Destroying by Creating: Exploring the Creative Destruction of 3D Printing Through Intellectual Property

Stephanie M. Santoso
Information Science
Cornell University
sms629@cornell.edu

Benjamin D. Horne
Computer Science
Union University
ben.horne@my.uu.edu

Stephen B. Wicker
Electrical and Computer Engineering
Cornell University
wicker@ece.cornell.edu

Abstract

In this paper, we examine the development of 3D printing through the lens of Schumpeter's creative destruction. Simply put, creative destruction is the idea that periods of innovation destroy established corporations, while new enterprises emerge, take root and become economic drivers. Intellectual property provides an interesting landscape to explore this question with regards to 3D printing because the technology has historically been characterized by strong patent protections, but in recent years has experienced democratization, through open source and peer production activities. The IP issues associated with 3D printing fall into two categories- those involving the technology itself and those related to the digital objects created by the technology. While the technology of 3D printing itself is not being destroyed, we observe that the control that key industry players have over the technology is eroding, leading to changes in who is developing the technology, who is using it and how it can be used. In addition, the sharing of digital object designs through the widespread use of Creative Commons illustrates that authors' sense of ownership is not exclusive, but amenable to sharing on a sliding scale. This research consists of a combination of case study analysis, informal discussions with members of the 3D printing community and an online survey designed to understand the sharing practices and intellectual property concerns of those who are using the technology.

I. Introduction

"A once-shuttered warehouse is now a state-of-the art lab where new workers are mastering the 3-D printing that has the potential to revolutionize the way we make almost everything."

-President Barack Obama

On February 12, 2013, President Obama gave his State of the Union address from the National Additive Manufacturing Innovation Institute (NAMII) in Youngstown, Ohio (The White House A, 2013). Youngstown had once been an industrial epicenter, first as a result of the coal and iron deposits discovered in the area in the 1800s and then as one of the nation's leading steel producers from the early 1900s until the 1960s. During the latter half of the 20th century, Youngstown saw a gradual decline in its local economy, with an estimated 50,000 jobs in steel and related industries lost by the early 1980s (Donahue, 2010). Today, Youngstown is on the road to reinventing itself- city and community leaders are cultivating a new type of manufacturing industry that will create a wealth of jobs.

The National Additive Manufacturing Innovation Institute was established in 2012 with the objective of utilizing 3D printing technology to increase U.S. competitiveness in manufacturing (NAMII, 2013; Mack, 2013). NAMII is a public-private partnership between the government, industry, academic institutions and non-profits. The U.S. Department of Defense put $30 million toward the creation of NAMII. In addition, industry players such as GE, Lockheed Martin, 3D Systems and Carnegie Mellon University are members funding the 3D printing research, development and worker training programs spearheaded by the Institute (NAMII, 2013). The Obama administration has asked Congress to create a total of 15 of these Manufacturing Innovation Institutes across the country through a one time $1 billion investment (The White House B, 2013).

The significant financial investment, R&D and training efforts put forth by the U.S. government, and key players across different industries and universities are strong indications that 3D printing is undergoing what Austrian economist and political scientist Joseph Schumpeter called, "creative destruction." Simply put, creative destruction is the idea that periods of innovation destroy established corporations, while new enterprises emerge, take root and become economic drivers. Entrepreneurs, Schumpeter argued, were the initiators of creative destruction, pushing industry players to make significant product improvements in order to remain competitive.

In this paper, we examine the development of 3D printing through the lens of Schumpeter's creative destruction, with a focus on how the tensions between the technology's open source movement, peer-to-peer sharing of digital object designs in recent years and efforts to protect intellectual property associated with the technology impact who can use the technology, how it can be utilized and how the technology will evolve moving forward.

This research consists of a combination of case study analysis, informal discussions with members of the 3D printing community and an online survey designed to understand the sharing practices and intellectual property concerns of those who are using the technology. The discussion is largely U.S. focused, and provides a starting point to understand how the handling of IP issues by one nation could have significant implications on a technology globally.

II. Background

Theoretical Framework: Schumpeter's Creative Destruction

In his book, Capitalism, Socialism and Democracy, Joseph Schumpeter sought to chronicle more than 40 years of research and thought on socialism, including a detailed and nuanced discussion on the future of capitalism in society. In considering what capitalism will look like moving forward, Schumpeter emphasizes that capitalism (and therefore economic development) are evolutionary processes (1942). Fragmentary analyses of capitalism which explore monopolistic or oligopolistic competition capture only certain phases of a process which "is by nature a form or method of economic change and not only never is but never can be stationary" (1942). Thus, capitalism could be viewed as a living, breathing organism, constantly in motion, with entities moving in and out of the market economy. This is where creative destruction comes in. The momentum and motion of capitalism can be attributed to new goods, methods of production, modes of distribution and new markets that are developed through capitalist enterprise. In this

sense, the capitalist enterprise self destructs in order to morph into something that will remain relevant, thus meeting the needs and demands of consumers (1942). Schumpeter describes creative destruction as a type of industrial mutation that internally revolutionizes the economic structure. The catalyst and drivers for creative destruction are entrepreneurs, who bring about innovation and growth, which results in the obsolescence of existing corporations. Thus, the technological progress is facilitated through creative destruction.

We use creative destruction to ask three main questions with regards to the evolution of 3D printing technology:

1) In what ways might intellectual property issues affect the process of creative destruction that could take place within the 3D printing industry?

2) How are long standing players in the 3D printing industry dealing with "creative erosion"? We define creative erosion as movement towards creative destruction, in which entrepreneurs have entered the market, but have not successfully eliminated existing players.

