IMAGINARY PANEL: Math communication for the future – A Vision Slam

Carla Cederbaum, Alicia Dickenstein, Gert-Martin Greuel, David Grünberg, Hyungju Park, and Cédric Villani

Abstract. The IMAGINARY panel held on August 20, 2014, consisted of a "Vision Slam" of ideas on mathematics communication. We give an account of the expositions and we highlight the ideas and history of the IMAGINARY project.

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1. Introduction : Alicia Dickenstein

The name of the IMAGINARY Panel on Math Communication, was inspired on the "Poetry Slam" competitions, at which poets read or recite original work and are judged by the audience. A "Theme Slam" is one in which all performances must conform to a specific theme. In the IMAGINARY panel, the theme was a vision on the communication of mathematics for the general public.

The first panelist was Gert-Martin Greuel, together with Andreas Matt the heart and soul of the IMAGINARY project, created during his term (2002-2013) as director of the Mathematisches Forschungsinstitut Oberwolfach (MFO), Germany. Greuel is a Professor at the University of Kaiserslautern, Germany, with an impressive record of service and editorial responsabilities. He is a recognized specialist in Singularity Theory and Computer Algebra.

The second speaker of the panel was Cédric Villani, who has applied mathematical analysis to various areas of partial differential equations, probability theory, statistical physics and differential geometry. Among his many prestigious awards is the Fields Medal which he received at the ICM 2010 in Hyderabad, India. Villani is also renowned for his numerous activities in mathematics outreach and communication.

The next speaker was David Grünberg, who pleaded for more involvement of mathematicians in communicating their research to the younger generation. Grünberg is a teacher of mathematics and theory of knowledge (so far, in Costa Rica, England, Tanzania, Austria, Togo and Switzerland) and holds an Engineering degree. He is currently the head of the department of mathematics at the International School of Lausanne.

The fourth panelist was Carla Cederbaum, a young and very active mathematician. She got her PhD in 2011 in Berlin, Germany, in the area of differential geometry and geometric analysis. She held an Assistant Research Position at Duke University, USA, and is now

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a postdoc at the University of Tübingen and at the MFO, Germany. She is the author of a popular science book in mathematics which has just been translated from the original German to Korean, and the Senior Editor of the "Snapshots of modern mathematics from Oberwolfach".

The last panelist was Hyungju Park, the chairperson of the successful ICM Seoul 2014. He is a professor at Pohang University of Science and Technology, Korea, and the director of the National Institute for Mathematical Sciences (NIMS), Korea. He has been elected as one of the Members-at-Large of the Executive Committee of the International Mathematical Union (IMU) for the period 2015-2018.

A Slam has winners. In this case, the winner was the audience. The "prize" was offered right after the panel. There were tours guided by volunteers through the fantastic NIMS-IMAGINARY exhibition, produced by the NIMS Institute from Korea in collaboration with the ICM committee and the Mathematisches Forschungsinstitut Oberwolfach (MFO) from Germany, and hosted by Hyungju Park. Some of the guides have produced material for the exhibition themselves. We would like to acknowledge the inspiration and support for this exhibit and for the panel from Andreas Matt, creative Project Manager of the IMAGINARY Project.

The IMAGINARY experience in Argentina

I was the moderator of the panel. I am a Professor in the Department of Mathematics of the School of Exact and Natural Sciences at the University of Buenos Aires, Argentina. I have been elected as one of the Vice-presidents of the IMU for the period 2015-2018. My area of research includes different aspects of algebraic geometry and its applications, including effective methods.

I first heard about IMAGINARY during a visit to MFO in November 2007. I was fascinated by the possibilities of the software Surfer that was been developed for the year of Mathematics in Germany in 2008. It can be freely downloaded from http://imaginary.org/program/surfer. It is now one of many free software available at the Imaginary web page http://imaginary.org/programs.

Surfer allows to visualize 3d images of algebraic surfaces, that is, the (real) solutions of a polynomial equation $\{f(x, y, z) = 0\}$ in 3 variables. The simplest such surfaces are a plane (where f is a linear polynomial) or a sphere of radius r centered at a point (x_0, y_0, z_0) (where f has the form $(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 - r^2$). The incredible diversity of real algebraic surfaces is astonishing! Most familiar objects can be approximated by unions of them. But what I found more interesting: it is very easy just to play with Surfer choosing one of the many images in the Gallery and changing the parameters, and ... almost anything one does is BEAUTIFUL. No deep knowledge is needed, one can just play and enjoy the beauty. On the other side, if one wants to get a particular shape, then it is necessary to pause to think and use mathematical concepts.

So, the first main effect is that the mathematical equations which are non tempting (and non beautiful) for most of the people, give immediately rise to objects that are in general not related to mathematics at all and that look pleasant to everybody. And secondly, the educational possibilities of this interaction between formulas and forms, between mathematics and art, are big.

A mathematical exhibit using Surfer and another interactive beautiful software called Morenaments (http://imaginary.org/program/morenaments) was first held in Argentina during the 2012 edition of the huge Science and Technology fair "Tecnópolis" organized by the

Argentinian Government. Millions of visitors attended this fair and were enthralled by the display.

