hausdorff center for mathematics

UNIVERSITÄT BONN

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Stephan Held Wins “Amazon Last Mile Routing Research Challenge” with Two Colleagues

How can parcel delivery be optimized with a mass of routes and parcels? More precisely, how can algorithms learn and use the knowledge and behavior of experienced drivers? To solve this problem, Stephan Held together with two colleagues from Canada and Denmark, has now emerged as the winner of a worldwide competition – the “Amazon Last Mile Routing Research Challenge”. The competition is organized by Amazon and the MIT Center for Transportation & Logistics in Boston. The prize money of $100,000 for the winning team attracted 2,285 participants from all over the world this year.

The goal of this competition was to develop algorithms that leverage the knowledge of experienced drivers, who often modify automatically computed routes based on their tacit knowledge about traffic congestion, ongoing road constructions or customer availability.

The mathematical approach of the problem is a new variant of the well-known traveling salesperson problem (TSP). The TSP asks for a shortest tour through a given set of points. The question if efficient algorithms for the TSP exist or not boils down to the open millennium problem P vs. NP.

In the first part of the competition, the algorithms´ should learn the driver knowledge from around 6000 historical routes using machine learning techniques. Then, for a different set of approximately 3000 historical instances with undisclosed routes, new routes should be computed. These computed routes were scored based on their differences to the actually driven routes.

The team by Stephan Held from the Research Institute for Discrete Mathematics and Hausdorff Center for Mathematics, William Cook (University of Waterloo, Canada), and Keld Helsgaun (Roskilde University, Denmark) tackled the contest by rather advancing traditional local search algorithms for the TSP. Indeed, by inspecting the driven routes they detected a two-level hierarchical cluster structure in most of the underlying routes. Adding these structures as a side-constraint leads to a new variant of the TSP with hierarchical cluster constraints. In addition, precedence constraints between clusters were derived from one of the known driver routes with the most similar cluster structure, leading to a new type of disjunctive precedence constraints.

Advancing existing combinatorial local search algorithms to efficiently handle the new constraint types, the team finished with a 42 percent better score than the runners-up. From the twelve hour time limit that was granted to learn from the historic routes the winning approach used approximately five

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minutes to extract the precedence constraints. ”To compute the 3000 new routes the strict time limit of four hours was almost consumed to improve the score as much as possible,” says Stephan Held. ”In retrospect, a ten minute computation time would probably have been sufficient to maintain the lead.”

Only a 35 percent minority of the participants pursued a machine learning approach for this learning competition. One reason might be that machine learning techniques did not yet prove particularly useful for the traditional TSP and other combinatorial optimization problems, despite great research efforts in this direction. ”Of course, in the future better combinatorial optimization algorithms, possibly in combination with machine learning techniques, will likely lead to even better results for this contest problem,” says Stephan Held, who is also a member of the Transdisciplinary Research Area ”Modelling” at the University of Bonn.

The source code of the winning team is published under the MIT open source license to spark future progress in the area: **https://github.com/heldstephan/jpt-amz**. A technical report with a detailed description will soon appear in the MIT technical report series.

Welcome!

Christian Brennecke has joined the Hausdorff Center as a Bonn Junior Fellow in October. He obtained his PhD from the University of Zurich in 2018. After his PhD he worked as a Benjamin Peirce Fellow at Harvard University from 2018 to 2021. His research area is mathematical physics. More specifically, Christian is interested in the rigorous understanding of many-body systems from quantum mechanics and statistical physics, using tools from analysis and probability. His current work centers around the spectral and dynamical analysis of Bose-Einstein condensates in ultra-dilute regimes as well as the understanding of classical and quantum spin glasses.

Maitreyee Kulkarni joined the Hausdorff Center as a postdoc in August. She completed her PhD at Louisiana State University. After graduating in 2018, she was a postdoctoral visitor at the Institute for Advanced Study, Princeton and a Paul Olum postdoctoral scholar at the University. In 2019 she moved to Germany for her postdoctoral position at MPIM, Bonn. She has been interested in the structure theory of algebras arising from the study of quivers with potential. She is most interested in the link between these algebras and their relationship with the categorification of cluster algebras. Her current work also involves the study of many combinatorial objects like plabic graphs, friezes, and associahedra, as well as their relations to certain algebraic objects. She is working on developing a combinatorial model for totally nonnegative partial flag varieties.

