Introduction

They are lined up by the hundreds in the factory, working with steadfastness and precision. They do not take breaks, and yet they don't get tired or make mistakes. They don't complain about working conditions or bargain for higher pay. They don't require much supervision – in fact, there is only one supervisor for the whole factory.

Of course, these workers are not humans. They are 3D printers.

3D printers build objects layer by layer, in contrast to traditional manufacturing processes like molding, casting, or sculpting. Simply put, 3D printers use bits to print atoms; the bits are the digital files that describe the object, and the atoms are the tangible objects made from the digital files. Much like a 2D paper printer deposits a layer of liquid ink, 3D printers create thin, sliced layers of an object. But instead of stopping at one layer, the 3D printer stacks layer upon layer until a 3D object is built, somewhat like how a brick wall is made. 3D printing is known by industrial users as additive manufacturing and rapid prototyping, among other terms, but the term 3D printing has captured the public's imagination and is here to stay.

3D printing technology is revolutionizing design, manufacturing, and innovation processes and is opening doors to new manufacturing possibilities. It was the second fastest growing technology between 2013 and 2017 as measured by published patent application growth rate, faster than machine learning (artificial intelligence), autonomous vehicles, and aerial drones.[1] By just about any metric, the industry has been growing at a dizzying pace. Revenues for the industry as a whole topped $7.3 billion (US billion) in 2017, and

[1] Michael Petch, *Interview: New Study of 3D Printing Patents Reveals Second Fastest Growing Technology of 2017*, 3D Printing Industry (Jan. 10, 2018, 5:14 PM), https://3dprintingindustry.com/news/interview-new-study-shows-3d-printing-second-fastest-growing-technology-2017-127179/. Only e-cigarettes experienced a faster growth rate.

enjoyed annual growth of 21 percent in 2017, 17.4 percent in 2016, and 25.9 percent in 2015.[2]

Scientific publications relating to the technology have increased at about 40 percent annually from 2002 to 2016.[3] In 1996, around 60 patents related to 3D printing were issued, but by 2016 that number was over 600.[4] And the rate of growth is increasing. The number of patents in the area almost doubled between 2014 and 2016.

Several factors are contributing to increased growth. First, researchers, entrepreneurs, and investors have responded to the technology's growth and market opportunities.[5] At the industrial level, the latest 3D printers serve as cost-effective final product manufacturers for a variety of goods. At the consumer level, sales of desktop 3D printers are accelerating, and their capabilities are rising.[6]

Second, a number of the pioneering patents covering some basics of 3D printing technology have expired or will soon expire.[7] As this book will discuss, patents can be great rewards for invention, but they can also block subsequent development. As key patents expire, the world is free to make, use, and sell the technology, which helps not only to drive down costs, but also to catalyze technological improvements. In the words of one industry expert, when a key patent on a plastic extruding 3D printer expired in 2009, "everything exploded."[8]

2 TJ McCue, *Wohlers Report 2018: 3D Printer Industry Tops $7 Billion*, FORBES (June 4, 2018, 4:03 AM), www.forbes.com/sites/tjmccue/2018/06/04/wohlers-report-2018-3d-printer-industry-rises-21-percent-to-over-7-billion/#27f2e4002d1a.

3 Felix W. Baumann & Dieter Roller, *Additive Manufacturing, Cloud-Based 3D Printing and Associated Services – Overview*, 1 J. MATERIALS PROCESSING & MFG SCI. 1, 11 (2017).

4 John Hornick, *3D Printing Patent Landscape*, 3D PRINT.COM (Jul. 17, 2017), https://3dprint.com/181207/3d-printing-patent-landscape/.

5 *See, e.g.*, Jing Li et al., *The Current Landscape for Additive Manufacturing Research*, 2016 ICL AMN REPORT 1, 13–36 (2016), https://spiral.imperial.ac.uk/bitstream/10044/1/39726/2/The%20current%20landscape%20for%20additive%20manufacturing%20research_AMN.pdf; Charlie Taylor, *Spending on 3D Printing Set to Explode over Next Five Years*, THE IRISH TIMES (Aug. 9, 2018, 5:00 AM), www.irishtimes.com/business/technology/spending-on-3d-printing-set-to-explode-over-next-five-years-1.3589789.

6 *See* Samuel Adams, *Half Million 3D Printers Sold in 2017 – On Track for 100M Sold in 2030*, 3D PRINTING INDUSTRY (Apr. 6, 2018, 11:46 AM), https://3dprintingindustry.com/news/half-million-3d-printers-sold-2017-track-100m-sold-2030-131642/(reporting 52% year-on-year growth in desktop 3D printer sales).

