Cultures of sharing in 3D printing: what can we learn from the licence choices of Thingiverse users?

1. Introduction

A growing literature in economics and social science has explored the practices of information exchange among online communities. A strong theme within this literature is that open cultures – characterised by reciprocal sharing, weak IP, and open flows of information among practitioners – are conducive to technological innovation. In Benkler's influential analysis, the end result is "a flourishing nonmarket sector of information, knowledge, and cultural production… subject to an increasingly robust ethic of open sharing, open for all others to build on, extend, and make their own" (2006, p.7). This phenomenon has been the focus of much recent research on collaborative production models, covering a range of topics including wikis, open-access publishing, free software and open science (e.g. Nielson 2011, Suber 2012, Anderson 2012, Hatch 2013, Phelps 2013).

One lesson from this literature is that sharing practices are context-dependent. Sharing is a social practice shaped by a range of variables, and sharing practices differ from community to community and from technology to technology (Kennedy 2013). Infrastructural issues, cultural factors and legal frameworks, both explicit and implicit, play a role in shaping the context in which collaboration occurs. It is therefore necessary to understand the norms, values, structures and systems that emerge around particular forms of practice. Scholars in various disciplines have taken up this challenge by documenting the specific (rather than universal) aspects of sharing practice, such as the regulatory frameworks that govern conduct and the variable properties of technological platforms (e.g. Berdou 2011, Currie, Kelty & Murillo 2013, Schweik & English 2012, Suzor 2012).

This article contributes to the discussion by analysing how users of the leading online 3D printing design repository Thingiverse manage their intellectual property (IP). 3D printing represents a fruitful case study for exploring the relationship between IP norms and practitioner culture. Although additive manufacturing technology has existed for decades, 3D printing is on the cusp of a breakout into the technological mainstream – hardware prices are falling; designs are circulating widely; consumer-friendly platforms are multiplying; and technological literacy is rising. Analysing metadata from more than 68,000 Thingiverse design files collected from the site, we examine the licensing choices made by users and explore the way this shapes the sharing practices of the site's users. We also consider how these choices and practices connect with wider attitudes towards sharing and intellectual property in 3D printing communities. A particular focus of the article is how Thingiverse structures its regulatory framework to avoid IP liability, and the extent to which this may have a bearing on users' conduct.

The paper has four sections. First, we will offer a description of Thingiverse and how it operates in the 3D printing ecosystem, noting the legal issues that have arisen regarding Thingiverse's Terms of Use and its allocation of intellectual property rights. Different types of Thingiverse licences will be detailed and explained. Second, the empirical metadata we have collected from Thingiverse will be presented, including the methods used to obtain this information. Third, we will present findings from this data on licence choice and the public availability of user designs. Fourth, we will look at the implications of these findings and our conclusions regarding the particular kind of sharing ethic that is present in Thingiverse; we also consider the "closed" aspects of this community and what this means for current debates about "open" innovation.

2. Thingiverse, design repositories, and intellectual property disputes

Additive manufacturing technology, more recently known as 3D printing, has been around for almost three decades, with widespread use in aerospace, medical, manufacturing and defence industries. Within the last few years the technology has crossed over into consumer space, with household-oriented printers capable of

coming onto the market at ever-lower prices. There is a continuing boom in public interest, resulting in significant commercial investment, venture capital speculation, and consolidation of what was previously a fragmented sector. It has also created a tsunami of hype, with magazines such as *The Economist* (*A third industrial revolution* 2012) heralding the arrival of a "third industrial revolution".

The story of 3D printing has been told many times, and we do not wish to repeat it here. Our focus is on one small, yet crucial, part of the ecosystem: the online design repositories that allow 3D printing enthusiasts, both professionals and non-professionals, to exchange design files. These repositories play a crucial role in linking experts with DIY enthusiasts who may not have the necessary skills in design to create complex Computer Aided Design (CAD) files. Parallel to the rise in 3D printing technology is the increasing numbers of distinct, online repositories, some of which are listed in Table 1.

Table 1: 3D printing design repositories

Thingiverse **(http://www.thingiverse.com/)**	The most popular 3D printing repository. Designs are free to upload and download. Has received the most media attention for Digital Millennium Copyright Act (DMCA) take-down notices.
Shapeways **(http://www.shapeways.com/)**	A leading commercial site that combines repository and print-on-demand functions. Users can create online shopfronts offering made-to-order products, printed by Shapeways that can be delivered to customers in finished form.
Cuboyo **(http://www.cuboyo.com/)**	A commercial site offering paid downloads of user-generated 3D objects. Cuboyo takes a 30% cut of the sale price.
MyMiniFactory.com **(http://www.myminifactory.com/)**	A mix of free and paid design downloads. The site is connected with iMakr, which opened a physical store in London in May 2013.

Repables **(http://www.repables.com/)**	Free, open-access repository founded by Gerrit Coetzee. Aims to be a non-commercial alternative to proprietary repositories like Thingiverse.
Fabster **(http://www.fabster.com/)**	A showcase for 3D printing designs, based on a popular Facebook page. Does not offer downloads.
Yeggi **(http://www.yeggi.com)**	A meta-'library' or aggregator where makers can search for designs across a number of the other depositories listed above.

