MACHAZINE

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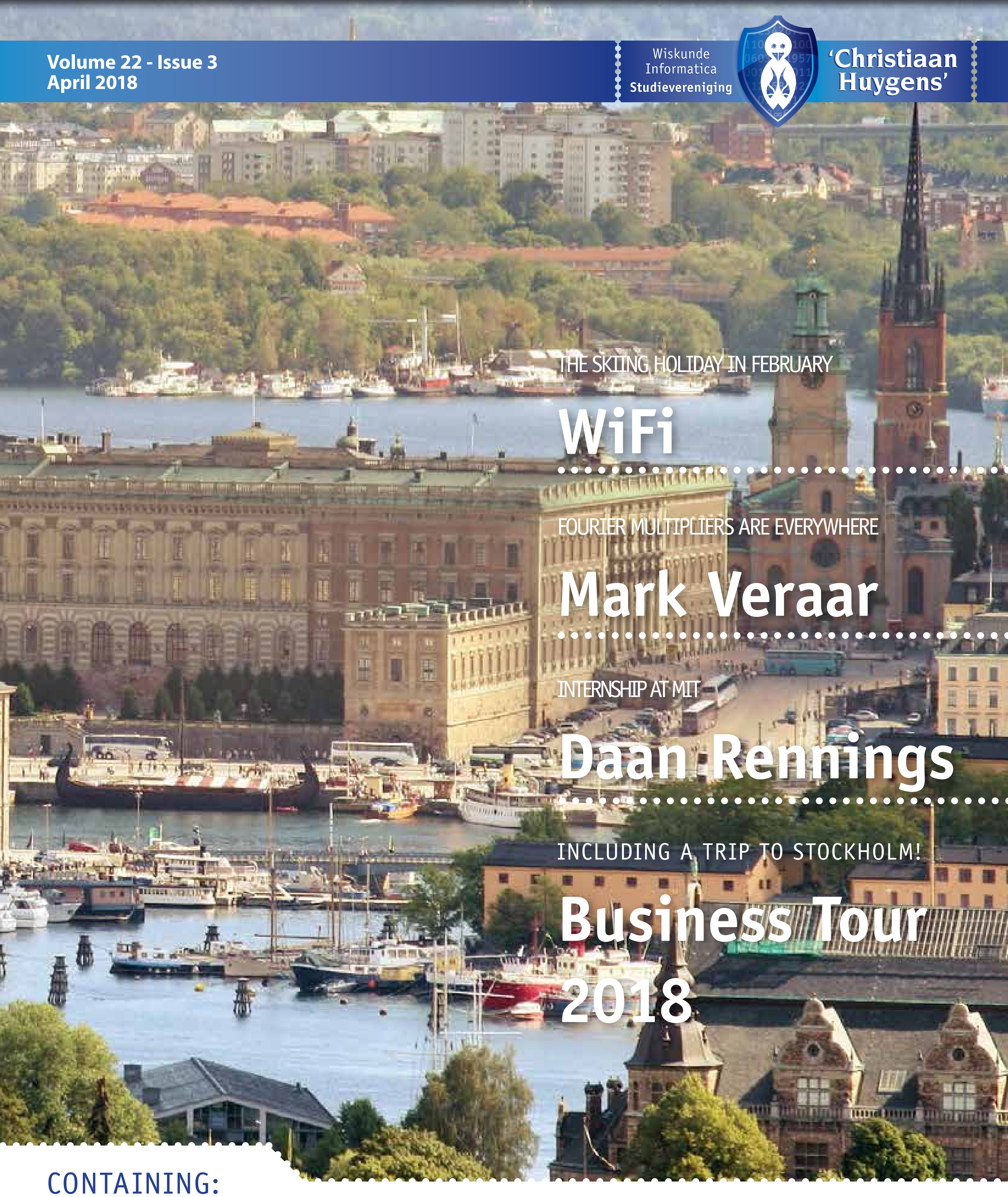
Wiskunde Informatica Studievereniging 'Christiaan Huygens'



THE SKIING HOLIDAY IN FEBRUARY

WiFi

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INTERNSHIP AT MIT

Daan Rennings

INCLUDING A TRIP TO STOCKHOLM!

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Advertiser index

Wouter Versteegh

Dear students, professors and other readers of this MaCHazine,

Recently the local council elections were held, and that meant that we, students, were allowed to vote for local political parties. Personally, I had to vote in Leiden because I was still registered in that city and also left my voting pass at my parents' house. At first, I didn't feel like voting because I had to travel back and forth between Delft and Leiden and also had other stuff to do such as writing this editorial. But then I realized that voting is still important, so I went.

Other story, a friend of mine was on the voting list for the political party STIP here in Delft. I'm not particularly interested in politics, so when he told me, (I didn't even know what STIP was at that time) I was like: 'Oh, well that's cool'. But then when I looked into the political parties in Delft, I was astonished to find out that STIP was the second largest political party here and on top of that, most of the party is made up of students! And that friend just started studying here.

I was surprised to see how quickly you can create a new and exciting environment for yourself.

It was a testament to what your time as a student can mean for you. You leave your old nest to spread your wings to other parts of the world. And with this whole new world comes a lot of freedom and opportunities, such as joining a political party. But there is so much more your time as a student has to offer. This is the time in your life where you can discover, experience and enjoy new things. When I was around 10, I played tennis for maybe 2 or 3 years. Then when I went to high school, I had to drop tennis because I had to choose between soccer and tennis. However, when I arrived in Delft, I wanted to practice some sport of course. I had stopped playing soccer, so this was an opportunity to finally play tennis again! This is maybe a small example, but the message is that you can do what you want. Your student time is what you make of it.

But enough about that serious stuff, spring has begun! That means we are another season closer to the best season: the summer, where we can all enjoy our well-deserved free time. Did you notice that we don't have a single week of vacation from February to July? Only some free days off here and there such as Easter and Ascension Day. But also in a way, lectures are not obligated and you can use Collegerama, so you have vacation all the time.

Well, that was all folks. Now start reading this MaCHazine which is full of interesting articles once again! Read about the recent winter sports vacation that CH organized, the in-depth symposium and the Sjaar-Ciefeest.

See you!

Wouter Versteegh

Also shoutout to the Bende

MACHAZINE


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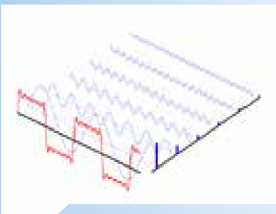


MACHAZINE

From the board

Irene Vooijs

Dear reader,

While I am writing this, I am almost at the end of a very busy week filled with lots of activities, where I've probably seen a lot of you as well: the Dies week. Two years ago, I organized this week with my committee, when it was all about AnarCHy. Some activities where the same; like the traditional reception and dinner, and a lecture about something else than mathematics or computer science. But of course, every committee gives its own spin on the events they organize and try to make them better.

As a Board, we also want to improve the association and the studies themselves. Maybe these things are not as visible as selling books, making sure there's enough coffee and supervising the committees as their QQ'er. As the second Commissioner of Career Affairs there are some interesting projects I have been busy with that you might not now that much about (yet), and I'll take this opportunity to tell you a little bit more about them.

The first project is a career event especially for Applied Mathematics (AM) students. The idea for this event came from the fact that it is not always clear for mathematicians what they can do with their math skills. We had to think about what kind of event would be the best solution to this problem, and we ended up with a Career day. Students can indicate which companies they want to have a chat with, and can also ask for possibilities regarding internships and graduation projects. This Mathematical Career Orientation Day will have taken place by the time this MaCHazine will be delivered, so I'm excited about how it will go and what you think of it!

Some projects can take more than one month, and others even take longer than one year. Two years ago, the idea arose to maintain connections with valuable people from the academic- and business world in the field of mathematics and computer science. These people will be called Ambassadors of the study association. We actually started with asking Ambassadors this year, and at the last General Assembly we had the honor to announce Bas van Staalduinen as the first Ambassador of our study association! If you are wondering who will be the next Ambassadors, I would like to invite you to the next General Assembly in May.

There are also smaller projects or adjustments to events that have been organized before. For Career College, we decided to do an event about graduating. Students who are graduating told us they could have used such an event to get more insight in what different options there are and what it's like. We thought a good way to do this, was a panel of different students with all sorts of graduation projects. The participants were very glad with the informality and the possibility to ask all their questions.

There are much more things I could tell you about, but there is not enough space for all the stories. If you are interested, you can always ask me at CH or in the /Pub, or get informed at the next General Assembly.

See you soon!

Current Affairs

TU Delft News

Wouter Versteegh

The Delft University of Technology is the biggest and oldest public technical university in The Netherlands, established by King Willem II on January 8th, 1842. But what is currently happening in and around the TU Delft? This article will list the most important events of the recent months.

TU Delft at the forefront of innovative education according to MIT criteria

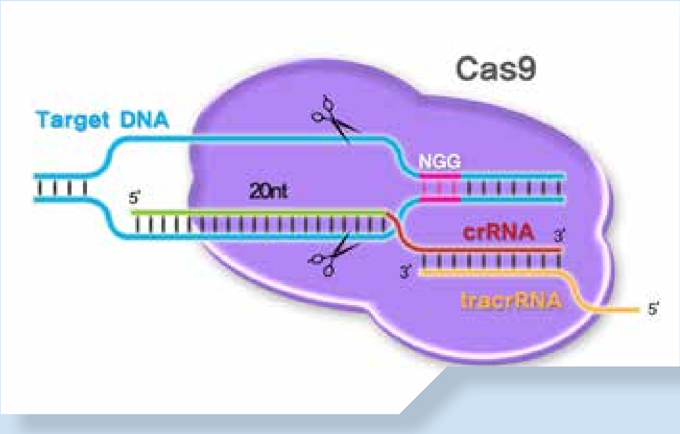
The Massachusetts Institute of Technology (MIT), widely regarded to be the best university of technology in the world, is in the middle of an "educational transformation", and has looked at the ways of teaching at the TU Delft and three other universities. To determine the criteria, MIT analyzed the best engineering education currently available and the education expected to lead the engineering field in the future. Fifty experts were interviewed and made a ranking of the current leaders and future leaders. As a result, TU Delft appears in the top 10 of both lists; 4th and 7th respectively. The factors that lead to the TU Delft appearing so high include innovative degree programs in Industrial Design Engineering and Aerospace Engineering, the fact that the TU Delft offers open and online education, and ambitious successful student projects. Some of the MIT experts also talked about the "Delft spirit"; an open attitude possessed by students and lecturers which allowed new ideas and innovative approaches to develop from inside the Delft community.

Mathematics explain why the Crispr-Cas9 protein sometimes cuts the wrong DNA

The discovery of the Cas9 protein has helped medical science a lot. It made gene editing much simpler and could possibly be used to eradicate many hereditary diseases in the future. Using Cas9, researcher can now cut DNA in a cell to correct mutated genes, or insert new pieces of genetic material into the newly opened spot. In the beginning, Cas9 seemed really accurate. But unfortunately, it now seems that Cas9 also cuts other DNA sequences that are similar to the targeted DNA.

Here is how it works: When a virus enters a cell but fails to take it over, the defense system cuts out a piece of DNA from the virus, and stores it in its own DNA as a kind of memory system.

Whenever the same virus tries to enter the cell again, the cell quickly recognizes it and sends out Cas9, who now knows the vital DNA to destroy. Where it goes wrong however, is when the DNA string that Cas9 checks has mutated too much. If the first few "letters" mismatch the DNA that Cas9 memorized, it is more likely that Cas9 detaches in search for other viruses, even though the virus he checked was actually hostile. A mathematical model using probability developed by scientists at the TU Delft now allows us to predict whether or not Cas9 removes a certain DNA string or when it detaches.



High speed charging of electrical cars using solar panels

Electrical cars are seen as the vehicles of the future, but they are only really sustainable if the electricity used to charge is sustainable themselves and not from fossil fuels. This is why developers and businesses are highly invested in finding a green way to charge electrical cars. Based on a doctoral research, the TU Delft has developed a quick charger together with some companies that can charge cars directly with electricity from solar panels.

What does code sound like?

Felienne Hermans

Reading language aloud

When children learn to read, they almost invariably start with oral reading: reading the words and sentences out loud, not just to demonstrate their newly acquired skill, but also because they simply cannot do it in a different fashion yet. Most children take years to learn to read silently, during which they go through a number of phases including whispering and lip movement. Several studies have shown that, for novice readers, reading aloud supports comprehension. This should not come as a surprise; sometimes when reading difficult English words, I still read aloud! While we do not know exactly how reading aloud helps, the fact that it does is often attributed to the fact that reading aloud focuses your attention to the text, and thus makes it less likely that you will skip letters or words.

Why do we not read code aloud?

This made us wonder, why do we not practice to read code aloud? In the same way that reading text aloud helps to understand meaning, so could reading source code! We call this idea code phonology. Settling on a phonology could be more challenging than you think, even for simple statements.

