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“Learning from Nature”: 3D printing of bamboo’s hierarchical structure

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Abstract:

This project is developed based on the needs for the Gateway Education course GE1330 “Learning from Nature” as well as some other related materials/mechanics courses: according to past teaching experiences and students’ feedbacks, there is a lack of a feasible hand-on practice and lab demo for the course while student only attend the lectures and literature reading. Importantly, most students have great interests in how natural structures (e.g. bamboo) possess superior mechanical properties while maintain their extreme lightweight.

Additionally, nowadays sustainability is one key issue that engineers need to consider when designing products, which can be achieved by switching to a greener source rather than using conventional materials in engineering designs. Among many “green” materials, bamboo is among the most fast-growing natural materials with excellent mechanical properties and ultralight structure suitable for many structural applications. With long-term evolution, bamboo also creates other countless mysterious beings with perfect abilities to adapt their surrounding environments. More and more western countries’ researcher recently started to research into this unique material (as bamboo are mainly in East and South Asia) on the potential applications of bamboo materials or bamboo-inspired structures [1,2]. With these endeavors, some bamboo-inspired products with outstanding properties have been fabricated to fulfil specific demands. These successful studies further broad our horizon in understanding the beauty of nature designs.

Furthermore, recently three-dimensional (3D) printing technologies allow the rapid prototyping/design and fabrication of metamaterials without the need for expensive tooling, dies or lithographic masks. They have led to a new era of manufacturing in which computers can control the fabrication of soft matter that has tunable mechanical, electrical and other functional properties. The expanding range of printable materials, coupled with the ability to control their composition and architecture across various length scales by using a program, is driving innovation in a myriad of applications, such as bio-inspired composites, shape-morphing systems, soft sensors/robotics that additive manufacturing can produce [3].

In this project, we propose to adopt the 3D printing technology to reproduce the amazing functionally graded, hierarchical, fiber-reinforced cellular structure of moso bamboo, which has been PI’s research focus in the past three years [4,5,6]. 3D printing gains increasing importance in advanced manufacturing, and teaching of related technologies and concepts has become a major challenge in various engineering subjects including mechanical, materials, manufacturing, and civil engineering. To find a right objective

and build a real 3D model can effectively inspire the students who learn some nature's magic designs in the class and know how to convert them into engineering designs. Overall there are 4 major steps in this project which starts by detailed microstructure characterization of natural bamboo, CAD design of bamboo's hierarchical structure, and 3D printing and prototyping of bamboo structure elements at different length scales, and ends with the final evaluations and testing of the as-printed "artificial bamboo" structures. With the successfully implementation of the project, we will effectively strengthen the course aims on "comprehending the state-or-art experimental techniques" and "understanding the engineering designing principles in biomimicry with a feasible solution", and extend our deliverables to other courses and university teaching enhancement-related activities.