Perio Interview: Harry Trentelman

Brainwork: We'll cross that bridge when we get there

Periodiek

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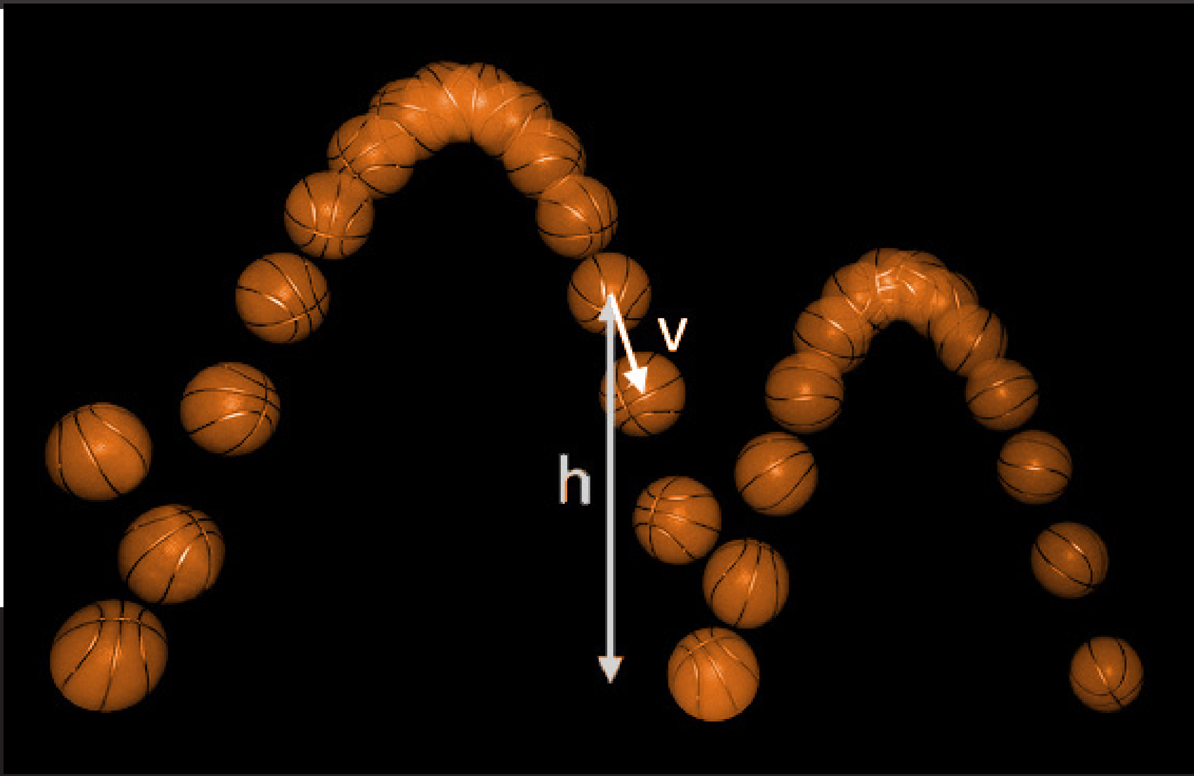
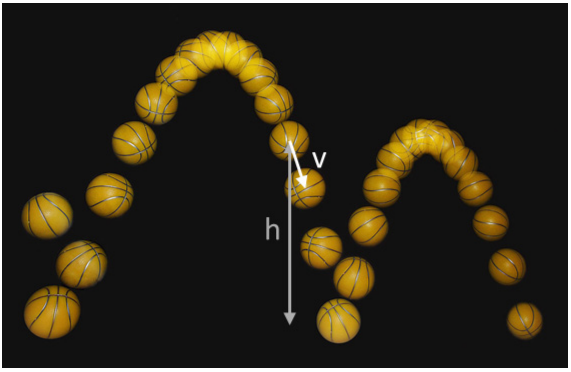


The Fastest Camera in the World

FMF

10 - Fastest Camera in the World



What do you do when you want to take pictures of one of the fastest things in nature? You use the fastest thing in existence: light!

This is an introduction to ultrafast Transient Absorption Spectroscopy, a technique which uses short laser pulses to take pictures of electrons moving through the energy levels within a material.

Conceptually explained so anyone can understand!

14 - Perio Interview; Harry Trentelman

Harry Trentelman is a professor of Mathematics that most maths students will know for teaching Linear Algebra II and a love for matrices that is perhaps only trumped by his love for cycling.

In this issue of the Periodiek, we have interviewed him and gotten to know a little bit more about him.

What is he planning on doing after his retirement? What is his favorite Matrix? What does he eat for breakfast? Find out this and more on page 14

27 - Brainwork: We'll cross that bridge when we get there

We dare you to solve a riddle in which you have to use the mathematics of awkward social situations to propagate yourself and your friends who do not mutually all know each other forward in a land whose infrastructure is falling apart.

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From the Editor in Chief

With 2022 well on it's way, we're happy to bring you another issue of the Periodiek. In this issue we have a contribution by Ronnie Tamming, who our older readers might remember.

Of course, the articles you are familiar with also make their return this issue with an interview with Harry Trentelman and an exchange article by our friends over at T.F.V. 'Professor Francken'.

As you may have heard if you attended the most recent GMA, the Periodiek will become opt-in! This mean we will be available online unless you sign up to get a physical copy. The next few issues will still be physical and in the meantime we will set up a way of signing up for the physical version.

Robert Mol

Editors
Robert Modderman,
Vedang Sumbre,
Robert Monden,
Tesse Tiemens,
Lucia Hereda,
Robert Mol

Authors
M. Grzegorczyk
Y. van Oppen
E. Rouwhorst
R. Tamming
S. Wobben
R. Monden
W. Krijnen
L. Hereda
A. Waters
A. Silvans
Y. Kırca
R. Mol

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In the News

Your triannual dose of latest news in the world of science and engineering

AUTHOR: **R. MODDERMAN**

What do a newly discovered exoplanet, the 2021 Nobel Prize in Physics, Donald J. Trump's new social media platform, and an auctioned original manuscript written by Einstein have in common? Precisely, they are all featured in this issue's *In the News*!

Exoplanet found outside Milky Way

Were we surprised to learn that all exoplanets to have ever been discovered were actually residing with us inside our own galaxy the entire time? Definitely! Since the first discovery of exoplanets in the early 1990s, it took three decades before astronomers were able to identify an exoplanet outside of our galaxy. Located in galaxy M51 - some 28 million lightyears from us - and as of yet unnamed, the newly discovered exoplanet has definitely beaten all previously discovered exoplanets, which all are positioned no farther than a few thousand light years away from us.[1]

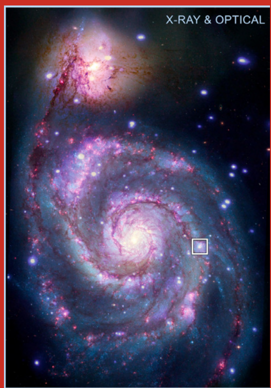


FIGURE 1: Galaxy M51 and the location of the exoplanet

It has been an American-Australian-Chinese collaboration, using NASA's satellite X-ray telescope *Chandra*, which led to the discovery of the exoplanet. The exoplanet orbits a so-called *X-ray binary*, which is a system of a "regular" star and a very dense celestial object, usually a neutron star or a black hole. This compact object sucks in matter from the star, during which a huge amount of X-rays is released. The exoplanet in question was identified, the astronomers argue[2], because Chandra was able to measure a brief decrease in X-ray intensity, which must have been caused by the exoplanet passing through the imaginary line connecting the X-ray binary with us.

It has only been due to this new methodology that an exoplanet this far away could be identified. *Within* our galaxy, exoplanets have been successfully identified by measuring brief decreases in intensity of *light* the star the exoplanet orbits emits. This technique does not work at the scale of tens of millions of light years away from us. At least, not at the moment; who knows what will be possible in the future.

FIGURE 2: NASA's satellite **X-ray telescope "Chandra" (NASA image)**

A terrestrial Nobel Prize in Physics

As was to be expected, the Nobel Prize in Physics was split --- again. One half was awarded to Giorgio Parisi, "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales." But it was the other Nobel Prize that caught our attention, as it is the first nobel prize in Physics to have a flavour of perhaps the biggest challenge humanity is facing today: climate change.

"For the physical modelling of Earth's climate, quantifying variability and reliably predicting global

1 https://www.newscientist.nl/nieuws/eerste-bewijs-voor-planeet-buiten-de-melkweg/

2 https://chandra.harvard.edu/photo/2021/m51/m51_paper.pdf

warming" Syukuro Manabe (90) and Klaus Hasselmann (90) received the other half of the 2021 Physics Nobel Prize, notably at high age. In a nutshell, they were recognized for laying the foundations of modelling man's influence on the world's climate. Fortunately for these brilliant scientists, they were still alive when they received the highest honour in science possible.

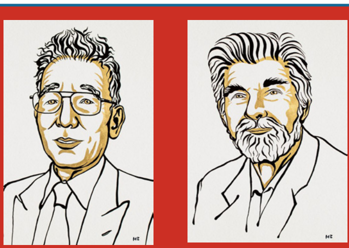


FIGURE 3: Syukuro Manabe and Klaus Hasselmann, winners of the 2021 Nobel Prize in Physics (drawings: Nobel Prize Outreach)

Truth Social - an enrichting alternative, or the return of the magaphone?

The riots at the US Capital in Washington, last January, made Facebook and Twitter decide to ban --- by now former president of the US --- Donald Trump for life. But, thinking from Trump's perspective, this was not the first time he was having issues with big tech and social media. Shortly after the US elections in November 2020, when he voiced his opinions on all related matters, Fox News partially refrained from giving him the full stage to freely speak his mind.

After the Facebook and Twitter ban, Donald Trump made an oath to his electorate to release his own alt-tech platform: *Truth Social*. The website[3] already exists, but the platform hasn't been rolled out officially yet. This year (2021 as of now), a limited launch is expected to be taking place in Apple™'s app store; the full launch will take place in 2022. Now, whether Trump wants to create a "safe space" for far-right people to share their thoughts or just wants to gather all his supporters in one place as he used to have when he still was on Twitter, is something time has to tell. Should Trump run for office in 2024, he'll at least have a way to let his followers know what he thinks.