3) What is the role of the open source movement and peer-to-peer sharing of information in facilitating creative destruction?

Overview of 3D Printing

Although 3D printing was developed in the 1980s, up until several years ago, the technology was used primarily for a limited range of industrial applications. Engineers, designers and architects leveraged 3D printing for rapid prototyping, creating structure models and producing complex, specialized one-off parts. In its early years and even up until the early 2000s, an individual needed a significant amount of training and knowledge to use the technology, including how to use CAD to digitally model objects. These industrial 3D printers were also extremely expensive- models ranged in price from thousands to hundreds of thousands of dollars.

3D printing is a term used to encompass several different additive manufacturing techniques. Additive manufacturing is a process in which three dimensional objects are built layer upon layer using different materials, including plastics, metal, food and today, even human tissue. Additive manufacturing differs from traditional methods of manufacturing which involve starting with a larger amount of material than required and cutting away from the material to make the objects. There are different technical approaches to 3D printing, which can be distinguished by the way in which layers of material are created and built, types of materials and print quality. For the purposes of this discussion, we will focus on two widely used methods: 1) Stereolithography (SLA); 2) Fused Deposition Modeling (FDM).

Stereolithography is the first 3D printing process to be patent protected in 1986. With SLA, the build process begins with a pool of resin. A laser beam is aimed at the pool of resin, tracing the cross-section pattern of the 3D object one layer at a time, simultaneously curing the layer before tracing the next layer (Additive Manufacturing, 2013).

Fused Deposition Modeling uses thermoplastic filament which is threaded through an extruder with a heating element. The heat melts the plastic at a specific temperature and as it passes through the extruder, gradually builds the 3D object layer by layer, again in a cross section pattern (Additive Manufacturing, 2013). The plastic cools and hardens by itself, so no additional laser technology is required for curing. FDM is the process used by the majority of consumer-oriented printers currently available, including RepRaps, Makerbots, Ultimakers and Type A Machines.

When key patents for Fused Deposition Modeling expired in the early 2000s, this prompted the creation of open source 3D printing initiatives such as RepRap and Fab@Home, which sought to democratize the technology and make it accessible to a wider audience. It was these open source projects which laid the groundwork for commercial 3D printing start-ups to sell 3D printer kits and fully assembled 3D printers to the general public. From the very beginning, the build instructions and plans for the plastic parts of the RepRap were made publicly available on the project wiki (reprap.org/wiki/) via the GNU general public license (Bowyer, 2009). Making this information freely available served as a catalyst for the peer-to-peer sharing of information about everything from how to improve the functionality, features and print quality of the earliest machines to troubleshooting printing issues with specific objects. The significance of RepRap and more generally the open source movement in 3D printing can be observed by tracing the numerous consumer-oriented 3D printers that are on the market which are derivations of RepRap or contain a substantial number of the same features and functionality. The most high profile example of this is that Makerbot, currently the most popular consumer-oriented 3D printing company, was started by one of RepRaps core developers, Zach Smith, along with Bre Pettis and Adam Mayer. The company even received some start-up funding from Bowyer (MakerBot, 2012; Prusa, 2012b).

Thus, open source projects can facilitate the development of a market; in some cases it sows the seed for a market where there once was none.

Identifying Key Intellectual Property Issues of 3D Printing

The intellectual property issues affiliated with 3D printing are becoming increasingly salient as the technology becomes more mainstream. Intellectual property has and continues to play a significant role in the development of the technology.

Recent discussions about IP issues and 3D printing has largely centered around how copyright and patent laws would apply to what is actually created through the use of the technology- more specifically, how digital object designs and the printed physical objects themselves might be protected. To date, there are no specific provisions in U.S. IP law which specifically address digital object designs or 3D printed objects, but the increasing use of the technology in various industries and by individual consumers prompted Victoria Espinel, the U.S. Intellectual Property Enforcement Coordinator to reference 3D printing as an innovation that would create new challenges to enforcing IP rights in the 2013 Joint Strategic Plan on Intellectual Property Enforcement (Espinel, 2013).

Patents on 3D Printing Technology

The different 3D printing techniques discussed above were developed independently by engineers who sought to protect their inventions through patents and generate revenue by providing rapid prototyping technology and services. The very first 3D printing patent was filed in 1984 and issued to Chuck Hull in 1986 for a technique he called stereolithography (Hull, 1986). This prompted Hull to create 3D Systems that same year, which today remains one of the two most prominent players in industrial 3D printing. Scott Crump filed a patent for in 1989 and subsequently created Stratasys, the other main player in the industrial 3D printing market (Crump, 1992). Crump's method would later be known as "Fused Deposition Modeling," a term which he later trademarked through Stratasys (other companies such as Makerbot which leverage the same technique use the term Fused Filament Fabrication instead) (Banwatt, 2013).

While patents are designed to provide incentives for inventors to continue to innovate, patents can also stifle the development of a technology or the quality level of products or services that can be provided to consumers. For example, companies that manufacture 3D printers using FDM or FFF technology can not currently include fully enclosed, heated build chambers as part of their machines because this feature has been patented by Stratasys and is still valid (Swanson, Turley, Leavitt, Karwoski, LaBossiere & Skubic, 1994). Enclosing the build area of a 3D printer is crucial to maximizing the print quality of objects because it maintains the temperature required to prevent materials like plastics, ABS and PLA from distorting.

From the beginning, the 3D printing industry has been characterized by the concentration and control of key patents among several companies. Even though the protection term for patents is finite, individual 3D printing users as well as civil society and consumer advocacy groups have voiced their concerns about how patents could continue to thwart the progress of the technology (EFF, 2013a).

