Ethical Considerations in the Age of 3D Printing

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ENG 5313: Ethics in Technical Communication

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Abstract

Until recently, the manufacturing of parts involved a lengthy production cycle that often relied on traditional, subtractive manufacturing techniques, such as cutting, drilling and grinding, to arrive at a desired product. With the introduction of additive manufacturing during the 1980s, a change in the manufacturing landscape took effect; indeed, a focus on the "rapid-prototyping" of future products ushered in different processes for creating parts using computer-controlled machinery, including the advent of 3D printing—an additive manufacturing technique that creates a product by joining materials together, layer by layer. But as with any new, disruptive technology, 3D printing has raised some concerns in terms of its paper offers an introduction to the age of 3D printing by illustrating the -3D printing process and considering the ethical questions facing this technology.

Introduction

In 2013, Defense Distributed, an American nonprofit organization that advocates for the development and publication of publicly-available firearms design schematics, shocked the world with its unveiling of the Liberator, the world's first fully 3D printed gun (see Fig. 1). Among a flurry of legal battles and ethical questions raised since, Defense Distributed emerged in 2015 with another product, the Ghost Gunner, a "gun machine" that uses open-source design files to “legally manufacture un-serialized AR-15’s in the comfort and privacy of [the user’s] home” (“Ghost Gunner”).

Figure 1. “The Liberator,” the world’s first 3D-printed firearm

In a similar, yet altogether differing manufacturing context, 3D bioprinting technology continues to approach what many can only label as science-fiction. Already in 2013, Hangzhou Dianzi University in China announced the printing of a small, working kidney using its biomaterial 3D printer Regenovo (Brown). Major advances in regenerative medicine resulting from 3D bioprinting were further highlighted when, in 2015, the Wake Forest Institute of Regenerative Medicine announced they kept a baby-sized ear alive on a mouse for two months (Brown). Furthermore, BioBots, a biotechnology company also specializing in regenerative medicine, launched the BioBot 1 in 2015—the first commercially-available desktop bioprinter capable of using computer-generated design files to print living tissue (“BioBot 1”).

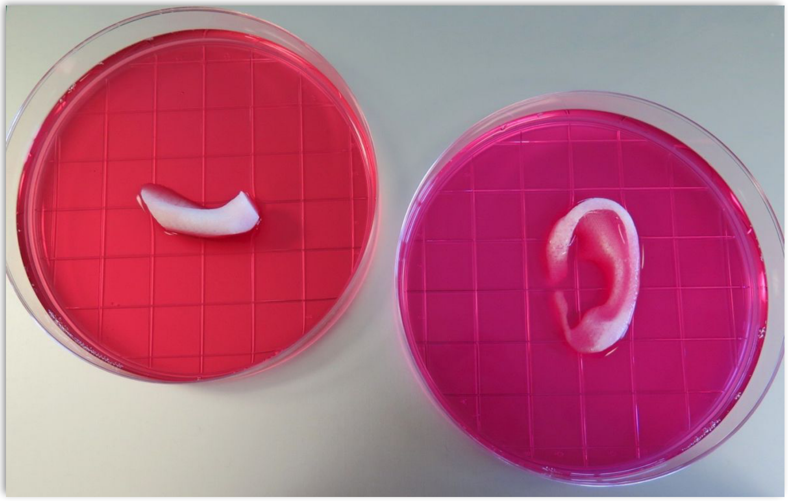

Figure 2. Organs printed by the Wake Forest Institute for Regenerative Medicine

3D printing technology is revolutionary, and its emerging applications continue to highlight significant advances in the manufacturing and medical industries. Yet its unintentional uses have and will continue to spark legal and ethical debates regarding publicly-available design schematics, intellectual property theft, security, and the potential misuse of biomaterial . The aim of this paper is to analyze current 3D technology through an ethical and utilitarian lens, and analyze . First, this paper will provide an overview of the 3D printing process and the scope of its societal impact; Next, it will discuss the open-source, public availability of 3D printer hardware and software and computer-designed files, and the questions in ethicality that this open accessibility raises; Finally, it will analyze the current and potential ethical questions surrounding 3D printing technology from a utilitarian perspective.

