3D printing a transposed design in biopolymer materials using an articulated robot and pellet-based extrusion

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Abstract

The aim of this project was to develop a new method of 3D printing. This method is a mix between Fused Deposition Modelling and freeform printing, using a 6 degree-of-freedom articulated robot and a pellet-based extruder to mix and distribute the biopolymer, to create commercial quality thin-shelled parts with aesthetic aspects unique to the process and with a reduced amount of material wastage. There is the potential for many industries to benefit from this new technology.

Initially this project is focused on applications for artists as thin-shelled designs rarely provide the physical properties required for functional parts. An artist has provided a design to test the printer.

The hopper is designed to work with a range of different polymer pellets. It is based off a previous student's design and mimics the operation of an injection moulder by pushing the pellets through a heating chamber with an auger.

The robot controlling the movement of the platform is an ABB IRB120. This robot has six degrees-of-freedom that allows it to reach several positions that would otherwise be impossible with a Cartesian system. The IRB120 has a very high spatial accuracy and repeatability.

The design's original format is converted to a flattened 2D format and the lines are interpolated to produce a 2D set of points. The overlaps in the shapes are removed to reduce the number of times the nozzle traces over previous paths, which helps to keep the layer thicknesses the same. These shapes are filled in with points so the contours are not empty. The points are then projected onto a mathematical model of the platform to produce a 3D point cloud. Finally, these points are converted into data for the robot to read. The design data points stream to the robot, which interprets them on the fly.

Many iterative changes and improvements were done to the hardware and software as the result of continuous testing of the process and analysis of the print.

The pellet-based extruder is an elementary design with numerous variables that affect the resulting extrusion. After many design iterations and improvements to the extruder, the extruder can produce a continuous strand of material, with relatively constant flow.

The software accurately converts a design from the given format into a path for the contours, and another path to fill the contours. These paths are projected onto a model of the moulded platform. Each point along the path is put through multiple affine transforms to generate a location and orientation for the end effector of the robot. The robot is moved by streaming each point to the robot one at a time. The extruder was controlled simultaneously to create a printed design.

The printed design is geometrically correct. However, the width of the extrusion path needs to be improved to increase the accuracy of the design to the reference one. The current prints achieve the correct visual properties in the extrusion. However, they require a secondary process to improve the surface finish.

This project has produced a new 3D printing process, mixing Fused Deposition Modelling and freeform printing. This process can be adapted to be used in a wide range of applications. It has also produced a low-cost, effective pellet-based extruder that can be used to test a range of different materials, and their effectiveness in being used for 3D printing.

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Table of Contents

List of Figures

List of Tables

List of Code Snippets

List of Equations

List of Terms

Abbreviation	Expansion
CAD	Computer Aided Design
CNC	Computer Numerical Control
DOF	Degrees of Freedom
FDM	Fused Deposition Modelling
IPC	Inter-process communication
ISR	Interrupt Service Routine
MDF	Medium Density Fibreboard
PCB	Printed Circuit Board
PID	Proportional, Integral, Derivative control
PLA	Polylactic acid
PWM	Pulse-width modification
STL	Stereolithography