For example, how should we pronounce an assignment statement like x = 5? Is it "x is 5"? Or "set x to 5"? Or "x gets 5"? And what about an equality check? Is it "if x is is 5"? Or "if x is 5"? Or "if x is equal to 5"?

As you see this could lead to tantalizing discussions!

A first experiment

To get an initial idea of how children even read code, we had 10 Dutch high school children read a bit of Python. These children all had some programming experience, including some Python. The code contained assignments, loops and conditions. Reading the code[1] in a consistent fashion proved a daunting task to our 10 participants. All of them read at least one symbol, keyword or variable in an inconsistent way! Some of the things they struggled with were:

Symbols

One of the things that the children clearly struggled with was reading symbols (symbols included were: (,), ==, !=, <, += and =). An interesting vocalization (which we hardly ever encountered with professional developers) is to say == as "is is", which 7 children in the experiment did. There were also other ways that the symbols confused the children. The symbol < was vocalized in many different ways, including "smaller than" and "lower than", but also "arrow" or "bracket", or skipped entirely. One participant struggled specifically with combinations of two symbols like != and ==, and systematically only read the first symbol. This behavior is likely to be influenced by their experience in mathematics where there usually is only one symbol, and that carries over as an assumption into programming. In a different experiment, we observed the same and asked the kid about it. He said that he indeed saw the two = symbols but assumed it was a typo, since "'is is' is nothing". That nicely stresses how important it is to draw attention to this type of differences and help children learn what they are!

Natural language effects

This experiment was made extra interesting by the fact that we did it with Dutch kids. We observed them choosing between Dutch and English for keywords and variables, for example saying "wheel" rather than "while". Two children spelled out if in Dutch, saying it as "ie-ef". The most interesting natural language effect though was on the variable i. In Dutch, i is read as "ee" as in "to breed". In English of course it is read as "ai" like in "fry". Just one child pronounced the variable in a consistent way (the Dutch way). The other 9 all mixed the Dutch and English vocalization, sometimes even within the same code block. A different effect was that on word order. One of the subjects changed the order of the words to form a proper Dutch sentence. Rather than saying "if temperatuur is 20", he said "als temperatuur 20 is" which is grammatically correct.

Syntactic versus semantic level

Some children read things that were not technically in the code, adding meaning. One participant read "for i in range(0,15)" as "for i in a range 0 comma 15", adding the meaning that the numbers occur in a range and making the sentence more like a sentence in natural language. Another participant read "def kwadraat(x):" as "def function kwadraat x colon" adding the meaning that this is a function definition. That might be good practice for novice learners, or a hint to language designers that function is a better keyword.

Summary

In the exploratory study we have seen confusion over how to pronounce source code, confirming our hypothesis that how to read code is not a given. We observed students struggling with reading keywords, pronouncing variables and symbols. Even though we did not explicitly measure cognitive load in our experiment, it seems that students were spending energy on deciphering symbols, such as < and ==, on what to read and what to skip, and on choosing between English and their native language. Cognitive load theory suggests that to free up mental room for more complex thoughts, easier processes must be automated. For example, before reading full words at once, children first automate the skill of reading letters. Before being able to process large multiplications, children need to have automated additions. Maybe we should automate how we read code too?

Some shameless marketing: Should these things interest you... in Q2 I will teach a new course called the psychology of programming!

[1] https://pastebin.com/n36Upp1p

English, please!

Fred Vermolen

Nowadays there is a tendency that more and more education at the Dutch Universities is offered in English. Is this a good or a bad thing?

To attract more international students, universities tend to offer their educational programs in English more often. The Delft university seems to be very successful in this sense because the number of international students in Delft is increasing. Of course this is a good thing for the university, but one may wonder whether this trend is beneficial to the country, or to the Dutch taxpayer. In the Netherlands, we want to uphold our high standard of life. This is necessary since the population is aging and more technology will be needed to get necessary things (such as medical care) done with a decreasing number of working people. Having less turnover from our gas reserves, we have to remain an exporting country in order to be able to maintain our high living standards. Among many other things, The Netherlands export a wide variety of vegetables, flowers and other agricultural products. This can be done thanks to the development of high-level technology, which should also meet international agreements in the wake of environmental and climate targets. Hence the export of agricultural products flourishes despite the fact that our country is so small and over-crowded, and despite our miserable climate. Therefore, it is crucially important that our country remains at a competitive level regarding technology, science and education. Hence an excellent educational system is indispensable for The Netherlands.

To keep on hovering near the global summit regarding technology, I think that The Netherlands need an influx of skilled people from abroad. It is a good thing to see many international (Chinese, Indian, ...) students in my courses. It would be even better if the best students among them remain in The Netherlands and help us maintain our international high standard in science and engineering. For this reason, I understand well that English has become crucially important in higher education.

Policies are directed towards a shift of language into English. However, many (and particular the relatively old) lecturers may not be good enough at English. Wrongful, and even confusing, literally translated Dutch expressions may be used during the lectures (funny example: In Dutch one uses the literally translated version of 'There is a little viper under the grass', which is Dutch idiom for 'there is a catch'; the expression 'a snake in the grass' should be used in a different context). Another issue is the very bad pronunciation of English by some professors and lecturers. Does English help improve the education of the smartest portion of our younger generations in this case? I wonder whether English will always help. I do not think that it always makes sense to use English in higher education. Consider for instance studies like Dutch Language and Literature, or Dutch Law. Our legislation has been formulated in the Dutch language, which makes perfect sense since Dutch is the official language here. Or look at the study Dutch Language and Literature, where a student was to submit his end-thesis in the English language (it really happened!). A natural advantage is that international readers can read the thesis and familiarize themselves with the (recent) discoveries and developments in the Dutch language. On the other hand, I wonder why a foreigner would be interested in the newest developments of Dutch if (s)he is not able to read or understand Dutch. I like to get familiar with foreign languages like Spanish or Italian, but on the other hand, I know my limitations regarding my skills in these languages very well. The latest developments in these languages are not interesting for me at all without having a solid basis in these languages (which I do not have). Therefore, I conclude that it does not make any sense to require an MSc-thesis about the Dutch language to be written in English unless you are studying in an English speaking country. Imagine the English exams these students in Dutch language have to take. Ridiculous!

Since we are providing education to international students, one may also argue that we are actually jeopardizing our leading position in science and technology. The reason why I am mentioning this issue is that it seems that most of the international students return to their home countries where they can help develop their home countries and help getting their home countries at international competing level. Of course, it is a good thing that Third World countries acquire more skilled people so that they can provide their people higher life standards. Further, many Dutch students also travel abroad to study at various good foreign universities to bring back new expertise to The Netherlands. But we should also realize that we are also helping other countries compete with The Netherlands. On the other side, one could argue that it is a good thing to have good competitors so that science and technology can reach higher levels. Hence, having a high level competition will be beneficial to humanity.

Furthermore, education in English will eventually create generations of students who do not know the Dutch translations for concepts like 'derivative (afgeleide)', 'anti-derivative (primitieve)', 'root (wortel)' and so on. This will also internationalize the education provided at secondary schools, where students also can choose between a bilingual (English-Dutch) program and a Dutch program. Also in this case I wonder whether teachers, in for instance mathematics, are sufficiently skilled in English. I know that in some cases teachers from English speaking countries are employed at secondary schools. This is good for the pupils' skills in English and also good for the internationalization of the Dutch market. English is getting more and more important in The Netherlands. Skills in other languages like French and German are, however, declining in The Netherlands. I often see Dutch people talking English to Germans, while German is much closer to Dutch than English. I find this a strange development. Possibly we will eventually abolish the Dutch language in The Netherlands, because of the large influx of foreigners. From a practical point of view, this would be the better option compared to keep maintaining Dutch as the official language in this country. Also, in the wake of the current large influx of immigrants from Africa and the Middle East, it is probably better to abolish Dutch in The Netherlands. We do not have to invest in Dutch courses any longer. This could save a lot of money.

I am sorry that I bored you with all this, let us change to beer öl, and other alcoholic beverages, skål!

Current Affairs

Association

WiFi... always stay connected!

Simone Vis

As a second-year student at study association Christiaan Huygens, you have the opportunity to do various committees. I myself was asked last year in October for the committee the WiFi. Together with 5 other second-year students and a member of the board, we organize 3 major events: a party, the skiing holiday and a rally. Every week we meet during a lunch break and it does not cost you more than 3 hours a week. Moreover, it is a very nice and useful experience to join a committee.

At the first committee meeting, the member functions were divided. So, you have the standard functions as chairman, secretary and treasurer. We then have one commissioner for publicity, one for logistics and one for planning.

After everyone was officially assigned, the first activity was scheduled in November: the party. We had very little time to arrange everything, on top of that the advertising started late as well. But fortunately, it was still a great success. After some brainstorming we had our theme "Beware escalation ahead". Soon we started working in Photoshop to make posters and tell people about the event. The party was in (disco)bar Steck in the center of Delft.

A few days before the party, there still was a little stress, because we had only sold 80 tickets. Luckily there was a lot of interest for the tickets during the last few days and we managed to sell more than 200 of them. The day before the event we went to a store to buy decorations and an outfit.

Just before the party, we ate a good full plate of pasta together at someone's home and afterwards it was time to cycle to the Steck. Thererwe had to wait in our bright orange colored safety vests for the first partygoers.

At half past 11 the Steck slowly filled up and 'escalation was ahead'. The drinks flowed richly over the bar and the party was on. The ones who had a little more trouble getting up the next day, could at least look back on a successful party.

Then it was time for our second activity: the skiing holiday, which is called the wispo. After an evaluation of the party, we immediately had to organize the wispo. We had to think of a theme, order sweaters for the participants, think about games and much more.

After some fumbling in Photoshop, we had a nice design for the sweaters. The theme was the "Olympic Wispogames" because just after the wispo, the Olympic Winter Games would start in South Korea. With some handy French phrases for beginners, a crazy 66 challenge and a ski map of the area, the information booklet for the participants began to take shape.

At the pre-wispogettogether we presented the theme and the room layout. Then, after a long time waiting, the end of the exam week was finally in sight. We left Friday evening the 2nd of February with almost 50 people to the village Risoul in the French Alps.

After a 17-hour bus ride with little sleep, we arrived in Risoul early on Saturday morning. There was a lot of snow and the sun was shining. That meant time for a terrace with beer or hot chocolate. In the evening we played games and we all went to the Jeti bar below our apartment complex. And finally, around three o'clock, everyone was laying in their bed deep asleep. Eventually ringggg ... at 8 o'clock in the morning our alarm went off again (our room was pretty fanatical when it came to skiing or snowboarding). Still sleepy, we got dressed in our ski clothing and ate fresh bread from the bakery. At half past 9 we were standing on the slopes while some others were still snoring in their bed. The grandmother of the chairman had made bright orange capes for us so that we would be well recognizable in the ski area. We wore our orange capes on the slopes every day and went down like real heroes (at least that's how it felt with our capes flapping in the wind). The weather was beautiful, and it was a perfect first day. After a day of skiing or snowboarding, many of us gathered at the Jeti bar for the Après-ski. The music was on and from all sides people sang along with the music as loud as possible. With a beer in the hand and our Husk beanies on our head everyone was dancing on the tables. Some drinks and songs later it was time to cook. Like real students, we cooked pasta with vegetables and some meat. It was simple, but that is what you as a student need to accept when you go on a ski holiday with other students. After dinner we usually went to the other CH rooms to tell what was planned for the next day and to see if there were any problems. We, among other things, organized a beer relay and a sleigh race. Fortunately, everything went well. Then the evening program started again with games, lots of fun and many of us ended up in the Jeti bar again. The study association of physics of TU Delft and a few other associations, like us, also went to Risoul for their winter sports holiday. You could say that Risoul became a small TU Delft party. So, every day of the week repeated itself. EAT, SKI, PARTY, REPEAT!

Wednesday afternoon, we made some time for the group photo on the mountain. At half past 3 we gathered at the top of a certain ski lift. After a while everyone was there and in the last sunrays we took a picture with a beautiful view. That evening we went out for dinner in a fine restaurant with the whole group. In our best French we tried to understand the waitress. After only a few minutes everyone had the right dish before their nose and everything tasted delicious. We enjoyed our meals after which it was time to party again.

After a week of crazy challenges, lots of skiing and snowboarding, parties and little sleep, it was Saturday evening and time to go home again. Dragging our huge backpacks, we walked back through the snow to the bus. On Sunday afternoon we returned to Delft. While looking back on a great wispo, everyone cycled back to their homes and everyone probably dived into their beds to sleep, because everyone was exhausted.

