Computational Aspects of Fabrication
Modeling, Design, and 3D Printing

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The digital age in manufacturing is giving rise to output devices that allow rapid customization and manufacturing, revolutionizing how we design, develop, fabricate, distribute, and consume products. 3D printing is considered a disruptive technology with a potentially tremendous socioeconomic impact. In recent years, 3D-printing technologies have progressed significantly in terms of sophistication and price. Devices now feature high-resolution, full-color, and multimaterial printing. Affordable 3D printers have entered the homes of common users, and professional 3D-printing services let anybody manufacture custom objects with a few clicks. Given the process’s digital nature, computational models that facilitate intuitive design, efficient representation, fast simulation, and visualization of physically realizable objects play a central role in modern fabrication.

Computer graphics researchers have long been involved in designing efficient, easy-to-use content creation methods. Recently, authoring workflows have increasingly incorporated real-world constraints, leading to new theoretical insights and sophisticated tools for creating content that can be fabricated.

One important aspect is creating physical artifacts with controllable appearance characteristics from digital models. Several recent publications deal with fabricating objects made from simple base materials to emulate a visually complex computer graphics model. Attempts range from the computational design of reliefs that let any surface with a significant diffuse reflection component serve as a display, to systems that fabricate surfaces with the desired spatially varying reflectance by assigning different ink combinations to facets with different orientations. All these approaches can reproduce a significantly wider variety of reflectance than the gamut of a printer’s available base materials. In a similar spirit, researchers have investigated designing objects with mechanical properties.

These are just a few specific examples. Active research, as well as challenges related to fabrication’s computational aspects, is often interdisciplinary, encompassing material science, mechanical engineering, geometry processing, human-computer interaction, and perception. However, to fully unleash this technology’s potential requires an understanding of computer graphics fundamentals: shape, the appearance of shape and materials, and physically based simulation and animation. All these aspects interplay when you design an object.

In This Issue
This special issue comprises three articles illustrating how novel computer graphics approaches are advancing digital fabrication.

In “Design-to-Fabricate: Maker Hardware Requires Maker Software” (this issue’s installment of the Applications department), Ryan Schmidt and Matt Ratto propose a class of design tools for the
growing user base of consumer-level 3D-printing devices. They provide several examples of recent “maker” tools, which achieve accessibility primarily by constraining functionality. Furthermore, they describe recent developments in meshmixer, a freely available 3D design tool for easy 3D mash-ups, virtual sculpting, and mesh repair. They aim to provide both accessibility and expressive power for makers by leveraging recent computer graphics research in geometry processing.

In “Fabricating 3D Figurines with Personalized Faces,” Rafael Tena, Moshe Mahler, Thabo Beeler, Max Grosse, Hengchin Yeh, and Iain Matthews present a computational pipeline that lets users efficiently create large quantities of personalized figurines. Their system seamlessly integrates 3D facial data with a predefined figurine body into a unique, continuous object that’s fabricated as a single piece. The combination of state-of-the-art 3D capture, modeling, and printing provides the flexibility to fabricate figurines whose complexity is limited only by the designer’s creativity.

Finally, in “3D-Printing Spatially Varying BRDFs,” we, together with Olivier Rouiller, Jan Kautz, and Wojciech Matusik, introduce an approach for fabricating custom surface reflectance and spatially varying BRDFs (bidirectional reflectance distribution functions). (This article was reviewed and accepted independently.) Our approach optimizes microgeometry to conform to a desired normal distribution that can be 3D-printed on surfaces. We optimize the microgeometry for a range of analytic normal distributions and simulate the resulting surface’s effective reflectance. This approach allows for printing svBRDFs on planar samples with current 3D-printing technology, even with a limited set of printing materials. It extends naturally to printing svBRDFs on arbitrary shapes.

Our young field is growing, and many research challenges wait to be addressed. We hope you enjoy reading the articles as much as we did.

References

Bernd Bickel is a research scientist at Disney Research Zurich, where he heads the research group on computational materials. His research involves acquiring, simulating, modeling, and physically realizing deformation behavior and visual appearance, with applications in animation, biomechanics, material science, and computational design for digital fabrication. Bickel received a PhD in computer science from ETH Zurich. Contact him at bernd@disneyresearch.com.

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