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ARTICLE

3D Printing and Patent Law: A Disruptive Technology Disrupting Patent Law?

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Abstract Concerns have been raised that the upsurge of 3D printing technology would disrupt the patent system. The central question the present paper aims to address is whether and to what extent the emergence of 3D printing technology indeed urges us to rethink patent law. The paper splits up this question by looking at two facets in more depth – patentability and infringement – through the lens of pertinent European and US law. In order to provide a better understanding on the reach of patentability and infringement theory and practice and their possible interpretation in a 3D printing context, a set of different scenarios is established covering the perspectives from rights holders (inventors/producers) and users (hobbyists/consumers). The paper concludes, first and foremost, that the wide uptake of 3D printing does not challenge the basic premises of patent law. As regards patentability, 3D printing does not upset patentability theory in general: it does not challenge prevailing concepts of patentable subject matter, nor current patentability requirements. On the other hand, digitized fabrication might well challenge the type/token dichotomy on which patent ontology is founded. As regards infringement, 3D printing does not really upset infringement theory either: it does not fundamentally alter the scope of rights, concepts or direct/indirect infringement assessment traditions. The paper further concludes that the emergence of 3D printing and the decentralization of production it entails, may lead to a wider and more dispersed scale of infringement, and does call into question the adequacy of current enforcement tools and strategies. A lack of adequate enforcement tools

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might well undermine the innovation incentive rationale dominating current patent law.

Keywords 3D printing technology · European and US patent law · Eligible subject matter · Substantive patentability requirements · Infringement · Enforcement · Inventor and user perspective

1 Introduction

1.1 3D Printing – Changing the Innovation Paradigm?

3D printing is hot and in the news. The concept is simple: an object is not created by juxtaposing separate parts along a production line, but by building up the object layer by layer, millimetre per millimetre, by one single machine. Rather than a traditional "subtractive" manufacturing method, 3D printing is an "additive" manufacturing method.[1] The term 3D printing initially referred to a specific additive process invented by the Massachusetts Institute of Technology (MIT)[2] (further referred to as 3D printing sensu stricto), but is used nowadays in a more generic sense to include a wide range of additive manufacturing technologies. The various different additive manufacturing techniques[3] now allow printing in different types of materials ranging from plastic[4] and steel, to chocolate and wool, to living human cells (often referred to as "bioprinting").

3D printing has many benefits and applications.[5] It allows printing of fragile structures that were previously impossible to manufacture at a low cost. This technique also offers strength, accessibility and precision that subtractive manufacturing cannot match. Furthermore, it is claimed that 3D printing has the potential to reduce physical transport[6] and storage space,[7] as products will only be printed where they are needed at the time they are needed.[8] Last but not least, the core benefit of 3D printing is personalization at a low manufacturing cost: the possibility to produce and commercialize goods for a market of only one person without extra

[1] Much has been written on 3D printing technology from various perspectives. For more on the concept and the mechanics of action, *see e.g.* Roth (2016). For more on the (societal and economic) challenges, *see e.g.* Birtchnell and Urry (2016); Heemsbergen et al. (2016); Lipson and Kurman (2012); Mueller (2016).

[2] Gershenfeld (2012).

[3] For an overview of the major additive manufacturing techniques, *see infra*.

[4] More in particular: polylactic acid (PLA), polycarbonates (PC) and acrylonitrile–butadiene–styrene (ABS).

[5] For general references, *see supra* note 1.

[6] *See* Birtchnell et al. (2016).

[7] *See* Mohr and Kahn (2015).

[8] One excellent example is NASA's 3D printer experiment aboard the International Space Station (ISS). Obviously, a space station is the prototype situation in which storage and transport of unused spare parts is very expensive (for more details, *see* "3D Printer Headed to Space Station". *See* https://www.nasa.gov/content/3d-printer-headed-to-space-station, last visited 5 August 2016).

costs.[9] Indeed, unlike subtractive manufacturing methods, a small change in the digital representation of the printable object – in the so-called Computer Aided Design file or CAD file – does not require substantial changes in the production line. To give just one example: a traditional manufacturer of iPhone cases needs to adapt his production line any time Apple brings out a new iPhone model. Since less iPhone 3s are sold, he might decide that the production line for that model has ceased to be commercially viable. For a 3D printer, it does not matter whether the CAD file of a specific iPhone case is designed for an iPhone 5 or for an iPhone 6. One 3D printer could print both; it is only the CAD file that must be adapted.

3D printing may well herald the third industrial revolution because of its capability to disrupt existing economic systems on a global scale.[10] Once 3D printing is available to consumers, the traditional production model where a producer offers standard products for sale to consumers, might evolve into a model where a consumer copies, shares and prints his/her own products at home. Put differently, the traditional product development process where a manufacturer explores user needs and develops responsive products, might be replaced by an alternative product development process, where a repartitioning of the innovation process tasks takes place and where a manufacturer provides standard solution-related information (e.g. a toolkit containing 3D printing CAD designs) and where the user adds need-related information (e.g. personalized design) and develops the final, responsive product himself (see Fig. 1).[11] This disruptive character of 3D printing technology will undoubtedly challenge current business models.[12] Producers will have to shift from mass production to the production (the printing) of consumer-selected, low-cost, low-value and on-demand goods. Possible higher cost of fabrication trough 3D printing could be offset by the otherwise assumed cost of distribution or shipping. Business models similar to iTunes will pop up, with the difference that iTunes collects and offers music, whereas "iThings" would provide trustworthy CAD files ranging from jewelry and bathroom tiles to spare parts for baby strollers.[13]

The disruptive effect of 3D printing has been compared with Gutenberg's invention of the (moveable type) printing press.[14] Before that, manuscripts were copied by hand in a limited number of places such as, at that time, monasteries. The printing press allowed the uncontrolled spread of the written word in many different places at the same time. 3D printing may have a similar disruptive effect, since it allows a decentralization of the production of goods by billions of dispersed

[9] Gershenfeld (2012) p. 46.

[10] "A third industrial revolution", *The Economist* April 21 2012 (available at http://www.economist.com/node/21552901, last visited 23 May 2015).

[11] Based on von Hippel and Katz (2002): Von Hippel and Katz describe this mode of repartitioning in general, without examining the translation to 3D printing yet; *also see* von Hippel (2015). *Cf.* Bechtold (2016) setting forth that 3D printing has the potential to disrupt traditional manufacturing and supply chains.

[12] Bechtold (2016); Anderson and Sherman (2007), p. 289; Rayna et al. (2016).

[13] Anderson and Sherman (2007), p. 289. For a further discussion, *see infra* Sect. 4.2.

[14] Finocchiaro (2013), p. 480; Hornick and Roland (2013).

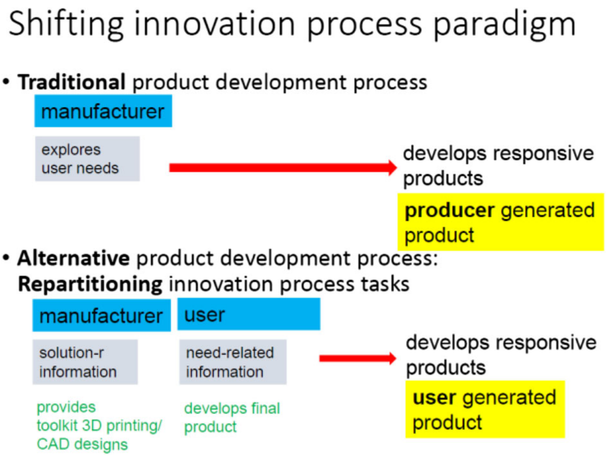

Fig. 1 The shifting innovation process paradigm with 3D printing (figure inspired by von Hippel and Katz (2002))

consumers instead of by a few well-known industrial producers, leading to the inception of a "prosumer" society.[15]

1.2 3D Printing and Intellectual Property – Threatening the Patent Paradigm?

The decentralization of the production process in the 3D printing ecosystem poses certain problems in different areas of law, such as consumer protection, product liability and intellectual property (IP).[16] IP scholarship has paid increasing attention to 3D printing and the interface with copyright law.[17] Also the relationship between 3D printing and trademark and design law has increasingly been explored.[18] Less consideration was initially given to the problems of 3D printing from a patent law angle, but academic interest has been growing in recent years. The present paper aims to enhance our understanding of the current problems patent law encounters when confronted with 3D printing and contribute to the current debate surrounding 3D printing and patent law.

The *central question* the present paper aims to address is whether and to what extent the emergence of 3D printing technology urges us to rethink patent law. Is the upswing of 3D printing upending the patent system? Is patent law "likely to be disrupted by 3D printing"?[19] Does 3D printing put into question the principles, limits and rationale of patent law? We will respond to the central question by dividing it up in *two sub-questions*. The first question relates to patentability: can 3D

[15] Mimler (2013), p. 55.

[16] *See e.g.* Van den Berg et al. (2016).

[17] *See e.g.* Dasari (2013), pp. 284–289; Osborn (2014b); Rideout (2011); Susson (2013); Weinberg (2010a).

[18] *See* Scardamaglia (2015). For a popularizing article on 3D printing and design, *see* Berger (2014).

[19] Ballardini et al. (2015), p. 851.

printing technology be patented? What elements in a 3D printing process can be secured with patent protection? Does 3D printing outgrow current theories on patentable subject matter? Does it force us to rethink the way patentability requirements are being applied? The second question deals with infringement: do 3D printed objects infringe existing patents? Under what conditions? Does 3D printing point to inadequacies or flaws in the basic infringement concepts and approaches? The two questions relate to *two* distinct *perspectives*. The first question looks at 3D printing and patent law from the perspective of the inventor of 3D printing technology, and mainly studies the patentability of the various steps or elements in a 3D printing process. The second question focuses on 3D printing and patent law from the perspective of the user of a 3D printer who personalizes and prints objects, and mainly relates to the possible infringement of objects which enjoy patent protection. Put differently, investigating 3D printing through the lens of patent law results in a Janusian approach[20]; it involves investigating the past (can 3D printed technology which has been developed be patented?) and the future (do physical objects which have later been made using 3D printing technology infringe on existing patents?).

The *objective* of the present paper is to carefully assess patentability and infringement questions in a 3D printing context, in order to contribute to the more fundamental conversation of whether or not 3D printing threatens the current patent paradigm.