Unauthorized use of a 3D object design created by one individual by others

Every object produced by a 3D printer begins with a Computer Aided Design (CAD) -based digital object design file. The object design file is similar to the architectural blueprints for a building or the sewing pattern for a dress- it is a digital 3D model which the printer uses to build the object using the specifications defined in the design. The design file for an object can be obtained in several different ways: 1) Create an object design file from scratch, using CAD or similar software specifically designed for creating 3D printed object designs; 2) Look through online repositories such as Thingiverse or Pirate Bay which provide free online design files created by others; 3) Scan the object with a laser scanner.

There has been significant debate about whether the IP issues associated with 3D printed objects will be played out in the realm of copyright or patents (Weinberg, 2010; Santoso & Wicker, 2013). This is because the nature of the technology involves the creation of a digital design, which one could argue should be protected by copyright and the production of a physical 3D object, the elements of which could be covered under patent law. It should be made clear that U.S. IP laws have not been revised to specifically address 3D printing.

According to U.S. law, copyright is designed to protect the work of authors who produce original works, which include literary, musical, artistic and architectural works (US Copyright Office,

2012b). In contrast, patents were established to provide the inventor of a process, machine, manufacturable object, composition of matter or improvements to these items the exclusive right to make, use or sell the invention during the protection term period (USPTO, 2012).

The copyright and patent issues associated with 3D printing are numerous and intertwined with one another in ways that could affect the way that individuals and companies alike choose to create and distribute their object designs and printed objects. The IP issues tend to emerge when commercial interests are at stake- when an individual or company attempts to leverage 3D printing to generate revenue, or from the other side, when an entity believes that another actor has unjustly used the technology in a way that undermines their rights and privileges as an intellectual property owner, thereby undercutting the profit that could be garnered.

Two markets have developed for object designs and 3D printed objects. We will call the first one the "open" market, which consists of users creating and uploading object designs to repositories, blogs and other online sites where other individuals can download, use and modify files for free, with the caveat that users abide by the licensing provisions (often secured through Creative Commons) specified by the original creator. Users in this market tend to be motivated to share their creations with others for altruistic reasons or for personal satisfaction, rather than financial gain. We will call the second market the "closed" market, primarily because access to object designs and objects are restricted and moderated by financial transactions. Users who create digital object designs and seek to make money from these works may post their designs to a third party printing service such as Shapeways, where their designs can be produced as physical objects and sold to consumers. The actual object design file for a 3D printed object purchased through Shapeways is not provided to the consumer, enabling the creator to maintain control over his intellectual property (Shapeways, 2013). Another variation of selling involves the outright sale of digital object designs, with sites like 3D Printing Model facilitating these transactions.

Yet "open" and "closed" markets are not mutually exclusive, making questions about intellectual property ownership complicated. Interactions between the two markets take place and create controversy when, for example Ulrich Schwanitz, a designer, successfully created the 3D object design for the Penrose Triangle, a geometric shape known as the 'impossible triangle' (Wolfram Mathworld, 2013; EFF 2013b). Schwanitz was selling 3D printed Penrose Triangles on Shapeways using his object design when Artur Tchoukanov recreated the 3D object design for the Penrose Triangle on his own after seeing Schwanitz's creation and posted it to Thingiverse (EFF, 2013). Schwanitz believed this to be a copyright violation which also undercut potential revenues he could have earned. The tensions between the "open" market and "closed" markets for digital object designs illustrates how various approaches to using 3D printing are struggling to co-exist, particularly as different business models that leverage the technology develop and conflict with the open sharing of designs among users.

Companies who own the rights to characters or franchises have taken legal action to prevent individuals from sharing designs and 3D printing objects which violate trademarks or copyrights. This was the case when Thomas Valenty received a cease and desist order from Games Workshop, which owns the rights to the tabletop game, Warhammer (Thompson, 2012). Valenty had uploaded object design files of several characters from the Warhammer game to Thingiverse.

Less attention has been played to the role of platforms or third party providers which house and/or sell digital object designs and digital objects. It is reasonable to consider that the safe harbor provisions provided to service providers through the DMCA will be extended to platforms which facilitate the distribution of digital object designs. However, one concern that users have expressed is the idea that a platform could claim ownership or leverage digital object designs they have created for commercial purposes. In 2012, Thingiverse members voiced concerns about the platform's terms of service, the wording of which suggested that all content uploaded to Thingiverse became the company's property (Walter, 2012). Josef Prusa, a Thingiverse member and core developer of the RepRap project, launched a campaign called "Occupy Thingiverse" after to protest the company's policy (Benchoff, 2012; Prusa, 2012a). These terms were eventually re-written to clearly articulate that users would retain full ownership of any content uploaded to the site, but the incident made the 3D printing community think twice about where and how to share object designs (Thingiverse, 2012).

DRM initiatives for 3D printing reflect regulation of use by industry

Digital rights management (DRM) approaches are already emerging which seek to manage how individuals can use technology and content. DRM techniques have historically been used to control the way consumers use various types of media, including digital music files, DVDs and e-books. They are largely developed and implemented to prevent IP infringement. They have also been largely criticized by individual consumers and consumer advocacy groups as business strategies that companies use to generate additional sales from individuals by locking them in to using proprietary products or products that are in formats that are not easily interoperable with different systems. The increasing permeation of 3D printing in the consumer market and more general questions about the regulation of the technology could result in the additional development of DRM solutions which could largely dictate the structure of the 3D printing consumer market, including the geographic regions where specific software, hardware or files could be used.