Einstein manuscript auctioned for €11.7m

In late November 2021, one of the only two physical documents containing Einstein's *general theory of relativity* was sold at an auction in Paris[4], for the ridiculously high price of €11,700,000. The paper this manuscript eventually led to was published in 1915, and the script itself was written around 1913-1914. Einstein wrote this manuscript together with his Swiss colleague Michele Besso. The fact that Einstein used to be very sloppy in properly archiving his notes contributes to the explanation why this script on relativity is special.

4 https://www.bbc.com/news/world-europe-59392771

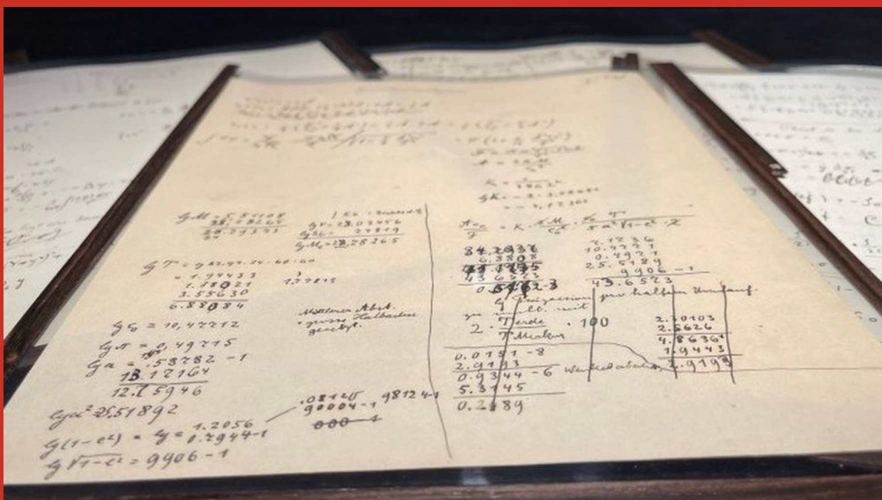


FIGURE 4: the auctioned manuscript, co-written by Einstein (photograph from REUTERS)

From the Board

Chair

AUTHOR: **Y. KIRCA**

Hey there!

First and foremost, I'd like to give you a very warm greeting on behalf of the 63rd board of the FMF. Even though we've only been board for around 8 months, it's been really fun being the bestuur of this wonderful association. I believe the rest of my board will agree when I say it's been an amazing experience so far.

What I love about FMF is the sense of community. Everybody knows each other and everyone is super welcoming to new members. As a result, it feels like a big family. A lot of members also choose to be active by joining committees, which we really appreciate! It's fantastic to see so many people willing to organize activities for each other to enjoy. Sadly, this sense of community took a bit of a hit when covid struck and we had to stop seeing each other in person.

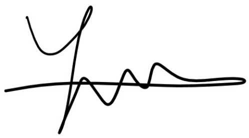
Therefore, our biggest focus from the beginning has been having as many social activities as possible and bringing back that association spirit all of us have been missing. Fortunately, covid cases were decreasing and rules were slowly being relaxed. Starting the year with the first physical GMA in a very long time, we were delighted to be able to hold events with very little limitation. It's been great to see members having a cup of coffee and hanging out at the FMF room again. We were able to hold fun, social events and educational activities alike. We celebrated the Dies Natalis. We started organising kamerborrels again, we also started having more career related events and we even had a Cantus! Besides, the attendance has been amazing. You could tell events like these were exactly what everyone needed after a year of lockdown.

One of my favorite moments of the board year so far has to be the Dies Natalis party. I feel like cutting the association's birthday cake with a bunch of members at the members' room perfectly captures what the FMF is all about. Sadly, shortly after our Dies, covid struck again. The rules seemed to change every few weeks and it's not certain what the situation will be at any point during the year.

We appreciate you putting your trust in us in such times of change and uncertainty. You can be sure that we're making every effort to provide you with the activities you're looking for. I hope, and I believe, that we've been achieving this so far. We'll keep doing our best to keep this up regardless of the situation; If we can't meet up in person, we'll hang out online. If we can't have physical events, we'll find a way to make online events fun.

It's been a really nice year so far and I'm looking forward to the rest of the year, and I'd like to wish you all the best of luck in your studies.

FIGURE 1: Yigit Kirca, the Chair of the FMF.



Modelling Lasers Using Gaussian Wave Packets

AUTHORS: **E. ROUWHORST, A. WATERS**

We give a short review on lasers and their modelling with Gaussian wave packets. Wavepackets are a popular choice for constructing solutions to mathematical physics problems due to their accuracy in solving conservative equations and nice localization properties. Here we make the connection to an example of a physical motivation for the choice-lasers.

Lasers

A laser, which stand for "light amplification by stimulated emission of radiation", is a device that generates focused coherent light using stimulated emission. When an atom is in an excited state, with some energy with respect to the ground state, and a photon of the same energy is incident on the atom, the photon can stimulate the emission of another photon from the atom. This additional photon has a couple of identical properties as the incident photon. The photons have the same energy, are in phase, have the same polarization and propagate in the same direction. Mathematically this phenomenon can be viewed as the waves adding constructively. If one manages to get a sample of atoms of which large percentage are in the excited state, a single photon of the right frequency can then trigger a chain reaction. Given the light wave is not scattered too much, this process keeps amplifying the wave. This continues as long as the active medium has more atoms that are in the excited state than in the ground state. The process is called population inversion.

Atoms that are in the excited state will eventually fall back to the ground state by spontaneous emission of a photon. These photons can be emitted in any direction. Without any intervention the material will just glow. However, if one places the active medium in a cavity with mirrors on both sides, a wave can then bounce back and forth, building up light strength with each pass through the active material. If the cavity is a cylinder with flat mirrors normal to the axis on both sides, all but the photons nearly parallel to the axis will quickly leave the cavity. Therefore, despite the spontaneous emission of photons being random, the axial beam will be the most dominant after a short while. The mirrors then cause the beam to be collimated to a large degree, effectively creating a coherent plane wave.

An additional effect of the mirrors is that standing waves will develop in the cavity. A node must occur at each mirror and hence only waves with a wavelength which is a half integer multiple of the length of the cavity can exist. The resonant modes of the cavity themselves have in general a smaller bandwidth than the bandwidth of the (broadened) atomic transition. Hence, depending on the length of the cavity, only some narrow bands will be sustained in the cavity. If the length of the cavity is selected such that only one frequency band will be amplified, the laser will produce only a 'single' frequency of light. As such it is often said laser light is monochromatic. Decreasing the length so that the laser only sustains one frequency, has as a disadvantage that the active medium will be smaller, which limits the power output of the beam. (Hecht, 2017)

Different standing waves can be distinguished: oscillations parallel and oscillations perpendicular to the direction of propagation, the so called longitudinal and transverse modes. The reason for the distinction made between transverse and longitudinal modes, despite a laser mode consisting of both simultaneously, is that they govern different properties of the beam. The line width and coherence length are mainly due to the longitudinal modes and the divergence, diameter and energy distribution of the beam are a result of the transverse modes. (Koechner, 2006) The transverse modes, also called transverse electromagnetic (TEM), can further be distinguished depending on the symmetry.

For TEM_{00}, the lowest order mode, the beam has a couple of interesting properties. First of all the intensity is Gaussian over the beam's cross section. Secondly the beam is spatially coherent, there are no phase shifts across the beam, unlike other modes.

Thirdly, the divergence is the smallest of all the modes. It can be focused down to the smallest sized spot. These reasons make it a popular mode used in lasers.

To model a laser beam the conventional method is to start from the wave equation for the electric field and make a few approximations. Assuming monochromatic light focused in a beam along the z-axis with slowly varying amplitude and ignorable vectorial nature, the wave equation can be written as the paraxial wave equation. (Peatross & Ware, 2015)

$$\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + 2ik\frac{\partial E}{\partial z} = 0$$

Where k is the wave number. If we assume the transverse modes are seperable in the cartesian coordinates x and y then the time-independent solution is given by the Hermite-Gaussian modes:

$$\begin{aligned} E_{mn}(x,y,z) = E_0 \frac{w}{w_0} H_m\left(\frac{\sqrt{2}x}{w}\right) \\ \times H_n\left(\frac{\sqrt{2}y}{w}\right) e^{-(x^2+y^2)/w^2} \\ \times e^{ikz} e^{ik(x^2+y^2)/2R} \\ \times e^{-i(1+m+n)\tan^{-1}(z/z_R)} \end{aligned}$$

Where m and n indicate the transverse modes in the x and y direction respectively with:

$$\begin{aligned} z_R &= kw_0^2/2 \\ w^2 &= w_0^2(1+(z/z_R)^2) \\ R &= z(1+(z_R/z)^2) \end{aligned}$$

As the name suggest the solution is a combination of the physicists Hermite polynomials and a Gaussian. Along the z-axis the radius of the beam is given by w. The beam radius depends on z_R, known as the Rayleigh range, which governs the distance starting from $z = 0$ over which the beam intensity halves and the width increases by $\sqrt{2}$. The term ikz describes the plane wave oscillations and $ik(x^2+y^2)/2R$ curves the wave fronts, with R being the radius of curvature. The final term with $\tan^{-1}(z/z_R)$ is called the Gouy phase, which is most pronounced near $z = 0$. A front view can be seen in figure 1.

For large z the intensity drops as

$$I(0,z) \propto |E_{mn}(0,0,z)|^2 \approx z_0^2/z^2$$

and the width goes as $w(z) \approx w_0 z/z_0$. Therefore a very small waist, and hence a very small Rayleigh range, causes the beam to diverge and lose intensity fast. The smaller the waist, the faster the divergence. This is an example of the uncertainty principle in action. (Feng & Winful, 2001)

Quantum Mechanics

If we now make the educated substitution

$$\Psi(x,y,z) = \psi(\xi,\eta,\tau)e^{\frac{ik(x^2+y^2)}{2R}}/w$$

with

$$\xi = \frac{\sqrt{2}x}{w},\ \eta = \frac{\sqrt{2}y}{w},\ \tau = \tan^{-1}(z/z_R)$$

and put it into the paraxial wave equation the result is

$$\left[-\frac{\partial^2}{\partial\xi^2} - \frac{\partial^2}{\partial\eta^2} + \xi^2 + \eta^2 - 2i\frac{\partial}{\partial\tau}\right]\psi(\xi,\eta,\tau) = 0$$

in which we recognize a two-dimensional Schrödinger equation for the harmonic oscillator. This substitution links the beam envelope amplitude with a two-dimensional harmonic oscillator wave function. The optics problem has been translated to a quantum problem. More specifically, the z-coordinate $z \in (-\infty,\infty)$ in the optics case is transformed to time $\tau \in (-\pi/2,\pi/2)$ in the quantum case but the time in the optics case does not have an analogue. This quantum mechanical solution we call a wave packet because it no longer represents a continuous beam like the optics solution but a short burst or packet. A wave packet is a superposition of various wave functions to from a localized wave, which is normalizable in contrast to plane waves.