Together with my colleagues Gabriela Jeronimo, Santiago Laplagne and Ursula Molter we presented an outreach project to the University of Buenos Aires, which was funded. During 2012 and 2013 we visited several public high schools in the city of Buenos Aires and worked with the students for around 90 minutes. These students come in general from low income families, which do not necessarily have a computer at home, but they do have in general small netbooks distributed by the national or the city governments. Even with these technical limitations, the activities were very successful. The students worked passionately and produced in this small amount of time interesting forms, that we posted in our website http://moebius.dm.uba.ar/ together with manuals for students and teachers (in Spanish). We also played with another basic free software called Britney created by Santiago Laplagne (available at: http://moebius.dm.uba.ar/page.php?code=1), which allows to visualize fractals.

Our conclusions are that having mathematics mediated by computers made the introduction of mathematical concepts easier. More importantly, we hope that revealing the beauty of mathematical objects to the general public will allow them to have a friendlier view of mathematics and will open the way for them to enjoy it while enhancing their mathematical thinking.

2. IMAGINARY – Mathematical creations and experiences : Gert-Martin Greuel

IMAGINARY is the name of a collaborative mathematics outreach project that aims to improve the image and understanding of mathematics and in this way awakes an interest and fuels passion for the subject in children and adults. This goal is achieved in different ways: on the one hand by showing the beauty and art in mathematics and on the other hand through surprising applications.

IMAGINARY is a project of the Mathematische Forschungsinstitut Oberwolfach (MFO) and it was born in conjunction with the Year of Mathematics in 2008 in Germany. It started with the travelling exhibition “IMAGINARY through the eyes of mathematics”, shown in many cities in Germany.

Exhibitions

Exhibitions are the IMAGINARY way to reach out to a broad public in real life. They are shown in galleries, at museums, in schools, banks, universities, parks or train stations. Exhibitions are diverse: they can include images, interactive programs, sculptures, puzzles, games, text boards, etc.. Visitors can take print-outs of their creations home and everybody can easily stage an own exhibition. In fact, many of the exhibitions were self-organized.

Let me give an impression of the original travelling exhibition. Since 2008, it has been shown in over 60 cities in Germany alone. But it has also travelled further afield to 4 continents, 29 countries and over 120 cities with more than 1 million visitors in total. In Europe, IMAGINARY has been presented in 17 countries with talks, workshops, media activities and, in most cases, exhibitions.

What made the exhibition unique from the beginning, is its highly interactive and in-

tuitive nature and its open access and open source philosophy. This is also reflected in the many positive comments left in the guest book by visitors having experienced the unexpected beauty and the "joy of comprehension": *- This already beautiful exhibition is obtaining a special liveliness by excellent leadership. - Super, especially that you can also use the program in the school. - A wonderful exhibition. I have spent much time here and met many beautiful things, it had to take place more often and actually as a permanent event! - Thank you and keep it up! - It is a fantastically beautiful exhibition. - The magic world of mathematics is not easy to understand. But you can bring them closer. - We were again there, because it was so fascinating. - I should have perhaps studied math .... - Simply gorgeous, cool programs. - Mathematics makes happy.*

Figure 1. Exhibition at the Leibniz-University Hannover, 2008

Figure 2. Cedric Villani inaugurating the exhibition in Paris, 2010

SURFER Creations

One of the main attractions of an IMAGINARY exhibition is the SURFER, a program that calculates and displays algebraic surfaces in real time. Visitors can enter and change polynomial equations on a large touchscreen with their fingers, shift parameters, determine the colours of the surfaces and turn the figures as they like. The great thing about SURFER is that you don't have to understand the underlying mathematics (algebraic geometry) a priori, you can experiment, try, follow your intuition and creativity and this way learn mathematics and create unique art work like pictures or animations.

SURFER was developed by the MFO in collaboration with the Martin Luther University Halle-Wittenberg and the University of Kaiserslautern, mainly by Christian Stussak. Many visitors of an IMAGINARY exhibition downloaded the SURFER and created their own algebraic surfaces, with sometimes really surprising results.

For example, Valentina Galata started in 2008 when she was a 17 years old high school student to remodel 'real world objects' based on algebraic surfaces with the SURFER. Other users of the SURFER created really artistic pictures of algebraic surfaces, like the beautiful Sunflower image by Torolf Sauermann.

Relation to Research

The origin of the SURFER is very closely linked with current mathematical research. A first version goes back to Stephan Endrass, a student of the mathematician Wolf Barth, who

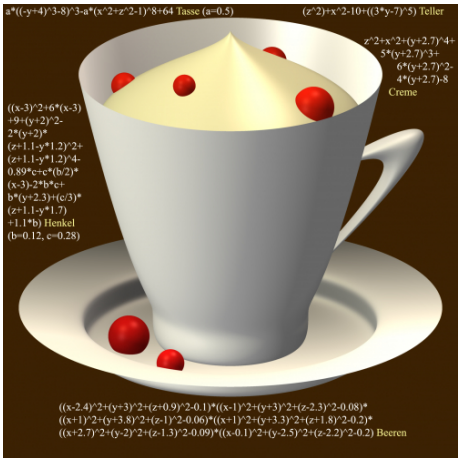
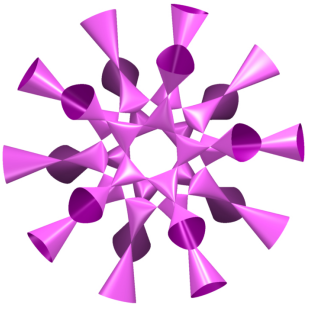


Figure 3. "Cappuccino" by Valentina Galata

Figure 4. "Sunflower" by Torolf Sauermann



discoverd the "Barth sextic". The Barth sextic' is a beautiful surface of degree 6 with the symmetry of an icosahedron (and with a terrible complicated equation). It holds the world record with 65 simple nodes, the maximum possible number of singularities. From degree $d = 7$ on, the maximum number of singularities on a surface of degree d is unknown.