Part One: A Background on 3D printing

3D printing is a form of additive manufacturing (AM), the process of joining materials layer-by-layer based on a computerized 3D model (Huang et al. 1192). This method for creating products counters the more conventional “subtractive manufacturing”—the process by which unwanted or superfluous material is removed by grinding, cutting or drilling to arrive at a desired part or artifact. By contrast, additive methods build the exact product, layer by layer, from the bottom up (Kietzmann et al. 210). Though a more complicated process, AM can be thought of as using a computer-controlled hot glue gun to create a three-dimensional object made of glue; similarly, the AM process resembles combining layers of simple Lego blocks to create a complex artifact (Kietzmann et al., 210):

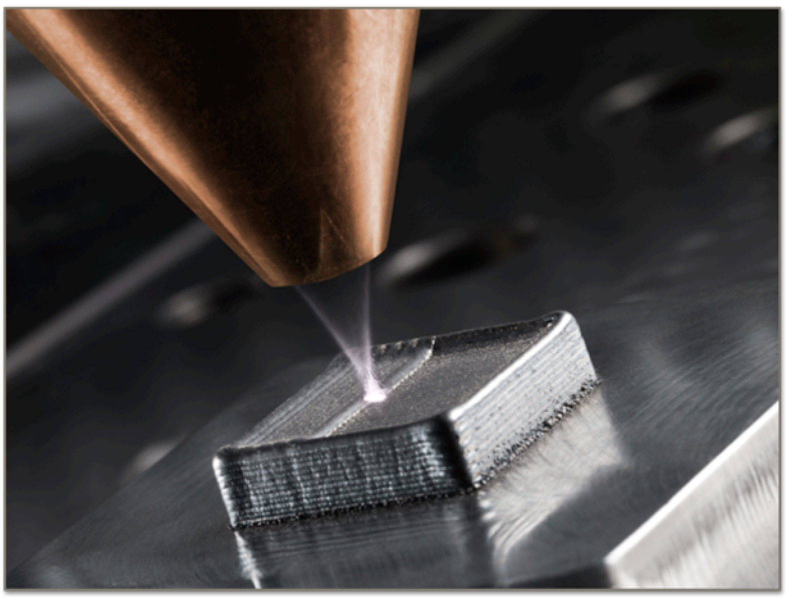

Figure 3. A 3D printer generating metal components, layer by later

In 1986, Charles W. Hull filed a patent for stereolithography, a form of AM (see Fig. 5), and he later founded 3D Systems, the first 3D printing company (Hull). Hull’s invention, the first patented additive method, provides the foundation for the commercialized 3D printing technology that is common today. In his 2015 Industrial Research Institute (IRI) Achievement Award Address, Hull describes the tedious process involved in manufacturing plastic parts during the early 1980s. Driven by the utilitarian need for a faster product "prototyping" and a more efficient product cycle, Hull printed the first 3D printed object, a small cup, in his lab in 1983—years before leaving his full-time engineering position at DuPont. But as with most emerging technology products, Hull's first, prototypal version of the 3D printer was expensive and bulky. Among the first customers of 3D printing were the automobile and aerospace industries (Hull), and Hull's technology has only recently found its way into smaller industries, major stores, universities, neighborhood schools, and homes across the globe.

Designing

The first steps in creating a physical 3D model require user access to digital design schematics, or 3D model data. Users can create or modify 3D model data using a wide range of computer-aided design (CAD) programs (Kietzmann et al. 211). With CAD software, users create blueprints to represent three-dimensional models of objects; likewise, users can modify existing designs available for download at websites like Thingiverse, a design community for "discovering, making and sharing 3D printable things" ("Thingiverse"). Many of these 3D modeling programs, such as Blender, Google SketchUp or Tinkercad, are web-based applications that vary in degree of complexity, though most are free to download and use; higher-end programs like AutoCad require a subscription or an educational license (Kietzmann et al. 211). Alternatively, users can scan physical objects for model data using desktop or mobile 3D scanners (ie., MakerBot Digitizer, 3D System's iSense Scanner, etc). Once an object is scanned, the resulting 3D model data can then be manipulated using a CAD program to recreate the original object or to create iterations of that object ("Digitizer").