7 John Hornick & Dan Roland, *Many 3D Printing Patents Are Expiring Soon: Here's a Round Up & Overview of Them*, 3D PRINTING INDUSTRY (Dec. 29, 2013, 12:04 AM), https://3dprintingindustry.com/news/many-3d-printing-patents-expiring-soon-heres-round-overview-21708/.

8 Christopher Mims, *3D Printing Will Explode in 2014, Thanks to the Expiration of Key Patents*, QUARTZ (July 21, 2013), http://qz.com/106483/3d-printing-will-explode-in-2014-thanks-to-the-expiration-of-key-patents.

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More Information

It is no coincidence that around 2009 desktop printers costing less than a thousand dollars became available.[9]

A third reason for growth is that many important aspects of the technology are being developed in an open source model, which allows collaborative learning and development. The best-known example of open source in 3D printing is the University of Bath's RepRap project, which sought to develop a basic, open source 3D printer that could print parts to make a copy of itself.[10] The RepRap development community is made of hundreds of developers all over the world sharing designs.

Fourth, the technology has several complementary parts, each of which is being deliberately developed. Improvements in 3D printer hardware, 3D printing software, and 3D printable materials all feed into a frenetic cycle of innovation. The results are stunning.

3D printers can manufacture objects in a variety of materials, including myriad plastics, metals, foods, and human tissues. They can print everything from microscopic objects to buildings, prototypes to finished goods, simple blocks to machines with moving parts. They can print statues, jet engine parts, shoes, and functional human organs.

Even beyond what can be printed, the technology's most fundamental impact is the bidirectional path it creates between physical objects and their digital counterparts. This phenomenon, which I call "physitization," challenges assumptions about tangibility and about laws constructed with physical objects in mind. It is no overstatement to say that just about every challenging intellectual property (IP) issue surrounding 3D printing technology is connected to the physitization phenomenon. Because of physitization, manufacturing is democratized, commoditized, and largely anonymized. Much of the economic value associated with goods shifts from their physical embodiment to their digital embodiment. This book explores the implications of these changes.

NOVEL LEGAL QUESTIONS

Though the technology dates back to the 1980s, it erupted into the public sphere beginning around 2012, spurred by technological advances, reduced costs, media attention, and investment opportunity.[11] Joining the media

9 Terry Wohlers & Tim Gornet, *History of Additive Manufacturing*, WOHLERS REPORT 2014 1, 15 (2014), http://wohlersassociates.com/history2014.pdf.

10 Rhys Jones et al., *RepRap – The Replicating Rapid Prototyper*, 29 ROBOTICA 177, 177 (2011).

11 *See, e.g.*, HOD LIPSON & MELBA KURMAN, FABRICATED: THE NEW WORLD OF 3D PRINTING (2013); *Special Report: A Third Industrial Revolution*, THE ECONOMIST (Apr. 21, 2012), www.economist.com/node/21552901.

attention, recent academic interest in 3D printing has been intense. Several works have explored legal ramifications of the technology,[12] but each suffers from limitations. Some are excellent but relatively narrow in focus, others misunderstand key aspects of the technology, and still others misunderstand where the new questions arise. Moreover, no work has covered IP law and policy in depth and holistically. This book accomplishes that task.

I will focus on the aspects of IP law that 3D printing technology stresses. And the technology will stress the law, just like past innovations did. The advent of airplanes wiped away centuries of law positing that ownership of a plot of land extended vertically to the heavens. Software continues to confound aspects of patent and copyright law.

With 3D printing, the challenges can be doctrinal, such as whether 3D printable files constitute patentable subject matter. They can also be normative, like whether 3D printing technology lowers the costs of innovation so much that patent rights should be weakened or abolished, or whether instead patent rights should be strengthened in the face of digital appropriations of patented goods. Should copyright law, which is geared toward expressive and aesthetic works, protect 3D printing files that will manufacture purely utilitarian articles?

This book avoids discussing the routine applications of law to the technology. For example, it goes without saying that new and nonobvious 3D printers can be patented. It also avoids legal issues that may be difficult – such as whether a particular 3D shape can be protected by trademark law or whether a particular object is creative enough to garner copyright protection – but that are no more difficult merely because they involve 3D printing technology. Instead, the book seeks to analyze technological nuances that raise novel challenges for IP law. It unpacks those areas doctrinally and theoretically and offers ideas for a way forward through each conundrum.

