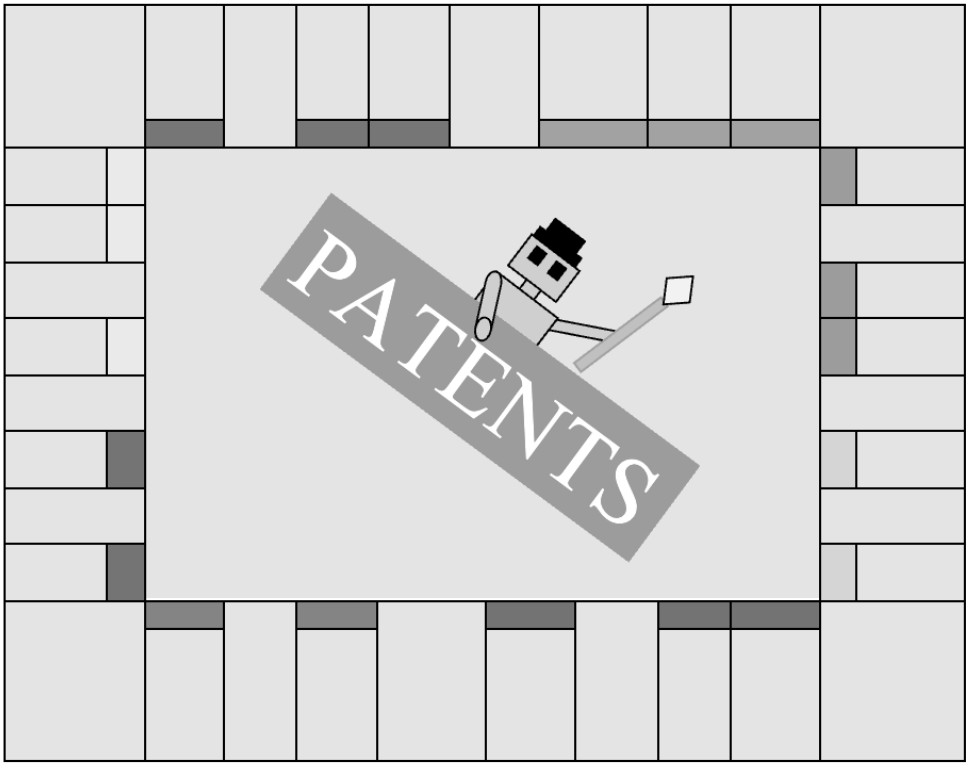

High Technology Patents

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To Mom, Brad, and Broderick

Contents

Chapter 1 Introduction

Open

The word patent has ancient roots, coming from the Latin *paten*, meaning open. Perhaps paradoxically, patents are simultaneously open and protected. By making an invention open to the public, patents allow the invention to be protected by law – assigning a monopoly right to make, sell, or use an invention to the holder. Throughout the ages, entrepreneurs and inventors have used patents as a means to build empires, fossilize genius, and change the world.

The patent system's story dates to the early fifteenth century. The first patent was granted in Venice to Ser Francisus Petri for a device for fulling wool.[2] In the United States, the patent system evolved symbiotically with the Government's founding. Still, most people think monopolies are illegal under the Sherman Act.[3] But the truth is monopoly is a guaranteed right pursuant to the United States Constitution.[4] So, patents are just a game, Monopoly! Everyone knows the rules, if you land on owned property, you have to pay up. And the more valuable the property the more expensive the fee for landing.

In the late 18th Century, Benjamin Franklin wrote, "[A]s we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously."[5] At the time, Franklin was already a wealthy businessman. While his words reflect a mind with good intentions, they also mirror a lack of financial need. Of course, not all great inventors are aristocrats. So, consider Franklin was wrong – nothing in life should be given for free. More scientist than inventor, Franklin's inventions left little legacy, and he is more memorable for discovering electricity.

Electricity

Electricity is a charged electromagnetic current. In fact, the entire world runs on a flowing electrical stream, which is now connected by various computers and other technical infrastructure. But the existing electrical architecture on Earth is still relatively new. Just before the turn of the 20th Century, Thomas Edison and Nikola Tesla were inventing new ways to harness electric power for the first time in human history, by manipulating the movement of electrons across conductive wire.[6]

[2] Stefania Fusco, Lessons from the Past: The Venetian Republic's Tailoring of Patent Protection to the Characteristics of the Invention, 17 Nw. J. Tech. & Intell. Prop. 101, 114 (2020).
[3] 15 U.S.C. § 1 (2021).
[4] U.S. Const. art. I § 8, cl. 8.
[5] Benjamin Franklin, Autobiography of Benjamin Franklin (1793).
[6] U.S. Patent No. 265,786 Apparatus for The Transmission of Electrical Power, to Edison (1882). *See also* U.S. 219,268 Electric-Light, to Edison (1879). *See also* U.S. Patent No. 382,282 to Tesla, Method of Converting and Distributing Electric Currents (May 1, 1888). *See also* U.S. Patent No. 428,057, to Tesla, Pyromagnetic Electric Generator (May 13, 1890).

At 31 years old, the Wizard of Menlo Park, Thomas Edison was the most respected and revered inventor on the planet. Ironically, the secret to his great success was failure. Edison completed over 100 failed attempts before inventing a safe and inexpensive light source to replace the gas lamp, powered by electricity.

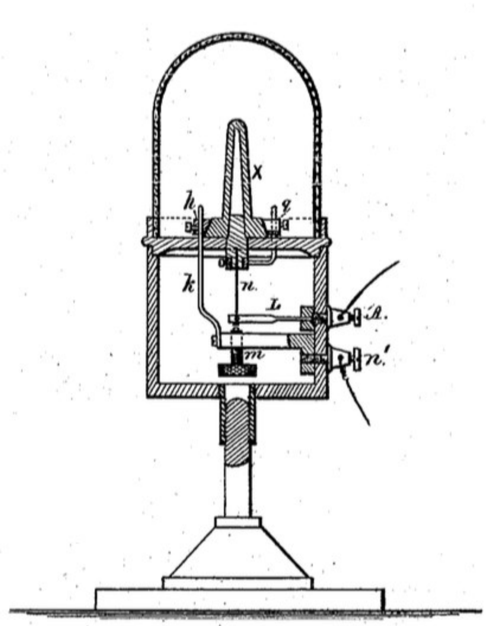

Figure 1[7]

Figure 1 is Edison's original patent for the lightbulb. For his most famous invention, Edison describes the light bulb in U.S. Patent No. 219,628 as an "electric-light giving body formed of a conductor, such as finely divided platinum, iridium, rutbinium, or other metal difficult of fusion, incorporated with non-conducting material."[8] But Thomas Edison did not stop at the light bulb, he harnessed electrical power to build an entirely new industry.

Edison's company, Edison Electric, which is now General Electric, developed a direct current system to power homes and businesses within a half mile radius of any power station. He started by building, Pearl Street Station in Manhattan – the world's first power plant. The direct current technology was thought to be a transformative innovation, which would power the world. However, a structural change in Edison's corporation in the year 1884, brought several new employees to the United States.

Among the newcomers to Edison's operation was perhaps, the generation's greatest inventor. Nikola Tesla began his career in the United States working for Edison. Tesla quickly became the

[7] U.S. Patent No. 219,628 to Edison, Electric-Light (September 16, 1879).
[8] U.S. Patent No. 219,628 to Edison, Electric-Light (September 16, 1879).

most successful inventor working at Edison’s labs.[9] But, after a feud over a $50,000.00 prize, Tesla resigned from the company. Unable to find work after his resignation, he took a job as a ditch digger to make ends meet.

After saving up some money, Tesla founded the Tesla Electric Company in the year 1887. A year later, the company secured a deal with the Westinghouse Company for the manufacture and sale of Tesla’s electric motor.

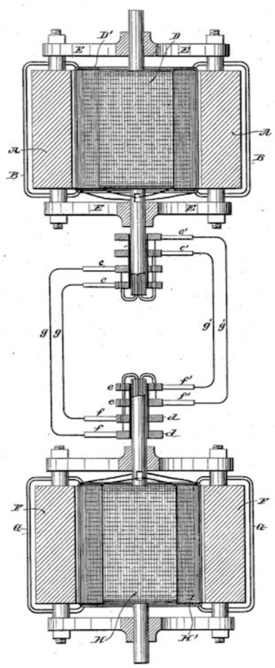

Figure 2[10]

Figure 2 is a diagram for an electric motor and generator combined and connected for operation. Tesla describes, “...currents of alternately opposite direction are sent through the energizing coils of the motor in such as manner as to produce a progressive shifting or rotation of the magnetic poles.”[11] Tesla’s innovation, expanding the scope for power supply, moved electricity generation from a direct current method to an alternating current method – providing an order of magnitude improvement. In other words, harnessing the motors naturally alternating current provided a stronger method than Edison’s direct current motor.

[9] Nikola Tesla, My Inventions, Electrical Experimenter (1919).
[10] U.S. Patent No. 381,69, to Tesla, Electro Magnetic Motor (May 1, 1888).
[11] U.S. Patent No. 381,69, to Tesla, Electro Magnetic Motor (May 1, 1888).

Inventing

Inventing is a process by which problems are solved anew – the ultimate form of freedom. Inventions are improved, new, and useful machines or processes. Like any skill, inventing is a learnable technique, which may be practiced with improvements emanating over time. Empowered by the ability to create something from nothing – inventors build portals to the future.

There are a potentially endless number of ways in which an invention can be brought to life. One way to invent is to converge existing technologies into something new. For example, the smart phone emerged as a confluence of the telephone and personal computer.[12] Another method for inventing is to simply bring science fiction to reality, as life imitates art. But the best way to invent, is to solve a problem.

Reframe impossible problems with questions beginning with the word, how. For example, rather than asking if we can cure a disease, ask how can we cure the disease? Similarly, changing can't statements to questions beginning with how questions, reframes the mind toward creative thinking. Consider the statement, humans can't travel through time. Now consider the question, how can humans travel through time? The former is a dead end, while the latter builds a bridge to opportunity. The ability to define problems evolves in symbiotic fashion with the ability to invent because the ability to define problems is the first essential step to inventing a new solution.

The secret to inventing anything has three steps. First, write down the problem. Second, study and think about the problem. Third, write down the solution in patentable form. With the inventive process, all creations are possible and writing down the problem completes one-third of it. Of course, failure is consistently inevitable – and the ability to overcome constant failure is what defines great inventors.

Edison's light bulb solved the problem of harnessing electricity for a stable light source. Until Edison, the main source of light was a gas lamp, but gas lamps were dangerous and limited in the amount of light it could produce. So, he built a better machine for generating light.

Tesla's alternating current generator solved the problem of how to expand the scope of where electricity could be delivered and generate more power. But it was not until his original plan for making it in America failed, when he quit his job as an inventor in Edison's labs, that he was able to realize the genius that washed away centuries of innovation. In fact, the Tesla Electric Company solved the problem Edison Electric faced in scale – specifically, the limited radius and power station requirement for their direct current technology.

[12] U.S. Patent No. D672,769, to Andre, et al., Electronic device (December 18, 2012).

Great solutions, new technologies, or inventions are best protected by patents. But, despite conventional wisdom, no patent can be wholly protective because of the fundamental attenuation between syntax and semantics. Moreover, every invention can always be improved because no invention is ever perfect. As such, the confluence of inventions and patents creates great opportunity for both personal and collective gain.

Patents

Patents are dynamic objects, with meaning and significance often dependent on perspective. To a computer scientist, a patent is a document with data about an invention, made up with information bytes, binary logic compressed to macro-scales. For lawyers, patents are a strategic tool to protect rights. For business executives, patents are like lotteries, a random chance huge winnings. To an engineer, patents are a blueprint to build something new. But to an inventor, patents are a game.

From a computer science perspective, a patent is a document with invention data, which comes in several forms such as binary logic and natural language. Databases like Google Patents, the European Patent Office database – Espacenet, and the United States Patent and Trademark Office (USPTO) database aggregate massive data volumes in searchable silos for users. The problem with an information theory approach to patents is it ignores the semantics; inventions have significance for which numbers are still unable to account.

For most lawyers, patents are strategic tools intended to protect legal rights in an invention. The United States Constitution provides for patent protection as a fundamental property right.[13] Legally, among other things, any new and useful machine or process is a patentable invention.[14] Upon issuance, an awarded patent confers the exclusive right to use and profit from an invention from the issuing authority to the holder for a specified term. For example, in the United States a patent's term extends twenty years from the date the USPTO grants the patent. From the lawyer's vantage point, the inventor's legal claims are the patent's most important part because only the legal claims are protected by law. While this basic assumption is generally true, the problem with the legal perspective is it fails to account for critical monetary considerations.

To business executives, patents are lotteries, a random chance huge winnings in patent litigation. In the year 2014, Tesla CEO, Elon Musk wrote on the Tesla Blog, "… I realized that receiving a patent really just meant that you bought a lottery ticket to a lawsuit."[15] In fact, recent high technology patent lawsuits have yielded verdicts in excess of one-billion-dollars. For example, in the year 2021 VLSI Technology successfully sued Intel for infringement on patents for integrated circuit technology, resulting in a $2.18 billion jury verdict.[16] But of course, patents are

[13] U.S. Const. art. I, § 8, cl. 8.
[14] 35 U.S.C. § 101 (2021).
[15] Elon Musk, All Our Patents Belong to You, Tesla Blog (June 12, 2014).
[16] VLSI Technology LLC v. Intel Corp., United States District Court for the Western District of Texas (2021).

so much more than a lottery ticket in a lawsuit. At a more fundamental level, the problem with the lottery analogy is that the winners are not random.

For engineers, a patent is a design plan to build something according to a model or prescribed method. One of the most important functions patents serve is acting as a blueprint and architectural plan for constructing inventions. In other words, given a patent and sufficient resources, an engineer should be able to construct the invention claimed in the patent. But the problem with the engineering approach is it fails to stimulate further innovation.

The only complete perspective on patents is that of the inventor because only the inventor must account for every other perspective, in addition to their own. Thus, to an inventor, a true patent pro, patents are the game. Thomas Edison is still the record holder for the most U.S. Patents ever awarded to an inventor, with 1,093 in total.[17] He was also awarded more than 1,000 foreign patents as well.[18] But patent quantity may not be indicative of invention quantity. In the patent game, and in inventing more generally, there are many ways to keep score.

Consider the greatest innovation to come from the inventors' clash was Tesla's AC generator. For example, Nikola Tesla's electric motor using an AC generator is foundational to electric cars today. At the time, the AC generator drew the attention of George Westinghouse, a powerful businessman during his era. But Tesla made a business mistake regarding his inventions, selling his patent rights to the Westinghouse Company, who offered to acquire his patent rights for a lump sum. As a result, Edison's business enterprise was far more profitable than Tesla's, which supported Edison's continued and sustained patent procurement. So, while Edison was awarded more patents, Tesla's inventions were more formative on the future.

Overview

Defined, the *raison d'etre* for *High Technology Patents* is to give inventors freedom and a book they love. Describing innovation as a productive process, this Book is a guide for bringing the imagination to life. Everyone has great ideas that can make the world a better place. But most of those ideas never become inventions because significant knowledge and regulatory barriers blockade the path to progress. Breaking the blockade, *High Technology Patents* clears the path forward by mechanically manipulating the mind toward innovative thought patterns and channels. This Book focused on three central pillars – the patent process, the state of the art in high technology, and the meticulous minutia by which inventing is done.

The first pillar is the patent process – which includes patent strategy, value, and drafting. Chapter 2 explores the key principles and differences for each type of legal protection, as well as instances and scenarios in which they are typically applied. Chapter 3 discusses patent valuation

[17] National Park Service, The Invention Factory: Thomas Edison's Laboratories, U.S. Department of the Interior (March 12, 2020).
[18] Arthur E. Kennelly, Biographical Memoir of Thomas Alva Edison 1847 – 1931, National Academy of Sciences, 301 (1932).

strategies, providing methodologies to predict patent price based on financial data. Chapter 4 details strategies for writing patent applications and trade secret documentation for high technologies; the basic drafting requirements of which include drawings, claims, detailed descriptions, and an abstract.

The second pillar is the state of the art in high technologies – AI, biotechnology, space, blockchain, and quantum computing. Chapter 5 explores AI technology, with a focus on machine learning and NLP. Specifically, Chapter 6 examines biotechnologies with respect to healthcare economics, IP incentives, and future technical convergence with nanotechnologies. Into the final frontier, Chapter 7 offers analysis for space technology patents with a focus on radiation resistant hardware processors, satellites, and rocket technologies. Lighting a torch toward the future of finance in a freer world, Chapter 8 dives deep into the digital underground by detailing blockchain technology and IP. Finally, Chapter 9 explains the technical art in quantum computing technologies – the world's most powerful hardware changing computing forever.

The third pillar is inventing – reverse engineering. Chapter 10 provides a guide on how to reverse engineer, advance, and patent any technology. Most importantly, it advanced the thesis that any new or even conceivable technology may be reverse engineered with consideration to two variables – time and money. Finally, Chapter 11 summarizes and concludes this Book, revisiting the story of Edison and Tesla.

Chapter 2 Strategy

Introduction

Intellectual property (IP) strategy is one of the most important aspects in inventing something new. Broadly, IP strategy refers to the way in which an invention is documented, protected, and liquidated for capturing value. The purpose for IP more generally is economic, to drive revenue, reduce risk, and promote innovation. As such IP strategy is intimately intertwined with business strategy for both firms and inventors. Thus, the general goal for IP strategy is to minimize costs and maximize profits for the underlying invention.

Intellectual property strategy is important because it provides economic benefits, technical roadmaps, and validity to the inventive process. At a high level, IP strategy allows businesses to take account of digital information and intellectual asset development. In doing so, this empowers firms to capture a higher percentage of the value they create in the global market. Thus, the way in which firms protect IP is critical to valuation, growth, and success.

Chapter 2 explores intellectual property strategy in four parts. First, proprietary protections are assessed including copyrights and trade secrets. Second, patent strategy is distilled with a focus on disclosure and post-patent availability. Third, technical data and associated rights are described with reference to creating invention documentation. Finally, approaches to intellectual asset liquidation are assessed.

Proprietary Protections

Proprietary protections are legal safeguards for inventions not known to the public. Entrepreneur Peter Thiel argues proprietary technology is the most substantive advantage a company can have because the secret nature makes the product difficult to replicate.[19] Proprietary technology may be protected under two legal corpi[20] in the United States, copyright law and trade secret law.

A copyright is a legal protection for "original works of authorship fixed in any tangible medium of expression."[21] The Copyright Act of 1976 was amended in the year 1980 to provide computer programs copyright protection.[22] As such, copyright protections have been available for software inventions for more than four decades in the United States.[23] For new software inventions, copyright protections have three important features.

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[19] PETER THIEL, ZERO TO ONE 48 (2014)
[20] The plural form of the word *corpus*, which is Latin for body.
[21] 17 U.S.C. § 102 (1976).
[22] Ralph Oman, Computer Software as Copyrightable Subject Matter: Oracle v. Google, Legislative Intent, and The Scope of Rights in Digital Works 31 HARV. J. L. & T. 638, 641 (2018).
[23] Lisa C. Green, Copyright Protection and Computer Programs: Identifying Creative Expression in a Computer Program's Nonliteral Elements, 3 Fordham Intell. Prop. Media & Ent. L.J. 89, 89 (1992).

First, copyrights provide functional protections for software innovations. While some suggest copyright protections are distinct from patents and trade secrets because copyrights do not protect machines or processes, United States Law has evolved to recognize functionality as a key protection of software copyrights. In fact, Scholar Ralph Oman argues, "[F]or purposes of understanding copyright protection for computer software … a literary work can be both functional and expressive."[24] Oman is correct, a vital principle for code copyright protection is that software can be both functional and expressive – meaning copyrights protect the literal text for the code and the mechanistic process it formalizes.

The second important feature for copyrights is protection against code copying and reverse engineering. Some suggest, "[V]irtually every court to consider the issue has concluded that there is a right to reverse engineer a copyrighted program for at least some purposes."[25] However, the United States Supreme Court recently decided that certain code copying is allowed.[26] The case, *Google v. Oracle*, revolved around software developers at Google using Code for an Application Programming Interface (API) which was written and copyrighted by Oracle. Still, the Court ruled in favor of Google because the Google developers had a limited purpose for using the copyrighted code, permitting Google's use under the Fair Use Doctrine.[27]

Finally, perhaps the most advantageous feature for protecting inventions with copyrights is that copyright protections are the least expensive and easiest to acquire. Providing copyright notice pursuant to 17 U.S.C. §401 simply requires: (1) the word "Copyright"; (2) the year of the work's first publication; and (3) the owner's name.[28] Still, given rising complexity in code and corresponding copyright protections, problems persist for programmers, firms, and universities. One reason is the Copyright Act is poorly written, leading many to question Congressional intent in interpretation.[29] In turn, more words and complex statutes yield less clarity and more deference to courts. Now, some simply reserve code copyrights as trade secrets.

A trade secret is a proprietary technology privately protected by a business or inventor. In *Ruckelshaus v. Monsanto Co*., the United Supreme Court held trade secrets are a form of property, which may be protected by the Constitution.[30] The Court reasoned trade secrets possess many characteristics of tangible property, for example they are assignable.

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[24] Ralph Oman, Computer Software as Copyrightable Subject Matter: Oracle v. Google, Legislative Intent, and The Scope of Rights in Digital Works 31 HARV. J. L. & T. 638, 644 (2018).
[25] Julie E. Cohen and Mark A. Lemley, Patent Scope and Innovation in the Software Industry, 89 Cal. L. Rev. 1, 17 (2001).
[26] Google LLC v. Oracle America, Inc., 593 U.S. __ (2021).
[27] 17 U.S.C. § 107.
[28] 17 U.S.C. § 401 (2021).
[29] Ralph Oman, Computer Software as Copyrightable Subject Matter: Oracle v. Google, Legislative Intent, and The Scope of Rights in Digital Works 31 HARV. J. L. & T. 638, 640 (2018).
[30] Ruckelshaus v. Monsanto Co., 467 U.S. 986 (1984).

New law developed to allow large firms to sue former employees for trade secret misappropriation. However, the Defend Trade Secrets Act (DTSA) has more important consequences for property strategy. According to the DTSA:

> "An owner of a trade secret that is misappropriated may bring a civil action under this subsection if the trade secret is related to a product or service used in, or intended for use in, interstate or foreign commerce."[31]

Recognizing trade secrets under federal law, Congress aggrandized the firm's ability to financially protect proprietary technology.[32] Some contend the added protections at the federal level make firms more likely to pursue trade secret protections as opposed to traditional patent protections.[33] Yet, despite the DTSA's added security, protecting confidential information in an arena with contrasting interests is a complex task.

Still trade secrets add real value. Trade secrets cost significantly less and both patents and trade secrets may be used successfully as leverage in negotiations. Unlike patent protections, which take years, bringing more liability than revenue, trade secret protections are immediate and free. In fact, trade secret protections simply require the firm take reasonable steps to prevent disclosure and protect the underlying invention. Some suggest trade secrets give rights to those who have yet had an opportunity to acquire the means to use for building or using technology.[34] Trade secrets are a great alternative early in an invention's development, particularly if the inventor has limited financial resources. One important consideration for trade secrets is that by their nature, secrets cannot be disclosed.

Disclosure

Disclosure refers to the process by which inventions are made public and accessible. Important for many reasons, disclosures come in various forms and serve several purposes. For example, disclosure puts the public on notice that an invention exists. Public revelations contribute several benefits, including creating a public good and intellectual asset. Protected disclosures and open disclosures are the two main types of intellectual property disclosures.

First, protected disclosures are publications, including code, documentation, and writings, which enjoy legal protection and property rights. However, most commonly, protected disclosures are in the form of patents. Patents are limited monopolies for making, using, and selling inventions. Based on more than five centuries of cultural cultivation, patents have been awarded for inventions since the early 15th century.[35]

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[31] Defend Trade Secrets Act of 2016 (May 11, 2016).
[32] Mark A. Lemley, The Surprising Virtues of Treating Trade Secrets as IP Rights, 61 STAN. L. REV. 311, 329 (2008).
[33] Stephen Yelderman, The Value of Accuracy in The Patent System, 84 U. CHI. L. REV. 1217, 1264 (2017).
[34] Camilla A. Hrdy, Mark A. Lemley, Abandoning Trade Secrets, 3 (2020).
[35] Stefania Fusco, Lessons from the Past: The Venetian Republic's Tailoring of Patent Protection to the Characteristics of the Invention, 17 NW. J. TECH. & INTELL. PROP. 101, 114 (2020).

The United States Patent and Trademark Office ("USPTO") reviews applications to determine whether a claimed invention is: (1) statutory subject matter, (2) useful, (3) novel, (4) nonobvious, and (5) sufficiently described.[36] Critically under U.S. Law, new and useful processes are inventions and thus, patentable subject matter. Processes take many forms, from software structures to architectural alignments. Upon issuance, patents confer the exclusive right to use and profit from an invention to the holder, a government backed monopoly. A U.S. Patent's term extends twenty years from the date the USPTO grants the patent.[37]

The patent process has five essential parts: prosecution, examination, responding to office actions, issuance, and disclosure. Patent prosecution is a long and arduous process, typically taking at least three years. Patent examination is the process by which patent examiners decide whether to grant or reject a patent. After an initial examination, the USPTO provides a formal response to the patent applicant regarding the examination result. If all goes well, the result of the patent prosecution process is a formal Issuance from the USPTO. An Issuance signifies the patent has been successfully awarded and thus granted to the applicant or designated assignee. Finally, the patent is published as a disclosure, protecting the invention for the patent's life – which may extend up to twenty years.

More often, firms developing high technologies are adopting open source strategies for their intellectual property. For example, the Allen Institute for Artificial Intelligence, utilizes open source licenses to allow public access to its code, which it owns under copyright law. The general effect for creating an open source license is to grant a free license, while limiting liability for the holder without warranty for the licensee. This methodology for open sourcing software is often advantageous for firms in drive licensing revenue because it introduces a limited software version for free, while retaining more important rights.[38]

The two most prominent open source licenses are the Apache License and the MIT License. The Apache License expressly offers the software – as is and without warranty. Below is the in-code citation for the Apache License.

> "Copyright [yyyy] [name of copyright owner]
>
> Licensed under the Apache License, Version 2.0 (the "License"); you may not use this file except in compliance with the License. You may obtain a copy of the License at
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>
> Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR

[36] 35 U.S.C. § 112 (2021).
[37] 35 U.S.C. § 154 (2021).
[38] Heli Koski, OSS Production and Licensing Strategies of Software Firms 111, 117 (2005).

> CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License." [39]

The main purpose for this language is to limit liability for the Copyright owner, while simultaneously granting a free license to grow a user base.

Next, the MIT License is relatively similar in structure. Like the Apache License, the MIT License grants a license to use the technology, while limiting liability for the copyright holder.[40] Below is the in-code citation for the MIT License.

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Both the MIT License and the Apache License are widely used in high technology software development. However, one main difference between the two licenses is that the Apache License is expressly irrevocable – meaning once the invention is disclosed, its permanent.[42] Thus, the Apache License, which also permits patent rights, grants more legal rights than the MIT License.

Thus, there are essentially two ways to disclose inventions, open disclosures and protected disclosures. Protected disclosures, namely patents, allow inventors and firms to disclose their inventions while retaining the legal rights to the underlying technology. By contrast, open

[39] APACHE LICENSE, VERSION 2.0 (2004), http://www.apache.org/licenses/LICENSE-2.0.
[40] The MIT License, Open Source Initiative (2021).
[41] The MIT License, Open Source Initiative (2021).
[42] APACHE LICENSE, VERSION 2.0 § 2-3 (2004), http://www.apache.org/licenses/LICENSE-2.0.

disclosures give away rights to the underlying technology, but still add value in capturing the invention through a public forum.

Technical Data

Data is any information about the world. According to some information theories, everything is data, even biological creatures are made up of genetic data structures. For example, Machine Learning Scholar, Ethem Alpaydin, argues the driving force behind the digital revolution is that all information can be expressed as numbers.[43] Indeed, in the information economy, data is important because it drives digital innovation.

More specifically, technical data refers to all information relating to software and hardware technologies. Technical data types are vast, including information silos, research, blueprints, software, documentation, and datasets. Data types may even be further classified depending on structure, or the lack thereof. Similarly, the protections and classifications available for technical data are also wide ranging, including patents, trade secrets, open source licenses, and copyrights.

In the inventive context, two types of technical data are most prevalent, software and documentation. Software refers to any computer code or digital data. Functionally, new and useful software innovations are patentable. And software code is also protectable under copyright law and trade secret law. Most important is to attached copyrights to code when developing because the protection enables the software engineer to take ownership of the work product produced.

Technical documentation describes a technology, which may exist as software, hardware, or both. Documentation is important because it serves as a roadmap and blueprint for understanding a technology. Technical documentation comes in many forms for inventions, machines, and software. Most commonly, software documentation is the means by which new code is communicated to the world. In other words, software documentation provides a set of instructions for developers to implement code. Generally, technical documentation may be protected under copyright law and trade secret law.

In large part the decision for how to protect technical documentation is dependent on the purpose of the technical documentation itself. For example, if the documentation describes how to build a proprietary missile system, the documentation will probably be protected as a trade secret. By contrast, if the technical documentation explains how to get started with open source software for blockchain technology, then the technical documentation will probably be protected with a copyright and likely made available under an open source license.

[43] Ethem Alpaydin, Machine Learning, MIT Press, 2 (2016).

Interestingly specific open source licenses exist which are tailored specifically to technical data. For example, the Open Data License provides a free license to otherwise copyrighted data.[44] Logically, all software is data, but not all data is software. As such, determining the exact protection to apply to technical data is highly dependent on the context for which the invention is being protected. One of the most common considerations in the protection decision is value creation and generation.

Liquidity

An important strategic consideration for new inventions is liquidity, which refers to the process by which inventions drive revenue. While patents add value in variety, revenue is one of the main sources by which value is produced. There are several ways in which patents can be liquidated and drive revenue. Three ways to drive revenue from patents are commercialization, licensing, and sales.

Commercialization is the process by which a patented invention is engineered and made available to market participants. In other words, commercialization describes the scenario where the patent owner makes and sells the underlying invention. In this circumstance, the monopoly value patents provide is advantageous in allowing the owner to exclude all other market participants.