FIGURE 1: Hermite-Gaussian modes, starting from TEM_{00}, m increases from left to right, n increases from top to bottom. Plotted is the the real part of the electric field at z = 0. Red indicates a positive value for

Wave packets are widely used throughout mathematical physics. The normalizability aids in the observability and controllability of solutions. (Waters, Observability for Schrödinger equations with quadratic Hamiltonians, 2020) Decomposing the free space Schrödinger equation into Gaussian wave packets to establish existence and uniqueness of solutions for a nonlinear Schrödinger equation is done in (Killip, Visan, & Zhang, 2012). And a wave packet transform is introduced in (Córdoba & Fefferman, 1978) as a generalization of the Fourier transform. These can also be used for wave equations with a complicated metric annd even the heat equation using the substition t to it. (Waters, A Parametrix Construction for the Wave Equation with Low Regularity Coefficients Using a Frame of Gaussians, 2010) and (Gimperlein & Waters, 2017). When considering a Schrödinger equation with a time independent Hamiltonian, we can formally write the solution using a time evolution operator:

$$\Psi(t,x) = e^{-i\hat{H}t}\Psi(0,x)$$

with $\Psi(0,x)$ the initial state of the system. Note that the evolution operator $U(t,x) = e^{-i\hat{H}t}$ is unitary if the Hamiltonian is Hermitian. The operator itself features an Hamiltonian in the exponent, and pulling out a calculator won't suffice to compute this. The way to make sense of this notation is by using the power series expansion of the exponential. Special care has to be taken for unbounded Hamiltonians because the series expansion need not converge. If separation of variables is applied, the evolution operator becomes e^{-iEt}, which is a lot more accessible but this assumes that the initial state is an energy eigenstate of the Hamiltonian: $H\Psi = E\Psi$, which means not every wave function can be evolved in time. For time dependent Hamiltonians a time evolution operator may also be found by adiabiatic expansion theory but the procedure is considerably more involved. Moreover adiabatic expansion theory is largely for semi-classical Hamiltonians.

A time evolution equation looks nice and is compact but for explicit computations it is not that useful. Enter propagators: the fundamental solutions of the Schrödinger equation. A fundamental solution is the solution $G(t,x,t_0,x')$ such that:

$$\left(i\frac{\partial}{\partial t} - \hat{H}\right) G = \delta(t-t_0)\delta(x-x')$$

By Duhamel's principle this corresponds to the homogeneous Schrödinger equation combined with the delta function only in space as initial condition:

$$\left(i\frac{\partial}{\partial t} - \hat{H}\right) K(t,x,t_0,x') = 0$$

$$K(t_0,x,t_0,x') = \delta(x-x')$$

where we can identify K as the kernel of the Schrödinger equation. The solution is then given by:

$$\begin{aligned} G(t,x,t',x') &= -i\int_{t_0}^{t} \delta(t'-t_0)K(t',x,t_0,x')dt' \\ &= -i\theta(t-t_0)K(t,x,t_0,x') \end{aligned}$$

with $\theta(t-t')$ the unit step function. From the fundamental solution the solution to any initial condition $\Psi(t_0,x)$ can be created as follows:

$$\Psi(t,x) = \int K(t,x,t_0,x')\Psi(t_0,x')dx'$$

For many Hamiltonians the propagator is known. For the harmonic oscillator there exists the well known Mehler kernel. The Mehler kernel is not easy to compute explicilty. This is why the wavepackets have such popularity in the litterature. The starting state is a Gaussian and it is propagated forward along curves related to the Hamiltonian flow which creates another Gaussian. A superposition of them can be used to solve conservative equations, even time dependent ones, accurately using Wiener's theorem.

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Fastest Camera in the World

AUTHOR: **R. R. TAMMING**

What do you do when you want to take pictures of one of the fastest things in nature? You use the fastest thing in existence: light! This is an introduction to ultrafast Transient Absorption Spectroscopy, a technique which uses short laser pulses to take pictures of electrons moving through the energy levels within a material. Conceptually explained so anyone can understand!

Getting the idea

Consider throwing a ball on the floor. What would you do if you want to know the total amount of energy within this system while it loses energy due to air friction and heat generation by the bounces? Ultrafast spectroscopists will immediately take out a stroboscope to illuminate the ball in a dark room at different points in time (on the millisecond timescale) while it is moving in space and capture an image using a camera. The result of this is shown in Figure 1. Using the frequency of the stroboscope, the velocity at distinct moments in time can be calculated, providing for the kinetic energy, while the height of the ball provides the potential energy.

Now, instead of a ball, consider an electron in a (semi)conducting material. Also, instead of a human bouncing the ball, the electron gets additional energy by absorbing a photon. Besides scaling down in size, we will also have to scale down in time as the lifetime of electrons, and their exchange of energy, occurs on a femtosecond (10-15 second) timescale. Note that this is equivalent to a second as one minute is equivalent to the age of the universe. No physical or electronic shutter is fast enough to capture something at this timescale, therefore a stroboscobic method is required. The only stroboscope fast enough to measure the energy dissipation of electrons is an ultrafast laser, generating laser pulses with a sub-100 femtosecond duration.

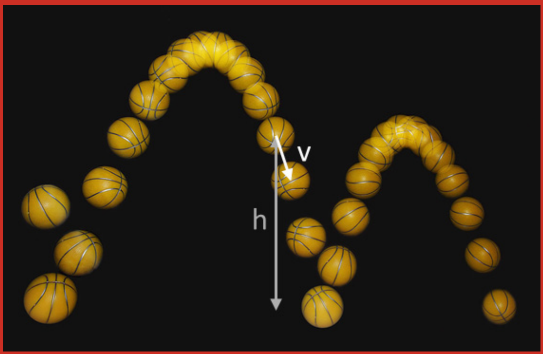

FIGURE 1: Basketball captured using a stroboscope in a dark room.

Why would we want to measure the energy dissipation of an electron? Say that the photon that provides the energy to the electrons comes directly from the sun. If we can now extract these electrons before the energy is lost to the environment, we have the principles of a solar cell. This has been applied successfully with the classic silicon solar panels. However, complex processing techniques are required to fabricate these panels which use a lot of energy and emits large quantities of greenhouse gasses. Because of this, researchers are looking for alternative active materials for solar cells, with the most promising candidates being organic photovoltaic materials and halide perovskites. The top efficiencies of these materials for a single-junction solar panel are 18.2% and 25.5% respectively, compared to 26.7% for silicon. Note here that the theoretical maximum efficiency (also known as the Shockley-Queisser limit) for a single junction solar cell is calculated at 33.7%. These high efficiencies were only achieved by understanding the properties of the material related to the energy dissipation. This information allows us to develop new materials to decrease the energy loss and increase the travel distance of these high energy electrons.

Transient absorbtion spectroscopy

One technique often used to understand the energy dissipation of electrons is ultrafast Transient Absorption (TA) spectroscopy, utilizing laser pulses with short temporal duration from an ultrafast laser. This technique measures the change in transmission of a material after illumination and is schematically shown in Figure 2. Using a partially reflective mirror, each pulse generated by this laser is split into two pulses, a pump and a probe pulse. The idea is that a part of the pump pulse is absorbed by the material of interest, exciting the electrons. The probe pulse then arrives later in time and the transmission is captured and compared to the ground state (no excitation) transmission of the sample. The final TA signal is calculated by the normalized change in transmission according to $\frac{\Delta T}{T} = \frac{T^* - T}{T}$, where T* is the excited state and T is the ground state transmission. This signal provides information regarding the occupancy of electronic energy levels of the material.

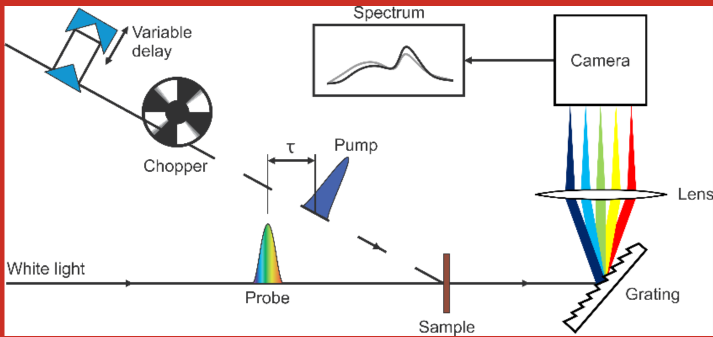

FIGURE 2: Schematic overview of an ultrafast transient absorption system

To measure the excited state in time, we make use of the speed of light. Knowing that 1 foot (30 cm) corresponds to approximately 1 nanosecond, we can physically move a mirror to delay the arrival time of the pump or probe pulse. By scanning the time delay, we observe an excited state spectrum which is dependent on the time delay between the pump and probe pulse. This provides us with information, equivalent to the photos of the basketball in Figure 1. Small variations in the environment can have significant impact on the pulses generated by the pulsed laser. A typical TA measurement takes about half an hour, during which the output power of the laser can fluctuate significantly. Therefore, we can't just take a measurement of the ground state and compare that to a measurement of the excited state. To account for this, we use a mechanical chopper which looks like a fan. This chopper blocks every other pump pulse so that we get a ground-state and excited-state probe pulse sequence, which we use in combination with a camera that takes photos of each individual pulses. As these pulses are less than 1 millisecond apart from one another, the environment is nearly identical. Using this technique, we can calculate the TA signal with sequential shots and average the TA spectrum over a lot of shot pairs to reduce the impact from long-term laser fluctuations.

Pulse preparation

There are several mechanisms in the material that are measured simultaneously and that can have spectrally overlapping features. An overview of the mechanisms for parabolic electronic bands is shown in Figure 3 and are, in order, the excitation event, state filling, bandgap renormalization, inter/intraband absorption and stimulated emission. Which of these features occur and the spectral fingerprint and the lifetime of these features, provide a lot of information on the electronic structure and the movement of electrons of the material of interest.

