific products. This inspired me to switch to Tecnotion.

Not long after I started at Tecnotion I was confronted with the birth of my son in the 23rd week of pregnancy. He was born lifeless. This was a huge loss for me and my family. It was not easy to over-

come such a traumatic experience and learning the ropes at a new company.

I am not the kind of person to sit down and develop something for a long time. I like to travel around the world and see high tech applications and sell products for that purpose. It thrills me to see a successful product in the market with Tecnotion motors in it. Being successful in my job takes a lot of time. In the linear motors market it can take up to 5 years until a prototype product finds its way to the market.

In February this year my son David was born. He is perfectly healthy and happy. Luckily I was able to finish most of the rebuilding in my house, like a new kitchen, a garden house etc. before he was born. With two children the amount of free time is very limited.

Travelling to customers is a big part of my job and I really like it. For me work-life balance is very important. I actively make sure that I spend enough time with my family even though I travel quite often. For example, when I travel to

South-Korea for a week, I take a day off during the week after. Just to do something or go somewhere with my family. This way I make sure that travelling does not get a negative impact on the personal life. Having time for friends is one of the most difficult things for me at the moment. I think that this will change for the better as soon as my son gets a little bigger. Baby time can be quite intense and time consuming.

Tecnotion is going through an enormous growth at the moment. I see a good future for myself and I hope to be very successful and happy. I believe a job should be challenging. As long as this is true, I do not think I will quickly move to another company.

A lot had happened since I got my master's degree. I tried to pick the most important ones for this article. As a conclusion I can truly state that I am happy with where I am at the moment.



Late, Again..

Author: Rik Engel

Being late is an issue we are all familiar with, some more than others. There are people that are almost always on time, people who are on time most of the time and people who are almost always late. During the first module, I fitted perfectly in the last category: I was late almost every day, varying from 5 minutes to an hour in extreme cases and very rarely I would show up after lunch. During module two things changed.



My times of arrival now ranged from 5 minutes too late to not showing up at all, which seems very similar but really isn't. The first few Mondays I was nowhere to be found, the Tuesdays I missed almost every morning and half the Wednesdays were like Tuesdays: me not being present during the mornings. And even when I only missed the morning, I would still be late for the first thing after lunch, most of the time around fifteen minutes. Thursdays I would be reasonably on time, missing the first fifteen to thirty minutes since I couldn't miss lab of course.

will be the same. After a few weeks, I decided to add a third alarm, half an hour after the second as a final chance for me to be on time. This worked sometimes, reducing the time I missed to around fifteen to thirty minutes. Other times I will just wake up at ten o'clock not remembering turning off any alarm or even waking up.

annoying for my lab and project partners, it is also devastating for my grades. Module 1 went fine, only requiring two IEEE resits for me to pass. This module however is not going too well. Missing almost all the circuit analysis lectures and tutorials has my grades being lower than ever and writing this article was basically me procrastinating studying for the next CA resit where I expected to have at least 5 subjects left (I was still waiting on the grades for the first resit). Don't feel sorry though, I should have just gotten out of bed.

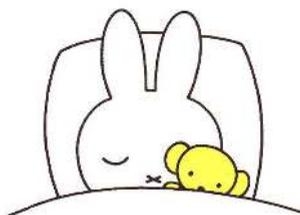
"After a few weeks, I decided to add a third alarm..."

"Life is so much easier when you don't miss half of it because you overslept."

All the excuses aside though, I should just get out of bed when that alarm goes off and I'm working on it (even though I failed miserably at that this morning, my apologies to my project group). I am working on it since it is not only

Being late has always been something I struggled with, I like taking my time and am not the fastest guy around. But never have I struggled this much. To myself and all the other me's out there (of which I hope there aren't many): Get out of that warm and cosy bed of yours, not just so others like you more for being on time, but mainly for your own sake. Life is so much easier when you don't miss half of it because you overslept.