A second way to drive value from patents is licensing. A patent license is a contractual instrument that allows the owner to give certain rights away in exchange for cash payments or royalties. Patent licenses can be very lucrative. For example, in the year 2020, International Business Machines (IBM) pulled $626 million in patent licensing revenue.[45]

[44] Open Data Commons, Open Data Commons Open Database License (ODbL) v1.0, (2021), https://opendatacommons.org/licenses/odbl/1-0/.
[45] IBM, Annual Report 37 (2020).

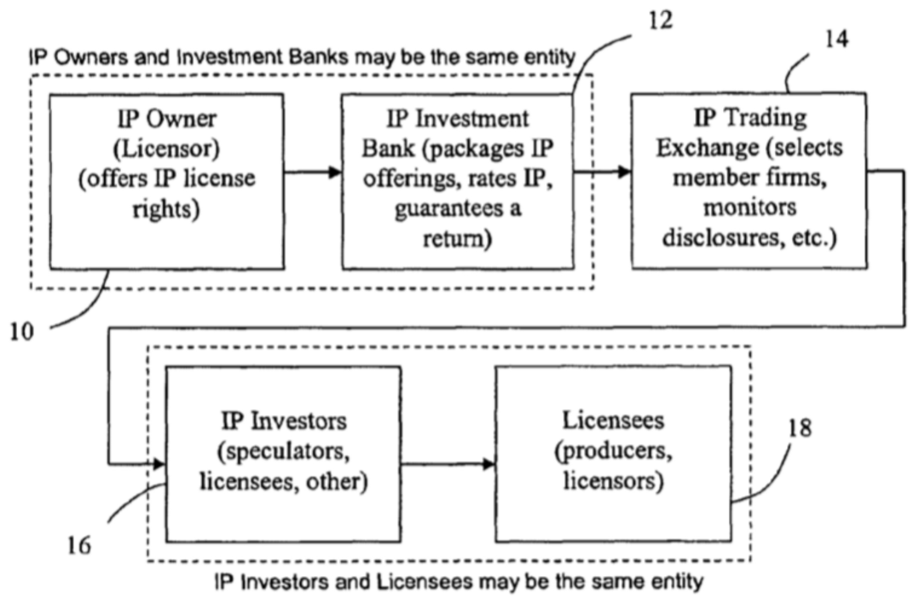

Figure 3[46]

Figure 3 is a patent drawing for a business method to license patents. There are many types of licenses. For example, exclusive licenses allow the licensees rights to an invention that no other licensees may obtain. In contrast non-exclusive licenses allow the patent owner to license the patent and underlying technology to several market participants.

A third way to liquidate patents is through direct sales. Patent sales are different than patent licenses because patent sales provide the buyer all the rights associated with a particular patent. For example, large companies often sell patents through multi-billion-dollar technology transfer deals. In certain corporate circumstances, patent portfolios may be bundled together to sell multiple patents for related inventions.

One way to sell patents is through a patent auctions market. Figure 4 is a drawing for a patent auction, patented by Ocean Tomo – a Chicago, IL based intellectual asset firm.

[46] U.S. Patent No. 8,554,687 to Malackowski et al., Intellectual property trading exchange and a method for trading intellectual property (October 8, 2013).

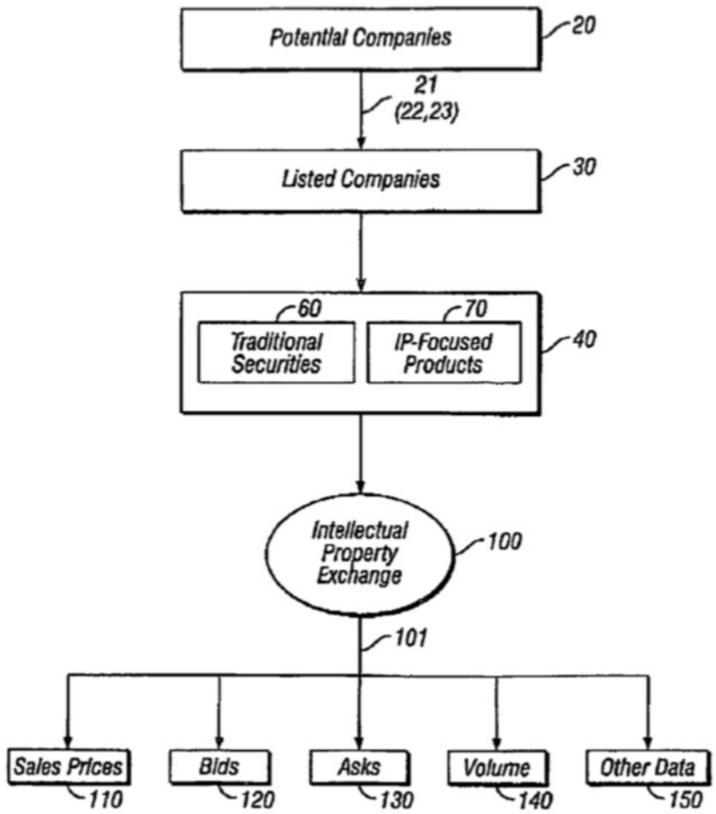

Figure 4[47]

The patent auction market allows participants to buy and sell patents in several ways including direct listing and auction style sales. Patent prices for sales using the patent market have a wide range, with some smaller sales around $100,000.00 and higher sales of more than $10,000,000.00. Ultimately, sales in this market are dependent on demand, but generally high technology patents tend to be worth more than other patents.

Liquidation is an important part of the patent process. Indeed, patents are an inherently economic tool and liquidity is the way by which the tool generates revenue. In sum, three main ways to liquidate patents are commercialization, licensing, and sales. There are certainly other ways to liquidate patents as well. For example, donating patents for the tax benefits is one common strategy. But in the end, the focus for liquidity is driving revenue for inventors to promote innovation and progress by appropriate capital allocation.

[47] U.S. Patent No. 9,058,628 to Malackowski et al., Marketplace for trading intangible asset derivatives and a method for trading intangible asset derivatives (June 16, 2015).

Conclusion

Chapter 2 explored strategy in four parts. First, proprietary protections were assessed including copyrights and trade secrets. Second, patent strategy was distilled with a focus on protected and open disclosure methods. Third, technical data rights were discussed with reference to creating the documentation for inventions. Finally, approaches to intellectual asset liquidation were assessed.

To create a great IP strategy, it is necessary to have access to unique information which provides an unfair advantage. There are many examples of such unique information, or secrets. For example, one of the law's biggest secrets is that all inventions are patentable. By definition an invention is a new, useful, and nonobvious machine or process.[48] So, not all ideas are inventions, but all inventions are property according to the law.

The purpose for IP strategies is to exploit secrets and create organizational value. Thus, more sophisticated and successful organizations have more sophisticated and successful IP strategies. Ultimately the main measure for success is revenue because ultimately IP strategy is a business function focused on economic returns. As a result, a central theme to consider in the innovative process is value, defined in terms of monetary return.

[48] 35 U.S.C. § 101 (2021).

Chapter 3 Patent Value

Introduction

In the year 1851, the Economist wrote, “Patents are like lotteries, in which there are a few prizes and a great many blanks.”[49] In 2016, Carnegie Mellon University successfully sued Marvell Technology for infringement on two patents for signal sequence detectors.[50] The litigation resulted in lottery-like winnings with a $1.54 billion jury verdict for the University. All the while, only 1.5% of patents are ever litigated and “most patents lose money.”[51] So, perhaps not much has changed in the seventeen decades since the first patent value techniques were conceived.

On the other hand, while the patent market has some characteristics still analogous to lotteries, others are starkly different. For example, in lotteries the numbers are drawn at random, so no one knows which numbers will win prizes and which will be blanks before the drawing. In other words, each ticket has a statistically equal chance to win. But patents are different because unlike lotteries, patents are not conceived, written, nor filed randomly. So, not only is patent value predictable, but one can increase a patent’s value proactively – improving the chance a particular patent will be relatively valuable.

Thus, the key difference between lotteries and patents is randomness, lottery tickets are randomly valuable, patents are not. While accurate and precise patent price prediction is still an elusive task for most, general correlations are certainly clear. Valuable patents protect inventions that solve real problems. In the words of Renaissance man, Mark Lemley, "The most valuable inventions do something the world needs."[52]

This Chapter provides a framework for measuring patent value volatilities, removing randomness from the patent pricing process. First, the Chapter explores various models for patent valuation. Second, Chapter 3 provides analytical metrics by which patent price may be assessed and ascribed. Third, options strategies for flexible intellectual asset value assignment are discussed and described. Fourth, Chapter 3 provides general rules and considerations for calculating damages in patent infringement lawsuits.

Models

One problem with the patent system is that it lacks standard models for valuation. As a result, some argue patent valuation involves substantial speculation. Thus, insights which help to improve patent value objectivity add value to an organization. In other words, an informed,

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[49] The Economist: Volume 9, Part 2, 811 (January 1, 1851).
[50] *Carnegie Mellon University v. Marvell Technology Group LTD* (2014).
[51] Author Interview with Mark Lemley.
[52] Author Interview with Mark Lemley.

transparent, and data-driven decision within a defined model isn't any more speculative than any other asset valuation. The way in which patents are valued is a crucial consideration for a firm or inventor in financial strategic planning.

One way in which patents may be valued is with models seeking to objectively assign worth to a particular asset. Models are important because they provide a formalized framework for intangible asset valuation. However, to properly value a patent, respect must be given to the diverse toolkit available in asset valuation. There are three leading models used for patent valuation: income models, cost models, and market models.

Income models value assets based on the economic benefit expected to be received over the asset's life. The theory is the extent to which patents affect a technologies ability to generate income influences valuation. Factors included in income models include unjust enrichment, lost profits, reasonable royalty, and cash flow analysis. Income models may be the strongest valuation for patents involved in infringement litigation. Generally, patent law provides patentees with payment for lost profits and other competitive harm resulting from infringement.

Particularly among income models, the reasonable royalty model is appealing as it can be implemented regardless of the alleged misappropriator's actions. Under a reasonable royalty model, patent law aims to provide patentees with payment for the rate that would have both compensated patentees and allowed users of the technology to make a reasonable profit. For example, the twenty-five percent rule may be taken into account in income models. The twenty-five percent rule suggests that a licensee pay a royalty rate equivalent to twenty-five percent of its expected profits for the patent or the product that incorporates the patent. The rule has been historically used as a bedrock technique in patent license valuation.

However, for high technologies, income models may be difficult to develop. For example, new AI software requires extensive R&D costs directed at dataset development before a technology may be commercialized. For this reason, it may be months or even years before a company derives income from AI technology. Additionally, marketing companies like Google and Facebook use AI to target ads at consumers – making the total amount of income derived from the models a hazy number to calculate. In other words, it is difficult to discern whether a consumer bought something because they wanted it or because they were manipulated with a deep learning algorithm.

Cost models are more favorable for valuing high technologies because they respect the upfront investment required to build great things, like reusable rockets or a quantum computer. Cost models consider factors including time, labor, and research and development expenses in the valuing process by accounting for cost in value. The assumption underlying cost models is the expense in developing a new asset is commensurate with the economic value the asset can provide during its life. In other words, cost models are based on the idea that the technology is worth the amount it cost its owner to develop and protect. As such, cost models incentivize firms to keep accurate accounts of R&D costs, making the model appealing for application ease.

However, one concern with cost models is simply because a firm or inventor spends time developing a technology does not mean the technology has value. As a result, cost models may reflect value extraneous to the technology's underlying value. But cost models also include more objective factors. For example, one factor which may be considered in a cost model is a patent's inventorship. A common argument is the greater the number and prestige of the inventors on a patent, the higher the patent quality because more intelligence and time was dedicated to the patent. It follows, the inventor's prestige and time spent developing a patent may be considered correlational with patent quality.

Cost models are most advantageous to inventors and startups developing high technologies – which have most value in the future. The main reason cost models are advantageous is because costs models include R&D expenses, patent prosecution fees, and engineering fees for the technology. Under a cost model, a technology has some value the moment the idea is formed, because developing an idea takes time, which is money. However, cost models are difficult to assert in litigation because the firm claiming infringement must value its own costs. This can be difficult, especially for startups, who may otherwise have no revenue in early stages. The task requires figuring out exactly how much time was spent developing the technology and what the hourly rates were for each person working on the technology.

Market models define fair market value for a technology by the price the market is willing to pay for the asset. Market models value assets based upon comparable transactions in the marketplace. In essence, the fair market value is determined by assessing the price a buyer would pay a seller for the technology. Other factors included in market valuations are sales and industry surveys.

Market models generate the widest value ranges compared to income and cost models. One reason for market model's higher variance is the subjectivity in measuring market value compared to other models. A second reason for the higher variance is dependent upon whether market analysis is conducted prospectively or retroactively. Prospective market valuations tend to be more grounded with supporting financial data as opposed to retroactive valuations. As such, it makes sense to understand a technology's market early in development.

Commercialization is critical to market value because establishing a market share influences buyers. As such, a patent's ability to trigger sales is also critical in valuation because a patent's ability to influence consumers to buy a product correlates with increase in value. For example, ownership rights in the latest technology for a cell phone increases firm value. Another example is a patent's ability to trigger sales in an entirely new market – like Edison's electricity empire in the late 19th century.

Market models are least favorable for valuing high technologies in the early stages, but most favorable in later stages. As a result, in the early stages the market often declares technology worthless. Until a technology has triggered sales, investors typically have no interest in new technologies and startups to move forward with development. However, for a larger firm like

Nvidia, market models may be favorable because niche market monopolies in industries like GPUs can be protected with robust patent portfolios. This reflects the idea that a patent has value in affording the owner an ability to exclude competitors from the market.

Metrics

While models provide a formalized framework for both patent valuation and technology valuation more generally, the real information is in the numbers. Metrics are a more precise methodology for patent valuation, defining a concrete number. And yet, despite a precise intention, the diversity in applied metrics across various industries creates a convoluted market. Two standard metric methods for patent value are profit calculation and market capture.

First, the profit calculation method for patent value defines a patent's value according to the bottom line. The profit calculation method is composed of three steps. The first step is defining the cost for the patent. If you search the internet with the question, "How much does it cost to get a patent?" the first results suggest $10,000 - $15,000. Generally, this estimate is fair for both large companies and inventors, reflecting the cost to pay an attorney to prosecute a patent.

Utility Patent Cost Chart			
	Micro-Entity	Small-Entity	General Fee
Filing Fee 37 CFR 1.16(a)	$00.00	$75.00	$00.00
Search Fee 37 CFR 1.16(k)	$165.00	$330.00	$660.00
Examination Fee 37 CFR 1.16(o)	$190.00	$380.00	$760.00
Total Filing Costs	**$355.00**	**$785.00**	**$1,420.00**
Issuance Fee 37 CFR 1.18(a)(1)	$250.00	$500.00	$1,000.00
Total Acquisition Costs	**$605.00**	**$1,285.00**	**$2,420.00**

Figure 5

But often, the high costs derive from market inefficiencies for patent prosecution services across larger organizations. At a more fundamental level, the minimum cost for filing a patent application with the United States Patent Office ranges from $605.00 to $2,420.00 depending on the entity size for the applicant. So, if a poor inventor files an application, they may file as a micro-entity, where a large corporation or university would pay the General Fee. In addition to the filing fees, engineering and attorney fees usually contribute to costs for companies acquiring patents.

The second step in the profit calculation method is calculating revenue from the patent, which is a more difficult task. Patents may generate revenue through several sources including licenses, sale, and commercialization. Additionally, patents have value because they legally protect monopolies, which includes the exclusive right to collect revenues from the underlying technology for twenty years. As such, in calculating revenue for a particular patent, considerations include sales, income, interest, and inflation.

The final step is actually calculating the profit margin for the patent, which is the easiest step. Under the profit calculation method, the metrics for calculating patent value are cost and revenue,

$$r - c = p$$

revenue (r) minus cost (c) equals profit (p). Of course, there is inherent ambiguity in defining these variables over time. But the profit calculation method is the simplest approach to patent value based on metrics. Perhaps simplicity is the sign of truth, *simplex sigillum veri*, or maybe more meticulous methods are more suited for modern market capture economics.

Next, the market capture method for metric based patent valuation calculates the monopolized market share for each patent. For example, the U.S. domestic market for reinforcement learning patents is roughly $49 billion.[53] Next, define the number of patents within that market – in the case of reinforcement learning patents, approximately 324 patents as of the end of the year 2019. Then divide the total number of patents by the total patent market value to define the captured monopoly share, establishing a baseline value for each patent in the market, in this case $151,234,567.90.

Once a baseline market value is established, objective features in the patents should be extracted and scrutinized for metric based per patent adjustment. This matches the intuition that every reinforcement learning patent is not worth $151,234,567.90 because some patents are worth more and some patents are worth less. Each of the 324 patents protects different inventions with wide ranging commercial applications and sales. All the while, objective features differentiate the patented legal rights in many ways. For example, younger patents tend to be more valuable than older patents because younger patents have a longer life remainder. Another key feature for

[53] Brian Haney, Reinforcement Learning Patents: A Transatlantic Review, Transatlantic Technology Law Forum, Working Paper Series No. 63, Stanford Law School at 28 (2020).

stricter patent value strategies is scope.[54] The patent's claim scope defines the market monopoly size protected by law.

The best way to adjust patent value according to quality metrics is to define a factor array and scoring system for each factor. Then adjust the baseline patent price according to the scoring system, establishing a standardized algorithm for the specific market. For example, a geometric mean measures the patent value similar to the way in which computer scientists measure the relative size of computational objects.

$$value = \sqrt[\sum_{j=1}^{n} w_j]{\prod_{i=1}^{n} F_i^{\,W_i}}.$$

Figure 6

In the above equation *n* represents the number of factors F_i; and W_i, is the per factor weight. The square root is a summation equation designed to calculate the total weight for all factors. The equation allows for a formal framework to take account of various factors and features which correlate with patent value. The main benefit for the market capture method is more information is taken into account in the valuation process, yielding a more statistically accurate result.

In practice, a meticulous mixture synthesizing patent value models and metrics may yield the most accurate results. The key difference between patent value models and patent value metrics is the metrics produce concrete numbers, where models produce estimates. Each model and metric method for patent valuation has benefits and drawbacks, creating an extremely volatile market. Over time, the market will likely stabilize to an assigned value like other securities. The process of stabilizing the patent market provides great opportunity for risk reduction and value capture. But, arguably, risk can never be completely eliminated. Now, the cutting edge in patent value techniques incorporates ideas from finance, applying options strategies to patent valuation.

Options

Options pricing is an innovative patent valuation technique designed to reflect real value. Borrowed from economics, real options are a financial derivatives contract creating the right to purchase an asset at a defined price. Options economics are applied in a variety of contexts for financial forecasting and strategic resource allocation. In other words, the real options approach flexibly formalizes intangible asset valuation. Options pricing for patents is a growing trend for top technology firms because patents are traditionally thought of as protecting an intangible value.

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[54] Mark A. Lemley and Mark P. McKenna, Scope, 57 WM. & MARY L. REV 2197 (2015). *See also* Julie E. Cohen and Mark A. Lemley, Patent Scope and Innovation in the Software Industry, 89 Cal. L. Rev. 1 (2001).

There are three key elements for options pricing: (1) a legal right to buy or sell an asset at; (2) a specified time; and (3) a specified price, subject to market volatility. Similarly, patent options also include three key elements: (1) a legal right to profit from an invention; (2) for a specified period of time; and (3) a specified price, subject to market volatility. Because volatile markets behave according to pseudo-random principles, most research on pricing patent options focuses on Black-Scholes, which is based on simplifying assumptions about statistical dynamics for stocks. In other words, given the market is liquid and random, Black-Scholes is an appropriate method.

So, consider patents as options. In fact, a firm can use options to value an ability to commercialize a novel rocket technology, like an autonomous control system. The price for the patent depends in large part on commercialization, and perhaps more importantly sales, because revenue should exceed the market cost, which is an element for the price. For example, a patent is an option because it gives the owner a legal right to choose between exclusively selling an invention or foregoing commercialization for competitive purposes. Indeed, every option has a price and every patent strategy decision available to a company can be characterized as an option, defined in terms including exercise price or expiration date. In short, using options pricing for patents is a way companies can capture value, reduce research risk, and produce profits by exploiting market uncertainties.

Patent options are a sophisticated financial tool, firms can exploit for profit. One financial goal for firms is using patents to capture value created through research and development (R&D) investment. As such, some argue R&D funding is the same as purchasing an option on commercializing the resulting technology. This is important considering high technology R&D is a trillion-dollar industry and patents are the ticket to returning revenue. Consider, in the year 2020 Microsoft alone spent $19.269 billion or 13% of its annual revenue on R&D.[55] Microsoft profits from this investment in various ways like commercial licensing and Government grants.

An application for patent options is in defining the cost to license technology. A common scenario is a licensing contract for high technologies, in which the licensee pays an initial fee to acquire the right to develop and commercialize the patented technology. Generally, licensing contracts provide the licensee with the opportunity to acquire cash flows from commercializing the patented technology, while the licensor retains the right to receive royalties as revenue in exchange for the license. As such, using options pricing in technology licensing contracts, which provide for using or selling an invention, supports varying fee structures and resource allocation.

For example, an aerospace startup may license Blue Origin's rocket technology, which is protected by patent,[56] for purposes of winning government contracts. The option to commercially exploit the rocket technology is valuable insofar as Blue Origin is able to profitably use the technology, exclude competitors from doing so, and license the technology to

[55] Microsoft Corporation Form 10-K, United States Securities Exchange Commission, 43 (June 17, 2020).
[56] U.S. Patent No. 8,678,321, to Bezos, et. al. Sea landing of space launch vehicles and associated systems and methods (March 25, 2014).

yield revenue. So, one of the first steps in framing Blue Origin's patents for rocket technology as options is to define the patent's purchase price. To define the price, the parties may take account of various variables. Perhaps consideration is given to the patent's scope as one component for the patent option price because the scope defines the legal rights being purchased. Thus, the benefit for the startup is becoming more competitive for launch contract awards, leveraging the license to use and sell the technology, while the return for Blue Origin may be an upfront fee plus royalties.

Options are a more nuanced methodology for patent valuation. And they are relatively rare due to their complexity. As such, for high technology patents, options pricing may be valuable, but requires a narrow and specialized skillset for proper drafting. Still, options fill a missing void in previous patent valuation techniques by accounting for strategic advantage as an intellectual asset. As a result, options pricing for valuing patents is more commonly used in business than law. A last resort to capturing patent value, litigation is the most traditional forum for patent valuation using damages calculations.

Damages

A contentious issue in intellectual property law, patent damages are the foundation for patent value because damages allow patent owners to recover if their rights are violated. In fact, one reason patents have value is because patents enable the owner to exclude others from the market or receive royalties by licensing the patent. However, a firm's ability to exclude others or collect royalties is dependent on the firm's ability to recover in litigation. For example, in the year 2016 The California Institute of Technology (Caltech) sued Apple and Broadcom for patent infringement.[57] Caltech successfully alleged Apple and Broadcom infringed on a small patent portfolio for Wi-Fi technologies.[58] The lawsuit resulted in a $1.1 billion verdict in favor of Caltech.

Generally, patent infringement assessment requires determining the meaning in each patent claim and then showing the accused infringement meets each claim term. Direct infringement is the broadest and most common liability. The Patent Act defines direct infringement as "Except as otherwise provided in this title, whoever without authority makes, uses, offers to sell, or sells any patented invention, within the United States or imports into the United States any patented invention during the term of the patent therefor, infringes the patent." In general, the law only requires the unauthorized use of a patented invention by making, using, or selling.

[57] *The California Institute of Technology v. Broadcom et al.* (2016)
[58] U.S. Patent No. 7,116,710 to Jin et al., Serial concatenation of interleaved convolutional codes forming turbo-like codes (October 3, 2006). *See also* U.S. Patent No. 7,421,032, to Jin et al., Serial concatenation of interleaved convolutional codes forming turbo-like codes (October 9, 2012). *See also* U.S. Patent No. 7,916,781, to Jin et al., Serial concatenation of interleaved convolutional codes forming turbo-like codes (March 29, 2011). *See also* U.S. Patent No. 8,284,833, to Jin et al., Serial concatenation of interleaved convolutional codes forming turbo-like codes (September 2, 2008).

If a patent is found to be valid and infringed, the owner is entitled to infringement damages. According to the Patent Act "[u]pon finding for the claimant the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty."[59] The words and process defined in the patent infringement statute have been successfully applied in many technology patents cases throughout American jurisprudence. Courts typically interpret the Patent Act to mean that patent damages may come in two primary measures, lost profits and reasonable royalties.

Lost profits provide the patentee with the profits the patentee would have made but for the infringing sales as damages in litigation. Proving lost profits, is a difficult endeavor. To prevail, the patentee must prove: (1) demand for the patented invention, (2) a lack of alternatives for the invention, (3) the patentee's ability to meet the additional demand, and (4) the foreseeable profits. However, it is difficult to prove these elements due to suspect speculation, or uncertainty in predicting future value.

The second measure for damages is reasonable royalties, which is the dominant damages determination. Today, most patent damage awards are calculated using reasonable royalties. As such, some describe the reasonable royalty model as the bedrock for valuing patent licenses. Under a reasonable royalty model, patent law aims to provide patentees with payment for the "rate that would have both compensated patentees and allowed users of the technology to make a reasonable profit."[60]

One way to assess reasonable royalties is the twenty-five percent rule. According to the twenty-five percent rule, the licensee pays a 25.00% royalty on profits. In valuing the patented technology, courts consider analytical factors set out in *Georgia-Pacific Corp. v. United States Plywood Corp* to determine reasonable royalty. For example, courts may consider comparable costs for licensing similar technology. As such, judicial discretion determines questions relating to conflicting evidence for exact amounts.

In 2016, Carnegie Mellon University (CMU) successfully sued Marvell Technology, a California electronics company, resulting in a $1.54 billion verdict in favor of CMU.[61] A key component in Marvell's business is selling foreign manufactured semiconductors domestically.[62] The case revolved around two patents for signal sequence detectors, which were invented by a professor

[59] 35 U.S.C. § 284 (2020).
[60] Mark A. Lemley, *Distinguishing Lost Profits from Reasonable Royalties*, 51 W.M. & MARY L. REV. 655, 669 (2009).
[61] *Carnegie Mellon University v. Marvell Technology Group LTD* (W.D. Pa. Jan. 14, 2014). (United States District Court)
[62] *Carnegie Mellon University v. Marvell Technology Group LTD* (Fed. Cir. Aug 4, 2015). (Court of Appeals for the Federal Circuit)

and graduate student at the University.[63] During the litigation, CMU proved direct infringement with evidence that the patented signal detectors were used in Marvels semiconductor technology.

Relying heavily on Marvell's sales the Court used the reasonable royalty method to calculate damages. As a result, the damages were meticulously calculated on a per unit basis, meaning sales for each product. In fact, the twenty-five percent rule was used to award CMU 25.00% of Marvell's profits for sales on all chips sold that infringed on CMU's patent rights. The verdict remains one of the largest damages awards for patent infringement ever.

In sum, patent damages vary according to many different factors on a case-by-case basis. However, some general rules are derivable from statutory authority and precedent. For example, most courts calculate damages for patents using the reasonable royalty method. A more recent trend is emerging with patent damages awards greater than $1 billion. This trend will likely accelerate fast given current market conditions in the global market for technology.

Conclusion

The key to properly projecting patent price is to reduce randomness in the process by applying tested and trusted strategies. In sum, Chapter 3 explored different techniques and strategies for patent valuation. First, various models for patent valuation were described and analyzed, including cost models, income models, and market models. Second, two methods for valuing patents with metrics were introduced and detailed, profit calculation and market capture. Third, the cutting edge in patent pricing, patent options strategies were discussed. Fourth, consideration to damages in patent litigation was provided as a last resort means to patent value capture.

Still all patents are market monopolies backed by the force of law as established by the United States Constitution.[64] Yet, some argue despite deceptive progress since the year 1851, when the Economist called patents lotteries, most patents are still worthless and patent valuation techniques lack legitimacy for predicting winners. In fact, Marvell appealed the $1.54 verdict, arguing the damages calculations were incorrect and illegitimate before the parties finally settled the dispute. Moreover, recovering lottery winnings from patents may require costly litigation.

But consider a different narrative because a lot has changed since the nineteenth century. Patents are most valuable insofar as they create freedom to innovate, drive licensing revenue, and attract investment. By meticulously applying models and metrics using validated market data, precise and prudent patent valuations are just as valid as any real property valuation, like a house or car. So, while most people think patent value is a highly speculative process, the truth is patent valuation can be just as secure as any asset valuation.

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[63] U.S. Patent No. 6,201,839 to Kavcic et al., Method and apparatus for correlation-sensitive adaptive sequence detection (March 3, 2001). *See also* U.S. Patent No. 6,438,180 to Kavcic et al., Soft and hard sequence detection in ISI memory channels (August 20, 2002).
[64] U.S. Const. art. I § 8, cl. 8.

Chapter 4 Drafting

Introduction

The most important concept in drafting patents is that any invention can be patented in many different ways. Most people start with asking if they can patent their invention, but it is a much better approach to start by exploring how one can patent the invention. While not all ideas are patentable, any new and useful process or machine is a patentable invention.[65] So, while details are important, there is never one right way to proceed with writing. This creates freedom for inventors, allowing them to express their minds according to variety. Indeed, inventions are dynamic constructs which evolve over time, providing flexibly and opportunity.

In addition to the several ways to patent an invention, there are also several types of patents to pursue. The three most common patents for high technologies are utility patents, design patents, and provisional patents. Generally, utility patents protect what the invention does, the process or machine. Next, design patents protect the inventions architectural appearance.[66] Third, provisional patents are a temporary patent application, which lasts one year, but is not reviewed.[67] Moreover, provisional patents are usually a waste of time and money for inventors and small businesses.

This Chapter will focus on utility patents because they are the most common type of patent application, comprising approximately 90.00% of all nonprovisional applications filed. The first part of every utility patent simply includes the title, inventors and abstract. The title should be as succinct as possible, while still capturing the invention's essence or *raison d'etre*. The abstract is a cogent description for the invention's essential elements. In fact, the abstract is arguably the second most important element when writing a patent because not only does it serve as an introduction to the invention, but it also may be the only part capturing the reader's attention.