Printing

CAD files ready for printing are converted to a 3D printing file format, such as .STL or .OBJ. Once the original CAD file is exported to a readable, 3D printer file format, the user must use third-party software to properly prepare and redact the file to ensure it is free of errors and ready for printing (see Fig. 4).

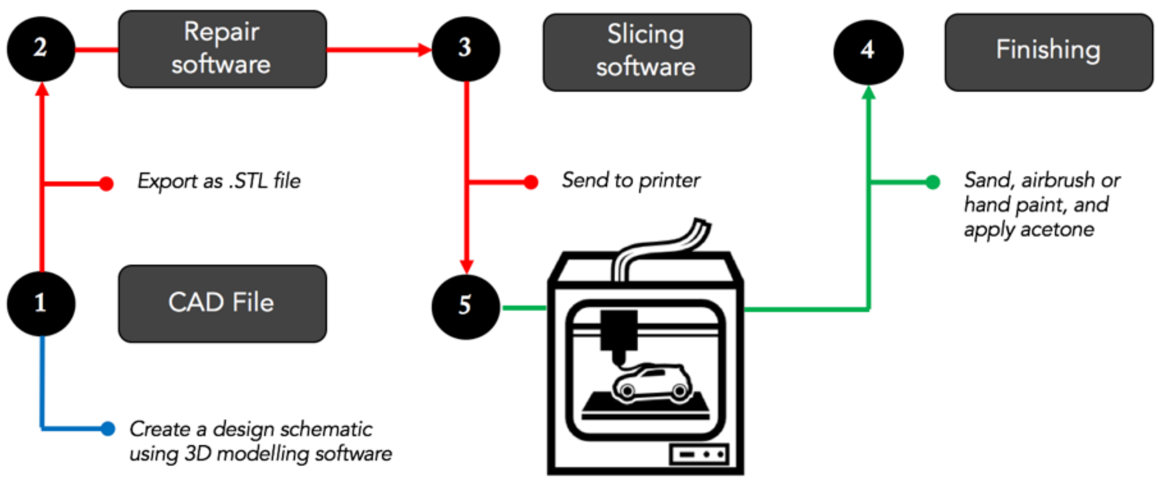

Figure 4. The 3D printing process, from CAD file to finished object

First, users open the exported .STL file using a 3D printing repair software to check for possible file imperfections. Repair software programs, such as Netfabb or Meshlab, can measure and analyze the 3D model to ensure it is strong enough to be produced as a physical object. After the .STL file is checked and repaired, it is sent through a slicing software. Slicing software programs, like Ultimaker's Cura, slice the 3D model into thousands of flat 2D layers. This slicing process converts the .STL file to G-code—instructions the 3D printer can read in order to fabricate the final object. The final step is to send the sliced file to a 3D printer for printing.

There are numerous industrial and domestic 3D printers available for purchase worldwide. These machines satisfy the printing needs of a wide range of users and consumers and therefore feature different forms of additive technology. As Huang et al. discuss in their article "Additive Manufacturing and Its Societal Impact: A Literature Review," there are are numerous 3D printing technologies or methods for creating objects using a CAD file (1192). Each of these methods used for domestic, non-industrial purposes are Fused Deposition Modeling (FDM), Stereolithography (SLA), and Selective Layer Sintering (SLS).

