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Dexterous Printing and Fabrication of Multi-Functional Parts: Design for Science and Engineering Education

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Abstract

With the introduction of precision additive manufacturing techniques, the complexity of a particular fabricated part rivals that which is possible with conventional manufacturing alternatives. The drawback to this, however, is the time investment required to bring an object to its completion, which limits the practicality of an otherwise advantageous shift in manufacturing. To counteract this, an ambidextrous multipurpose hybrid machine (DEXTER), operating dual SCARA has been developed to reduce the time of single and multi-material builds. While the SCARA functionality brings forth new obstacles not inherent in conventional gantry setups, optimization studies were performed to minimize the irregularities in print performance. Ensuring a natural lateral movement in manufacturing practices between the traditional and dual arm approach. During prototyping, the current DEXTER model is being used to train the next generation in additive thinking, and to educate them on current manufacturing methods and devices. Doing so creates a generation with the skill set to join the workforce ready to take on the new revolution in manufacturing.

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1. Introduction

The objectives of this educational/research pursuit is twofold: (1) demonstrate the ability to teach the basics of electronics, and 3D printing using a novel printing prototype named for its dexterity and modularity (i.e.'DEXTER'); (2) utilize a gamified prototype printer as a teaching module and distribute to neighboring K-12 schools (i.e. Leon County School systems), to demonstrate advanced manufacturing concepts with 3D printing basics, in an easy to learn construct. The additive manufacturing (AM) prototype utilizes multiple Selective Compliance Assembly Robot Arms (SCARA) in a compact and modular environment in order to print materials simultaneously. Not only does robotic printing bring the opportunity to reduce the time required to complete a prototype, but current trends in "Hybrid Machines" dictate versatility in the application that could produce more complicated and structurally sound products in the aerospace, automotive and biomedical fields (to list a few)[1]. Although the principle of AM hasn't changed since its emergence (starting with a CAD model, separating the model into slices via STL, and constructing one layer at a time) the devices carrying out the process certainly have evolved. Multifunctional machines, such as the nScrypt line of 3D printers [2, 3], allow for the printing of conductive material within the layers of its thermoplastics, while the Matsuura LUMEX Avance-25 incorporates CNC milling alongside the laser sintering of metals [4-6]. The only drawback shared by each machine is the lack of a cohesive process when a change in material or process arises in more complicated builds. Essentially the time gap required takes away from one of the largest allures of AM, which is an increase in part complexity unachievable by conventional methods.

DEXTER aims to improve upon this, as each arm is fully customizable to better suit the needs of complex structures; effectively shortening the time spent printing each layer. The key to DEXTER lies within the use of multiple SCARA, which establishes a firm base for a multitude of different end effectors and manufacturing operations to be utilized. The first potential setup is allocating a single material to both arms for printing in nearly half the time. Another setup that could be used is the ability to utilize multiple materials, which are printed simultaneously, to allow seamless integration of electrical circuits, dissolvable support material, or other structural materials. Lastly, the function of one arm could be replaced with that of another manufacturing processes like CNC milling to further customize parts to shorten the distance to completing industrialized or reconfigurable manufacturing. In total, a faster turnaround for product completion means a considerable reduction in production cost as well as "Time-to-Market" and an increase in supply, which is an improvement for both consumer and manufacturer.

As a prototype, a modular ambidextrous printer (mini-DEXTER) has been developed by participating undergraduate students in an NSF and AFRL sponsored Research Experience for Undergraduates (REU) associated with the Industrial & Manufacturing Engineering Department at the High Performance Materials Institute, along with graduate mentors to teach the basics of robotics and additive manufacturing. The final edition of this prototype will be delivered to schools as a kit as a classroom tool to teach robotics and manufacturing. This project is also being used to determine the machine vision and path planning of the actual printer to be built. Controllers have been added to control each arm manually, and a game has been programmed to represent AM working. Two people have to work together to create a pyramid, without blocking each other in or colliding. The game is won when the last block is placed on the top of the pyramid, and the time to completion is recorded in a beat the clock type game. Each person places blocks as fast as they can while building up the pyramid. This game was created to mimic additive manufacturing, and to teach the basics of AM by having players work together to build a part using blocks in a layer by layer manner. This type of competitive gamification teaches concepts such as path planning, robotic movements, and industrial controls. Kits to be constructed by the students are being compiled, along with a manual so that they are able to build their own DEXTER platform, thus teaching beginner electronics and engineering. The hopes are to inspire the next generation of engineers and scientists looking forward to entering the workforce in manufacturing associated with increasing materials technology at commercial industries, NASA, and Department of Defense.

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