Unfortunately, often great inventions can be poorly described in the abstract, reducing value and dissemination for the patent more generally. Consider the following example, an abstract for an invention pertaining to powerful quantum computing technologies.

> "The subject matter relates to multiple parallel ensembles of early stage spherical pulses radiated through engineered arrays forming the foundation for quantized computer processors taking advantage of integer thermodynamics. The materials, architecture and methods for constructing micro- and/or nano-scale three-dimensional cellular arrays, cellular series logic gates, and signature logic form the basis of small- and large-scale apparatuses used to execute logic, data bases, memory, mathematics, artificial intelligence, prime factorization, optical routing and artificial thought tasks not otherwise

[65] 35 U.S.C. § 101 (2021).
[66] Jeanne C. Fromer and Mark P. McKenna, Claiming Design, 167 U. Penn. L. R. 123 (2018).
[67] 35 U.S.C. § 111 (2021).

> replicated in electron-based circuits. Unlike prior art electric-current based computational devices--that by definition dissipate heat and consume significant power to achieve computational output--the types of logic gates described do not shed waste heat and minimally consume power, which is desirable for embedded computers, ultra high-throughput computation, low-power consumption data centers and extended battery life devices."[68]

The abstract is long, wordy, and generally convoluted. Moreover, it is plainly an eyesore that most readers will want to skim, or skip all together, to avoid the pain in reading.

A better way to introduce the invention in the abstract is to describe the invention in three parts. For example, consider the following abstract for the same invention, but using the rule of three.

> The invention is methods and an apparatus for quantum computing. In embodiments, the invention comprises three parts. First, spherical pulses are received and recorded. Second, the spherical pulses are processed with logical gates according to various algorithms including artificial intelligence, prime factorization, or statistical analytics. Third, the system produces an output while using less power than any existing computational process.

Here, the invention is cogently described, allowing any reader to get the gist of the invention. The number of parts is arbitrary, any process may be described in *n* parts, but the rule of three is generally appreciated.

Chapter 4 explains the process for writing patent applications in three parts. First, patent drawings are discussed and described, detailing the process by which inventions are illustrated. Second, the specification is explained, setting the stage for securing legal protection. Third, claims are explored, providing a means by which inventions are legally monopolized. Generally, the goal for Chapter 4 is to provide a roadmap for writing patent applications, allowing inventors to write an application for their inventions, or at least get a good start.

Drawings

Drawings are a useful illustration for new inventions. In fact, at least one drawing is usually required for patent applications.[69] The goal for drawings is to depict the invention in an accessible and viewable way, to allow readers to understand an invention from an illustration.

[68] U.S. Patent No. 9,607,271, to Papile, Isothermal quantum computing apparatus and materials (March 28, 2017).
[69] 35 U.S.C. § 113 (2021).

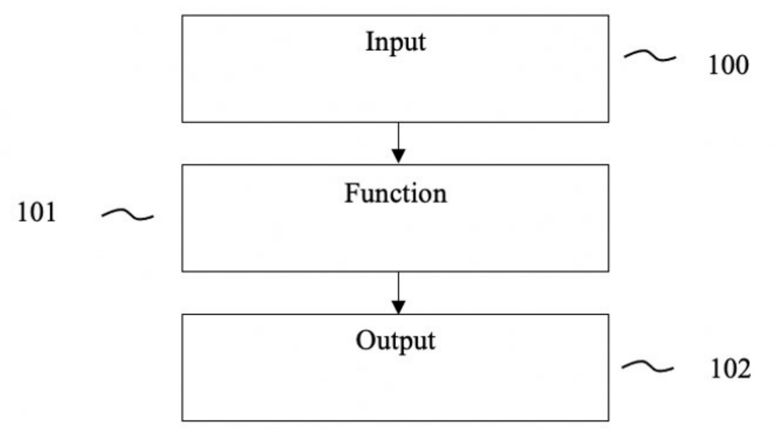

Figure 7

Figure 7 is an open-ended drawing for a basic process. A great way to start inventing is to create a three-step information flow model for a process or machine with an input, function, and output. The model simply consists of three boxes, with arrows connecting the steps, and numeric labels for identification and further description.

Even the most complex technologies are capable of description with the simplest drawings. For example, Figure X is a drawing for a biotechnology used to monitor control of the human heart.

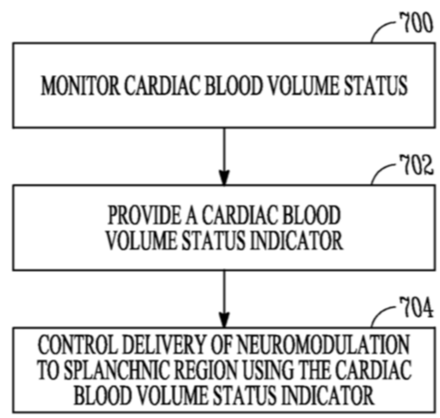

Figure 8[70]

Despite the deep complexity involved in inventing the technology's technical detail, Figure 8 illustrates embodiments of the invention in three simple steps. Indeed, the three-step process includes monitoring blood volume **700**; providing a blood volume indicator **701**; and using the blood volume indicator to control neuromodulation delivery **702**.

[70] U.S. 9,526,893 to Averina et al., Blood volume redistribution therapy for heart failure (December 27, 2016).

While it is generally good to start simple, other great patent drawings are more mechanically meticulous. For example, Figure 9 is a drawing from the first airplane, invented by the Wright Brothers in the early 20th Century.

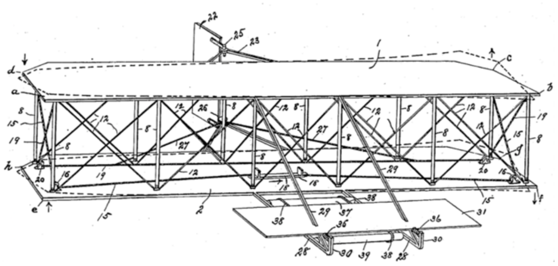

Figure 9[71]

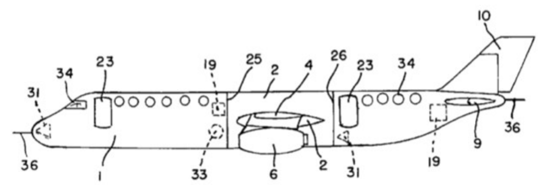

Figure 10[72]

The detail with which the invention is drawn demonstrates the design for one of the most marvelous creations in human history, the airplane. Consider no technology has had a more profound impact on the world because the airplane has singularly globalized the world. Figure 10 is a patent drawing for a more modern airplane. The drawings should then be described and discussed throughout the patent's specification.

Specification

At a high level, the specification is a blueprint for the invention. Its intention is to provide enough detail, such that one skilled in the art could build the invention.[73] In other words, the specification must be specific enough that an engineer working in the field of the invention could construct the invention according to the specification. The specification has four parts, the background, summary, brief description of the drawings, and detailed description of the invention.[74]

Perhaps the most important element for the background is to define the problem the invention solves. To be an invention, an idea must be useful. A rejection for lack of utility may occur when the examiner finds: (1) the invention's use is not apparent, or (2) an assertion for use in the application is not credible.[75] Thus, a keystone to utility is solving a problem because the problem the invention solves defines an immediate use. Thus, the problem statement is a critical component for the background section.

The specification should also provide a technical narrative description for the prior art, which is another key element for the patent's background. The technical narrative is an opportunity to set

[71] U.S. Patent 821,393 to O. & W. Wright, Flying Machine (May 22, 1906).
[72] U.S. Patent 7,234,667 to Talmage, Jr., Modular Aerospace Plane (June 26, 2007).
[73] 35 U.S.C. § 112 (2021).
[74] 37 CFR § 1.77 (2021).
[75] MPEP § 2104, Retirements of 35 U.S.C.§101 (2021).

the invention apart, explaining the background against which the innovation leading to the invention occurs. In fact, including a technical narrative in the background is the best way to prevent against an obvious objection from an examiner. Usually, the best way to innovate is to erase history. In other words, an invention evolving out of work from the 19th Century will foster more progress than an invention building on work in the 20th Century.

Another stipulation for patents is that the invention cannot be obvious. The nonobviousness requirement's goal is to limit patents for only those inventions representing a sufficiently large advance over previously known technology. Specifically, the statute requires that obviousness be judged from the perspective of the person having ordinary skill in the art, and claims be invalidated if that person would find the claimed invention to be obvious.[76] NYU Patent Law Professor, Jeanne Fromer, explains, "The nonobviousness doctrine seeks to ensure that patents are granted only for technologically significant advances to foster the patent system's goal of stimulating useful innovation."[77]

As such, it is best to not focus on the prior art during the inventive process because it opens the invention to criticism and may affect the way in which the inventor conceives their own creation. This way, no other work pertains to the invention's patentability within the inventor's knowledge. This allows the inventor to honestly explain there is no known prior art for their invention, ignorance is bliss. In other words, it's the examiners job to do the patent search, in fact it is a mandatory service fee for filing which the inventor must pay.[78] So, it is not the inventor's job to pay an attorney to conduct a search, instead it's a mandatory service the USPTO provides for a cost.

Next, the summary succinctly describes the invention claimed.[79] Moreover, the summary should illustrate the problem the invention solves and articulate the invention's substantive advantages. The summary is distinct from the abstract because the summary should focus on the invention, rather than the entire disclosure.[80] Thus, the summary is a great opportunity to clearly convey the essential essence for the invention.

There are two required references to the drawings which must be included in a patent application.[81] First, the brief description of the drawings is an opportunity for inventors to provide context for patent illustrations. In this section it is important to list all references to the drawings by number. The brief description should also provide numeric reference to be discussed further throughout the patent's detailed description.

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[76] 35 U.S.C. § 103 (2021).
[77] Jeanne C. Fromer, The Layers of Obviousness in Patent Law, 22 HARV. J. OF L. & TECH., 75 (2008).
[78] 37 CFR § 1.16 (k) (2021).
[79] 37 CFR § 1.73 (2021).
[80] MPEP § 6.02 Content of Specification (2021).
[81] 37 CFR § 1.74 (2021).

Second, the detailed description should describe the machine or process fully and completely.[82] In other words, the detailed description must be sufficient so that a professional in the field of the invention could build or create the invention described. For this reason, it is also worthwhile to add copyright protection to the patent application.[83] The detailed description may contain both chemical equations and mathematical formulas. In writing the application, chemical equations and mathematical formulas are considered part of the surrounding paragraph and should not be independently numbered.

The specification, and application more generally may be arranged according to the details laid out in the Manual of Patent Examining Procedure (MPEP).[84] The MPEP provides guidance for examiners on the examination process and is a useful reference for inventors as well because it is open and public. Ultimately, the specification is the blueprint, enabling one skilled in the art to create the invention described. It allows the inventors to publicly disclose the inventions design details, while protecting the rights to the underlying technology.

Claims

Claims define and describe each element for the invention in detail.[85] The purpose for claims is to specify and clearly convey the components for the invention as broadly as possible to maximize the patent's legal protection. Moreover, claims are the patent's most important feature because claims are the only part of the patent that can be legally infringed. In other words, claims are the critical component for the patent when determining the result of patent lawsuits.[86]

Syntactic claim structures are a cogent way to draw an invention with a textual corpus. Often, claim construction is complicated by confusing analysis. But don't be fooled by complexity, simplicity is truth. Every claim should have three parts: (1) a preamble, (2) a transitional phrase, and (3) a body. The preamble describes the invention type, the transitional phrase sets the scope, and the body defines the invention.

Consider the following example for a patent claim, for writing patent claims.

> A method for writing patent claims, the method comprising, writing the preamble, describing the inventions utility, writing the transitional phrase, defining the claim's scope, and writing the body, detailing a novel process.

Here, the preamble is *A method for writing patent claims* which establishes the invention's purpose. The transitional phrase is *comprising* – the broadest transitional phrase. The transitional phrases *consisting of* and *consisting essentially of* may also be used and are narrower in how they

[82] 37 CFR § 1.71 (2021).
[83] 17 U.S.C. § 101 (2021).
[84] MPEP § 6.01 Arrangement of the Sections of the Specification in a Utility Application (2021).
[85] 35 U.S.C. § 101 (2021).
[86] 35 U.S.C. § 271 (2021).

are interpreted.[87] The body for the claim is *writing the preamble, describing the inventions utility, writing the transitional phrase, defining the claim's scope, and writing the body, detailing a novel process*, which defines the invention's elements.

A claim's scope defines the patent's protectable rights. Many lawyers think scope is the keystone to patent valuation – more scope means more legal protection and freedom to act the argument goes. To an extent this is may be true, particularly from a lawyer's perspective because arguing about scope in the context of examination or in litigation for infringement is common. But most patents are never litigated.[88] So, as an asset to a firm or inventor, more patent scope often means more cost and potentially more liability.

Consider the following claim:

> "1. A computer-implemented method, comprising: receiving, from a server associated with an application, a first indicator representing an intent to invoke the application; receiving, from the server, a second indicator representing a content type, the content type corresponding to content accessible by the application; using the first indicator and the second indicator to train a natural language understanding (NLU) component of a system; generating output audio data soliciting a spoken utterance, wherein the output audio data represents the intent and the content type; causing a first device to output first audio corresponding to the output audio data; receiving, from the first device, first input audio data; performing automatic speech recognition (ASR) processing on the first input audio data to generate first text data, the first text data including a first portion and a second portion; associating the first portion with the first indicator; associating the second portion with the second indicator; using the first portion associated with the first indicator and the second portion associated with the second indicator to further train the NLU component; after further training the NLU component, determining, using the NLU component, that a user input corresponds to the intent and the content type; and causing the application to perform an action based at least in part on determining that the user input corresponds to the intent and the content type."[89]

The claim comes from an Amazon AI patent for natural language understanding. The transitional phrase *comprising* allows for a broad reading. The invention utilizes natural language understanding to cause an application to take certain actions. The detailed description in the claim body provides a meticulous account for the patentable invention including the server, the application, as well as the natural language processing algorithm responsible for processing the data. This text fine tunes the claim scope to the specific invention patented.

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[87] *Genentech, Inc. v. Chiron Corp.*, 112 F.3d 495, 501, (Fed. Cir. 1997). *A method comprising* means the invention includes but is not limited to the elements identified in the claim.
[88] Shawn P. Miller, *What's The Connection Between Repeat Litigation And Patent Quality? A (Partial) Defense of The Most Litigated Patents*, 16 Stan. Tech. L. Rev. 313, 317 (2013).
[89] U.S. Patent No. 10,163,436 to Janet Slifka and Elizabeth Baran, Training a speech processing system using spoken utterances (December 25, 2018).

As a second example, consider the claim:

> "1. A processor-implemented method for cognitively summarizing one or more collaborative moments, the method comprising: receiving, by a processor, a plurality of communications sent during a collaborative session; grouping the plurality of received communications into one or more bursts based on temporal relatedness of each message by analyzing inter-message time intervals, total elapsed conversation duration, and message topic, wherein the beginning and end of the one or more bursts are computed using an assigned relevance score for each message based on associated keyword, wherein the associated keywords are extracted and assigned to each burst utilizing one or more natural language processing techniques, wherein a burst continues to exist so long as the assigned relevance score for each message remains above a preconfigured threshold value; generating a summary for each burst using one or more natural language processing techniques to identify key messages based on the assigned one or more keywords or one or more entities, where in the one or more natural language processing techniques include the use of one or more natural language classifiers to select messages to be included in the generated summary; and transmitting the generated summary to each user participating in the collaborative session."[90]

Note the explicit detail with which the invention is described, establishing a narrow scope for this claim. Indeed, the summarization technology is limited in scope by implementation on a processor, using interval-based communications and keyword extraction. Similar to the first example, the transitional phrase is *comprising*, which should be read broadly. Still, the balance of interest in claim drafting is not a dichotomy, but rather a continuous scale, which may be measured with objective metrics.

Scope is critical in software thickets, which are several patents for suggestively similar inventions. Consider the following examples comparatively. In 2013 the United States Patent Office, awarded two patents for resource management using reinforcement learning. The first, U.S. Patent No. 8,429,096, *Resource isolation through reinforcement learning*, was awarded to Amazon in April, which claimed the following.

> "1. A method, comprising: performing, by a computer: storing data on behalf of a plurality of subscribers in a shared storage system; receiving input specifying one or more service level parameter values, each parameter value specifying a quantity of a respective resource that can be allocated for use in executing one or more queries in the shared storage system; receiving a plurality of queries directed to the data; and executing the plurality of queries, wherein said executing comprises: monitoring resource utilization, wherein the monitored resource utilization is resource utilization by the plurality of queries of resources for which service level parameter values have been

[90] U.S. Patent No. 10,417,340, to Applegate, et al., Cognitive collaborative moments (September 17, 2019) (Assigned to International Business Machines Corporation).

> specified, wherein said monitoring is performed during execution of the plurality of queries; determining whether the resource utilization by the plurality of queries is consistent with the one or more specified service level parameter values; and in response to determining that the resource utilization by one or more of the plurality of queries is not consistent with the one or more specified service level parameter values, attempting to correct the determined inconsistency, wherein said attempting comprises applying a reinforcement learning technique to automatically update an execution parameter of at least one of the plurality of queries, wherein an execution parameter is a modifiable parameter affecting execution of the plurality of queries, and wherein the update is performed during execution of the plurality of queries."[91]

The first problem with this claim is the preamble does not include any description for the methods use. If an idea is not useful, it is not an invention. Regardless, the transitional phrase *comprising* indicates a broader reading, but the word count at 247 narrows the claim's scope. Moreover, the syntax choice which includes, *plurality of queries*, *monitoring resource utilization* and *the determined inconsistency* may render the claim altogether indefinite.

Two months later the second patent, U.S. Patent No. 8,468,041 to Vengerov, *Using reinforcement learning to facilitate dynamic resource allocation*, was awarded to Oracle in June. Oracle's patent claim is slightly better because it is more concise, clear, and cogent in form and substance.

> "1. A method for allocating resources to projects in a computer system, comprising: in a resource allocation mechanism in the computer system, for each project, at least one processor of the computer system performing operations for: determining a current demand by the project for a resource; determining a current allocation of the resource to the project; using a computational model for the project to compute an expected long-term utility of the project for the resource; and using a reinforcement learning technique to update parameters of the computational model for the project based on performance feedback parameters; and trading the resource between the projects in the computer system to optimize a weighted summation of the computed expected long-term utilities of all the projects, wherein the weighted summation of the computed expected long-term utilities is a measure of a single common benefit of all the projects."[92]

The preamble phrase *for allocating resources to projects in a computer system* illustrates useful purpose. As for scope, the transitional phrase is comprising which denotes a broader reading. However, similar to the Amazon patent, the syntactic choice for the claim body is atrociously indefinite. Critically, the claim is written in passive voice *processor of the computer*, *parameters*

[91] U.S. Patent No. 8,429,096 to Soundararajan, et al. Resource isolation through reinforcement learning (April 23, 2013).
[92] U.S. Patent No. 8,468,041 to Vengerov, Using reinforcement learning to facilitate dynamic resource allocation (June 18, 2013).

of the computational model, and *utilities of all the projects*. Consider, the passive voice reflects a more passive claim.

Critically, claims are the most important part of the patent because they define the legal rights. Key considerations for writing patent claims include scaling scope and parsing parameters. It is important to narrow the scope to the specific invention, while adjusting parameters to the widest possible reading to maximize protection. Conceptually this allows the patent to take its maximum form from an object oriented approach. However, narrowing the claim scope in certain circumstances may help the patent to evade obviousness objections from the examiner.[93] Finally, the object oriented approach to claim drafting also allows for higher quality patents, in specifying the essence of claim quality with metrics by which quality may be both measured and maximized.[94]

Conclusion

Chapter 4 explained the process for writing patent applications in three parts. First patent drawings were discussed and described, detailing the process by which inventions are illustrated. Then, the specification was explained, setting the stage for securing legal protection. Third, claims were explored, providing a means by which inventions are legally monopolized.

Again, the most important concept in drafting patents is that any invention can be patented in several different ways. Inventions are intellectual assets which are dynamic and constantly changing. In fact, most inventions permeate the social mind for years before being realized by small teams or individuals on the edge. Additionally, many great inventions have several patents – for example, the Macintosh Computer is protected by more than three-dozen patents.[95]

In concluding, the Latin Maxim *calamus gladio fortior* stands for the principle that the pen is mightier than the sword. Remember, when drafting a patent – you have the opportunity to do great work, to create an artifact of history, and to foster a finer future for humanity. The best inventions usually start with a problem, and any new and useful technical solution can be patented. In solving problems with patents, the details matter, and meticulous focus yields the best work product when drafting. Ultimately, the ability to invent is a blessing, but to hone the skill to invent is the product of tireless work.

[93] *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398 (2007).
[94] MPEP § 2173, Claims Must Particularly Point Out and Distinctly Claim the Invention (2021).
[95] U.S. Patent No. 8,989,206 to Zhang, et al., MAC packet data unit construction for wireless system (March 24, 2015). See also U.S. Patent No. 8,166,144 to Siegmund, Network identification and configuration using network signature (April 24, 2012).

Chapter 5 Artificial Intelligence

Introduction

The term artificial intelligence (AI) has been discussed at length by various scholars and industry leaders. Generally, AI refers to any machine capable of learning, remembering, and taking actions. AI technology is affecting industries across the economy including law, healthcare, and defense. For example, in the legal industry, technology assisted review is changing the discovery process. In other words, AI programs now complete tasks previously only lawyers could do, like classify documents based on relevancy during discovery. While AI development is challenging, the resulting programs are no accident. In fact, academics, researchers, and industry professionals have been working on AI systems since the early nineteenth century.

AI is a field uniquely positioned at the intersection of several scientific disciplines including computer science, applied mathematics, and neuroscience. The AI design process is meticulous, deliberate, and time-consuming – involving intensive mathematical theory, data processing, and computer programming. All the while, AI's economic value is accelerating. As such, protecting the intellectual property (IP) springing from this work is key for technology companies in competitive markets. In fact, by the end of the year 2020, the USPTO had awarded approximately 94,000 patents for AI technologies.

Chapter 5 explores AI patents, with a specific focus on machine learning and natural language processing. First, the Chapter describes deep learning technologies, applications, and patents. Second, Chapter 5 explores economics, market capture, and intellectual property for reinforcement learning technologies. Third, technical convergence toward deep reinforcement learning and software code copyrights are discussed. Fourth, Chapter 5 explains the state-of-the-art in natural language processing (NLP) and critically examines virtual assistant intellectual property. Finally, a general theme throughout the Chapter is acceleration.

Deep Learning

Deep learning is a type of machine learning concerned with acquiring knowledge from large amounts of data.[96] Rina Dechter first introduced the term deep learning in the year 1986.[97] But, the technology's technical roots date back to the middle of the twentieth century. In 1957, Frank Rosenblatt published an algorithm that automatically learned the optimal weight coefficients for an artificial neuron – the perceptron. Rosenblatt's perceptron is still the foundation for most artificial neurons today.

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[96] EUGENE CHARNIAK, INTRODUCTION TO DEEP LEARNING (2018).
[97] Rina Dechter, Learning While Searching in Constraint-Satisfaction Problems, AAAI-86 Proceedings (1986). Rina Dechter is a professor of computer science at University of California, Irvine.

The deep learning process is inspired by the neurological structures found in the human brain. Both artificial and biological neurons receive input from various sources and map input information to a single output value. Each biological neuron in the brain is connected to other neurons through structures called synapses. Artificial neurons model the strength of synapses, the connectivity between neurons, with weight coefficients. Thus, neural information transfer in the biological brain inspires the way in which modern deep neural networks operate.

Importantly, learning is a process by which matter rearranges to improve its ability to compute a desired function. In deep learning, the idea is to learn patterns in information, deriving knowledge from data with minimum human contribution. As such, the internet is the driving force behind deep learning strategies because the internet enables humanity to organize and aggregate massive amounts of information. In fact, every day humans create roughly five exabytes of data, as much as civilization created from the dawn of time until the year 1999.[98] The explosion in information collection since the internet's inception is resulting in rapidly improving deep learning applications in both research and industry. Generally, deep learning systems are developed in four parts: data pre-processing, model design, training, and testing.

The majority of the time spent with deep learning system development is during the pre-processing stage. During this initial phase, machine learning researchers gather, organize, and aggregate data for analysis with neural networks. The types of data neural networks process vary. For driverless cars, the data are often camera images and LiDAR pixels. For a friend recommendation software, the data relate to user behavior and identifiable features like location, work, and school. The goal for a particular deep learning system largely defines the data's organizational structure. In other words, the problem's definition guides the way in which data is obtained and pre-processed. For example, if a system is being developed for predictive purposes, the data may be labeled with positive and negative instances of an occurrence to support a supervised learning model.

A deep learning system's model is the part of the system which learns and analyzes the data. The most common deep learning model is the deep neural network (DNN). A DNN is an organized structure of interconnected neurons. The network's interconnected neurons are modeled with weight coefficients, which are adjusted through a learning process until a model is optimized for performance. Typically, matrix multiplication and partial derivative calculations are the mathematical core for learning algorithms. Importantly, neural networks are universal function approximators, meaning they can approximate any function with desired accuracy. Since all information can be represented as numbers, the neural network's ability to generalize to new information is a critical component for deep learning. Consider theoretically a neural network can process any information.

Every neural network has an input layer and an output layer. And the depth of the model is defined by the number of hidden layers between the input and output layer. For example, a DNN

[98] For reference, one exabyte is one quintillion, or 10^{18} data bytes.

contains many hidden layers between the input and output layer. The number of hidden layers may vary and is dependent on the particular model. Each layer of hidden neurons acts as a feature extractor by providing analysis of slightly more complicated features. The layers in a neural network are represented as a matrix, a rectangular array of numbers, symbols, or expressions, arranged in rows and columns. The mathematics for a forward pass —input to output— in a neural network is matrix multiplication.

But for machines to learn, there must be a way in which matter evolves itself to improve performance. In other words, the machine must have a method of interacting with its environment that recursively self improves. Backpropagation is a training algorithm for updating the weights in a neural network, improving accuracy over time. In other words, backpropagation is how neural networks learn. In the 1970s and 1980s, researchers developed backpropagation as a way to train neural networks. Paul John Werbos is considered the first person to explore backpropagation through neural networks.[99] By applying a temporal element to the learning process, Werbos showed neural networks iteratively learn through time.

Generally, a backpropagation algorithm has three steps: (1) an instance enters the network, flowing forward until the network generates a prediction; (2) the network's error for the prediction is calculated by comparison to the correct output; and (3) the error is propagated back through the network, updating the weights. Technically, backpropagation's central task is training the deep learning program. Another way, backpropagation is a method for computing the partial derivatives of error functions in neural networks. The algorithm iterates through the network toward a set of weights producing a desirable result. After consistent iteration, the network converges, capturing a pattern and allowing the network to generalize about new instances, rather than merely memorizing training data. The keystone to deep learning technologies, backpropagation remains a foundational achievement in AI studies because it enables machines to learn from the data they perceive.

Finally, the trained model must be validated and tested. Probably the most important aspect for testing is safety. Various safety issues arise depending on the specific system but include robotics crash or inadvertent user manipulation. Ethics are a critical component in the testing process due to the powerful manipulative influences deployed machine learning programs have on social, political, and economic decision making. As such, various ethical considerations relating to testing and deploying deep learning programs include alignment, containment, and performance.

Convolutional Neural Networks (CNNs) are a specific type of neural network used for deep learning in computer vision tasks. A CNN contains at least one convolution layer; a layer whose parameters are learnable kernels. Each kernel is convolved across an input matrix and the resulting output is called a feature map. CNNs are used for a variety of computer vision tasks, including object classification, image recognition, and action detection.

[99] PAUL JOHN WERBOS, THE ROOTS OF BACKPROPAGATION FROM ORDERED DERIVATIVES TO NEURAL NETWORKS AND POLITICAL FORECASTING (1994).

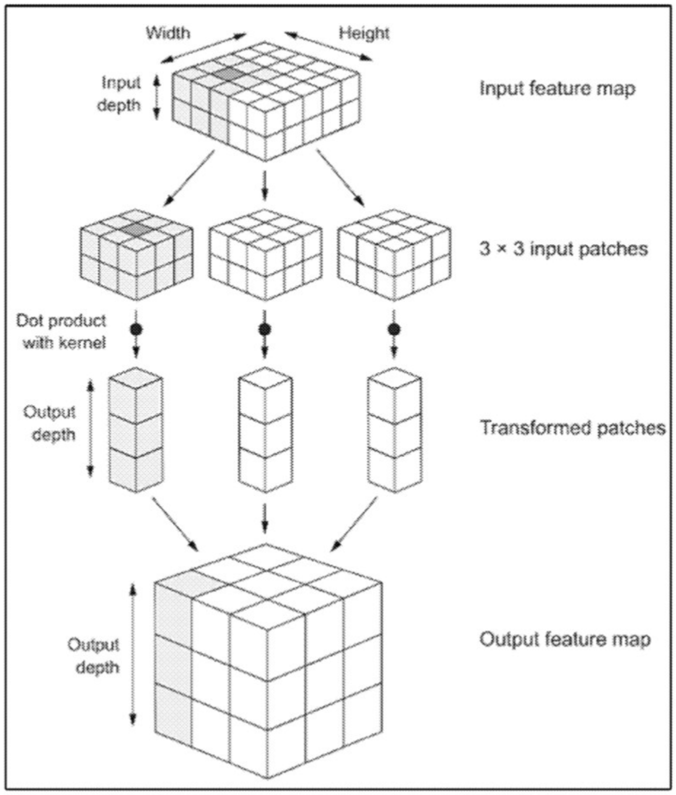

Figure 11[100]

The full output of the layers is obtained by stacking all of the feature maps to create dimensionality. Figure 11 is a patent drawing for a CNN, from a patent owned by Illumina, a California Biotech company. Illumina's patent protects computer vision technology using a deep learning mechanism for classifying computer images.

In image classification, pixels are the basic input. The neurons in the CNN's first layer detect basic image descriptors such as strokes and edges of different orientations. Later layers combine the previous layers forming longer lines, arcs, and corners. Layers that follow learn more complex shapes such as circles, squares, and rectangles. Eventually, the layers are pooled together, classifying objects, such as faces, landing zones, or handwritten letters. The CNNs essential purposes are the transformation of visual images into digital descriptions and appropriate class ascription.