Fused Deposition Modeling

The Fused Deposition Modeling (FDM) process is similar to using an extremely precise glue gun for drawing. FDM (also known as Fused Filament Fabrication, or FFF) uses colored plastics from a spool called "filament." This spooled filament, similar in thickness and texture to a weed-eater line, is fed to a printer by motors, and is then melted through a heated nozzle. The liquid is extruded onto a print bed where it immediately hardens and binds to the layers below. The 3D object forms as the process repeats itself, layer by layer (see Fig. 5):

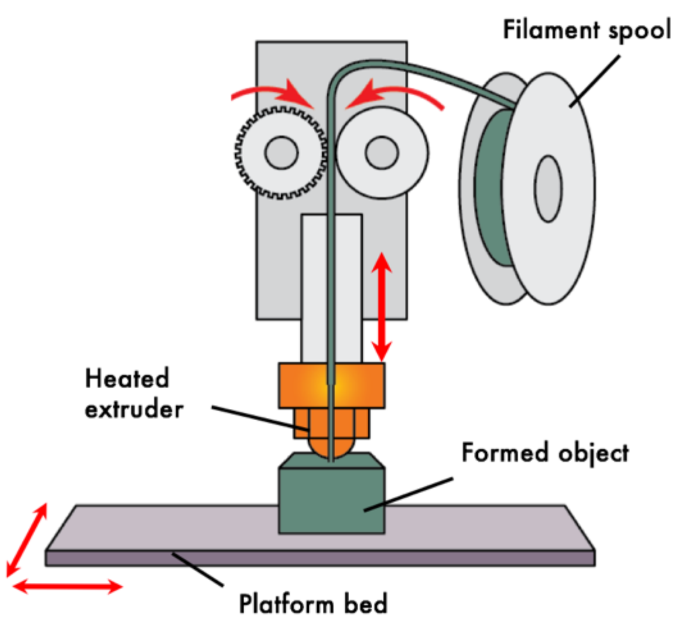

Figure 5. Fused Deposition Modeling (FDM)

The FDM process is the most common among desktop 3D printers because it cost effective ("3D Printing Processes”). However, this form of printing struggles with sharp corners, seam lines between layers, and lower print resolutions as a result (Huang et al. 1192).

Stereolithography

Stereolithography (SLA) is another form of 3D printing that uses a different process to create additive layers of material (see Fig. 6). Instead of extruding melted layers of filament onto a platform, SLA uses an ultraviolet laser to turn photo-reactive chemical resins (ie., liquid plastics) into solids (Kietzmann et al. 211):

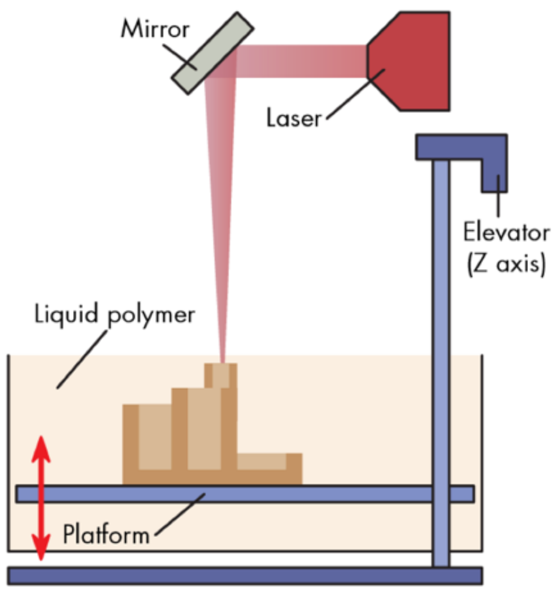

Figure 6. Stereolithography (SLA)

Similar to beaming a concentrated light through a magnifying glass, the SLA method uses a computer-controlled laser to trace a cross-section of a 3D model. With each cross-section traced, a new layer of liquid resin is spread over the forming object. This liquid hardens when the beam of UV light touches it, causing it to become solid. The newly hardened layer is then repositioned so the process can repeat. As each cross-section is drawn and adheres to the previous layer, it stacks up to create the finished 3D object ("3D Printing Processes”). SLA is particularly suitable for the manufacturing industry as it lessens the time it takes for a prototype part to be produced and can achieve a good surface finish. However, a main limitation of SLA is that the build or product size is relatively small. Moreover, the SLA printing process is costly; the photopolymer resin alone costs from $100 to $300 to replace, and the printers themselves typically range from $3000 and up (Huang et al. 1192).

