Forensics: 3D Printed Parts - What Do We Know At the Macro Scale?

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Introduction

With new 3D printing technology debuting regularly, forensic examinations of 3D printers and their products are difficult due to a lack of forensic research and validated test procedures (The National). [1] Forensic scientists are limited when concluding results regarding 3D printing technology and its products during investigations.

Open-source files also cause concern because the download and modification of open-source files are not federally regulated which means anyone may access them. 3D printers and their products, as well as the associated software and files, are likely to have evidentiary value with a greater understanding of this technology (The National). [1] The long term goal is to trace a generated part to its source.

The hypothesis states that there are physical differences in 3D printed products generated from the same file in the macro scale. Experiments were designed to determine parameters which have significant effects at the macro scale.

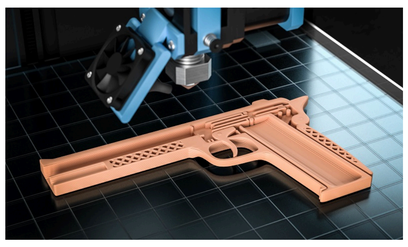

Figure 1. 3D printed firearm [3]

Methods

1. 3D computer aided design file - .stl file format

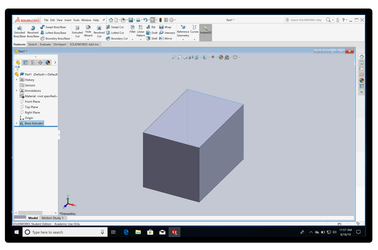

Figure 2. 3D design in SolidWorks

Software
SolidWorks
Fusion 360
AutoCAD

2. Computer aided manufacturing - .gcode file format

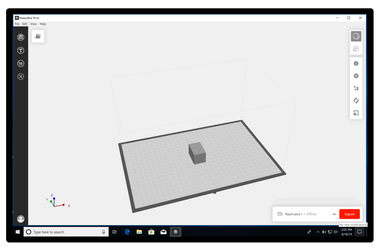

Figure 3. Cube imported into MakerBot Print

Printer
Stratasys Dimension sst 1200es
MakerBot Replicator 5th Generation
MakerBot Replicator Plus
Sindoh 3DWOX

3. Print the object by depositing layers of materials using FDM

- Fuse deposition modelling (FDM) or Extrusion

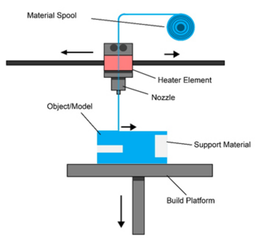

Figure 4. Extrusion Schematic [4]

Material
ABS
PLA
PLA Tough

4. Measure dimensions and mass of the object

5. Statistical analysis using One factor ANOVA P-test and JMP

- Statistical differences in measurements enable parts to be differentiated later by an examiner
- No difference = null hypothesis would not be rejected
  - No reason to test on a larger sample size

Sample Results: Parameter Investigated - Orientation

Are there distinct physical differences in 3D printed products generated from the same file?

Measurements of mass and dimensions (x, y, z, inner and outer diameter) were taken of each generated part designed using SolidWorks® .

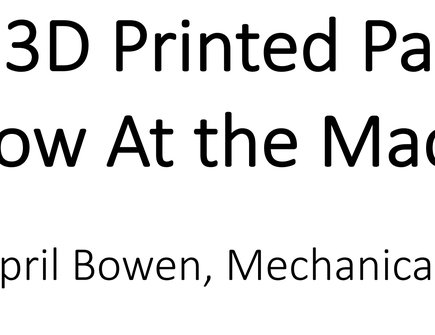

Figure 5. Graph displaying the z axis dimensions of a wedge printed from the Plus.

Figure 6. Graph displaying the y axis dimensions of a wedge printed on the Plus.

Figure 7. Accuracy was determined by the difference between the expected file value and the measured value.

A **statistical analysis** for each dimension was carried out.

Y Axis SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Bottom	9	8.7843	0.97603333	1.9435E-05
Adjacent	9	8.9615	0.99572222	4.5069E-05
Hypotenuse	9	8.837	0.98188889	4.6361E-05

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0018399	2	0.00091995	24.8937051	1.402E-06	3.40282611
Within Groups	0.00088692	24	3.6955E-05			
Total	0.00272683	26				

Z Axis SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Bottom	9	9.017	1.00188889	4.3111E-05
Adjacent	9	8.9838	0.9982	7.16E-06
Hypotenuse	9	9.035	1.00388889	4.0236E-05

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00014991	2	7.4957E-05	2.48456538	0.10454646	3.40282611
Within Groups	0.00072406	24	3.0169E-05			
Total	0.00087397	26				

Figure 8. The z-axis on the Plus shows to have no significant differences between orientations.

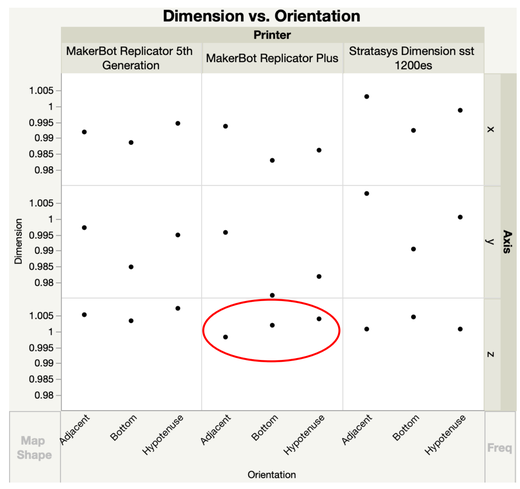

Figure 9. The p value for the z axis on the MakerBot Plus is greater than.05. The graph supports that claim with little difference in values due to orientation.

A generated part may potentially be traced to a specific printer or model/manufacturer if the parts produced by a single printer (i.e., within group) have less differences/variance than those from different printers (i.e., between group).

Work Done

The MakerBot Replicator 5th Generation, MakerBot Replicator Plus, Stratasys Dimension SST (Soluble Support Technology) 1200es, and Sindoh 3DWOX were used to create rectangles, cylinders, and wedges using acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), and Tough PLA Material. Programs such as SolidWorks, and Fusion 360, AutoCAD were also tested on the 5th Gen, Plus, and Dimension.

Measurements of mass and dimensions (x, y, z, inner and outer diameter) were taken of each generated part. **The analysis of variance (ANOVA) of the physical measurements indicated there are statistically significant differences (p-value less than 0.05) between 3D printed parts that are manufactured with different printers, software, orientation, and material.**

As the database increases in size, there is a possibility to determine the discriminating potential of physical measurements for the identification and categorization of 3D printing characteristics, which ultimately has the potential to help trace a printed part to its source.

Key Points:

- ANOVA confirms there are significant differences in 3D generated parts
- As information is added to this database the results of the ANOVA test may provide more insight

Future Work

- Continue to print and analyze 3D generated parts by expanding the number of datasets by outreaching to other universities
- Investigate if there are identifiable characteristics at the microscopic level (e.g., striations produced during printing)
- Explore more parameters and statistical analysis tools

References

1. The National Institute of Justice. (April 2018). How Forensic Science is Transforming Criminal Justice. (B. Bratburd, Ed.), (279).

2. "3D-Printed Guns: Regulations and Legal Implications." *In Public Safety*, 3 Oct. 2018

3. *Blog - MakerBot's Tough PLA Filament Bundle*, www.daemon3dprint.com/blog/tough-pla-filament.

4. "Material Extrusion: Additive Manufacturing Research Group: Loughborough University." *Material Extrusion | Additive Manufacturing Research Group | Loughborough University*

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