[100] U.S. Patent No. 10,558,915 to Gao et al., Deep Learning-Based Techniques for Training Deep Convolutional Neural Networks (Feb. 11, 2020).

The first patent for deep learning technology was awarded to InsideSales.com, Inc., in the year 2014.[101] The patent protected deep learning technology integrated with a user interface for processing information across a network architecture. The other deep learning patent from 2014, was awarded to SRI International for autonomous vehicle technology.[102] The technology used a deep learning algorithm for image classification, to detect pedestrians in the vehicle's field of vision.

Since then, there has been a sudden and rapid growth in the number of patents granted each year for inventions using deep learning. Figure 12 charts the number of patents the USPTO awarded by year for deep learning technologies.

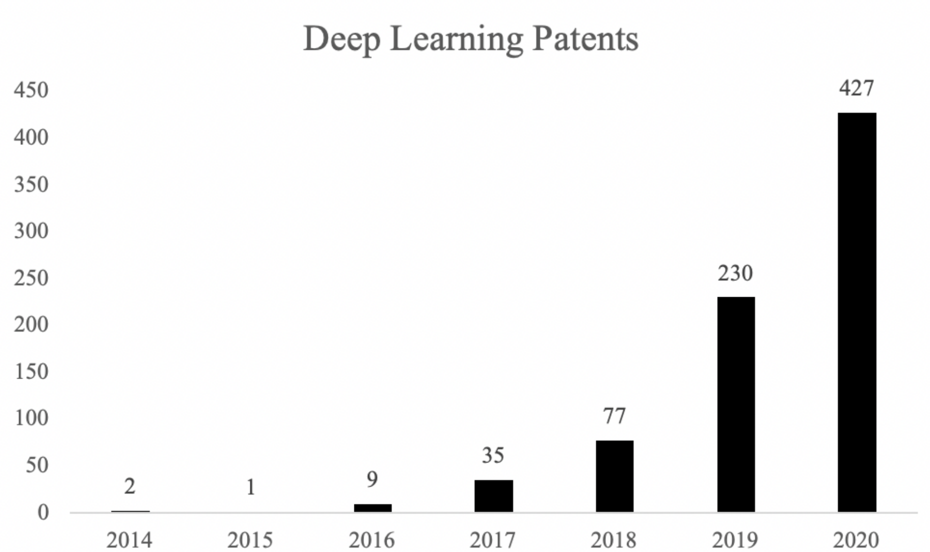

Figure 12

The major players in the technology industry including Google, Apple, Microsoft, and Amazon all own several patents for deep learning technologies. Moreover, IBM, Siemens, and Baidu are also significant stakeholders in the deep learning market. At the end of the year 2020, 781 total U.S. patents were awarded for deep learning technologies. Additionally, it is likely as many as 3,300 U.S. patents more broadly discuss deep learning technologies. At global scale, there are over 24,000 total patents for deep learning technologies. By far, the Chinese Patent Office is awarding the most, granting more than 21,000 patents, approximately 88% of the world total, before the year 2021.

Driven by data, deep learning is a defining technology for the millennia. In sum, deep learning technologies are integrating with industries across the economy. Due to their ability to

[101] United States Patent No. 8,775,332, to Morris, et al., Adaptive User Interfaces (July 8, 2014). (The first patent granted with the term deep learning appearing in a claim.)
[102] United States Patent No. 8,861,842 to Jung, et al., Method and Apparatus for Real-Time Pedestrian Detection for Urban Driving (Oct. 14, 2014).

generalize, deep learning programs reflect the state-of-the-art in transportation, defense, and healthcare. As these systems evolve, they may be integrated with action-oriented programs, like reinforcement learning software for general application.

Reinforcement Learning

Reinforcement learning is a machine learning technique for computer programs to achieve goals. For example, reinforcement learning algorithms drive cars, land rockets, and diagnose patients. As a field of research, reinforcement learning rests at the intersection of computer science, philosophy, and mathematics. Reinforcement learning software is a critical component for many AI software systems in industry and research. As such, protecting the property rights to reinforcement learning technologies is a differentiating factor for firms advancing AI technology.

Reinforcement learning's inception may be traced to the year 1846 when the late mathematician, P.L. Chebyshev, developed a general probability theory.[103] Chebyshev's work was a heavy influence on Andrei Markov, whose writing on probability theory resulted in one of the world's most important ideas, the Markov Decision Process (MDP).[104] MDPs trace the probabilistic transitions from one state to the next through time. In short, the MDP is a statistical tool for predicting the future. The MDP was adopted and critically analyzed by great pioneers in AI throughout the 20th Century, like Claude Shannon and Noam Chomsky.[105] Today, Markovian techniques remain a central theme for AI researchers and professional computer scientists. As such, the MDP is a keystone reinforcement learning architecture.

Reinforcement learning software optimizes agent performance according to a reward. The process involves building models and developing systems for decision making embedded in software programs. In practice, engineering reinforcement learning systems is a meticulous, time consuming, and data-intensive task process. But the effort is worthwhile because reinforcement learning learns without supervision. Reinforcement learning software contain three elements a: (1) model: the description of the agent-environment relationship; (2) reward: the agent's goal; and (3) policy: the decision function.

The MDP is still the standard model for reinforcement learning. The model describes the relationship between an agent and an environment over time. The environment is made up states, which are instances of the environment passed to the agent. In return, the agent returns actions to the environment given each state. In an MDP, the interaction begins when an agent chooses an action in the environment's initial state. The model continues to the next state, where the agent

[103] P.L. Chebyshev, D*émonstration élémentaire d'une proposition Générale de la théorie des probabilities*, 33 J. Reine Angew. Math. 259 (1846). *See also* Paul Butzer, *P. L. Chebyshev (1821-1894) A Guide to his Life and Work*, 96 Journal of Approximation Theory 111, 118-119 (1999). ("Remaining unnoticed at the time, this paper had thus no effect on the controversy about laws of large numbers then going on in France.")
[104] Gely P. Basharin, et. al, *The Life and Work of A.A. Markov*, 386 Linear Algebra and its Applications 1, 15 (2004).
[105] C.E. Shannon, *A Mathematical Theory of Communication*, Bell Systems Technical Journal 8 (1948). *See also* NOAM CHOMSKY, SYNTACTIC STRUCTURES 17 (1957).

receives a reward and a set of actions from which to choose, the agent selects an action, the environment returns a reward and the next state. This process continues iteratively until the environment's final state, with the agent learning to take actions optimizing a reward.

In reinforcement learning, the agent's decisions are correlated with maximizing some reward, like safety and efficiency for driverless cars, or value for a portfolio of stocks. As such, the goal for any agent in an MDP is to maximize its expected reward during an episode, which is the total of all states in an environment. The reward acts as a feedback mechanism, allowing the agent to learn independent of human training. Rewards are used to update the agent's knowledge, so it learns to take actions returning the highest rewards over time.

An important distinction in reinforcement learning is the relationship between reward and value. Reward defines the response from taking an action in a given state, where the value refers to the total amount of reward over an episode. In short, reward is a measure of short-term gain and value is a measure of long-term reward. Defining the reward for a reinforcement learning system is often one of the most challenging aspects in machine learning development. The object by which an agent pursues reward is the policy.

The policy is the way in which the agent decides which actions to take given certain information about the environment. The goal is for the agent to select the policy which maximizes both short term reward and value for the episode. In reinforcement learning systems, the policy results from both exploratory and exploitative decision making, informed by the agent's rewards in previous states. Policy iteration, the process of testing various policies for performance, is an effective method for computing optimal policies because the number of policies for an agent in an MDP are finite. Thus, the iterative process of updating policies eventually converges to an optimal, or at least acceptable solution.

Now, reinforcement learning technologies are defining industry anew with novel AI applications. The simplicity in design is an advantage for reinforcement learning programs because there are only three essential elements, model, policy, and reward. In short, reinforcement learning is a method for statistically selecting a policy which maximizes expected reward for an agent acting in an environment.

Propelling the state-of-the-art in transportation, defense, healthcare, information technology, and cybersecurity, reinforcement learning systems cut across several sectors in the economy. For example, in the transportation sector, Toyota, Ford, and Waymo are all using reinforcement learning for their driverless car technology.[106] *Figure 13* depicts the industrial breakdown for reinforcement learning patents.

[106] U.S. Patent No. 10,061,316 to Nishi, Control policy learning and vehicle control method based on reinforcement learning without active exploration (August 28, 2018). (Assigned to Toyota) *See also* U.S. Patent No. 10,703,370 to Kusari, et al., Vehicle action control (July 7, 2020). (Assigned to Ford) *See also* U.S. Patent No. 10,254,759 to Faust, et al., Interactive autonomous vehicle agent (April 9, 2019). (Assigned to Waymo)

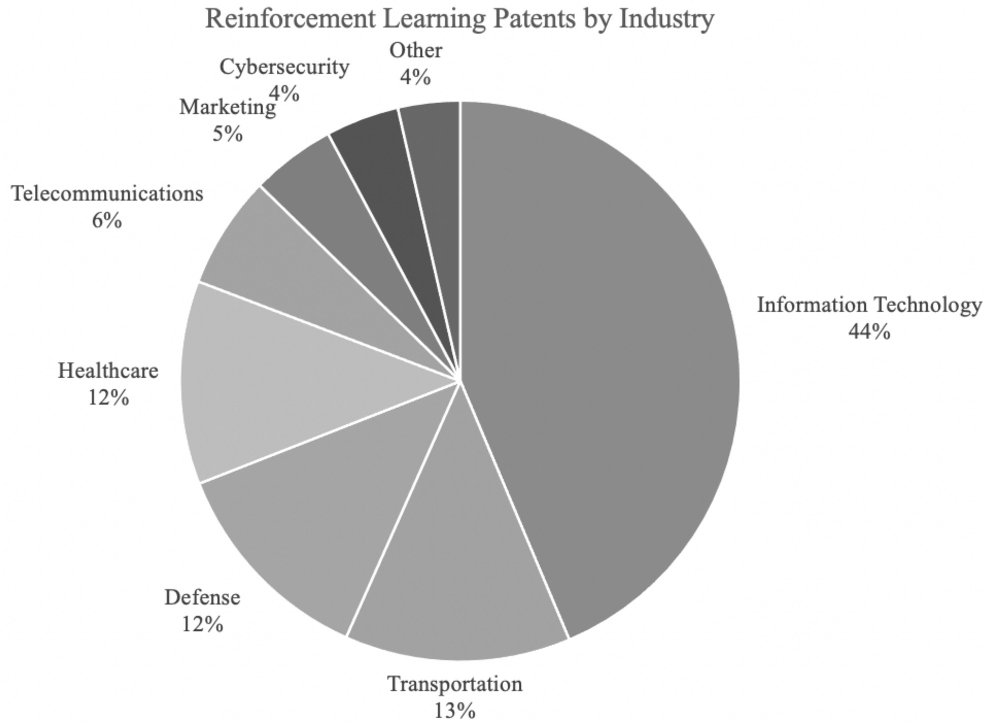

Figure 13[107]

The most common application for reinforcement learning is information technology, which may be unsurprising given reinforcement learning methods are at the bleeding edge in machine learning optimization. For example, in the Information Technology sector, both Oracle and Amazon were awarded patents for resource management using reinforcement learning in the year 2013.[108]

Healthcare is a leading domain for reinforcement learning technologies. For example, Siemens is using reinforcement learning as the backbone for developing new medical technologies. One specific application is medical image segmentation, which is a process by which digital images are rendered in a meaningful and accessible format.

[107] Brian Haney, *Reinforcement Learning Patents: A Transatlantic Review*, Stanford-Vienna Transatlantic Technology Law Forum, Working Paper Series No. 63 (2020).
[108] U.S. Patent No. 8,429,096 to Soundararajan, et al. Resource isolation through reinforcement learning (April 23, 2013). (Assigned to Amazon) *See also* U.S. Patent No. 8,468,041 to Vengerov, Using reinforcement learning to facilitate dynamic resource allocation (June 18, 2013). (Assigned to Oracle)

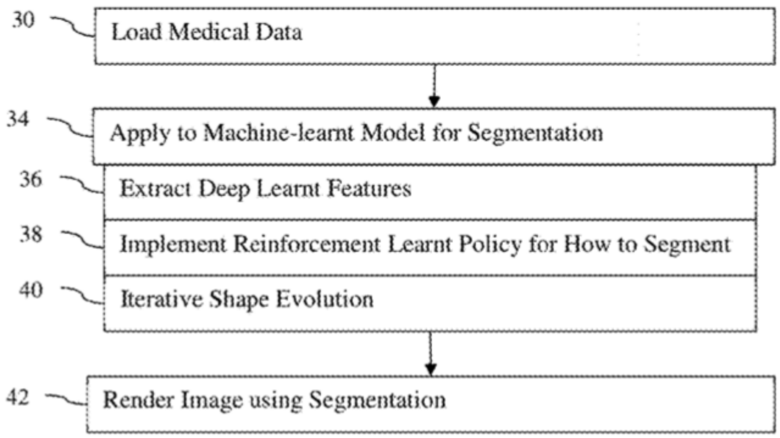

Figure 14[109]

Figure 14 is a patent drawing from a patent owned by Siemens for medical imaging technology using reinforcement learning. The drawing illustrates the technology's essential concepts in a relatively simple format. First, medical data is loaded to the machine. Second, the machine applies a trained model to the data to perform segmentation. Third, the machine renders an image with the segmented data.

The technology may be applied in various healthcare contexts to provide medical information derived from data. Siemens is using the technology in multiple products including software applications and magnetic resonance imaging (MRI) machines. As such, Siemens invests in creating and maintaining a robust patent portfolio to protect its technology in the competitive market.[110] Other companies including Mindray, a Chinese medical device maker, are also developing reinforcement learning technologies for medical imaging and other healthcare purposes.[111]

More than a century after Markov conceived the basic architecture, reinforcement learning is an edge technology with application for automation and optimization in virtually every industrial sector. But still, reinforcement learning technologies alone have limits, with capabilities depending on other software architectures for prime performance. New technologies often result

[109] U.S. Patent No. 10,032,281 to Ghesu, et al., Multi-scale deep reinforcement machine learning for N-dimensional segmentation in medical imaging (July 24, 2018). (Assigned to Siemens)
[110] U.S. Patent No. 10,762,626 to Hu, et al., Activity image reconstruction using anatomy data (September 1, 2020). (Assigned to Siemens) *See also* U.S. Patent No. 10,733,788 to Ceccaldi, et al., Deep reinforcement learning for recursive segmentation (August 4, 2020). *See also* U.S. Patent No. 10,733,788 to Zhou, et al., Method and system for artificial intelligence based medical image segmentation (December 29, 2020).
[111] U.S. Patent No. 10,682,098 to McLaughlin, Predictive Use of Quantitative Imaging (June 16, 2020). (Assigned to Mindray) *See also* U.S. Patent No. 10,304,565 to Barr, et al., Systems and methods for collecting medical images (May 28, 2019). (Assigned to Mindray)

from a technical convergence including various techniques, devices, and machines.[112] For example, personal computers and mobile phones converged, forming the smart phone. As reinforcement learning models continue converging with deep learning software in new ways, AI programs continue outperforming humans in virtually all tasks.

Deep Reinforcement Learning

Deep reinforcement learning is a new type of machine learning resulting from the technical convergence of two more mature machine learning methods, deep learning and reinforcement learning. The technology is important because it is scalable toward general intelligence – a machine capable of achieving any definable goal. The algorithms underlying the technology are capable of sensing their environment and achieving goals, representing the integration of machine intelligence and perception technologies. This algorithmic class developed as machine learning techniques merging research in reinforcement and deep learning technologies.

Deep reinforcement learning systems have three capabilities that set them apart from all previous systems: (1) generalization; (2) learning; and (3) intelligence. As such, attention is rapidly turning to deep reinforcement learning as the hottest area in AI research. For example, according to MIT Professor, Max Tegmark, "deep reinforcement learning is a completely general technique."[113] Convergent systems integrating reinforcement learning and deep learning technologies, represent an unprecedented breakthrough for AI, showing state-of-the-art performance in nearly all industrial domains – from healthcare to modern warfare. There are three architectural frameworks for deep reinforcement learning software Q-Networks, policy optimizers, and actor-critic networks.

From an architectural perspective, deep reinforcement learning technology developed as a result of using deep neural networks for Q-Learning, a model-free reinforcement learning technique using an explicit trial-and-error algorithm. The goal for Q-Learning is solving for the optimal policy in an MDP. In other words, the goal is finding policy which maximizes the value returned to the agent over the course of an episode. Ideally, this method for decision making allows the agent to deploy its policy in a new environment, enabling it to account for uncertainty while acting with the highest success probability. Thus, Q-learning solves the problem of discovering the optimal policy for an agent by maximizing a Q-value function, which describes the value of a state-action pair. Practically, this helps to account for instances in which reward for particular actions is delayed until the future.

Q-Networks are neural networks embedded in the reinforcement learning architecture. An example of a deep reinforcement learning algorithm is the Deep Q-Network (DQN). The DQN algorithm is a type of model-free-learning which is used to develop an optimal policy for an agent with a Q-learning algorithm. More specifically, the DQN algorithm combines Q-learning

[112] PAUL E. CERUZZI, COMPUTING: A CONCISE HISTORY 74-76 (2012).
[113] MAX TEGMARK, LIFE 3.0: BEING HUMAN IN THE AGE OF ARTIFICIAL INTELLIGENCE 83 (2017).

with a neural network to maximize an agent's reward. The DQN algorithm's most important aspect is the Bellman Equation.

The Bellman Equation expresses the relationship between the value of a state and the values of its successor states. The algorithm iterates perpetually until the Q-value function's convergence with an approximate maximum. The Q-value function satisfies the Bellman Equation upon convergence with an approximated maximum.

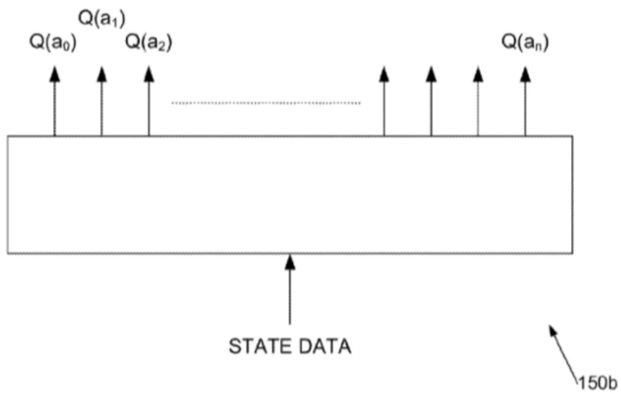

Figure 15[114]

Figure 15 is a patent drawing from a Google patent, illustrating state data as input and an associated Q-value for each action as corresponding output. The agent's optimal policy corresponds to taking the action in each state defined by the optimal Q-value. In other words, the Bellman Equation does two things; it defines the optimal Q-value function and allows the agent to consider the reward from its present state to be worth more than similar rewards in the future.

Thus, a neural network is used as an approximator for a state-action value function, allowing for more efficient programming and model development. After the optimal policy is defined, the agent engages in the exploitation of its environment. During the exploitation phase, the agent maximizes its reward by making decisions according to the optimal policy. The DQN is an off-policy algorithm, meaning it uses data to optimize performance. In essence, DQN is a means by which a reinforcement learning algorithm uses a neural network to decide which actions to take.

A second class of deep reinforcement learning software is policy optimizers. For example, the Proximal Policy Optimization ("PPO") algorithm is a general policy optimization technique. Similar to the DQN algorithm, the PPO algorithm is a method of model-free learning. In contrast to the DQN algorithm, PPO is an on-policy algorithm, meaning it does not learn from old data and instead directly optimizes policy performance. One advantage of the PPO model is utility in environments with either discrete or continuous action spaces. PPO computes policy gradient

[114] U.S. Patent No. 9,679,258, to Mnih, et al., Methods and apparatus for reinforcement learning (June 13, 2017).

estimation and iterating with a stochastic gradient optimization algorithm. In other words, the algorithm continuously updates the agent's policy based on the old policy's performance.

The PPO algorithm's key to the success is obtaining good estimates of an advantage function. The advantage function describes the relative difference between two policies. The algorithm's goal is to make the largest possible improvement on a policy, without stepping so far as to cause performance collapse. To that end, PPO relies on clipping the advantage function to remove incentives for the new policy to step far from the old policy. In essence, the clipping serves as a regularizer, minimizing incentives for the policy to change dramatically.

A third deep reinforcement learning variant is actor-critic networks. For example, the Deep Deterministic Policy Gradient ("DDPG") algorithm uses the actor-critic approach. Similar to both DQN and PPO, DDPG is a model-free learning method. Yet, unlike PPO, the DDPG algorithm is only applicable in continuous action spaces. By comparison, DDPG is relatively similar to the DQN in form and structure. For example, DDPG is also an off-policy algorithm and it iterates to learn from prior training data. Importantly, DDPG learns a deterministic policy, meaning the state defines the action. In short, DDPG is a method of deep reinforcement learning using two neural networks for approximation, an actor and a critic.

Ultimately, the actor decides which action to take. But, to optimize an agent's reward, after each action, the critic defines the necessary adjustment for performance improvement. The DDPG algorithm shows promise in continuous control tasks for robotics systems. For example, DDPG has shown state-of-the-art success for self-driving cars. However, the off-policy nature of the algorithm makes it much slower because it takes more computational power to train compared to the PPO and other on-policy algorithms. As computational hardware develops, quantum computers provide a faster method of computing than classical methods and may be able speed up off-policy machine learning algorithms.

Deep reinforcement patents are rarer than both deep learning and reinforcement learning patents. In fact, by the end of the year 2020, the USTPO had only awarded 35 total patents for deep reinforcement learning technologies. However, similar to deep learning and reinforcement learning, deep reinforcement learning is impacting all sectors in the economy. Consider the way deep reinforcement learning technologies manipulate user behavior on social media platforms is transforming the marketing industry.

For example, Facebook uses deep reinforcement learning software on its social media platform,[115] which yielded $70.697 billion in revenue during the year 2019.[116] In one patent, Facebook discloses methods using deep reinforcement learning to determine friend

[115] U.S. Patent No. 10,387,161to Tian et al., Techniques for capturing state information and performing actions for threads in a multi-threaded computing environment (August 20, 2019). (Assigned to Facebook) *See also* U.S. Patent No. 10,432,749 to Foged, Application bookmarks and recommendations (October 1, 2019).
[116] Facebook, Inc. Form 10-K, United States Securities Exchange Commission, 74 (December 31, 2019).

recommendations for users.[117] Snapchat is another media platform using patenting deep reinforcement learning technologies for multiple applications and purposes. Indeed, Snapchat owns patents for picture framing, filtering, and formatting using deep reinforcement learning. [118]

Information technology is another sector changing because of deep reinforcement learning technologies. In fact, International Business Machines (IBM) was the first company to patent technology integrating neural networks in a reinforcement learning architecture during the year 2008.[119] At the time, the technology was novel because it was a completely new method for control optimization and statistical estimation. The essential invention protected by IBM's patent is a computer circuit capable of learning and generating simultaneously using AI.

Then in the year 2017, Google patented a novel methodology for reinforcement learning using Q-learning. From the patent, Figure 16 illustrates a computer system programmed to implement a deep reinforcement learning program.

[117] U.S. Patent No. 10,313,456 to Ma, et al., Multi-stage filtering for recommended user connections on online social networks (June 4, 2019).
[118] U.S. Patent No. 10,467,274 to Ren, et al. Deep reinforcement learning-based captioning with embedding reward (November 5, 2019). (Assigned to Snap Inc.) *See also* U.S. Patent No. 10,623,662 to Li, et al., Processing and formatting video for interactive presentation (April 14, 2020). (Assigned to Snap Inc.) *See also* U.S. Patent No. 10,672,136 to Duan, et al., Active image depth prediction (June 2, 2020).
[119] U.S. Patent No. 7,395,251, to Linsker, Neural networks for prediction and control (July 1, 2008). (Assigned to International Business Machines Corporation)

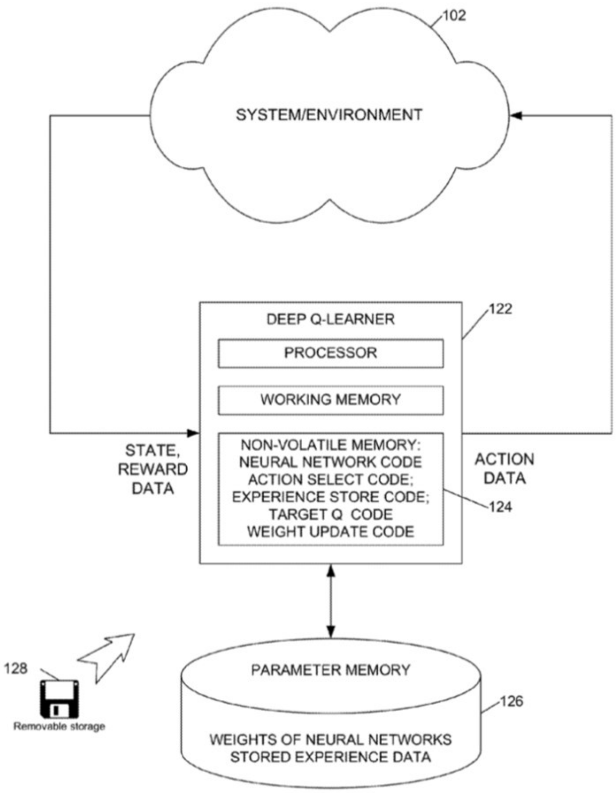

Figure 16[120]

Google continues developing deep reinforcement learning software with a growing patent portfolio protecting the technology.[121] Interestingly, Google uses a mixed IP strategy because the software code for the Deep Q-Learner is publicly posted on GitHub under the Apache License.[122]

As a result, defining the protectable limits for software code copyrights and corresponding patented inventions involves sophisticated technical, legal, and strategic skill. Technically, deep reinforcement learning is on the bleeding edge. So, the technology's language has yet to fully evolve into the patent system's prior art. Legally, the most common copyright protection ascribed to deep reinforcement learning software programs is the Apache License. Generally, the Apache License grants a license to the public, with a limited liability warranty. So, from a strategic perspective, inventors seeking to win patents for their inventions may use technically specific language, focusing syntax on novel contributions.

[120] U.S. Patent No. 9,679,258 to Mnih, et al., Methods and Apparatus for Reinforcement Learning (June 13, 2017). (Assigned to Google)
[121] United States Patent No. 10,346,741 to Mnih, et al. Asynchronous deep reinforcement learning (July 9, 2019). (Assigned to DeepMind Technologies)
[122] Apache License, Version 2.0 (January 2004).

The ultimate strategy decision largely depends on the purpose for which the patent is sought. For example, there are also drawbacks to being specific, like limiting the scope of legal protection. Regardless, there is much room for growth in deep reinforcement learning intellectual property considering DQN, PPO, and DDPG are all foundational algorithms for the state-of-the-art in AI technology. While the mathematical models underlying these systems are not new, their computational capabilities recently began improving rapidly. Perhaps the ultimate test for deep reinforcement learning systems will be conquering the most complex matrix, language.

Natural Language Processing

Similar to the way the physical Universe expands with time, our cognitive Universe widens with language. Because, just as entropy guides the cosmos from order to disorder,[123] time drives the expansion of language. Ancient texts tell a story of a time when the whole world had a common language. As a result, humans were powerful and decided to build a bridge to the heavens. But then God said, "If as one people speaking the same language, they have begun to do this, then nothing they plan to do will be impossible for them. Come, let us go down and confuse their language so they will not understand each other."[124] So, God scattered the people's language across the Earth, preventing construction of the heavenly bridge.

Defined, NLP is the study of computational linguistics, which includes natural language understanding and natural language generation. Modern theories of NLP began in 1948, with Claude Shannon, who applied Markovian techniques to linguistic processing for natural language generation, developing a statistical theory for communication.[125] Almost a decade later, Noam Chomsky's key insight was advancing grammar as a device generating all of a language's grammatical sequences and none of the ungrammatical devices.[126] However, no one has successfully proved Chomsky's mechanistic theory for grammar. Still to this day, mastery of language is thought by many to be the most difficult task for computers to conquer.

The divide between syntax and semantics remains one of the most challenging problems in artificial intelligence. Today, NLP techniques form the backbone for commercial products including virtual assistants, trading algorithms, and security architectures. For example, NLP technologies decode the user's speech, which instructs virtual assistants to respond. If the user requests an answer to a query, then NLP enables the virtual assistant to generate a spoken answer. There are three prominent AI architectures in NLP research and industrial application, recurrent neural networks, autoencoders, and cognitive computing.

A recurrent neural network (RNN) is a neural network tailored for processing sequential series of information. RNNs use an artificial memory mechanism to improve the quality of machine learning methods in NLP. In fact, the term recurrent refers to the way in which the network

[123] BRIAN GREENE, FABRIC OF THE COSMOS 151 (2005).
[124] Genesis 11:7-8
[125] C.E. Shannon, *A Mathematical Theory of Communication*, Bell Systems Technical Journal 8 (1948).
[126] NOAM CHOMSKY, SYNTACTIC STRUCTURES (1957).

processes information with a dependency on preceding calculations. The memory mechanism is inspired by a biological counterpart in the human brain, where memories are formed by the strengthening of synaptic connections. As such, RNNs work by strengthening the relationships between certain nodes in the network through a recurrent feed-forward model.