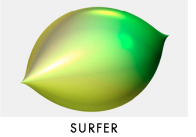
A new IMAGINARY project is to connect modern mathematics and current research to outreach. Mathematicians visiting the MFO are asked to write about their current work but for a general public. These so-called "snapshots of modern mathematics" are then reviewed and edited and distributed through the project. For details see the overview by Carla Cederbaum in this article.

IMAGINARY in schools and classrooms

First schools started to copy the exhibition or parts of it, for example the pictures or the programmes by a high school in Saarbrücken. Also first self-organized exhibition were held e.g. in Kiev and IMAGINARY competitions were organized e.g. by a newspapers in Greece. The Girl's Day at the TU Berlin was a one day event to attract school girls to study mathematics by using the SURFER. Especially the programme SURFER is ideal to be used in the "school context", for example a 4-days workshop for school students aged 12-14 in Vienna, called "Kinder-Uni-Kunst". The idea was to create mathematical animations with music and while making the films with SURFER learning basic underlying concepts of algebraic geometry. See also the personal point of view by the mathematics teacher David Grünberg about IMAGINARY in school in this article.

A collection of IMAGINARY worksheets of different levels of difficulty has been developed for school children aged between 5 and 17 years. IMAGINARY booklets with questions and explanations are used during exhibitions for guided school tours or at special workshops. The so-called "Entdeckerbox" (discovery box) is primarily aimed at use

in the classroom and provides resources for teachers in order to make mathematics lessons more interactive and interesting for the pupils. It contains 3D-sculptures, nine programs and films and, as a special highlight, the booklet "Problems for children from 5 to 150" by V.I. Arnold. This text has been translated into 6 languages and may be downloaded at imaginary.org/search/node/arnold.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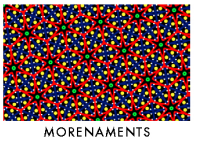
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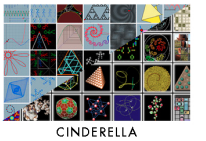
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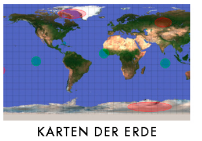
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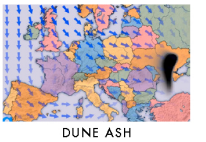

DUNE ASH


DIE ZUKUNFT DER GLETSCHER


FLASCHEN UND OZEANOGRAPHIE

ENTDECKERBOX-BEGLEITHEFT

The mathematics of planet earth

However, the original exhibition was not enough; it focused on a very beautiful yet small part of mathematics. The project needed to grow further and the Mathematics of Planet Earth Year 2013 (MPE) presented a good opportunity to do so. A competition for virtual exhibition modules themed around MPE was announced, and IMAGINARY provided the required web infrastructure in order to make the modules of the competition available online. At the launch of the MPE year in Europe at the UNESCO in Paris, the web interface to IMAGINARY - open mathematics (imaginary.org) went live, displaying entries for the competition and, of course, the winners.

At the same time, a complete MPE exhibition is also available, consisting of a series of modules with a more applied mathematics focus, such as a program that calculates the displacement of volcanic ash clouds (Dune Ash) or a film discussing how mathematical modelling of glacial movement works in order to predict the future behaviour of glaciers.

International spreading

The "travelling exhibition" IMAGINARY developed into a "spreading exhibition" through many partners who independently started to stage it and further expand it. IMAGINARY exhibitions were shown in 4 continents, 29 countries and over 120 cities with more than 1 million visitors. An example is the RSME (the Royal Spanish Mathematical Society) who took the exhibition at the occasion of its Centennial, added new texts and translations and staged it in more than 13 cities. Another wonderful example is the cooperation with National Institute of Mathematical sciences (NIMS) and the ICM 2014 in Korea that was made possible mainly by Hyungju Park. The exhibition NIMS IMAGINARY during the ICM was visited by about 12.000 visitors, among them many school classes, and attracted a lot of media coverage.

The exhibits were also installed and shown in science and mathematics museums. For example the MiMa Museum for Minerals and Mathematics in Oberwolfach, the new MoMath in New York, the "Mathematisches Kabinett" in the Deutsches Museum in Munich, the Forms & Formulas exhibition in the National Museum of Natural Sciences and History in Lisbon, and the CosmoCaixa museums in Barcelona and Madrid.

In 2014, many new exhibitions have been launched around the world. In particular, IMAGINARY has started a collaboration with the African Institute for Mathematical Sciences (AIMS) and, in association with AIMS, an interactive IMAGINARY event was organised for the first time in Africa at the 10th anniversary of the pi-day celebrations in Dar es Salaam, Tanzania. In November 2014, a workshop and exhibition will be organised in Cape Town to plan future mathematics communication activities with partners on the African continent. IMAGINARY exhibitions are currently on tour or planned in Germany, Russia, Spain, Norway, Portugal, and Hungary, and new projects in France and in Turkey are on the way.

Who stands behind IMAGINARY?