Jacob Matherne joined the Hausdorff Center in August as a Hirzebruch Research Instructor jointly at the Mathematical Institute of the University of Bonn and the Max Planck Institute for Mathematics. He obtained his PhD from Louisiana State University in 2016, was a Visiting Assistant Professor at the University of Massachusetts Amherst from 2016 to 2018, a member at the Institute for Advanced Study in Princeton from 2018 to 2019, and since 2019 he has had positions as a Paul Olum postdoctoral scholar at the University of Oregon, as well as a postdoc at the MPIM and HIM. His research is at the intersection of algebraic geometry, representation theory, and combinatorics. He enjoys both solving combinatorial problems by using representation theory and geometry, as well as using combinatorics to explicitly compute examples in geometric or representation-theoretic problems. As a specific example, recently together with Braden, Huh, Proudfoot, and Wang, he solved a long-standing conjecture in matroid theory by developing a combinatorial notion of intersection cohomology for matroids. While at the HCM, he intends on exploring more deeply the Kazhdan-Lusztig theory of matroids as well as introducing other representation-theoretic notions into the field.

Inga Berg took over the position of Program Manager at HIM at the beginning of October. She graduated with a degree in mathematics from Bielefeld University and will now apply her many years of experience in science management and controlling to the organization of the trimester programs and team management at HIM.

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Paul Wedrich Appointed as W2 Professor at Hamburg University

Paul Wedrich received a call from the University of Hamburg for a W2 professorship in “Mathematics, in particular, cohomological methods” in December 2020 and started this position in September 2021. He has been one of the first Hirzebruch Research Instructors since October 2019 (and with a small interruption February-May 2020 due to MSRI stay) – a at that time new type of position, shared between the University of Bonn and the MPI for Mathematics. During this time, Paul Wedrich has mainly interacted with Catharina Stroppel‘s group and was one of the group leaders at the JTP “New Trends in Representation Theory” at HIM in Fall 2020. In his research, Paul Wedrich focuses on topics in low-dimensional topology and representation theory, often motivated by physics. His area of expertise is knot homology theories and related structures. Congratulations on the call!

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HCM-Symposium – a Sign of a New Start

n August, for many months first major HCM in-place event took place. The HCM Symposium was originally conceived as the final event of HCM2 and had already been postponed twice due to the pandemic.

However, in its new guise, it also served as a sign of new beginnings after the pandemic. On three consecutive days, the former 10 Research Areas presented current research topics, together with cooperation partners from academic countries abroad. In the afternoon sessions, numerous young scientists from HCM were given the opportunity to present their research to a larger audience. Overall three days, nearly 200 participants were present. They visibly enjoyed the opportunity to exchange ideas over a cup of coffee or the rich buffet and to build new networks. Susanne Lonski has compiled a few photos and videos with self-composed music **here**.

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Mathematics Meets Life Sciences – Joint Symposium Brings Disciplines Even Closer Together

The aim of the symposium “Interdisciplinary Research in Mathematics and Life Sciences”, which has now been held for the first time on August 30, was to provide an overview of research in Bonn, to promote networks and to initiate new collaborations.

The symposium was jointly organized by the two Clusters of Excellence Hausdorff Center for Mathematics and Immuno-Sensation2 as well as the Transdisciplinary Research Units “Modeling” and “Life and Health”. The organizing committee was formed by the managing directors Sonja Dames, Catherine Drescher, Julia Belau and Meike Brömer. The professors working at the interfaces and their colleagues presented their research and invited other groups to participate. The thematic core was formed by the research areas of the three IRUs. Among the participants were scientists from the University of Bonn and the University Hospital Bonn as well as from cooperating institutions. The symposium took place in the lecture hall and was broadcast online. **Here** a few impressions were recorded.