One example of how DRM software is being used to regulate 3D printing activities is the recent development of a program by a Danish company, which can detect when files for gun parts are being used and will prevent a user from printing them (Farivar, 2013; Create it Real, 2013). The software is designed to be used in conjunction with a 3D printer so that when a file is opened, the program will run a scan to determine whether the file resembles those of gun parts. If a match is established, the program will shut down, making it impossible for the user to print the object. The software was created in reaction to Defense Distributed's development of an almost fully 3D printed gun (Hutchinson, 2013).

At least one consumer-oriented 3D printer has been widely criticized for its closed system, which locks consumers into using their products and services. 3D Systems' Cube is billed by the company as one of the most affordable, easy to use 3D printers on the market (3D Systems, 2013). The Cube uses fused filament fabrication, but instead of using standardized rolls of ABS or PLA plastic filament, the machine uses specially designed cartridges which snap into the machine. Replacement cartridges can only be purchased from 3D Systems. The printer also uses a proprietary software called Cubify (CNET, 2012). The company operates an online store where consumers can purchase object design files specifically for Cube printers. While individuals also

have the option of downloading files from other online repositories, the problem is that the Cubify software is overly simplistic and lacks the features necessary to tweak a file that was originally designed for another printer. Thus, purchasing designs from the Cube's online store becomes the best option for producing higher quality objects with ease.

III. Survey: Information Sharing Practices and Intellectual Property Concerns of 3D Printing Users

3D printing users stand at the center of the debates around not only issues of intellectual property and 3D printing, but more general questions around how the technology will be used. Because 3D printing users are known for open collaboration, sharing information and congregating both online and offline to exchange ideas and work on projects centered around the technology, it is important to understand the perspectives of the 3D printing community of users with regards to their information sharing practices, approaches to claiming ownership of their creations and concerns about IP issues. We designed and deployed an online survey for 3D printing users to explore these issues. Because intellectual property can be used as a mechanism for creative destruction, we contend that examining these issues is crucial to considering the role of creative destruction in the development, expansion and advancement of the 3D printing industry, the technology itself and its applications.

There has been very little quantitative research done around the 3D printing community, primarily because this community is relatively new. The first and only publicly available survey on the 3D printing community was conducted by Jarkko Moilanen and Tere Vadén in 2012. This survey sought to explore 3D printing as a form of commons-based peer production, surveying 350 people using 3D printers and people who develop 3D printers and related software (Moilanen & Vadén, 2012). The survey found that individuals are using the technology for a number of different purposes and that many participants identify themselves as being part of the open source and/or maker movement (Moilanen & Vadén, 2012). The average member of the 3D printing/manufacturing community is described as being over 30 years old, male, and has a college degree or at least some college studies (Moilanen & Vadén, 2012).

Survey Design

The online survey was designed to gain insights into what are two seemingly contradictory activities- the practice of information sharing that widely takes place among 3D printing users and the concerns that they have around intellectual property in relation to the technology. The survey consisted of 27 questions, consisting of a combination of scaled, close-ended (yes/no; multiple choice), partial open-ended (multiple-choice w/other option) and open-ended questions. The survey asked users more specifically about how they acquire and use digital object designs. They were also asked about steps that they've taken to claim ownership of their works using Creative Commons. Finally, users were requested to reflect on their concerns around various types of IP issues related to 3D printing.

Because 3D printing users are still a relatively niche group of individuals, a snowball sampling technique was used in the distribution of this survey. Snowball sampling was chosen because it is a more purposeful approach to sampling than other non-random sampling techniques (USGS, 2013). This approach also enabled us to gradually develop a well-rounded sample of different

types of 3D printing users, including those who use the technology as hobbyists, those who leverage 3D printing for their own non-3D printing related businesses and individuals that work for companies in the 3D printing industry.

The survey was initially sent to 3D printing users through listservs for makerspaces, Fablabs, hackerspaces, 3D printing meetup groups and online forums. An additional round of survey distribution involved reaching out to individual 3D printing users through blogs, digital object design repositories and 3D printing community/group leaders. We received a total of 59 survey responses. The process of soliciting survey responses from 3D printing users proved to be more challenging than initially envisioned, but we believe that despite the smaller sample, our survey responses offers empirical evidence that intellectual property is being used to both propel and restrain creative destruction.

IV. Survey Findings and Analysis

3D printing takes place in local, collaborative environments

The current niche market for desktop 3D printing has been built from, and will continue to be built from, community collaboration and activities. Our survey data confirms this by showing that about 23% of 3D printing users print at makerspaces/DIY spaces/hackerspaces/Fab labs. These spaces are shared workspaces built for collaboration and to combine resources. Our survey also revealed that about 43% of 3D printing users print from home. Thus, roughly 66% of 3D printing users have access to 3D printing right in their own neighborhood or in their own homes. This finding is salient because it suggests that the technology is increasingly accessible and geographically localized.