The excitation event occurs when the pump is absorbed. Electrons obtain the energy from a photon and go from the valence band (bottom parabola) to the conduction band as shown in Figure 3a. The remaining vacancy is classified as a positively charged pseudo particle called a hole. Now that the electronic states in the conduction band are filled (and the valence band are depleted), absorption of the probe light with this photon energy is reduced as indicated in Figure 3b. This results in more transmitted light corresponding to the photon wavelength with the corresponding energy, leading to a positive TA signal. The second observable signal is the bandgap renormalization, depicted in Figure 3c. As the freely moving electrons, that is electrons in the conduction band, have a different Coulomb interaction with the lattice than the electrons in the valence band. This can result in a change in the available electronic states in the material, reducing the bandgap. The reduction creates new available energy transitions which were not possible previously before the excitation. This leads to an increase in absorption corresponding to this wavelength and a reduced transmission of the probe, hence a negative TA signal is observed. These newly created states, however, will quickly be occupied by the electrons in the states above as they lose energy to the lattice by generating heat.

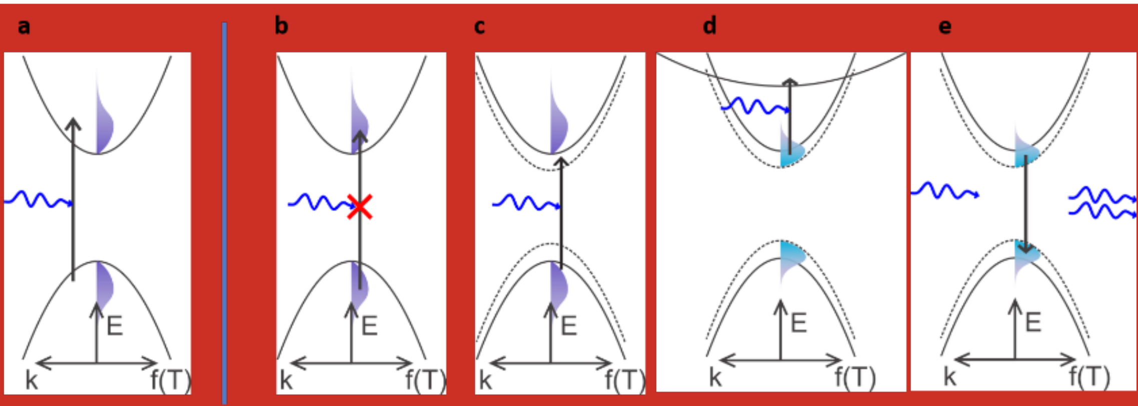

FIGURE 3: Transient absorption signal origins. A) indicates the excitation event while b-e indicate various possible physical excited-state mechanisms.

The third signal is a result from inter/intraband absorption. This is the absorption of a photon by an electron (hole) in the conduction (valence) band so that it obtains the energy to occupy a higher energy state shown in Figure 3d. This transition is not available in the ground state, as there are no electrons (holes) to excite in their corresponding bands. This leads to a reduced transmittance of the probe pulse and a negative TA signal.

The last signal is from stimulated emission, displayed in Figure 3e. The electric field of a photon can be absorbed, however, the opposite can also occur. That is, a photon is emitted by an electron going back to the ground state. This process can be stimulated by photons that have the same energy as this transition and is the fundamental process occurring within lasers. The generated photons will be emitted in the same direction as the incident photon and thus results in additional photons in the probe beam, leading to a positive TA signal.

Signal contributions

Now that we know (and hopefully understand) some of the dynamics which we can observe, let's have a look at a real-life example. Figure 4a shows the surface plot for a transient absorption measurement on methylammonium lead iodide (MAPbI3) perovskite sample. If we now take slices at different times and wavelengths, we can see the response a bit more clearly.

Figure 4b shows the spectral slices at different time points. This shows that a large positive signal and a smaller positive signal arise at 740 nm and 490 nm, respectively. These correspond to the state filling (Figure 3b) of two distinct energy bands. The rise time and signal level are shown in Figure 4c, where temporal slices at key wavelengths are shown. This shows a two-fold rise time for the signal at 740 nm. Whereas the sharp rise indicates the direct excitation, and rethermalization of the electrons/holes, the slow increase afterwards is caused by "hot" carriers cooling down. These hot carriers are electons/holes which are excited to above the band edge and thus contain more energy. This energy is lost as the carriers scatter with the lattice so that the carriers cool down to the band edge, slightly heating up the sample. These hot carriers are observed between 520 nm and 690 nm, where a positive signal is observed at time zero. This signal is indicated by 675 nm in Figure 4c, which shows a rapid decrease, corresponding to the depletion of these higher energy levels.

The last important signals are the negative signals. For this, there are two regions: one at early times above 750 nm and one at later times between 520 and 690 nm. Scientists have pretty much agreed that the early signal is a result from bandgap renormalization (Figure 3c). These instantaneously newly created states allow for additional absorption at these wavelengths, but these states are quickly filled by carriers cooling down. This is shown in Figure 4d, where a negative signal is observed between -200 fs and 200 fs which turns positive at later times. The negative signal at later times, however, is still under debate. Some researchers suggest it's a result from the bandgap renormalization (Figure 3c) that extends to higher energy levels, while others suggest it is a result from interband absorption (Figure 3d). This shows that signal interpretation is not as straightforward using this technique and collaboration with other research fields is crucial to unravel the mysteries of these materials.

Besides appointing spectral features to physical mechanisms, the spectral shape of the transient absorption spectrum and the timescale of the kinetics provide all sorts of additional information such as, but not limited to, hot carrier cooling rates, carrier diffusion lengths and excited carrier lifetimes, all of which are related to the efficiency of solar cell and LED applications. Understanding these mechanisms and timescales will help device manufacturers to optimize their next generation photovoltaics.

Endnote

Now that you've read this article, I hope that you understand the power and relevance of this technique. In case you would like to know more about the technique, or the information that is obtained with it, there are some references below to read further into it. These references also include results from, and advances made in this field by me and my research group.

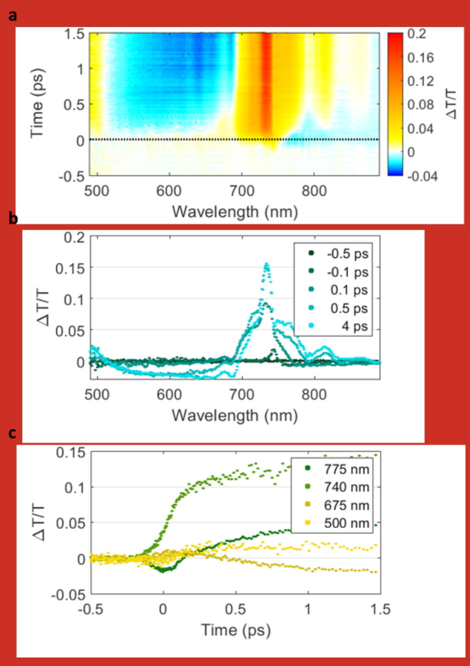

FIGURE 4: Results from a transient absorption measurement on MAPbI3 perovskite

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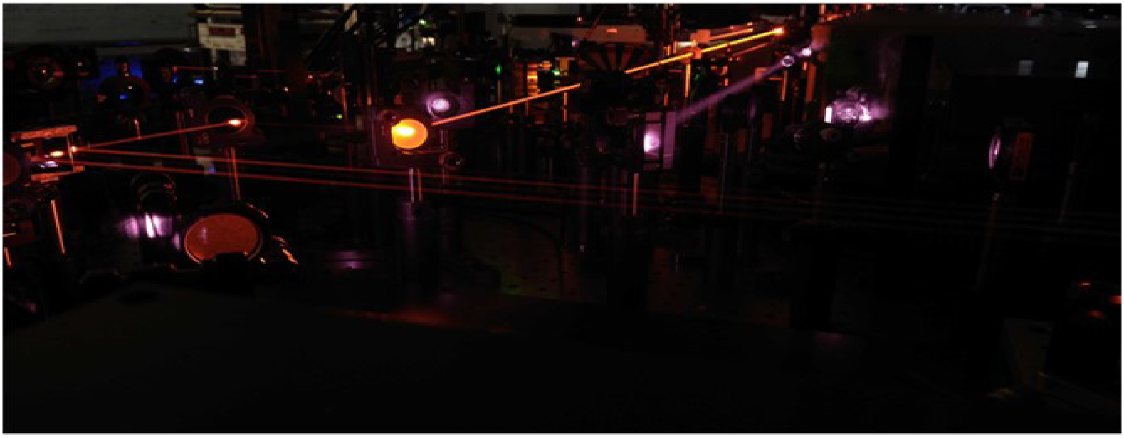

Perio Interview: Harry Trentelman

Cycling, Teaching, and Retirement

AUTHORS: **R. MOL, R. MONDEN**

Harry Trentelman is soon-to-be retired professor at the University of Groningen who takes a special interest in all things cycling. Teaching Linear Algebra II, Harry has left an impression on many Mathematics students throughout the years. In this issue of the Perio Interview, we got to know him a little better.

We have heard that you are going to retire soon. Are you looking forward to your retirement, and why (not)?

On the one hand, yes, on the other hand, no. When you are retiring it means that you have gotten older and that is never a pleasant realization. I would much rather still be forty. On the other hand I'm quite looking forward to having few obligations. No more unpleasant obligations, because there are some unpleasant aspects to this line of work.

I do really enjoy doing research and teaching, but on the other hand tasks such as grading exams and administration are unpleasant, yet important aspects of teaching. In that sense, I'm quite looking forward to retirement: the feeling of freedom and being able to do whatever you want, whenever you want.

What are some of the things you are looking forward to do after your retirement?

It might sound as if my retirement will be nothing but a smooth ride. In anticipation of my retirement I bought a camper, for example, with the idea to use it to visit southern Europe for longer periods of time, also out the summer. With my bike on the back, because I love cycling. On the other hand, my wife is younger than I am (she is 54 years old) and still has twelve years left before retirement. Therefore it is simply not possible to travel for longer periods.

However, some of my fellow cycling enthusiasts, who are all between 65 and 70 years old, go cycling every Tuesday and Thursday morning, but I can not always join them because I have to work the on those days. I would like to join them more often, if possible.

In addition, I'll still be doing some work here. I'm writing a book with Kanat Camlibel, for example, and we still have plans for a second book.

Generally speaking, what do you like the most (and the least) about working at the University of Groningen?

