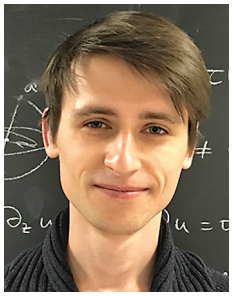
AMS Short Course

3D Printing: Challenges and Applications

January 3–4, 2022



Andrew Yarmola

Maria Trnkova

Organizers: **Andrew Yarmola**, Princeton University, and **Maria Trnkova**, University of California, Davis.

This two-day course combines seven introductory lectures and tutorials with two workshops that offer a hands-on experience with 3D printing and model design. These will be complemented by an exhibition of 3D printed art and visualizations and a concluding panel discussion. Our speakers comprise a diverse team of multidisciplinary experts including members of underrepresented groups and early career researchers.

Introduction

Centered around the idea of additive manufacturing, as opposed to subtractive methods, 3D printing has quickly become a powerful tool for prototyping, design, and visualization and has opened up many new avenues in art, education, engineering, and applied sciences. Even as access to 3D printing facilities is quickly becoming ubiquitous across college campuses, the process of taking a mathematical idea and making it into a printable model presents a big hurdle for most mathematicians. Alongside two hands-on workshops which tackle this task, the Short Course will focus on the role of 3D printing in mathematical art, education, and visualization together with a thorough discussion of the challenges in current approaches to the technology. The main objectives of the course are to build skills and confidence with 3D modeling and to provide a springboard for future engagement with 3D printing.

The course is oriented towards a broad audience and requires an elementary background in undergraduate mathematics. Participants will be able to use their own computers and tablets for several stages of the training sessions through easily accessible software. Instructions and guides on the software will be available prior to the Short Course. Participants are also encouraged to bring their model ideas and visualizations including objects from geometry, topology, combinatorics, dynamical systems, algebra, and any other area of mathematics.

Topics and Lectures

The primary goal for the first day will be to introduce participants to 3D printing concepts and to provide a hands-on experience with printing their first model. The first two lectures, "Visualization of Mathematics with 3D Printing" and "Introduction to 3D Printing," will showcase existing works and give a detailed dive into printing technology. The afternoon of day one will be devoted to a tutorial of printing software aimed at learning slicing, infill, supports, and model clean-up techniques, followed by a workshop where participants will collaborate to prepare a model for printing. Each group will be able to pick up their printed model at the end of the course. Day one will conclude with an Art Exhibition of works by the speakers, participants, and local artists. Participants should contact the organizers if they would like to exhibit their work.

Day two will begin with a discussion of the speakers' experiences with "3D Printing and the Classroom" as well as an overview of projects and efforts at other institutions. This will be followed by a lecture on the "Mathematics and Challenges behind 3D Printing," which will discuss the geometric and algorithmic aspects and constraints of current 3D printing technologies. The afternoon will begin with a lecture on "Designing a Model with Mathematics" to illustrate the process of going from a mathematical concept, to a visualization, and finally to a printable model. The tutorial for that day will focus on using different software tools and techniques for building and editing mathematically inspired models. During the workshop, participants will get help and guidance while designing a model themselves or in groups. Several guided examples will be provided, but participants are always encouraged to be creative and work on their own ideas.

The course will conclude with a Panel Discussion with speakers and outside experts. The panelists will speak on their motivations, successes, and failures in working with printing technologies and mathematical visualizations from artistic, research, and pedagogical perspectives. They will also discuss available resources, training, and objects that desperately need to be printed. The panel will include a Q&A and discussion with participants.

Speakers


Silviana Amethyst

Silviana Amethyst

Dr. Silviana Amethyst is a visualizing mathematician at the University of Wisconsin-Eau Claire. Her favorite subjects are singular algebraic surfaces. Lately, she's been getting into hybrid printed and electronic projects. Silviana's love of the Barth Sextic knows no bounds. She rejects white supremacy in all forms.