Thingiverse is the largest and most important of the repositories. The site's history can be traced back to the RepRap project. Founded in 2007 by Dr Adrian Bowyer (a Senior Lecturer in mechanical engineering at the University of Bath), RepRap was an initiative to develop a 3D printer that could re-print most of its own components. The RepRap project releases all of the designs it produces under the GNU General Public licence, in line with free software principles. Designers are free to modify RepRap designs so long as they shared their creations back with the RepRap community.

However, three of the organisers of the NYC Resistor Hackerspace in Brooklyn, NYC (Bre Pettis, Zach Smith and Adam Mayer) had other ideas. They "threw out the self-replication requirement" of RepRap (Courtland 2013), and focused their energies on developing a consumer-friendly printer. Their company, MakerBot Industries, was founded in January 2009, and had sold several thousand printers by 2011. In 2012 it attracted US$10 million in venture capital funding. In 2013 the company was bought, with much fanfare, by the 3D printing giant Stratsys – along with 3D Systems, one of the 'big two' 3D printing corporations – which paid $400 million in stock: the MakerBot crew were now millionaires.

Thingiverse plays the role of the design hub within MakerBot's 3D printing ecosystem. Users can post and collaborate on design files for 3D printable 'Things', and find new and interesting uses for their MakerBot printers. Thingiverse has

become the leading repository of user-submitted CAD files, and the world's largest online 3D printing community. At the time of writing, there are over 100,000 Things listed on the site (Howard 2013).

Sharing is central to the commercial and ethical norms of Thingiverse. To quote Bre Pettis: "[i]f you're not sharing your designs, you're doing it wrong" (*More Than Just Digital Quilting* 2011). The community feel is further espoused on the website: "We're hoping that together we can create a community of people who create and share designs freely, so that all can benefit from them" (MakerBot a). This sharing ethic has been institutionalised across the site, which models itself on other Web 2.0 user-generated content sites. Designs are "encouraged to be licensed under a Creative Commons license" (MakerBot b).

In the next section we examine three recent controversies concerning Thingiverse and IP regulation, before considering in more detail the licence options available to Thingiverse users.

Controversy 1: Occupy Thingiverse

The Occupy Thingiverse incident has its origins in Thingiverse's 2012 decision to alter its Terms of Use to include the following:

> You hereby grant, and you represent and warrant that you have the right to grant, to Company and its affiliates and partners, an irrevocable, nonexclusive, royalty-free and fully paid, worldwide license to reproduce, distribute, publicly display and perform, prepare derivative works of, incorporate into other works, and otherwise use your User Content, and to grant sublicenses of the foregoing, solely for the purposes of including your User Content in the Site and Services. You agree to irrevocably waive (and cause to be waived) any claims and assertions of moral rights or attribution with respect to your User Content. (MakerBot c)

This marked a significant departure from the previous Terms of Use, which had a more narrow scope, were revocable in nature, and concerned Thingiverse's rights to use the content across its platforms:

> However, by posting, uploading, inputting, providing or submitting your content to Thingiverse.com, you are granting Thingiverse.com, its affiliated companies and partners, a worldwide, revocable, royalty-free, non-exclusive, sub-licensable license to use, reproduce, create derivative works of, distribute, publicly perform, publicly display, transfer, transmit, distribute and publish that content for the purposes of displaying that content on Thingiverse.com and on other Web sites, devices and/or platforms. (Walter 2012)

One major difference in the wording is that the previous Terms had a more narrow scope than their replacement, and seemed to restrict the use of user designs to similar platforms to Thingiverse. The consequence of this appears to have been that MakerBot was limited in its ability to incorporate designs uploaded to Thingiverse into 'closed' hardware products, such as their 3D printers. The change in language, however, seemed to allow Thingiverse to assert moral rights over any design uploaded to the platform, as well as enabling it to use those designs for its own commercial purposes (Santoso, Horne & Wicker, p.7). One of Thingiverse's lawyers defended the moral rights waiver, stating that these rights were not part of American copyright law and that the purpose of the waiver was to 'lend certainty' to the licences upon which MakerBot relies to operate Thingiverse – to prevent, for instance, users claiming that their moral rights against the 'mutilation' of a work had been infringed (McCarthy 2012). Interestingly, Thingiverse's actions were also framed within a discourse of sharing: they suggested the assertion of moral rights by the original users would be 'fundamentally inconsistent with the intention of Thingiverse, which is to share things and their derivatives'. Reference was also made to the fact that these updated ToU were "structured similarly to any large website that hosts user-content".

Yet Thingiverse's assertion that moral rights were not part of US copyright law was inaccurate – some operation of moral rights had been recognised in case-law, and then statutorily in the Visual Artists Rights Act 1990 (Rosenblatt 1998), which was enacted to implement some moral rights provisions of the Berne Convention that was eventually signed by the US in 1989. However the bigger issue was the widespread disquiet within Thingiverse's maker community, many of whom took to the Internet to argue that Thingiverse was no longer 'open', and that the new Terms betrayed the community ethos. This user backlash came to be known as Occupy Thingiverse. The movement was initiated by Josef Prusa (2012a), a former employee of MakerBot, who wrote an open letter to Bre Pettis which drew attention from other Thingiverse users (Prusa 2012b). The Occupy Thingiverse meme quickly gained traction, and many users chose to remove their designs from the Thingiverse site so that they might retain more control over them. Following Prusa's suggestion, many of these users reposted their designs at GitHub, a popular data repository for open-source projects, and at various other sites (Molitch-Hou 2013). Forums were created to discuss alternatives (RepRap 2013).