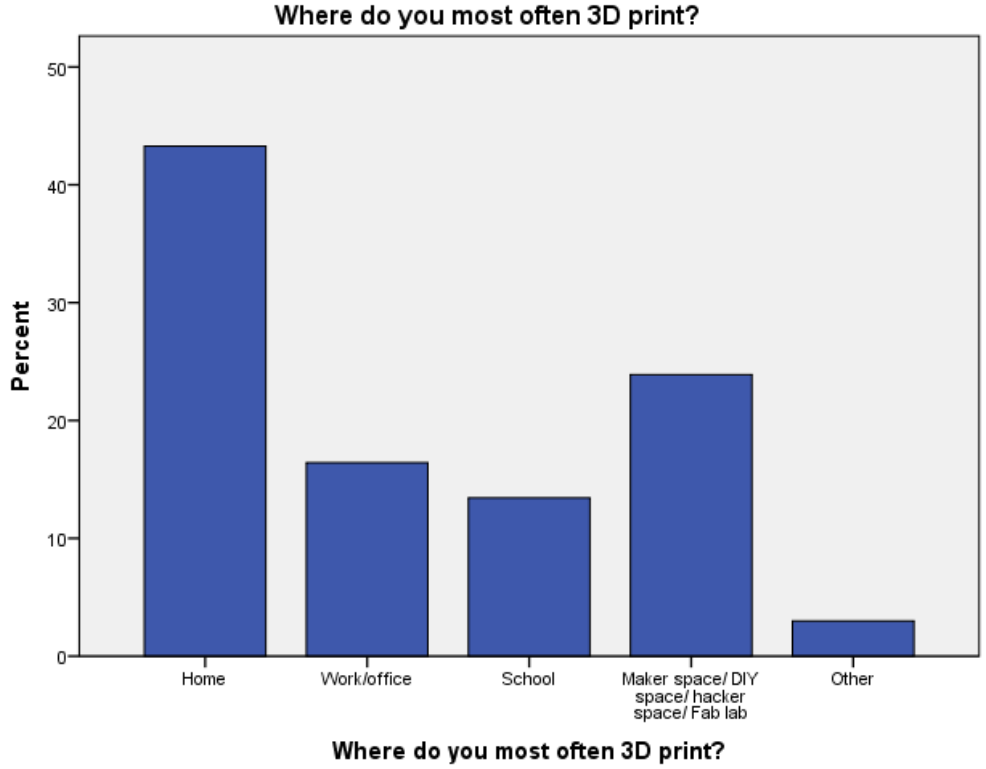

Figure 1: Where do users 3D Print

This growing number of shared workspaces also exemplifies users' motivation to play, tinker, and develop 3D printing technology independently, in a non-corporate environment. Yet companies in the 3D printing industry are recognizing that makerspaces, Fablabs and hackerspaces are hubs of innovation where interesting applications of the technology and improvements to the technology are taking place. To support these activities and have access to these ideas, 3D printing services, online repositories and 3D printing manufacturers have developed programs which offer collaborative work environments instructional support for 3D printing projects, as well as opportunities to use their products at a discount or even for free.

Instructables, the DIY project-sharing platform owned by Autodesk (the creators of 3D design software) sponsors "Build Nights" at makerspaces and hackerspaces across the country. Each month Instructables chooses a specific DIY material, process or technology to focus on and provides these spaces with free materials to conduct these events. Several of the authors attended a recent Build Night at the Ithaca Generator, a makerspace in upstate New York. 3D printing was the technology featured on that evening and Instructables provided a $150 gift certificate to the Generator for the 3D printing service, Shapeways (Ithaca Generator, 2013). For companies like these, such initiatives simultaneously serve as both a marketing approach and an opportunity for these businesses to build relationships with these spaces, perhaps for future collaboration.

Sharing object designs is widespread, but conditional

The practice of sharing information between 3D printing users can be examined by taking a closer look at one particular type of activity- the flows of digital object design files throughout the 3D printing community. According to our survey, those users who share objects are most likely to upload those objects to a printer-neutral platform such as Thingiverse or email files to individual people, 43% and 28% respectively. The rest of those who share digital object designs use commercial 3D printing platforms such as Shapeways or upload objects to a personal website. Users not only distribute their own digital creations using online repositories, but also obtain a significant amount of designs from those repositories. Specifically, our survey found that majority of users obtain existing object designs from the online repository, Thingiverse. The users who obtain existing object designs are also likely to modify those existing designs and share those modified designs. As a result, a non-linear cycle of creating, sharing, modifying and obtaining design files is prevalent.

With the growing distribution of object designs and the cycle of sharing this distribution creates, the process of mediating ownership through licensing becomes more relevant. According to the survey, 61% of users surveyed always use Creative Commons when sharing their object design files. Another 13% of individuals surveyed also use Creative Commons for some, but not all of their files. Thus, roughly 74% of 3D printing users are using Creative Commons to some extent. This finding is salient in that it illustrates that intellectual property does not always suppress sharing, but in some cases, facilitates sharing.