[12] Some of the most relevant early publications exploring 3D printing and IP include Simon Bradshaw et al., *The Intellectual Property Implications of Low-Cost 3D Printing*. 7 Scripted 5, 29 (2010); Deven R. Desai & Gerard N. Magliocca, *Patents, Meet Napster: 3D Printing and the Digitization of Things*, 102 Geo. L.J. 1691 (2014); Timothy R. Holbrook & Lucas S. Osborn, *Digital Patent Infringement in an Era of 3D Printing*, 48 U.C. Davis L. Rev. 1319, 1353–56 (2015); Michael Weinberg, *It Will Be Awesome If They Don't Screw It Up*, Public Knowledge 12 (2010), www.publicknowledge.org/files/docs/3DPrintingPaperPublicKnowledge.pdf. In addition, legal scholarship has also looked at areas outside of IP law. *See, e.g.*, Nora Freeman Engstrom, *3-D Printing and Product Liability: Identifying the Obstacles*, 162 U. Pa. L. Rev. Online 35 (2013) (discussing the possible impact of 3D printing on the future of products liability law); Lucas S. Osborn, *Regulating Three-Dimensional Printing: The Converging Worlds of Bits and Atoms*, 51 San Diego L. Rev. 553 (2014).

Indeed, digitization has impacted several industries before. Most notably, people previously bought music in some physical form: first as sheet music, then as records and tapes. Beginning in earnest in the 1990s, music was digitized, a phenomenon that struck fear in the hearts of the music industry's stakeholders. Individuals could copy MP3 files costlessly, and, with the roll-out of the internet, "share" those files with the world for copying. Why buy music when you can download it for free? A similar question will now arise with respect to numerous digitized objects and machines.

If music, movies, photographs, and books have already survived digital disruption, one might ask whether anything needs to be said about 3D printing. Is it just more of the same? This book will show why 3D printing raises many issues beyond those already settled by previous rounds of digitization.

Most fundamentally, the digitization of music, movies, photographs, and books all implicated primarily one branch of IP law: copyright. 3D printing brings digital disruption to patent law, trademark law, and design law in addition to copyright law. Whereas copyright law is generally well prepared for 3D printing's challenges – with an important exception – other branches of IP are not. Even copyright law will face a unique challenge: how to treat digital versions of physical objects when the physical object is not protected by copyright law. Design law has a similar question to answer.

Patent law, including utilitarian and design patents, faces several difficult questions. Which kinds, if any, of 3D printable files are eligible for patenting? Does the making, using, and selling of those files constitute direct patent infringement? Trademark law also must contend with disruptions. Trademarks have traditionally indicated the source of manufactured goods. But 3D printing technology commoditizes manufacturing and separates design from manufacturing. It also bifurcates questions of source: those related to source of the physical object and those related to source of the file.

This book analyzes these and other questions doctrinally but recognizes that doctrine alone cannot supply the answers. They are inescapably matters of policy, and this book analyzes them as such.

OVERVIEW

I write for a wide audience. This book aims to be helpful not only to lawyers, lawmakers, and judges, but also policymakers, technologists, and artists. It considers IP laws in numerous jurisdictions, with a strong focus on the United States and the EU/Europe, but also including other large jurisdictions like Australia, Canada, and Japan.

Chapters 1 and 2 introduce key aspects of 3D printing technology. Chapter 1 describes the technology's capabilities and its limitations. It also explains the important concept of physitization, which is the term I use to describe the bidirectional path that 3D printing creates between physical and digital versions of objects.

Chapter 2 tackles a key technological concept – the various file formats used in the design and manufacturing process. Collectively, I refer to these files as digital manufacturing files (DMFs). 3D printing technology shifts economic value from tangible objects to DMFs. Understanding how IP law will apply to 3D printing requires an understanding of these file formats because the law will treat each format differently. The chapter also describes the various kinds of 3D printers on the market and important complementary technologies, like 3D scanners. Finally, it describes the many participants in the IP ecosystem.

Chapter 3 provides a short overview of IP law for those not familiar with it. It introduces the major concepts of patent law, copyright law, trademark law, and design patent law, focusing on internationally agreed upon frameworks and treaties such as the Berne Convention, the Paris Convention, and TRIPS. It also walks readers through fundamental concepts like territoriality, validity, direct and indirect infringement, and remedies.

Chapters 4, 5, and 6 concern patent law. Chapter 4 analyzes the doctrine of patentable subject matter in American, European, and Japanese patent jurisprudence. It applies that jurisprudence to 3D printable files to demonstrate why only one of the three DMF formats is likely to constitute patentable subject matter. Chapter 4 also analyzes jurisdictions' differential treatment of patent claims directed to electronic signals, which is important because most 3D printable files are sold as internet signal transmissions.

Chapter 5 turns from patentable subject matter to patent infringement. It introduces a fundamental tension between patent holders and good-faith users of the technology. 3D printing will expose unsuspecting individuals and 3D print shops to patent infringement liability when they print patented objects. To spare unintentionally infringing individuals and 3D print shops the ruinous costs of litigation, I explore options for exemptions and safe harbors that simultaneously consider the rights of patentees.