What I like the most and the least about working here? Difficult question. Currently there is nothing I dislike, since I'm currently working on the book, which I quite enjoy. However, five years ago I resigned from my position as deputy director of Mathematics at the RUG. This meant being responsible for ensuring the educational program runs smoothly and ensuring there is a substitute for a teacher who calls in sick on Sunday evening, these kinds of organizational matters. The rapid switches between tasks was also quite frustrating: at one moment I needed to give a lecture, then grade exams, then I had to take care of some matter, then finally I had to attend a board meeting. This rapid switching is probably what I disliked the most.

I often had trouble with meetings, which were often unproductive and made me question what I was actually doing there. Of course, such tasks are part of the job description and you cannot simply decline because you do not feel like going.

What is your favorite matrix?

The movie.

How did you end up in the academic world? What made you decide to pursue a career in math?

Well, quite simple really. I was studying math in university and at some point was pursuing a master's degree (then called a doctoraal). There was a professor called Jan Willems, who invited me to become an Assistent in Opleiding (AIO). Jan Willems was a great guy, quite a renowned expert in his field. I considered it a great honor and accepted. He requested a scholarship at the Nederlandse Stichting voor Wetenschappelijk Onderzoek (NWO).

"I probably should not have said that, but everyone thought it was funny."

The request was accepted and I started working on my PhD. I enjoyed doing research so much that I knew that it was what I wanted to do for the rest of my life. The idea of sitting behind a desk and to keep learning new things greatly fascinated me.

During that time the situation was a lot different from now and after getting my PhD I was quickly offered a permanent job at the Eindhoven University of Technology, with another professor who is quite renowned: Hautus. In Eindhoven I became an assistant professor.

At a certain point there was a vacancy for an associate professor with Jan Willems, my promotor. We got along quite well and subsequently I was hired as an associate professor. Eventually I became a professor. First as an adjunct professor in 2004, because I had not yet received enough grants. Then, in 2009, I was promoted to a full professor.

It was quite amusing, because there were around twelve applicants and I found it quite surprising that I was the one chosen. When I mentioned my desire to become an associate professor in Eindhoven, no positions were available, but when I said I would leave for Groningen they suddenly changed their minds. I still left for Groningen, however.

What did you admire the most about Jan Willems?

He simply was incredibly clever, mathematical, creative, he had a sharp mind and above all, he was a true scientist. It was clear that science was his passion. It all seemed to come naturally to him: it was his hobby. When I do research, ninety percent of the time I make little progress, making me question what I'm even doing, but with him it all seemed to come naturally.

But he was also incredibly nice, sweet, kind and humble. He died in 2013. He was really like how people imagine scientists to be. Kind of looked like one, too.

Are there any other people who you admire, either scientists or non-scientists?

Do you know Alex Friedrich, who works at the UMCG? During the coronavirus pandemic he often appeared on television.

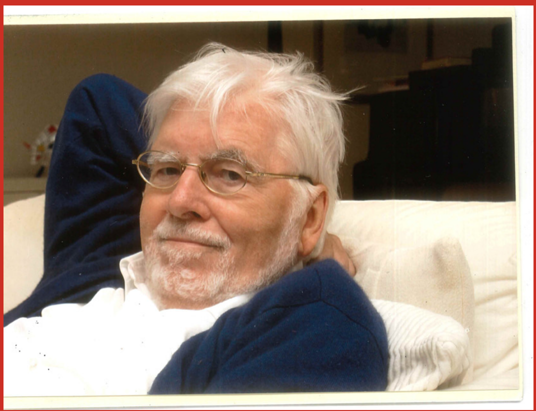

FIGURE 1: Harry's photo of Jan Willems.

I'm not exactly sure what field he is in; I know it is related to viruses, but he is not a virologist. I quite liked how he did that. Some time ago he received a royal decoration and he is leaving to become the director of a hospital in Münster, I believe. He's the first person that comes to mind.

As for other people? Who else do I admire? Oh dear, I really need to think hard about this. I find Mathieu van der Poel to be absolutely incredible, I truly admire him. The way in which he approaches his sport: he doesn't care and he doesn't always win, but he always rocks the boat. Other people who I really admire? As for politicians, I cannot think of anyone in particular who I really admire. They are just not it. Actors? Well, difficult. Truly a difficult question.

What is your favorite equation?

My favorite equation is the Riccati equation, because you can see it everywhere: in optimal control, robust control, it is truly incredible. The name Riccati comes from some Italian count, called Riccati, who I believe lived next to lake Como near Como. Math was his hobby. The rest of his spare time he spent hunting and hiking. This is truly my favorite equation, a matrix equation.

What do you like most about teaching?

When I'm standing in front of a class of students, I like to present information in such a way that students understand it. Often study material looks very difficult, while in reality it is very straight-forward. I usually mention this in class as well. This is truly a challenge.

This might be a bit cliché, but I like explaining topics in a structured manner. Showing students how simple the topic really is, but I of course also know that often it does not appear that way. When you are seeing something for the first time it can be incredibly intimidating. I try to take away the feeling that many students have, the feeling that they should just give up because they will not be able to understand it anyway.

"Whenever I'm teaching a class, both humorous and less humorous statements frequently occur to me and many times I blurt these out."

Whenever I'm teaching a class, both humorous and less humorous statements frequently occur to me and many times I blurt these out. It is like a theater show. I cannot help it, this is just the way I act in front of a group of people. I simply like making jokes and comforting people.
Students have generally reacted to this in a positive manner, however I do need to be careful, of course. Sometimes I say things that do not come out as I intended them. At some point there was a girl reading the newspaper and I carefully threw a piece of chalk towards her. Clearly you cannot do this anymore these days, but in the past you could. Later, during the student evaluation for that course, someone wrote that professor Trentelman 'creates a hostile teaching environment'. This is of course not true at all, I am the friendliness itself.

Some time ago, I came across the daughter of a friend of mine, who took my Linear Algebra class and during one of the lectures, which must have been some time ago, someone fainted. I cannot recall exactly what happened, but as he left the classroom I seem to have said something like "It's not that difficult what I'm explaining here, is it?" I probably should not have said that, but everyone thought it was funny. It did leave an impression.

During the pandemic, how did you deal with the transition to online teaching?

Everything closed down two weeks before the Linear Algebra II course. I had never taught online before, so the transition look some time. I purchased an iPad Pro, which can be connected to a MacBook. For each lecture I made slides on that iPad, writing down the definitions and theorems beforehand and then writing down additional notes during the lecture itself. To my experience this went quite well, much more structured. I was able to cover more material because I was wasting less time on writing down frivolous things. It was a very interesting experience, being able to write out all detailed information in advance and then calmy explain that information during the lecture. Usually around seventy to eighty students enrolled for the course, but only about thirty students attended the lectures. I think many students just watched the recording. The percentage of students passing the course actually remained the same as when the course was given physically. I think it was a really interesting experience to do it this way. I can imagine that partially online education would remain for larger groups, allowing for more time and space for physical lab sessions. Then students would watch the recordings on their own computers. This may be much more efficient, I think. On the other hand you would miss interaction with students that way.

Do you have any hidden talents?

Well, I think I am a pretty good painter. Not really paintings, but houses. This is also pretty convenient. I have also installed electricity in my shed, laying the cables underground and installing a socket. In addition I would say I am a pretty good cook.

Tell us about cycling.

Cycling is my passion. On my whiteboard there are a few numbers. These are the numbers of kilometers I cycle each year. The bottom one is from this year. Each year I cycle about twelve thousand kilometers, which is also recorded on Strava. I would say cycling is probably my greatest hobby. Each week I cycle about 200 to 250 kilometers. I own several racing bikes, about four of them. In addition, I also own a gravel bike, a mountain bike and some city bikes. You may ask yourself: why does someone have that many racing bikes? Well, I have one for speed, one for cycling here in the neighborhood and one for traversing hills or mountains. With the latter bike I sometimes go to Limburg, the Alps or the Pyrenees. Since this usually involves camping there, I prefer not to take my most expensive racing bike. Then I also have another racing bike for during the winter, in case there's brine on the road. This one is the cheapest one I own. I use the gravel bike for forests, which is another fad. It's a bit in-between racing bikes and mountain bikes. It look likes a racing bike, but the tires are between 35 to 40 millimeters and the wheels have a higher tread depth, allowing you to cycle on sand or gravel paths. I also love watching cycling, however. Some time ago I watched the Tour de France on television and it was fantastic. It truly lights me up, not just because of the cycling but also the culture surrounding it. It's incredible. It's actually a way of life. A lifestyle.

How expensive if your most expensive racing bike?

€12,000. I have an S-works Tarmac sl6. If you watch, for example, the peloton, such as Fabio Jakobsen, Julian Alaphilippe, and Peter Sagan, they also ride on S-works bicycles. It is not something you do lightly, buying such an expensive bike. That is something you do at a later age when you think ''Now it has to happen''. Of course I didn't start with that, my first bike costed around €1,200.

What academic achievements are you most proud of?

Until recently, I was senior editor of the scientific journal, "IEEE Transactions on Automatic Control". That is the leading journal in our field. 'Senior editor' means that you are one of the five people responsible for actually making the journal. If somebody writes an article then it is sent to the journal and then this article is sent to reviewers by so-called ''associate editors''. These reviewers then write review reports. There are usually three or four of these per article. Then, the associate editors make a decision about the article, based on these reviews: either to reject, to approve, or to revise. But, those decisions have to be approved by the senior editors. There are just five of those. I have done that for six years. I was quite proud of the fact that they asked me for that. You have a complete overview of everything that happens in such a journal. It's quite an honor.

FIGURE 2: Harry in his sports attire

What did you have for breakfast this morning?

Oatmeal with nuts, fruit, and honey. I eat that every morning. That is an easy question. In the past, I just ate bread. At some point, my oldest son told me ''Dad, you should eat oatmeal. That's so tasty, and there's a lot in it. You mix it with some fruit and some nuts and some honey, and then you are ready for the day." That was six years ago. I started that then and I eat it every morning, except when I go camping. I have a small camper, and when I go camping I eat a few slices of bread with hagelslag every morning. Camping is also a big hobby of mine.

Exchange Article

A study of stress concentrations on a copper surface by means of simulation

AUTHOR: **S. WOBBEN**

This article is a crossover between the Periodiek and the Francken Vrij from T.F.V. 'Professor Francken', of which one of the editors wrote this piece on the finite element method.

In the past one would usually set up a laboratory experiment with the goal to research some physical principle, however, since the invention of the computer, simulations and computations have become powerful tools to perform all kinds of experiments. In this column we'll be looking into a method of analyzing partial differential equations applied to objects, something one might want to do when designing a product.