David Bachman

David Bachman

David Bachman is a professor of mathematics at Pitzer College in Claremont, CA. He received a PhD in 1999 from the University of Texas at Austin, and has since published over 20 research articles and three books, and received two grants from the National Science Foundation. Eleven years ago, David's background in mathematics and his affinity for working with his hands converged when he began to experiment with 3D printing. Since then he has created unique two- and three-dimensional pieces by using several CAD modeling packages (most notably, Rhino 3D and Grasshopper), a variety of laser cutters, pen plotters, and 3D printers, and a garage full of tools. David is a certified Rhino specialist (Levels 1 and 2) and has written a book on Grasshopper, the visual scripting plug-in for Rhino.


Gabriel Dorfsman-Hopkins

Gabriel Dorfsman-Hopkins

Gabriel Dorfsman-Hopkins (he/they) is an RTG Postdoctoral Scholar at the University of California, Berkeley, specializing in arithmetic and p-adic analytic geometry. They also have research interests along the intersection of art and math, working with 3D printing, fiber arts, and electronics, with an interest in interactive models and installations. Before arriving in Berkeley, Gabriel was a postdoc in residence at ICERM for the semester program titled "Illustrating Mathematics." Gabriel received their PhD from the University of Washington in 2019, with a dissertation exploring foundations of perfectoid geometry, and while at UW, they managed the digital fabrication lab space in the Washington Experimental Math Lab.


Elisabetta Matsumoto

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Elisabetta Matsumoto is an assistant professor in the School of Physics at Georgia Institute of Technology. Her physics research centers around the relationship between geometry and material properties in soft systems, including liquid crystals, 3D printing, and textiles. Her lab studies knitted textiles from the point of view of knot theory and as an additive manufacturing technique. She is also interested in using sewing, 3D printing, and virtual reality in mathematical art and education.


Henry Segerman

Henry Segerman

Henry Segerman received his master's in mathematics from the University of Oxford, and his PhD in mathematics from Stanford University. He is an associate professor in the Department of Mathematics at Oklahoma State University. His research interests are in three-dimensional geometry and topology, and in mathematical art and visualization. In visualization, he works in 3D printing, spherical video, virtual reality, and augmented reality. He is the author of the book *Visualizing Mathematics with 3D Printing*.


Bethany Weeks

Bethany Weeks

Bethany Weeks has been passionate about the additive manufacturing (AM) industry for almost a decade. She was a founding member of the University of Washington's 3D printing student group and helped create the world's first 3D printed full-sized boat using 100% post-consumer plastic as material. She is currently an engineer performing research in AM at Boeing Additive Manufacturing (BAM), identifying the capabilities of the technology and releasing design guidance for how to incorporate AM into production. Prior to Boeing, she was a R&D engineer at Stratasys, tasked with optimizing the printing parameters for new materials and FFF systems.

References

- David Bachman, *Grasshopper: Visual Scripting for Rhinoceros 3D*, Industrial Press, 2017.
- E. Canessa, C. Fonda, and M. Zennaro, *Low-cost 3D Printing for Science, Education and Sustainable Development*, ICTP Science Dissemination Unit, 2013, `http://sdu.ictp.it/3d/book.html`.
- Diana J. Davis, *Illustrating Mathematics*, American Mathematical Society, 2020.
- Stephen K. Lucas, Evelyn Sander, and Laura Taalman, *Modeling Dynamical Systems for 3D Printing*, Notices of the American Mathematical Society **67** (2020), no. 11.
- Stepan Paul, *3D Printed Manipulatives in a Multivariable Calculus Classroom*, Primus **28** (2018), no. 9, 821–834.
- Ben Redwood, et al., *The 3D Printing Handbook: Technologies, Design and Applications*, 3D Hubs, 2018.
- Henry Segerman, *Visualizing Mathematics with 3D Printing*, Johns Hopkins University Press, 2016.

Registration

This Short Course will take place on January 3–4, 2022, the Monday and Tuesday before the Joint Mathematics Meetings (JMM). The registration fees are US$151 for AMS members; US$232 for nonmembers; and US$84 for students/unemployed or emeritus members. These fees are in effect until **December 20, 2021**. After this date, the fees will be US$185 for AMS members; US$275 for nonmembers; and US$105 for students/unemployed or emeritus members. Online registration is expected to open by mid-August. Please see the Short Course webpage at `www.ams.org/short-course` for more information and course updates. In-person registration will take place on Monday, January 3, 2022, exact location to be determined.

Credits

Photograph of Silviana Amethyst is courtesy of Shane Opatz.
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