IMAGINARY is a project by the MFO, accounted by its director Gerhard Huisken, with funding from the Klaus Tschira Stiftung. It is maintained by a committed core team (mathematicians, software engineers, graphic designers, etc.), who run the project, develop the Internet platform and give advice on how to coordinate exhibitions, but also dream up new ventures of where IMAGINARY will go in the future. The excellent achievements and the impact of the project was acknowledged in November 2013 by the Deutsche Mathematiker Vereinigung (DMV) when the German Media Prize for Mathematics was awarded to Gert-Martin Greuel, the former director of MFO and scientific advisor of IMAGINARY, and An-

dreas Daniel Matt, the curator and project manager of IMAGINARY.

Besides the core team, and most importantly, IMAGINARY it is a community driven project by and for the community. This means that anyone who has an interesting piece of software, film or other type of interactive material can upload this to the website and make it available to the rest of the community. Of course, anyone can just use the material and create a mathematics event, exhibition or workshop. In this way, the community becomes an integral part in the communication process by not only experiencing but also creating content and thus advancing mathematics communication to the 21st century. We hope that many institutions make use of the content and infrastructure of IMAGINARY, and take an active part in shaping its future.

Parts of this text have been published in Gert-Martin Greuel, Andreas D. Matt & Antonia S. J. S. Mey: IMAGINARY- Mathematics Communication for the 21st Century, in EMS Newsletter 92, June 2014.

3. Mathematicians, journalists and the general public : Cédric Villani, notes by Bianca Violet and Severina Klaus

I appreciate very much that the ICM here in Seoul takes care of these global issues about not just doing mathematics but also communicating about mathematics. I think it is so important.

In the past years I have been involved in various activities at institutional level and at personal level. I already have been working in the project of a math museum at the Institute Poincaré in Paris for some years as well.

But in this slam I will only talk about my personal experience of communication as a mathematician, not about my institutional experience.

My first encounter with a journalist from the outside world, not a scientific journalist, was about 10 years ago and it was a disaster! After the interview, the guy went back to his boss and said "I met a crazy guy; I did not understand a single word". He had not dared to tell me that he did not understand anything, so I kept on talking. It was a complete disaster and we had to rearrange things and so on. Thinking of the first encounter I can say that mathematical communication is not something that you are born with, it is not something that is natural, it is something that you train.

My second encounter was in fact a training operation in 2007 - Etienne Ghys had recommended that I attend this training session, so I went. Four persons of our laboratory attended the training, and we were all delighted with this experience.

This is my first advice: If you want to do some serious math communication - get some training with an inspiring guide!

And this guy who trained us, he was a media person and an expert in communication; and in particular he explained about the psychology and constraints of journalism. How you have to put him with you on your side, what are his difficulties, his expectations, what is he afraid of, what is the margin, etc. It was really interesting.

And years later when I was invited by a school of scientific journalists to give a lecture I reversed the sides. Trying to put them into the brain of a mathematician and explain how we have difficulties when we face a journalist and how the contact can be difficult. It is important to be aware of this.

And this changes everything. We already have enough trouble communicating with each other and explaining mathematical research, so why should we bother to communicate to

general non-mathematicians? There are various reasons for this and it is good to have all of them in mind.

First, which we are very sensitive to, is making sure that the young generations are interested in this and know that these are good jobs, inspiring jobs. Maybe these are not the jobs in which you make the most money, but these are jobs in which you feel good - and you may recall, by the way, that in 2009 mathematicians were ranked as the number one job in the world in terms of how rewarding it is by the Wall Street Journal.

This is the goal we think of in most countries, but that is not the only one. Another goal is to feel good about the way people look at us. You don't want people thinking that these are crazy nerds doing their stuff and we don't know what these mathematicians are doing. People say that it is good to give them money, but who knows what the hell they are doing with that money. It is important that people have a good opinion about us as a profession and so on. And just to be heard. It may be sad, but nowadays if you don't remind people that you exist as a job, as a community, people completely forget. Then one day you lose your funding, one day people will say I don't think this is a good job and so on. And we don't want this to happen.

Another important goal is to maintain the link and coherence of society. All pieces of society are important, this we know; and we have to recall how important we are to other people, the same as we need the engineers, we need finance people, we need artist people, we need everybody to make the world run, and we are part of this. And it is known, by the way, that the part of mathematics and mathematical research in the GDP is much higher than one would guess and it is increasing year after year.

And a final thing is that sometimes many people, people who take decisions, who run things, are very much in need of our advice on many things. Not really about explaining mathematics, but over the past years I got plenty of invitations for instance from clubs with people running companies or administrations etc. looking for general guidance on how to approach complex problems, on how you do it in your research work. And all the time they say it reminds them of some expertise this is so inspirational and so on. The whole world is full of people with difficult decisions to make and they don't know whom to ask advice of. We as researchers always have decisions to make which are complicated; and they are in demand of our advice in this.

What does a general audience want? This is a mixture of many things. Some of them are at a university. Some of them are thinking "will this be a good job for my kids?" Many of them think "I was so bad in math, I am angry by this, at least maybe I have a chance to understand at last, prove myself that I was not so dumb". Many people at the end of talks, they come and tell me "ah, if only I had a teacher like you! I would not have been so bad at math." I really think if they had a teacher like me it would probably have changed nothing. But it is good that they have this feeling, that the guilt was not on their side, that they were not intrinsically dumb and so on. And also some people, they just need to inquire about the world. They heard that mathematics has part in finances, in the economy, in space exploration, in whatever. And they wonder what do they do, these mathematicians? It is curiosity. And even those people who are very bad at math, they have the right to understand what we are doing, in the same way as people who are bad at writing for instance have the right to follow and see what is going on in literature and get informed about the trends in culture. Mathematics is technology and science but it is also part of the culture, and many people are interested in this.