Most products you use on a daily basis are carefully crafted. Even a simple system like a pen has about five components. It can be frustrating when your pen doesn't work, but it's not the end of the world. However, a more impactful example, which every physicist must have seen, is the videos of the Tacoma Narrows Bridge, which started to shake violently due to resonance (if you do not know what I'm talking about I suggest Googling '*The collapsing bridge*'). Design flaws alike can have devastating effects and may cost a fortune.

So then, how can we research this? Understanding the effects of partial differential equations (PDEs) on complex systems is usually quite difficult, especially for humans. By dividing our system into a finite amount of small *elements* we only have to study many linear approximations instead, making our calculations much easier. Combining the results of all these calculations gives a general understanding of our systems[1]. The system can be divided into a set of M elements called the finite element mesh[2]. There are multiple ways of applying the finite element method, but in general you start looking at a variable u that is the dependent variable in a PDE. Then, u can be approximated using a function u_h such that

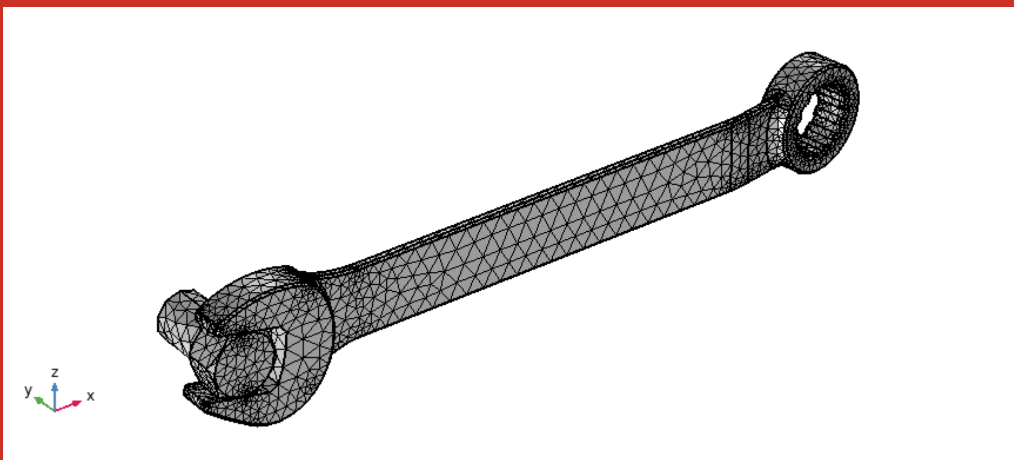

FIGURE 1: An image of a wrench divided in a finite amount of elements

$u \approx u_h$ and $u_h = \sum_i u_i \psi_i$, where ψ_i denotes the basis functions and u_i the coefficients of the functions that approximate u with u_h. These can generally be solved using numerical analysis[3].

So now that we have a basic idea of the finite element method, let us do the fun part and perform a small scale experiment. In this experiment we would like to find the maximum stress in a wrench turning a bolt. When defining a mesh we usually get something that looks like[4] figure 1.

In general, this is still quite a big mesh for such a small object, but the more nodes that are added the larger your computing time becomes. If we now apply a small force (or displacement) at the end of the wrench, then we can study the behavior of the stress within the system, as can be seen in figure 2.

For simplicity, the deformation of the wrench has been neglected. As we can see, most of the stress can be found in the wrench and not necessary in the bolt. The applied load at the end of the wrench was set to 150 Newton, which results in a maximum *von Mises stress* of $3.45 \cdot 10^8$ Nm^{-2}. In COMSOL we can find that *Young's modulus* for the used material (structural steel) is 200 GPa, meaning that we have a long way to go before we start to plastically deform the wrench. If only we had this technology available when designing the Tacoma Narrows Bridge.

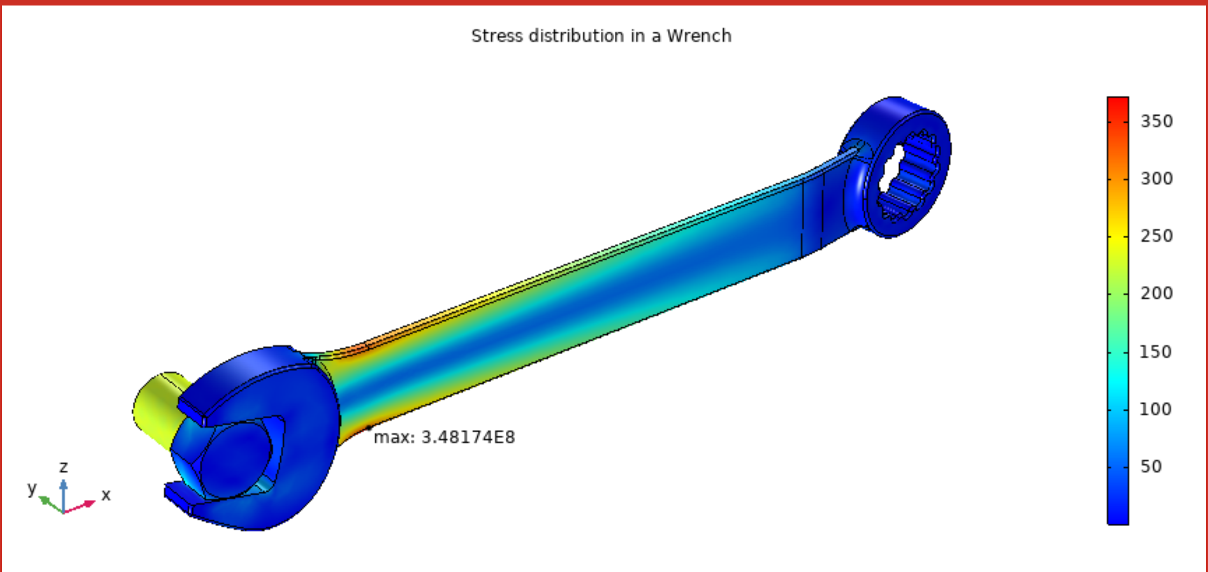

FIGURE 2: A continuous stress distribution resulting from computations performed on the previously mentioned mesh

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Statistical analysis of the green hawker dragonfly populations in the Northern Netherlands

AUTHORS: **M. GRZEGORCZYK, W. KRIJNEN, Y. VAN OPPEN**

This article is about the statistical analysis of dragonfly populations in the Northern Netherlands. Dragonflies were counted by Bureau Biota (Groningen, NL) in four consecutive years 2015-2018, and we (Bernoulli Institute) supported Bureau Biota with the statistical analysis of the data. For the data analysis we designed a tailored new mixed effects model for bivariate count data that can deal with zero inflations and large outliers. The results of our statistical analyses became part of a status report for the ecological managers. We would like to thank Gabi Milder-Mulderij, Christopher Brochard, Rink Wiggers, and Saskia de Vries from Bureau Biota for this interesting collaboration.

Background

The dragonfly species 'green hawker' (Aeshna viridis) is rare and threatened. Therefore, in the year 2001, the Dutch Ministry for Agriculture, Nature, and Fisheries published a protection plan for the green hawker (de Jong, Verbeek, & Smolders, 2001). Green hawkers only lay their eggs into the 'water soldier' plant (Stratiotes aloides) which is typically found in ditches that separate patches of agricultural land. But agriculture leads to increased proliferation of the water soldier. This proliferation deteriorates the water quality and decreases the water depth, since decaying plants build a layer of sludge at the bottom of the ditches. Ecological managers thus have to control and to reduce the amount of water soldier plants on the water surfaces. Typically managers periodically clean a maximum of 50% of the water surface from the water soldier. The available data consist of green hawker population counts from five ecological managers covering 17 ditches across three Dutch provinces of the Northern Netherlands, namely Groningen, Friesland, and Drenthe. The ditch locations are indicated in the map in Figure 2. For the data collection, Bureau Biota conducted ecological field studies. These field studies were financed by the ecological managers and the three Dutch provinces. Each of the 17 ditches was divided into two equally spaced parts, to compare the effects of two water-surface cleaning strategies ('human interventions'), which we here call 'treatments'.

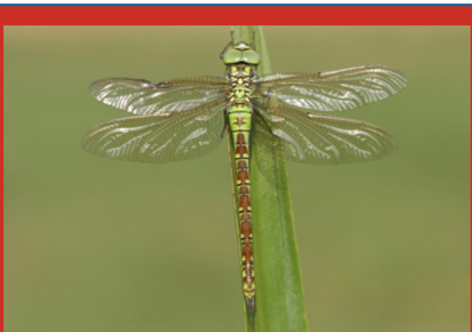

FIGURE 1: Photo of a green hawker (A. viridis). Photo copyright by Bureau Biota

The two different treatments were randomly assigned and differed in how 50% of the water surface was cleaned: (T1) 'Clean 50% of the surface in form of one single large rectangle.' vs. (T2) 'Clean 50% of the surface in form of several small rectangles arranged like a chessboard.' Figure 3 shows an example of treatment (T2). While (T1) is easier/cheaper to achieve, (T2) creates more natural water surfaces that might be preferred by the dragonflies. The dragonflies were counted in the years 2015 to 2018, and the population sizes were quantified in two ways. First, the exoskeletons (exuviae) shed during metamorphosis from larva to adult were counted. Second, the spotted flying egg-laying females were counted. Figure 4 shows a photo of a green hawker

FIGURE 2: Map of the 17 ditches in the Northern Netherlands

and an exoskeleton. In addition, water quality factors such as the host plant emersion, the pH value, the redox potential, the oxygen concentration, the electrical conductivity (EC), the water temperature, the water depth, and the sludge layer thickness were measured for each ditch in every year. For a list of these factors and a few summary statistics we refer to Table 1. A scatter plot of the two dragonfly count quantification measures (exoskeletons vs. egg-laying females) is provided in Figure 5. The two marginal distributions for exoskeletons and egg-laying females along with fitted zero-inflated geometric distributions (see section Concept for some explanations) are shown in Figure 6.

FIGURE 3: Photo of the part of ditch 'GL1' where treatment T2 ('chess-board') was applied. Photo copyright by Bureau Biota

FIGURE 4: Photo of green hawker (left) and an exoskeleton (right). Photo copyright by Bureau Biota

Our statistical analysis aimed to identify those factors that influence the dragonfly population sizes. Thereby our main focus was on the treatment effect (i.e. the effect of the water surface cleaning method). Another important aim was to investigate whether the two dragonfly population size measures (exoskeletons vs. egg-laying females) are influenced by the same environmental factors so that they can be used interchangeably in ecology. In the literature, there is disagreement about which count type is better suited (Hardersen, Corezzola, Gheza, Dell'Otto, & La Porta, 2017).