It is worth noting that Thingiverse's Terms of Use take precedence over any of the more "open" licence choices that users make on the site. While Thingiverse still gives users a choice of licence (a point we will discuss in more detail shortly), this is a 'secondary' licence on top of the 'primary' licence over uploaded content that this language in the Terms of Use grants to Thingiverse. The licence with Thingiverse is a standard form, non-negotiable contract – users must sign up to Thingiverse and accept these terms, or not have a Thingiverse account at all. The offending language which led to the Occupy Thingiverse movement is still present in Thingiverse's Terms of Use at the time of writing.

Controversy 2: The Replicator 2

A further controversy to plague Makerbot relates to the Replicator 2 printer, the infamous "fork" of the original open-source RepRap project, which MakerBot released in September 2012. Although it incorporated a number of new features, the

printer was not received positively by the open 3D printing community. Unlike previous MakerBot printers the Replicator 2 was 'closed' and did not follow the principles of open hardware. – i.e. that the 'design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design' (OSHWA). The open hardware movement can be conceptualised as an extension of the free/libre/open source software ideology to physical technological artefacts, designed and disseminated in an "open fashion". The difference with the Replicator 2 was that MakerBot did not publish details of how the printer was designed. To make things worse, MakerBot released new 3D printing software to accompany the new printer which also did not comply with open source principles.

On the MakerBot blog, Bre Pettis defended his actions:

> For the Replicator 2, we will not share the way the physical machine is designed or our GUI because we don't think carbon-copy cloning is acceptable and carbon-copy clones undermine our ability to pay people to do development. (Pettis 2012)

Among the many reasons cited, Pettis focused on the idea that "running a business is complicated" and required MakerBot keeping control of the core technology. It seemed that the Replicator 2 was aimed at a different demographic than those tinkerers involved with the open hardware movement, i.e. people "who want to make gorgeous models instead of hack the machine". Furthermore, it also came to light that MakerBot had filed for, and been granted, a patent in the US relating to 3D printing building processes (Patent Genius). Unsurprisingly, MakerBot's actions caused a great deal of controversy within the 3D printing community. The decision to become closed source was again criticised by Prusa (2012b), as well as Zach Smith, another founder of MakerBot who subsequently left the company. Smith (2012) refers to this departure from open to closed source as the "ultimate betrayal", underscoring the bitter disputes about intellectual property and sharing norms that have been part and parcel of the 3D printing boom.

Controversy 3: DMCA take-down notices

A third IP-related controversy concerns the issuing of Digital Millennium Copyright Act (DMCA) take-down notices to Thingiverse users. The DMCA is a US statute which was intended to update American copyright law for the 'digital economy' of the 21st century, and implement two 1996 World Intellectual Property Organization treaties. One of its features is the 'safe harbor' given to Internet intermediaries including online content platforms and Internet service providers against liability for copyright infringement by their users, providing they fulfil certain requirements. These include the prompt blocking/removal of material to which these intermediaries provide access once they receive a takedown notice, i.e. notification of an infringement claim from the copyright holder or their agent. Thingiverse, as an online content platform, has not been immune from these takedown notices.

In early 2011 a Thingiverse design incorporating the famous Penrose Triangle (Wong 2011) – an illusionistic "impossible object" that is popular with 3D printing enthusiasts – received what is thought to be the first takedown notice, allegedly for reproducing another Penrose Triangle design for 3D printing that had been uploaded to rival repository Shapeways. It is unclear whether the former design infringed the copyright in the latter: the designer who alleged copyright infringement was not the original creator of the Penrose Triangle, Oscar Reutersvald, nor is the process of converting the Penrose Triangle image to a 3D printing file a clear infringement of any copyright that might subsist in the initial idea. Furthermore, it was not clear what the copyright assertion was in: the structure itself, the design file, or the image of the Penrose Triangle. Both the design file itself and the physical object that it produces may be protected by copyright, but the independent creation of an object using a different file, which was the case here, is probably not a copyright infringement, since copyright protects the expression of an idea, rather than the idea itself.

The legal status of puzzle-like 3D objects such as the Penrose Triangle, which are based on ideas, is rather complex. There is some intellectual property protection of physical objects – US copyright law applies to 'pictorial, graphic and sculptural works', including 'technical drawings, diagrams and models' – but 'useful articles' are excluded from copyright protection (though they could be patentable, possibly via a design patent). The original 3D Penrose Triangle design, which is unlikely to be considered a useful object, was based on the 2D design from the 1930s, which is

now in the public domain. Later 3D designs can also be conceptualised as independent interpretations of the public domain 2D original, rather than copies of the first 3D design, and so are probably not infringements, assuming copyright actually subsists in the original 3D design in the first place (Rideout 2011, pp. 160-170). In the end, Thingiverse complied with the takedown request by removing the controversial design, 'but eventually public outcry convinced Schwanitz to dedicate his design to the public domain and retract the takedown request' (Weinberg 2013, p.6).

