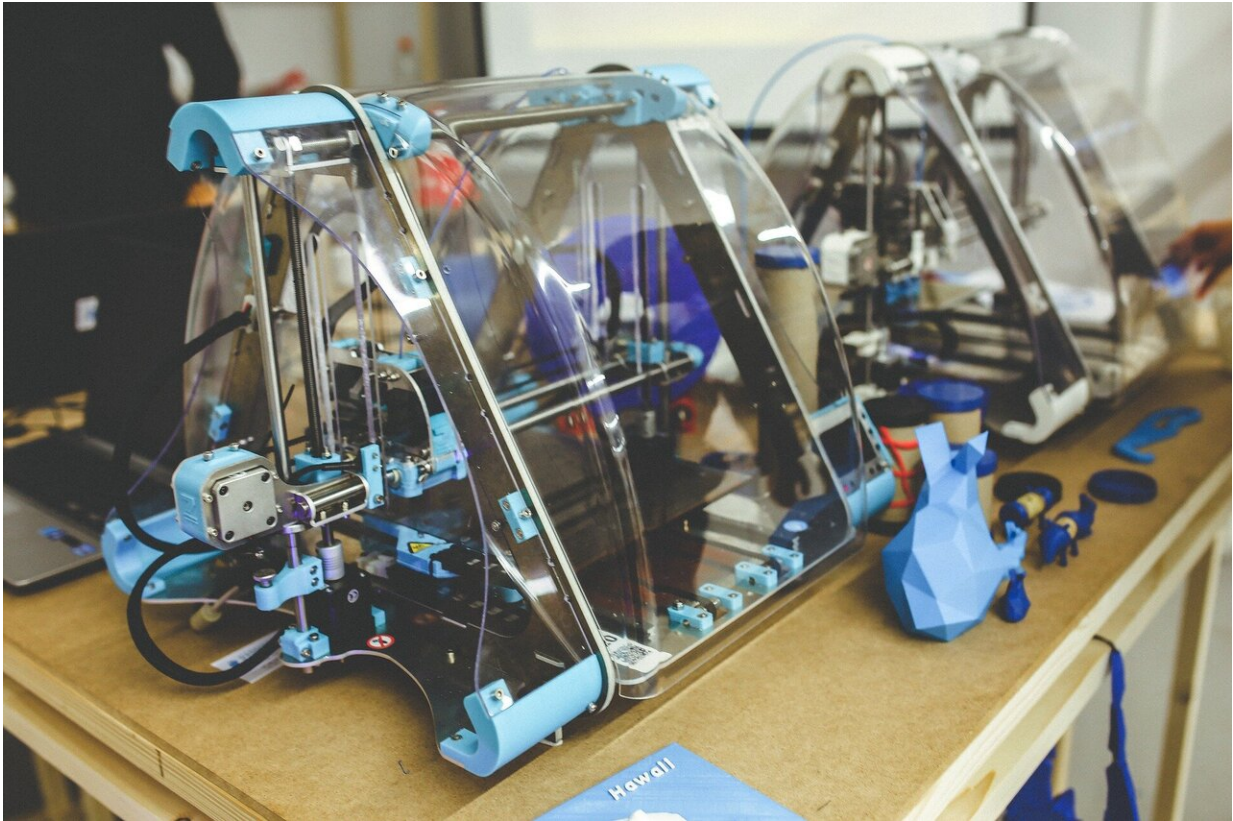# Researchers revolutionize 3-D printed products with data-driven design method

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Additive manufacturing (AM), also known as three-dimensional printing, is a process that fabricates parts in a layer-by-layer manner by adding and processing materials. Advancements in AM technology have

enabled the processing of a wide range of materials to create products in varying scales which span from medical implants to aircraft engine parts. These products, which can be rich in shape, material, hierarchical and functional complexities, offer high potential to revolutionize existing product development processes.

However, it can be a difficult process to fully realize the potential of AM's unique capabilities for product development as it requires product designers to change their design mindsets.

In conventional manufacturing processes, the main task for designers is tailoring their designs to eliminate manufacturing difficulties and minimize costs. On the contrary, AM has fewer manufacturing constraints while offering designers with much more design freedom to explore. Therefore, designers must search for optimal design solutions out of millions of design alternatives that are different in geometry, topology, structure, and material. This can be a tedious task with current design methods and computer-aided design (CAD) tools due to the lack of ability to rapidly explore and exploit such a high dimensional design space.

To address this issue, researchers from Digital Manufacturing and Design (DManD) Centre from the Singapore University of Technology and Design (SUTD) proposed a holistic approach that applies data-driven methods in design search and optimization at successive stages of a design process for AM products.

First, they used simple and computationally inexpensive surrogate models in the design exploration process to approximate and replace complex high-fidelity engineering analysis models for rapidly narrowing down the high-dimensional design space. Next, they conducted design optimization based on refined surrogate models to obtain a single optimal design. These surrogate models are trained based on an updated

dataset using the Markov Chain Monte Carlo resampling method.

This design approach was demonstrated in the design of an AM fabricated ankle brace (refer to image) that has a tunable mechanical performance for facilitating the recovery process of joints. In this design, the researchers selected a metamaterial which has a horseshoe-like structure, where its stiffness can be tailored. The proposed design approach was applied to optimize the orientation and dimensions of the horseshoe-like structure's geometry in different areas to achieve desired stiffness distributions.

Such geometry complexities enabled by AM offer the ankle brace design unique and favorable behaviors. The ankle brace is very soft within the allowable range of motions which provides comfort to patients. However, once the movement is out of the permissible range, it becomes stiff enough to protect the users' joints from extreme load conditions due to its geometrical design.

"Previously, it was hard for designers to imagine a design of such complex geometry due to the limitations in conventional manufacturing, but now this design is easily achievable with AM. Our new approach allows designers to embrace the design freedom in AM that comes with the shift in design paradigm and create more optimal products similar to the ankle brace," said first author Dr. Yi Xiong, Research Fellow from SUTD.

With the design space exploration and exploitation capability developed, the research team is working towards a more ambitious goal—to develop a next-generation CAD system for AM.

"This CAD-AM system will enable designers to design complex geometric and material structures that exhibit behaviors that are unobtainable with conventional design and manufacturing tools.

Designers can rapidly examine design alternatives 10 times more compared to what the current methods allow," said SUTD Professor David Rosen, lead of the research team and co-director of the DManD Centre.

 **More information:** Yi Xiong et al, Data-Driven Design Space Exploration and Exploitation for Design for Additive Manufacturing, *Journal of Mechanical Design* (2019). DOI: 10.1115/1.4043587

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