	Min	Median	Max
Exuviae	0	3	99
Egg-laying females	0	3	31
Emersion(fraction)	0.00	0.84	1.00
pH	4.90	6.96	8.10
Redox (V)	-0.09	0.11	0.28
Oxygen (fraction)	0.00	0.56	1.44
EC (mS/cm)	0.13	0.49	1.08
Temperature (°C)	5.50	15.20	21.00
Water depth (m)	0.23	0.65	1.10
Sludge thickness (m)	0.06	0.28	0.75

TABLE 1: Summary statistics (minimum, median, and maximum) for the 2 count responses and the 8 environmental factors

Concept

The geometric distribution describes the distribution of the number of failures when conducting independent experiments with success probability $p \in [0,1]$ until a success is observed. Its density f and cumulative distribution function F are

$f(x \mid p) = (1-p)^x p$ and

$F(x \mid p) = 1 - (1-p)^{x+1}$ for $x = 0, 1, 2, \ldots$.

It is the integer-valued sample space that renders the geometric distribution a popular choice for statistically modeling count data. Moreover, as every probability parameter p implies a unique expectation

$$\mu = \frac{1}{p} - 1 \Leftrightarrow p = \frac{1}{\mu + 1}$$

The geometric distribution can also be parameterized in terms of its expectation parameter . This makes it easy to employ the geometric distribution in so-called generalized linear modes (GLMs).

Data are sometimes zero-inflated with respect to a distribution, D, in which case the data feature too many zero counts. To account for this, one can consider a zero-inflated variant of the distribution. This effectively yields a mixture distribution $\tilde{D}$ given by

$$\tilde{D} \sim \begin{cases} 0, & \text{with probability } \pi, \\ D, & \text{with probability } 1 - \pi. \end{cases}$$

where π is the so-called zero-inflation probability parameter. For the zero-inflated geometric distribution, the CDF becomes

$$F(x \mid \mu, \pi) = \pi + (1-\pi)\left(1 - \left(\frac{\mu}{\mu+1}\right)^{x+1}\right)$$

for $x = 0, 1, 2, \ldots$.

If we relax the integer restriction on the median, we can define a ('continuitized') median M by solving

$$F(M \mid \mu, \pi) = \frac{1}{2} \Leftrightarrow M = \frac{\log\log(2(1-\pi))}{\log\log\left(\frac{\mu}{\mu+1}\right)}$$

$$\Leftrightarrow \mu = \frac{1}{(2(1-\pi))^{1/(M+1)} - 1}$$

Since there is a one-to-one mapping between the expectation μ and the median M, we can also parameterize the zero-inflated geometric distribution in terms of M and π. Using the latter parameterization facilitates decreased sensitivity of the maximum likelihood (ML) estimate of (M, π) towards large outliers (van Oppen, et al., 2021). The curves in Figure 6 refer to the ML estimated zero-inflated geometric distributions for both count types.

For the statistical analysis of the bivariate dragonfly data, we started with a zero-inflated variant of the bivariate geometric distribution and we parameterized

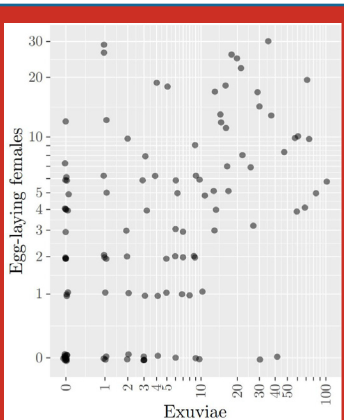

FIGURE 5: Scatter plot of the dragonfly counts in log-log scale

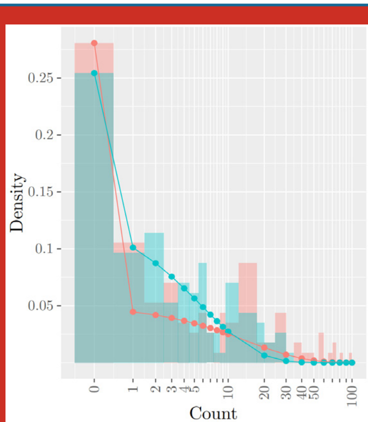

FIGURE 6: Overlaid histograms showing the marginal count distributions along with fitted distributions in semi-log scale (red: exuviae, green: egg-laying females)

this bivariate distribution in terms of its two marginal medians and a third correlation parameter. As the mathematical derivations and expressions are much more involved than those provided above, we refer to (van Oppen, et al., 2021) for the mathematical details.

Bayesian generalized linear regression model (GLM) approach

The dragonfly data have a relatively small sample size (m=114 observations), include yearly measurements at 17 ditches, and feature many zero counts (potential zero inflation) as well as many large counts (potential outliers). For the statistical analysis, we thus had to develop a tailored probabilistic model.

We designed the model in successive steps in a manner analogous to (Burger, Schall, Ferreira, & Chen, 2020), but for a bivariate geometric distribution. First, we derived the density of the bivariate geometric distribution from (Jayakumar & Mundassery, 2007) and we included zero-inflation parameters to be able to deal with unreasonably many zero counts. Subsequently, we parameterized the distribution in terms of its two marginal medians and a third correlation parameter. Modeling the marginal medians yields a decreased sensitivity towards large outliers. Finally, we used a generalized linear regression model (GLM) framework to describe the dependency of the marginal medians on the environmental factors, the ditches, the treatment, and the year. The advantage of the resulting model is that it intrinsically can cope with zero inflation and outliers, and that it is conceptually straightforward to let the marginal medians depend on environmental factors (fixed effects) and ditch-specific effects (random intercepts). Because of the relatively small sample size, we decided on a Bayesian modeling approach and we used Markov Chain Monte Carlo (MCMC) simulations for the model inference.

Brief summary of the empirical results

Table 2 provides the estimated effects of the covariates on the marginal medians of the dragonfly counts. An increase of [u] units of the indicated covariate is associated with the percentage changes in the median dragonfly counts (cf. median M in equation (1)). For instance, we observe that a 10% increase in the dissolved Oxygen percentage is associated with a 23.4% (11.1%) decrease in the median M of exuviae (egg-laying female) counts. Likewise, the year 2018 is associated with an 85.8% (92.9%) decrease relative to the reference year 2015, indicating a clear yearly trend of the population sizes.

		Relative effect on median M	
	Covariate unit [u]	Exuviae	Egg-laying females
Treatment (T2)	-	-11.9%	-4.6%
Year (2016)	-	76.5%	-52.5%
Year (2017)	-	**-75.2%**	-19.6%
Year (2018)	-	**-85.8%**	**-92.9%**
Emersion	10%	8.8%	-6.6%
pH	1	12.1%	**86.0%**
Redox	100 mV	-1.2%	8.3%
Oxygen	10%	**-23.4%**	**-11.1%**
EC	100 µS/cm	-6.8%	**27.9%**
Temperature	1 °C	**10.4%**	**-12.2%**
Water depth	10 cm	0.1%	2.6%
Sludge thickness	10 cm	-12.0%	-4.6%

TABLE 2: **Estimated relative covariate effects per unit [u] on the marginal medians M of exuviae and egg-laying females. Based on a threshold criterion we divided the effects into potentially significant (in boldface) and potentially insignificant (normal font) effects. For the details we refer to (van Oppen, et al., 2021)**

The results of our statistical analysis clearly showed that the two response types can lead to different conclusions. That is, although we found the two responses (marginal medians) to be slightly correlated, the two responses seem to be subject to different covariate effects. The most important finding is that the surface cleaning method had no effect on the dragonfly population sizes. We observed this for both response types. Two more covariates (yearly trend and oxygen) were found to affect the two responses in the same way, while other covariates (temperature and electrical conductivity) had opposite effects on the two response types. In light of these results, we conclude that the two population measures differ in nature and cannot be used interchangeably. Therefore, we advise to always use both measures or to very carefully choose the measure to quantify the dragonfly population sizes in future ecological studies.

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ASML innovates with the future in

Advertorial

To work with extreme specifications to build a machine that meets the requirements that are still years ahead from now. For ASML's engineers, it's everyday's business. They follow the in 1965 invented Moore's Law[1], that serves as the heartbeat for technological evolution that manufacturers of microchips, ASML's customers, strive for. So, ASML basically has a glass sphere that predicts what its lithography machines should be able to do. However, the development of these machines requires ASML to venture on technological adventures – expeditions that often seem impossible, but are ever surprising.

Those adventures of development demands from ASML's engineers a strong mindset: to keep believing that you can make the impossible possible. To see setbacks as challenges and to practice solution-oriented thinking. Exactly this mindset lays the groundwork for one of the most complex machines that was ever made by men: the EUV.

Engineers as inventors

Twenty years ago the starting point was that lithography machines should be able to use light with a wavelength of 13.5nm around the year 2020. The technology to do so didn't exist, basically everything had to be thought up. So ASML's engineers from different fields of expertise started to think up ideas and invent technologies themselves.

Its goes without saying that they needed to find answers to complex questions. Because how will you generate this light in the first place? How do you increase the energy density to the levels that you need? What kind of optics do you need to conduct and guide the light? And how do you create those optics at all? What 'mask' do you need to make the chips' pattern? How can you make the moving parts of the machine (the 'stages') actually move fast enough? And how do you deal with the heat that's produced during those immense high speeds? How can you meet the precision requirements for your servo systems? And when you've found all of those answers: who can build those parts? How do you build, test, integrate, ship and install all this extremely sensitive equipment? It may not surprise you that many industry veterans predicted that ASML would fail to build a machine that did not only work, but that would also meet all the specifications to make a success story of EUV.

1 Moore's Law states that the number of transistors in an integrated circuit grows exponentially due to technological progress.