The *methodology* applied to answer the questions set forth includes an in-depth analysis of legislation, case law and legal doctrine pertinent to patenting and infringement of 3D printing. The present article makes the legal implications of 3D printing more palpable by sketching and investigating a set of scenarios, where different perspectives (ranging from inventor/producer to user/prosumer) and different acts (from developing/making to using/reproducing/sharing printers, materials, CAD files, software and physical artefacts) are scrutinized. In doing so, the paper investigates patenting and infringement in both European and US patent law.

The *structure* of the present paper follows our two sub-questions. The first, backward-looking and inventor-related question will be addressed in Sect. 2. The second, forward-looking and user-related question will be dealt with in Sect. 3. Conclusions and avenues for further research will be articulated in Sect. 4.

2 Inventor Perspective: Patentability of 3D Printing Elements

Let us now explore Janus' first face and analyze to what extent 3D printing technology can enjoy patent protection.[21] In order to do so, we will divide 3D printing technology into its constitutive elements, notably hardware (printers),

[20] In Roman mythology the God Janus is usually depicted as having two faces, since he looks to the past and to the future (*see* Graf 2016).

[21] The present article will primarily focus on the European and Unitary patent routes, as these routes have gained the most attention compared to the national routes.

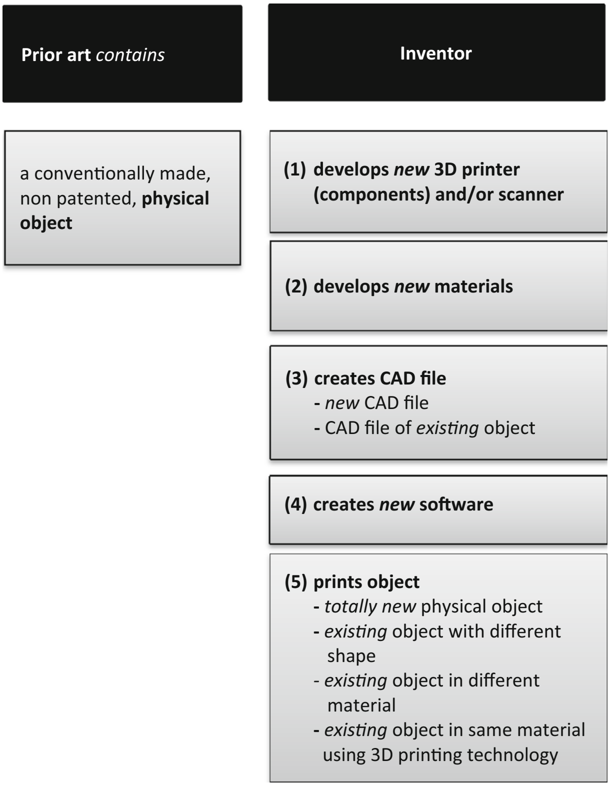

Fig. 2 3D printing and patentability: patentable elements

materials, CAD files, software programs and physical objects (see Fig. 2). We will investigate whether, when a (professional) inventor gets to work with 3D printing technology, these elements can qualify as patentable subject matter, and whether they can meet the substantive criteria of novelty, inventive step and industrial application under prevailing European patent law (notably Arts. 52–57 EPC) or the corresponding criteria of novelty, non-obviousness and utility under US patent law (notably 35 USC § 101 ff.). As the type of hardware and printing method applied are closely intertwined, they are discussed jointly here.

2.1 The Inventor

2.1.1 Developing a 3D Printer and Printing Methods

The major types of additive printing methods and accompanying printers were developed in the mid-1980s. Roughly speaking, five types of additive printing methods and accompanying printers can be distinguished[22]:

[22] *See* Braun and Taylor (2012), pp. 54–55; JTEC/WTEC (1997). *Also see* references in *supra* note 1.

1. Stereo lithography: involving shining ultraviolet light to harden the liquid input material at a specific location;
2. Selective laser sintering (SLS): involving infrared laser light to fuse plastic or metal powder;
3. Fused/selective deposition modelling (FDM): jetting a bead of viscous material with continuous feeding of materials such as plastic or chocolate (well-known examples include the RepRap printer[23] and the Cube printer[24]);
4. 3D printing sensu stricto: using print heads jetting droplets of material;
5. Layered manufacturing: using stacking of solid layers and glue.

The patentability of additive printing methods, printers as a whole and printer parts, such as printer heads, has been rather straightforward. Hardly any discussion seems to have taken place in case law and in academic literature on the principle of patentability of 3D printing methods, printers or printer components, or on meeting the patentability standards of novelty, inventive step/non-obviousness and industrial application/utility. To provide some insight into the type of patents that have been awarded, but far from pursuing completeness, we list the very first patents on 3D printing methods and hardware – mostly dating back to the late 1980s and early 1990s – and refer to some more recent ones.[25] It is remarkable that for the early achievements, mainly US patents could be retrieved and no European counterparts could be uncovered.[26]

1. The first patent relating to stereo lithography was filed in 1984 as US patent 4.575.330 entitled "Apparatus for production of three-dimensional objects by stereolithography" and was awarded on 11 March 1986 to Chuck (Charles) Hill.[27]
2. The first patent for selective laser sintering (SLS) was filed in 1986 as US patent 4.863.538 entitled "Method and apparatus for producing parts by selective sintering" and was granted on 5 September 1989 to Deckard.[28]

[23] *See* http://reprap.org/ (last visited 5 April 2016).

[24] *See* http://www.seido-systems.com (last visited 30 May 2016).

[25] Most of the first US patents were found in West and Kuk (2014) (Table 1) and were checked for European counterparts in Espacenet (*see* http://worldwide.espacenet.com/). Most of the recent European patents were found thanks to the expertise of Allard Van Wallene (Examiner patent examination, European Patent Office, Rijswijk).

[26] A very interesting and detailed analysis from the Intellectual Property Office UK (2015c) *3D Printing: A Patent Overview* confirms that US inventors were dominant in the early stages of 3D printing technology. In the same line, Gridlogics Technologies (2014).

[27] Source: West and Kuk (2014) Table 1 and the European Patent Office (EPO) website (*see* https://worldwide.espacenet.com/, last visited 18 October 2016). *Also see WIPO Magazine* 2013 and https://en.wikipedia.org/wiki/Chuck_Hull (last visited 24 May 2016). *Also see* US patent 4.929.402 entitled "Method for production of three-dimensional objects by stereolithography", which is a continuation of application 4.575.330, submitted on 19 April 1989 and awarded on 29 May 1990 to Charles W. Hull. For a more recent patent, *see* US patent 7.758.329 entitled "Optical modeling apparatus", granted 20 July 2010.

[28] Source: West and Kuk (2014) Table 1 (erroneously referring to US patent 4.863.539), Google Patents and EPO website. Another relevant patent is US patent 5.597.589, likewise invented by Deckard, entitled "Apparatus for producing parts by selective sintering", applied for in 1994 and granted 28 January 1997.

3. The first US patent for fused/selective deposition modelling (FDM) was filed in 1989 as US patent 5.121.329, entitled "Apparatus and method for creating three-dimensional objects" and was awarded on 9 June 1992 to Stratasys.[29]
4. For an example of a patent relating to 3D printing sensu stricto, one can turn to US patent 8.481.241 entitled "Compositions and methods for use in three dimensional model printing", granted on 9 July 2013 to Stratasys.[30]
5. For an example of a patent relating to layered manufacturing, one might care to look at US patent application 2009/261067 entitled "Methods and apparatus for prototyping three dimensional objects from a plurality of layers", submitted on 22 October 2009.

The initial development of these printers and their constituting elements, and the constant improvement and perfection efforts, often result in new and inventive inventions which have been awarded patent protection without a great stir.[31]

2.1.2 Developing Materials

3D printing has come in the news through the use of many different applications and materials. Witness the 3D printing of food, chocolate figures,[32] woolen teddy bears,[33] concrete houses,[34] or living human tissue.[35]

The question concerning the patentability of the materials involved in 3D printing technology is more difficult to answer. Other than the method to preserve, or the device or method to insert the material in the printing head,[36] materials such as chocolate[37] or wool will face a hard time in meeting the standards of novelty and inventive step/non-obviousness. The same applies to the concrete with which houses

[29] Source: West and Kuk (2014) Table 1 and EPO website. A later example is US patent 6.027.326 entitled "Freeforming objects with low-binder slurry", granted 22 February 2000. Yet another example is US patent 9.022.769, entitled "Multiple-zone liquefier assembly for extrusion-based additive manufacturing systems", granted to Stratasys on 5 May 2015.

[30] *Also see* US patent 7.569.273, entitled "Thermoplastic powder material system for appearance models from 3D printing systems", granted August 4 2009. *Also see* EP patent 1.163.999, entitled "Material system for use in a 3D printing process", granted 12 October 2005.

[31] In the same sense Intellectual Property Office UK (2015c) *3D Printing: A Patent Overview* stating that technology breakthroughs in 3D printing date from the 1980 s (note the patents from 1980), but that the tools which allow the underlying technologies to be exploited have undergone substantial improvement over this period of time, explaining the upsurge of patents in 3D printing since then. There has been a significant increase in the numbers of patent filed starting in about 2000 (p. 11).

[32] *See e.g.* https://www.youtube.com/watch?v=MDEdGhE2dUk (last visited 30 May 2016), for a 3D chocolate printer creating squares.

[33] *See* http://www.zdnet.be/nieuws/155285/disney-print-zijn-eerste-wollen-teddybeer/ (last visited 4 April 2016).

[34] *See e.g.* https://www.youtube.com/watch?v=DQ5Elbvvr1M (last visited 30 May 2016), for a 3D concrete printer building a castle.

[35] *See e.g.* https://www.youtube.com/watch?v=HhbViORMop0 (last visited 30 May 2016).

[36] For an example of an apparatuses for management of the supply of modeling materials for use in three-dimensional object printing, *see* EP patent 2.298.539, entitled "Three-dimensional object printing method and material supply apparatus", granted 2 January 2013.

[37] *See,* however, Li et al. (2014).

are printed or the different types of plastic most inventors tinker with. On the other hand, the materials used to create so-called supporting structures[38] or the materials used for bioprinting[39] might well live up to the patentability threshold of novelty and inventive step/non-obviousness.