Now, with that in mind, we see there are very different audiences we need to reach. And

you have to make sure, if you communicate, that part of what you say will be interesting for this or that audience. The best is if you can mix a little bit of everything in your talk; you cannot always do it, but sometimes it works.

I have tried a number of different forms of communication. Some are good for this and others are good for that. After the ICM of 2010 I received a lot of invitations. And after each talk you have to think: what did work? what did not work? what lesson can I draw for the next speech?

I did radio. Radio is good because you can say things and people listen to you. I did television. Television is good because people see the attitude that you have; but don't expect that they listen to you. They are not interested in what you are saying when you are on TV, but it is very efficient to reach people.

I was in some movies, I prepared some articles for some newspapers, I also did some exercises in which they ask you for some text which is a mixture of something like poetry or literature and something like mathematics. I did a lot of public lectures, for example in High Schools, for little kids, 10 year olds, for older kids, for students, for politicians, CEO's, workers - all kinds of possible things. I never went on Facebook or twitter out of a lack of time though.

There are many obstacles. And it happened more than once that after something went wrong I thought I should stop and did it again, and in the end it was a big success.

To single out just one experience which was the most life-changing in this, it was the book. Seriously speaking though, this book, Théorème Vivant, came by accident because I met some editor in a dinner. He understood I wanted to do math communication, and he had no interest whatsoever in explaining me the mathematical concepts. All he wanted to know was how I work in my daily life, what I do, what I think, what is my life and so on. It was very embarrassing. And in the end I decided I would go for a concept that described our theorem but not its meaning. Just how we made it. It was a long work and as in all long works it was full of unexpected things, two years and a half full of ups and downs. And I just put in the mathematical equations, the mathematical words with no explanation, and this was contrary to any classical work of communication. It just gives you an impression of what it is to be in the brain of a mathematician.

And the first day it was out I was worried about what people will say? What will the colleagues say? But it worked beautifully. And then I started to receive these comments. Hundreds of comments, comments like "Your book changed my life"- and nothing can make you feel prouder than that.

It's a thing we all have to learn. There are many people out in the world that are looking at us mathematicians for inspiration. There are people somewhere who would be happy to listen to what we do and our fears and anxieties and how we overcome them and so on. So share with them; that's the most important thing.

4. Communicating math research to the younger generation : David Grünberg

- **Open Mathematics - what it is and why you should do it.**
- **Mathematics teachers are in the "trenches" fighting for the mathematics of tomorrow. We need Mathematicians to help us.**

I like to believe in the multiverse theory! The reason is that, in a multiverse, maybe

there's a region of space-time in which I, after school, continued with pure Mathematics! This is our reality, though, and in this one, this, is what happened: I learnt the same mathematics in school as you, but then our paths diverged: you guys kept going with the equations, and you are here at the ICM with your bright lemmas and elegant proofs. Whereas I ... I went travelling and started teaching Mathematics in schools to help my finances along the way. I taught Mathematics simply because at that time, this was the only subject I might conceivably teach. Oh, and just before that, I got myself a degree in Engineering, but I can't say that too loud, otherwise someone will say: "An engineer was let into the ICM ?! - someone call security!"

But don't get me wrong. I have learnt to love Mathematics! As a math teacher, I do math every day, I learn math, I teach math... And I don't even have to publish anything. I get to do maths with fabulous people - my students! Looked at it like this, I rather like my corner of the multiverse... I am here to talk to you about something that reunites, us, though, in this very real universe: Mathematics Communication. Mathematics Communication is a network of bridges spanning the divide between Mathematics research and the wider population, which includes those young people who, we are hoping, will one day continue what you guys are doing. I'm here to give you my take on one of these bridges: the IMAGINARY project. And my aim is to convince you to take some steps on that bridge, should you not have tried yet.

IMAGINARY is something that can reunite you, the mathematician, with school pupils. My first contact with IMAGINARY was when I followed a link to the web platform. *"Open mathematics" mmh... - I'm wondering what that might mean! Woa, these pictures look really attractive.!... Ah, algebraic surfaces (Picture 4), mmh... oh that looks like a 3D version of what my students do with functions. I've always thought it's a good idea to introduce area via 3D shapes and surface area - our surrounding is 3 dimensional, after all. Perhaps something similar can be said about functions: work in 3D seems so much more real than in the coordinate plane....*

Such thinking got me going with IMAGINARY. Note the importance of the aesthetic appeal here, something I'm particularly sensitive to. I dreamt of organising an IMAGINARY exhibit in my school. After all, our art department does exhibits as a matter of course - why not the Mathematics department? No - wait! Why not the mathematics department TOGETHER with the art department? I started to understand what 'open mathematics' means.

"Open Maths" is all about exchanges. Once I heard a TED-talk in Paris by a mathematician on the "ingredients of good ideas". And one of these ingredients was "EXCHANGES". You know who was talking? A certain Cedric Villani.