Selective Laser Sintering

Selective Laser Sintering (SLS) is very similar to stereolithography, though instead of using a liquid resin for 3D printing, a fine powder is used. The powder can be made out of a variety of materials including metal, plastic, glass or ceramic. A roller deposits this powder and then a laser, which traces the shape of the 3D model, is used to sinter or fuse the powder together by bringing it to its melting point. This creates one layer of the 3D object. The roller then puts down another layer of powder on top of the previous and another cross-section is built. The process repeats until the model is formed (see Fig. 7):

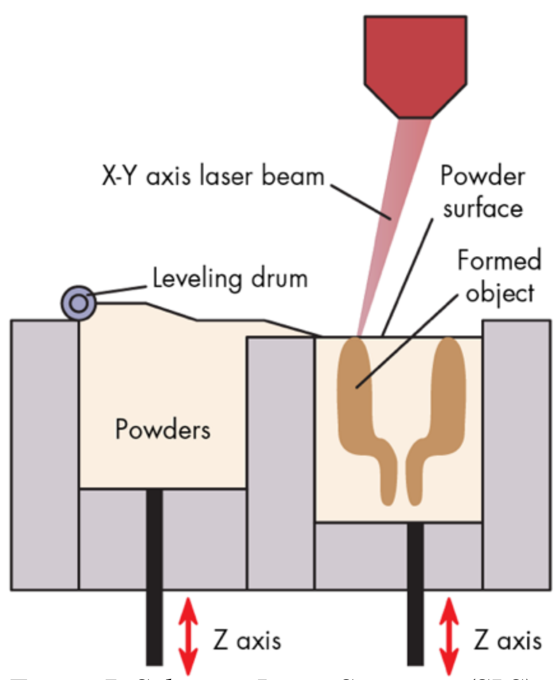

Figure 7. Selective Layer Sintering (SLS)

At the end of this process, the remaining powder is removed, and the newly-formed 3D object is removed ("3D Printing Processes”). Compared with other AM processes, the SLS method can quickly build complex parts that are durable and more functional (Huang et al. 1192); however, SLS operation is complicated, and the surface finish of the printed object may not be as good as that from SLA (Huang et al. 1192).

Part Two: The Ethical Implications in 3D Printing

In 2011, a designer named Ulrich Schwanitz succeeded in 3D-printing the Penrose Triangle, an illusory “impossible” object popularized by the Dutch graphic artist M.C. Escher (see Fig. 8):