2.1.3 Creating a CAD File

More than in other manufacturing methods, the CAD file – the digital representation of a physical object – is a crucial component of the 3D printing process. Two methods are available to create the necessary CAD file. Either the inventor uses software to independently digitally create the CAD file from scratch,[40] or he/she uses a 3D scanner to scan an existing object and thus create a digital copy of it.

An interesting question is how patent law treats claims directed to such CAD files. The major line in scholarly thinking sets forth that CAD files cannot be considered patentable subject matter.[41] It is argued that in the absence of a newly invented CAD file format or printing method to accompany a newly created digital product, there can be no meaningful patent protection for a CAD file.[42] Quite often, the CAD file itself and the accompanying instructions are made using existing technology. The most probable alternative IP protection for CAD files is copyright.[43] A minority thread in academic literature claims that CAD files should be considered patentable. One way to obtain patent protection for CAD files would be to claim them as software. However, such claims may face considerable patentable subject matter challenges (notably under Art. 52(2) EPC in Europe and 35 U.S.C. §101 in the US), similar to traditional software application claims. Moreover, a finalized CAD file is not software but data, just like the JPEG family picture or MP3 music are data on your computer. In view of these challenges, these scholars have come up with an alternative way to gain patent coverage. Rather than arguing that CAD files should enjoy patent protection as software, these scholars set forth that CAD files should enjoy protection as physical objects. The frontrunner of this school of thought, Lucas Osborn, argues that unlike subtractive manufacturing methods where the CAD file was literally a whole production line away from the finalised product, 3D printing makes the CAD file almost equally valuable to the actual object, maybe even more valuable.[44] The CAD file is not only one "print"-button away from the materialisation of the physical object, the digital file is easily adaptable,

[38] *See e.g.* Weiming et al. (2013).

[39] *See* Li (2014).

[40] *See infra.*

[41] Bradshaw et al. (2010), p. 24; Finocchiaro (2013), p. 477; Desai and Magliocca (2014), p. 1691; Mimler (2013), p. 63.

[42] Brean (2013), p. 807.

[43] Bradshaw et al. (2010), p. 24.

[44] Osborn (2014a). *Cf.* Bechtold (2016) pointing to the impact of disentangling the design information of an object from the production of the object in business models.

sharable and copyable.[45] If in modern society, digital representations of patentable objects are only one click away from the materialization of such objects thanks to 3D printing, courts should consider an equal protection for the CAD files as exists for the actual printed objects.[46]

2.1.4 Creating Software

An often overlooked, but essential component in the 3D printing process is software. Software must be distinguished from the data involved, notably the CAD file. The most evident examples of software are the software to design CAD files from scratch,[47] software to scan existing objects and translate them into CAD files, or software transposing the CAD files into printable stereolithography (STL) files.[48] But software comes into play in many more stages. Large 3D printing companies, offering printing services to consumers uploading their own CAD files, often use automated software to enhance the structural design of the uploaded CAD files, thus ensuring the printability of the uploaded models. Just think of software automatically calculating the amount, placement and material of the necessary supporting structures. Other software calculates the best possible combination of print orders in one 3D printing machine to enhance printing efficiency and printing quality. It is no secret that it is often this type of software that determines the competitive advantage between the different 3D printing companies.[49]

When examining the patentability of software in the context of 3D printing, there is no need to distinguish software applied in the area of 3D printing from the use of software in other technologies. The question of the patentability of software is complex and heavily debated. Diving into that question goes beyond the scope of the present paper.

[45] Osborn (2014a). More-or-less in the same line of thinking, West and Kuk (2014) who argue that platforms such as Thingiverse form an important bridge for the transition between the digital to the physical worlds.

[46] An alternative approach to scrutinizing the patent potential of CAD files is arguing that CAD files, rather than as with software, are akin to data sets. Osborn follows this line of thinking and points to a recent decision of the US International Trade Commission, where data sets were considered "articles" in the sense of 19 U.S.C. § 1337, a provision concerning unfair practices in import trade (Osborn 2014a). Ballardini et al. (2015), p. 850 seem to support the opposite view where – albeit cautiously – CAD files are qualified as software.

[47] For instance Google Sketchup (*see* http://www.sketchup.com/, last visited 5 April 2016), Blender (*see* http://blender.stackexchange.com, last visited 5 April 2016), Autocad (*see* http://www.autodesk.nl, last visited 5 April 2016), Solidworks (*see* https://www.solidworks.com, last visited 5 April 2016), etc.

[48] 3D systems created the STL file format, a way to communicate between CAD and drivers, which quickly became the de facto standard for digitally defining the surface of a three-dimensional object using a series of triangular facets (*see* Jacobs 1996).

[49] Personal communication Peter Leys, Director and Chairman of Materialize (*see* http://www.materialise.com/) during a site visited on 30 April 2015.

2.1.5 Printing an Object

When making use of 3D printing technology and printing a 3D object, a distinction can be made between four different hypotheses. First and foremost, an inventor or designer may put 3D printing technology to work to print a *totally new* object, which was (almost) impossible to make before by conventional means. The Dodecahedron lamp by California artist Bathsheba Grossman,[50] the Gaudi chair designed by the Dutch designer Bram Geenen,[51] the foldable stool designed by Patrick Jouin,[52] the Airbike created by the European Aerospace and Defense Group,[53] the Nemours Foundation's Wilmington Robotic Exoskeleton ("WREX")[54] or the implantable bone augment developed by Mobelife,[55] are wonderful examples of such artefacts. Second, an inventor may make use of 3D printing to develop an object which *existed* before, but which is now produced with a somewhat *different shape*. Third, an inventor may use 3D printing to assist in manufacturing an object which *existed* before, but which is now produced in a *different material*. For example, a key that was produced before in metal can now be made in plastic thanks to 3D printing.[56] Or a spectacle frame that was produced before in plastic can now be produced in titanium.[57] Fourth, an inventor may apply 3D printing technology to craft an *existing* object with *identical materials*. For example, a metal object that was initially made by conventional means is now produced via 3D printing.[58] An oft-cited example in this regard is the Haberman

[50] *See* https://www.pinterest.com (last visited 4 April 2016).

[51] *See* http://www.ground3d.nl/bram-geenen/ (last visited 26 April 2016).

[52] *See* http://www.patrickjouin.com/en/ (last visited 12 October 2016).

[53] Reorganised as the Airbus Group in 2014, *see* http://www.airbusgroup.com/int/en/toolbox/site-search.html?queryStr=airbike (last visited 26 April 2016).

[54] *See* http://usglobalimages.stratasys.com/Case%20Studies/Medical/CS-FDM-Med-Nemours-06-13.pdf?v=635616661738784406 (last visited 19 May 2015). *Also see* Doherty (2012), p. 359.

[55] *See* http://hospital.materialise.com/aMace-titanium-hip-joint-replacement (last visited 18 October 2016). Mobelife, a 3D printing company established in 2008 and specialized in hip and shoulder implants was integrated in Materialize on 1 March 2016 (*see* http://hospital.materialise.com/mobelife-as-a-materialise-company, last visited 18 October 2016).

[56] *See* http://eclecti.cc/hardware/physical-keygen-duplicating-house-keys-on-a-3d-printer (last visited 4 April 2016).

[57] *See* the 3D laser-printed eyeglasses made of titanium developed by Hoet (http://couture.hoet.eu/en/, last visited 18 October 2016). Should the 3D printing technique allow the glasses to be held in the spectacle frame in a non-standard manner, then the first hypothesis might apply.

[58] Another, more complex example might be an "Extractor hood with function of reducing vibration and noise", a device *originally* produced with conventional machinery techniques, for which a patent was awarded (CN 102.635.887) and *now* (re)produced with 3D printing technology (with thanks to Xiang YU from the Huazhong University of Science and Technology for bringing this example to my attention during the ATRIP conference in Montpellier, July 2014).

"Anyway" Baby Feeder,[59] but we can think of other examples, such as Crocs shoes[60] or folding chess sets.[61]

With regard to the patentability of 3D printed objects, the answer will be provided following the four aforementioned hypotheses. With regard to the first hypothesis – the making of a *totally new* physical artefact – the use of 3D printing techniques resulted in a novel object. In the case that the other patent requirements of inventive step/non-obviousness and industrial application/utility are fulfilled, patent protection is within reach. Exemplary in this regard is the implantable bone augment developed by Mobelife.[62] [63] With regard to the second hypothesis – the making of an *existing* artefact, albeit with a *different shape* – it may well be that the modified object is novel. However, when it comes to the requirement of inventive step/non-obviousness, it may well be that the product will not be considered inventive/non-obvious.[64] With regard to the third hypothesis – the making of an *existing* artefact, albeit in a *different material* – it may equally be true that the object printed with 3D printing techniques is novel. The printed artefact (a key in plastic) differs in (at least) one characteristic from the prior art (a key in metal, a glasses frame in titanium). However, when it comes to the requirement of inventive step/non-obviousness, chances may be fairly low that the product will pass this test. A person skilled in the art "would" easily have come up with the idea to print the object in a different material.[65] Furthermore, the substitution of an element by another element, thereby producing an analogous, well-known effect, will most probably not meet the inventive step/non-obviousness requirement.[66] With regard to the fourth

[59] Bradshaw et al. (2010) p. 26. It has to be noted, however, that the present example was protected with a US Design patent, rather than with a US Utility patent, which is the protection modus at stake here (*see* http://habermanbaby.com/anywayup-cow-cup, last visited 5 April 2016). Ballardini et al. (2015) discussed the same Anywaycup and thereby refers to GB patent 2.169.210, entitled "Baby's feeding apparatus" granted to Haberman on 5 January 1989. On closer inspection, it seems that the baby bottle from 1989 is totally different from the cow-cup mentioned earlier. Has some confusion crept in on the storytelling about this legendary item?

[60] US patent 6.993.858, entitled "Breathable footwork pieces", granted to Crocs Inc. on 7 February 2006.

[61] US patent 7.568.702, entitled "Folding chess set", granted to W. & C. Holden on 4 August 2009.

[62] *See* international WIPO/PCT application WO2013170872 EP 2.849.682, entitled "Implantable bone augment and method for manufacturing an implantable bone augment", filed 14 May 2012, more in particular the product claims (claims 14 ff).