The very idea of IMAGINARY is that people can exchange and participate. Our slogan, "OPEN Mathematics", says IMAGINARY wants to be an ingredient in the Villani-"Good-ideas" formula. 'Open' means something like "open house"- you are free to come and go, there are no locked cupboards. You can take things out or bring things. An open house becomes YOUR house; I know a family with 5 adolescent children. Their parents are very much 'open house', and so the kids bring their friends home all the time. I can tell you: that house is alive! You've got the core of my message right here: An OPEN house makes for a house that is ALIVE!

Open Mathematics lives through participation. You upload your maths or download someone else's. The main point is not THAT someone downloads your work, but it is WHAT that person will do with it - given some quality control, people will start to use stuff you put out there in ways you couldn't imagine. Other mathematicians will use it; Museums will

use it (for instance the "FormulaMorph" installation at the MoMath, New York, based on IMAGINARY material); schools will use it (for example: me!); artists will use it (as a visit at the IMAGINARY exhibition will make obvious); even chefs will use the material! (a chef cook actually got inspired after visiting an IMAGINARY exhibit in Spain!)

It's amazing what people will do! They will even translate texts into Korean for you! Right now this summer, I have a student doing a project based on some research material made available on the platform. Point is: At IMAGINARY we have witnessed that process of creative transformation of content into new ideas that NO ONE could anticipate.

In my town in Switzerland, there's periodically a "free market". People bring things that they want to pass on - for free. And you can come and take anything you want - for free, you cannot pay. Even the food is free! IMAGINARY is often asked: where can you buy the exhibit? Now you know the answer: There's nothing to buy at IMAGINARY - it's based on **participation**.

Let me tell you a little more about my job: You know, Mathematics teachers worldwide are facing some tough challenges with modern developments in mathematics. First, there is the splintering of mathematics research into many highly specialised nooks and corners. This makes the transfer of new mathematics into school curricula difficult. But at the same time, technology, like computer algebra systems for example, questions whether schools can teach mathematics for much longer the way it is still mostly done today. And then, as you know, our subject is under a lot of pressure and scrutiny, squeezed somewhere between PISA evaluations and back-to-basics prophets.

I've heard someone say: "Mathematics could one day disappear, like the classics did (Latin and Greek)" I wish I could have taken that person to Villani's talk at 'Bridges' on Monday, where he explained that the movie industry is one of the biggest consumers of mathematics. I say: We could well see too few students choosing to continue their study of mathematics if school mathematics doesn't somehow stay connected to maths research and change the way the subject itself evolves. And we need YOU to help schools adapt!

My students need you. In order to keep mathematics irrigated with young talent, we DEFINITELY need the cooperation between those involved in mathematics research, mathematics communication and mathematics education. It is one of the ambitions of IMAGINARY to provide a platform for such collaboration.

You might think: why should I spend effort making my mathematics approachable to wider crowds? Why should my mathematics be "open"? My students, and my colleagues and myself at school, and teachers worldwide are one of the reasons why I'd like you to consider communicating your work as much as possible to the wider community: We need you. We maths teachers are at the forefront of teaching YOUR subject, so if you aim to stay in touch with us, it will be a lot easier for us to connect with mathematics research.

With my class of Grade 10, we did a unit on algebraic surfaces, something I would not have dreamt of doing had not a mathematician gone through the trouble of producing a quality and user friendly software to experiment with. It was an interesting experience. In the end, we did a competition about who can produce the most fanciful snowman, using a single formula. What I'm trying to say is this: I can guarantee you one thing: If you can spot an area of your work that can be somehow transmitted at a lower level, create high quality, user-friendly material about it, make it available for free, then there's a maths teacher somewhere in the world who will use it, but probably much more than one, because we are talking to each other.

You know what: In my school there is a large magazine stand in front of the library. In

envy the science teachers: they have several magazines they can read to keep up-to-date with what's happening in science (New Scientist, Nature. . .). There's no magazine that tells me with simple language and cool graphics what's going on in mathematics today because no one is writing one for our sort of audience - A colleague joked that I can always read the numbers in the science magazine...

I find initiatives like IMAGINARY useful in helping me keep in touch with what's happening in mathematics TODAY.

This session here is about VISIONS FOR MATHEMATICS COMMUNICATION. Here is my vision:

In the near future, there will be more sharing between mathematicians, more "open mathematics", and an increased focus by mathematicians on communicating their work.

5. Snapshots of modern Mathematics : Carla Cederbaum

In the last year, a team of mathematicians and mathematics communicators at the Mathematisches Forschungsinstitut Oberwolfach (MFO) has developed a new scheme to communicate modern mathematics and mathematics research in writing to a wide audience. The resulting texts are called "snapshots of modern mathematics from Oberwolfach" and have been collected and made available for free via www.imaginary.org since January 2014 as part of the project *Oberwolfach meets IMAGINARY*, funded by the Klaus Tschira Foundation and the Oberwolfach Foundation.

Our goals for the snapshot project are to show that mathematics

- can be understood,
- is diverse,
- has surprising practical applications,
- is fun, elegant, and creative,
- . . .

and that mathematicians

- are individual people,
- are diverse in personality etc.,
- have different motivations,
- are approachable,
- . . .

In particular, we want to encourage the readers to be curious about modern mathematics and mathematical research.

