Exploratory Study of Analytical Methods for 3D Printing Plastic Filaments

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Introduction

Additive manufacturing, more commonly known as three-dimensional (3D) printing, has been a rapidly developing technology since it's introduction in 1986 [1]. With 3D printers being relatively inexpensive and a large variety of open-source computer aided design (CAD) blueprints, there has been a widespread usage of printing across commercial, private, research, and other industrial sectors. As is common with many modern technologies, there is already a wide array of illicit applications of 3D printing. One of the most notable and concerning applications is the creation of 3D printed firearms and other weapons [2,3]. The prevalence of 3D printers and 3D printed illicit objects is only expected to increase in the coming years as the technology continues to improve and costs continue to decline. Thus, there is a significant need to understand and develop forensic capabilities to analyze 3D printed exhibits or evidence associated with a given criminal investigation. Currently, there are no established protocols or standards for the examination of 3D printed filament, meaning that even if the evidence were to be detected and recovered, there is not a way to forensically associate them to a specific source. ***The purpose of this project was to contribute to the understanding of 3D printed filament and develop an analytical scheme for the examination of 3D printed evidence.***

Methodology

All samples were printed from two Creality Ender 3-Pro 3D printers, using six different 1 kg, 1.75mm black, polylactic acid (PLA) rolls of filament. Five, 1 inch x 1 inch samples were printed from the beginning and end of each roll and with both printers. This gave 20 samples total for each roll. Once printed each sample was scanned in 5 sections with a Perkin Elmer UATR-FTIR spectrometer. The XY data of the resulting spectra was used in data analysis. The following questions guided the data analysis performed in this project.

- Can extruded samples collected from a crime scene be compared to a suspect roll or does the filament need to be extruded for comparison?
- Is there sufficiently limited variability within a single roll to attribute the source of a sample to a particular roll?
- Is there enough variability to individualize or attribute a crime scene sample to a particular roll?

To answer these questions, we ran correlation tests to look at the variability within a roll, between rolls, within a printer and within printers. These tests were done using a data analysis software called "R."

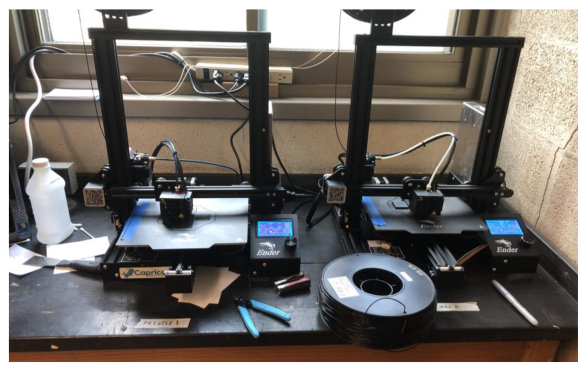

Image 1. The two 3D printers used in this project printing samples

Results

Sample Name Key

P=Which printer, 1 or 2, the sample set was printed on*

R=Which roll, 1, 2, 3, 4, 5 or 6 that the filament came from

S=What sample, 1, 2, 3, 4, or 5 was analyzed from the set

a, b, c, d, or e indicates which section of the sample was analyzed

F=The filament came from the beginning or 'front' of the roll

B=The filament came from the end or 'back' of the roll

* All samples within a set were printed at the same time

Image 2. Images of the Liberator, a fully functioning firearm that is almost entirely 3D printed [4].

