Design for Additive Manufacturing

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Joint Science and Technology Institute, Virtual 2021

Introduction

Additive manufacturing, or 3D printing, is present in an ever-increasing number of industries, from 3D printed phone cases to medical uses to aerospace applications.

- **Additive Manufacturing** is the construction of three-dimensional objects from a computer-generated model. The 'additive' stems from the creation process in which a machine adds material in layers.
- **Possible uses of Additive Manufacturing** are prototyping and construction of models. The use of a machine streamlines the creation process and allows for more dynamic pieces without cost overruns. Printing through machines reduces human error, and allows for constant and consistent production of parts. Use in prototyping allows for creation of prototypes much quicker than prototyping with traditional manufacturing. This allows problems to be resolved faster.
- **The Additive Manufacturing industry** has exploded in popularity in the last few years. Although still considered new technology, it is growing commonplace in a multitude of fields such as biotechnology, agriculture, aerospace, and dentistry.

Terminology

- **CAD (Computer Aided Design) -** Using CAD gives the user the ability to accurately create, modify, and print 2D and 3D designs. There are a myriad of free software, however more expensive subscription-based software gives more options and tools. Can be used at any experience level.
- **STL (Standard Triangle Tessellation) -** A popular file format for 3D models
- **Filament -** A thread-like plastic. There are many types, including PLA, which stands for "polylactic acid." Being one of the more popular types, this material comes in all colors and a variety of sheens and textures.

Common Types of Additive Manufacturing:

- **Vat Photopolymerization -** Photopolymer resin is cured through selective exposure to light (Figure 1a).
- **Powder Bed Fusion -** Select powdered materials are melted and combined using a heat source such as a laser (Figure 1b).
- **Binder Jetting -** Liquid bonding agents are applied to thin layers of powdered material (Figure 1c).
- **Material Jetting -** Droplets of material are deposited layer by layer to make parts (Figure 1d).
- **Sheet Lamination -** Sheets of material are stacked and laminated together to form an object (Figure 1e).
- **Material Extrusion (FDM) -** Material is extruded through a nozzle in the shape of tracks or beads, and then combined into multi-layered models (Figure 1f) .
- **Directed Energy Deposition (DED) -** Powder or wire is fed into a melt pool which has been generated on the surface of the part where it sticks to the underlying layers (Figure 1g).

Figure 1: Simple visual description of each type of additive manufacturing. From left to right is Figure 1a, 1b, 1c, 1d, 1e, 1f, 1g. (Diagrams courtesy of Hybrid Manufacturing Technologies)

Materials and Methods

Prusa MK3 - The 3D printing machine used during the research.

Figure 2 (right): Parts of the Watch Escapement Toy being printed on the print bed.

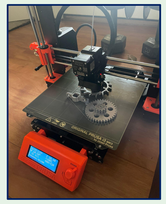


Figure 3 (left): Two brackets being printed for the Watch Escapement Model.

Prusa Slicer - Program used for the conversion of the 3D models (Figure 4) to 'GCODE' files, which are instructions the printer reads. The program scaled the models, moved them around in space, estimated the time to print, and interpreted color changes (Figure 5).

Figure 4 (right): User Interface, viewing the part as it would be printed on the sheet.

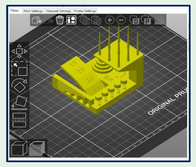


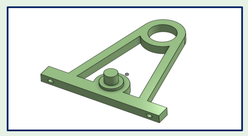
Figure 5 (left): Advanced settings in the program. User can change how the filament is deposited.

CAD - CAD software such as: OnShape, TinkerCAD, and nTopology are used with 3D printers. These programs are used primarily for product and machinery design, and are present in many industries such as consumer electronics, medical devices, industrial equipment, and of course, additive manufacturing. Through experimenting with designing a range of models, such as modifying certain parts for the Watch Escapement Desk Model, a deeper understanding of the programs and functions was gained, much like a professional designer would utilize.

Results

- 3D printing has a place in many industries in the near future. The technology will continue to improve over time, taking on new adaptations and functions.
- Additive manufacturing is still in its early days and is continuing to grow and evolve.
- There are different uses for each of the seven different types of additive manufacturing.
- Use of CAD to model custom objects:

Figure 6 (right): A CAD image of a custom piece from the Watch Escapement Model.



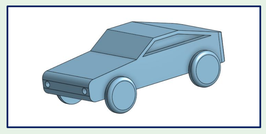


Figure 7 (left): Casey's CAD toy car model.

Final Project

- The final project, the **Watch Escapement Desk Model**, an assembly of over twenty individual parts:

Conclusions

Learning how to 3D print can prove to be difficult, but once building and slicing has been mastered, practically any object can be printed (Figure 8). 3D printing is the next step in how parts are manufactured. It presents many benefits opposed to traditional machining, such as the ability to create complex figures much cheaper, and print complete assembly as one piece, reducing time and labor required. The technology is quickly becoming a part of everyday life. 3D printing machines are finding their way into the typical household. Before any successful prints, there were errors, and fixing them provides knowledge and patience for handling advanced machinery. Overall, additive manufacturing is important now and in future due to its varied applications in research, manufacturing, and daily life.

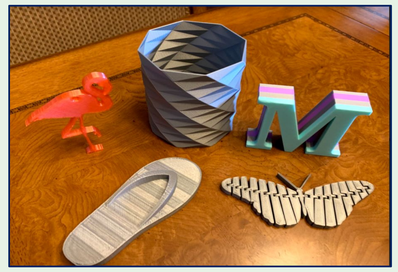
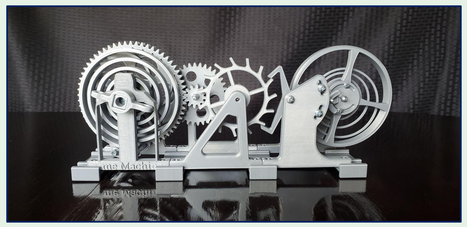


Figure 8: Successful parts printed from members of the research group. Top left is A. Top right is B. Bottom left is C. Bottom right is D. Provided from Kaden, Christian, and Misha.

Acknowledgements

Thank you to:

- Michael Geuy, Mentor
- Anna Hilburgh, JSTI Alumni
- Arlene Huber, IT
- Dr. Nick Misel
- Dr. Joe Bartolai
- NASA Goddard Visitor Center
- nTopology Inc



We appreciate the opportunity provided to us by Oak Ridge Institute for Science and Education, and the Defense Threat Reduction Agency's Joint Science and Technology Office for Chemical and Biological Defense.