Hybrid Bonn Mathematics Tournament

At the end of September, the Bonn Mathematics Tournament took place in a hybrid format in the Poppelsdorf Mensa CAMPO. Compared to last year‘s purely virtual tournament, this year‘s event radiated a bit more of a tournament atmosphere. Ten schools were present with their teams, furthermore – as always out of competition – a teachers‘ dream team and a dream team of the HCM, consisting of Sergio Conti, Christoph Thiele, Bertram Arnold, Pavel Zorin-Kranich and Iris Hebbeker. Another nearly 60 schools from all over Germany participated via Zoom. The tournament began with a detailed and appreciative greeting from Bonn‘s mayor Katja Dörner. Thoralf Räsch and Janna Schmidt led through the program the whole day. This year‘s winner of the Bonn Mathematics Tournament was the Amos Comenius Gymnasium. Con-

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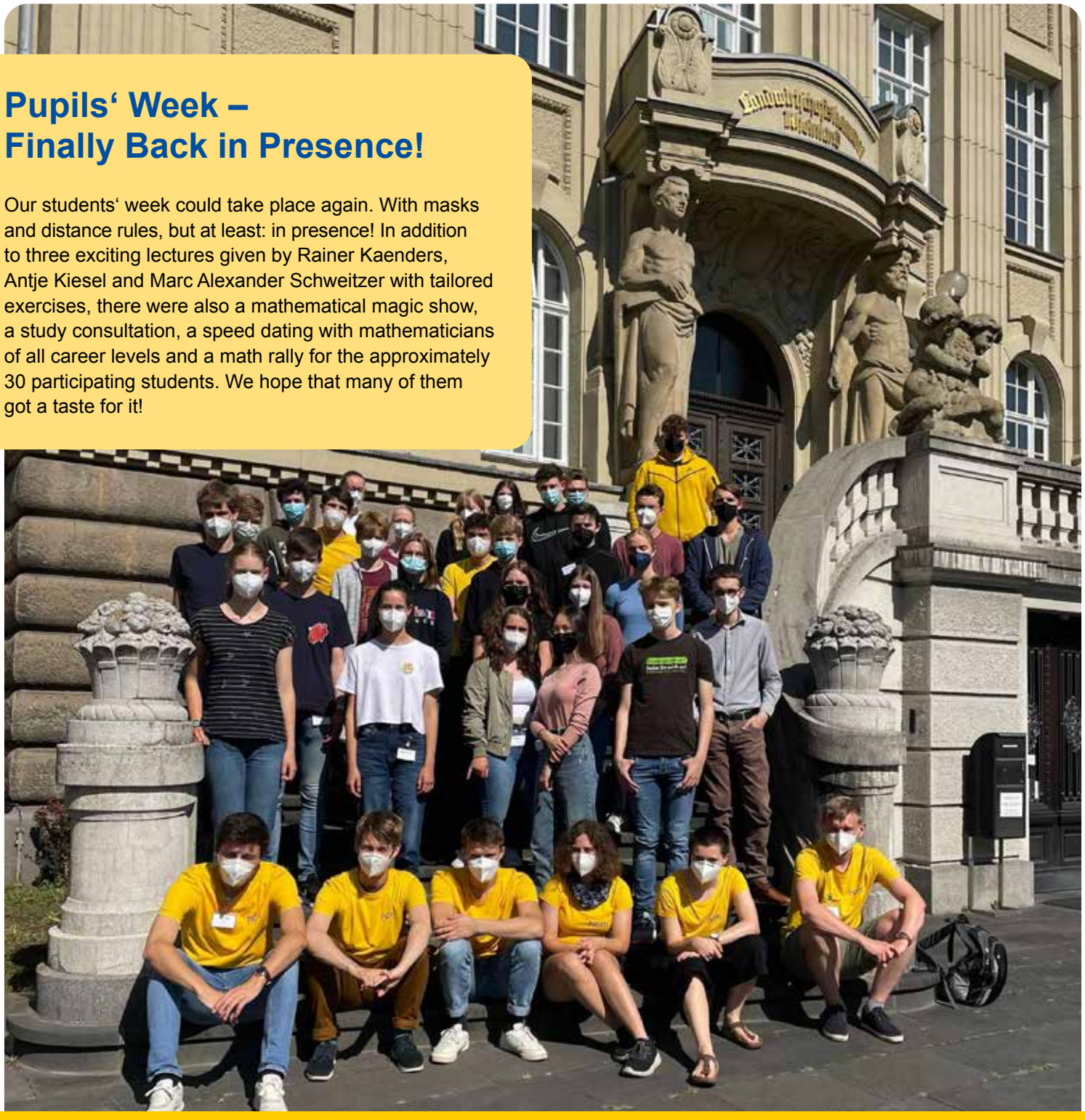
gratulations! The tournament's topic was "Bayes' theorem, ambient filters and clusters – how Amazon and Netflix predict your preferences" and on this topic Marcus Kleiner also gave an exciting and critical talk. Wolfgang Riemer gave practical teacher training on "Probability densities: Challenging mathematics – in an action-oriented package". At the beginning of November, the Amos Comenius Gymnasium from Bonn, the Stiftisches Gymnasium from Düren (2nd place), the Ernst Moritz Arndt Gymnasium from Bonn and the Städtisches Gymnasium from Leichlingen (shared 3rd place) will go on a prize trip to the Netherlands. Further prizes were donated by Casio, Maple, Quecke-Verlag and Springer Nature. Many thanks on behalf of the many winners! **Here** you can watch a short impression video.