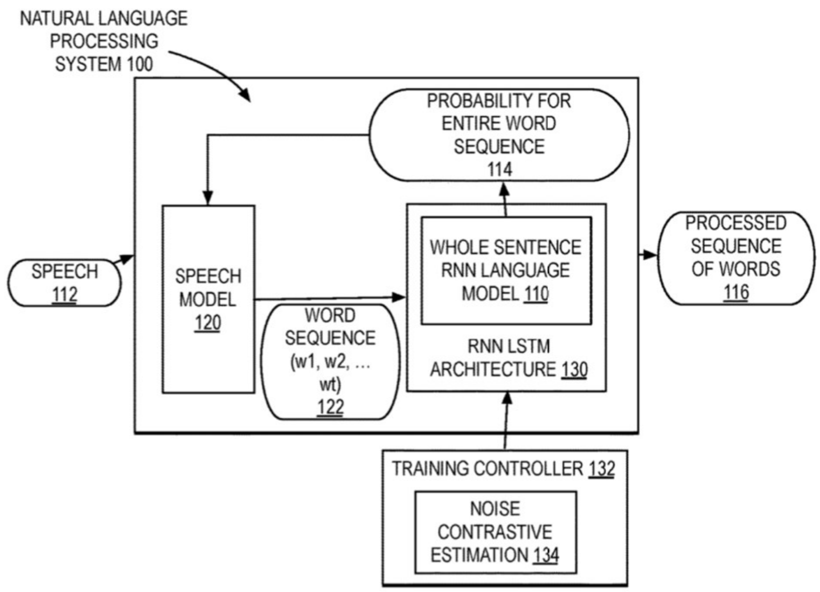

Figure 17[127]

For example, Figure 17 is a patent drawing for NLP technology using an RNN developed and owned by IBM. In general, RNNs are appropriate for problems where specific prior nodes influence later nodes in the network because RNNs process sequences of data one element at a time. Thus, RNNs are frequently used for NLP tasks like machine translation.

Next, an autoencoder is a type of neural network trained to reconstruct its input at its output. Because there are fewer intermediary hidden units than inputs, the network learns a compressed representation to perform abstraction. The autoencoder model makes two foundational assumptions about linguistics. First, language understanding is a process of encoding where humans extract high order abstraction. Second, language generation is a process for decoding and synthesizing natural language sentences from higher order representations.

Prior NLP systems needed hundreds to thousands of examples to induce functions which generalize well. As a result, the training process took a lot of time. However, transfer learning with autoencoders is changing NLP with customized, out-of-the-box performance. In transfer learning, the autoencoder is pretrained on large datasets maintained by institutions with the capability to process big data. Then, the institutions make certain products relating to the datasets

[127] United States Patent No. 10,431,210 to Huang et al., Implementing a whole sentence recurrent neural network language model for natural language processing.

available via cloud computing resources. Finally, developers may access, modify, and adjust pretrained autoencoders for specific tasks and purposes using the masked language model for narrower niche training.

Cognitive computing is a class of NLP technology using knowledge models to provide a way in which humans and computers interact, to collaboratively perform intelligent activities. In other words, cognitive computing is a broad field in computer science focusing on AI with a greater emphasis on human decision making. Cognitive computing development is a three-step process; developers: (1) outline analytical functions; (2) develop an information flow model; and (3) organize information. According to common innovation strategies, iteratively developing the cognition system is most efficient because it allows developers to progressively process information to achieve design goals.

Another advantage to using cognitive computing for development is faster solving times for commonsense problems. Solving most commonsense problems via software requires access to a large database to provide background knowledge, which may not already exist when development begins. So, for solving commonsense problems a cognitive computing model assigns the analytical function to the developer, rather than pursing data for automation. Understanding the capabilities and liabilities of both data models and knowledge models illuminates ways to improve AI systems.

The first U.S. Patent for NLP was awarded to a Japanese electronics company, which is now Toshiba, in the year 1986.[128] Figure 18 graphs the number of NLP patents the USPTO awarded each year.

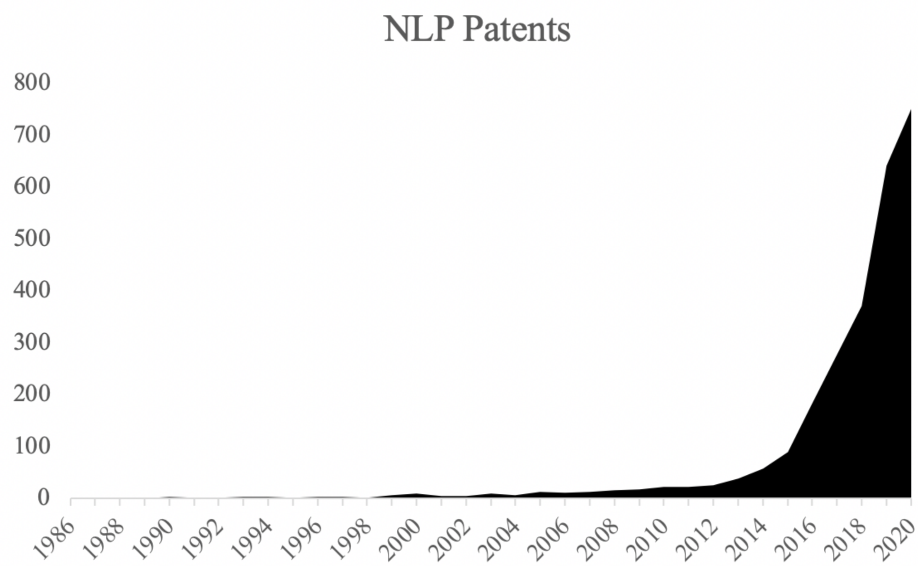

Figure 18

[128] U.S. Patent No. 4,586,160, Method and Apparatus for Analyzing the Syntactic Structure of a Sentence (April 29, 1986).

In total, at the end of the year 2020 there were 2,608 U.S. Patents for NLP software. In fact, 750 patents for NLP technology were granted in the year 2020 alone.

Similar to other AI technologies, NLP technology is being used all across the world. Globally, there were 7,360 total patents for NLP technology at the end of the year 2020. Compared to all other patent offices, the United States Patent Office produces the most patents for NLP technology at 53% of the total and the Chinese Patent Office is second with 21% of the total.

United States progress in this domain is driven largely by publicly traded telecommunications companies and government contracts. In fact, NLP technology is having an immense impact in the telecommunications sector, which physically stores and supports all communications networks, computer systems, and digital data. For example, AT&T patented search technology using quantum computation, which is both significant as an innovation and now an essential element for maintaining cybersecurity.[129] Another example is Cisco, which owns the rights to an alert system for digitally tracking an individual's location using NLP.[130]

NLP technologies are also at the cutting edge in online shopping and consumer markets. For example, Wal-Mart owns a patent for influencing online shoppers using NLP.[131] And, eBay patented technology for optimizing consumer spending given various financial features about individual users.[132] In fact, most online shopping websites use NLP technology.

In consumer markets, Amazon has a growing NLP patent portfolio. One example is using real time data to inform predictive NLP, which manipulates consumer choice.[133] A second example is technology for audio message extraction in a virtual assistant.

[129] U.S. Patent No. 9,697,252, to Hall, Methods, apparatus, and computer program products for quantum searching for multiple search targets (July 4, 2017). (Assigned to AT&T).
[130] U.S. Patent No. 8,626,133 to Kuhlke et al., Matching a location of a contact with a task location (January 7, 2014). (Assigned to Cisco Technology, Inc.)
[131] U.S. Patent No. 10,346,895 to Stoll et al., Initiation of purchase transaction in response to a reply to a recommendation (July 9, 2019). (Assigned to Walmart Apollo, LLC)
[132] U.S. Patent No. 8,484,142 Integrating an internet preference learning facility into third parties (July 9, 2013). (Assigned to eBay Inc.)
[133] U.S. Patent No. 9,336,772 to Salvador et al., Predictive natural language processing models (May 10, 2016). (Assigned to Amazon Technologies, Inc.)

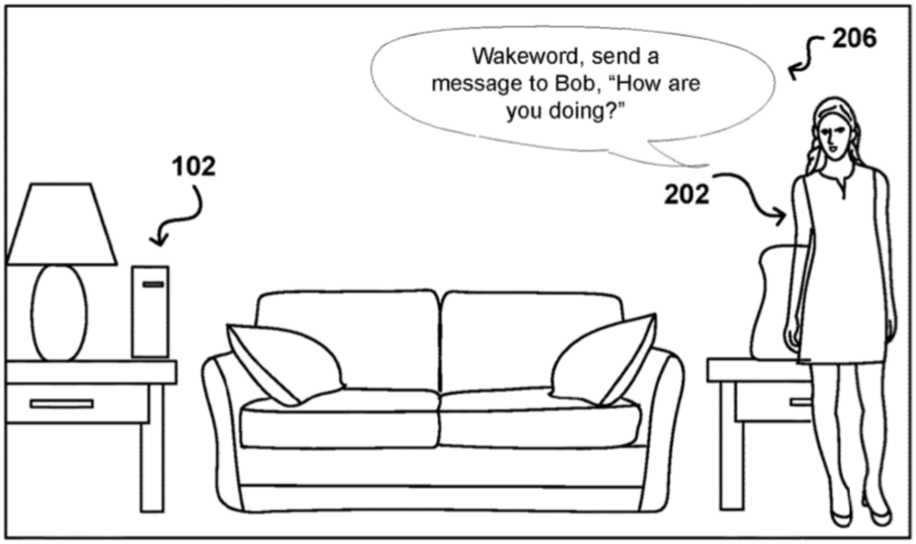

Figure 19[134]

From an Amazon patent, Figure 19 is a patent drawing for a virtual assistant that can listen and interact with a user via voice commands. Patents for NLP at top firms like Amazon and Apple, reflect highly a competitive industry. For example, Apple also owns patents for similar virtual assistant technology using NLP.[135] Moreover, Apple has been awarded patents to protect NLP technologies for search, navigation, and accelerated task performance.[136]

There are still limits in technical capabilities for AI programs using NLP. Data driven technologies using machine learning, along with knowledge models based on logical form, are propelling the technical art forward. Globally, companies across industry are advancing NLP technologies to create better products and services. In fact, NLP is an essential element for most online stores and virtual assistant technologies.

Conclusion

Chapter 5 explored AI patents, with a specific focus on machine learning. First, the Chapter discussed deep learning intellectual property and computer vision technologies using CNNs. Second, the Chapter analyzed reinforcement learning applications in healthcare and medicine. Third, deep reinforcement learning technology, software copyrights, and the Apache License

[134] U.S. Patent No. 10,319,375 to Fritz et al., Audio message extraction (June 11, 2019). (Assigned to Amazon Technologies, Inc.)
[135] U.S. Patent No. 10,318,871 to Cheyer, et al., Method and apparatus for building an intelligent automated assistant (June 11, 2019). (Assigned to Apple)
[136] U.S. Patent No. 10,565,262 to Lobo, et al., Methods for refining search results in an application (February 18, 2020). (Assigned to Apple) *See also* U.S. Patent No. 10,169,431, to Van Os, Device, method, and graphical user interface for mapping directions between search results (January 1, 2019). (Assigned to Apple) *See also* United States Patent No. 10,504,518 to Irani, et al. Accelerated task performance (December 10, 2019). (Assigned to Apple)

were described in detail. Finally, the Chapter traced trends in NLP, analyzing applications for virtual assistants using AI and corresponding intellectual property.

Consider the driving force of computing technology is the realization that every piece of information can be represented as numbers.[137] It follows logically that all information can be processed with computers. As such, data not programmers, drive the cutting edge in AI. The explosion in data across the internet continues to propel AI technology toward accelerating trajectories. In concluding, the patents protecting AI technology reflect rapid industrial growth across the global economy.

[137] ETHEM ALPAYDIN, MACHINE LEARNING 2 (2016).

Chapter 6 Biotechnology

Introduction

An old saying goes, whether you think you can, or you think you can't – you're probably right. Still, a great delusion in modern society is that there are diseases which cannot be cured. But this is a completely groundless assumption without evidence. Instead, make a different assumption – every human disease can be cured. In fact, simply because we have not cured a particular disease yet, does not mean we can't cure the disease or that we won't in the future.

Healthcare will be the field having the most impact on humanity's future. As such, human health is the most pressing issue across political, economic, and industrial enterprise. Biotechnologies are new systems and methods for breaking barriers in human health and wellbeing. Now, consider with biotechnology, every human disease, or perceived defect, is not only treatable, but curable given sufficient resources are allocated to solving the underlying physiological problem.

To invent a great biotechnology, simply start by defining the problem. Next, imagine the desired result, and then think critically to get from start to finish. Throughout Chapter 6, analysis will be provided for the state-of-the-art in biotechnologies driving the bleeding edge. Broadly speaking biotechnology refers to healthcare innovations including new pharmaceuticals, hardware, and software. Focus will be centered on technologies tackling the most difficult and pervasive diseases and medical challenges.

Chapter 6 explores biotechnology patents through five subjects on the edge in human health. First, the Chapter discusses deep diagnostic technologies, which use deep learning to supplement physician diagnostics. Next, the new neurotechnologies are navigated, including brain-machine interfaces and neuropharmacuticals. Third, exorobotics are analyzed with reference to rehabilitation and spinal supplementation. Fourth, Chapter 6 provides critique for DNA sequencing and genetic editing technology. Finally, heart technologies are investigated, from foundational functions to a fully synthetic form.

Deep Diagnostics

Early disease detection is important in clinical decision making.[138] On the fringe in innovation, diagnostics are being automated with deep learning technologies.[139] Medical professionals practicing in modern hospitals now store patient data in electronic databases with Electronic Healthcare Records ("EHRs"). This allows machine learning algorithms to analyze patient healthcare data and drastically improve patient care by identifying dangers in advance of common symptoms. In addition to the fact that EHRs allow medical professionals to know

[138] U.S. Patent No. 9,754,220 to Brestoff et al., Using classified text and deep learning algorithms to identify medical risk and provide early warning (September 5, 2017).
[139] Ava P. Soleimany, Activity-Based Diagnostics: An Emerging Paradigm for Disease Detection and Monitoring, 1 (2020).

virtually everything about a patient's medical history without ever meeting the patient, data driven analytics and automated patient diagnostics drastically reduce costs associated with healthcare.

Much work in deep diagnostics is now based on images and probabilistic classification.[140] Convolutional Neural Networks (CNNs), a specific type of neural network, are often used for computer vision and classification tasks to perform the diagnostic function.[141]

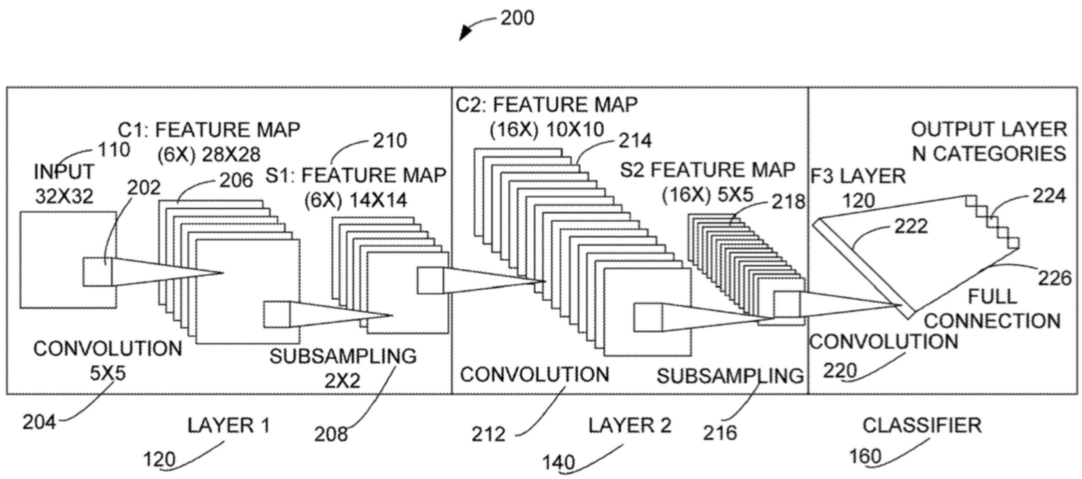

Figure 20[142]

Figure 20 is a drawing for a convolutional neural network used for medical methods. The CNN model is widely effective for diagnosing disease. Two deep diagnostic applications using CNNs are classifying skin lesions and early detection for diagnosing cancer.

Deep dermatology is a field of research at the intersection of two broader fields of study, deep learning and dermatology. The intuition behind deep dermatology is straightforward – create an intelligent system for diagnosing dermatological disease. Indeed, the state-of-the-art in computer vision systems are readily able to observe and record visual data in a manner far superior to human medical professionals.

[140] U.S. Patent No. 10,176,580 to Pauly, Diagnostic system and diagnostic method (January 8, 2019).
[141] Serena Yeung, et al., A computer vision system for deep learning-based detection of patient mobilization activities in the ICU, npj Digit. Med. 2, 11 (2019).
[142] U.S. Patent No. 10,242,443 to Hsieh et al., Deep learning medical systems and methods for medical procedures (March 26, 2019).

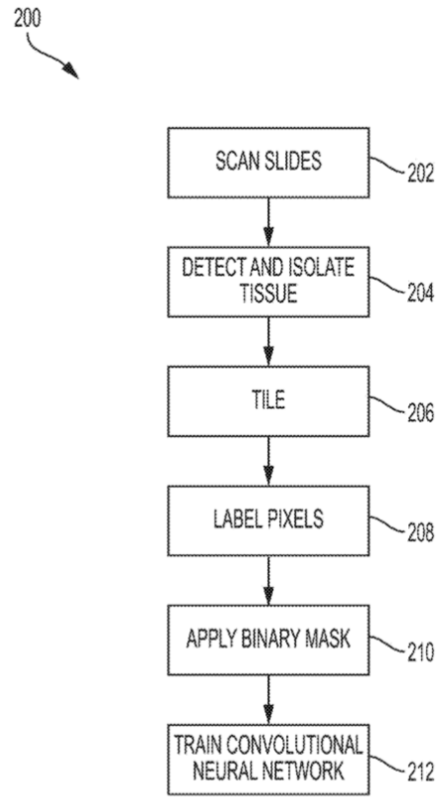

Figure 21[143]

Figure 21 is a drawing of deep dermatology technology for training a deep learning model to diagnose skin tissue. Interestingly, the skin is often described as a series of matrix graphs, which are coincidentally the inputs for CNNs. So, machine learning systems are able to classify skin information in accordance with defined optimization metrics, performing the diagnostic function.[144]

Once a skin lesion appears, there needs to be a method by which the lesion can be diagnosed. A problem currently exists because early analysis for skin lesions is often limited, lacking biological foundation for informing decisions. In other words, there should be a way to say with a certain degree of accuracy that a skin lesion is of a certain type, such as a bacterial infection, fungal infection, or viral infection. Instead, the current practice is for a medical professional to eyeball the lesion and make an informed decision based upon their expert judgement, but failure often occurs. Thus, deep dermatology offers a solution, driving decision making with data.

[143] U.S. Patent No. 10,460,150 to Jackson et al., Deep learning automated dermatopathology (October 29, 2019).
[144] United States Patent No. 10,049,301 to Kluckner, et al., Medical scanner teaches itself to optimize clinical protocols and image acquisition (August 14, 2018).

Deep dermatology techniques may be especially useful for early identification of skin cancer.[145] For example, classifying lesions as basal cell carcinoma may be accomplished with a CNN. Additionally, taking camera images of skin diseases will help providers to improve treatment effectiveness over time.[146] Combing more efficient data collection and storage methods, with EHRs and computer vision technologies will enable radically improved dermatological diagnostics.[147] This is particularly important in instances where clinical manifestations of underlying conditions are insufficient to differentiate certain diseases like differentiating herpes simplex from impetigo, which is not always obvious to practitioners. As such, a data driven assessment will provide value to patients in the diagnostic process.[148] In addition to early skin cancer detection applications for deep diagnostics may provide early warning for certain cancers including neuroendocrine carcinoma, lung cancer, and breast cancer.

First, neuroendocrine tumors (NETs) are one of the most rare and deadly carcinogens.[149] One current problem with NETs specifically is clinical symptoms manifest in myriads, making diagnosis particularly difficult during the early stages. Already, a recent invention uses deep learning to predict drug response in patients suffering from neuroendocrine carcinoma.[150] Likely, new inventions will allow doctors to pull data from EHRs relating to NETs to predict probabilities for patients' risk in advance of current methods.

Second, lung cancer is the leading cause of cancer death in the United States with over 220,000 new cases diagnosed each year.[151] Deep learning technologies are pushing boundaries for lung cancer diagnostics and treatment. For example, new inventions use deep learning to predict response for treating tumor-infiltrating lymphocytes.[152] Another example uses deep diagnostic technology to identify lung cancer risks early on, to support better care.[153]

[145] U.S. Patent No. 10,627,338 Haji Reza et al., Camera-based photoacoustic remote sensing (C-PARS) (April 21, 2020).
[146] U.S. Patent No. 10,607,341, Rules-based processing and presentation of medical images based on image plane (March 31, 2020).
[147] U.S. Patent No. 10,210,609, Integrated deep learning and clinical image viewing and reporting (February 19, 2019). *See also* U.S. Patent No. 10,586,330, Detection of outlier lesions based on extracted features from skin images (March 10, 2020).
[148] U.S. Patent No. 10,242,443 to Hsieh et al., Deep learning medical systems and methods for medical procedures (March 26, 2019).
[149] U.S. Patent No. 10,180,422 to Sigal, Methods of treating neuroendocrine tumor (January 15, 2019).
[150] U.S. Patent No. 10,907,214 to Knudsen, Methods for predicting drug responsiveness in cancer patients (February 2, 2021).
[151] U.S. Patent No. 10,829,819 to Faruki et al., Methods for typing of lung cancer (November 10, 2020).
[152] U.S. Patent No. 10,902,256 to Madabhushi, et al., Predicting response to immunotherapy using computer extracted features relating to spatial arrangement of tumor infiltrating lymphocytes in non-small cell lung cancer (January 26, 2021).
[153] U.S. Patent No. 10,037,874 to Roder, et al., Early detection of hepatocellular carcinoma in high risk populations using MALDI-TOF mass spectrometry (July 31, 2018).

Third, breast cancer is the second most common cancer diagnosed in women worldwide.[154] Personalized treatment for breast cancer requires a precise assessment to reduce recurrent risks, which may involve patient chemotherapy. However, conventional diagnostics for breast cancer fail as often as 66.00% of the time.[155] Addressing this problem, one invention generates a report based on deep learning image classifications to improve diagnostics and informed treatment.[156] The invention was made by researchers at IBM, who created a new way to process medical images, training computer programs to diagnose patients on par with doctors.

Given new capabilities in deep learning technology, the diagnostic function doctors perform on a daily basis may be supplemented to radically improve accuracy. As such, preventative care and personalized medicine should soon become the new norm. Over time, deep diagnostics will become more ubiquitous, distinguishing disease with meticulous specification and enabling improvements in quality of life.

Neurotechnology

Neurotechnologies are innovations relating to the human brain. The brain is composed of billions of neurons, nerve cells, and neurochemicals, which are chemical collections in the brain.[157] Sensory neurons carry afferent information from receptors in skin, skeletal muscles, tendons, joints, and blood vessels, to and from the brain.[158] Moreover, the brain is subdivided into several regions including the prefrontal cortex, which is the place where most cognition takes place.

Still, neurological disease is ubiquitous throughout modern society. As such, new drugs and technologies for the brain seek to provide novel cures and treatment methods, improving neurological function and life quality. In fact, new neurotechnologies are often specifically developed for regenerative care and reducing symptoms for brain disorders.[159] There are two types of neurotechnologies, brain machine interfaces and neuropharmacuticals.

Brain-machine interfaces (BMIs) have the potential to help people with a wide range of clinical disorders.[160] For example, researchers have demonstrated human neuroprosthetic control of computer cursors, robotic limbs, and speech synthesizers using 256 microelectrodes, small electrical circuits.

[154] U.S. 10,937,159 to Madabhushi, et al., Predicting outcome in invasive breast cancer from collagen fiber orientation disorder features in tumor associated stroma (March 2, 2021).
[155] U.S. Patent No. 10,779,785 to Itu et al., Semantic segmentation for cancer detection in digital breast tomosynthesis (September 22, 2020).
[156] U.S. Patent No. 10,916,341 to Stoval, III, et al., Automated report generation based on cognitive classification of medical images (February 9, 2021).
[157] Alex Korb, The Upward Spiral 15 (2015).
[158] Larry R. Squire, et al., Fundamental Neuroscience 33 (2008).
[159] U.S. Patent No. 10,869,804 to Ang et al., Method and system for using haptic device and brain-computer interface for rehabilitation (December 22, 2020).
[160] Elon Musk, An integrated brain-machine interface platform with thousands of channels, Neuralink (2019).

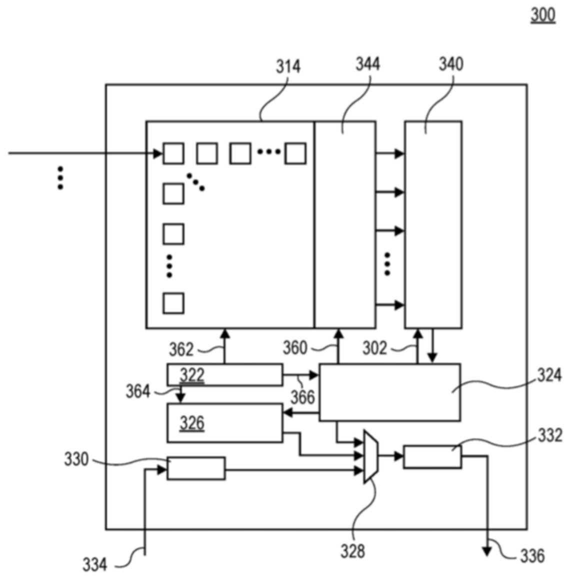

Figure 22[161]

Figure 22 shows the programming instruction and architecture for a brain chip. Neuroprosthetics are devices which improve performance and efficiency for neurological systems.

Microelectrodes are the best technology for recording potential neurological energies, but there has not been a clinically translatable microelectrode technology for scalable recordings. In fact, the first invention using microelectrodes for neural interface was patented by the University of Utah in the year 1993.[162] However, clinical translation requires a system with material properties that provide high biocompatibility, safety, and longevity. Moreover, brain devices will also need a practical surgical approach and high-density, low-power electronics to ultimately facilitate fully implanted wireless operation.[163] To meet this need, companies like Neuralink are developing microelectrode technologies on chips to improve BMI capabilities.

Some BMIs are developing toward specific utilities, such as linking the human brain directly to the internet.[164] Other examples of BMIs include neuromodulation systems. Neuromodulation technologies use electrical stimulation to treat brain disorders.

[161] U.S. Patent No. 10,824,579 to Seo et al., Network-on-chip for neurological data (November 3, 2020).
[162] U.S. Patent No. 5,215,088 to Normann et al., Three-dimensional electrode device (June 1, 1993).
[163] Elon Musk, An integrated brain-machine interface platform with thousands of channels
Neuralink (2019).
[164] U.S. Patent No. 10,849,503 to Melodia et al., Internet-linked ultrasonic network for medical devices (December 1, 2020).

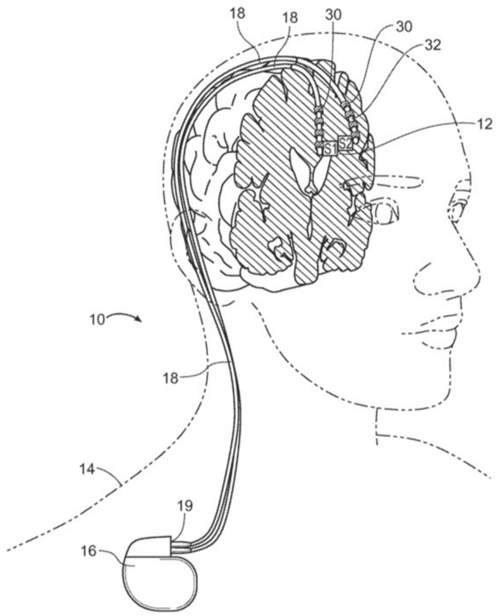

Figure 23[165]

Figure 23 is a schematic view for a neuromodulation system with a feedback mechanism using an electrical field optimized for central nervous system stimulation. One application for neuromodulation may be neurolimbic manipulation. The limbic system refers to the brain's reward mechanism, which involves transfer for various electrical impulses between neurons.[166] Some suggest advantages for neuromodulation techniques are that, unlike pharmaceuticals, they are reversible and less addictive. Nonetheless, in addition to BMIs, neuropharmaceuticals offer methods, which are tested and currently considered safer, for changing the human experience through neurochemical manipulation.

Neuropharmacuticals are drugs relating to neurochemistry in the human brain. Three of the most pervasive neuropharmacuticals are thyroid hormones for metabolic control, endocannabinoids for treating anxiety, and amphetamine for treating psychiatric abnormalities. Hypothyroidism is one of the most common neurological disorders in the world. Patients with hypothyroidism have deficiencies in the Hypothalamic-Pituitary-Thyroid Axis, which defines the relationship between the brain and thyroid. The brain produces stimulating hormone, which the thyroid produces to create Thyroxine (T_4), an endocrine hormone responsible for metabolic control. Hypothyroidism is a ubiquitous endocrine disease, affecting an estimated 9,900,000 people in the United States, 37,070,000 in Europe, and 104,000,000 people globally.

Medication options for treating thyroid disease range depending on the clinical diagnosis and individual patient response. Oral levothyroxine (LT_4) is the standard therapy for patients with

[165] U.S. Patent No. 10,857,364 to Soin, Neuromodulation system and method with feedback optimized electrical field generation (December 8, 2020).
[166] MOHEB COSTANDI, NEUROPLASTICITY 6 (2016).

hypothyroidism.[167] Both brand-name and generic (LT_4) tablets are available. Yet, key problems persist. For example, pharmacists often switch between (LT_4) formulations which have been determined bioequivalent. However, even small differences between (LT_4) formulations can cause significant changes in TSH levels. Changes may cause clinical symptoms, some of which can be caused by inactive ingredients. As such, pharmaceutical swapping is a particular concern in vulnerable populations, including elderly, pregnant, and pediatric patients.

One problem with the current treatment is it only involves supplementing Thyroxine (T_4) in the human body. However, the Hypothalamic-Pituitary-Thyroid Axis is also responsible for triiodothyronine (T_3) production in the body. As such, new neuropharmacuticals are developing to treat hypothyroidism with both thyroxine (T_4) and triiodothyronine (T_3).[168] Additionally new pharmaceutical compositions provide liquid agents using both thyroxine (T_4) and triiodothyronine (T_3), moving away from the prior art, which only offered solid tablets.[169] In addition to metabolic control, neuropharmacuticals are also able to treat clinical psychiatric disorders for focus and attention.