Later in 2011, the Penrose Triangle incident was followed by a more high profile takedown notice issued by Games Workshop (the owner of Warhammer) concerning a Warhammer-style figurine designed by a Thingiverse user (Thompson 2012). Thingiverse complied with the notice and removed the designs for the figurines. Again, it is unclear whether these files actually infringed copyright since the figurines seemed to be a kind of 'fan art' inspired by Warhammer, rather than a direct copy of official Warhammer figures. Indeed, the figurines 'may well have been better characterized as non-infringing original works inspired by Warhammer pieces than as infringing copies or derivative works of Warhammer pieces' (Brean 2013, p.37). The designer's 'main mistake' may have been to associate his designs with Warhammer, thus drawing attention from Games Workshop, yet in terms of legal liability at most this may be a trademark or trade dress infringement - which are not covered by DMCA takedown notices (Andersen & Howells 2014, p.32).

A third takedown notice controversy concerning 3D printing objects occurred in January 2013, when a Tintin rocket design was also allegedly taken down from Thingiverse via a DMCA notice (Kahler 2013). Here, the design was based on drawings by Tintin creator Herge in two published works, *Destination Moon* and *Explorers on the Moon*, which would still be under copyright protection according to the 'life plus 70' terms contained in the DMCA, as Herge died in 1983. Their reproduction in the form of this design would be the strongest candidate of the examples listed here to be an actual copyright infringement, as well as possibly being another case of trade dress infringement due to wrongful association with the original creator.

Yet, regardless of whether there have actually been copyright infringements in practice, the DMCA takedown mechanism is appealing to those who wish to prevent the further dissemination of designs such as those detailed above. This is due to the effectiveness of these notices in actually causing the controversial files to be taken offline promptly by intermediaries such as Thingiverse, lest they lose their 'safe harbor' against potential secondary liability for copyright infringement (Brean 2013). There is no equivalent to this process for other intellectual property rights, such as patents and trademarks, which thus provides an incentive for claims to be framed in copyright terms even if in practice copyright may not even subsist in the relevant file or object. In other words, rightsholders are increasingly turning to the takedown notice model – which can be easily scaled, automated and outsourced to third parties as well – as a key weapon in their in their IP protection arsenal, even when the legal foundations for such notices is questionable. As Seng (2014, p.3) notes, the takedown process is currently "the mainstay of content providers for managing online infringement because it is fast, cheap and efficient", partly due to it "bypass[ing] judicial oversight over copyright disputes". The end result is a "chilling effect" whereby even material that may not infringe copyright is still taken offline on receipt of such a takedown notice.

The use of, and reaction to, DMCA takedown notices also evidences the *de facto* application of US law over Thingiverse and its users. While the site's Terms of Use assert that it operates under New York State law, Thingiverse users are not all geographically based in that jurisdiction – yet US law prevails when it comes to takedown and removal disputes. Furthermore, Thingiverse's approach to the question of moral rights also demonstrates the supremacy of a US law approach over the operation of the site.

These takedown notices and the subsequent removal of the Thingiverse files, even if it is not clear that they are in breach of copyright laws, show one limit to sharing on Thingiverse. Even if Thingiverse users are happy to share their designs via Creative Commons licences, that does not mean that others are also happy for this to happen.

3. Licence options and sharing culture in 3D printing

We now turn to the question of licensing and what this can tell us about how cultures of sharing are framed, understood and practiced among Thingiverse users. Thingiverse encourages users to list their designs under one of the Creative Commons licences. Thingiverse states that licensing under this banner means "that anyone can use or alter any design" (MakerBot b). While such an arrangement seems conducive to open sharing, there are a number of issues here that warrant attention.

A brief description of Creative Commons licensing may be helpful at this point. CC licensing provides a unique combination of conditions that give users a form of copyright that is more tailored to their personal needs. They can be seen as a level to which the user wishes to free their works into the public domain, reflecting the extent to which they reserve, or do not reserve, their rights. CC licensing can be seen as an unorthodox use, or 'hack', of intellectual property law. Traditionally, copyright has worked by granting the creator of a work a bundle of exclusive rights over that work, governing how the work is shared, copied and modified - usually these activities cannot be done without the permission of the copyright holder (which is not necessarily the original creator as these rights can be assigned to others). CC licensing differs from this model inasmuch the copyright holder can choose to allow the future distribution of copies and modified versions of the original work without users needing to ask specific permission, while requiring that these same rights are preserved in any future modified versions.

When uploading a CAD file, Thingiverse contributors are asked to attach a secondary licence to their product, which includes the core suite of six CC licences (Creative Commons b). This possibility to choose a licence acts as a flexible tool to respond to the needs of creators and the demands of users. The licences are grouped under four 'modules', each representing the extent to which certain rights are (or are not) withheld. The four modules are: Attribution; Commercial Use; Share Alike; and Derivatives. Combinations of these result in six unique licences: Attribution (CC BY); Attribution-ShareAlike (CC BY-SA); Attribution-NoDerivs (CC BY-ND); Attribution-NonCommercial (CC BY-NC); Attribution-NonCommercial-

ShareAlike (CC BY-NC-SA); and Attribution-NonCommercial-NoDerivs (CC BY-NC-ND). Thingiverse also gives its users the choice to use a CC-Public Domain Dedication licence, although CC has officially 'retired' this licence. Its successor is the CC0 "No Rights Reserved" dedication, by which creators of copyrighted material can waive their interests in those works and 'place them as completely as possible in the public domain, so that others may freely build upon, enhance and reuse the works for any purposes without restriction under copyright or database law' (Creative Commons a).