[63] Many of the objects listed earlier are not protected with patent rights but with design rights. This is the case, for example, with the foldable stool from Patrick Jouin, which is protected with a US Design patent (US D560.377) granted 29 January 2008.

[64] The question whether the object with a modified shape is patentable, differs from the question whether that object infringes on the existing patent. The first question relates to the extent that the object with the modified shape meets the patentability requirements of novelty, inventive step/non-obviousness and industrial application/utility. The second question relates to the extent to which the modified object falls within the scope of the existing patent and qualifies as a dependent invention. For more on different shape and patent scope, *see* Dolder and Faupel (2004), p. 393.

[65] *Cf.* EPC Guidelines G VII.5.3 (available at http://www.epo.org/law-practice/legal-texts/guidelines.html, last visited 7 April 2016). *Cf.* EPO, Technical Board of Appeal, Case 0002/83 (Simethicone Tablet), 15 March 1984 (available at http://www.epo.org/law-practice/case-law-appeals/pdf/t830002ep1.pdf, last visited 7 April 2016).

[66] *See* Remiche and Cassiers (2010), p. 111. *Also see* the following cases of the EPO's Technical Board of Appeal: T 21/81, T 192/82 (referring in this context to "analogous substitution"), T 130/89 (referring in this context to "similar use" and T 213/87 (available at http://www.epo.org/law-practice.html, last visited 18 October 2016).

scenario – an *existing* object in the *same material* – it must be admitted that, in view of the fact that the manufacturing method applied is a known technique and the resulting object is not novel, patent protection will not be available.

2.2 The Hobbyist

Most, if not all, activities attributed to the inventor could in principle also be carried out by an active hobbyist, and could be subject of patent protection. When discussing patentability, we took the view that the position of the active hobbyist can be subsumed under the position of the inventor. When discussing infringement, we decided to uncouple both positions, to allow the reader to better understand the various possible infringement acts at stake.

3 User Perspective: Infringement of Existing Patents

Let us now turn to the second face of Janus and inspect the perspective of a user of 3D printing technology. The point of interest for such a user would be to know whether and how he may use (components of) a patented 3D printing technology, or print a patented object making use of a 3D printer, without any risk of infringement, in other words, to identify his “freedom to operate”.[67]

In what follows, the general European and US rules[68] for direct and indirect infringement will be applied to 3D printing technology, with special attention given to private users.[69] To limit the scope of the analysis, the investigation will focus on literal infringement approaches with regard to products, more in particular the final product printed by a hobbyist or a consumer. We assume that the active hobbyist lawfully purchased or built[70] the hardware (printer, scanner, or parts thereof) he uses for printing the end product, and that he also lawfully acquired the materials used for printing the end product. We also assume that the manufacturers of printers, scanners or materials acted lawfully.[71]

[67] “Freedom to operate” is defined as a situation where “the commercial production, marketing and use of a product, process or service does not infringe the patent rights of others (‘third party patent rights’)”.

[68] The present section will primarily focus on the Unitary Patent route (Arts. 25–26 UPCA) as this route might become the most prevalent in the near future. For more details on national approaches, *see* Brinkhof and Kamperman Sanders (2015); Osterrieth (2015); Rennie-Smith (2015); Romet et al. (2015).

[69] For a legal and empirical infringement analysis under UK law, *see* Intellectual Property Office (2015a) *Study I*; Intellectual Property Office (2015b) *Study II*. For an infringement analysis (of CAD files) under Australian law, *see* Liddicoat et al. (2016).

[70] With respect for applicable open source license conditions.

[71] In other words, we will not scrutinize the potential role of manufacturers as indirect infringers, when supplying such items to the hobbyist for printing the patented object. According to Ballardini et al. (2015), p. 862 it is most likely that actions against these parties would fail anyway, either through lack of the required knowledge and intention (3D printers are generic, with many uses, and print whatever the CAD file tells them to print, including staple products), or because the product (e.g. raw material) would be considered as staple products and would only be qualified as indirect infringement under the extra condition that the supplier sought to induce infringement (*supra*).

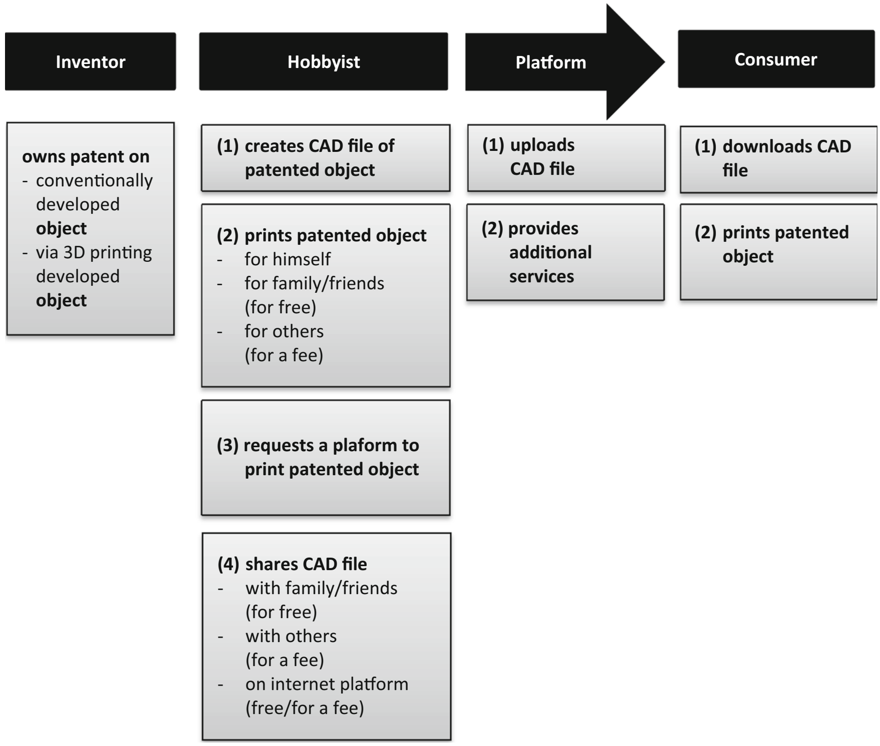

Fig. 3 3D printing and infringement: potential infringing acts from the (active) hobbyist, the online platform and the (passive) consumer[72]

In order to provide a better understanding on the reach of infringement theory and practice vis-à-vis patented products and on their possible interpretation in a 3D printing context, we have defined a set of scenarios (see Fig. 3).[73] When unfolding the scenarios we distinguish between two types of *users*, notably the active hobbyist and the (more) passive consumer, in an attempt to get away from the binary producer/consumer typology, and to give room for a more nuanced approach, where producer/hobbyist–prosumer/consumer all stand on a continuum from more to less (professional/industrial) innovation activity.[74] Furthermore, we distinguish between

[72] Fig. 3 starts where Fig. 2 ends, namely with the "Inventor" who received a patent for an object. Please note that the numbers of the acts in Fig. 3 coincide with the numbers of the subsections. *E.g.* "Hobbyist creates CAD file of patented object" is discussed in subsection 3.1.1.; "Platform (2) provides additional services" is discussed in subsection 3.2.2., etc.

[73] When we were conducting the research for our scenarios in the current paper, the foundational paper by Ballardini et al. (2015) (also setting forth scenarios) was not yet published. We decided to stick to our scenario approach and our initial set of scenarios, as we have distinguished *more* scenarios and believe that these extra scenarios may contribute to adding more depth and contrast to the current debate.

[74] By separately focusing on the active hobbyist and the consumer, our analysis differs from the scheme set forth by Bradshaw et al. (2010), p. 12, where the hobbyist and the consumer are subsumed. In their scheme the consumer designs/scans, shares and prints and no hobbyist is present. Even though such a scheme has the benefit of simplicity, we decided to distinguish between hobbyist and consumer to allow

two types of patented objects: on the one hand, conventionally developed artefacts, later reproduced by a hobbyist via 3D printing; and artefacts developed by making use of subtractive manufacturing and then reproduced by a hobbyist via 3D printing, on the other.

To make the scenarios somewhat more palpable, let us picture the inventor/producer who developed a lemon squeezer allowing to obtain juice directly from the citrus fruit via conventional techniques and who obtained a patent on this object (see Fig. 4).[75] An active hobbyist creates a CAD file from the lemon squeezer (see Fig. 3(1)). He then prints a dozen copies of the squeezer and decides to keep one squeezer for himself, to give away a few squeezers as presents to family members and to sell some squeezers to friends (see Fig. 3(2)). Alternatively, he requests a platform to print the objects (Fig. 3(3)). Later on, he decides to share the CAD file with some family members (for free) and with some of his friends (for a fee). At the end of the day, he wishes to give more exposure to his CAD file and decides to upload his CAD file onto an online platform such as Thingiverse (see Fig. 3(4)).[76] Or picture the inventor who developed and patented a housing for an electronic device, such as an iPhone,[77] and the housing is then recreated by an active hobbyist using 3D printing technology.[78]

Or let us imagine a sophisticated inventor who developed an implantable bone augment via 3D printing techniques and who obtained a patent on this object[79] (possibly also the producer/manufacturer). An active hobbyist then creates a CAD file from the bone augment and conducts the same acts as above. Even though the distinction between a conventionally made or a 3D printed patented object might

Footnote 74 continued
us to focus on yet another possible infringing act, namely the single act of downloading a CAD file (*see infra*, Sect. 3.3.1). Yet another distinction than the one set forth in the present article (inventor/producer – active hobbyist – passive consumer) is the one introduced by Bechtold (2016) disentangling the industrial 3D printing sector on the one hand, and the personal 3D printing sector on the other. As relevant as this distinction may be, in view of the detailed infringement analysis which is conducted in the present paper, we opt for a more fine-grained division.

75 *See* EP 2.698.084 for a “Device for obtaining juice directly from the fruit”, developed by Jordi Olucha Soler and Alberto Arza Moncunill, and granted to Lekué on 3 September 2014. Neither the patent description nor the patent claims refer to the method of making or to the material in which this device can be manufactured.

76 *See* https://www.thingiverse.com (last visited 12 October 2016).