At this moment we are organizing our last activity. After some consultation, we decided to organize another rally this year, just like last year. The rally will take place in the Ascension weekend in May. For those who do not know what a rally is; at a rally you drive in a team in one car to a certain location. You can only discover the route to this location by solving puzzles. The first one to reach the location wins the rally. At this moment we are making funny complicated puzzles to (mis)lead everyone to the location. We already have a location in mind, but that is of course still a secret. All you need for this activity is:

1. A nice bunch of friends with whom you can survive 2 days in a car.

2. A driver's license and car are certainly handy.

3. And lastly, some brains to solve the riddles.

So, looking at all the activities the WiFi needs to organize, it is therefore a busy but very instructive committee. Besides the fact that you organize things for your fellow students, you also get to know a lot of new people from different study years. To get some experience with committee work and to have an awesome time, the WiFi (or any other committee which seems fun to you) is definitely something I recommend.

SjaarCie Party

Karel Bouwmeester

After weeks of careful deliberation and intensive preparation, the biggest party of CH was finally here: the annual SjaarCie party, organized by yours truly. The SjaarCie party occurred on the 21st of February from 10pm until 4am and was curated by a committee of freshman students (if you're wondering why it's called the SjaarCie: the Dutch word for committee is 'commissie' and the word for first years is 'sjaarsch' thus the combinative name SjaarCie). The party was meant to be for everyone, including people from different studies, by us.

The party was held in the Bierfabriek and attendees were able to buy tokens with which they could buy consumptions. The night was a lot of fun with a lot of different types of people attending, despite the obvious majority being applied mathematics or computer science and engineering students. We also

had a couple of different DJ's— including the one and only DJ PJ— each with their own style, so the music varied a lot too. This also helped in maintaining a fun vibe so the party didn't become a monotonous bore.

Preparations for the party proved to be a lot of effort from everyone involved. We had to obtain a location, decorate the location, arrange DJ's, do promotion for the event so people would actually want to come, sell the tickets, and make it at least look like we're having fun! This may not sound like a lot but it can be quite tough when you're given a budget. Of course the board of CH takes good care of everything so they gave us enough money to arrange everything. In order to plan all of this we met weekly in EWI (the TU building for Electrical Engineering, Applied Mathematics and Computer Science and Engineering). Intense discussions were held about what we wanted to do with check-off items, including things like who we wanted to have as DJ, who we wanted to have attend our party, etc.

When all of our plans finally came into fruition and the party began, all went well and the party was a great success! A lot of people seemed to have a really great time, and there were no complaints from people about the lack of certain desirables. The music was fun, people were having a good time, and the party really was going quite well.

That is to say, downstairs. Concurrently, upstairs there was a lot of chaos. This was all due to the wardrobe not having been handled with quite as much care as could have been. A lot of coats were missing and everyone was running and trying to look for astray coats, sweaters, scarves, and the like. This luckily did not translate into ruining the mood downstairs and seemed to be completely separate from the rest of party. Not all of it was easy fun. We all had a few tasks to fulfill, like selling tickets outside, for people who decided last minute that they wished to attend, or having to manage the wardrobe, or tending the vodka-slushy machine. Yes, you read that right, the vodka-slushy machine. As a little treat for our guests we made vodka-slushies for the first 100 people to arrive. Of course this was only for people over 18, so the first few after the first hundred managed to get lucky and still get one. The slushies proved to be a problem at first as well because when the clock struck 10, the substance inside the machine was way too watery still and not yet the fine, thicker substance it was supposed to be.

Problem after problem having been solved, challenge after challenge having been faced, the clock struck 4am, and the party was over. The last remaining people were asked to leave and all of us from the SjaarCie committee were left to clean in a daze of ecstasy. After coming down from the high of the amazing festivity, having cleaned everything, having sorted the last few remaining items and the like, we left the vicinity. Content with ourselves, and how the night had went, we left for bed and let the employees of the Bierfabriek do whatever their rules tell them to do after such an occasion.

All in all there were quite a few obstacles for us to tackle but we managed to get through them all as a team and to say that it was fun would be an understatement. Now it's onto the next event: the BBQ!

Organizing a Department Symposium

VerdiepCie 2018

You all probably heard of the Department Symposium. Such a day isn't organized by itself. We've got the VerdiepCie for that! Organizing such a spectacle, happens with the six of us, with our QQ'er Marc. How this works might be a mystery for some, just like all the floors of EEMCS!

Of course we have a meeting every week and we have lots of fun. Besides all the fun, the Oud-VerdiepCie dinner and reception, we also have to get serious. This means we have to send (many) e-mails to make sure there are enough lecturers on the big day to tell you all something about their department. That way you can get to know more about our great faculty and make a profound decision for your minor!

Furthermore we look for some nice clothes, so you can recognize us in an instant and of course some nice original presents to thank the lecturers. We also have to arrange drinks and food for all the visitors, which we do a few days before. Moreover, on the big day itself is a big task to make sure everything goes well. We have to make sure there are enough breaks, the lecturers have enough time and we have to act fast when something unexpected happens.

How did it go this year?

This year the Department symposium was on the 13th of February on a Tuesday. It began at around 9 o' clock at the halls Boole and Pi. Lots of you were present on this early morning. The lecturers talked about their departments, from optimization to quantum computing. There were also presentations about the bachelor thesis, for everyone who wanted to know from a student how it works and what is important. After the presentations there was a lunch in the /Pub where you could have some delicious sandwiches and beverages.

Additionally, there was a second part of the symposium at noon about the master studies and was organized by the Marketing & Communication division of EEMCS, which we assisted. Here you could get to know more about the different tracks of the Master. There was information about the tracks specifically and also some general information about the Master itself.

Altogether it was really fun organizing the Department Symposium of this year and we hope next year it will be an even bigger success!

Kind regards,

VerdiepCie 2018

David Sarkisian – Chairman
Raoul Bruens – Secretary
Marijn Waaijer – Treasurer
Maaike Visser – Commissioner of Computer Science
Jette van Schoor – Commissioner of Mathematics
Marc Corstanje – Qualitate Qua

Sioux creates a fully digital workflow

Sioux

3D models are widely popular in various applications and the demand for their automatic handling is increasing. Sioux software and mathware engineers have teamed up to develop an extension to an existing application for a customer in the orthodontic domain. This customer digitizes dental impressions for orthodontic and dental applications. The impressions are scanned directly into a computer avoiding very dusty and labour consuming step of plaster models production. The specialized viewing software is developed by Sioux. Apart from 3D models viewing, it facilitates measuring, manipulating and reporting. One of the important features added by Sioux is fully digital workflow to create aligners ("invisible braces").

Invisible braces

Transparent orthodontic aligners can straighten a patient's teeth without the use of wires and brackets of traditional braces. The aligners consist of a sequence of clear, removable trays that fit over the teeth to straighten them (image 1). They must be worn daily for a period of two weeks, before moving on to the next tray.

Digital workflow

In order to create aligners, the individual elements (teeth and molars) of the digital model should be separated from the jaws, so that they can be manipulated (translated and rotated) into their desired position. When the user has modelled this set-up of multiple aligners, the jaw and the individual elements on the jaw are then again combined into one model. These combined models, one for each aligner, are exported as STL files, which are then used to create 3D-printed models. On these 3D-printed models, the aligners are formed by a deep drawing process.

The challenge in this development process is the design and robust implementation of a full-automatic tooth recognition algorithm and combine it with fluent manipulation and intuitive tooling.

Creating a segmentation algorithm|

It's important to segment a patient's teeth to accurately set-up a reliable dental model. This should involve as little manual interactions as possible. Teeth occur in different shapes and their arrangements vary from one patient to another. A 3D surface model of the patient's teeth is represented as a mesh: a set of vertices, edges and faces. An automatic algorithm needs to assign labels to each vertex; each tooth or molar should get their own label, and all other vertices should be labelled as "gum".

When the orthodontist looks at a 3D jaw model, the hollow (concave) areas give him an indication about the boundaries between teeth and gums or two neighboring teeth (Image 3). This inspired Sioux to use mean principal curvature as a cost function for further segmentation. In order to improve the robustness of the noisy data, the curvature is computed for parabolic neighbourhood approximation.

The user starts the segmentation process by placing a seed point on each tooth and some seed points on the gum. When all seed points are placed, the automatic segmentation algorithm can start. The algorithms labels all non-seeded vertices based on the original set of labels and seeds. The challenge is to extend the segmentation tools on a 3D surface instead of a 2D surface. Two classical techniques are particularly useful in this case: flood fill and random walker.

Random walker's main idea is to determine the probability of a random walk starting at the certain label to reach the non-labelled vertices. The label with the highest probability gets assigned. Mean curvature is used to define probability to be able to walk from one vertex to another. The drawback of the approach is a need to do manipulations on NxN matrix, where N is a number of yet non-seeded labels.

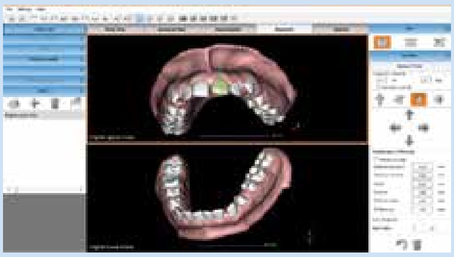
Advertorial

In order to decrease complexity and computation time, the flood fill is an important and linear in N step. The flood fill allows us to grow original manual seeded areas safely: if neighboring vertices is almost the same as already labelled one, it gets the same label. Similarity in our case is defined by flatness: we do not propagate labels through curved areas.

The resulting segmentation requires cleaning up steps with additional mathematical and implementation challenges, i.e. boundary smoothing.

Digital modelling saves time and effort

When the automatic segmentation process is finished, the user can make some manual corrections to the segmentation result before proceeding to the set-up step. In the set-up step, the user can select each individual tooth or molar, and manipulate it in any of the six degrees of freedom. When the user has created a set of (usually 4 to 6) aligners, they can be exported as STL files and sent to the laboratory where the models will be 3D-printed and used to manufacture the clear aligners. This new digital workflow saves orthodontists a significant amount of time in modelling a patient's aligners and improving their overall experience.



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The Business Tour

Business Tour Committee 2018

On the 19th of March the triennial Business Tour finally commenced.

Thirty Applied Mathematics and Computer Science & Engineering students

of W.I.S.V. 'Christiaan Huygens' and 2 professors set off to visit 9

companies in 5 days and end the week in the lovely city Stockholm. An

intense but very worthwhile trip!

After months of planning and organizing, a pre-activity in March where the participants could already meet one another, and a good night sleep, the Business Tour group convened bright and early at EWI on Monday morning. After giving our participants a goodie bag and some practical information, we embarked on what was going to be a very busy week.

Visiting the companies

Throughout the week our schedule was steady: each day consisted of 2 company visits, one in the morning and one in the afternoon. At night we stayed in a hostel either in Diemen (near Amsterdam) or The Hague where we could discuss the day with each other, make use of the hostel happy hour and play (board-) games. The mornings were filled with early breakfasts, last-minute bag packing and frequent (goodie bag provided) Smint-eating to mask the beers of the previous night, before eventually getting on the bus off to the two companies of that day.

At the beginning of the week a lot of adjusting had to be done. Getting used to waking up on time, visiting two companies each day (each with an intense program consisting of presentations, tours and cases), and finding the balance between being social with the other participants and getting enough sleep. Fortunately, everyone's enthusiasm and eagerness to "get inspired" got them through the week.

The goal of the Business Tour is to help (master) students find a company for an internship, thesis project or to start their career. During a company visit we got to know the company formally, through a presentation, and informally, through a tour or talking with employees during panels and lunch or dinner. We got to know their different company cultures, why people applied and stayed, and how each company envisions their future.

Our theme, "get inspired", was aimed at offering a variety of companies in different fields and encouraging the participants to be inspired by companies they might not have previously considered. We visited KPN, Bol.com, Adyen, Optiver, ING, Deloitte, Deltares, Fox-IT and Shell (in that order), providing a broad range in topics such as consultancy, finance, cybersecurity and research.

During the different cases and workshops, we also got a taste of the different problems these companies encounter and the different technologies they use. This ranged from designing use cases for new technologies like Blockchain and Artificial Intelligence to practical issues like testing our fast decision making when trading options or coming up with feasible polder management solutions for farmers in Bangladesh. This resulted in learning different approaches and ideals both from the companies and from each other.

Even though the companies participating in the Business Tour were as diverse as possible, they clearly had one thing in common: buzzwords. Not a day would go by without a company talking about agile working, blockchain, sustainability, AI, 5G and so on. The frequent occurrence of these buzzwords led to the creation of the BT-bingo: a bingo with a very high win rate.