Attention Deficit Hyperactivity Disorder (ADHD) is a commonly diagnosed psychiatric disorder in the United States. ADHD is a developmental disorder characterized by symptoms such as impulsiveness, hyperactivity and inattentiveness.[170] A pervasive treatment option for ADHD is daily oral amphetamine salt, which stimulates the central nervous system.[171] As awareness relating to the neurochemical conditions giving rise to mental health disorders begins to permeate the social mind, physicians are exploring more methods for treating the array of conditions manifesting. For example, in addition to treating ADHD, amphetamine salts are also effective for treating depression.[172]

One problem with amphetamine treatments was maintaining consistent dosing over time for patients. As such new inventions spawned to correct the problem. Now, amphetamine salts may be taken in several forms, including instant release and extended release depending on patient response and preference.[173]

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[167] U.S. Patent No. 7,342,127 to Washburn, et al., Substituted anilide ligands for the thyroid receptor (March 11, 2008).
[168] U.S. Patent No. 9,012,835 to Soldin, et al., Methods for simultaneous quantification of thyroid hormones and metabolites thereof by mass spectrometry (April 21, 2015).
[169] U.S. Patent No. 9,551,723 to Onuma, Liquid reagent of thyroid hormone-immobilized carrier and use thereof (January 24, 2017).
[170] U.S. Patent No. 9,511,032 to Lickrish et al. Compositions for treatment of attention deficit hyperactivity disorder (December 6, 2016).
[171] U.S. Patent No. 6,913,768 to Couch et al., Sustained release delivery of amphetamine salts (July 5, 2005).
[172] U.S. Patent No. 9,877,994 to Gazley, Methods and compositions for treatment of ADD/ADHD, depression, memory problems, and other conditions (January 30, 2018).
[173] U.S. Patent No. 9,839,619 to Tengler, et al., Method for treating ADD or ADHD comprising administering amphetamine complexed with ion-exchange resin particle (December 12, 2017).

Over time, amphetamines have been shown to improve cognitive functioning, when taken at therapeutic dosages. However, stimulant medications have several side effects including appetite suppression, insomnia, and weight loss. As such, new neuropharmacuticals are aimed at reducing such symptoms.[174] Still, amphetamine remains one of the most commonly prescribed neuropharmacuticals in the United States offering a viable treatment option for patients with several neurological conditions. In addition to treating ADHD and depression using amphetamine, new neuropharmacuticals are making their way to market for novel application.

Marijuana legalization is spreading across the United States. In fact, marijuana was illegal in the United States for nearly the entire 20th Century. However, in the year 1996 California enacted the Compassionate Use Act of 1996, allowing patients an exemption from criminal penalties for medical marijuana use.[175] Marijuana can be used to treat a variety of clinical conditions including epilepsy.[176] Additional therapeutic effects have been observed in patients with Parkinson's Disease, Alzheimer's Disease, and autoimmune disorders.[177]

The two main active agents in marijuana Tetrahydrocannabinol (THC) and Cannabidiol (CBD). These chemicals are known as endocannabinoids, which improve appetite and increase feelings of peacefulness and well-being.[178] The endocannabinoids activate the brain's cannabinoid receptors, which control pain, memory, and mood.

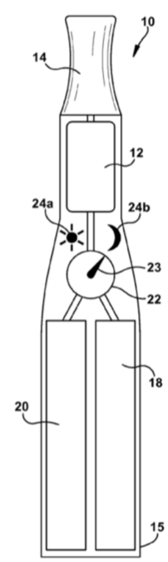

Figure 24[179]

[174] U.S. Patent No. 9,511,037 to Desai, Compositions for reduction of side effects (December 6, 2016).
[175] Dean M. Nickels, Federalism and State Marijuana Legislation, 91 Notre Dame L. Rev. 1253, 1255 (2016).
[176] U.S. Patent No. 10,849,860 to Guy et al., Use of cannabinoids in the treatment of epilepsy (December 1, 2020).
[177] U.S. Patent No. 10,934,554, to Boudko, et al., Cannabis plants having modified expression of THCA synthase (March 2, 2021).
[178] Alex Korb, The Upward Spiral, 15 (2015).
[179] U.S. Patent No. 9,730,472 to Farrow, Vaporization device and method of preparation and use (August 15, 2017).

The chemicals may be ingested in several forms including edibles, inhalation, and vaporization. Figure 24 is a vaporizer for marijuana. As marijuana legalization spreads across the United States, driving research and innovation for medical treatments, the neurotherapeutic applications are bountifully opportunistic.

Neurotechnologies stand to have a significant impact on humanities' future. From a philosophical perspective, the entirety of the Universe humans perceive is nothing but a projection from the brain. Needless to say, the brain's substance, architecture, and interaction with technology matters in our every day experience. Both BMIs and neuropharmacuticals offer the potential for great gain in neuroscience understanding and innovation. Moreover, new neurotechnologies will likely impact more than just the brain because the brain controls the human exoskeleton.

Exorobotics

Exorobotics is a field in biotechnical engineering concerning robotic human skeletons and muscular movements. Similar to the way in which AI programs seek to replicate the human mind's thoughtful processes, exorobotics seeks to replicate the kinematics and natural motion for patients with physical impairments and disease.

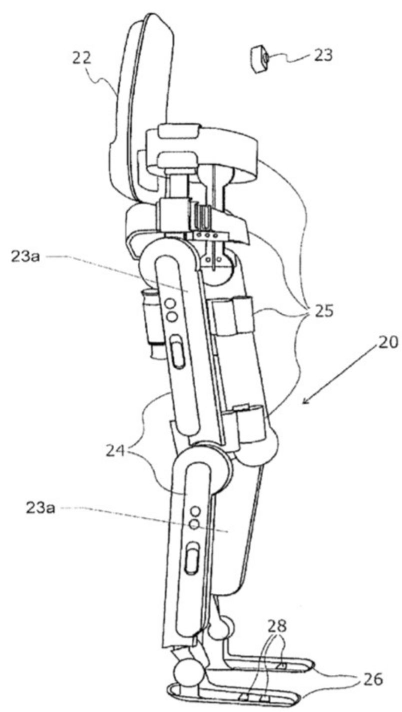

Figure 25[180]

[180] U.S. Patent No. 8,905,955 to Goffer et al., Locomotion assisting device and method (December 9, 2014).

Figure 25 is a locomotion assisted exoskeleton. An industry relating to autonomous robotic support systems, exorobotics consistently produces cutting edge biotechnologies.

For example, interactive real-time biofeedback systems (IRTBs) are new exorobotic technology relating to evolving the human condition. IRTBs are used for several purposes including motion sensing, physical training, and rehabilitation. IRTB inventions are being spearheaded by Dr. Blynn Shideler at Stanford Medical School.[181]

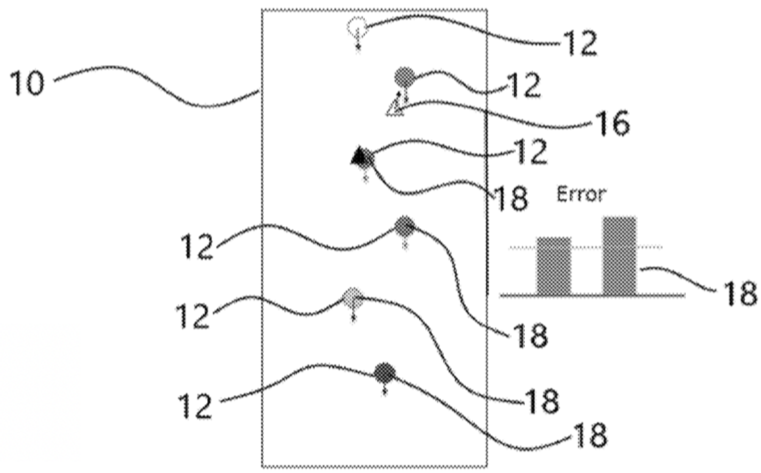

Figure 26[182]

Figure 26 is a schematic representation of a real-time biofeedback rehabilitation tool for guiding foot placement during gait training. Shideler began his groundbreaking work at Washington and Jefferson College in Washington, Pennsylvania before traveling the globe developing motion tracking technologies to better understand the human body. After global studies around the world, Shideler took his work to Columbia University, where he began collaborating with other students and invented BUDI, the Biofeedback Upper-limb Device for Impairment.

BUDI is an IRTB application for gait analysis, allowing people with severe skeletal struggles to learn to walk. Schideler's work is driving the edge in IRTB and now focuses specifically on tracking limb movements in real time. One particular invention is targeted at helping patients with cerebral palsy and neuromuscular disorders.

[181] Jody Berger, The BUDI system, Stanford Report (July 22, 2022).
[182] U.S. Patent 10,722,149 to Shideler, et al., Real-time biofeedback rehabilitation tool for guiding and illustrating foot placement for gait training (July 28, 2020).

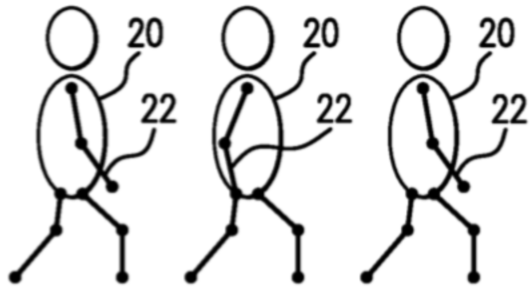

Figure 27[183]

Figure 27 is a schematic view of a patient moving with a motion tracking smart watch. While cerebral palsy affects approximately 17 million people worldwide, prior robotic support systems were not practical for scalable daily use. Thus, new inventions are targeted at simplifying devices for measuring and improving limb movements in patients using technologies connecting smart devices, patients, and doctors.

Composed of nerve tissue and bone, the spinal cord is the human backbone and a major section in the central nervous system. The spinal cord transfers nerve signals between the brain and the body, coordinating reflexes for motor control. Spinal implant technologies are integrating with the human skeleton to provide various functional improvements.[184]

There are many different types of implants for skeletal injuries and bone disorders for the spine.[185] Figure 28 is a drawing for an intervertebral disc implant. The patented invention depicted in Figure 28 is a spinal implant for restoring motion to a damaged spine unit.

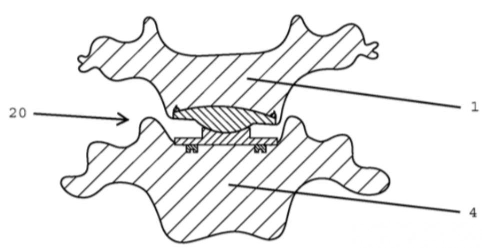

Figure 28[186]

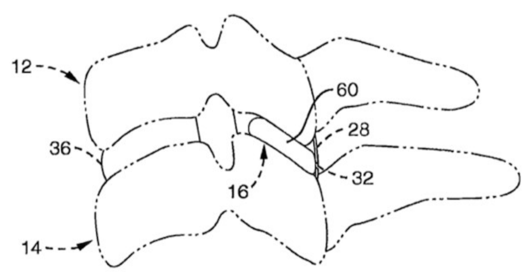

Figure 29[187]

[183] World Patent Application 2021/035208, to Shideler, et al., Limb motion tracking biofeedback platform and method of rehabilitation therapy for patients with spasticity (February 25, 2021).
[184] U.S. Patent No. 10,881,522, to Hibri, Radially expandable annulus reinforcement prosthesis (January 5, 2021).
[185] United States Patent No. 7,270,665 to Morrison et al., Variable offset spinal fixation system (September 18, 2007).
[186] United States Patent No. 10,603,184 to Muhlbauer, Intervertebral disc implant and method for restoring function to a damaged functional spinal unit (March 31, 2020).
[187] United States Patent No. 10,219,910 to McCormack, Cervical distraction method (March 5, 2019).

Figure 29 is an illustration for a spinal implant with a detached catheter. Cervical discs are a type spinal implant allowing patients to recover biomechanical function after damage or injury. For example, the invention depicted in Figure 29 is an implant, which uses multiple parts to maximize flexibility in functionality.

Exorobotics technologies stand to change the future for human motion, flexibility, and strength. Specifically targeting technical development toward problems plaguing patients with muscular diseases and spinal injuries provides grand opportunity for innovation. As the technology evolves, a central theme will be converging the human brain and spine, the two fundamental elements in the central nervous system to a more singular structure.

Genetic Editing

Genetics is a field within molecular biology relating to the genome, which includes Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA). DNA is a molecule composed of two polynucleotide chains, which form a double helix with genetic information.[188] RNA is a polymetric molecule responsible for various messenger functions within the genome. Genetic editing is a process by which genes are manipulated and engineered. For example, specific genetic material that may be harmful could be destroyed using genetic editing technologies.[189]

Genetic disorders are health problems resulting from atypical genomic structure. Researchers driving the edge spent much time iterating through multiple rounds of editing to try new strategies and experiments for cures. As such, need evolved for systems to automate the process by which biological molecules could be edited for further experimentation.

[188] U.S. Patent No. 10,876,125 to Jarvis et al., DNA recombination (December 29, 2020).
[189] U.S. Patent 10,927,075 to Mills, et al., Compositions and methods relating to the treatment of cancer, autoimmune disease, and neurodegenerative disease (February 23, 2021).

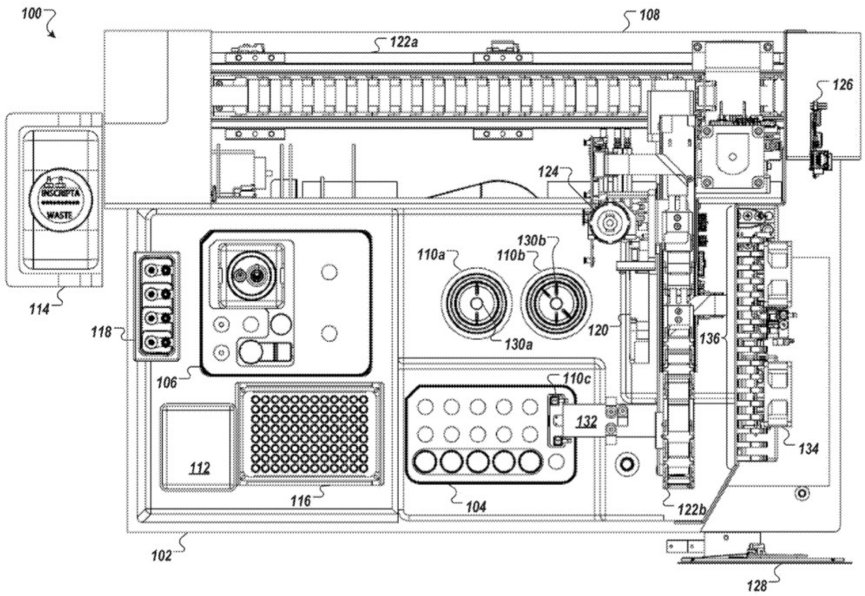

Figure 30[190]

Figure 30 is an illustration for an automated multi-mode cell processing instrument for multiplexed genome cell editing using replaceable cartridges. The goal for genetic editing is to improve DNA structures with computational methods.

CRISPR/Cas9 is a biotechnical breakthrough changing genetic research. Collaboratively CRISPR DNA sequences and Cas9 enzymes form the basis for CRISPR/Cas9 technology, which edits genetic material.

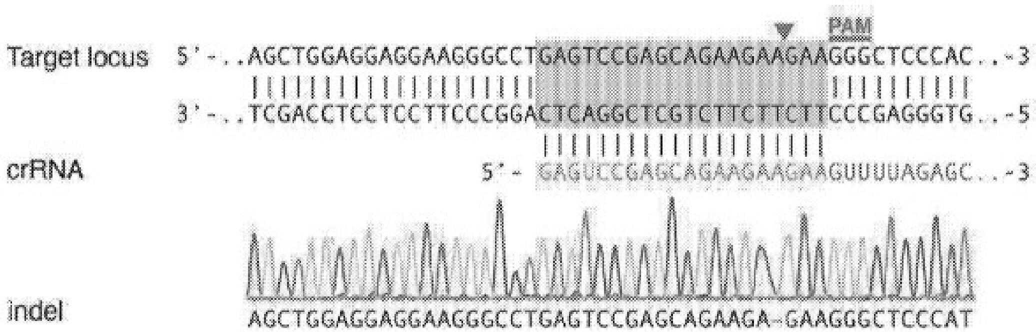

Figure 31[191]

[190] U.S. Patent No. 10,465,185 to Masquelier et al., Automated cell processing methods, modules, instruments, and systems (November 5, 2019).
[191] U.S. Patent No. 8,795,965 to Zhang, Crispr-cas component systems, methods and compositions for sequence manipulation (August 5, 2014).

Figure 31 is a CRISPR system and sequence. Crispr-Cas9 technology was invented to meet the need for new systems and methods for DNA sequence targeting.

Certain derivatives for the CRISPR-Cas9 technology have three parts. First, a specific section in an organism's DNA is identified. Next, the Cas9 enzyme removes the DNA segment. Third, the deleted section is replaced. CRISPR/Cas9 gene editing has a variety of applications, including biological research, biotechnology development, and disease treatment. In fact, genetic engineers believe CRISPR/Cas9 has the potential to advance gene therapies to eliminate genetic disease altogether.

Several genetic diseases manifest as autoimmune disorders, a ubiquitous plague across modern life, which often require indefinite treatment. For example, multiple sclerosis (MS) is an autoimmune disease, which causes inflammation in the central nervous system.[192]

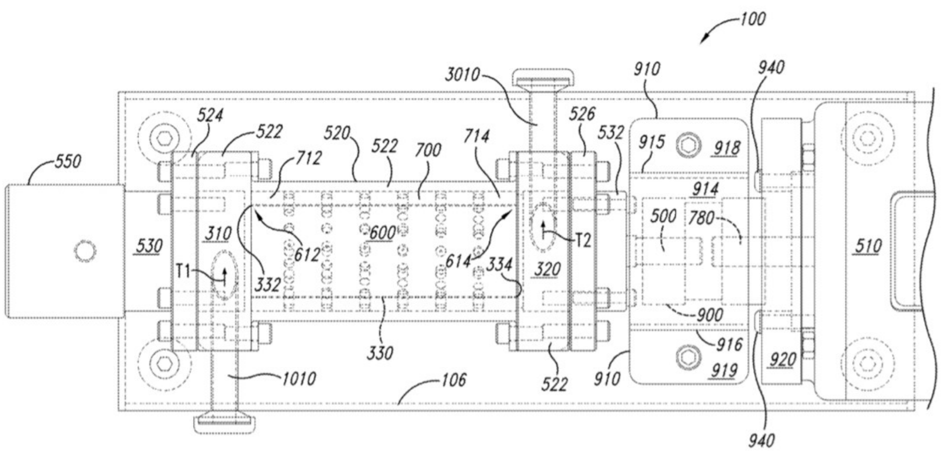

Figure 32[193]

Figure 32 is a device for mixing chemicals, to create compositions for treating MS. Various genetic technologies are evolving to treat autoimmune disorders. In fact, researchers at Stanford University invented a vaccine for autoimmune disorders using DNA injection.[194]

Genetic editing technologies provide the opportunity to eliminate genetic disease. Specifically, genetic engineering allows for directly altering genetic material.[195] At the same time, new pharmaceutical compositions and creations also respond directly to genetic defects with more

[192] U.S. Patent No. 10,487,360, to Rus et al., Diagnosis and prognosis of multiple sclerosis (November 26, 2019).
[193] U.S. Patent No. 9,745,567 to Watson et al., Compositions and methods for treating multiple sclerosis (August 29, 2017).
[194] U.S. Patent No. 7,704,970 to Steinman, et al., DNA vaccination for treatment of autoimmune disease (April 27, 2010).
[195] U.S. Patent No. 8,771,945 to Zhang, Crispr-cas systems and methods for altering expression of gene products (July 8, 2014).

immediate scalable implications. Indeed, applications for new genetic technologies will tackle some of the most pervasive human diseases.

Heart Technology

Globally, heart diseases are the most common cause of human death. Presently, there are at least 31 million Americans living with heart disease. As such, research, development, and new inventions for heart technologies are critically important to ensuring a healthier future for humanity. However, to this point, new innovations in heart technology are stifled relative to other biotechnologies because the heart is notoriously one of the most complex organs in the human body. Thus, opportunity exists in reducing the heart's natural complexity to a more cogent form, formalizing systems and methods for new cardiac creations.

The heart is an organ which pumps blood through the circulatory system, carrying oxygen and nutrients throughout the body. Further, the heart is composed of four chambers, the upper left atria, the upper right atria, the lower left ventricle and the lower right ventricle. The heart is protected by the pericardium, a wall surrounding the heart with two layers.

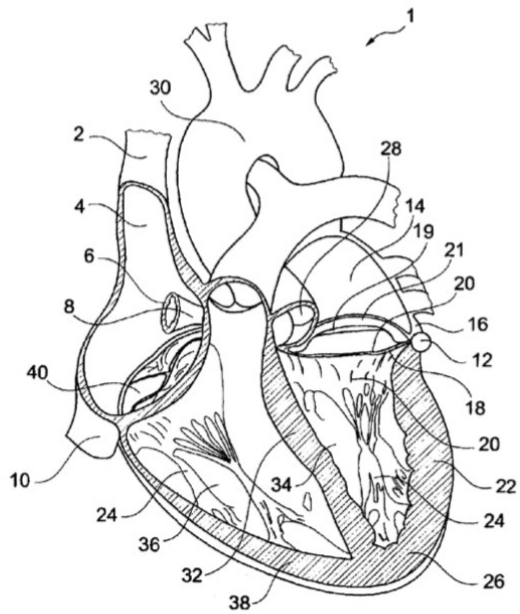

Figure 33[196]

Figure 33 is a schematic for the human heart. From a patent for technology augmenting heart functionality in the human body, Figure 33 depicts structures in the human heart with meticulous detail. Functionally, the heart pumps blood rhythmically, generating current with contractions. Uniquely, heart cells do not regenerate after damage.

[196] U.S. Patent No. 10,881,771 to Solem, Device and a method for augmenting heart function (January 5, 2021).

New technologies are evolving integrating artificial intelligence and biotechnology for new cardiac applications. One recent invention uses deep learning technologies for heart beat detection.[197] Another recent invention uses machine learning to classify cardiac images.[198]

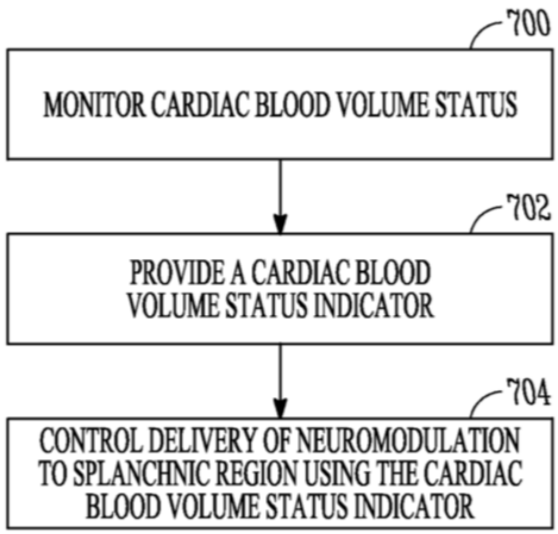

Figure 34[199]

Figure 34 illustrates a method for controlling fluid volume in the heart. The invention underlying figure 34 set out to solve problems relating to heart failure, which stop proper blood perfusion. Typically, heart fluid flows through the heart in one direction and is controlled by various vales.

However, the artificial heart has been an evasive technology due to technical complexities. Still heart disease is pervasive in the world. For example, congestive heart failure is a condition where the heart is unable to support the body. Most lethal instances of hearth diseases result from coronary artery disease or stroke. Thus, new technologies resolving heart related conditions have the floor in biotechnology innovation. Tackling the toughest challenge, technologies simplifying the heart's functionality to fundamental principles and engineering biotechnologies from the ground up will likely result in the greatest inventions.

Conclusion

Chapter 6 explored biotechnology patents through five innovations on the edge in human health. First, the Chapter discussed deep diagnostic technologies, which use deep learning to supplement doctors in the diagnostic process. Next, the bleeding edge in neurotechnology was navigated, including BMIs and neuropharmacuticals. Third, skeletal robotics were analyzed, including

[197] U.S. Patent No. 10,709,390 to Qian et al., Deep learning algorithms for heartbeats detection (July 14, 2020).
[198] U.S. Patent No. 10,595,727 to Lu et al., Machine learning-based segmentation for cardiac medical imaging (March 24, 2020).
[199] U.S. Patent No. 9,526,893 to Averina et al., Blood volume redistribution therapy for heart failure (December 27, 2016).

IRTBs and spinal implants. Fourth, Chapter 6 provided critique for CRISPR and DNA sequencing technologies, which are being used to cure genetic disease. Finally, heart technologies were investigated and analyzed, particularly for function augmentation.

Every human disease, or perceived defect, is not only treatable, but curable given sufficient resources. Drafting documentation for a new invention in biotechnology is a great way to start in curing any disease because it provides a mechanism for formalizing a solution to biological problems. In fact, many cures for biological diseases are already patented, but unknown to the general public. For example, the first universal coronavirus vaccine was patented in the year 1993.[200] Yet this didn't stop the Department of Health from spending billions in public funds to develop a new vaccine in response to COVID-19, despite the fact the patent had expired.[201]

But in time, biotechnologies should improve life for humanity. However, improvements will not come without barriers, particularly relating to healthcare access. Nonetheless, the path forward should be paved with great innovation in human health. Some speculate we may even be on the verge to creating synthetic humans. But of course, as Shelley wrote in Frankenstein, "Nothing is so painful to the human mind as a great and sudden change."[202] Not much has changed in the centuries since Shelly scribed Frankenstein, one of the great science fiction novels ever written. So, we should expect progress to proceed at a slow pace, with incremental gains along the way.

[200] WO 93/23421, to Miller, et al., Universal Coronavirus Vaccine (November 25, 1993).
[201] U.S. Department of Health and Human Services, Explaining Operation Warp Speed (2020).
[202] Mary Shelley, Frankenstein (1818).

Chapter 7 Space

Introduction

The heavens have long been an object of wonder for humans. For example, the Roman Emperor, Marcus Aurelius said the entire Earth is merely a minute point among the stars.[203] The Seventeenth Century brought two major space science breakthroughs. First, Johannes Kepler, published the orbital laws in the year 1609 and then, Issac Newton published *Principia* in the year 1687, introducing the laws of motion.[204]

Three centuries later, Konstantin Tsiolkovsky is largely credited with inventing the rocket because of the famous rocket equation. In his seminal work, *Reactive Devices*, Tsiolkovsky described the fundamental laws for rocket mechanics in the year 1903.[205]

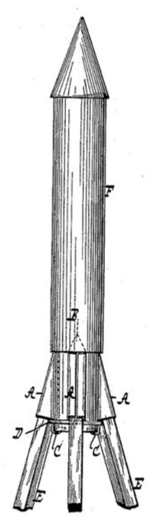

Figure 35[206]

However, the first rocket patent was filed with the U.S. Patent Office by Philip Licht, Jr., of East Williamsburg, New York in the Year 1888. Figure 35 is a drawing from the first rocket patent.

Still today, the road ahead offers limitless opportunity. Consider the Milky Way, one of several hundred billion galaxies in the Universe, each galaxy containing several hundred billion stars. [207]

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[203] Marcus Aurelius, Meditations, Book 4 (c. 180 AD).
[204] ROGER R. BATE, ET. AL., FUNDAMENTALS OF ASTRODYNAMICS, UNITED STATES AIR FORCE ACADEMY 2-3 (Dover 1971).
[205] Константин Эдуардович Цколковский, Исследование Мировых пространств реактивными приборами (1903).
[206] U.S. Patent No. 393,990, to Licht, Jr., Rocket (Dec. 4, 1888).
[207] CARL SAGAN, PALE BLUE DOT A VISION OF THE HUMAN FUTURE IN SPACE 21 (1994).

The great cosmologist Stephen Hawking argued the Universe is infinitely expanding, with no boundary, no beginning, and no end.[208] Now, new space technologies are driving the next generation of explorers toward boundless wonders in space. Some suggest our species has only two possible paths forward. The first path is our species stays on Earth forever and some eventual extinction event wipes us out. The alternative is humanity becomes a spacefaring species, exploring the cosmos and inhabiting new worlds. Others reject the dichotomy, contending human space exploration should stay subject matter limited to science fiction and fantasy.

Chapter 7 explores space technology patents with a focus on space processors, satellites, and rocket technologies. First, radiation hardened processors are described, detailing the state of the art in space hardware. Next, space satellites are analyzed from the original invention in the 1960s, to the future satellite constellations surrounding Earth. Then, reusable rocket technologies are explained, including stage design, engine types, and control systems. Finally, the *SpaceX v. Blue Origin* lawsuit is examined along with rocket patent litigation considerations.

Radiation Hardened Processors

Electronic devices utilize processors to carry out various commands necessary to enhance functionality. For example, electronic devices can be designed specifically for use in hostile environments, like space which is highly radioactive. Communications systems used in spacecraft face challenges generally not encountered by Earth based communication systems, such as radiation exposure and mission specific reliability requirements.[209] As such, hardware technology which adapts to various mission specific capabilities in space is proving exceptionally valuable.

The state of the art in rocket control hardware is field programmable gate arrays (FPGAs), an integrated circuit designed to be configured by a designer after manufacturing. The FPGA configuration usually runs on a hardware description language, similar to computer languages used in integrated circuits. From an architectural perspective, FPGAs contain an array of programmable logic blocks and reconfigurable connectors, for wiring logic blocks together.[210] As a result, logic blocks can be configured to perform complex convolutional functions. For example, the FGPA may be embedded with an artificial intelligence computer program, using a convolutional neural network for computer vision.

FGPAs typically have both memory and processing capabilities, to support dynamic programming techniques and operations. Figure 36 is an information flow diagram, illustrating data path processing performed by a reconfigurable computer for use in space.

[208] STEPHEN HAWKING, A BRIEF HISTORY OF TIME 145 (Bantam Books 1996).
[209] United States Patent 9,680,527 Radiation Hardened 10Base-T Ethernet Physical Layer (PHY) (2017).
[210] U.S. Patent No. 7,073,158 to McCubbrey, Automated system for designing and developing field programmable gate arrays (July 4, 2006).