77 *See* US patent 8.342.325, covering a basic iPhone cover developed by Gary Rayner and awarded patent protection to Treefrog Developments on 1 January 2013. Generally speaking, the patent relates to an apparatus for housing an electronic device with a touch screen interface, such as a digital tablet computer or a mobile telephone. Later on, iPhone covers were improved to also be waterproof, drop-proof and self-charging (*see* http://www.lifeproof.com/en-us/iphone-6s-plus/fre-power-for-iphone-6-plus-6s-plus/lppw-apl-iphp15.html, last visited 12 October 2016). These improved covers were equally protected with various patents (*see* http://www.lifeproof.com/en-us/intellectual-property.html, last visited 12 October 2016). For the sake of argument, it is not relevant which of the housing systems is reproduced by the hobbyist.

78 For other examples, *see* Wessing (2013) referring to some simple patented products that are capable of being produced by 3D printing, such as “plastic laboratory equipment with patented “twist to lock” sealing mechanism between parts”, which could be produced by 3D printing.

79 *Cf. supra* the international WIPO/PCT application WO2013170872 (A1) entitled “Implantable bone augment and method for manufacturing an implantable bone augment”, filed 14 May 2012.

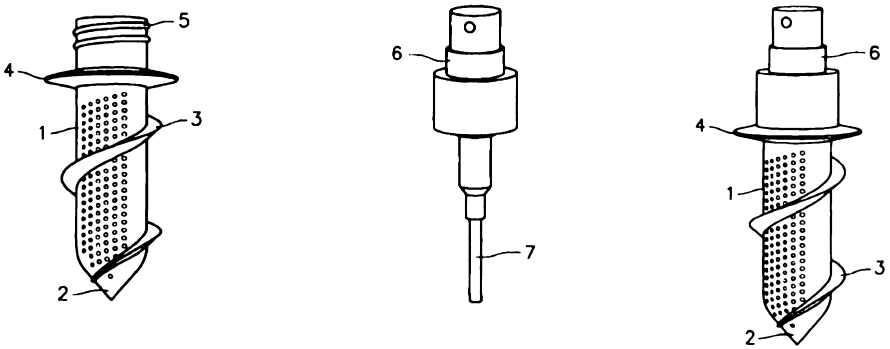

Fig. 4 Device for obtaining juice directly from the fruit (EP 2.698.084) (B1)

not play a decisive role in the context of *infringement* assessment, the distinction does have relevance in the context of *incentive* theories.[80]

3.1 The Hobbyist

3.1.1 Creating the CAD File

With the goal in mind to reproduce a patented object via 3D printing, two ways are available to create the necessary CAD file. Either the skilled hobbyist uses software[81] to independently digitally create the patented object from scratch, or the hobbyist uses a 3D scanner to scan the patented object. In doing so, he "reverse-engineers" the design of the patented object.[82]

Conventional scholarship, viewing the CAD file as mere data and thus as mere information, would claim that creation of the CAD file would not constitute *a direct* infringement, since it does not imply the "making or the using" of the patented object. "Making" or manufacturing of a patented object is generally understood to include the construction of the thing,[83] which is not the case here.[84] "Using" a patented object is understood as putting a patented object into service, in accordance with its intended functions,[85] which is not the case here either.

However, as explained earlier, some authors propose an alternative approach and argue that a CAD file must be considered to be more than just data. Where a traditional industrial blueprint was still miles away from the realization of the final object, arguably, a 3D printable CAD file could be considered practically the same

[80] *See infra.*

[81] *See supra.*

[82] *Cf.* Intellectual Property Office UK (2015b) *Study II*: Scanning technologies offer an alternative solution to creating digital content from existing physical objects – a technique commonly referred to as "Reverse Engineering".

[83] *Chisum on Patents* (2016). Part I. Chapter 16 – § 16.02[3][b].

[84] Doherty (2012), p. 360.

[85] *Chisum on Patents* (2016). Part I. Chapter 16 – § 16.02[4][b]. *Cf.* Brean (2013), p. 801; Doherty (2012), p. 360; Mimler (2013), p. 60.

thing as the physical product.[86] Therefore it is argued that the making of the CAD file should be equated with the making of the patented object and should be considered patent infringement.[87] This alternative approach has been criticized as "improper and inaccurate at the least".[88]

Does the simple creation of the CAD file by the hobbyist constitute *indirect* infringement? Indirect infringement under European law would take place if the hobbyist

1. supplies or offers to supply,
2. means,
3. relating to an essential element of the invention,
4. suitable and intended to put the invention into effect,
5. while he knew or should have known that such means are suitable and intended to put the invention into effect.[89]

It looks like the very first condition is not met in this particular scenario: as long as the hobbyist produces the scan for his own pleasure within the confines of his own home and does not share the file with others, he does not "supply".[90] The answer might change drastically in the scenario where the hobbyist distributes the file or puts the CAD file on an online website (*infra*).

3.1.2 Printing the Patented Object

There are several ways a CAD file-based object can be printed. The active hobbyist may turn to a specialized 3D print shop or cafe, he may decide to make use of a 3D printer in a community space,[91] he may send the CAD file to an on-demand 3D printing platform,[92] he may print the patented object on a bought 3D printer,[93] or he may choose to print the patented object on a self-made 3D printer.[94]

[86] Osborn (2014c). Various scientific authors support this position, *see e.g.* Gershenfeld (2012).

[87] Osborn (2014c).

[88] *See* Ballardini et al. (2015), p. 856.

[89] The breakdown of indirect patent infringement conditions in constitutional elements is always somewhat arbitrary. We opted for an enumeration based on the list of conditions set forth in AIPPI (2010). Bently and Sherman (2004), p. 532 opt for a three-fold catalogue; Ballardini et al. (2015), p. 857 prefer to slice up the conditions in eight sub-conditions, whereas Mimler (2013), p. 60 opts for a different, albeit also five-fold enumeration.

[90] *Similarly*, Ballardini et al. (2015), p. 855.

[91] For instance a FabLab, *e.g.* FabLab Leuven, Belgium (https://www.fablab-leuven.be/?q=node/17, last visited 5 April 2016) or FabLab Genk, Belgium (http://www.fablabgenk.be/, last visited 5 April 2016).

[92] For instance i-Materialise (*see* https://i.materialise.com/, last visited 5 April 2016), Sculpteo (*see* http://www.sculpteo.com/en/, last visited 5 April 2016), 3Dhubs (*see* https://www.3dhubs.com, last visited 5 April 2016).

[93] For instance a selective deposition modelling printer, such as the Makerbot Replicator (*see* http://www.makerbot.com/, last visited 5 April 2016).

[94] For instance a selective deposition modelling printer built from a DIY kit for self-assembly, or built from scratch, such as the Prusa Mendel RepRap printer (*see* http://reprap.org/wiki/Prusa_i3, last visited 5 April 2016).

Does the printing of a patented object by the hobbyist – starting from the self-created CAD file and without the permission of the patent holder – constitute *direct* infringement? In principle, anyone who uses a 3D printer to print an object encompassing all the features of the claimed object without permission from the patent holder would be directly infringing.[95] In the framework of an infringement analysis it does not really matter whether the initial patented object was developed by conventional means or by applying 3D printing techniques.[96]

Under European patent law, however, the so-called "private use exception" exempts a printed patented object that is only meant for strict personal use from constituting *direct* patent infringement, because acts done privately *and* for non-commercial purposes are exempted from patent infringement (Art. 27 UPCA).[97] Use which meets the cumulative[98] condition of private *and* non-commercial use qualifies as a valid exception from infringement under the three-step test of Art. 30 TRIPS Agreement.[99] Private use covers use in the private sphere (e.g. family, household, sports, games, entertainment).[100] Non-commercial use encompasses use that has no economic benefit and is performed without financial gain or profit.[101] So, if the hobbyist prints some extra copies of the patented object to give to family members, he would probably be shielded from infringement under the private use exemption. Printing specimens of a patented object to sell to acquaintances would probably no longer fall under the private use exemption. Conduct going beyond private and non-commercial use cannot be excused and will be considered direct infringement.[102] But where exactly can the line between legitimate and non-legitimate private use be drawn? What about a hobbyist who produces large quantities of a patented object and gives them away for free? Would that be shielded from direct infringement under the private non-commercial use exception? It has been suggested that on top of qualitative elements (business purpose or economic gain), quantitative factors (volume of production, circle of potential beneficiaries) should play a role as well in deciding on the applicability of the private use exemption.[103] Weighing both qualitative and quantitative factors requires a repeated and case-by-case analysis. Would mimicking the US approach and crafting a *de minimis* exception be worth considering as a more efficient way?[104] In contrast to the US, current European

[95] *Cf.* Weinberg (2010b), p. 8.

[96] As we have indicated earlier, even though the distinction between a conventionally made or a 3D printer made object does not play a role in the context of *infringement* theory, the distinction might well play a role in the context of *incentive* theories (*infra*).

[97] *Also see* WIPO (2014a). Similarly, Bradshaw et al. (2010), p. 27.

[98] *See* Haedicke and Timmann (2014), p. 791.

[99] De Jonge and Maister (2016).

[100] Haedicke and Timmann (2014), p 791.

[101] De Jonge and Maister (2016); Haedicke and Timmann (2014), p. 792. *Similarly*, WIPO (2014b), p. 5.

[102] Ballardini et al. (2015), p. 855.

[103] Senftleben (2006), p. 418, in his comment on the decision of the WTO panel from 17 March 2000 on patent protection of pharmaceutical products in Canada (WTO Document WT/DS114/R available at https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds114_e.htm, last visited 24 December 2016).