Thingiverse users can also choose from a number of other, non-CC, licences, which are derived from free software licences: while broadly similar to CC licenses, these are designed to deal with different situations. CC licences typically apply to 'traditional' or 'conventional' types of copyrighted material such as music, film, photography, literature - and also apply to websites. Free software licences typically apply to software, which has been protected by copyright in the US since 1980 when computer programs were defined as falling within the 'literary works' category. The inclusion of software code in categories of copyright protection has been controversial (Samuelson 1988), as has the recognition by US courts from the 1970s that software could also be patentable (which is not the case for more 'conventional' literary works). In response to this software 'land grab', free software licences have been created and used to make the works accessible and allow others to build upon them. Thingiverse offers a choice of three free software licences for uploaded files in addition to the CC options: two GNU licences – GNU General Public Licence (GNU-GPL) and GNU Lesser General Public Licence (GNU-LGPL) – and the BSD (Berkeley Source Distribution) licence.

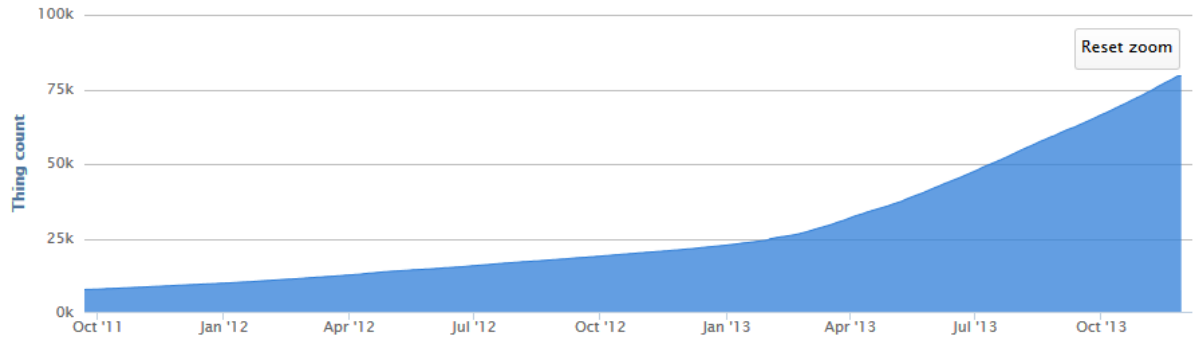
In addition to the choice of (secondary) licence, Thingiverse users also have the ability to make their files 'public' or 'private'. Public Things are publicly available to see and download from Thingiverse's website. Private Things are those which have not yet been officially 'published', because they are still in draft form or because the person uploading the file does not wish to make it publicly available for some other reason. There is also a box that can be ticked to signal that a Public Thing is a 'Work in Progress', to alert others to the fact that it may be updated in some way in the future but is still available publicly in its current form. By analysing these user

choices, both of secondary licence and whether a Thing is public or private, we can gain a valuable insight into the motivations of Thingiverse users through revealed preference.

To this end, in 2013 we conducted an empirical analysis of the metadata of 117,450 Thingiverse objects to find information about licence choice and public/private status. Thingiverse has an open API which can be used to collect metadata about Things (MakerBot d), but in practice it proved complicated to use for our purposes, mostly due to a lack of code examples and insufficient documentation; so we chose to screen-scrape with a custom-built Ruby program, which extracts information from the site by parsing its web pages.

Thingiverse's service has attracted a lot of designers who upload their designs, but around Jan-Feb 2013 the curve became steeper. One reason for that might be the fact that in January 2013 Thingiverse launched a new online application, MakerBot Customizer, which allowed users to create easily new things from parametric designs.[1] Another possible reason is the counter effect of the negative publicity around Thingiverse discussed above.

Figure 1: Number of Things in Thingiverse



[1] Parametric design is a design method in which the output is generated by a set of rules or an Algorithm, normally by using a computer program.

The data scrape, conducted between 16 and 18 August 2013, collected and stored metadata about 117,450 Things, dating from Jan 2009 to Aug 2013. Private Things could be coded for their status only, while Public Things offered a wealth of other data, including the database identifier, author handle, secondary licence choice, creation date, comments count, views count, and attached tags. It also revealed makes count (how many times other Thingiverse users have reportedly printed the item), collections count (how many user-generated collections the given Thing appears in) and remixes count (how many times the Thing has been used as starting point for derived works). There are of course limitations to such an approach, which provides a wide-angled overview of IP practices rather than the deep analysis that might result from other methods, such as community ethnographies or sample studies.[2] These limitations notwithstanding, we were able to uncover a number of aspects of Thingiverse's operation and use by employing this method.

Table 2: Top 5 secondary license choices among Thingiverse users, 2013

Licence type	**Percentage of Things**
Attribution (CC BY)	36%
Attribution-ShareAlike (CC BY-SA)	36%
Attribution-NonCommercial (CC BY-NC)	10%
Attribution-NonCommercial-ShareAlike (CC BY-NC-SA)	8%
GNU General Public Licence (GPL 2.0)	4%