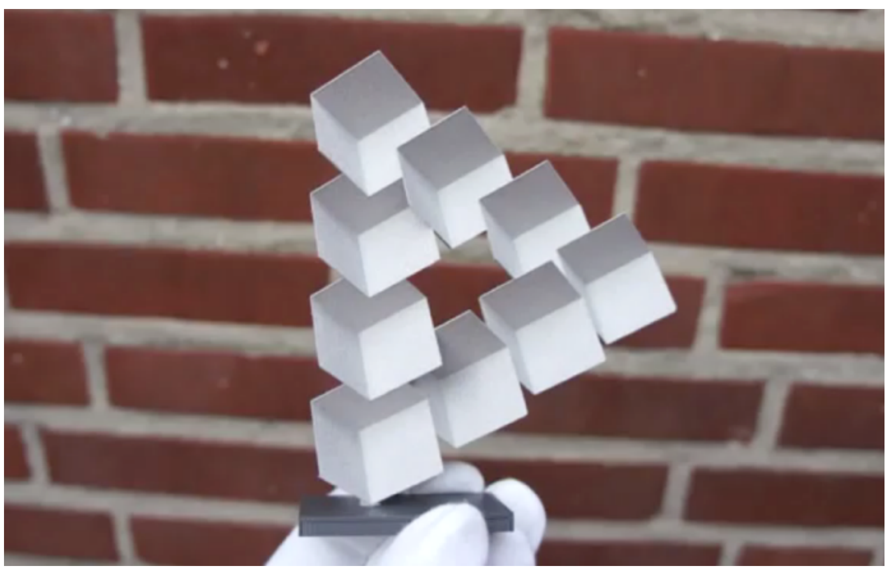

Figure 9. Schwanitz’s 3D-printed Penrose Triangle

Though Schwanitz posted a YouTube video to demonstrate his finalized 3D-printed object (see Fig. 9), he chose not to make his design schematic public domain. Instead, Schwanitz issued a “design challenge” for 3D modelers and offered the 3D-printed Penrose Triangle for sale through Shapeways, an online 3D marketplace (Hanna). Weeks later, a 3D modeler named Arthur

Tchoukanov produced a design solution to Schwantiz's intriguing "impossible" object challenge, and subsequently uploaded the CAD file to Thingiverse, where users downloaded the CAD file free of charge (Hanna).

But unlike Shapeways, a website that allows designers the ability to make objects based on their design files available for purchase, Thingiverse exists on the notion that 3D modelers share their design schematics with the 3D printing community for free so that anyone may download and print objects at home ("Thingiverse"). When a news outlet highlighted Tchoukanov's contribution with a story that credited him as the original creator of the printed Penrose Triangle, Schwanitz issued Thingiverse a request to remove the CAD file from its repository, alleging that Tchoukanov's file infringed on his copyright claim (Hanna). This conflict resulted in the first 3D printing-related takedown notice issued in accordance with the Digital Millennium Copyright Act (DMCA).

Copyright and Intellectual Property

The complications resulting from the 3D-printed "impossible" triangle debacle in 2011 provided the backdrop for what is considered the "most disruptive technology" since Gutenberg's introduction of the printing press (Source). In the article "Printing the Impossible Triangle: The Copyright Implications of Three-Dimensional Printing," Brian Rideout notes that Schwanitz's takedown notice "did not specify whether [he asserted copyright] in the structure itself, the 3D design file, or just the image of the Penrose Triangle" (2011).

Security and 3D-printed firearms

Part Three: An Ethical Appraisal

3D printing and utilitarianism

Applying a utilitarian lens on the ethical use and regulation of 3D printing technology allows for an objective, "quantitative calculation" of how to use it ethically (Dombrowski 54). As opposed to relying on one's individual, personal system of values to make a deliberate decision about the ethics underlying this technology, a utilitarian approach to 3D printing "[measures its usefulness] for the appropriate number of people, [compares] it to measures of ill effects of the remaining people, [plugs] it all into an algorithm, and [calculates] the solution (Dombrowski 54).

With this perspective in mind, researchers have already provided an abundance of evidence endorsing the widespread societal impact of 3D printing technology. Among these benefits, included are customized healthcare products (ie., prosthetics, surgical implants, etc.) to provide increased general health and quality of life; reduced environmental impact compared to conventional machining processes resulting in less pollution; on-demand manufacturing which results in reduced need for warehousing, transportation and packaging (Huang et al., 1195); 3D bio-printed tissues aiding in regenerative medicine, including the printing of multilayered skin, bone, aortic valves, and cartilaginous structures (Murphy and Atala). These benefits do not include the driving major innovations and advances in other areas, such as engineering and education.