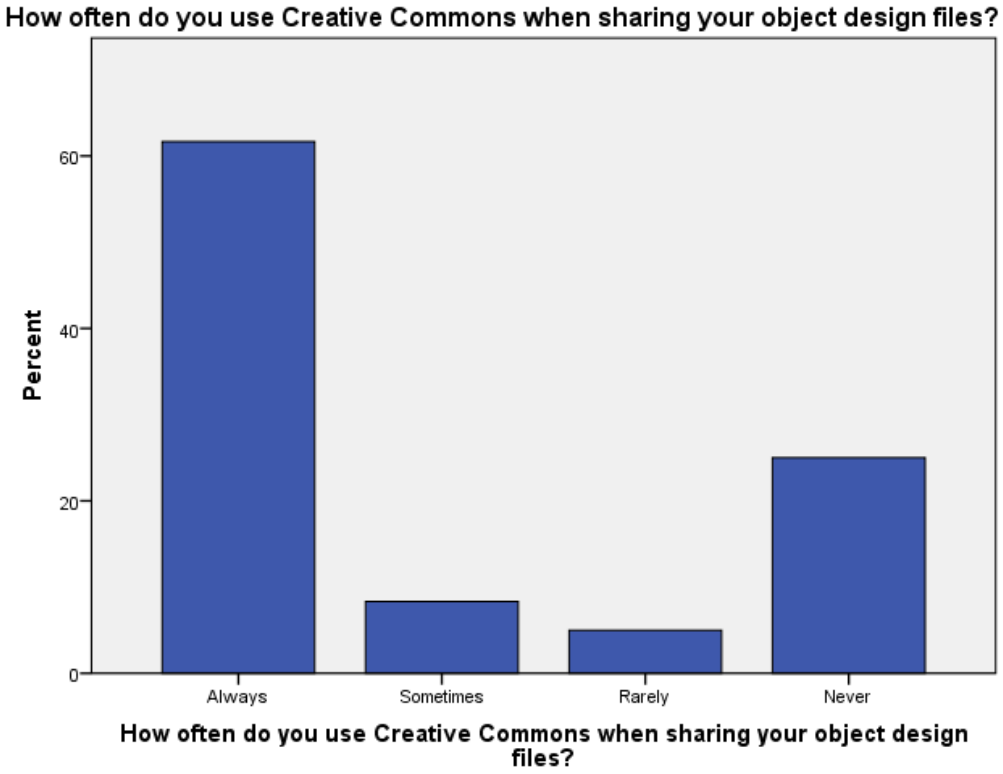

Figure 2: Creative Commons

Our survey data also found that 28% of those who use Creative Commons use the Attribution Creative Commons license and 30% of those who use Creative Commons use the Attribution-Noncommercial-ShareAlike license. Attribution allows work to be used and remixed for both commercial and non-commercial uses as long as credit is given to the creator, while Attribution-Noncommerical-ShareAlike lets others remix and build upon your work non-commercially, as long as credit is given to the creator and the license of the new creations must be under the identical terms as the original (Creative Commons, 2013).

3D printing IP concerns and how these concerns are mitigated

As the cycle of sharing and obtaining design files is cultivated, intellectual property concerns transpire. How do the current sharing practices affect intellectual property policies? And how will those policies look in the future? Do intellectual property concerns stifle sharing? Or merely invoke sharing? As discussed previously, of those users who are aware of intellectual property issues, 61% always use Creative Commons when sharing files. This statistic brings evidence that despite policy concerns, users are sharing openly, but conditionally. In the face of the great number of users uploading to printer neutral platforms, 54% of those surveyed listed online repositories later claiming ownership over 3D object designs as one of the top three intellectual property issues with which they were concerned. This majority percentage demonstrates, once again, that regardless of the concerns when uploading objects to sites like Thingiverse, users want to share their designs with the peer-to-peer community at large. The push for sharing is also a push for technology advancement and flexibility, hence, creative destruction.

Of all 3D printing users surveyed, the vast majority stated that they are aware of intellectual property issues involving the technology. The survey data illustrates that over 39% of users surveyed are primarily concerned about ownership of key patents limiting the development of the 3D printing technology. This concern that commercial enterprises could continue to exert over the technology is a major concern. Fascinatingly, users who are concerned with patent issues limiting the technology are not likely to be concerned with the lack of patent and copyright protection for 3D printed objects. Figure 3 illustrates this data.

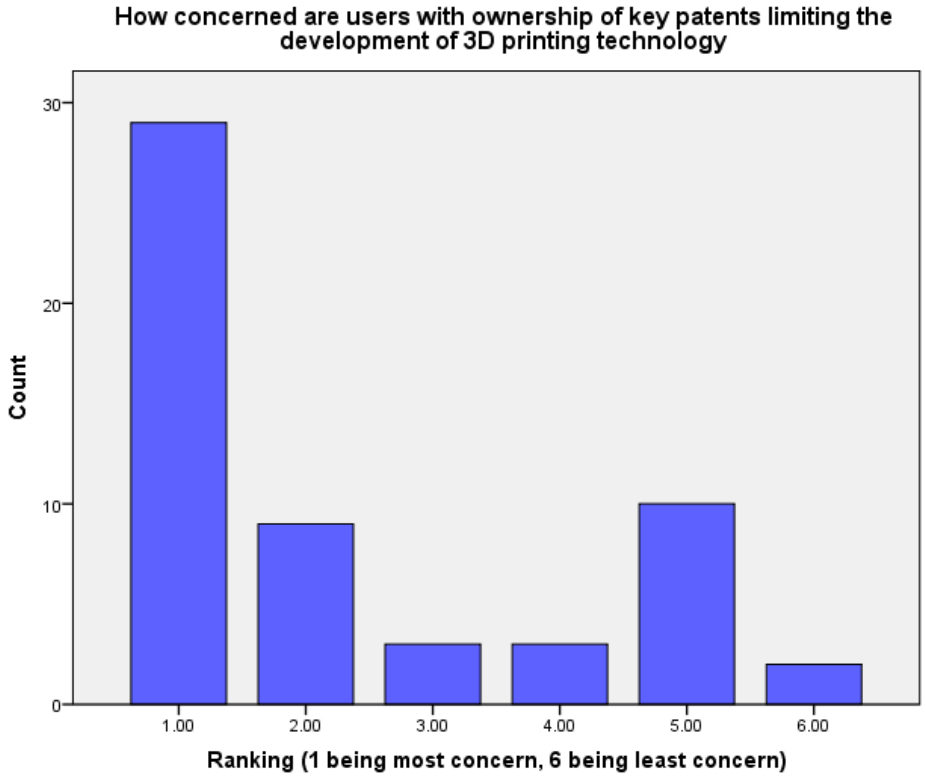

Figure 3: User Concern with ownership of patents

Thus, the consumer market's intellectual property concerns, in a sense, are split between the objects created by the technology and the technology itself. Consequently, thought provoking questions emerge about the future of intellectual property laws for 3D printing. Could this mean that regulatory regimes for these two types of IP concerns will be different? Is it possible that one of these intellectual property concerns could stop creative destruction before the other? The answers to these questions are not clear. However, both key players in the industry and policy makers will need to understand the consumer market of 3D printing in depth in order to develop practices and policies which do not stifle creative and innovative potential of the technology and the community of users moving forward.