"How?!" you might ask, and that is a reasonable question but I have no good reason for this. Getting out of bed has always been one of my struggles and since I moved to Hengelo (to avoid traveling 6 hours per day) I have a pretty cold room. Getting out of bed is like stepping outside, so whenever the alarm on my phone goes off, I step out of bed press the off button and get back in my warm and cosy nest. Five minutes later my second alarm will go off and my reaction



Puuzle

The puzzle of last year did not result in any correct submissions. So I guess I will share this editions' pie with the committee of 'De Vonk' for all of their hard work.

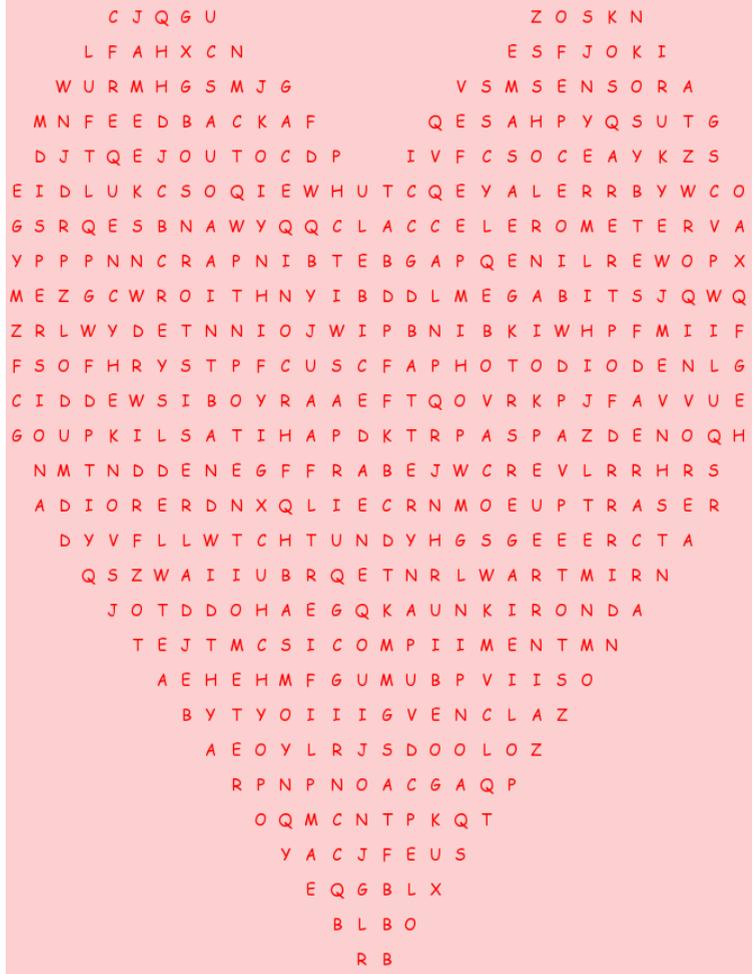
This edition, I wanted to send some electrical engineering love to all our readers.

Did you find all words in the puzzle? Send it to de Vonk and maybe you win a cake next time!

Lots of love,

Truusje

Find the EE words



ACCELEROMETER
BANDWIDTH
CONVERTER
FEEDBACK
HARMONIC
INFRARED
NANO
PHOTODIODE
PROGRAM
SCINTILLA
VONK

AMPERE
BATTERY
DECIBEL
FREQUENCY
IMPEDANCE
INVERTER
PEAK
POTENTIOMETER
RELAY
SENSOR
WATT

AMPLIFIER
CAPACITANCE
DISPERSION
GAIN
IMPULSE
MEGABITS
PHASE
POWERLINE
RESISTOR
SWITCH

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For TNO innovation means demonstrating how significant knowledge is for society, being aware of the latest developments, both now and in the future.

WHERE DOES YOUR CHALLENGE LIE AT TNO?

LET'S FIND OUT



BOB DIRKS

"There are so many opportunities here. The huge diversity of disciplines and projects at TNO means that you're never at a loss for something new to do."

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