Stockholm, Sweden

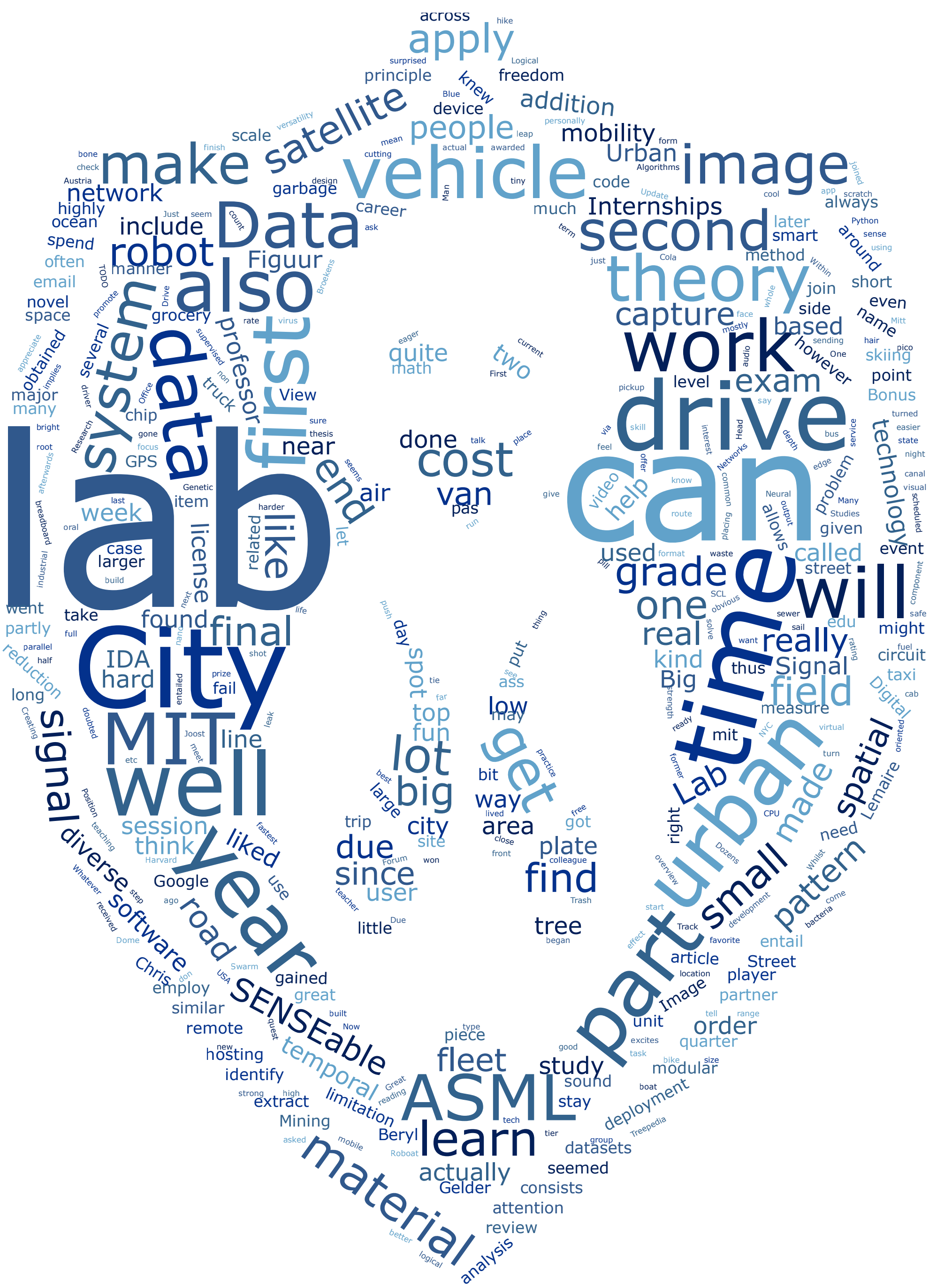
You could already sense it on Thursday, but by Friday everyone's energy sources were close to depleted. Luckily, we still had our weekend trip to Stockholm to look forward to, which brought the life back into the group!

After a late-night flight, everyone got up early on Saturday to do some sightseeing before we would meet for lunch. Some even went for a morning run! After meeting up at food hall K25 for a delicious lunch, we left to Kista Science Centre; the so called European Silicon Valley. There, we enjoyed an interesting presentation about the science center: their incubator, connections to the largest tech firms in Sweden and e-Government lab. As a bonus, our guide taught us about the history of Stockholm and current workings of the city. Many participants were impressed by the possibilities and what is left to see in Stockholm and want to go back!

Our last group activity was experiencing the Stockholm nightlife that evening, despite the early check-out the next morning. Luckily, we had some time left to walk around the city on Sunday before our flight back home.

It was an intense week with a packed program and short nights, but it was fun and worthwhile. Each company was interesting in their own way and we all learned more about what to expect when starting your career. We definitely got inspired but it wouldn't have been such a successful week without the enthusiastic and reliable participants. Thanks again everyone, we (literally) couldn't have done it without you!

Computer Science



Internship at MIT

Daan Rennings

About a year ago, I received an email with subject "Position Update". At that time I was on a skiing trip in Austria and after a few nights of overthinking, I decided to accept the offer: I was going to spend half a year at the SENSEable City Lab at MIT, Cambridge, USA, conducting research as a so-called Visiting Student.

Now, a year later, people often ask me how I got this position, so let me share this with you as well. Initially, I applied for an exchange program at the EEMCS International Office. Whilst awaiting my application, I was thinking: what if I can get into even more prestigious universities? I knew several other students who had gone to MIT and Harvard, so why won't I give it a shot? After sending a few emails to (current and former) professors that supervised me on my bachelor thesis, I worked for as a TA or knew through the study association, I was surprised by the close ties these professors have with colleagues from the other side of the ocean. After a few talks, I decided to apply at MIT's SENSEable City Lab.

In front of the characteristic Great Dome at MIT

The SENSEable City Lab

The SENSEable City Lab is a multidisciplinary lab in the Department of Urban Studies and Planning at MIT. Their projects range from mapping trees around the world to promote tree cover (Treepedia), to developing autonomous boats that will sail the canals in Amsterdam (Roboat), to tracking waste across the globe (Trash Track), to detecting viruses, bacteria and chemicals in urban sewers (Underworlds)\footnote{I can highly recommend checking out the visualizations of these projects at senseable.mit.edu.}. The common denominator in these projects is their impact on both science (in top-tier journals and conferences) and society (through developing extraordinary visualizations and tools for the public, featured in various media and expositions, as well as leap-frogging in the adoption of smart urban systems). In executing these projects, multidisciplinary teams of urban planners and designers that are closest to the department's roots, as well as electrical engineers, computer and data scientists, but also data visualization experts, work together. For the majority of these projects, the lab has worked closely with other labs at MIT and in collaboration with leading companies across industries (the World Economic Forum, Uber, Cisco, Coca Cola - to name a few).

At the beginning of my stay as a visiting student, I was free to join an ongoing project I liked. After an initial discussion with researchers from the lab, I decided to join the City Scanner project, since I found it a very interesting and promising project. In short, City Scanner is about capturing urban phenomena at an unprecedented spatiotemporal scale at low cost through drive-by sensing for advanced smart city services, but let me tell you the whole story.

The promise of drive-by sensing

Urban phenomena are typically continuous signals in both the temporal and spatial dimension. Today's technology allows us to capture these phenomena through attaching sensors to different carriers, e.g. satellites, airplanes, taxi cabs, bikes, and stationary units. Such approaches have different capabilities to capture changes in phenomena over space and time, but can roughly be assigned to one of three categories: airborne, stationary or drive-by sensing. Urban phenomena are not strictly bound to one category. For instance, air pollution can be measured through satellite images, drive-by measurements or stationary sensors. The difference in such measurements is the spatiotemporal coverage of these sensing approaches for the target area and time window.

As examples, consider the use cases of greenery mapping, parking spot identification and measuring temperature. Greenery mapping can be achieved by the analysis of satellite images or through more novel approaches that benefit from drive-by images. Likewise, parking spots can be identified by a network of stationary parking sensors or, more efficiently, via a cost-effective drive-by approach. In the case of measuring temperature, we would traditionally employ meteorological stations to measure air temperature or remote satellite-based measurements to capture near-surface temperatures. A larger fleet of satellites or larger network of stationary sensors could then be employed to respectively achieve a higher temporal and spatial coverage. Such coverage allows you to identify patterns that are not visible in data acquired at a lower spatiotemporal frequency. However, the prohibitive costs of such deployments may very well make it more cost-effective to employ a drive-by approach instead.

Drive-by sensing thus enables us to overcome the limitations of stationary and remote sensing – the traditional means for urban sensing. Though, drive-by sensing also faces constraints: it is limited in time due to the cost of deploying a large fleet of mobile sensors, and in space as road vehicles are confined to a street network. Within these limitations, drive-by sensing has nonetheless resulted in multiple orders of time reduction, cost reduction, and increase in spatial precision and spatiotemporal coverage compared to the de facto methods for capturing urban phenomena. In addition, drive-by sensing has paved the way for new applications, such as the prevalent Google Street View, but also cyclist experience mapping, the assessment of street lightning infrastructure and the near real-time publication of localized fuel price information.

City Scanner

In line with this ideology, City Scanner is a modular sensing platform for capturing the spatiotemporal variation of environmental indicators in urban areas. Different from related works in the field of drive-by sensing, City Scanner is encapsulated in a non-intrusive platform that can be installed on any four-wheeled road vehicle. Instead of relying on a dedicated fleet and bringing additional vehicles on the roads, this method piggybacks on an existing fleet of vehicles that go about their business as usual. This however implies that the spatiotemporal dimensions of the traversed urban area are subject to the mobility patterns of the hosting vehicle – different from Google Street View drivers that actually get driving directions. These trajectories largely differ between scheduled (e.g. buses, garbage trucks) and unscheduled vehicles (e.g. taxis) and although all exhibit some spatial and temporal mobility patterns, this field has gained little attention in research so far.

As a first deployment, City Scanner was installed on top of garbage trucks in Cambridge, MA, to acquire 1.6 million measurements over the course of eight months in 2017. These measurements included thermal images that can be used to assess the energy efficiency of building envelopes, temperature and humidity readings to understand heat island effects, particulate matter counts for identifying the signature of air pollutant sources and accelerometer signals to assess the road quality based on the vehicle's vibrations. These measurements have been analyzed and visualized in an interactive tool that overlays the city with data in a near real-time manner. My tasks within this project ranged from cleaning and analyzing the data and extending the visualization, to conducting a literature review in the field of drive-by sensing which was used in our journal submission.

Sensors that comprise the modular sensing platform

City Scanner empowers municipal authorities and the general public with advanced analytics solutions for urban sensing. In future work, the lab will further analyze mobility patterns of potential hosting vehicles and continue deploying the City Scanner platform on various vehicles around the globe to capture urban phenomena at an unprecedented spatiotemporal scale, visualizing the signature of the city.

Snapshots of the City Scanner visualization, accessible at senseable.mit.edu/cityscanner/app/

Off duty

During my stay in the US, I have not solely spent my time on the City Scanner project. Outside the lab I joined a soccer team, went on a hike to Mt. Washington, visited NYC and DC, and even went on a short skiing trip. I also attended cool events, such as debate sessions with Hillary Clinton's and Mitt Romney's campaign managers, performances by the Blue Man Group and 2Cellos, as well as a Celtics game and the Head of the Charles regatta.

In retrospect, I can highly recommend going abroad during your studies. Although it is a big step, as a student you have a unique chance to take this opportunity, with few restrictions such as a house, tree and animal - as the Dutch saying goes. And when you are looking into a spot abroad, don't be afraid to include top universities such as MIT, Stanford and Caltech in your search: students from these universities would also include Delft in their exchange options, and professors at these institutions are much closer to your lecturer on Monday morning than the billions of liters of water between them would make you believe.

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These days, you can find 16 GB USB sticks on supermarket shelves for as little as €10. In hospitals, a camera the size of a pill can be swallowed to survey a patient's intestines. And in the oceans, tiny GPS transmitters track endangered turtles to help protect them. While each of these devices is incredibly small, it actually represents a big milestone in technological progress.

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ASML supplies lithographic equipment to all the world's major microchip manufacturers. These include Samsung, Intel and TSMC. For these companies – and for ASML – the quest is always to produce chips that are smaller, faster, more effective and less expensive. Never satisfied, the people at ASML measure their performance in units that begin with pico or nano. The smaller, the better.

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Advertorial

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Student reviews: Choosing a variant track

Daniël van Gelder, Beryl van Gelderen, Chris Lemaire

First year Computer Science students will have to choose a variant track of courses for their second year. Many students are not sure which track to choose, since they often do not have a good overview of what subjects each course covers. Therefore, we have interviewed three second year bachelor students to find out for each track what it entails and what the students think of it.

Intelligent Data Analytics track – Daniël van Gelder

Due to my interest in Machine Learning and Data Analytics, although I was completely oblivious to what these subjects entailed, choosing the Intelligent Data Analytics (IDA) variant track seemed obvious to me. However, all the variant tracks seemed very interesting with great courses. So when the second year began, I was ready to go and see whether the variant track lived up to my expectations.