[104] On *de minimis* activity, *see Chisum on Patents* (2016). Part I. Chapter 16 – § 16.03[1]. For further thoughts on the expansion of the current personal use exemption, *see* WIPO (2014b). *Also see* Karapapa (2012).

patent law does not apply a *de minimis quantities* exemption, let alone a large quantities exemption. Or would transposing the common law doctrine of fair use to patent law be a meaningful step?[105] At this point in time, European case law and scholarship have not discussed questions relating to the private use exception in a comprehensive and decisive manner, let alone in the context of 3D printing. Further research is needed to examine thorny questions relating to (the control of) the number of (patented) replicated objects satisfying the private use exception in more depth.[106]

In the US, the private use exception does not exist. Therefore, the printing of a patented object could constitute the making of the protected invention and could be considered as a direct infringement under 35 USC § 271(a) even if the printed product is used in the private non-commercial sphere.[107] Although the private use exception does not exist in the US, the difference between the European and the US system must not be exaggerated. Where it is true that in theory, a US patent holder could hold the printing hobbyist (and also the printing consumer, see *infra*) liable for direct infringement, reasons of efficiency often discourage the patent holder to track every single direct infringer who has downloaded a certain CAD file from the Internet, especially if the infringement concerns low-cost 3D printed items.[108] Therefore, even if in the US it is in theory possible to file a claim against a private and non-commercial hobbyist (or consumer, see *infra*), only very few patent holders will find it worthwhile to do so. In that sense there exists a "natural private use exception" in the US.[109] Some authors even suggest to install an explicit private use exception in the US precisely to protect unknowing users of 3D printers from unintended patent infringement.[110]

It remains unclear to what extent the conduct of a hobbyist who does not "make" an existing patented object, but replaces parts or "repairs" a patented object, will be qualified as direct infringement.[111]

3.1.3 Requesting a Platform to Print the Patented Object

Does the printing of a patented object by a platform on the request of a hobbyist constitute *indirect* infringement? In other words, does the hobbyist

[105] On the application of the fair use doctrine in US patent law, *see* O'Rourke (2000); Strandburg (2011). On the application of fair use in the context of 3D printing, *see* Grossman (1990). On the transposition of the US fair use doctrine into European patent law, *see* Van Overwalle (2014).

[106] Inspiration might be found in the legislation and case law of Israel and the Philippines explicitly taking the scale of the activity into account (*see* WIPO (2014b), p. 6).

[107] Brean (2013), p. 788.

[108] Banwat (2013). For more, *see* http://lawitm.com (last visited 5 April 2016).

[109] Desai and Magliocca (2014), p. 1704.

[110] Desai and Magliocca (2014), p. 1716; Doherty (2012), p. 368.

[111] For a detailed analysis for the issue related to "making" versus "repairing" in general, *see* Bently and Sherman (2004), p. 523. For a detailed analysis of the make-repair issue as applied in 3D printing, *see* Ballardini et al. (2015), p. 853 ff; Wilbanks (2013); Intellectual Property Office UK (2015b) *Study II*, pp. 5–28.

1. supply or offer to supply,
2. means,
3. relating to an essential element of the invention,
4. suitable and intended to put the invention into effect,
5. while he knew or should have known that such means are suitable and intended to put the invention into effect?

By supplying the CAD file to the printer service in order to print the patented object for him, the hobbyist contributes to the infringement of the printer service. Indirect infringement may indeed arise in respect of the person or company – *in casu*: the hobbyist – who provides the CAD file to the printing service, as the printing service by printing out the object will put the patented object into effect without authorization, and might thus become a target for liability claims.[112]

3.1.4 Sharing the CAD File

Within a conventional view on CAD files (looking at CAD files as data), the sharing of the CAD file will not constitute a *direct* patent infringement as the subject of the action is data, not the patented object itself. When applying an alternative view on CAD files (equating CAD files with the physical object, *in casu* the patented object), the sharing of the CAD file might constitute direct patent infringement.

Does the sharing of the self-made CAD file by the hobbyist constitute an *indirect* infringement? Let us assess the various constitutional elements of indirect infringement one by one:

1. Does the hobbyist supply or offer to supply? It is quite clear that when the hobbyist shares the file directly or indirectly (via an online platform) to others he supplies.
2. Can the CAD file that the hobbyist created be qualified as a means? “Means” has been generally understood to refer to physical objects, having a tangible nature and not to simple and abstract instructions, which are not considered tangible in nature.[113] However, there seems no apparent objection to extend the concept of “means” to encompass software,[114] and one could imagine the concept to stretch out to digital works, such as CAD files.
3. Can the CAD file be considered an essential element? There is quite some divergence on the actual notion of “essential”, but there seems to be consensus that for the means to be an essential element of the invention, they must play a role in producing the “effect”. It is beyond doubt that providing someone with a kit of all tangible parts of a patented object may constitute an indirect infringement.[115] Likewise, it is beyond doubt that supplying a 3D printer, all necessary materials and a CAD file would equally constitute indirect infringement. But, what about providing someone with only a CAD file of a

112 *Cf.* Ballardini et al. (2015), p. 862, under (ii).

113 Mimler (2013), pp. 64–65.

114 Ballardini et al. (2015), pp. 858, 862 ff and the case law cited there.

115 Bradshaw et al. (2010), p. 27; *Rotocrop v. Gentbourne,* [1982] FSR 241.

patented object? Does the simple provision of a CAD file suffice to constitute indirect infringement?[116] Some authors believe so, as they deem the CAD file as such as being sufficient as a tangible, essential element of the invention that is likely to put the invention into effect.[117] However, uncertainty about this position creeps in again when it comes to defining whether elements that are not part of the claims of the patented object can amount to essential elements.[118] One could contend that the CAD file might be considered essential, even when no reference is made to a digital file in the claims of the patented object.

4. Is the CAD file suitable and intended to put the invention into effect? The file *is* definitely suitable, as others will be able to access the file and print the embedded patented object. Furthermore, it seems most probable that the file is also intended to put the invention into effect. Last but not least, placing a CAD file on a sharing platform may be considered as a supply that helps to print the patented object and thus put it into effect.[119]
5. Did the hobbyist know or should he have known that such means, notably the CAD file, are suitable and intended to put the invention into effect? It is most probable that the hobbyist knew that the CAD file was suitable to put the patented object to work and could facilitate infringement. The nature of the CAD file itself reveals that the creator of the CAD file knew or ought to have known that the CAD file could be suitable and intended to print the invention and thus infringe the patented object. Can the CAD file creator be excused from indirect infringement if he did not know and could not possibly have known that the printed object was actually patent protected? Some scholars argue that in today's minefield of very technical patents, it cannot reasonably be expected that every active hobbyist knows that an object is covered with patents. They conclude that if the hobbyist did not know or could not have known that the object was patent protected, knowledge is not present.[120] On the other hand, one might also contend that knowledge of the suitability to make an object suffices, and that knowledge about the actual patent coverage of the object at hand is not required to fulfill the knowledge condition.

All in all, the answer to the question whether sharing a CAD file by a hobbyist equates to indirect patent infringement is not straightforward. Some authors are inclined to think so,[121] but an opposite position has been supported as well, based on a diverging interpretation of the "knowledge" requirement.[122] But, at some point patent law will have to come to grips with this issue: 3D printing technology has catapulted patent law into the era of digitization. Whereas inventors traditionally

[116] Bradshaw et al. (2010), p. 27.

[117] Mendis (2013, 2014), p. 161.

[118] Ballardini et al. (2015), p. 859.

[119] On the exculpatory role of staple goods, *see* Bently and Sherman (2004), p. 532 (who talk about "staple commercial product exemption"). On the qualification of a computer, a 3D printer or glue as a staple good, *see* Mimler (2013), p. 66. *Also see* Weinberg (2010b), p. 13.

[120] Mimler (2013).

[121] *See* Ballardini et al. (2015), p. 862, under (i).

[122] Mimler (2013).

directed their patent claims to physical objects and have not sought to protect digital representations of physical products, patent owners may be on the cusp of their own digital patent war, much as music and movie industries had to battle digital copyright infringement.[123]

An open, remaining question is whether and to what extent the private use exception shields private sharing from indirect patent infringement. We tend to think that it does not, as it might ultimately enable others to print the patented object and put the patented object into effect.

3.2 The Online Platform

CAD files can be shared in many ways, one of which is putting the file on an online 3D printing platform (e.g. Thingiverse[124] or Shapeways[125]). Although these platforms do not create CAD files themselves, they allow skilled hobbyists to upload their CAD files on their website and thus make CAD files available to millions of viewers every year.[126]

3.2.1 Uploading the CAD File on Its Platform

Does an online platform commit *indirect* infringement when allowing a CAD file supplied by a hobbyist on the platform? Let's run through the various conditions set forth in European patent scholarship one by one again[127]:

1. Does the online platform supply or offer to supply?
2. Can the CAD file the hobbyist created be qualified as a means?
3. Can the CAD file be considered an essential element?
4. Is the CAD file suitable and intended to put the invention into effect?

The first, second, third and fourth requirement to be held liable for indirect infringement are clearly met: allowing a CAD file on an online platform may be

[123] Osborn (2014a).

[124] *See* https://www.thingiverse.com (last visited 12 October 2016). The design files in Thingiverse are primarily code base and subject to copyright protection. The rights in the content created by and individual designer rest with the designer, but Thingiverse encourages contributors to employ Creative Commons licenses and freely share their designs with others, conditioned on attribution of designed works. Thingiverse is claimed to be the first open repository for digital 3D designs. As the design files are free, but the printers cost money; the slogan among open source hardware businesses is: bits are free, atoms cost money (*see* West and Kuk 2014).

[125] *See* http://www.shapeways.com/ (last visited 18 October 2016). Shapeways allows purchasing or customizing of 3D printing objects at a reasonable price.

[126] *See* Phillips (2014).

[127] For the sake of the argument we will not examine whether online 3D printing platforms can be considered as "intermediaries" as discussed in Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society, *OJ L* 167, 22 July 2001 (the so-called InfoSoc Directive). The main reason is that it does not contain a clear-cut definition of the notion of "intermediary". Point 59 of the Preamble refers to services of intermediaries but does not really clarify the concept. A further reason is that the Directive seems to focus on the *passive* status of intermediaries, which, however, does not exempt them from intellectual property (IP) infringement, more in particular indirect IP infringement.

considered as a supply that helps to print the patented object and thus put it into effect. The most cumbersome condition is the fifth one.