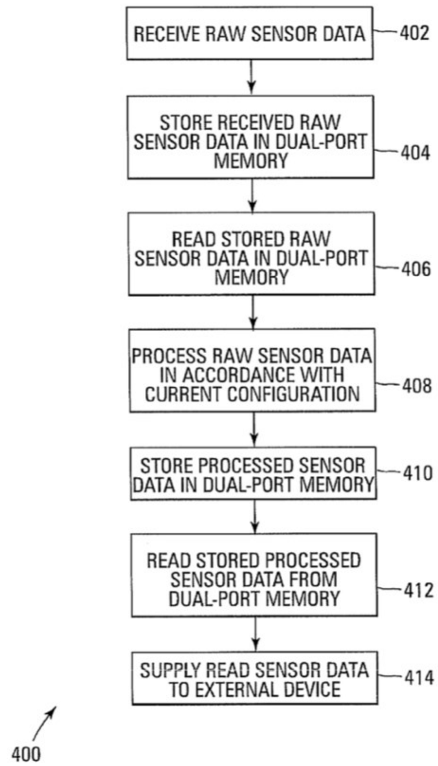

Figure 36[211]

In short, FPGAs are modularized logic unit arrays with interconnection resources. The utility for engineers is a configurable array of uncommitted gates with uncommitted wiring channels, which allows for custom application. Each logic unit can be programmed to implement a particular logic function. To implement a particular circuit function, the appropriate connections are programmed for integration by mapping the circuit to an array and configuring the necessary wiring connections.[212] As such, FGPAs provide flexible hardware structures, which optimize tradeoffs between circuit building blocks, including performance, efficiency, and costs. However, for space applications, the FPGA must be radiation hardened to combat radiation effects in space.[213]

SpaceCube is a radiation hardened FGPA and data processing system developed at the NASA Goddard Space Flight Center. Moreover, SpaceCube is a patented processing system including

[211] U.S. Patent No. 7,320,064 to Ramos et al., Reconfigurable computing architecture for space applications (January 15, 2008).
[212] U.S. Patent 7,193,436 to Wang et al., Fast programming path using field programmable gate array logic units (March 20, 2007).
[213] U.S. Patent No. 6,175,940 to Saunders, In-flight programmable spacecraft error correction encoder (June 16, 2001).

an FGPA having a dual port RAM and for use in hostile environments.[214] In other words, the SpaceCube is a reconfigurable, modular, compact, multi-processing platform for space flight applications demanding extreme processing power.[215]

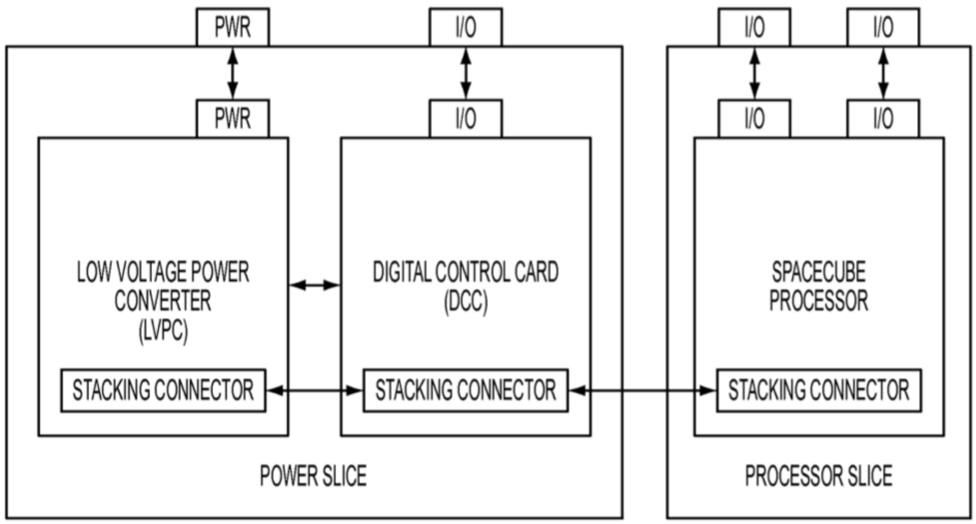

Figure 37[216]

Figure 37 is a schematic diagram illustrating an embodiment of an independent set of processor card slices. The power slice includes two processor cards, a low voltage power converter and a digital control card, connected with stacking connectors.[217]

There are three levels of electrical device component radiation tolerance. First, the unprotected level, which can experience both recoverable errors and destructive errors in space. Second, the radiation tolerant level includes electrical device components designed so destructive errors are avoided. Third, the radiation hardened level includes electrical device components experiencing no errors in space.[218] The goal for the NASA SpaceCube is to operate on the third level, so there are no errors for the processing hardware in space. This is critically important for mission performance because hardware errors during a mission may be fatal.

Thus, the purpose for radiation hardened processors is to allow flawless performance for space vehicles, like satellites orbiting the Earth. In fact, recent research at the NASA Goddard Space Flight Center provides promise for embedded hardware with artificial intelligence for

[214] U.S. Patent No. 8,484,509 to Espinosa et al., Radiation-hardened processing system (2013).
[215] U.S. Patent No. 9,851,763, Spacecube V2.0 Micro Single Board Computer (2017).
[216] U.S. Patent No. 8,484,509 to Espinosa et al., Radiation-Hardened Processing System (2013).
[217] U.S. Patent No. 10,715,073 to Orlowski et al., Robot electronics unit (REU) motor controller board (MCB) (July 14, 2020).
[218] U.S. Patent No. 8,484,509 to Espinosa et al., Radiation-Hardened Processing System (2013).

applications such as computer vision and control.[219] As a result, radiation hardened FGPAs provide processing for next generation space technologies including both satellites and rockets.

Satellites

Throughout history, satellites have advanced globalization. Indeed, consistent global satellite coverage emerged in the 1970s, fostering innovation in military and commercial applications. Simply, satellites are objects in orbit around the Earth. In 1975 there were approximately 3,500 detected objects in orbit around the earth. Still, one of humanity's most profound technological accomplishments is the existing Earth-orbiting infrastructure of satellites. Today, there are more than 6,000 satellites in orbit. This infrastructure is now an indispensable feature of modern humanity.

Most satellites are concentrated in one of three orbital zones: geostationary orbit (GEO) 22,300 miles above sea-level; medium Earth orbit (MEO) 11,000 – 12,000 miles above sea-level; and low Earth orbit (LEO) 100 – 1,200 miles above sea-level.[220] In practice, most LEO satellites orbit between 200 – 600 miles altitude, after which are the strongest parts of the Van Allen Belts, which are radioactive zones with charged particles surrounding Earth. Generally, networks of satellites and ground stations provide three main benefits including: global navigation; global communication; and intelligence information.

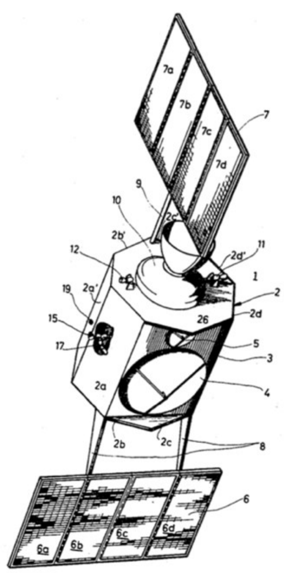

Figure 38[221]

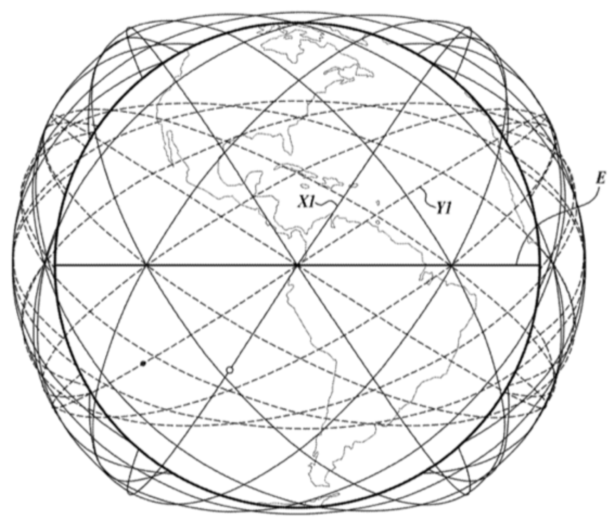

Figure 39[222]

[219] Justin Goodwill, et al., NASA SpaceCube Edge TPU SmallSat Card for Autonomous Operations and Onboard Science-Data Analysis, NASA Goddard Space Flight Center (2021).
[220] Michael J. Neufeld, Spaceflight: A Concise History, 110 (MIT Press, 2018).
[221] U.S. Patent No. 3,559,919 to Sass, Active Communication Satellite (February 2, 1971).
[222] U.S. Patent No. 10,843,822 to Herman et al., Satellite Constellations (November 24, 2020).

Figure 38 is a communications satellite invented in the year 1968. Figure 39 is a drawing from a SpaceX patent for satellite constellations which surround the planet in the future. The constellation will include 30,000 satellites, which will serve several purposes including enabling a global internet network.

First, satellite navigation allows Global Position Systems ("GPS") to help guide and navigate travelers across the globe. GPS is a radio navigation system allowing the determination of an entities location using satellites. And today GPS is embedded into modern industry for technologies including Uber, Google Maps, and Snapchat. Generally, GPS satellites operate along twelve-hour orbits in MEO. Moreover, most satellites have precise atomic clocks, consistently transmitting a time signal along with orbital information. Then, GPS receivers on Earth calculate positions and altitudes by triangulating signals from at least three satellites.

A GPS receiver has to carry out a myriad of calculations to obtain a location. For example, GPS receivers must determine relative orbital positioning, calculate distances, and integrate results with mapping software in real time.[223] All of these functions are capable of completion with a microprocessor.[224] However, there is still room for innovation.[225] Indeed, GPS signals often perform poorly in urban environments, under tree cover, and are too weak to work indoors. For example, GPS turn-by-turn navigation systems in smartphone applications often fail for people walking in major cities.

Second, satellite telecommunications allow for people all over the world to share information, nearly instantaneously. The study of satellites for telecommunications began in the early 1960s during the Kennedy Administration as part of the Cold War effort, after the Soviet Union successfully launched Sputnik 1 in the year 1957.

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223 Paul E. Ceruzzi, GPS, 127 (The MIT Press).
224 U.S. Patent No. 3,821,715 to Hoff, Jr., et al., Memory System for a Multi-Chip Digital Computer (June 28, 1974).
225 U.S. Patent No. 10,859,712 to Soualle et al., Method for each of a plurality of satellites of a secondary global navigation satellite system in a low Earth orbit (December 8, 2020).

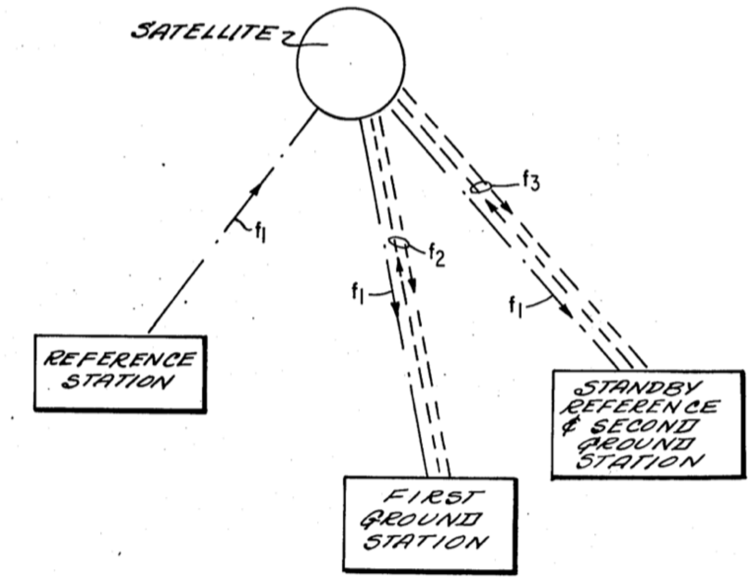

Figure 40[226]

Figure 40 is a schematic for a communication satellite relay system. Ground stations called an uplink act as a connector between devices – transmitting waves to satellites. In the 1990s, satellites for global telephone communications emerged. Today, satellite technologies enable Wi-Fi networks, linking users across the globe via the internet.[227]

Most satellite communication still occurs through the radio wave transmission. Satellite receivers amplify signals, retuning them to another ground station called a downlink. The, second ground station relays the message to the final receiver device. This process allows information to be transferred between nearly any two places on earth. As a result, satellite technology continues to foster innovation for globalizing communications technologies. For example, a cell phone's position is found by the strength of its signals with respect to nearby cell towers. And images of Earth from space shared via television and the internet help to create a cultural planetary identity.

Third, satellite technologies are critical to gathering intelligence information. Indeed, many modern satellites are the result of military innovations during the Cold War. In 1961, the National Reconnaissance Office was created as a U.S. civilian space agency to develop reconnaissance satellites as part of the Cold War effort. One of the most valuable characteristics for Earth satellites is the ability to pass over large portions of the earth's surface in a relatively

[226] U.S. Patent No. 3,982,075 to Jefferis et al., Synchronization system for time division multiple access relay communications system (September 21, 1976).
[227] U.S. Patent No. 10,812,949 to Zhao, Systems and methods for determining a starting location of a service using a wifi network (October 20, 2020).

short time.[228] As such, two examples of critical information satellites collect are foreign military information and missile defense data.

Interestingly, the evolution of satellite intelligence and reconnaissance imaging bolsters nuclear war capabilities, while simultaneously improving global transparency.[229] In fact, some suggest space surveillance is an outgrowth of intercontinental ballistic trajectory monitoring because most radar systems are located in the Northern Hemisphere.

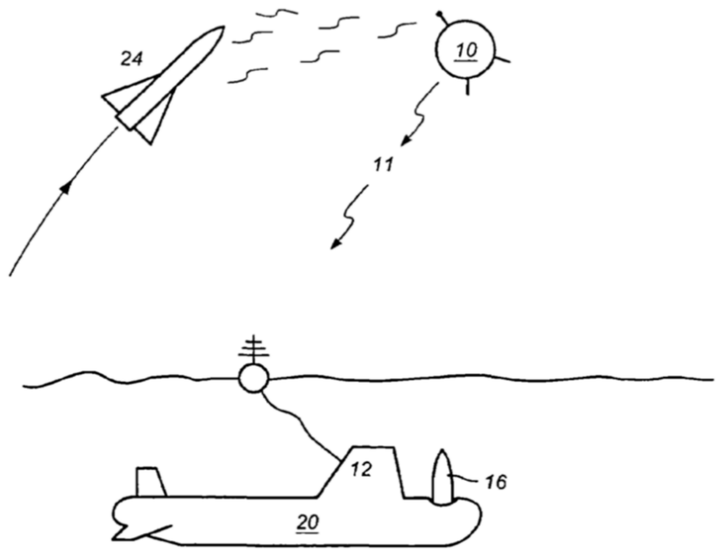

Figure 41[230]

Figure 41 is a schematic for a missile defense system invented by Lockheed Martin. The invention is a system using a naval ship and satellite receiver to detect and intercept ballistic missiles. As such, satellites are crucial to modern powered missile warning systems.

Militaries invest fortunes in sensor development, for example infrared region sensors for detecting global rocket launches. The main reason for investing in military satellites is to strengthen the Government's military power. As such the United States, Russia, China and other western countries have military satellite operations.[231] Some speculate satellites bolster the ability to fight global nuclear war – but simultaneously making such a catastrophe less likely through global transparency.[232] For example, the U.S. Army routinely gathers data relating to

[228] U.S. Patent No. 10,302,769 to Delay et al., System for monitoring marine vessels using fractal processing of aerial imagery and related methods (May 28, 2019).
[229] U.S. Patent No. 9,105,128 to Robinson et al., Adaptive image acquisition and processing with image analysis feedback (August 11, 2015).
[230] U.S. Patent No.7,348,918 to Redano, Mobile ballistic missile detection and defense system (March 25, 2008).
[231] U.S. Patent No.10,634,457 to Shi, et al., Stealth method by use of three-dimensional spraying (April 28, 2020).
[232] U.S. Patent No. 9,389,048 to Revord, Nuclear missile firing control and inventory reduction system (July 12, 2016).

Earth's shape and gravitational field, information critical to long range missiles. In short, satellites have tremendous potential as an instrument for both scientific and military surveillance.

As satellites continue to serve an integral function in modern society, there still exists profound opportunity for innovation. Indeed, the development of reusable rocket booster technology instantaneously produced an order of magnitude improvement in the cost-efficiency of satellite launch to orbit. Now, a private competition is emerging with companies competing for lucrative government contracts to advance global satellite infrastructure. While questions remain regarding the pace in satellite innovation, which has been relatively slow since satellites emerged in the 1950s, orbital satellite infrastructures continue as a vital feature for global navigation, military application, and telecommunications.

Rockets

A rocket is a contained propulsion system capable of delivering payloads to orbit or space. Generally, rockets carry all propellants internally and force is created through the expulsion of a jet of hot gas. Until the early part of the twenty first century, rockets were fully expendable, meaning they could only be used once.[233] The major innovation of modern rocket technology is the reusable rocket.[234] The innovation is well displayed in the price to performance ratio for launch vehicles.

From a financial perspective rockets are much like jets because the fuel of a trip is only a small fraction of the cost. So, the major cost of launching a payload into orbit is the rocket itself. By making rocket boosters reusable, like jet airplanes, spaceflight cost-efficiency is experiencing exponential improvements. In fact, in 2013, the Department of Defense paid as much as $1.63 billion for a single launch.[235] Where in the year 2019 orbital launch may be achieved for as little as $5 million.[236] The lower cost for launch to orbit today is only made possible because rockets are now reusable.

In November 2015, Blue Origin launched its' rocket, New Shepard to the Karman line, an altitude of roughly 62 miles above Earth and the point at which space begins. After reaching space, the rocket returned to Earth and completed a vertical powered landing. The event was the first time a rocket booster was launched to space with a successful return landing on Earth.

[233] U.S. Patent No. 6,158,693 to Mueller et al., Recoverable Booster Stage and Recovery Method (December 12, 2000).
[234] U.S. Patent No. 6,454,216 to Kiselev et al., Reusable booster for the first stage of a launcher (September 24, 2002).
[235] Alexander Rogosa, *Shifting Spaces: The Success of The SpaceX Lawsuit and The Danger of Single-Source Contracts in America's Space Program*, 25 Fed. Circuit B.J. 101, 103 (2015).
[236] Brian Bozzo*, Not Because Its Easy: Exploring National Incentives for Commercial Space Exploration through a Geopolitical Lens*, 11 Drexel L. Rev. 595, 598 (2019).

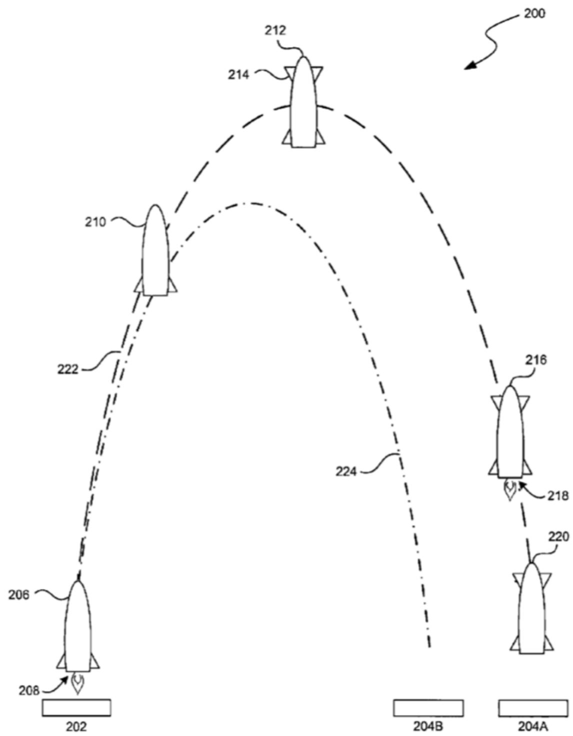

Figure 42[237]

And the same booster was relaunched in January of 2016. Figure 42 is a patent drawing for New Shepard's trajectory control system, mapping methods for the rocket's trajectory. More generally, intellectual property for rocket technology may be analyzed through three rocket components, the rocket body, the propulsion system, and the control system.

Generally, rocket bodies are differentiated by certain metals, structural stages, and reusability. For example, SpaceX's Falcon 9 is a two-stage rocket using a niobium metal alloy, with a reusable booster stage.[238] The Falcon 9 has a height of 230 feet, a diameter of 12 feet, and a mass of 1,207,920.00 pounds. However, there are several sizes and shapes for rockets.

[237] U.S. Patent No. 8,729,442 to Boelitz et al., Predicting and correcting trajectories (May 20, 2014).
[238] U.S. Patent No. 10,844,464 to Garside et al., Niobium metal alloy (November 24, 2020).

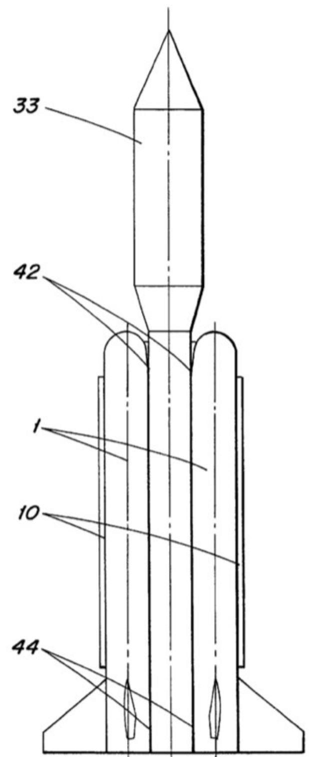

Figure 43[239]

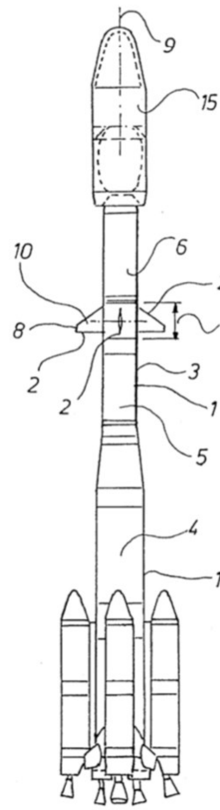

Figure 44[240]

In fact, global launch firms have been patenting different reusable rocket technologies and methods for several decades. Figure 43 is a drawing from a Russian owned rocket patent for a reusable first stage rocket booster, awarded by the USPTO in the year 2002. From a German owned patent awarded in the year 1997, Figure 44 is a booster rocket with fins for control.

Despite structural differences, all rockets need an engine to generate thrust for liftoff. As such, rocket propulsion systems apply force to a vehicle which accelerates velocity. Rocket engines generally include a vessel with a nozzle, a combustion chamber with propellant, and an ignition system which ignites the propellant.[241] Additionally, rocket engines may also include a coolant system or protective shield, depending on the engine type.[242] There are three main types of rocket propulsion systems.

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[239] U.S. Patent No. 6,454,216 to Kiselev et al., Reusable booster for the first stage of a launcher (September 24, 2002).
[240] U.S. Patent No. 5,593,110 to Ransom et al., Apparatus for controlling the structural dynamic response of a rocket (January 14, 1997).
[241] U.S. Patent 3,965,676 to Schaffling, Solid Rocket Motor (June 29, 1976).
[242] U.S. Patent No. 10,844,808 to Bahn et al., Rocket engine systems with an independently regulated cooling system (November 24, 2020).

First, the most common type of rocket engine is a liquid chemical engine, a rocket propulsion system based on the chemical reactions using liquid propellants.[243] The majority of rockets today, especially those for low Earth orbital launch purposes are powered by the energy released from exothermic chemical reactions of propellants.[244] For example, SpaceX's Merlin engine, which propels the Falcon 9 and Falcon Heavy, uses liquid oxygen and rocket-grade kerosene.[245] Another example of a liquid chemical rocket engine is Blue Origin's BE-4 engine, which uses liquefied natural gas for propulsion. In both engines, chemical reactions release heat causing rapid thermodynamic expansion of propellant gases. The expulsion of these gases at extremely high velocities generates the momentum and propels rockets forward.

The second type of rocket engine uses solid rocket propellants. Solid rocket motors generally include a pressure vessel, solid propellant structure, and a nozzle.[246] In other words, solid propellant rocket engines use a solid core propellant which ignites, creating high pressure ejections from a nozzle.[247]

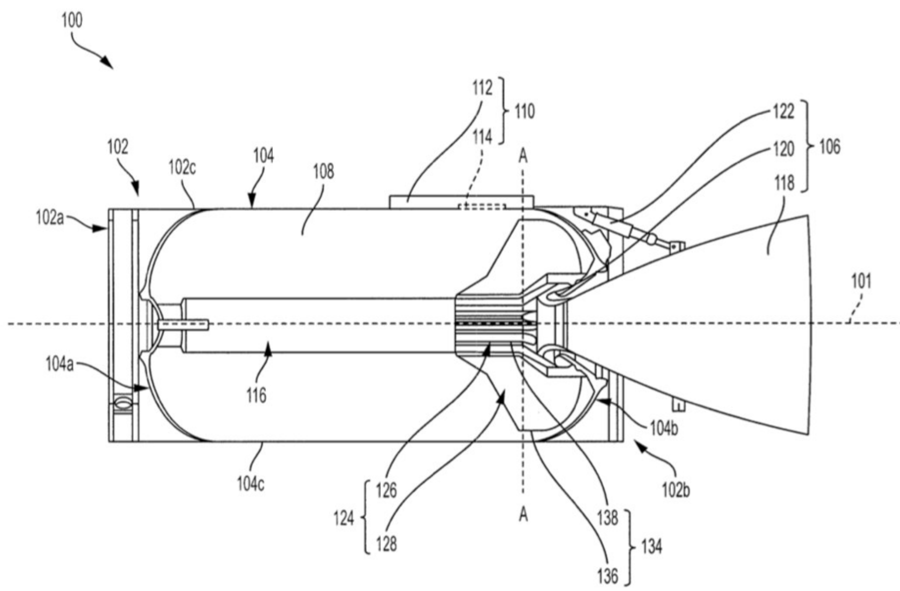

Figure 45[248]

Figure 45 is a drawing for a solid rocket motor patented by Northrop Grumman, the American aerospace and defense contractor. The most common oxidizer used in solid rocket propellants is

243 U.S. Patent No. 3,945,203 to Kayser, Liquid-fueled rocket (March 23, 1976).
244 U.S. Patent No. 3,934,512 to Adachi, Liquid fuel multistage rocket (January 27, 1976).
245 U.S. Patent No. 7,503,511 to Mueller, Pintle injector tip with active cooling (March 17, 2009).
246 U.S. Patent No. 3,974,772 to Pelham et al., Rocket igniter (August 17, 1976).
247 U.S. Patent No. 7,254,936 to Knight, Simple solid propellant rocket engine and super-staged rocket (August 14, 2007).
248 U.S. Patent No. 10,781,773 to Kliger et al., Solid rocket motors including flight termination systems, and related multi-stage solid rocket motor assemblies and methods (September 22, 2020).

ammonium perchlorate (NH_4CIO_4).[249] Ammonium perchlorate is particularly popular because it has a high oxygen content which corresponds to large gas volumes generated during combustion.

The third, and most cutting edge, engine is the nuclear rocket engine. Nuclear propulsion is a recent innovation changing the future of spaceflight.[250] Nuclear propulsion systems provide mission flexibility, decreased costs, and shorter travel time. Rockets with nuclear engines generally use both solid and liquid fuels to power a nuclear reactor.[251] Figure 46 is a patent drawing for a nuclear rocket engine.

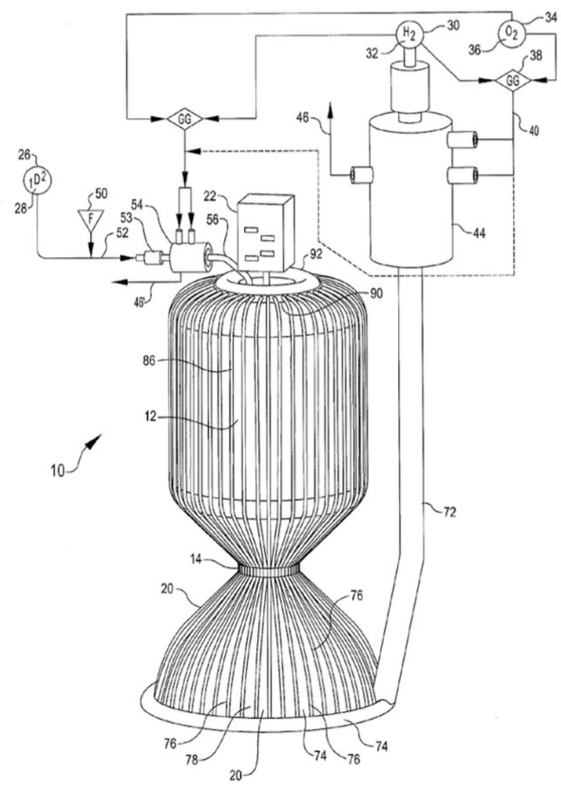

Figure 46[252]

Richard Hardy, the inventor behind the art in Figure 46, is one of the generation's great inventors. Before inventing nuclear rocket propulsion systems, the Air Force veteran invented the F-22 Fighter Jet at The Boeing Company.[253] Hardy's work focuses on using plutonium and

[249] U.S. Patent No. 10,519,075 to Terry et al., Solid-rocket propellants (December 31, 2019).
[250] U.S. Patent No. 10,414,520 to Hardy et al., Fuel retention reactor for nuclear rocket engine (September 17, 2019).
[251] U.S. Patent No. 5,873,239 to Culver, Nuclear rocket engine incorporating a heat exchange (February 23, 1999).
[252] U.S. Patent No. 9,346,565 to Hardy et al., Nuclear thermal propulsion rocket engine (May 24, 2016).
[253] U.S. Patent No. 5,636,813 to Hardy et al., Fighter Aircraft (June 10, 1997).

hydrogen to generate nuclear force for propulsion. Still today, Hardy's work in nuclear rocketry defines the edge in space propulsion systems.[254]

Indeed, the most significant advantage of nuclear propulsion is nuclear reactions generate considerably more energy than chemical reactions.[255] Thus, the prospect of nuclear propulsion in deep space, provides an opportunity for developing breakthrough space technology. In addition to the propulsion system, all rockets have a control system for manipulating trajectory and flight path.