The IDA track has three courses: Computational Intelligence, Big Data Processing and Data Mining. Computational Intelligence covers some machine learning techniques. This was personally my favorite course; partly due to the enthusiasm of Joost Broekens, the teacher of the course, and his great lectures and partly due to the interesting course material. In the course you'll learn about several machine learning techniques: Neural Networks, Genetic Algorithms, Reinforcement Learning and Swarm Intelligence. The course also has a lab where you'll apply these techniques by teaching a virtual robot to do groceries for you. The robot thus had to identify items you need, learn the best order to pickup the groceries, considering their location in the supermarket, and then find the fastest route between each item. The lab was concluded with a small competition where the team with the 'smartest' robot was awarded a small prize. All in all, this course combined theory and practice very well in a fun and interactive manner.

The second course of the IDA track is Big Data Processing which, unsurprisingly, covers theory on processing big data, which is quite harder than it seems in the first place. Not only will you learn how you need to consider what your data is and how you can format it in order to extract information from it, but you'll also learn techniques to process and store it efficiently. This course is less abstract than Computational Intelligence, since you'll learn about low level and real world applications of the theory discussed. This, due to the infancy of the field itself, can entail very recent and well-known examples. In addition, a lot of attention is given to programming techniques for Big Data as well, namely: functional programming. There was a lab with some really tough exercises where you had to apply theory on big datasets. Personally I found this course to be quite difficult and at the time found it less interesting than expected. However, later I learned to appreciate the material since lots of the theory discussed has applications in other fields of Computer Science (e.g. Distributed Systems and Functional Programming).

To conclude the variant track, there is the course called Data Mining. What made this course really interesting to me was the application of a lot of the theory of Computational Intelligence on real world problems, in addition to a lot relatable theory. In this course we focused on how one can extract useful information from big datasets. For example: If we have a news site full of articles, what articles are related to each other? The course has both a lab component and a small project, the lab contains assignments for practicing with the theory from the lectures and in the project we developed a system to predict how users will rate a Netflix movie based on other ratings of the user and similar users. The project was fun to do and we got a lot of freedom to experiment with different techniques learned in the lectures.

Multimedia Computing track – Beryl van Gelderen

Actually, I was very much in doubt between the Digital Systems track and the Multimedia Computing track. I tried both for the first few weeks and then choose Signal Processing (part of the Multimedia Computing track), because I liked the lab assignments there the most. The subject is math-oriented, while always keeping the practical applications in view. You get to be creative with applying math in ways that work for your particular situation. It is not necessary to prove the mathematical side; you just have to show how well it works.

The first course of the track, Signal Processing, covers the basics for the other courses of this track. As the name says, it is about processing a signal. You work mostly with audio signals, and at the end, you create your own mp3 player. A large part of this course is the lab, which consists of weekly assignments in Matlab that are graded pass/fail. There is a midterm that consists of 30% of the grade, and the end term makes up the other 70%.

Image Processing continues with the principles learned in signal processing, and applies them to images. At first, this course puts more emphasis on lectures, with three lectures a week at the beginning of the course. As the course progresses, more emphasis is being put on the lab sessions, which get up to two times a week. This year, there was an oral exam that made up 60% of the final grade, however, this might change for next year to a written exam. The lab part makes up 40% of the final grade, and is done together with a lab partner. In the end, a license plate recognition system is made in Matlab. Bonus (up to 1 point) can be obtained with weekly lab homework in Matlab.

In the final course called Multimedia analysis, you apply the principles from before to many different types of data, from recommender systems to GPS data to video with sound. In the lab, which is done together with a designated-partner, you make weekly assignments in Python. For the last assignment, a bit more freedom is given as to what problem you would like to solve. The lab assignments are pass/fail, and the lab sessions are mandatory to go to. A final exam determines your grade.

I like Signal Processing because of the versatility of the lab assignments and the depth of the material. I think this course is where I learned most. However, I did find it challenging. The courses afterwards seem to be easier.

Creating a license plate recognition system during the Image Processing lab was a lot of fun, and I think the lab assignments built up very well to this assignment.

Modifying sounds, images and videos is a very rewarding experience, because the output is diverse, visual and sometimes unexpected.

Embedded Systems track – Chris Lemaire

Choosing a variant track was a hard decision for me. I have doubted for a long time between the Multimedia track and the Embedded Systems (ES) track. In the end it turned out that the three ES courses were definitely right for me.

The first course is Digital Systems. This course is really Computer Organization (CO) 2.0. The material covered and the exam were actually really similar to the kind of material and kind of questions that were in CO (Logical circuits, state machines, general CPU architecture, etc.). If you had a hard time with CO, you might very well also have a hard time with the material for this course.

However, there was one thing in the course very different from CO: the lab. During the lab, a breadboard was used on which we were supposed to make actual physical logical circuits after first designing them in a hardware modeling language. This part of the course was very exciting as it covered different aspects of using and designing hardware than the Assembly lab of the first year covered. If you liked CO, you will definitely like DS.

The second quarter had a course on Embedded Software. Embedded Software is basically all software that is supposed to run on a low-level piece of hardware. It turns out that programming these bare-bones pieces of hardware comes with quite a few complications. This is what is covered during the lectures. The lab consisted of two parts. The first part covered the C programming language and the different ways one may check their code for memory leaks and other programming mistakes. During the second part, we were asked to form groups of two and program a small line-follower robot from absolute scratch, combining some bits of image processing and C programming. Personally, I had trouble with the second part as it was more or less constantly troubleshooting with the robot. However, that is also a part of embedded software, so it was realistic in that sense.

Lastly, this quarter, the course on Operating Systems finishes the Embedded Systems variant. During this course we use the knowledge gained during the first few periods to understand Operating Systems (mostly Linux). The course consists of weekly lectures and a C-programming lab. The weekly lectures cover the general design of and problems with operating systems. During the lab, we have to complete a variety of assignments to essentially break the Raspberry PI provided during the lab and see what is done by OSes to prevent complete failure in such cases. Personally, this was my favorite of the three, as there were relatively little hardware problems and the assignments were fun to work through. This is one of the few bachelor courses during which you will work mostly with the terminal. If you like that kind of stuff, I recommend OS.


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Importance sampling can get you closer to variance zero than you think.

Ludolf Meester

Would you believe that some Monte Carlo simulation algorithms converge at an exponential rate, knowing the square-root law? This article tells part of the story why you should.

This cannot be true

Standard Monte Carlo is pretty basic from a mathematical point of view. In the simplest form you have an integral I that may be written as $I = \int_D h(x)f(x)\mathrm{d}x$, where $h : D \to \mathbb{R}$ and f is a probability density on D. The domain D may be anything: a subset of $\mathbb{R}$, of $\mathbb{R}^d$, of a function space, or of an even more complex space, like that of the possible realizations of a process simulation. From the MC perspective $I = \mathbb{E}[h(X)]$, where X is a random variable with probability density f, and if an algorithm is available to simulate from f, one generates independent copies $X_1, \ldots, X_n$ and sets $I_n = \frac{1}{n}\sum_{i=1}^n h(X_i)$, thus producing an estimate of I. If $\sigma^2 = \mathrm{Var}(h(X))$ is finite, the central limit theorem tells us

$$\sqrt{n}(I_n - I) \xrightarrow{d} N(0, \sigma^2), \quad \text{as } n \to \infty,$$

where $\xrightarrow{d}$ stands for convergence in distribution, and $N(\mu, \sigma^2)$ for the normal distribution with parameters μ and σ^2. For n large enough (which can be arranged), the interpretation is

$$I_n - I \approx \frac{\sigma}{\sqrt{n}} Z, \text{where } Z \text{ has a } N(0,1)\text{-distribution.}$$

The practical implication is that it is unlikely that I_n is off more than 3 times the standard error $\sigma/\sqrt{n}$ and more than 5 times is virtually impossible. Here we have the square-root law: the error decreases at the rate $1/\sqrt{n}$. For an extra digit of accuracy the standard error should be reduced by a factor of 10, i.e., n increased by a factor of 100. Knowing all this, what do you think of convergence claims with $\sqrt{n}$ replaced by $n^{1.8}$ or even e^{cn} (with $c > 0$)?!

Importance sampling

There exist many so-called variance reduction methods that make MC algorithms more efficient. Their effect, however, is replacing σ by some smaller number $\tilde{\sigma}$; the $\sqrt{n}$ is unaffected. This should not be looked down upon: if $\tilde{\sigma} = \sigma/10$ the same CPU time now yields an extra digit of accuracy (assuming that the program speed is unchanged). Importance sampling is among the most powerful variance reduction methods; its name describes the main idea: to sample important values with higher probability. Suppose g is another probability density (which should be non-zero where f is non-zero), then

$$I = \int_D h(x)w(x)g(x)\mathrm{d}x, \quad \text{where } w(x) = f(x)/g(x).$$

This means that $I = \mathbb{E}[h(Y)w(Y)]$ for a random variable Y with density g and if g is such that $\mathrm{Var}(h(Y)w(Y)) < \sigma^2$, one could simulate by sampling copies of $h(Y)w(Y)$ instead of $h(X)$.

From now, consider nonnegative h. Note that $h(Y)w(Y) = \frac{h(Y)f(Y)}{g(Y)}$, so to make this less variable, the best choice is a g that is a multiple of hf. The excitement that the corresponding variance is zero is quenched very quickly: one needs the value of I! However, this so-called zero-variance importance sampling distribution can still be used as a theoretical inspiration in several ways. One is as a guideline to find good candidates for g, another to build even closer approximations to the zero-variance g while simulating.

Adaptive algorithms

One algorithm was analyzed by Arnout Boks in his Master's thesis[1], which can be found in the TU Delft repository. The main idea is to construct an approximation to the zero-variance g, using kernel density estimators, in such a way that the approximation improves with every iteration. This implies that every simulated value comes from a different distribution, constructed from the preceding samples. So, not independent and not from the same distribution. Using martingale techniques, however, analysis is possible and he shows that in terms of the number of samples n the convergence rate is better than $O(\ln(n)n^{-7/6})$, which is much faster than the canonical $O(n^{-1/2})$. An honest analysis in terms of CPU time spent on the first n samples should take into account that the effort per sample is not constant but grows with n. Exact analysis is difficult, also because the efficiency is implementation dependent.

There is another collection of Monte Carlo problems that admit adaptive algorithms that "find" the zero variance distribution and an example based on something that is close to home may be the best way to introduce this.

Importance sampling for binomial tail probabilities

Suppose, one wants to determine by simulation the probability that N tosses with a biased coin produce at least K times the outcome 'heads', which per toss has probability p. In particular, you should think about parameter combinations where this tail probability is small. It is, of course, just a probability from the binomial distribution with parameters N and p, so the answer is known (this is used to evaluate the results below). Write B_i for the result of the ith toss, it is 1 with probability p and 0 with probability $q = 1-p$: a *Bernoulli* random variable with parameter p. The number of heads is $S_N = B_1 + \cdots + B_N$. The tosses are independent, so $\mathbb{P}(S_N = k) = \binom{N}{k}p^k q^{N-k}$ for $0 \le k \le K$.

Simulating for this problem is easy: simulate the N tosses; count the number of heads; if this is smaller than K, a 0 is tallied, and otherwise a 1; repeat a large number of times. The fraction of 1s is our estimate for $\mathbb{P}(S_N \ge K)$. This simulation is most efficient when the probability that is estimated is around 0.5, and very inefficient for values near 0 or 1.

Importance sampling in this example is easy: replace p by $\tilde{p}$, then $\tilde{\mathbb{P}}(S_N = k) = \binom{N}{k}\tilde{p}^k\tilde{q}^{N-k}$. This change of measure, as it is called, makes our simulation program estimate $\tilde{\mathbb{P}}(S_N \ge K)$ instead of $\mathbb{P}(S_N \ge K)$: the frequency of the outcome $S_N = k$ is off by a factor $\tilde{\mathbb{P}}(S_N = k)\,/\mathbb{P}(S_N = k)$. This can be corrected by giving this outcome a weight that is the inverse of this, after simplification: $(p/\tilde{p})^{S_N}(q/\tilde{q})^{N-S_N}$. For every $0 < \tilde{p} < 1$ this yields a valid simulation scheme and choosing $\tilde{p} = K/N$ is close to optimal, because now $S_N \ge K$ will occur close to 50% of the time.

Mathematics

Dynamic importance sampling schemes

Within this class of IS algorithms, no $\tilde{p}$ can be found that results in zero variance. This is because the zero-variance distribution is not a member of the binomial family: $\tilde{p}$ should be made toss-dependent, and in a dynamic way. First, consider the simulation from a different perspective: At the start you have N tosses at your disposal and you need at least K heads; you are in *state* (N, K). If the first toss is tails, you have spent one toss and still need K heads: the state becomes $(N-1, K)$; if the first is heads, you move to $(N-1, K-1)$. State (n, k) means that there are n tosses to go and another k heads to produce in order to reach our "goal" $S_N \geq K$; the next state is $(n-1, k-1)$ if $B_n = 1$ and $(n-1, k)$ if $B_n = 0$ (reversed indices on the B_i). If $k = 0$ while $n > 0$, a 1 is recorded; the other possibility is that $k = n$ at some point, and then the goal can only be reached with a sequence of n heads; therefore, p^n is recorded, because this is the probability that will happen.