V. Research Implications

The findings from the survey we conducted provide some salient insights which should be taken into account in the future design and development of the technology and the development of policies governing the use of 3D printing:

3D printing users are already exhibiting a heightened level of awareness of and concern about the intellectual property issues associated with the technology. Recent cases suggest that users will continue to find ways to actively participate in the conversations and debates around the way in which the technology can be used and the perceived and/or actual limitations to use that are due to IP. 3D printing manufacturers, software designers and other companies in the 3D printing industry will need to play close attention to these conversations. The 3D printing user community is rooted in an open source mentality. Product or service providers which do not align with this sensibility could face criticism and lack of support from a substantial portion of 3D printing consumers.

It should be noted that there are two distinct conversations taking place about IP when it comes to 3D printing: 1) Debates around the IP of the technology itself; 2) Dialogue around the IP of the digital object designs and the printed objects. Certain users appear to be significantly more concerned with one of these two types of IP issues over another. With regards to creative destruction, the IP issues affecting the technology, more specifically the utility and design patents and what the companies that own them choose to do with them are a determining factor in whether the technology will experience a long lasting period of innovation or whether a rerun of stifled/stunted technological development is in the cards.

Finally, the terms “sharing,” “open source,” and “openness” have widely been used to describe the 3D printing community. We now know that these terms are relative and context specific. The sharing of information, such as digital object design files and the openness of such an activity does not always happen unconditionally, but rather in degrees and on a sliding scale. 3D printing users have adeptly leveraged Creative Commons licensing to maintain various degrees of ownership over the things that they create. As a whole, 3D printing users are willing to contribute to a knowledge commons which grows and strengthens not only their community, but provides the industry which creates products and services for them with a wealth of information and resources.

VI. Conclusion

Creative destruction has not taken place in the 3D printing industry, but creative erosion, which is a movement towards creative destruction is in full swing. It is not that 3D printing as a technology is moving towards destruction or obsolescence, but rather, the concentrations of power that have controlled the technology through intellectual property that are eroding. There are many examples of the different ways that key industry players have successfully sought to combat this process. Some companies are leveraging digital rights management mechanisms to lock consumers into a long term relationship to decrease the chances that these individuals will make purchases from another competitor.

Perhaps the most recent high profile move from a long standing 3D printing enterprise to fend off creative erosion was Stratasys’ acquisition of Makerbot in June 2013 for $406 million in stock. Makerbot had cornered the consumer 3D printing market in a manner that Stratasys was not able to do despite several previous attempts (Alden, 2013). Makerbot’s successful capitalization upon the expired patents that were previously owned by Stratasys made it an

attractive purchase for the veteran 3D printing company. Makerbot's contribution to the process of creative erosion was more clearly defined during the earlier stages of the company. Back then, Makerbot was a scrappy start-up which abided by an open source philosophy. As the company grew in size and expanded its market share, other start ups positioned themselves as viable competitors. Maintaining tighter control over its intellectual property became part of Makerbot's business model. Its absorption into an Stratasys raises questions about whether this will further perpetuate this process of closure, effectively removing what was a dynamic source of creative erosion from the industry.

While there are many unknowns with regards to the development, use and regulation of 3D printing moving forward, what we can confidently assert is that the peer-to-peer sharing of information, open source movement and collaboration which takes place online and in shared work spaces provides a counterbalance to the forces which seek to control the technology in ways that would make it less accessible, transparent and flexible. Without these initiatives, the likelihood of creative destruction decreases and thus the innovation required to propel the technology forward. In his essay on Innovation and Creative Destruction, economist William Baumol notes that markets and government engage in a dialectic relationship in facilitating technological innovation (2002). The negotiations, debate and dialogue that compose this relationship will weigh heavily on the development on 3D printing.

References

3D Systems (2013). Cube 3D Printer. Available from: http://cubify.com/info/faq/faq_3dprinter.aspx

Additive Manufacturing (2013). AM Basics. Available from: http://additivemanufacturing.com/basics/

Alden, W. (2013, June 19). Larger Rival to Acquire 3-D Printing Start-Up MakerBot. New York Times. Available: http://dealbook.nytimes.com/2013/06/19/larger-rival-to-acquire-3-d-printing-start-up-makerbot/?_r=1

Banwatt, P. (2013, March 7). 3D Printing Law: Trademarks- Why "FDM" isn't for everybody [Blog Post]. Available from: http://lawitm.com/3d-printing-law-trademarks-why-fdm-isnt-for-everybody/

Baumol, W.J. (2002). Creative Destruction and Innovation. In McKnight, L., Vaaler, P.M. & Katz, R.L. (Eds.), Creative Destruction: Business Survival Strategies in the Global Internet Economy. Cambridge: MIT Press.