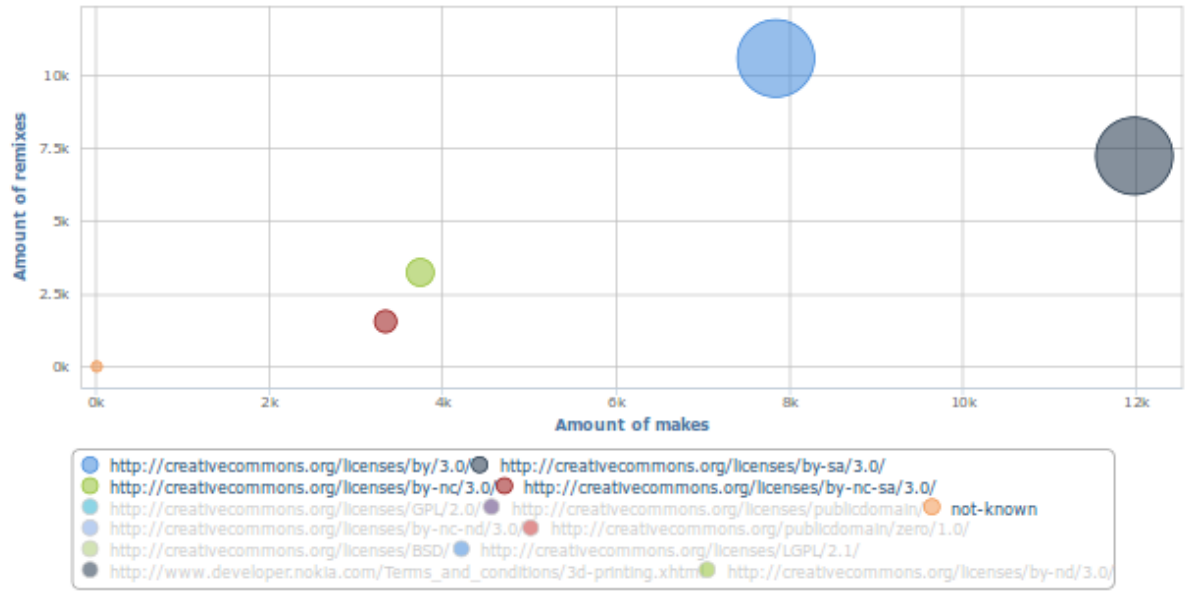
Our first finding, based on an analysis of metadata from the 68,618 Public Things in our sample, was that the CC licences were by far the most popular licences used. The top 4 licences were all CC, representing 89.84% of all Public Things (see Table 2). Interestingly, the two most popular choices -- Attribution (CC BY) and the 'sticky' Attribution-ShareAlike (CC BY-SA) – both allow commercial usage. It is worth noting

[2] Since data collecting is not continuous, collected data offers only a snapshot view at a particular point in time. Our selected method enables automated processing of large data sets with minimal human intervention and resources, lending itself to generalisations and a broader view; however, the downside is that data often is shallow and does not contain the nuances or hidden meanings which only humans can operate regarding the phenomenon at hand. Community-based ethnographies could offer more in depth view, but not at the same extent and certainly not with same small amount of resources and time. Sample studies would also enable detailed exploration of selected items, but the generalisation of results gained would be difficult or impossible.

that the order of popularity here is fairly similar to the order in which licence options are listed in Thingiverse's licence drop-down menu, so it is possible that many users do not venture far down the list or are happy to go with the default option (CC BY-SA).

Further analysis of remixed objects in our sample reveals more interesting details. Licence choices for these objects are illustrated in Figure 2. Note that, while the amounts of CC BY (blue circle) and CC BY-SA (grey circle) licensed Things are almost the same, CC BY licensed Things are remixed far more often (10,569 times) than CC BY-SA (7,225) Things. In other words, non-sticking licences seem to be preferred when remixing objects.

Figure 2: License choices – by makes and remixes

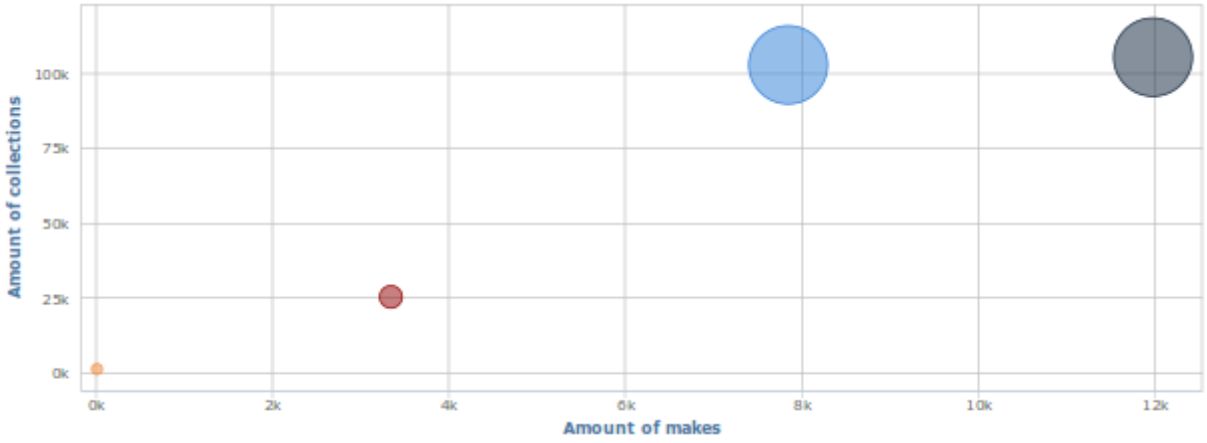


The most frequently remixed item we found was a customisable iPhone case, licensed under CC BY, which had been remixed 2,153 times. The licence used in the example is not "sticky", but requires attribution. In theory this gives remixers more freedom in selecting other licences for their work, particularly compared to the

commonly used CC BY-SA license, which requires that derivative works be licensed under ”same or similar” terms.