But while it is difficult to argue against the large-scale societal impact of 3D printed technology and biomaterial, ethical questions still persist. The sheer availability of CAD files available for immediate download to be used in domestic 3D printers, for example raises questions of copyright law infringement and intellectual copyright theft. Gartner, a research and advisory company firm, predicts that by 2018, 3D printing will result in the loss of at least $100 billion per year in intellectual property globally (“DEMM”). Furthermore, other technological applications for 3D printing technology, such as those involving freely-available design schematics for 3D-printed firearms and automatic weapons, also raise both legal and ethical questions. In the case of 3D-printed firearms and other controversial iterations of 3D technology, government agencies must decide that the benefits of such technologies outweigh the potential costs in order maintain their access free to users and consumers (Dombrowski 54). While 3D-printing technologies involves risking continued intellectual property loss, misuse of biomaterial and even death by a 3D-printed firearm, agencies mandate regulations according to the greater good. While a mandate to shutdown open-access websites containing copyrighted material and firearm schematics might lead to saving some lives and property over the years, for example, the greater, over-reaching benefits of allowing open-access websites to continue fostering new innovations through 3D-printed technology may outweigh the costs of a few.

Utilitarian theory, which amounts to a technical approach to ethics, applies to situations in which ethical judgments are weighed on the basis of whether or not a product or action, be it the introduction of a new medicine or the advent of a technological product, “benefits the greatest useful goodness for the greatest number of people” (Dombrowski 54). Utilitarianism and the rise of industry and technology are therefore invariably linked, in that consumers of technology endorse continued efforts to create better, widely-used products driven by utilitarian and practical needs. 3D printing technology, for instance, has paved the way to efficient and low-cost digital and medical manufacturing worldwide, becoming a cornerstone to the third industrial revolution

(Hull). Yet the ethics behind creating and regulating its use, as with any new technology, continues to spark debate.

In the medical field, prosthetics are being 3D-printed to exact specifications (see Fig. 9):

Figure 9. A 3D-printed prosthetic

Furthermore, 3D printed tissues and mini-organs are slowly eliminating the need for animal testing. From the utilitarian perspective, the 3D printing technology, particularly bioprinting, will have a tremendous impact in terms of its overall utility in providing transplants and other body parts to patients in need. Yet the misuse of 3D technology can backfire, and legal action may eventually have to interrupt certain aspects of this rapidly-growing and useful technology.

Works Cited

"3D Printing Processes." PrintSpace 3D. Web. 12 Apr. 2016.

"3D printing will 'ignite major debate on ethics'." *DEMM: Engineering & Manufacturing* (2014): 24. *Business Source Complete.* Web. 1 Mar. 2016.

Brown, Kristen V. "How Close Are We to a 3D-printed Human Heart?" Fusion. 17 Feb. 2016. Web. 12 Apr. 2016.

"Digitizer." MakerBot. Web. 12 Apr. 2016.

Dolinsky, K. "CAD's Cradle: Untangling Copyrightability, Derivative Works, and Fair Use in 3D Printing." *Wash. & Lee L. Rev.* (2014): n. pag. Web. 1 Mar. 2016.

Dombrowski, Paul M. *Ethics in Technical Communication*. Boston: Allyn & Bacon, 2000. Print.

Huang, Samuel et al. "Additive Manufacturing and Its Societal Impact: A Literature Re view." *The International Journal of Advanced Manufacturing Technology* 67.5-8 (2012): 1191–1203.

Hull, Charles W. "The Birth Of 3D Printing." *Research Technology Management* 58.6 (2015): 25-29. *Business Source Complete*. Web. 1 Mar. 2016.

Kietzmann, Pitt, and Berthon. "Disruptions, Decisions, and Destinations: Enter the Age of 3-D Printing and Additive Manufacturing." (2015) : n. pag. Web. 1 Mar. 2016.

Murphy, Sean V., and Anthony Atala. "3D Bioprinting of Tissues and Organs." *Nature Biotechnology* 32.8 (2014): 773-85. Web. 22 Mar. 2016.

Neely, Erica. "The Risks of Revolution: Ethical Dilemmas in 3D Printing from a US Perspective."*Science and Engineering Ethics* (2015): n. pag. Web. 1 Mar. 2016.

"Thingiverse 3D Printing Community." MakerBot. Web. 12 Apr. 2016.

Walther. “Printing Insecurity? The Security Implications of 3d-Printing of Weapons.” (2015): n. pag. Web. 1 Mar. 2016.