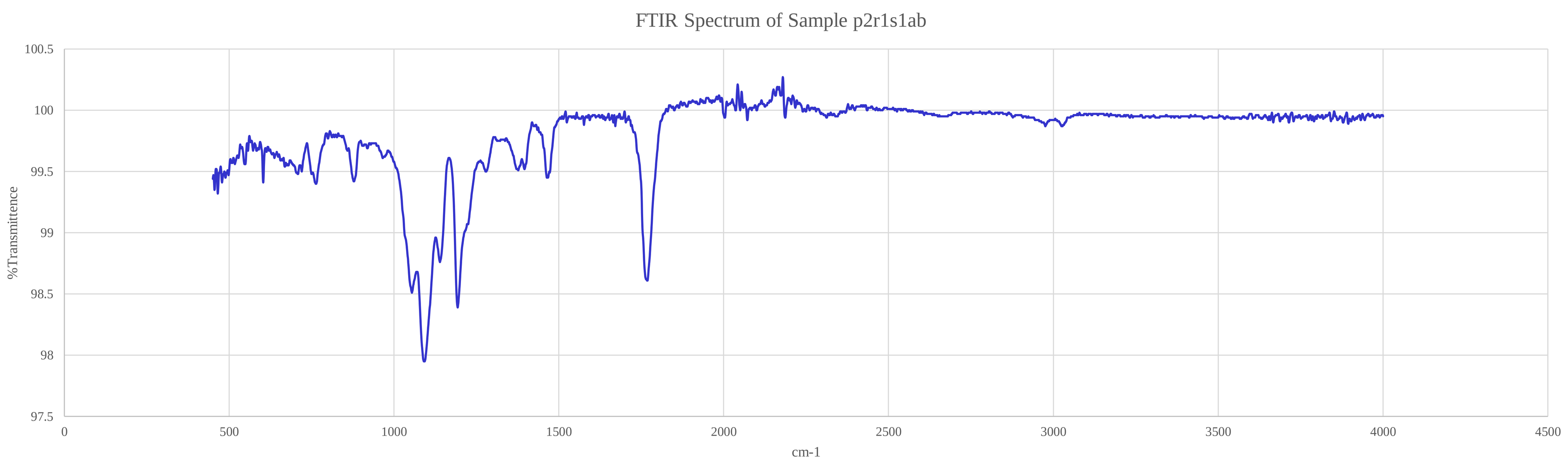

Figure 1. An IR spectrum of sample p2r1s1ab, which is the sample all other samples in Figure 2. are compared to. The spectrum shows characteristic peaks at around 900 cm-1, and 1200 cm-1 seen in all of the spectra produced in this study.

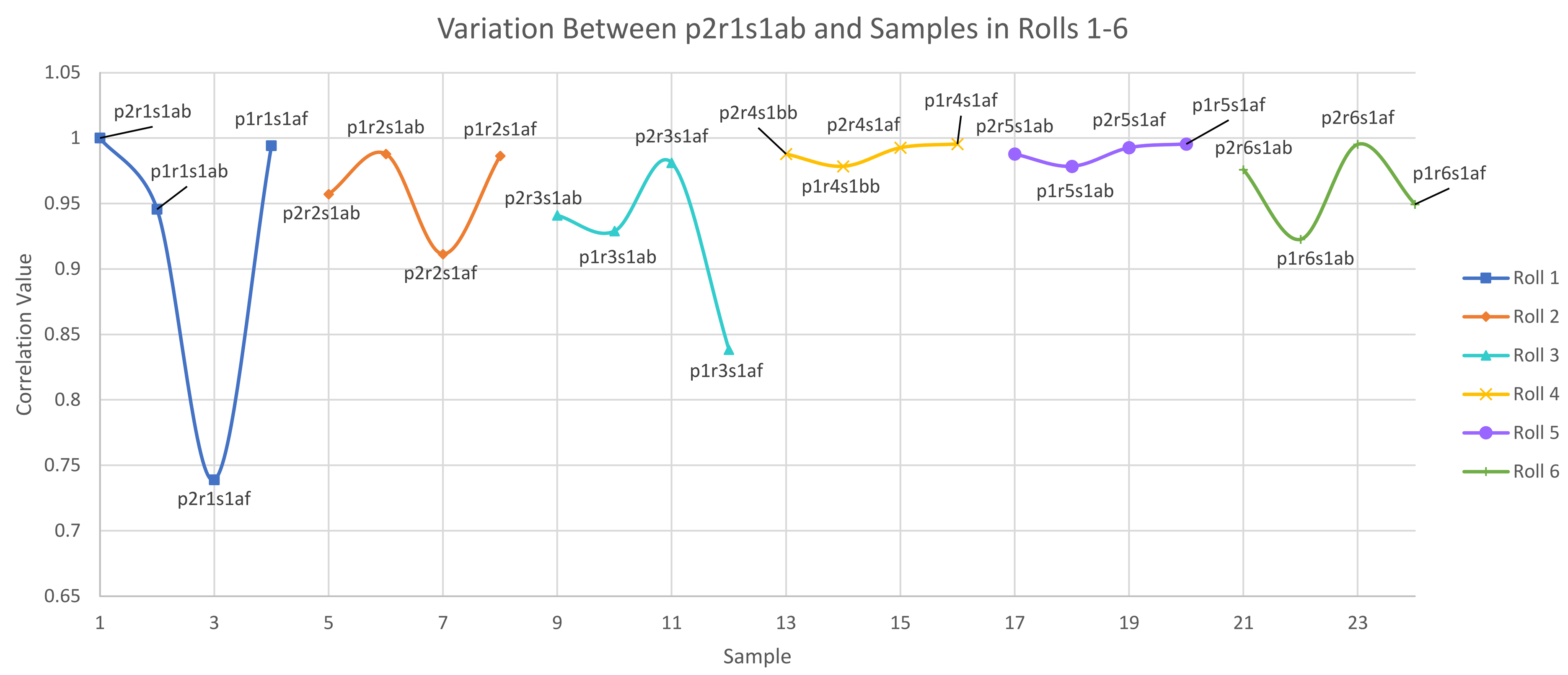

Figure 2. This graph shows the correlation values between sample p2r1s1ab and samples from rolls 1-6, which are defined by name on the graph. The points on the graph depict the correlation between two samples and is indicative of how similar, chemically, they are.