Visions. I am the senior editor of the snapshots; my vision is that the snapshots will be widely read by a diverse worldwide community, used in or for secondary and tertiary education and as a source of inspiration by journalists, and that other institutions adopt the format we have developed to contribute their own snapshot series on the IMAGINARY platform for

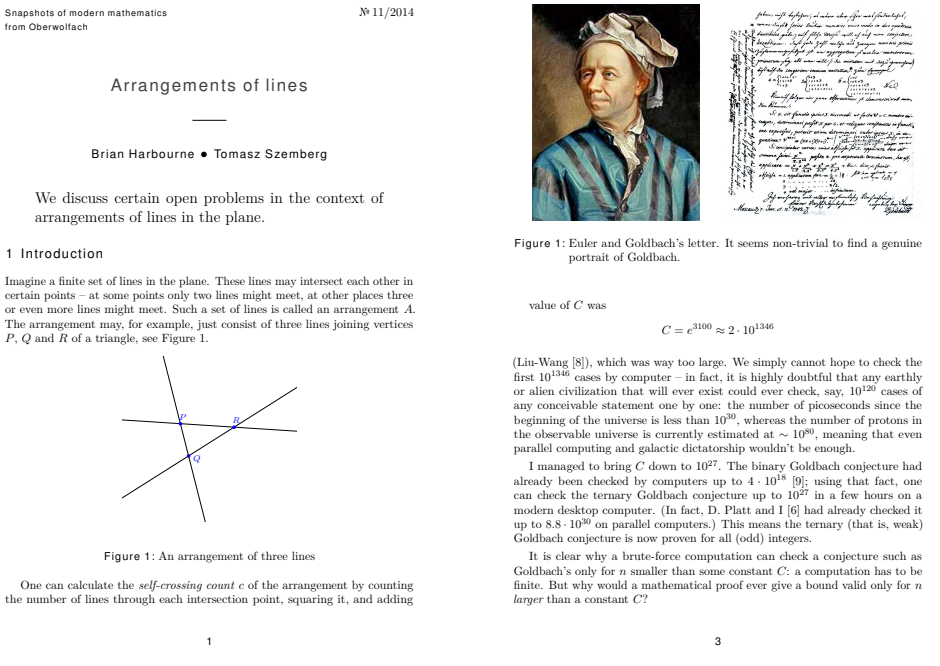
the worldwide community. Furthermore, it would be great if volunteers from all around the world would take the time to translate their favorite snapshot(s) into their native language and upload the translation on the IMAGINARY platform so that others can benefit and read a snapshot in a language that might be easier for them than English.

In the following, I will provide more information on the idea of snapshots in general and some of the specifics about the snapshots from Oberwolfach.

What is a snapshot? A "snapshot of modern mathematics" is a short text

- written by a (group of) mathematician(s),
- edited by mathematics communicators,
- peer-reviewed by specialists,
- possibly illustrated by a designer, and
- distributed for free via the IMAGINARY platform www.imaginary.org
- under a Creative Commons license.

See Figure 5 for excerpts of some examples and www.imaginary.org for all snapshots that are currently available.



Snapshots of modern mathematics from Oberwolfach

№ 11/2014

Arrangements of lines

Brian Harbourne • Tomasz Szemberg

We discuss certain open problems in the context of arrangements of lines in the plane.

1 Introduction

Imagine a finite set of lines in the plane. These lines may intersect each other in certain points – at some points only two lines might meet, at other places three or even more lines might meet. Such a set of lines is called an arrangement A. The arrangement may, for example, just consist of three lines joining vertices P, Q and R of a triangle, see Figure 1.

Figure 1: An arrangement of three lines

One can calculate the *self-crossing count* c of the arrangement by counting the number of lines through each intersection point, squaring it, and adding

1

Figure 1: Euler and Goldbach's letter. It seems non-trivial to find a genuine portrait of Goldbach.

value of C was

$$C = e^{3100} \approx 2 \cdot 10^{1346}$$

(Liu-Wang [8]), which was way too large. We simply cannot hope to check the first 10^{1346} cases by computer – in fact, it is highly doubtful that any earthly or alien civilization that will ever exist could ever check, say, 10^{120} cases of any conceivable statement one by one: the number of picoseconds since the beginning of the universe is less than 10^{30}, whereas the number of protons in the observable universe is currently estimated at $\sim 10^{80}$, meaning that even parallel computing and galactic dictatorship wouldn't be enough.

I managed to bring C down to 10^{27}. The binary Goldbach conjecture had already been checked by computers up to $4 \cdot 10^{18}$ [9]; using that fact, one can check the ternary Goldbach conjecture up to 10^{27} in a few hours on a modern desktop computer. (In fact, D. Platt and I [6] had already checked it up to $8.8 \cdot 10^{30}$ on parallel computers.) This means the ternary (that is, weak) Goldbach conjecture is now proven for all (odd) integers.

It is clear why a brute-force computation can check a conjecture such as Goldbach's only for n smaller than some constant C: a computation has to be finite. But why would a mathematical proof ever give a bound valid only for n *larger* than a constant C?

3

Figure 5. Sample excerpts from different snapshots. The snapshot on the right is by Harald Helfgott.

Snapshots are aimed at a wide audience, including

- secondary school teachers and instructors of undergraduates,

- science journalists,
- secondary school and undergraduate students, or
- just anyone with an interest in modern mathematics and mathematical research.

For example, teachers and instructors might use some snapshots to demonstrate to their students that mathematics is still an active research field: What kinds of questions do mathematicians research? What other fields are intertwined with mathematics? Are notions we teach in secondary school and in the undergraduate curriculum relevant for or at least used in mathematical research?