A probabilistic framework for the simulation is the set of states $\{(n, k) : 0 \leq n \leq N, 0 \leq k \leq K\}$, where N and K are fixed, and an independent collection of Bernoulli random variables, B_{nk} for state (n, k), having outcome 1 with probability p_{nk} and 0 with probability $q_{nk} = 1 - p_{nk}$. With each state an X_{nk} is associated that is distributed as the outcome of an importance sampling simulation that starts in state (n, k). It is defined through the recursion

$$X_{nk} = \begin{cases} \frac{p}{p_{nk}} X_{n-1,k-1} & \text{if } B_{nk} = 1, \\ \frac{q}{q_{nk}} X_{n-1,k} & \text{if } B_{nk} = 0, \end{cases} \tag{1}$$

where the importance weights p/p_{nk} and q/q_{nk} are added to correct the probability p_{nk} that is used for the current toss instead of p. To complete the recursion, add boundary conditions $X_{n0} = 1$ (all n) and $X_{kk} = p^k$ (all k). Taking expectations results in $\mathbb{E}[X_{nk}] = p\,\mathbb{E}[X_{n-1,k-1}] + q\,\mathbb{E}[X_{n-1,k}]$, and since this is the recursion (including the boundary conditions) that is satisfied by the probabilities γ_{nk} of producing k or more heads in n independent tosses of a coin with $\mathbb{P}(\text{heads}) = p$—the probabilities we try to determine—it follows that $\mathbb{E}[X_{nk}] = \gamma_{nk}$, for every state (n, k). Which is to say: for any choice of the p_{nk} the importance sampling scheme is valid (the values 0 and 1 should be excluded).

The non-dynamic importance sampling described earlier can be obtained by setting all $p_{nk} = K/N$, then generating a number of iid copies of X_{NK} and averaging them to get the estimate for γ_{NK}.

A zero-variance scheme

From the recursion on the X_{nk} a recursion for Var(X_{nk}) can be obtained, from which a guess can be made about the variance-minimizing choice for the p_{nk}; it is:

$$p_{nk} = p\,\frac{\gamma_{n-1,k-1}}{\gamma_{n,k}}, \quad q_{nk} = q\,\frac{\gamma_{n-1,k}}{\gamma_{n,k}}. \tag{2}$$

Instead of considering the variances, consider the X_{nk} themselves, by substituting this into (1) and solving the recursion (start at the boundary); the result: $X_{nk} = \gamma_{nk}$ for all (n, k). Whatever the outcomes of the sequence of tosses, the outcome is the same constant: the X_{nk} have variance zero!

An adaptive algorithm

Alas, again the scheme is not valid because it is circular: for the definitions (2) one needs the numbers that one is trying to determine.... However, after one small change (to avoid $p_{nk} + q_{nk} \neq 1$) where (2) is replaced by

$$p_{nk} = \frac{p\,\hat{\gamma}_{n-1,k-1}}{p\hat{\gamma}_{n-1,k-1} + q\hat{\gamma}_{n-1,k}}, \quad q_{nk} = \frac{q\,\hat{\gamma}_{n-1,k}}{p\hat{\gamma}_{n-1,k-1} + q\hat{\gamma}_{n-1,k}}, \tag{3}$$

an adaptive algorithm saves the day:

Figure 1: Maxima (solid lines) and RMS averages (dashed) of ^{10} *logs of relative errors in* $\hat{\gamma}^{(m)}_{N,k}$*,* $24 \leq k \leq 59$*, versus iteration number* m*; colors correspond to three groups of* k*-values, black to all. Parameters:* $N = 2000$*,* $p = 0.01$*,* $R = 25$*.*

1. start with initial guesses $\hat{\gamma}^{(0)}_{nk}$; set $m = 0$;
2. determine the p_{nk} by substituting the $\hat{\gamma}^{(m)}_{nk}$ into (3);
3. for each (n, k):
   - simulate R independent replications of X_{nk};
   - set $\hat{\gamma}^{(m+1)}_{nk}$ equal to the average of these values;
4. add 1 to m and repeat from 2.

Figure 1 displays some overall information on an example simulation with $N = 2000$, $p = 0.01$, $K = 59$, $R = 25$. Interesting values to look at are $\gamma_{N,k}$ for $24 \leq k \leq 59$: the exact values range from 0.16 to $3 \cdot 10^{-13}$. The k-range is split into three groups and per group the relative errors are summarized by looking at the maximum (solid lines) and the root-mean-square average (dashed lines, slightly below the solid ones). The red lines go down first—they correspond to the lowest k-values (with larger probabilities that are more easily determined accurately)—, then the green ones (middle group), and the blue ones (highest k's). The black lines plot overall statistics and correspond more or less with the worst, i.e., blue, group. In all cases, after a warm-up phase, the ^{10}logs of the errors go down approximately 0.6 per iteration, meaning more than one extra digit of accuracy per two iterations. As can be expected, at some point numerical inaccuracies start playing a role, relative errors leveling off just above 10^{-15}. The whole simulation took 0.048 seconds of CPU time on a regular TU desktop computer.

Exponentially converging Markov chain algorithms

There is not enough space to give a rigourous description of the general problem class, its algorithm, and the convergence proof, but by expanding from our toy example one can get some idea. The coin tossing algorithm is an example of a Markov chain, with the collection of states as its state space. In lieu of X_{nk} there is a series of rewards earned, one for each transition made, and one is concerned with the total reward. In the binomial example, the only non-zero rewards are those earned when hitting $k = 0$ (reward 1) or $n = k$ (reward p^k). In the general model, the chain is run until a graveyard set is reached and then accumulation of rewards is terminated. In the binomial example the graveyard consist of (n, k) with $k = 0$ or $n = k$.

A general description can be found in the overview [2], a more detailed treatment in [3]. Its main theorem states that a minimum sample size r_0 exists such that, if the adaptive algorithm is run with $R \geq r_0$, then a constant $c > 0$ exists, such that the errors in the estimates after n samples go to zero at a rate faster than e^{-cn}, almost surely, i.e., exponential convergence.

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[2] Paritosh Y Desai and Peter W Glynn. A Markov chain perspective on adaptive Monte Carlo algorithms. In *Proceedings of the 33nd conference on Winter simulation*, pages 379–384. IEEE Computer Society, 2001.

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Plastic litter in the ocean; modeling of the vertical transport of micro plastics in the ocean

Nelleke Scheijen

From September till January I did my BEP (bachelor end project) as a final part of the bachelors Applied Mathematics and Applied Physics. The project was provided by Deltares, a water research institute just outside of the campus of TU Delft. I really enjoyed doing my BEP at Deltares and in this article I will tell something about my experiences and results.

Start of the project

Before I could start with my BEP, I had to choose which subjects I liked and find a matching project. I chose to look for a project that had something to do with transport phenomena and mathematical physics. Because my BEP is 24 ECTS and I had half a year full time to carry out this project, I decided I would like to do my BEP at a company. Martin Verlaan, professor at TU Delft and researcher at Deltares, had a really interesting project which suited my interests: modeling of plastics in the ocean.

Introduction plastic problem

Before I started with my project, it was important to become familiar with the plastic problem and to establish a research question. Plastic pollution is a big problem all over the world. Every year more plastic gets produced and a lot of plastic litter is mismanaged and enters the ocean. It's important to know where these plastics accumulate. With this information the problem can be quantified and the plastic litter can be cleaned up. In this project micro plastics are studied (< 5mm), because of the small size the plastic particles can be modeled as particles in fluid. There are two common ways to model particle transport. One way is solving the advection-diffusion equation to find a concentration function. Another way is to derive a stochastic model from the advection-diffusion equation, called a random walk model. With this model a single particle trajectory can be simulated. When a large amount of particles is simulated with this model, the spread of the particles is equal to the concentration function found from the advection-diffusion equation. It can be mathematically derived that the methods are equal for an ideal situation. Both models have their own specific advantages and disadvantages for specific (not ideal) cases. The interesting part about modeling plastics in the ocean, is the physical properties of plastics, that needs to be included in the model. Plastics have a floating character, because most of the time, the density of plastics is lower than the density of water. The two existing models have to be adjusted to be adequate for modeling plastic transport. Because the floating character of plastics is the most important factor of plastics, this project is about the two-dimensional vertical transport of plastics. In conclusion, I established the following research questions for the project:

- Which adjustments are needed to adjust existing transport models in a way that they are adequate for modeling plastic?
- Are the two explored models equally efficient for the modeling of plastics?
- How can the transport model be used to obtain results for a real-life situation?

Theoretical review

As already said in the introduction, there exist two well known models for the transport of particles in fluid. The first one is the advection-diffusion equation, the general form is:

$$\frac{\partial c}{\partial t} = \nabla \cdot (D\nabla c) - \nabla \cdot (\vec{u}c) + R \tag{1}$$

with c as the concentration of particles, D as the diffusion coefficient, $\vec{u}$ as the velocity field of the ocean and R as the term of sources or sinks of the particles. The physical explanation of the left term is the change of concentration of particles per time. The first term on the right is the diffusion part. It is the random spread from regions with a high concentration to regions with a low concentration due to molecular motion. The second term on the right is the advection term, due to the velocity field of the fluid. The third term on the right is as already said the source or sink term.
The second model is the random walk model; to find a model which is mathematical equivalent to the advection-diffusion equation, we use the Fokker-Planck equation and find the following result:

$$dX_t = u_x dt + \sqrt{2D_x} dW(t) \tag{2}$$

$$dZ_t = u_z dt + \sqrt{2D_z} dW(t) \tag{3}$$

Intuitively this can be explained as the displacement of a particle, which is due to the velocity of the particle times the time plus the displacement due to diffusion.

Plastic characteristics

These two general models have to be adjusted such that they take into account the physical properties of plastics. The forces which act on a particle are the buoyancy force upwards, the gravitational force downwards and the resulting drag force. The goal of looking at the different forces on a plastic particle is to find a vertical buoyancy velocity V_b which can be added to the existing models. In this project I looked at the steady state solution of the forces and I found the following buoyancy velocity:

$$v_b = \sqrt{2g\frac{\rho_p V_p(\frac{\rho_w}{\rho_p} - 1)}{\rho_w C_d A}} \tag{4}$$

with ρ_w as the density of the water, ρ_p as the density of the plastic, A as the cross section of the particle, V_p as the volume of the particle, C_d as the drag coefficient (dimensionless) of the particle, g as the gravitational acceleration and v_b as the velocity of the particle relative to the water.

Mathematics

Ocean characteristics

To be able to understand the motion of plastic particles in the ocean, it is important to know the main components which are responsible for the ocean velocity field: currents, gyres and eddies. The most interesting components are the gyres and the eddies, here the phenomena Ekman pumping occurs, this is shown in figure 1. As you can see in the figure, for the downwelling Ekman transport, a convergent flow occurs at the surface of the water. Therefore, if the upwards buoyancy velocity of plastics is higher than the downwards velocity, the particles will float at the surface and will accumulate.

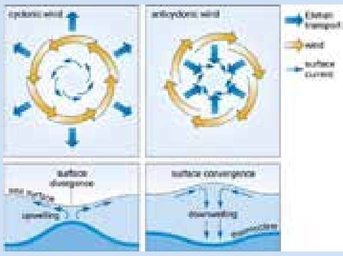

Figure 1: Schematic figure of Ekman transport in an eddy or gyre

Currents in the ocean are turbulent; these turbulent flows have to be taken into account. This is done by using the eddy diffusivity coefficient ϵ. This is a measure of diffusion due to turbulence. The molecular diffusion coefficient can be neglected in this case, because this term is much smaller.

When both adjustments described in the above section are implemented in equation 1 and 2, we find the final two-dimensional formulas:

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}(\epsilon_x \frac{\partial c}{\partial x}) + \frac{\partial}{\partial z}(\epsilon_z \frac{\partial c}{\partial z}) - \frac{\partial((u_z + v_s)c)}{\partial z} - (\frac{\partial u_x c}{\partial x}) \qquad (5)$$

$$\begin{aligned} dX_t &= (u_x + \frac{d\epsilon_x}{dx})dt + \sqrt{2\epsilon_x}dW(t) \\ dZ_t &= (u_z + \frac{d\epsilon_z}{dz} + v_b)dt + \sqrt{2\epsilon_z}dW(t) \end{aligned} \qquad (6)$$

Results and conclusion

To check and show the results, I implemented both models in MATLAB using a numerical approach. I used four test cases in my project to show the different aspects (diffusion, advection and buoyancy velocity) of particle transport. I will show the most interesting test case here; this test case has a velocity field similar to that of an eddy, as shown in figure 2. First, I show the result of a simulation of 10 particles with the random walk model; figure 2 shows the trajectories of 10 buoyant plastic particles. The buoyancy velocity is higher than the downwards velocity, therefore the particles will float and accumulate.