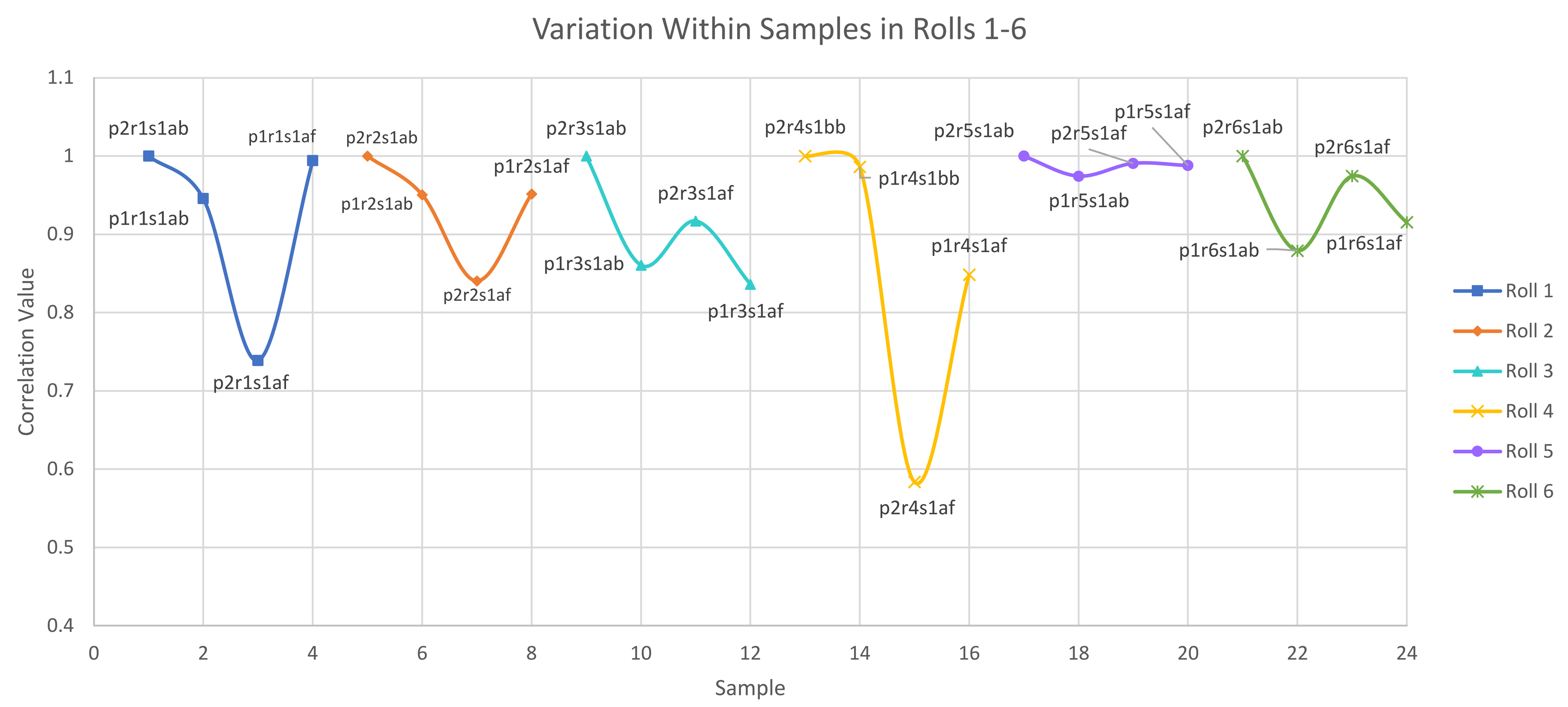

Figure 3. This graph shows the correlation values of samples within the same roll. Each sample defined by name, was compared to the first sample printed on the back of it's respective roll.

Findings

- **General trend of high correlations between rolls of filament.**
  - Looking at Figure 2. majority of the comparisons have a correlation value of 0.90 or higher. This indicates a small amount of variability between rolls of filament. Ideally there would be a greater amount of variability between rolls in order to better distinguish samples from one another.
- **Moderate amount of correlation within rolls of filament**
  - Figure 3. shows a general pattern of decreasing correlation within the rolls as the samples become farther apart on the roll. This indicates that there is some amount of variability between the two ends of the roll. Further analysis is needed to determine the standard deviation in the variability in order to make any statements on the statistical significance of the variability.

Deliverables

- This study has provided an insight on the ability of FTIR to chemically distinguish 3D printing plastic filament.

Future Directions

- Perform a similar analysis with other chemical analytical techniques to see if they have any individualization capabilities of 3D printer filament.
- Extend study to different types of 3D printing filament, such as ABS which is another popular plastic filament within the printing community.

References

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