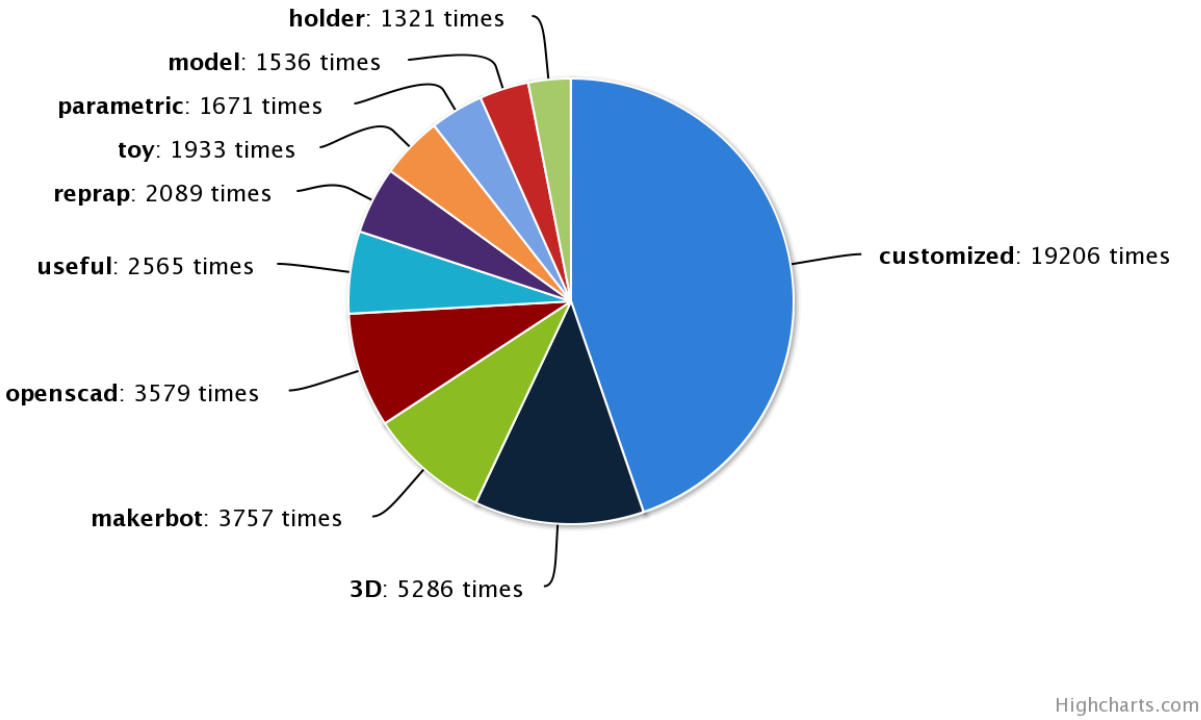
This remixing pattern can be compared with how users use the “collection” function. CC BY (blue) and CC BY-SA (grey) licensed Things are almost equal in terms of how many times they are included in user collections. In comparison, BY-SA licensed items (11,964 times) are significantly more frequently printed out than BY (7,833 times). Licence choice does not seem to make a difference in collections. In reproduction, “sticky” licenced models are far more popular.

Figure 2: Licence choices – by makes and collection count



Analysis of Thingiverse tags can also reveal insights into intellectual property norms on the site. These are listed in Figure 3 below. The most common tag that users attach to Things is *customized* (19,206 times). This tag, which refers to Thingiverse users handling Things in a way more close to ‘remixing’ these designs than ‘building them from scratch’, reveals the iterative, collaborative kind of production model on which that Thingiverse prides itself. However our next finding, discussed below, gives us a slightly different picture of this process.