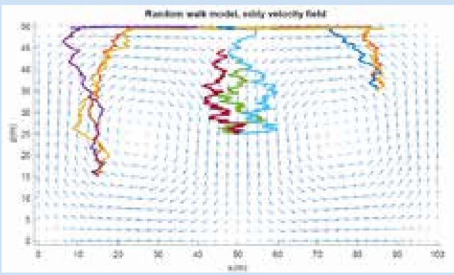

Figure 2: The velocity field of the test case and the trajectories of 10 particles with three different initial locations

The second figure (figure 3) shows the numerical solution of the advection-diffusion equation. The left top box shows the initial concentration field of particles, the other figures show the concentration field for different times. As you can see, the particles behave as expected and will be floating at the surface after some time.

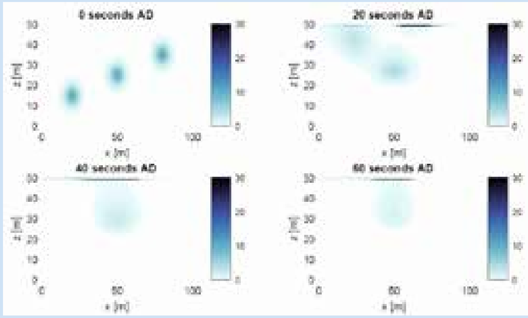

Figure 3: The numerical solution of the advection-diffusion equation with implementation of the buoyancy velocity and an eddy velocity field.

To compare the advection-diffusion equation with the random walk model I modeled the trajectories of 100.000 particles and counted the particles per box to find a concentration field. This is shown in figure 4. As expected, the behavior of the particles is the same as the solution of the advection-diffusion equation.

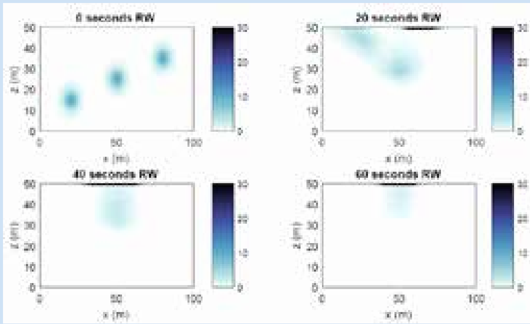

Figure 4: The concentration field found by simulating 100.000 particles with the random walk model with implementation of the buoyancy velocity and an eddy velocity field.

The adjustments to the transport model are adequate to model plastic particles, as can be concluded from the different test cases. After looking at different test cases and the theoretical background of the models, I also found some advantages and disadvantages for both models. The advection-diffusion equation has mainly numerical problems, a numerical solution for this model is either hard to obtain or very time consuming. The random walk model will become inaccurate at larger distances and larger timescales due to a finite amount of particles. The best solution would be a combination of both models, in order to use the advantages of both models.

My BEP was definitely a challenge, because it was the first time I had to do such a big project on my own. I really liked working at Deltares, because my research could really be implemented as a small piece of a running research project at Deltares. It was nice to use my theoretical knowledge of mathematics and physics in practice. Do you want more information about the project or are you interested in my final report? You can find it online at the TU Delft repository: `https://repository.tudelft.nl/islandora/object/uuid%3Ab17ae877-d2db-4ea8-8280-394741395224`

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Fourier multipliers are everywhere

Mark Veraar

Below we will give a short introduction into the world of Fourier multipliers. This is a topic within analysis which has been extensively studied since the beginning of the 20th century. Fourier multipliers are an important tool in many parts of mathematics. Below we introduce some of the basics of the theory.

The Fourier transform

Let $\mathbb{R}^d$ denote the d-dimensional Euclidean space with its standard norm $|\cdot|$. Let $\mathbb{C}$ denote the complex numbers.
For $p \in [1,\infty)$, let $L^p(\mathbb{R}^d)$ denote the space of all measurable functions[1] $f : \mathbb{R}^d \to \mathbb{C}$ such that

$$\|f\|_p := \Big(\int_{\mathbb{R}^d} |f(x)|^p \, dx\Big)^{1/p} < \infty.$$

Let $L^\infty(\mathbb{R}^d)$ denote the space of (essentially) bounded measurable functions endowed with the (essential) supremum norm. Then $(L^p(\mathbb{R}^d), \|\cdot\|_p)$ is a Banach space for any $p \in [1,\infty]$.
For $f \in L^1(\mathbb{R}^d)$ the *Fourier transform* of f is the function $\mathscr{F} f : \mathbb{R}^d \to \mathbb{C}$ defined by

$$\widehat{f}(\xi) := \mathscr{F} f(\xi) := \int_{\mathbb{R}^d} e^{-2\pi i x\cdot\xi} f(x)\, dx$$

The Fourier transform is a linear mapping and it is immediate from the definitions that $\|\mathscr{F} f\|_\infty \le \|f\|_1$. In other words $\mathscr{F} : L^1(\mathbb{R}^d) \to L^\infty(\mathbb{R}^d)$ is *bounded*[2]. One of the basic results in the theory is that $\mathscr{F}$ extends to a unitary operator[3] $\mathscr{F} : L^2(\mathbb{R}^d) \to L^2(\mathbb{R}^d)$.

A motivating example

In order to introduce the concept of a Fourier multiplier we will first consider a motivating example based on a partial differential equation (PDE):

$$u - \Delta u = f \tag{1}$$

Here $\Delta = \sum_{j=1}^d \partial_j^2$, $f \in L^2(\mathbb{R}^d)$ is given and u is the unknown. Formally applying the Fourier transform on both sides we obtain

$$\widehat{u}(\xi) + 4\pi^2|\xi|^2\widehat{u}(\xi) = \widehat{f}(\xi), \quad \xi \in \mathbb{R}^d.$$

Here we use the fact that[4] $\mathscr{F}(\partial^\alpha u) = (2\pi i\xi)^\alpha \widehat{u}(\xi)$ which follows by integration by parts. The solution to the above equation is given by

$$\widehat{u}(\xi) = \tfrac{1}{1+4\pi^2|\xi|^2}\widehat{f}(\xi).$$

[1] More precisely we consider equivalence classes of functions that are almost everywhere equal.
[2] A linear mapping $T : X \to Y$ between two Banach spaces X and Y is called bounded if $\exists C \ge 0\ \forall x \in X\ \|Tx\|_Y \le C\|x\|_X$.
[3] This means $\|\mathscr{F} f\|_2 = \|f\|_2$ and $\mathscr{F}^\star = \mathscr{F}^{-1}$.
[4] For $\alpha = (\alpha_1, \ldots, \alpha_d) \in \mathbb{N}^d$ we write $\partial^\alpha = \partial_1^{\alpha_1} \ldots \partial_1^{\alpha_d}$

Since $f \in L^2(\mathbb{R}^d)$ also $\widehat{f} \in L^2(\mathbb{R}^d)$, and thus we find that $\widehat{u} \in L^2(\mathbb{R}^d)$. Much more can be said: for any $j,k \in \{1,\ldots,d\}$, $\mathscr{F}(\partial_j\partial_k u)(\xi) = -4\pi^2\xi_j\xi_k\widehat{u}(\xi)$, and therefore

$$\mathscr{F}(\partial_j\partial_k u)(\xi) = -\tfrac{4\pi^2\xi_j\xi_k}{1+4\pi^2|\xi|^2}\widehat{f}(\xi) =: m(\xi)\widehat{f}(\xi).$$

Now by the properties of the Fourier transform we find that

$$\|\partial_j\partial_k u\|_2 = \|\mathscr{F}(\partial_j\partial_k u)\|_2 = \|m\widehat{f}\|_2 \le \|\widehat{f}\|_2 \le \|f\|_2,$$

where we used $|m| \le 1$. In a similar way one sees that $\|u\|_2 \le \|f\|_2$ and $\|\partial_j u\|_2 \le \|f\|_2$. Finally, the linearity of (1) together with the provided estimates imply uniqueness in $L^2(\mathbb{R}^d)$ of the solution to (1). Summarizing we have sketched a proof of the following result.

Proposition 1. *For each $f \in L^2(\mathbb{R}^d)$, there exists a unique solution $u \in L^2(\mathbb{R}^d)$ of (1). Moreover,[5] $\forall |\alpha|_1 \le 2$, $\partial^\alpha u \in L^2(\mathbb{R}^d)$.*

What is a Fourier multiplier?

In the above proof we *multiplied* the Fourier transform of the function f by m. This is where the name Fourier multiplier comes from: for a given measurable function $m \in L^\infty(\mathbb{R}^d)$ one can consider the linear mapping $T_m : L^2(\mathbb{R}^d) \to L^2(\mathbb{R}^d)$

$$T_m f = \mathscr{F}^{-1}(m\widehat{f}), \quad f \in L^2(\mathbb{R}^d).$$

As before one sees that

$$\|T_m f\|_2 = \|m\widehat{f}\|_2 \le \|m\|_\infty\|\widehat{f}\|_2 = \|m\|_\infty\|f\|_2,$$

Thus T_m is bounded. The following natural question arises:

Question 2. *For which values of $p \in [1,\infty]$ and for which $m \in L^\infty(\mathbb{R}^d)$ does one have $T_m : L^p(\mathbb{R}^d) \to L^p(\mathbb{R}^d)$?*

The condition $m \in L^\infty(\mathbb{R}^d)$ turns out to be necessary, but far from sufficient for $p \ne 2$. In particular, the above question is relevant for (1). Indeed, it turns out that in Proposition 1 one can replace $L^2(\mathbb{R}^d)$ by $L^p(\mathbb{R}^d)$ as long as $p \in (1,\infty)$. The result turns out to be false for the end-points $p = 1$ and $p = \infty$. Solutions with derivatives in $L^p(\mathbb{R}^d)$ with higher p have more smoothness, a fact which is crucial in the modern theory of PDEs [2].

The Hilbert transform

We have already seen a natural example of a function m in order to study the problem (1). Another natural example is $m : \mathbb{R} \to \mathbb{C}$ given by $m(\xi) = -i\text{sign}(\xi)$. Here $\text{sign}(\xi) = 1$ if $\xi \ge 0$ and $\text{sign}(\xi) = -1$ if $\xi < 0$. Since $\|m\|_\infty \le 1$, the *Hilbert transform* $\mathscr{H} := T_m$ is bounded from $L^2(\mathbb{R})$ into itself. The Hilbert transform is a natural object in complex function theory: If $f : \{z \in \mathbb{C} : \text{Im}\,(z) > 0\} \to \mathbb{C}$ is a holomorphic function and $g(x) := \lim_{y\downarrow 0} f(x+iy)$ exists for almost all $x \in \mathbb{R}$, then under certain technical conditions on f, we have the remarkable property that $\mathscr{H}(\text{Re}\,(g)) = \text{Im}\,(g)$.
The Hilbert transform is arguably the simplest example of a nontrivial Fourier multiplier operator. In [8] Marcel Riesz proved that $\mathscr{H}$ is bounded on $L^p(\mathbb{R})$ if and only if $p \in (1,\infty)$. Moreover, it also follows from his work that in Proposition 1 one can replace $L^2(\mathbb{R}^d)$ by $L^p(\mathbb{R}^d)$ if and only if $p \in (1,\infty)$.

[5] Here $|\alpha|_1 = \sum_{j=1}^d \alpha_j$

Figure 1: David Hilbert 1862-1943

Fourier multiplier theorems

Question 2 is still not well-understood and only sufficient conditions for being a Fourier multiplier are known. The first Fourier multiplier theorem was obtained in [6].

Figure 2: Józef Marcinkiewicz 1910-1940

Theorem 3 (Marcinkiewicz)**.** *Assume $m : \mathbb{R} \to \mathbb{C}$ is bounded and C^1 on $\bigcup_{j\in\mathbb{Z}}\{\xi \in \mathbb{R} : 2^j < |\xi| < 2^{j+1}\}$ and*

$$\sup_{j\in\mathbb{Z}} \int_{2^j<|\xi|<2^{j+1}} |m'(\xi)|\, d\xi < \infty.$$

Then T_m is bounded on $L^p(\mathbb{R})$ for all $p \in (1, \infty)$.

Obviously, $m(\xi) = -i\text{sign}(\xi)$ satisfies the condition of the theorem since $m'(\xi) = 0$ for $\xi \neq 0$. The following d-dimensional result was derived in [7].

Theorem 4 (Mihlin)**.** *Let $m : \mathbb{R}^d \to \mathbb{C}$ be a bounded function such that*

$$|\xi|^{|\alpha|_1}|\partial^\alpha m(\xi)| < \infty, \quad \forall \alpha \in \mathbb{N}^d \text{ with } |\alpha|_1 \leq \lceil \tfrac{d}{2} \rceil.$$

Then T_m is bounded on $L^p(\mathbb{R}^d)$ for all $p \in (1, \infty)$.