5. Did the online platform know or should have known that the CAD file is suitable and intended to put the invention into effect? Some scholars argue that it is unreasonable to demand that an online platform is expected to check upon every upload whether the file infringes an existing patent. Hence, it seems only fair that sharing platforms may lawfully exonerate their liability through their terms and conditions. Such an exoneration clause would entail the absence of constructive knowledge regarding the infringing nature of a specific CAD file.[128] In contrast, after a takedown notice from an alleged patent holder, the online platform might be required to assess whether specific uploads infringe a patent. Other scholars equate online platforms hosting CAD files with internet service providers (ISPs) and claim they are to be held liable in the same way as intermediaries in the music and film industry.[129]

US scholarship has zoomed in here on the two different types of *indirect* infringement: contributory infringement (35 USC § 271c) on the one hand, and active inducement of infringement (35 USC § 271b) on the other.[130,131]

As regards the existence of *contributory* infringement, so far there have been no cases before US courts where sharing platforms like Thingiverse or Shapeways, involved in the sharing of CAD files, have been sued for patent infringement. Hence, we turn to case law on contributory infringement in general for guidance. Based on current case law, two arguments may be developed against contributory infringement in a 3D printing, patent dominated context. First of all, the so-called Staple Article of Commerce Doctrine often applies when it comes to the assessment of contributory patent infringement. According to this doctrine,[132] there is no contributory infringement if a technology could also be used for non-infringing uses. Translated to the realm of patent law and 3D technology, the Staple Article of Commerce Doctrine would mean that the manufacturer of the 3D printers, 3D scanners and 3D software, as well as the hosts of online sharing platforms, could not be held liable for contributory infringement as long as their activity has a substantial alternative legal use.[133] Secondly, even if the sharing platform received a cease-and-desist letter from an alleged patent holder, it is not yet certain that the platform risks liability for contributory infringement. In the past, the US Supreme Court took a restrictive view of the meaning of "component" necessary.[134] In *Microsoft Corp. v.*

[128] Mimler (2013), p. 66.

[129] Ballardini et al. (2015), p. 862 under (iii).

[130] *See supra* and the references to *Chisum on Patents* (2016). *Also see* Brean (2013), pp. 783–784; Doherty (2012), p. 360.

[131] For the sake of the argument, we will not examine the intricacies of the Digital Millennium Copyright Act (DMCA) as applied in several famous cases concerning copyright law. For more, *see* Finocchiaro (2013).

[132] *See supra,* and the references to *Chisum on Patents* (2016). *Also see* Brean (2013), pp. 783–784; Doherty (2012) p. 360.

[133] In the same line, Finocchiaro (2013), p. 491.

[134] Brean (2013) p. 796.

AT&T Corp., the Court held that software is not, until it is expressed on a computer readable medium, a component. Software *in abstracto* is mere information. The Court set forth that if Congress would have considered the provision of abstract information sufficient for a contributory infringement, it would have written so in its legislation, notably in 35 USC § 271.[135] The US Supreme Court thus seems to distinguish abstract instructions, from material or physical components of a patented invention.[136] Since the CAD file is not software, but data, could it not be argued that the reasoning in the Microsoft case applies *a fortiori*? However, even if the CAD file would be considered a component of a patented invention, the question whether it would be considered a *material* component in the sense of 35 USC § 271(c) is doubtful.

As regards the occurrence of indirect *active* inducement, the possibility that online platforms will be held liable under 35 USC § 271b is rather limited,[137] since active inducement requires the active encouragement to engage in infringing activities with the knowledge that the induced acts constitute such infringement.[138] Online 3D printing platforms such as Thingiverse or Shapeways do not usually actively direct users towards infringing content on their platform. Merely allowing CAD files from patented products on their website will probably not be considered a sufficient active encouragement to engage in infringing activities.

Finally, for both the contributory infringement and active inducement scenarios, the US Supreme Court held in *Global Tech Appliances v. SEB*[139] that indirect infringement requires actual knowledge of both the existence of the patent *and* the fact that a certain activity infringes upon that patent. For most online sharing platforms, such required knowledge of the infringing character of the final prints using their CAD files is missing. Sharing platforms explicitly provide in their terms and conditions that the users who upload their CAD file are responsible for their uploads. As such, sharing platforms explicitly attempt to avoid any knowledge of potentially infringed patents or infringing behavior. Plaintiffs will have to establish that the online platform had knowledge of the underlying patent *and* the infringement made possible by its provision of the CAD file. It is thus safe to say that, as long as the sharing platform did not receive a takedown request,[140] and if it did not remain willfully blind towards possible infringing content on its site,[141] the platform cannot be held liable for any indirect-based infringement under US law.

Further research is needed to see whether and to what extent the US analysis can be translated to the European scene, and the application of Art. 26(1) and (2) UPCA (contributory and induced infringement).

[135] *Microsoft* 550 U.S. at 451.

[136] Brean (2013), p. 799.

[137] Brean (2013), p. 793.

[138] Brean (2013), p. 793.

[139] *Global-Tech Appliances, Inc. v. SEB S.A.*, 131 S.Ct. 2060, 2068 (2011).

[140] Takedown requests are not yet possible under the DCMA, but may be possible under a Digital Millennium Patent and Trademark Act (DMPA). *See* Doherty (2012), p. 365; Desai and Magliocca (2014), p. 1713; Osborn (2014c).

[141] Doherty (2012), p. 361.

3.2.2 Providing Additional Services

Does an online platform commit infringement when, apart from hosting a CAD file, it provides additional services, such as customizing the CAD file, printing the patented object or shipping the patented object to customers? It has been argued that *direct* infringement may take place if the platform prints the patented object and/or ships them. *Indirect* infringement may arise if online platforms both host and customize.[142]

3.3 The Consumer

3.3.1 Downloading the CAD File from the Online Platform

Rather than scanning an object for 3D printing purposes or designing a CAD file from scratch, the consumer envisaged here mainly downloads a CAD file. It remains to be seen to what extent the simple downloading of a CAD file constitutes an infringement.

3.3.2 Printing the Patent Protected Invention

It is crystal clear that the printing out of a patented object constitutes *direct* infringement, unless of course it is restricted to personal and non-commercial use in Europe.[143]

4 Conclusion

4.1 Safeguarding of Patentability and Infringement Theories

The central question the present paper addresses is whether and to what extent the emergence of 3D printing technology urges us to rethink patent law. Is the upswing of 3D printing upending the patent system? Is patent law "likely to be disrupted by 3D printing"?[144] The present paper investigates the relationship between 3D printing and patenting from a twofold, Janusian perspective. First, the paper examines the relationship from the perspective of the inventor and studies the patentability of the various elements in a 3D printing process. Second, the paper looks at the interface from the perspective of a user and investigates the infringement of patented objects – developed by conventional or 3D printing technologies – which are reproduced by making use of a 3D printer.

As to the first, patentability perspective, the paper concludes that the upswing of 3D printing does *not* put into question the principles and rules applying to the coming into *existence* of patents: 3D printing does not upset prevailing theories and

[142] Ballardini et al. (2015), p. 862 under (iii).

[143] For the arguments, *see supra.*

[144] Ballardini et al. (2015), p. 851.

practices relating to patentable subject matter, nor does it trigger prevailing patentability requirements.[145]

The one issue which escapes this conclusion might be the CAD file, and the controversial discussion to qualify CAD files as inventions. So, on second glance, we do contend that digitized production and fabrication enabled by 3D printing *does* challenge the foundational type/token distinction in patent law and fuels the debate on the delineation between the abstract/concrete object of IP. Although the type/token ontology has been addressed in the software area[146] and has been discussed in the physical world with the upsurge of human genetics and biotechnology,[147] reflection in the area of 3D printing has just started.[148] An in-depth and broad analysis of the impact of digital fabrication on the traditionally accepted types/token paradigm is missing at present. Future research should look into the impact of digitization and new modes of production on the foundational binary ontology in patent law and address the question whether and how IP law in general, and patent law in particular, should re-cast the binary ontology to resonate the changes following from digitized modes of production.

As to the second, infringement-oriented perspective, the paper recognizes that the owner of a patent may find it difficult in practice to enforce his patent against an active hobbyist who creates and shares his CAD file and subsequently prints the patented object, or against an online 3D printing platform which allows CAD files on its platform, or against a consumer who downloads a CAD file and prints a patented object at home. This being said, the paper nevertheless concludes that 3D printing does *not* fundamentally question principles revolving around the *exercise* of patent rights: 3D printing does not turn prevailing theories on scope of rights or on direct and indirect infringement upside down, but rather offers an opportunity to apply these theories with more nuance and precision.

4.2 Major Challenge of Enforcement Theory and Practice

Rather than completely challenging the very *essence* of patentability and infringement theories, perceived problems with 3D printing seem to relate to the *scale* of infringement, resulting from the eminent use of CAD files and their decentralization effect. In other words, 3D printing mainly seems to challenge current instruments to adequately address widely dispersed infringement and triggers problems of effective and efficient enforcement,[149] rather than of patentability or infringement sensu stricto.

Looking at the enforcement issue from a conceptual-theoretical angle, we argue that the current patent paradigm *may* well be challenged. Patent law originally relies on the premise that the cost of infringement is relatively high and that infringement is often centralized in the buildings of well-known competitors. Such

145 Similarly, Bechtold (2016).

146 Peukert (2016).

147 Godt (2007).

148 Osborn (2014c).

149 Similarly, Bechtold (2016); Desai and Magliocca (2014); Hornick (2016).

a view is no longer tenable when 3D printing technology is within reach of vast numbers of users/consumers. The upsurge of 3D printing, and in particular the use of digital files allowing large scale infringement, *does* challenge the foundational premise of centralized, singular infringement in patent law, allowing as it does decentralized, frequent and low-cost infringement leading to interesting comparisons with (digital rights problems) in copyright.[150] The large scale on which infringement may materialize and the remedial gap it entails will have undeniable consequences for the innovation incentive – the commonly accepted consequentialistic underlying rationale of patent law[151] – as it may ultimately jeopardize the innovation incentive for the development of new and inventive 3D printing artefacts. If 3D printing becomes generally available to consumers printing patented objects on a large scale at home and if enforcement options for patent holders remain limited, only few inventors will be inclined to further invest time and money in the development of 3D inventions. Rather than the individual profit of a single patent holder, the innovation incentive as a main objective of the patent system would be at stake.

On the other hand, looking at the enforcement issue from a more practical perspective, thoughtful observers have argued that while inventors were successful in creating new technologies and winning patents, the technology often faced a long, slow road to win widespread adoption.[152] One may argue that the remedial failure will only emerge if three conditions are fulfilled simultaneously: first, 3D printing technology extends beyond a purely professional use and becomes widely available to hobbyists, consumers and other non-commercial tinkerers; second, these actors use 3D printing technology to design and print highly innovative, patentable artefacts; and third, these actors not only print patented objects, but also share related CAD files over the Internet.