Figure 3: Most common tags used with Thingiverse objects



4. Closed aspects of an open platform: Private Things

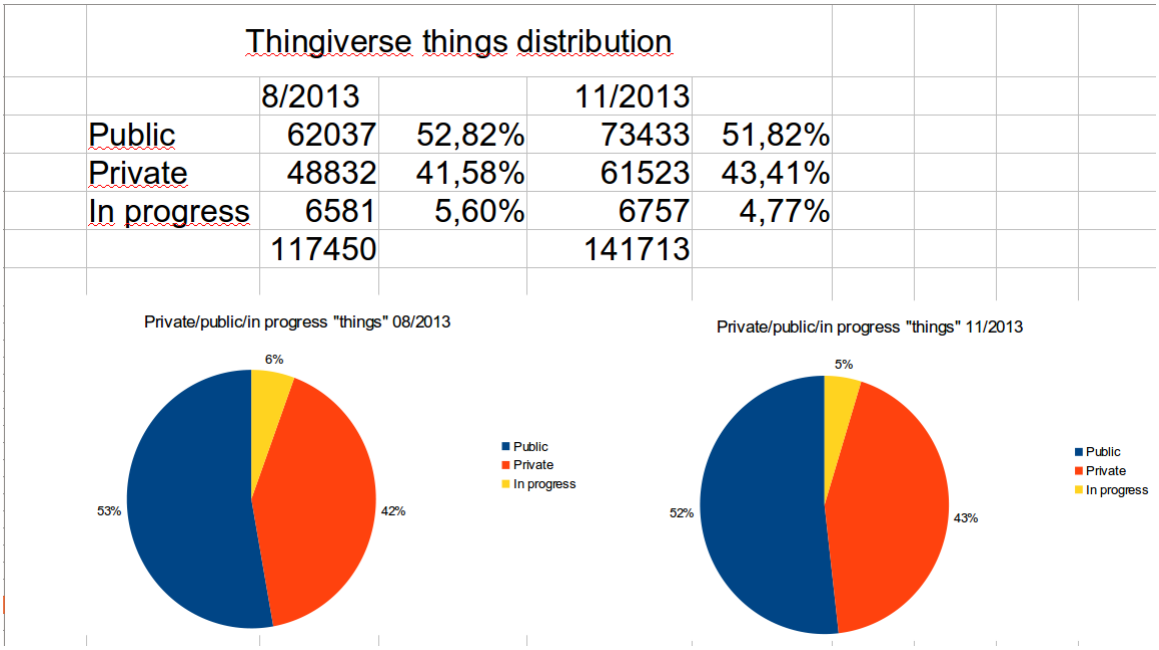
In the previous section we discussed a range of findings that broadly conform to the image of Thingiverse as a platform dominated by derivative works and collaborative projects. The aforementioned data supports the notion of Thingiverse as an open sharing service. Yet other findings from our study tell a different story.

Our scrape of the site revealed that nearly 42% of the files hosted on Thingiverse are Private – in the sense that they have not been made available to internet users according to the process described above, whereby a user selects a “Public” status for their creation and the file is published on Thingiverse. In other words, they are not shared – or if they are shared, the sharing is limited to a small group of collaborators who have access to the login and password details of the particular Thingiverse user account. This was a rather surprising finding. Why are there are so many private

things? It is unlikely that all of them are “not yet finished and shareable”. This conflicts with other data from our study, which revealed that only 6% of things have an in-progress status.[3] Some other reasons should therefore be explored.

Things with “private” status have been saved as drafts. Interestingly, it seems that over time the share of Private Things among all Things has been growing.

Figure 4: Types of Thingiverse Things



We were unable to collect any more information about why Thingiverse users were marking their Things as private at the time of writing. In order to explain better users’ motivations in not sharing their creations, further qualitative research here would be highly informative. We can only speculate as to why there are so many Private

[3] These are not included in the “Private” status percentage

Things and why their numbers are growing as an overall proportion of Thingiverse files. Yet from the information we have, it seems that 'sharing' by Thingiverse users is not as prevalent or dominant a practice as the rhetoric suggests, notwithstanding the fact that Thingiverse itself is happy for its users to share with it yet less willing to share back since it transitioned to 'closed' design and software.

5. Conclusion

The design repository Thingiverse has had a rapid and spectacular rise, and is now a vital component in global 3D printing culture and practice. As our study of the site has demonstrated, Thingiverse sits at the nexus of a number of intellectual property tensions and disputes. As such, it is a useful site from which to view wider IP power struggles within peer production arenas.

We have demonstrated that Thingiverse's IP policies are profoundly contradictory. On the one hand, Thingiverse and the practices it enables are the ultimate by-products of user innovation, fertilised by open-source culture. On the other hand, it is a commercial, proprietary platform, owned by a large, global corporation, which has been widely criticised for its own intellectual property offences. Recent controversies around Terms of Use reveal the contentious nature of Thingiverse's actions, and the ethical gulf that divides MakerBot and Thingiverse from their users.

Yet the behaviour of Thingiverse users is also somewhat contradictory. As our analysis has shown, only a proportion of users license their content in ways that take full advantage of open licensing norms. Creative Commons licences are used for 89% of all Public Things. Yet users also keep a surprisingly large proportion of their designs private. Whether by accident or design, this adds a thick layer of 'off-stage' activity to what is intended to be an open, transparent system dedicated to sharing.

The data collected clearly identifies the dualistic nature of Thingiverse. On the one hand it is clearly a central location for sharing 3D model designs for others to utilise, use in production and remix with other designs. On the other hand, Thingiverse

seems to function as online storage for private unshared 3D models, yet the users' motivation(s) for keeping these files private remain unknown. If it is true that closed systems tend toward control, while open ones tend toward innovation, then the enclosure of Thingiverse may suggest that it is losing its innovative character. Since the data collected is only a snapshot in time, whether the large proportion of Private Things signals a deeper and more fundamental tendency is not known. Longer term research is needed as well as more qualitative investigation to identify users' reasons for keeping their Things private.

Looking into the horizon, we anticipate a number of future developments for Thingiverse. Takedown notifications are likely to become an increasingly common occurrence, and the site is likely to deepen its reliance on the kind of complex, automated regulatory systems that characterise other major user generated content platforms, notably YouTube. This is, in part, a natural consequence of the 3D printing boom. As awareness of the technology rises, hardware gets more sophisticated, and design options proliferate, the level of concern among rights holders will naturally increase. Takedowns will continue to be seen as the most convenient and scalable recourse for them to enforce their intellectual property.

The rise of 3D scanners is another factor to watch. Take-up of scanning technology, and its integration into handheld devices, will likely reduce the reliance on user-created designs, thus relocating (although possibly not reducing) some of the existing IP tension, with ethical choices being devolved to software rather than human designers.

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