Extreme innovation

The answers were found with creativity and the courage to research ideas anyways, no matter how out-of-the-box they seemed. By taking calculated risks. With an adamant belief and incredible amount of faith, supported and sustained by the freedom to fail and experiment, thus pioneering on and stretching the limits of what's physically possible. And then, twenty years and 15.000 patents later, this resulted in the birth of the EUV machine, a system that will never cease to amaze you and that keeps even the best engineer wondering how it's possible that a machine like this actually works. What to think of:

- The generation of EUV light by shooting 50,000 tin droplets (of 30 micrometer) with a laser. Twice!
- Stages that accelerate 10 times fasters than a Formula 1 car, and still move with an accuracy of less than a nanometer;
- Dynamic measurements of distance with a picometer resolution and temperature management with a precision of millikelvins;
- Optics that are polished to atom levels;
- Overlay (placement of layers) with a precision of 1 nanometer (approximately 5 Si atoms) on a wafer.

Production and maintenance

The list of technological miracles seem endless. What's more: an EUV machine has to be able to perform 24 hours a day, 365 days a year at the customer's sites, with a little time loss for maintenance. Only the teamwork of thousands of engineers with one goal in mind – to build the most advanced machine in the world – can take credit for it. And now that we know how EUV machines can be built, we'll move on to the next challenge. Because Moore's Law waits for no one!

Company profile

ASML provides chipmakers with hardware, software and services to mass produce patterns on silicon, helping to build the electronic devices that keep us informed, entertained and connected.

We're a dynamic team of 28,073 people from 120 different nationalities and counting. Headquartered in Europe's tech hub, the Brainport Eindhoven region in the Netherlands, we have over 60 locations in 16 countries and annual net sales of €14.0 billion in 2020.

Be part of progress. Visit www.asml.com/careers.

Figure 1: Questions? Interested? Contact the ASML student ambasadar: david@workingatasml.com

Recipe

Homemade Gyozas

AUTHOR: **L. ÁLVAREZ HEREDA**

Ingredients

- 340 g of chicken or pork
- 140 g of cabbage (2-3 leaves)
- 2 green onion/scallion (15 g approximately)
- 2 mushrooms (optional)
- 1 clove garlic (minced)
- 2 g of fresh grated ginger
- 1 package of gyoza wrappers (52 sheets)
- 1 pinch of salt and black pepper
- 1 teaspoon of sesame oil
- 4 teaspoons of soy sauce and teriyaki sauce

Cooking

1. Gather all the ingredients and open the wrapper package (make sure to cover them with a damp towel or plastic wrap so they won't dry out).
2. Remove the core of the cabbage leaves and cut into very small pieces.
3. Cut green onions and mushrooms (optional) into small pieces and combine them with the meat, cabbage and green onion in a large bowl.
4. Add minced garlic and grated ginger to the bowl.
5. Add the seasonings (1 pinch of salt,1 pinch of black pepper,1 teaspoon sesame oil, 4 teaspoons soy sauce, 4 teaspoons teriyaki sauce).
6. Mix well and knead the mixture with your hands until it becomes sticky.
7. Next, take the wrapper and put it in the palm of your hand. Take a small amount of filling and put it in the center of the wrapper.
8. Dip one finger in a bowl of water and draw a circle around the outer edge of the wrapper until it's wet all around. Fold the wrapper in half over the filling, and using your left thumb and index finger, start making a pleat about once every ¼ gross on the top part of the wrapper.
9. Once you make each pleat, press it down with your right thumb and make pleats toward the left side. Continue all the way until there is no more top wrapper to pleat.
10. Press the pleats and shape the gyoza. Repeat for all of them. Heat the oil (sesame oil or sunflower oil) in a large frying pan over medium heat.

FIGURE 1: Gyozas filled with chicken (L. Álvarez

11. When the pan is hot, place the gyoza separated from each other, flat side down in the pan.
12. Cook until the bottom of the gyoza turns golden brown, about 3 minutes.
13. Add ¼ cup of water to the pan. Immediately cover with a lid and steam the gyoza for about 3 minutes or until most of the water has evaporated.
14. Remove the lid to evaporate any remaining water and cook uncovered until the gyoza is crisp on the bottom.
15. Put everything on a plate and serve with dipping sauce. For the dipping sauce, soy sauce is more than enough, but feel free to combine the seasoning ingredients in a small plate to make a tastier sauce.

Brainwork

We'll cross that bridge when we get there

AUTHOR: **A. SILVANS**

You are traveling with your friends Alice, Bob, and Carol across the country but you are stuck on one side of a river because the bridge is out. You happen to have a boat with you, so you and your friends can cross. As you are the strongest in the group, you agree to take everyone across the river. The problems don't end there: the boat only has space for one more passenger besides you. Furthermore, each member of your group is friends with you, however, they do not all get along with each other: (a) Alice and Carol are friends, and (b) Alice and Carol are not yet friends with Bob. You don't want to have awkward moments, so you try to avoid leaving people who are not already all friends alone on one river bank, while you boat someone to the other bank.

Conundrum 1. *How do you get all your friends across the river without creating awkward moments?*

You are not sure how you managed to get everyone across the river, but you know your arms are aching. Soon your friend Dave arrives with his car, so the trip continues. Lady luck is not on your side today, your group stops at another broken bridge. Where is the taxpayer money going to anyway? The setup and goals are the same as before except, now Dave has joined, we have the extra condition: **(c)** nobody knows Dave.

Conundrum 2. *Can your friends cross the river without awkward moments? If not, what is the least number of such moments? What is the least number of friends you must fit on your boat to avoid awkward moments?*

How your arms are still attached to your body you don't know, but somehow you still have enough energy to worry about awkwardness. Third time's the charm, as they say, and Emily arrives with her car, and the trip continues. All good things come in threes, your group arrives at another broken bridge. Someone is doing this on purpose, it seems. Once again you must boat your friends. Thankfully, Emily has friends: **(d)** Emily is friends with Alice, Bob, and Carol.

Conundrum 3. *Repeat conundrum 2 including Emily.*

You consider applying for the national rowing team. The last friend touches soil on the other bank. Your friend Fred arrives, and you all safely get to your destination. You are glad there were no more broken bridges because Fred is only friends with you. At the hostel your friends are partying, apparently they all got to know each other in the car, and you shouldn't have worried that much in the first place. They ask you why you won't join the party but they don't realize you are exhausted.
In bed your thoughts drift and you begin to dream. Your friends are now numbers 2, 3, 4, etc. You are number 1, of course. Their mutual friendships are governed by precise mathematical statements.

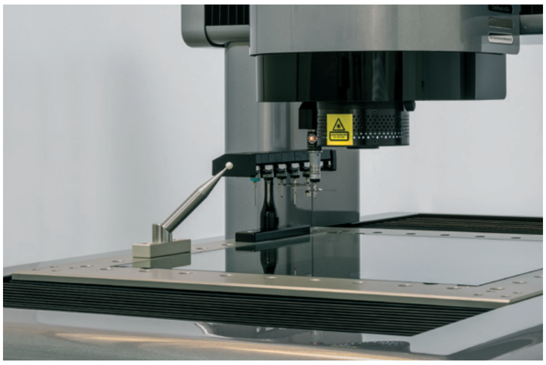
Let $n \geq 3$ be the number of friends (including you) you need to get across the river, and label your i-th friend $2 \leq i \leq n$. Let m be the number of seats in the boat. You can only leave a group of friends alone, if for each pair of friends i, j in this group the numbers i, j satisfy $\gcd(i, j) > 1$ (where "gcd" stands for *greatest common divisor*), or else the group is awkward.

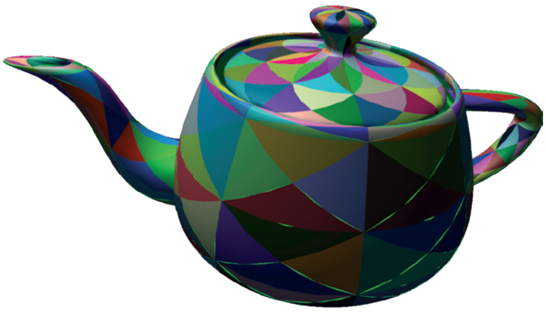
Conundrum 4. *What is the smallest m for which there are no awkward moments when boating, and how does the minimal number of awkward moments relate to m?*

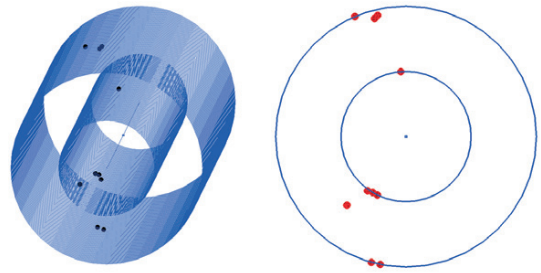
Solution Brainwork 2021-2: "1, 2, 3, cube!"

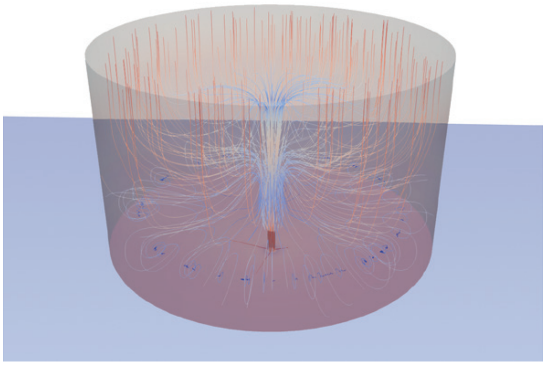
SOLUTION BY: **EGGE ROUWHORST**

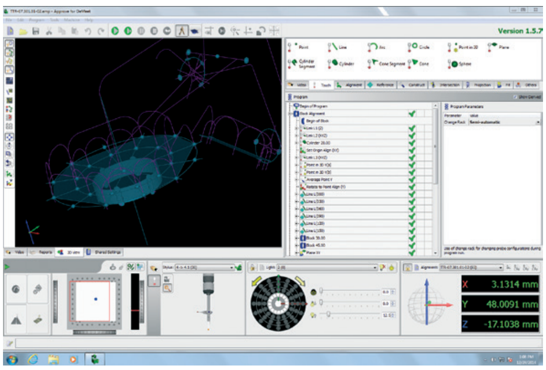
Given a single cube is already placed in a corner, the smallest number of cubes that have to be passed to reach the middle is 61*3=183. By the nature of the puzzle, (similar to a chessboard) the parity (even or odd) of steps to reach another cube is conserved (need an even number of steps to return to a location due to 90° angles). So we can only reach the middle in an odd number of steps. Sadly, the number of steps to complete the task "visiting every cube exactly once" requires 123^3-1 (-1 due to starting on a corner), an even number, steps. Therefore it is impossible to satisfy both the task of visiting every cube exactly once and ending on the middle cube simultaneously.











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