Benchoff, B. (2012). Makerbot, Occupy Thingiverse, and the reality of selling Open Hardware [Blog Post]. Available from: http://hackaday.com/2012/09/20/makerbot-occupy-thingiverse-and-the-reality-of-selling-open-hardware/

Bowyer A. (2009) RepRap [Video]. Available at: http://vimeo.com/5202148#

CNET (2013). Locked-down, underfeatured Cube underwhelms. CNET. Available from: http://reviews.cnet.com/3d-printers/3d-systems-cube/4505-33809_7-35473913-2.html

Create it Real (2013). Gun printing: new software prevents 3D printing of guns [Press Release]. Available from: http://createitreal.com/download/English%20Press%20Release%20%231.pdf

Creative Commons (2013). Licenses. Available from: http://creativecommons.org/licenses/

Crump, S. (1992). U.S. Patent No. 5121329. Washington, DC: U.S. Patent and Trademark Office.

Donahue, B. (2010, May 1). Semper Youngstown. Inc. Available from: http://www.inc.com/magazine/20100501/semper-youngstown_pagen_2.html

EFF (2013a). EFF's Fight for Open 3D Printing Continues at Ask Patents. Available from: https://www.eff.org/deeplinks/2013/03/effs-fight-open-3d-printing-continues-askpatentscom

EFF (2013b). Ulrich Schwanitz - Penrose Triangle - 3D Design Takedown. Available from: https://www.eff.org/takedowns/ulrich-schwanitz-penrose-triangle-3d-design-takedown

Espinel, V. (2013) Joint Strategic Plan on Intellectual Property Enforcement. Available from: http://www.whitehouse.gov/sites/default/files/omb/IPEC/2013-us-ipec-joint-strategic-plan.pdf

Farivar, C. (2013, June 26). Worried about accidentally 3D printing a gun? New software will prevent it. Ars Technica. Available from: http://arstechnica.com/business/2013/06/worried-about-accidentally-3d-printing-a-gun-new-software-will-prevent-it/

Hull, C. (1986). U.S. Patent No. 4575330. Washington, DC: U.S. Patent and Trademark Office.

Ithaca Generator (2013). Instructables Build Nights. [Blog Post]. Available from: http://ithacagenerator.org/instructables-build-nights/

Mack, E. (2013, February 12). Here's the 3D-printing institute in Obama's State of the Union. Available from: http://news.cnet.com/8301-17938_105-57569093-1/heres-the-3d-printing-institute-in-obamas-state-of-the-union/

MakerBot (2012). TV MakerBot TV S02E01 - History of MakerBot. [Online Web Series]. Available at: http://makerbot.tv/eBJ5/makerbot-tv-s02e01-history-of-makerbot/

Moilanen, J., Vadén, T. (2012). Manufacturing in motion: first survey on 3D printing community. Statistical Studies of Peer Production. Available from: http://surveys.peerproduction.net/2012/05/manufacturing-in-motion/

NAMII- National Additive Manufacturing Innovation Institute (2013). Available from: http://namii.org/

Prusa, J. (2012a). Occupy Thingiverse. Available from: http://www.thingiverse.com/thing:30808

Prusa, J. (2012b). Open Hardware Meaning. [Blog Post]. Available from: http://josefprusa.cz/open-hardware-meaning/

Santoso, S., Wicker, S. (2013). Exploring the Unchartered Territory of Innovation and Intellectual Property in 3D Printing.

Shapeways (2013). Make + Sell. Available at: http://www.shapeways.com/create?li=nav

Swanson, J., Turley, P., Leavitt, P., Karwoski, P., LaBossiere, J.,Skubic, R. (1994) U.S. Patent No. 6722872 B1. Washington, DC: U.S. Patent and Trademark Office.

Thingiverse (2012, February 10). Thingiverse Terms of Use. Available from: http://www.thingiverse.com/legal

Thompson C (2012) Clive Thompson on 3-D Printing's Legal Morass. Wired, 30 May. Available at: http://www.wired.com/design/2012/05/3-d-printing-patent-law/

US Copyright Office (2012a) How Long Does Copyright Protection Last? Available at: http://www.copyright.gov/help/faq/faq-duration.html

US Copyright Office (2012b) Copyright Basics. Available at: http://www.copyright.gov/circs/circ01.pdf.

USGS (2012). Snowball sampling. Fort Collins Science Center. Available from: http://www.fort.usgs.gov/landsatsurvey/SnowballSampling.asp

USPTO (2012) What is a Patent? Available at: http://www.uspto.gov/patents/index.jsp

Weinberg M. (2010) It Will Be Awesome If They Don't Screw This Up: 3D Printing, Intellectual Property, and the Fight Over the Next Great Disruptive Technology. Public Knowledge. Available at: http://publicknowledge.org/it-will-be-awesome-if-they-dont-screw-it-up (accessed 16 May 2012).

Walter (2012). The MakerBot/Thingiverse move to the Dark Side [Blog Post]. Available from: http://blog.hackerspaces.org/2012/09/23/the-makerbotthingiverse-move-to-the-dark-side/

The White House (2013, February 12). President Barack Obama's State of the Union Address -- As Prepared for Delivery. Office of the Press Secretary. Available from: http://www.whitehouse.gov/the-press-office/2013/02/12/president-barack-obamas-state-union-address

The White House (2013, May 9). Obama Administration Launches Competition for Three New Manufacturing Innovation Institutes. Office of the Press Secretary. Available from:

http://www.whitehouse.gov/the-press-office/2013/05/09/obama-administration-launches-competition-three-new-manufacturing-innova

Wolfram Mathworld (2013) Penrose Triangle. Available at: http://mathworld.wolfram.com/PenroseTriangle.html