Science journalists who are searching for research results and stories that are of interest for their readers/listeners/viewers. In mathematics, this is particularly hard as our research publication are very difficult to read for outsiders. Instead of doing this hard work or going by word of mouth, journalists could use the snapshots to identify topics they would like to report on. At the same time, a snapshot's reference list and its authors might be a good place to start if a journalist would like to find out more about the topic.

Students, on the other hand, may find the snapshots helpful when trying to decide if they would like to pursue an undergraduate or graduate degree in mathematics.

All snapshots are assigned to categories specifying their "mathematical subject(s)" and possible "connections to other fields". This allows readers to learn about the different areas of mathematical research and their interconnections. At the same time, they can get a first impression of the diverse applications of mathematics in other areas of research as well as of the influences other fields have and have had on the genesis of mathematics as a discipline.

The first snapshots have been collected in the Fall of 2013 at the MFO. However, the idea of producing such snapshots and distributing them via the IMAGINARY platform is by no means protected by the MFO. To the contrary, we are happy to support and/or advise other institutions (institutes, national or international societies) who are interested in setting up their own snapshot scheme along the above lines. We are in the process of producing hands on guidelines for institutions who are considering to do so.

Snapshots of modern mathematics – from Oberwolfach. The snapshot project started in January 2014 at the MFO. We find the snapshot **authors** among the participants of the scientific programs of the institute. They are volunteers identified by the scientific organizers of the respective program. To facilitate writing for such a general audience, we provide writing guidelines including hints how to make a text more accessible, see http://mfo.de/math-in-public/snapshots. Moreover, we have prepared a LaTeX class and template that support authors in giving adequate copyright credit etc.

Our editors suggest editorial changes to the authors, thus making the snapshots more accessible and understandable and generally easier to read. To do so, they make thoughts present in the snapshots very explicit, bridge gaps to the secondary school curriculum and its scope (as far as possible), introduce redundancy, illustrate ideas, formulate questions to the reader, check language and grammar, insert cross-references between the snapshots, etc. When a snapshot is finalized, the organizer(s) of the scientific program at MFO who selected the author(s) also act as reviewers ("communicated by"). The editors then make approved snapshots available on the IMAGINARY platform.

Our team consists of currently 2 junior editors – mathematics graduate students who are also mathematics communicators, Sophia Jahns and Lea Renner. We get tremendous support from the IMAGINARY team, in particular from Christoph Knoth (web design), An-

dreas Matt (coordination), Antonia Mey (author contacts), Konrad Renner (design and web design), Christian Stussak (IT), and Bianca Violet (author contacts) as well as from the MFO staff.

Getting involved. If you are interested in joining our team, contributing material for schools, translating snapshots into other languages, or setting up a snapshot series at your institution, reporting on the snapshot project or using snapshots in other publications, please feel free to get in touch with me via cederbaum@mfo.de.

6. The KAOS initiative – Knowledge Awake On Stage : Hyungju Park

Many accomplishments of modern mathematics can often be explained quite clearly to the public when they are presented in connection with their implications in other intellectual areas. In this regard, KAOS (Knowledge Awake On Stage) started aiming to be a long series of conversations with the audience about the intricate web of mathematical structures that run through the fabric of contemporary civilization. It features lectures enhanced by stage effects, given by experts in various sectors of academia and society including natural scientists, social scientists, writers, critics, musicians, and artists, each of which are followed by a conversation with two host mathematicians (Minhyong Kim of Oxford and Hyungju Park of POSTECH).

General Vision: The guests will have varying degrees of interest in mathematics and science, and one goal of the conversation will exactly be to uncover the connection and relevance of mathematics to their work through a careful combination of questions and interactions. The series is aimed at the educated public. Efforts will be made to keep the lecture and the entire conversation at a level accessible to any educated person or student with a serious interest. Technical portions will be supplemented by explanatory material to be supplied by the two hosts

KAOS 1. November 28, 2012
Title: Mathematics of Match Making

The lecture was given by one of the hosts, Minhyong Kim of Oxford University, on the Nobel Economics Prize winning work of Lloyd Shapely and Alvin Roth. The subsequent talk-show part was presided by the other host, Hyungju Park of POSTECH, with the participation of two guests.

KAOS 2. May 29, 2013
Title: Geometry, Topology and Matters*

The lecture was given by a renowned physicist, Philip Kim of Columbia University (now at Harvard University), on Graphene Physics. The subsequent talk show was conducted by the speaker and two host mathematicians.

KAOS 3. October 5, 2013
Title: Fantasy of Music and Mathematics*

The master of ceremony was a well-known Korean pop singer, Lucid Fall. After a 20 minute long introductory lecture given by Hyungju Park, the main lecture was given by a renowned Berlin-based opera composer Eunsuk Chin on Contemporary Music. Minhyong Kim gave a concluding lecture on various aspects of mathematics and music. The talk show part was led by Lucid Fall with the participation of the main speaker and the two host mathematicians.

KAOS 2014
A yearlong program consisting of five lectures by renowned Korean mathematicians are planned in celebration of Seoul ICM 2014 on the theme of "Essence of Mathematics"

1. Number by Minhyong Kim of Oxford University, Mar 2014
2. Function by Seungyeol Ha of Seoul National University, May 2014
3. Structure by Seok-Jin Kang of Seoul National University, in the fall, 2014
4. Shape by Jun-Muk Hwang of Korea Institute for Advanced Study, in the fall, 2014
5. Counting by Jeong-Han Kim, Korea Institute for Advanced Study, in the fall, 2014

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