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A Modular Self-Adaptive System for Hybrid Manufacturing Solutions

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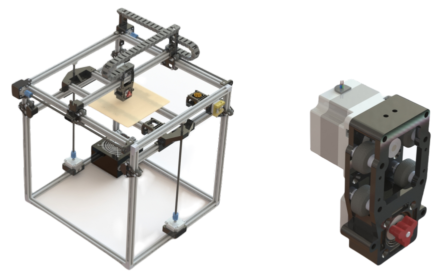
I. Abstract

In recent decades, Hybrid Manufacturing (HM) has garnered significant attention due to the integration of additive manufacturing with other production techniques using multitasking machines. This approach promises commercial advantages by enabling the fabrication of intricate geometries, reducing production costs, and optimizing energy usage. However, it is essential to also bring these technologies into the academic realm, using them as essential tools for rapid prototyping projects. This will enable efficient and versatile 3D printing, CNC machining, and PCB routing on a single machine, fostering innovation and preparing students and researchers for future technological challenges. For this, a hybrid machine is presented that integrates 3D printing and milling in a Cartesian configuration, which incorporates a modular tool exchange system. G-code instructions and a spline interpolation algorithm enhance kinematic control. The modular system allows for easy integration of additional tools like lasers for engraving or cutting, enabling diverse manufacturing processes with simple tool additions and programming adjustments. Future applications hold great promise for advancing environmental sustainability and cost-effectiveness in custom part manufacturing.

Initially, the resolution of the kinematic and dynamic analysis of the robot was addressed in MATLAB-Simulink, determining its Cartesian configuration, the actuators to be implemented, and the development of a cubic interpolator. A dual-module system was developed for hybrid manufacturing, comprising one module for additive processes and another for subtractive operations. The system automates module exchange based on the selected procedure. For the electrical components, Nema 17 and Nema 23 stepper motors were used, along with a DRV8825 controller. A JR PSU004 power supply and a Geeetech GT2560 control board, which integrates the Arduino Mega2560+Ultimaker and Arduino Mega2560+ramps 1.4 functions (See Fig. 1).

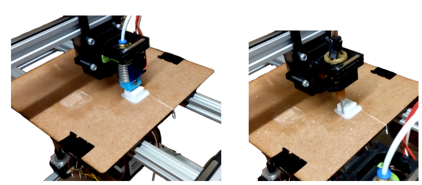
For the implementation of a cubic spline interpolator, an algorithm was developed in MATLAB using mathematical formulations to calculate the coefficients of cubic splines that describe a segmented trajectory, based on the number of points at specific moments in time. It was not necessary to define the step velocities before calculating the coefficients; According to a heuristic rule, these velocities can be set as the average of the slopes of the previous and next segments, or assigned a null value of zero. Different tests were simulated by varying the number of samples in relation to the computational costs of the system to ensure continuity in the trajectories.



(a) (b)

Fig. 1: (a) Prototype; (b) Module exchanger

To validate the machine's performance, individual examination of each process was conducted. A standard part measuring 20x20x10 mm was designed in CAD software for the hybrid manufacturing process. The Hotend module was utilized for material extrusion during printing, with customized ”Extruder initial Gcode” and ”Extruder final Gcode” commands adjusting depth and height parameters for module exchange. The machining was satisfactory, complying with the indicated measurements and without experiencing any unforeseen events during the test (See Fig. 2).



(a) (b)

Fig. 2: (a) Three-dimensional printing process; (b) Machining process.

As a conclusion, this poster presents a modular robotic system for hybrid manufacturing applications. In dimensional terms, satisfactory results are achieved in both printing and machining, with a tolerance that remains within the narrow range of 0.1 mm to 0.21 mm. Closed-loop control can optimize dimensional parameters, and computer vision integration enhances accuracy. The system's flexibility allows easy incorporation of additional tools by adding a new module and programming necessary routines.