It requires some tedious calculations to derive Proposition 1 from Theorem 4. The condition of Theorem 4 was further weakened by Hörmander in [4] and a connection with the theory of singular integrals of Calderón–Zygmund [1] was established. For further details on Fourier multipliers and singular integrals we refer to the monograph [3].

Current research and education in our group

The modern form of Fourier analysis is often called harmonic analysis. This is a popular research area in mathematics at the moment. Some of the research on harmonic analysis within the Analysis group at TU Delft includes: vector-valued Fourier multipliers (see my recent books [5]), weighted theory, applications of harmonic analysis to PDEs, functional calculus, harmonic analysis on manifolds and Fourier analysis on locally compact groups. In the Analysis group we offer an elective course on Fourier Analysis in the Bachelor. At Master level we offer several courses related to Fourier analysis (functional analysis, spectral theory, advanced topics in analysis, partial differential equations and functional analysis). This year's topic of the internet seminar on evolution equations was functional calculus, which has deep connections with Fourier analysis.

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Mathematics

Historical Person: John von Neumann

Daniël van Gelder

We all know that one fellow student, who seems to know everything. And when he doesn't, he can almost instantly learn it. Whenever you have been studying for an exam for days on end, this student seems to revise his notes for 10 minutes and then proceeds to score a ten. This must be how John von Neumann's colleagues must have felt when they were near him. It is widely known and has been very accurately described how John von Neumann amazed the people around him with his intelligence. The man, born in 1903 and died in 1957 aged 53, had published over 150 papers in his lifetime in the fields of: Mathematics, Physics, Economics, Computing and Statistics. Who was this man and why is he considered such a genius?

Early and Private Life

Already at a very young age von Neumann stood out among his peers; at the age of six he could already divide two 8-digit numbers in his head and speak Ancient Greek fluently. He was born into a wealthy Hungarian Jewish family in Budapest. Although Hungarians at that time did not start school until they reached the age of ten, von Neumann was home schooled due to his apparent aptitude for learning. It is rather difficult to imagine the amount of knowledge this child already had obtained at such a young age. Not only was he fluent in many languages— English, German, French and Italian—, he was also familiar with differential and integral calculus and ancient history. I think it is already clear that this was not a child destined for a normal career. Although von Neumann had a passion for mathematics, his father persuaded him to follow a career path which would be more financially rewarding. He eventually decided he wanted to be a chemical engineer. Since he was not proficient in the field of chemistry yet, he followed a two year course and thereafter applied to the prestigious university ETH Zürich, in 1923. At the same time he applied to Pázmány Péter University in Budapest for a Ph.D. in mathematics; apparently following 'just' a graduate degree program was not enough for him. He graduated as a chemical engineer in 1926 and almost simultaneously was awarded his Ph.D. He then continued to study mathematics in Göttingen. Later he continued to lecture at Princeton University where he was appointed professor for life at the faculty of Princeton's Institute for Advanced Study. He then continued to work there until his death. During the second world war, von Neumann was involved in the Manhattan Project which would eventually produce the two atomic bombs dropped on Nagasaki and Hiroshima.

Contributions to Mathematics and Computer Science

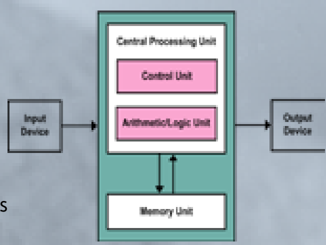
Unfortunately this article will be too short to list the majority of von Neumann's contribution to science so I will cherry pick some of his contributions, namely in the fields of Mathematics and Computer Science.

Game Theory

Von Neumann is known for being a founder of game theory as a mathematical discipline. One of his well-known theories is the 'minimax' theory which demonstrates that in a zero sum game of two players with perfect information, meaning that all moves at any time are known to the players, each player can devise a strategy to minimize his maximum loss (hence the name of the theory). These strategies are optimal and the maximum losses are both equal in their absolute value and contrary in sign. His theory was proven in 1928 and expanded to games of more than two players in 1944.

The Von Neumann architecture

Any computer scientist that has followed a course on computer organization will have heard of the 'Von Neumann' architecture. John von Neumann described the basic computer model, that we know today, in 1945. His model consisted of a procession unit (CPU) with a control unit, containing an instruction register and a program counter; an arithmetic and logic unit, for performing mathematical operations; a memory unit, for data and program instructions, external mass storage and mechanisms for input and output devices. This architecture made it possible to have stored programs in memory, moving computers from using punch cards as programs to digitally stored programs. Many of the concepts von Neumann introduced in his architecture were inspired by the work of Alan Turing who he was acquainted with during his time at Cambridge University as a visiting professor during 1935.



Want to know more?

We only just scratched the surface of the brilliant character of John von Neumann, but there is so much more to find out. Unfortunately, this article can't even cover a fraction of the discoveries that this man made. If you are eager to find out more about this man, there are lots of biographies out there or you can search through the internet, which is full of interesting and sometimes humorous anecdotes of his life.

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Miscellaneous

Section

Science Trends

Rebecca Glans

On this page you will find some brief info on recent scientific breakthroughs or interesting news. Whether they're big or small, if we think they might interest you, we will mention them here! Do you miss a certain trend or want to inform your fellow readers of an interesting innovation? Feel free to contact us.

Do you mind?

Looking at what currently is possible with technology, successfully reading people's mind— with or without their consent— is extremely difficult in practice. But, (un-)fortunately not difficult to imagine. New Scientist gives 3 techniques that are currently used to scan brain activity. Functional Magnetic Resonance Imaging (fMRI) requires subjects to enter a narrow tunnel and keep their head still. An electroencephalogram (EEG) does not require large equipment but can be applied with a simple headband and requires the subject keeping his/ her head still. The data (images) produced by these scans do not give us much information, yet. Combining these techniques with artificial intelligence (AI) seems to be the solution: with enough training it may filter out useful information from noisy data. Disregarding the controversial aspect, being able to read people's minds could be useful in many ways. Accessing the minds of those in a minimal conscious state or those accused of a crime, are some examples. In India, the controversial Brain Electrical Oscillation Signature (BEOS) profiling is still being used in their legal system. [3]

R.I.P. Stephen Hawking

On March 14th the world lost an extraordinary scientist: Stephen Hawking died at the age of 76. A miraculous age, considering he was diagnosed with amyotrophic lateral sclerosis (ALS) at the age of 22 and only given 2 years left to live. He was a well-known physicist with many contributions to science; especially on space and the understanding of black holes. Many scientists and other people around the world he inspired during his lifetime, showed their admiration for his work by means of tributes. [2]

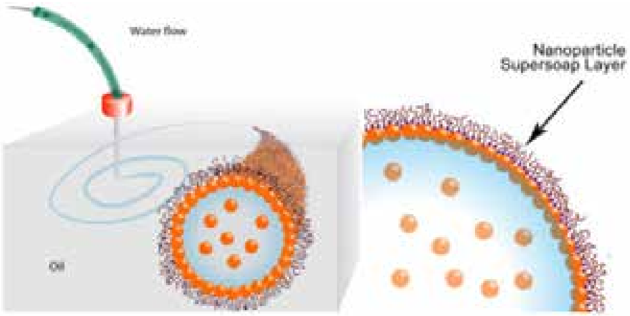
A homemade battery by grandma!

To let the technology for wearable electronics (like smartwatches) keep progressing, we will need to be able to overcome the challenges of durability, deformability, versatility and comfortability. All while keeping the device chargeable. Scientist Chunyi Zhi and his colleagues thus wanted to create a rechargeable zinc-ion battery in the form of yarn. The yarn is made out of twisted carbon nanotube fibers. Two pieces of yarn, where one functions as a cathode and the other as an anode, are twisted like a double helix and coated with a polyacrylamide electrolyte and encased in silicone. When tested, the battery was stable, rechargeable and waterproof. It could also be cut, stretched and knitted with and still work! [1]

3D-printing liquids which are solid?

Scientists of the Berkeley Lab have found a way to 3D-print structures with liquids that stay liquid! This all-liquid material could, among others, "be used to construct liquid electronics that power flexible, stretchable devices". Two steps were needed to gain this material; learning how to create liquid tubes inside another liquid, and then learning how to automate this process.

Basically, water is injected in a so-called nanoparticle supersoap: it prevents the water tube from breaking and locks the water in place. The water, holding gold nanoparticles, is being injected in oil holding polymer ligands. The gold and polymer want to both attach to each other and stay in their own liquid mediums. This creates a tube wherein the water is fixed within the oil. Meters of water, between 10 microns and 1 millimeter in diameter, have already been printed, and in different shapes. The material is can conform to its surrounding and repeatedly change shape.



Science Trends.jpg2 "These schematics show the printing of water in oil using a nanoparticle supersoap. Gold nanoparticles in the water combine with polymer ligands in the oil to form an elastic film (nanoparticle supersoap) at the interface, locking the structure in place."

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Computer Science puzzle

Koen du Buf

Answers from the previous issue

In the previous issue we asked you if you knew what this program would print, without actually running it on your computer! The answer to this puzzle was:

```
@SuppressWarnings("ALL")
public class MaChazinePuzzle {
    public static void main(String[] args) {
        System.out.println(
                "M" + (char)((0b0110 ^ 0b1001) - 0b111)
            + 'a' + (char) ('C' + 32
            + (int) ((0.7 - 0.3) / 0.1 * 3))
            + (char) (0x19 == 25 ? (('h' + 'a' + 'z' + 'i' + 32)/4) : 420 % 42) + (char) ('n' + 3 * Math.PI)
            + (!System.out.equals(42) ? 'e' : '\r')
            + args.getClass().getSimpleName().charAt(2)
        );
    }
}
```

New puzzle

This program will print something intersting. Can you figure out what it prints without running the program on your computer? To make it extra challenging: do you also know **why**? The answer to this puzzle will be published in the next MaCHazine.

```
Integer a = 42;
Integer b = 42;
System.out.println(a == b);
Integer c = 666;
Integer d = 666;
System.out.println(c == d);
```

Miscellaneous

Mathematical Puzzle

Average

Image all the numbers consisting of 4 digits in which each of the numbers 1, 2, 3 and 4 appear exactly once. (i.e. 1234 belongs to this list, but 1224 doesn't).

What is the average of these numbers?

Division

The number a = 11...111 exists of 2011 ones.

What is the remainder when dividing by 37?

Biggest number

For the integers a, b, c, d and e, the following holds:

$a + b + 1 = b + c - 2 = c + d + 3 = d + e - 4 = e + a + 5$

Which of the 5 numbers is the biggest?

Solutions from last issue

7	3	9	5	8	1	4	6	2
8	5	1	6	2	4	3	9	7
6	2	4	3	7	9	5	8	1
9	6	8	7	4	3	2	1	5
2	4	7	9	1	5		3	6
5	1	3	2	6	8	7	4	9
4	9	6	8	5	7	1	2	3
3	8	5	1	9	2	6	7	4
1	7	2	4	3	6	9	5	8

3	5	2	9	6	8	7	1	4
6	8	7	1	3	4	9	2	5
1	4	9	2	5	7	3	6	8
5	7	1	3	8	9	2	4	6
2	6	8	7	4	3	1	5	9
4	9	6	5	1	2	8	3	7
8	2	4	6	9	1	5	7	3
7	3	5	8	2	6	4	9	1
9	1	3	4	7	5	6	8	2

HackDelft

Join 100 other students interested in math, computer science or design for 24 hours of learning, building, and having fun in the second hackathon organized by the HackCie!

For more information about HackDelft, go to HackDelft.com.

WiFi Rally

During the weekend of the 12th and 13th of May the WiFi committee wil host a rally through the Benelux. Solve puzzles to get to the right locations and beat other teams while doing so! Registrations are now open at wisv.ch/rally

iCom

The iCom will organize a trip from 12 to 16 June to Milan. 30 students and two teachers from EEMCS will visit several companies, bring a visit to the the University and have a look at the cultural aspects of the city and country.

April

28-29 Hackathon

30 ComMA pubquiz with fries

May

1 T.U.E.S.Day lecture with drinks: Booking.com

2 Freshmen Programming Contest

3 Career College 4.1

4 MaPhyA Activity

7 General Assembly

8 T.U.E.S.Day lecture

8 Yearbook drinks

9 MatCH Just Dance tournament

12-13 WiFi Rally

14 MaPhyA activity: CH vs. VvTP

15 T.U.E.S.Day General lecture

17 Career College

24 Members lunch

June

5 T.U.E.S.Day lecture: ASML

5 MatCH activity

6 SjaarCie barbecue

7 Career College 4.3

12 T.U.E.S.Day Education lecture

12-16 iCom Milan

19 T.U.E.S.Day Education lecture

19 MesCie activity

26 T.U.E.S.Day lecture