With regard to the *first* condition, literature is divided as to whether the technology of 3D printing will ever reach the level of full-scale consumer availability. A first stream of authors claims that 30 years after its introduction as an industrial, alternative manufacturing technology, 3D printing has now reached the point where private individuals may print complex engineering parts from CAD files, which are shared through the Internet, at home.[153] They support the scenario that we are heading towards a world in which consumers will not buy products from producers, but only download the digital design, customize it and print it at home. The uses they have in mind vary from spare parts, to hobby items, to tailored MP3

[150] It has been argued that just like what happened with copyright in the music industry a decade ago, users/consumers will cease to pay for patent protected creative inventions if the (CAD) designs are freely available on the Internet, and producers will desperately try to protect their IP. *Cf.* Osborn (2014c); Hornick and Roland (2013).

[151] *See* Van Overwalle and Van Zimmeren (2009) and the references cited therein.

[152] *See* West and Kuk (2014) identifying six broader categories of limiting factors. As with personal computers, penetration of the consumer market began with the early adopters in the hobbyist market, termed the "maker movement" at the time. *Also see* Anderson (2012).

[153] Bradshaw et al. (2010), p. 11; Finocchiaro (2013), p. 473; Doherty (2012), pp. 356–358; Desai and Magliocca (2014), p. 1691; Brean (2013), p. 771; Mimler (2013), p. 55; Harrison (2013); Mendis (2013, 2014), p. 158; Anderson and Sherman (2007), p. 283.

player attachments and fashion accessories.[154] As the key patents covering 3D printer techniques (hardware and methods) are about to expire,[155] 3D printers will be manufactured in large numbers by mass production companies. Competition in the 3D printer industry will rise, prices will drop, open source initiatives will become more important and everyday consumers will have access to 3D printing technology at a low cost.[156] And even if consumers are not interested in making a printer (e.g. an open source RepRap printer) or buying one (e.g. a desktop Makerbot printer), sufficient alternatives exist to print in community spaces (e.g. FabLabs) or at on-demand 3D printing platforms (e.g. Materialise, Sculpteo, 3Dhubs).[157] Some authors even go one step further and consider the 3D printing technology as only one example of a broader and more fundamental Copernican revolution: the democratization of manufacturing.[158] A second strand of authors is more reluctant in tone and argues that 3D printing is still at an early stage of widespread commercial use,[159] or as a hobbyist-driven enterprise with a high barrier to entry.[160] These authors claim that the technical knowledge necessary to operate a 3D printer together with the technological disadvantages still form a threshold preventing the everyday consumer from using 3D printers.[161]

With regard to the *second* condition, that actors use 3D printing technology to design and print highly innovative, patentable artefacts, it has to be admitted that today's consumer-affordable printers do not (yet) have the precision to print complex, high-tech inventions in different materials. However, it is beyond doubt that future printers will gain accurateness, which might lead to the creation of more genuinely innovative artefacts meeting patentability requirements[162] on the one hand, and – if those printers decrease in price – more printing at home, thus more infringement on the other.[163]

The *third* condition, that CAD files are shared over the Internet, is already a reality.[164] The way in which CAD files are currently uploaded, shared and downloaded from sites like Thingiverse or Shapeways can easily be compared with

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154 Bradshaw et al. (2010), p. 12.

155 Doctorow (2013).

156 Doctorow (2013).

157 Mota (2011), p. 280.

158 Mota (2011), p. 279. Similarly, Gershenfeld (2012); Hornick (2016).

159 Finocchiaro (2013), p. 478; Weinberg (2010b). Similarly, Intellectual Property Office UK (2015a) *Study I*: "[…] in view of the increased rise in online platforms, it is suggested that the number of intellectual property issues in relation to 3D printing will concurrently grow. However, at the moment it is not widespread and as such does not give rise to major concern"; Intellectual Property Office UK (2015b) *Study II*, stating: "In conclusion, this research would suggest that it is unlikely that additive manufacturing will present significant challenges to the UK's existing intellectual property framework over the next ten years. The limitations of the technology are substantial – especially with regard to consumer-level technology – and this will hinder widespread adoption within this time frame".

160 Hanna (2011).

161 Finocchiaro (2013), p. 489.

162 *See supra* for some concrete examples.

163 Mimler (2013), p. 55.

164 Mota (2011), p. 282; Finocchiaro (2013), p. 475.

well-known peer-to-peer services like Napster and the (former) Pirate Bay in the entertainment industry.[165]

So, even though there is no unanimous answer (yet) as to the actualization of the first condition, it is clear that the scenarios developed in the present paper may well extend beyond the mere hypothetical and may become reality. Thoughtful scholars have come up with a variety of solutions to deal with the anticipated legal implications of 3D printing, encompassing public ordering initiatives, such as legislative action introducing some sort of infringement exemption for 3D printing in the home in the US,[166] a completely new Digital Millennium Patent Act,[167] or new institutional frameworks enhancing the finding of relevant prior art.[168] In addition, private ordering tools have been suggested, such as new licensing models,[169] or new business models. One of the alternatives for inventors (producers) owning patented objects lies indeed in further embracing 3D printing technologies, rather than rejecting them: a practical response to the potential remedial gap in 3D printing may well be the design of new business models.[170] Smart producers could change their business model and counter free sharing and downloading of CAD files of patented objects by offering lower prices for single items, by guaranteeing file safety over corrupted or malfunctioning files, by ensuring easy access to CAD files, etc. Another competitive advantage of a new business model could be consumer safety and consumer liability: "If you buy your CAD file with us, we guarantee product quality and safety and accept (higher) liability in cases of malfunctioning". In this way, (higher) consumer liability would be turned into a competitive advantage for professional producers offering certified CAD files, rather than "unauthorized" versions offered by hobbyists and online platforms. Further development of the technology might also solve several of the issues discussed above and further research on secured connections between the servers of businesses selling their CAD files and consumer 3D printers might be most welcome. By encrypting the CAD file and sending it directly, not to the consumer but to the (leased) printer, CAD files could be better protected from being copied or shared.[171]

4.3 Testbed for Cooperation

Next to further exploring public and private ordering tools to deal with the digitization of patent law and the decentralization of infringement, a totally different

165 *See* Desai and Magliocca (2014), pp. 1691–1719; Finocchiaro (2013) p. 475.

166 *See* Desai and Magliocca (2014), pp. 1691–1719; Holbrook and Osborn (2015).

167 *See* Doherty (2012).

168 *See* Doherty (2012).

169 *See* Hornick (2015).

170 In the same sense, Hornick (2016); Weinberg (2010b). For some seven concrete suggestions, see Bechtold (2016).

171 *Cf.* the recommendation in a recent report from the Intellectual Property Office to check out the business model of companies such as Authentise (www.authentise.com, last visited 8 July 2016), Secure3D (http://www.secure3d.com/, last visited 8 July 2016) and ToyFabb (http://www.toyfabb.com/, last visited 8 July 2016), which allow the secure streaming of 3D CAD files, adopt a "pay-per-print" business model and protect intellectual property (Intellectual Property Office UK (2015a) *Study I*).

aspect which might deserve further attention is the increasing tendency for co-creation. Co-creation between individual artists or co-editing between individual writers, and the problems of co-authorship this entails, have been the object of study in copyright scholarship. Co-invention between commercial firms or firms and universities, and the resulting problems of co-ownership have been examined by patent law scholars as well.[172] The upsurge of 3D printing, and the collaboration between individual designers and industrial firms[173] or between user innovators and commercial firms[174] has equally led to challenges relating to co-ownership. It remains to be seen to what extent the co-creation process is different in a 3D printing context, and to what degree the related co-ownership issues are distinct from these problems in other technological co-creation domains making use of IP.

4.4 Testbed for Sharing

Last but not least, future research may also explore non-proprietary approaches to 3D printing technologies in more depth. While many 3D printing inventors or companies see their successful applications as a commercial competitive advantage and opt for patents,[175] other developers are committed to a non-proprietary strategy and apply the open source philosophy to hardware.[176] It has been argued that the real breakthrough on the consumer market came from the open design RepRap Project announced in 2005.[177] The RepRap appealed to do-it-yourself (DIY) hobbyists – referred to as "makers" or "hackers" – and led to the widespread diffusion of the 3D printing technology.[178] Hardware in general and 3D printing in particular may be ideal playgrounds to test new and imaginative open source and copyleft-type approaches in technical areas going beyond information technology and biotechnology, and challenge open patent and open design models for physical products in highly technological fields.[179]

[172] Gorbatyuk et al. (2016).

[173] *See e.g.* the Co-Creation Lab at Materialise (*see* http://manufacturing.materialise.com/co-creation-lab, last visited 26 April 2016).

[174] Bechtold (2016).

[175] Ballardini and Ituarte (2016).

[176] *See* Bechtold (2016); Gershenfeld (2012); Söderberg (2013); West and Kuk (2014). A highly controversial case relates to MakerBot, founded in 2009 and acquired by Stratasys in 2013. MakerBot initially started as an open source initiative, with a payable assembly kit to construct the Cupcake printer and freely available printer designs using GNU GPL licenses. However, gradually Makerbot adopted a closed strategy, including proprietary hardware – most notably the Replicator 2 printer – components and software applications (for more details, *see* West and Kuk (2014)). This closed strategy resulted in some high-level patent infringement lawsuits, notably between Stratasys and Afina, the importer of a low-cost Chinese fusion deposition modelling printer (for some critical comments, *see* Weinberg (2013)). For a more recent update on the *Stratasys v. Afina* case, *see* a press release from Stratasys from 15 June 2015 (Stratasys successfully defends validity of fused deposition modeling patents, available at http://investors.stratasys.com/releasedetail.cfm?ReleaseID=917703, last visited 5 August 2016).

[177] *See* http://www.reprap.org/ (last visited 24 May 2016).

[178] Bechtold (2016); West and Kuk (2014).

[179] *See e.g.* Moilanen et al. (2015); Van Overwalle (2015). For a comparison with similar research in the robotics field, *see* Cooper (2013).

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