Hardware Design and Evaluation of Non-planar Fused Deposition Modeling on a 3-axis printer

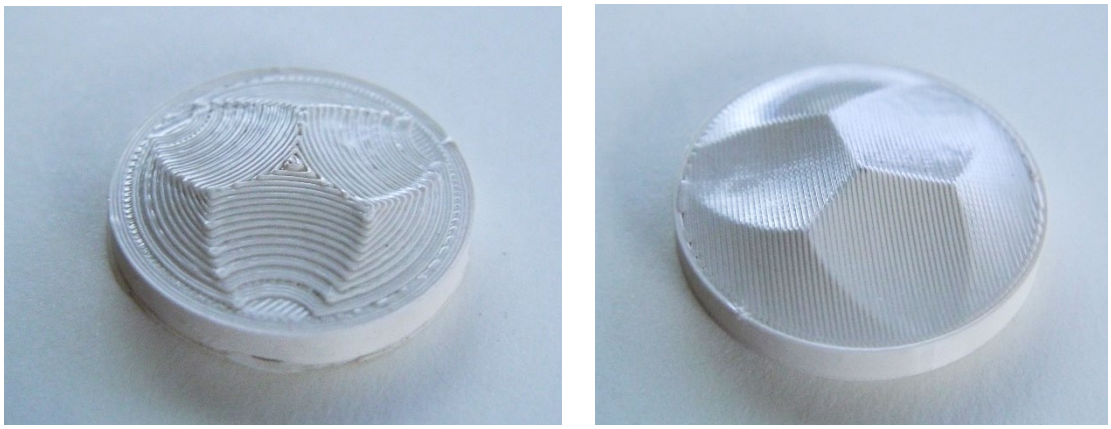

Figure 1: Two printed parts one using conventional FDM (left) and one using non-planar paths (right). Both prints had the same layer height and had a printing time of approximately 24 minutes.

Fused Deposition Modelling (FDM) is a rapid prototyping technology based on extruding a filament of material through a nozzle to build shapes based on 3d model data. The technology has become commonplace and is used both by hobbyists as well as businesses for a wide range of purposes.

In this work a relatively new branch of FDM is tested in which the printing is done in a non-planar fashion in contrast to the flat layers usually employed by FDM printers. A demonstration of the results possible can be seen in figure 1. The added usefulness of this is the opportunity to eliminate stair-stepping artifacts, better reproduce complex surfaces and in general create a larger possible design space with FDM printing.

This project aimed to test this technology and its application on a consumer 3-axis printer by first making the necessary changes to its hardware and then using a non-planar FDM capable software to test the print performance. To measure the print performance of a non-planar print a novel system of its measure was defined and used alongside a Design of Experiments approach. In doing so a structured result could be gained showing what influence the hardware changes had relating to printer parameters.

The need to modify the hardware was mainly driven by the fact that a standard printer generally has the capability for non-planar FDM, but not the clearance required to create any meaningful curvature due to risk of collision. The changes made were in an effort to minimize permanent changes to the machine, and instead work within the confines of it. In this way the work would have a greater applicability to many different printers and therefore reduce the threshold for others to continue the exploration of non-planar FDM.
The adjustments made to the hardware were as follows: nozzles extending further from the hot-end were machined and tested with different tip geometry; a fan shroud solution was made to direct the air of the now lower

nozzle; a mount for the bed-level sensor to allow for raising to allow for levelling as well as clearance. These changes were made in such a way that regular planar printing was also possible.

The main effect noted was the part that the filament extrusion nozzle played in the performance measured in the non-planar process. With only a modest change to tip geometry a significant change was measured in the surface of the non-planar prints. Showing a strong correlation between the diameter of the flat spot of the nozzle tip and surface defect minimization, reaching beyond what was possible with just print parameter variation.

These hardware changes were made in a reversible way and could reasonably be adapted to most consumer printers.