In addition, Chapter 5 demonstrates how the patent protection gap described in Chapter 4 carries over into the infringement analysis. DMFs will not infringe traditional patent claims directed to tangible objects, and claims directed to digital files suffer from severe limitations. Attempting to alleviate some of the protection gaps for patent holders while balancing the needs of users, I consider a novel theory of "digital patent infringement," whereby commercializing a DMF would constitute infringement but merely creating and manipulating the file would not.

Chapter 6 explores the doctrines of indirect patent infringement in the United States, Europe, and Japan, focusing primarily on novel statutory interpretation issues brought about by 3D printing technology. Indirect infringement generally requires knowledge of the patent or some sort of intent to infringe. Because 3D printing technology will empower many legally unsophisticated actors to assist – even if unwittingly – others to infringe, virtually every jurisdiction will need to clarify how to measure knowledge or intent when numerous individuals or small businesses are involved. In Europe, courts will also need to decide the fundamental issue of whether the knowledge requirement implies a culpable mental state. After discussing additional statutory interpretation issues, the chapter concludes by recommending that courts and lawmakers resolve interpretive issues in a manner that captures at least the most egregious actors, namely, those who repeatedly and knowingly facilitate infringement by distributing DMFs. How much further the law should go depends on the overall effect of 3D printing technology on innovation incentives, a topic more fully considered in Chapter 10.

Chapters 7, 8, and 9 cover trademark law, copyright law, and design law, respectively. One might fairly ask why patent law deserved three chapters while each of these areas of IP law only receives one chapter. In part I believe that patent law is less doctrinally and theoretically equipped to contend with 3D printing technology than these other areas of law. In addition, Chapters 5 and 6 introduce the concepts of direct and indirect infringement and describe some basics of litigation realities. For the benefit of nonlawyer readers, I spend a bit more time on these topics when I first introduce them because they have relevance for other areas of IP as well.

Chapter 7 begins by considering how 3D printing technology will disrupt trademark law's core function of indicating the source or origin of manufactured goods. The technology dissociates product design from product manufacturing. Design is embodied in a 3D printable file, while manufacturing is commoditized and democratized. These changes result in a world where source indication works very differently for digital versions of tangible objects. They also fundamentally upset the doctrine of post-sale confusion.

Chapter 8 focuses on a specific issue created by 3D printing technology: whether DMFs of purely (or primarily) utilitarian objects should receive copyright protection. Tangible objects dominated by utilitarian concerns do not receive copyright protection. Neither should the corresponding DMF, I argue. This novel argument has attracted criticism, but I defend it as a matter of doctrine and policy. Doctrinally, most jurisdictions around the world extend copyright protection only to works containing creativity, and I argue that DMFs of utilitarian objects contain no copyrightable creativity. As a matter of policy, allowing copyright protection for DMFs of useful articles would cause copyright law, which is geared toward aesthetic works, to trespass on patent law, which is geared toward utilitarian works.

Chapter 9 considers the role of design rights for DMFs. In it, I argue that DMFs should only receive design protection if the object they will print would receive such protection. Current practice in many jurisdictions is to the contrary. It protects any qualifying images if they appear on a computer screen. I argue that this approach impermissibly protects mere artistic images, which should be protected, if at all, by copyright law. I offer a framework for a teleological approach to design right in digital images and focus the approach on DMFs specifically. In addition, I describe how, unlike the situation in the United States, the EU Design Directive includes many important safeguards for free speech, experimentation, and private use.

Chapter 10 takes a broader look at IP protection as an incentive to innovate. Patent protection gaps brought about by 3D printing technology must be viewed in conjunction with how the technology lowers the costs of innovation and imitation for 3D printable goods. Moreover, although patents serve as a primary incentive to innovate, they are not the only incentive. The chapter looks at other IP rights, contracts, and extralegal appropriability mechanisms, as well as nonmonetary incentives to innovate, to determine how the IP regime should respond to 3D printing technology. I describe the need for a better empirical understanding of 3D printing technology's effects on innovation incentives and make recommendations for what to do as we await that evidence.

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Technological change can be disruptive, even uncomfortable, but that alone is no reason to resist it. In the face of 3D printing technology, the desires of IP owners will skew toward stronger protections, and the desires of the technology's users will skew in the opposite direction. Bowing to neither but balancing both, I offer an expert appraisal of the changes and challenges wrought by 3D printing technology. I recommend numerous avenues for balancing the rights of IP owners and technology users while leaving ample space for the technology itself to achieve its full potential.