Pupils' Week – Finally Back in Presence!

Our students' week could take place again. With masks and distance rules, but at least: in presence! In addition to three exciting lectures given by Rainer Kaenders, Antje Kiesel and Marc Alexander Schweitzer with tailored exercises, there were also a mathematical magic show, a study consultation, a speed dating with mathematicians of all career levels and a math rally for the approximately 30 participating students. We hope that many of them got a taste for it!



Artificial Intelligence to Detect Brain Hemorrhages

Cerebral hemorrhages are among the clinical emergencies in which rapid intervention is essential for the further course of the disease. In this context, radiology plays a central role, because only the reliable diagnosis of brain hemorrhage by means of CT (computed tomography) enables the correct classification of the hemorrhage and the initiation of further therapeutic steps. In order to be able to automatically detect brain hemorrhages in the future using artificial intelligence, mathematicians and physicians are working closely together.

“The collaboration with medicine is so important because artificial intelligence systems can only get as good as the data they are trained on. Cooperation with the Clinic for Neuroradiology at the UKB, which has large amounts of image data on brain hemorrhages, is therefore essential,” says Alexander Effland, one of the three project leaders. He is a group leader of HCM‘s Interdisciplinary Research Unit (IRU) Mathematics and Life Sciences and a member of the Transdisciplinary Research Area (TRA) “Modelling” at the University of Bonn.

“The advantage of the new techniques is that they don‘t get tired and deliver the same performance even at three o‘clock in the morning,” emphasizes Daniel Paech, senior physician in the Clinic for Neuroradiology at UKB and also head of the project. While doctors run the risk of overlooking minor bleeding after long working days and especially during night duties, this does not happen to artificial intelligence, he adds.

“In Bonn, we have the great advantage of having an optimal partner for translational projects in the field of artificial intelligence in the form of Bonn‘s strong mathematics department,” emphasizes Alexander Radbruch, Director of the Clinic for Neuroradiology at the UKB.” This cooperation is to be further expanded.

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What Factors Impact the Spread of Viruses? Funding by the DFG

The German Research Foundation (DFG) is funding a transdisciplinary project with several hundred thousand euros, of which 270,000 euros will go to Bonn. The goal is to determine new factors that are relevant for the transmission or containment of SARS-CoV-2 viruses. Two of our HCM members are involved in this major project: mathematician Jan Hasenauer, who works on computational life sciences, and microeconomist Lena Janys, who researches decision-making models.

Report on the "Tea Time with Women in Mathematics"

In the penultimate issue of the "Mitteilungen der Deutschen Mathematiker-Vereinigung" Anna Kraut and Clelia Albrecht reported about our "Tea Time with Women in Mathematics", a regular networking series where we invite all female students*, postdocs and professors* (*including non-binary, intersex and trans people) to share personal experiences over a cup of tea. We are very proud of this great initiative and are happy to support it!

IMPRINT

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