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Development of Adaptive Proportional-Integral-Derivative Feeding Mechanism for Robotic Additive Manufacturing System

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Abstract : In this work, a robotic additive manufacturing system (RAMS) that is capable of three-dimensional (3D) printing in six degrees of freedom (DOF) with very high accuracy and virtually on any surface has been designed and built. One of the major shortcomings in existing 3D printer technology is the limitation to three DOF, which results in prolonged fabrication time. Depending on the techniques used, it usually takes at least two hours to print small objects and several hours for larger objects. Another drawback is the size of the printed objects, which is constrained by the physical dimensions of most low-cost 3D printers, which are typically small. In such cases, large objects are produced by dividing them into smaller components that fit the printer's workable area. They are then glued, bonded or otherwise attached to create the required object. Another shortcoming is material constraints and the need to fabricate a single part using different materials. With the flexibility of a six-DOF robot, the RAMS has been designed to overcome these problems. A feeding mechanism using an adaptive Proportional-Integral-Derivative (PID) controller is utilized along with a national instrument compactRIO (NI cRIO), an ABB robot, and off-the-shelf sensors. The RAMS have the ability to 3D print virtually anywhere in six degrees of freedom with very high accuracy. It is equipped with an ABB IRB 120 robot to achieve this level of accuracy. In order to convert computer-aided design (CAD) files to digital format that is acceptable to the robot, Hypertherm Robotic Software Inc.'s state-of-the-art slicing software called "ADDMAN" is used. ADDMAN is capable of converting any CAD file into RAPID code (the programing language for ABB robots). The robot uses the generated code to perform the 3D printing. To control the entire process, National Instrument (NI) compactRIO (cRio 9074), is connected and communicated with the robot and a feeding mechanism that is designed and fabricated. The feeding mechanism consists of two major parts, cold-end and hot-end. The cold-end consists of what is conventionally known as an extruder. Typically, a stepper-motor is used to control the push on the material, however, for optimum control, a DC motor is used instead. The hot-end consists of a melt-zone, nozzle, and heat-brake. The melt zone ensures a thorough melting effect and consistent output from the nozzle. Nozzles are made of brass for thermo-conductivity while the melt-zone is comprised of a heating block and a ceramic heating cartridge to transfer heat to the block. The heat-brake ensures that there is no heat creep-up effect as this would swell the material and prevent consistent extrusion. A control system embedded in the cRio is developed using NI Labview which utilizes adaptive PID to govern the heating cartridge in conjunction with a thermistor. The thermistor sends temperature feedback to the cRio, which will issue heat increase or decrease based on the system output. Since different materials have different melting points, our system will allow us to adjust the temperature and vary the material.

Keywords : robotic, additive manufacturing, PID controller, cRIO, 3D printing
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