The rocket's control systems include the attitude control system, reaction control system, and other software part specific control systems. The reaction control system governs the rocket's response to the environment in which it operates. Additionally, an attitude control system allows reductions in thruster output using vectorized controls, to manipulate the rocket's position.[256] A thruster is an object generating thrust to propel the rocket with output generating force.

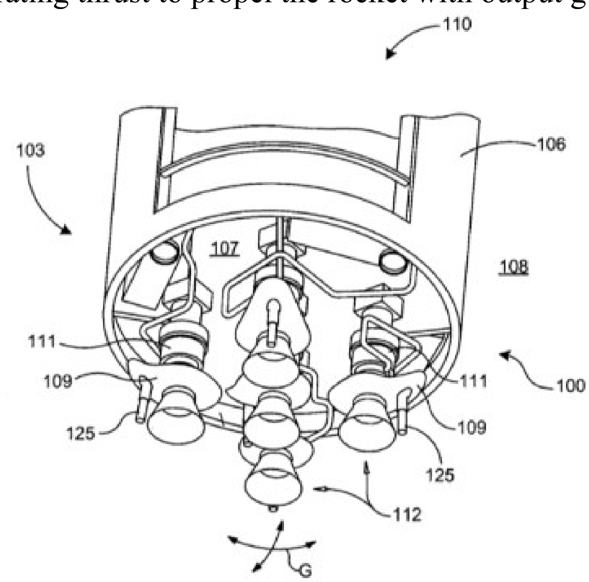

Figure 47[257]

Figure 47 is a patent drawing for a propulsion control system using turbopump valves for thrust command. During flight, thruster commands manipulate rocket positioning including roll, pitch, yaw, and attitude.

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[254] The patents for the inventions are owned by Hardy Engineering Manufacturing, Inc., the Hardy family business in Auburn, Washington, which is now run by Jonathan Hardy.
[255] U.S. Patent No. 5,410,578 to Walton, Nuclear propulsion rocket (April 25, 1995).
[256] U.S. Patent No. 9,429,105 to Barker, et al., Rocket vehicle with integrated attitude control and thrust vectoring (August 30, 2016).
[257] U.S. Patent No. 9,217,389 to Lee et al., Rocket turbopump valves and associated systems and methods (December 22, 2015).

The essential purpose for control systems is to support stabilizing the rocket during the mission for safety and performance.[258] The task is critical for extraterrestrial missions, requiring landing in uncertain environments.[259] In fact, the first space control system for which the USPTO awarded a patent was NASA's lunar landing system, which put humans on the moon in 1969.[260] Control is essential for reusable rockets, which use a control system to perform vertical powered landings.[261] In fact, a recent patent litigation lawsuit centered around whether a certain control system for reusable rockets was patentable.

SpaceX v. Blue Origin

Litigation is a necessary part of the patent system's private enforcement scheme. Palfrey argues, having a clearer certainty in IP rights helps to lead to faster and less expensive settlements.[262] And having control of IP rights from the outset generally decreases the risk of litigation. Generally, there are two types of patent litigation. The first is litigation for patent infringement. The second is *Inter Partes* Review (IPR). The role IPR plays in patent strategy is illustrated well in the 2015 lawsuit between two reusable rocket manufacturers, *SpaceX v. Blue Origin*.[263]

Interestingly, in March of 2015, SpaceX filed a lawsuit against Blue Origin. The lawsuit was filed as an IPR before the Patent Trial and Appeal Board (PTAB). An IPR allows any third-party to request to cancel as unpatentable one or more claims of a patent.[264] During an IPR, the PTAB reviews the patentability of claims in a patent only on the grounds that the claims lack novelty or were obviously in use prior to the filing date, and only on the basis of prior art or existing publications.

Perhaps the most prestigious rocket patent, U.S. Patent No. 8,678,321 (321' Patent) protects reusable rocket technology. In fact, two major inventions originally enabling reusable rocket technology were propulsion assisted landing and first stage booster control. Blue Origin Founder, Jeff Bezos, is the lead inventor on the 321' Patent, which captures a monopoly on certain technology for landing and recovering a Reusable Launch Vehicle (RLV) at sea.

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[258] U.S. Patent No. 5,873,549 to Lane, et al., Vehicle Rotation and Control Mechanism, (February 23, 1999).
[259] U.S. Patent No. 7,967,255, to Head, et al., Autonomous space flight system and planetary lander for executing a discrete landing sequence to remove unknown navigation error, perform hazard avoidance and relocate the lander and method (June 28, 2011).
[260] U.S. Patent No. 3,181,821 to Eddins, Space Craft Soft Landing System (May 4, 1965).
[261] U.S. Patent No. 10,822,122 to Grose et al., Vertical landing systems for space vehicles and associated methods (November 3, 2020).
[262] JOHN PALFREY, INTELLECTUAL PROPERTY STRATEGY 32 (MIT Press 2012).
[263] *Space Exploration Technologies v. Blue Origin*, USPTO Trial and Appeal Board, Judge Carl M. DeFranco, et. al. (2015).
[264] 35 U.S.C. § 311 (2021).

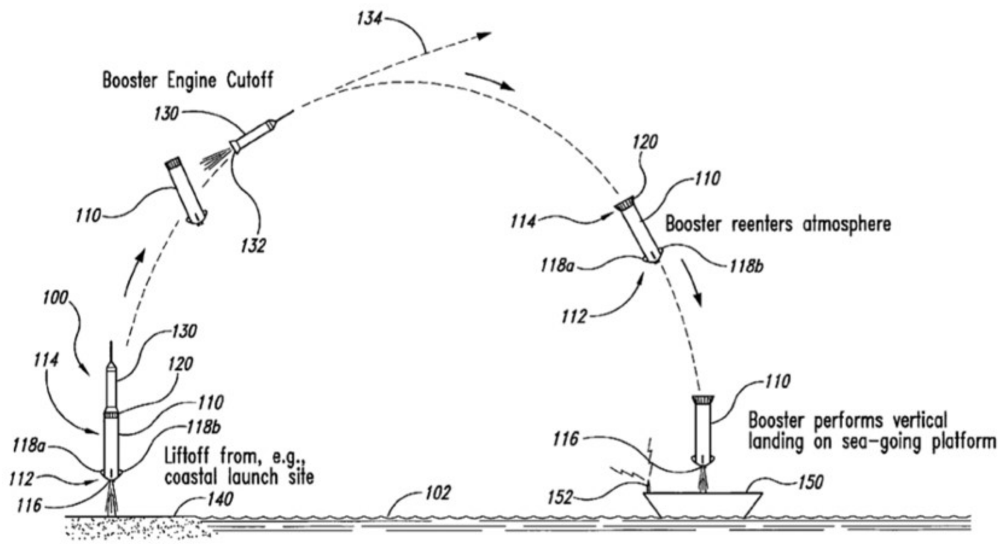

Figure 48[265]

Figure 48 is a schematic illustrating an RLV flight profile with a vertical powered landing on a sea-going platform. Further, Figure X shows a multi-stage orbital launch vehicle including a booster stage and an upper stage, which separates to orbit.

According to the 321' Patent, the RLV comprises a reusable lower booster stage and an upper payload stage. After the stages separate, the RLV's booster stage returns to Earth and performs a controlled landing on a sea-going platform. As a result, the process reduces reconditioning costs for reusing the RLV in a subsequent launch. During reentry, the booster stage reorients itself into a tail-first position, gliding toward the sea-going platform. Once the booster descends to a suitable position over the platform, the engines on the booster stage reignite, slowing the booster's descent. The booster stage then performs a vertical powered landing at low speed, landing on sea-going platform's deck.

Generally, the most important part of a patent are the claims, which mark the legal boundaries for the invention. Patent claims generally define devices, structures, or methods. As such, the claims are the only part of the patent which can be infringed. In the 2015 lawsuit, SpaceX specifically challenged the patentability of claims 14 and 15 from the 321' Patent.

There are several claim formats. For example, the patent statute permits functional claims, providing the scope for functional claim elements are described in means-plus-function

[265] U.S. Patent No. 8,678,321, to Bezos, et. al. Sea landing of space launch vehicles and associated systems and methods (March 25, 2014).

format.[266] The 321' Patent utilizes means-plus-function format, giving Blue Origin the exclusive right to:

> "
>
> 14. A system for providing access to space, the system comprising: A space launch vehicle, wherein the space launch vehicle includes one or more rocket engines; a launch site; a sea going platform; means for launching the launch vehicle from the launch site a first time, wherein the means for launching include means for launching the launch vehicle in a nose-first orientation; means for shutting off the one or more rocket engines; means for reorienting the launch vehicles from the nose-first orientation to a tail-first orientation before landing; means for reigniting at least one of the one or more rocket engines when the launch vehicle is in the tail-first orientation to decelerate the vehicles; means for landing at least a portion of the launch vehicle on the sea going platform in a body of water, wherein the means for landing include means for landing in the tail-first orientation while the one or more rocket engines are thrusting; and means for launching at least a portion of the launch vehicle from the launch site a second time.
>
> 15. The system of claim 14 wherein the means for landing include means for vertically landing at least a portion of the space launch vehicle on a floating platform.
>
> "[267]

SpaceX challenged the patentability of claims 14 and 15, arguing the claims had obviously been in use prior to the patent's award pursuant to 35 U.S.C. § 103.

According to 35 U.S.C. § 103, a patent for a claimed invention may not be obtained, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art. By law, an invention fails the nonobvious requirement for patentability if it "would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art."[268]

SpaceX argued the 321' Patent is silent as to the structure of how the booster engine is ignited, shut-off, or re-ignited to perform the landing, and thus obviously similar to vertical powered

[266] 35 U.S.C. § 112 (2021).
[267] U.S. Patent No. 8,678,321, to Bezos, et. al. Sea landing of space launch vehicles and associated systems and methods (March 25, 2014).
[268] 35 U.S.C. § 103 (2011).

landing methods described in the prior art.[269] However, the Court explained that because the 321' Patent lacked any discussion of how the booster engine is ignited, shut-off, or re-ignited, there existed a lack of corresponding structure for one skilled in the art to determine what exactly is being claimed. As a result, the Court decided the claims were not amenable to construction and therefore did not rule on the legitimacy of SpaceX's argument. In other words, the Court denied SpaceX's petition for IPR because the challenged claims were determined indefinite.

The *SpaceX v. Blue Origin* litigation illustrates the importance of patent strategy because the Court's sophisticated analysis creates flexibility for launch firms. From one perspective, the practical result was Blue Origin's patent claims are still intact. Interestingly, Blue Origin could still sue SpaceX for infringing on the 321' Patent because claim 14 and claim 15 are still valid, even though the PTAB ruled they were indefinite because the PTAB never conducted the IPR. Even so, SpaceX continues to launch and land rockets at sea, despite the Court's ruling and the apparent scope of the 321' Patent.

Conclusion

Chapter 7 explored space technology patents with a focus on space processors, satellites, and rocket technologies. First, radiation hardened FGPAs were described, detailing the state of the art in space hardware processors. Next, space satellites were analyzed from the original invention in the 1970s, to the future satellite constellations surrounding Earth for decades to come. Then, reusable rocket technologies were explained, including rocket designs, engines, and control systems. Finally, the *SpaceX v. Blue Origin* lawsuit was reviewed, along with patent IPR litigation and rocket patent strategy.

Most people think you need a new idea to have a great invention impacting the future. Instead, consider the future for human space exploration will be defined by technology conceived in the past. More than a Century ago, Tsiolkovsky provided the calculations for humans to escape Earth, travel through space, and reach planets.[270] Yet, the world is still waiting for Tsiolkovsky's vision to come to life. As such, the final frontier will be conquered with meticulous mechanical manipulation, and breakthrough engineering for inventions conceived long ago.

A paradox is a set of arguments with apparently true propositions, leading to a false conclusion.[271] Consider again, the Milky Way is one of hundreds of billions of galaxies in the Universe, each containing hundreds of billions of stars.[272] Commonly, stars contain Earth-like planets. As a result, it is almost certain life developed somewhere else in the Universe before life on Earth. And yet, humanity finds itself on the outskirts of the Milky Way, apparently alone in

[269] Yoshiyuki Ishijima et al., Re-entry and Terminal Guidance for Vertical- Landing TSTO (Two-Stage to Orbit), A Collection of Technical Papers Part 1, AIAA Guidance, Navigation and Control Conference (1998).
[270] Константин Эдуардович Цколковский, Исследование Мировых пространств реактивными приборами (1903).
[271] MARGARET CUONZO, PARADOX 2 (2014).
[272] CARL SAGAN, PALE BLUE DOT A VISION OF THE HUMAN FUTURE IN SPACE 21 (1994).

the Universe. Fermi's Paradox asks the question, "Where are they?"[273] The answer will come in time.

[273] Nick Bostrom, In the Great Silence there is Great Hope, 5 (2007).

Chapter 8 Blockchain

Introduction

Writing under the pseudonym Publius in the year 1787, Alexander Hamilton wrote in Federalist No. 30, "Money is, with propriety, considered as the vital principle of the body politic; as that which sustains its life and motion, and enables it to perform its most essential functions."[274] Hamilton is widely regarded as the founding father most largely responsible for America's early economic growth because his writing during the revolutionary period laid the framework for the American economic system. More than two centuries later, in the year 2008, an unknown person with the pseudonym Satoshi Nakamoto sent an email to a cryptography mailing list to announce he had produced a "new electronic cash system that's fully peer-to-peer, with no trusted third party."[275] Later that year, Nakamoto published the Bitcoin White Paper, which serves as the foundation for a new economic system spawning today, the blockchain.

In the Bitcoin White Paper Nakamoto presents a problem, "Commerce on the Internet has come to rely almost exclusively on financial institutions serving as trusted third parties to process electronic payments."[276] Nakamoto defines a need for an electronic payment system based on cryptographic proof, allowing any two willing parties to transact directly without the need for a trusted third party. However, for such transactions to be valid there must be a way in which to verify electronic coins are only spent once. In other words, there must be a way for the receiver to know the previous owners did already spend the electronic coin. Thus, Nakamoto proposes a peer-to-peer distributed ledger generating a computationally proof to validate transactions.[277]

To this day, no one has validated Nakamoto's true identity. Nonetheless, Chapter 8 discusses blockchain technology, the major innovation for which Nakamoto is responsible in four parts. First, the Chapter explores fundamental architectures for blockchain computing. Next, the Chapter provides comparative critique for cryptocurrency markets, finance, and exchange. Third, decentralization is distilled with a focus on ownership and legal property rights to blockchain technologies. Finally, Chapter 8 examines security concerns relating to blockchain mining and transactions.

Architecture

In short, blockchains are decentralized databases, maintained by distributed networks of computers. Scholars, industry leaders, and commentators rave about blockchain technology. For example, Primavera De Filippi asserts, "blockchain technology constitutes a new infrastructure for the storage of data and the management of software applications, decreasing the need for

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[274] Alexander Hamilton, Concerning the General Power of Taxation, Federalist No. 30, New York Packet (December 28, 1787).
[275] SAIFEDEAN AMMOUS, THE BITCOIN STANDARD xv (2018).
[276] Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System 1 (2008).
[277] Riley T. Svikhart, Blockchain's Big Hurdle, 70 STAN. L. REV. ONLINE 100, 101 (2017).

centralized middlemen."[278] As an architecture, a blockchain is a distributed ledger which records transactions between parties. In other words, blockchain technology is both an infrastructure for data storage and management.

From a computational perspective, the programming language C++ is the most commonly used for blockchain software development.[279] However, other languages are used in development, for example both Python and C support blockchain construction. Additionally, blockchain networks are typically open source, meaning the software code necessary for the network's operation is publicly available. The structure for the blockchain may be considered to have four parts: the network, the public-private key system, the transactional process, and mining. Figure 49 is a system for optimizing blockchain performance.

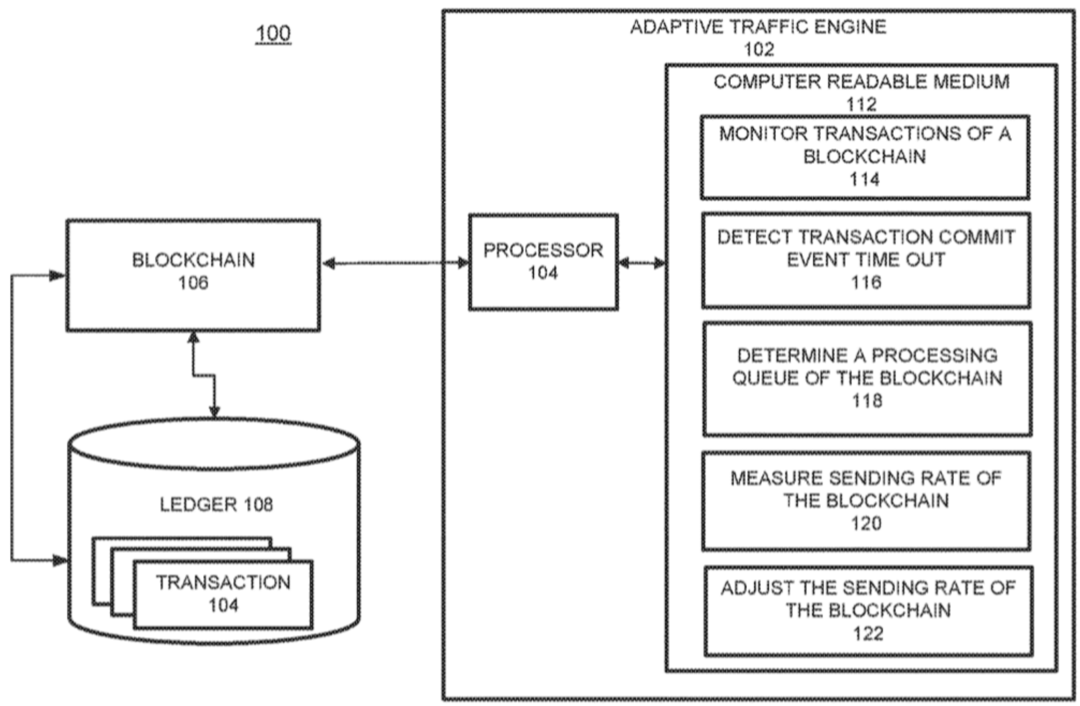

Figure 49[280]

The blockchain network consists of several computers, called nodes, which are connected via the internet.[281] Each node in the network maintains a transaction record called a ledger, which acts as a parasitic function of the internet. The internet has two fundamental layers, the Transmission Control Protocol (TCP), which manages packet assembly, and the Internet Protocol (IP) which

278 PRIMAVERA DE FILIPPI, AARON WRIGHT, BLOCKCHAIN AND THE LAW 33 (2018).
279 Bjarne Stroustrup, The C++ Programming Language (2013).
280 U.S. Patent No. 10,880,073 to Hwang et al., Optimizing performance of a blockchain (December 29, 2020).
281 David Mills et al., Distributed Ledger Technology in Payments, Clearing, and Settlement, Fed. Reserve Bd. Fin. & Econ. Discussion Series, Working Paper No. 95, 10 (2016).

passes packets from one computer to another.[282] Blockchain networks like Bitcoin, ultimately rely on TCP and IP to operate and can be viewed as application protocols, sitting on top of the transport layer.

The Bitcoin White Paper makes clear there are no central coordinators who can change the network rules. The principle is vital to the blockchain economy because it offers a decentralized mechanism by which parties may transact. So, blockchain networks are described as peer-to-peer, a network structure in which all members have equal privileges and obligations toward one another. Blockchain users each have a unique address for identification on the network, similar to an email address.[283]

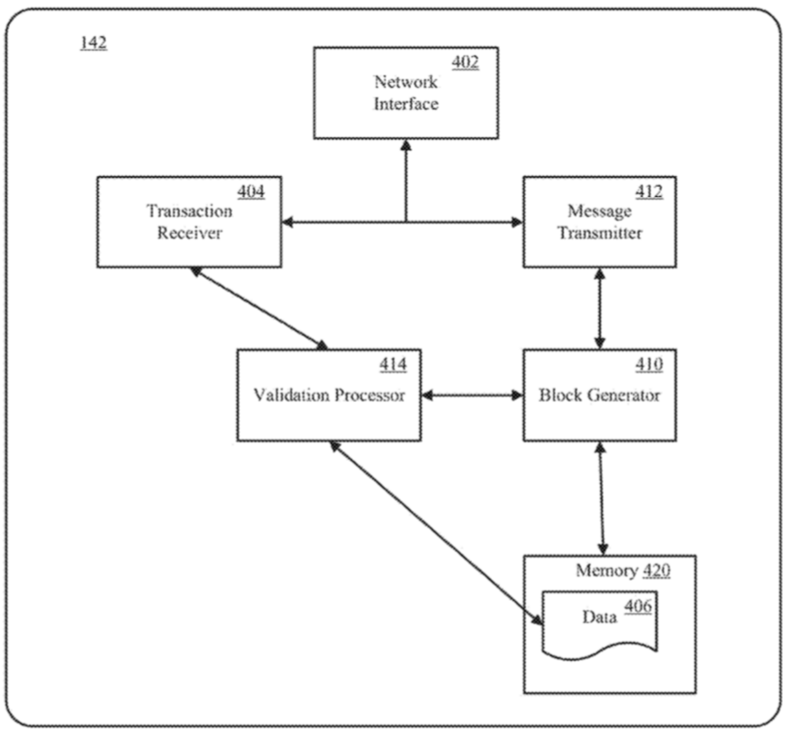

Figure 50[284]

Figure 50 is a systemic blockchain module. Often times, users interact with a network via a wallet, serving as a primary user interface.

The peer-to-peer network developed as a way to solve the double spending problem, where the same digital coin is spent more than once. For example, the blockchain protocol uses timestamps

[282] PAUL E. CERUZZI, COMPUTING: A CONCISE HISTORY 121 (2012).
[283] ANDREAS M. ANTONOPOULOS, MASTERING BITCOIN 65 (2017).
[284] U.S. Patent No. 10,417,217 to Pierce et al., Systems and methods for blockchain rule synchronization (September 17, 2019).

and a proof-of-work to record a public history of transactions. The timestamp captures the time of transactions on the network, while the proof-of-work validates transactions. The idea is nodes consider the longest chain to be the correct one and will continue working to extend it. The means by which nodes transact is through a system of Public-Private Key Cryptography.

Public-Private Key Cryptography (PPKC) is a method for authentication, relying on two codes, a private key and a public key. The methodology developed to meet the need for a secure key distribution method allowing authentication, similar to the way in which serial numbers identify paper currency.

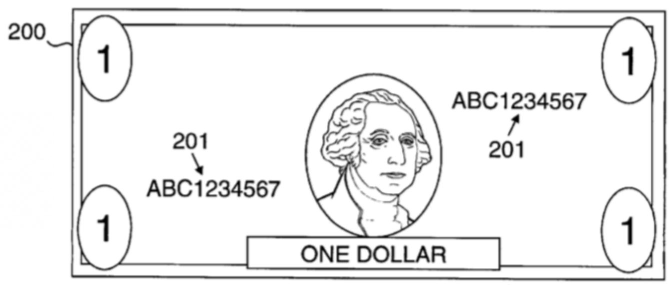

Figure 51[285]

Figure 51 shows a dollar bill with an affiliated unique serial number. The key pair consists of a private key – derived from a unique public key. The public key is used to receive funds and the private key is used to sign transactions to spend the funds. In essence, the public key is an address, and the private key is a secret password.

In short, PPKC enables encrypted messages to be sent without the need for a shared key.[286] For example, one of the first PPKC systems was the Rivest–Shamir–Adleman (RSA) algorithm.[287] The RSA algorithm creates a mathematically linked kay pair by multiplying two prime numbers together. While, multiplying two prime numbers is computationally inexpensive, figuring out which prime numbers were multiplied to get a number is computationally complex, making it possible to broadcast a public key while reserving a secure private key.

As such, PPKC allows parties to pseudonymously exchange messages across a blockchain. Further, blockchains use PPKC to validate the integrity of data recorded across a distributed ledger.[288] This process produces digital signatures which represent a sender's intent to transfer a message to the receiver. From one perspective, a Bitcoin is simply a chain of digital signatures.

[285] United States Patent No. 6,363,483 to Keshav, Methods and systems for performing article authentication (March 26, 2002).
[286] PRIMAVERA DE FILIPPI, AARON WRIGHT, BLOCKCHAIN AND THE LAW 14 (2018).
[287] R.L. Rivest, et. al., A Method for Obtaining Digital Signatures and Public-Key Cryptosystems (1977).
[288] United States Patent No. 10,439,812 to Patin, Technologies for private key recovery in distributed ledger systems (October 8, 2019).

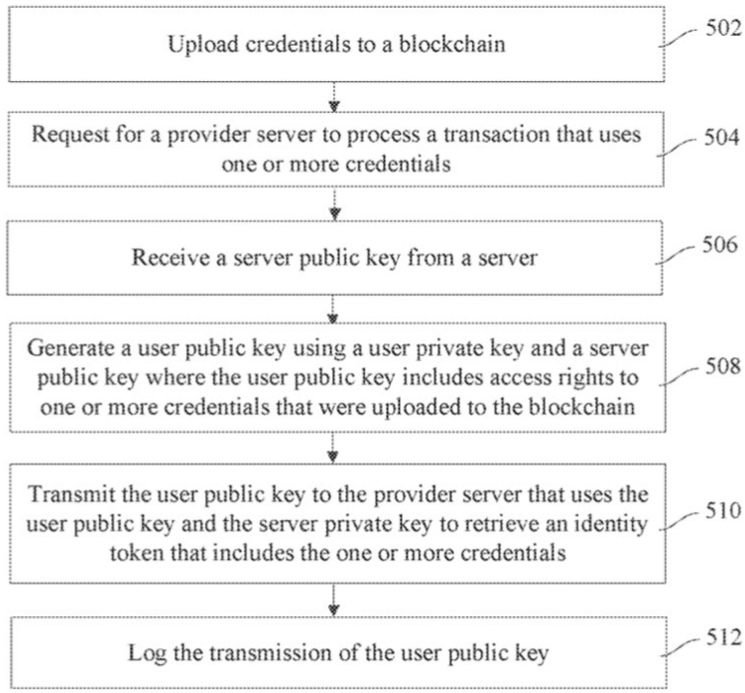

Figure 52[289]

Figure 52 is a flowchart for generating a user public key from a patent assigned to PayPal. However, validating a chain of digital signatures to allow secure transactions requires a more complex process. Indeed, some claim the key innovation of blockchain is its ability to process secure transactions.

In a blockchain, the transactions are bundled into blocks. A block is a data structure, aggregating transactions for inclusion in a public ledger. Each block consists of a hash value from the previous block, which are transactions happening in the last ten minutes, and a random integer called a nonce. Each block is broadcast to the network, presenting a complex algorithmic problem for validation. Solving blocks typically requires an enormous amount of computation, but verifying the solution is relatively simple. As such, graphics cards are the most popular hardware tool for blockchain technologies.

Once a block is verified, each transaction is recorded as a public entry in a distributed ledger, the blockchain. Indeed, every transaction is registered by each member in the network, so all nodes share one common ledger with balances and transactions.

[289] United States Patent No. 10,855,667 to Breu, Using keys with targeted access to the blockchain to verify and authenticate identity (December 1, 2020).

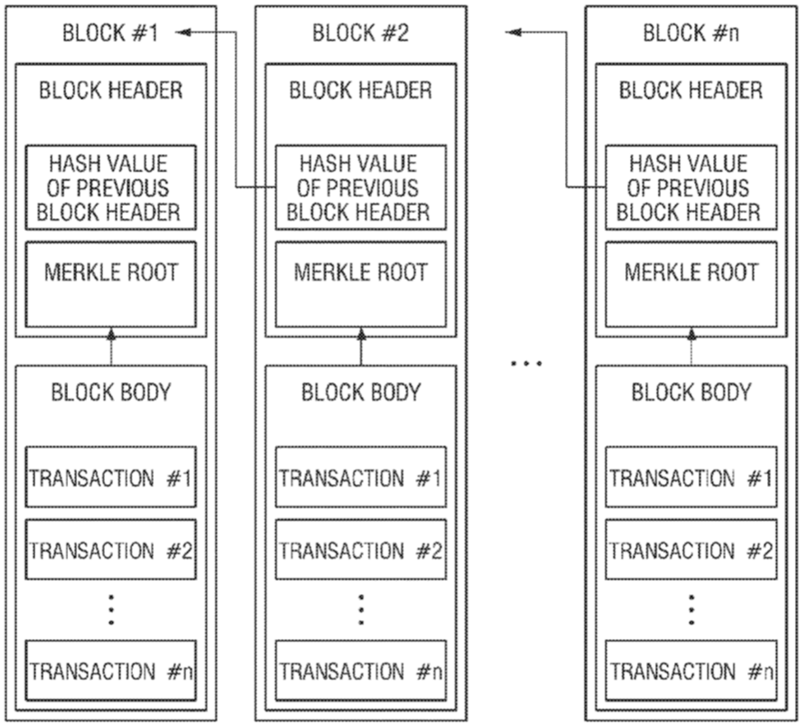

Figure 53[290]

Figure 53 illustrates blockchain data moving across a transactional network. However, contrary to conventional wisdom, which purports blockchain transactions are processed instantaneously without any fees, most transactions include processing fees. Generally, fees are calculated as the difference between the input sum and the output sum. Any excess amount that remains after all outputs have been deducted from all inputs is the fee collected by miners. In fact, blockchain transactions would not be possible without block validation, which occurs through a process called mining.

A financial transaction communicates to a network an authorized money movement has occurred. The essential elements are a network of parties, an asset moved among those parties, and a process defining the procedures and obligations associated with the movement. In other words, transactions are data structures encoding the value transfer between participants in a system. While costly financial institutions have policed such transactions in the past, blockchain supports a network of traders to perform this function itself. As such, one of the most interesting aspects of blockchain technology is that a central authority does not need to verify transactions.

Instead, mining is the process by which blockchain transactions are validated. Generally, the purpose for mining is to enable network-wide consensus without a central authority. For

[290] U.S. Patent No 10,762,479 to Hyun et al, method and system for processing blockchain-based real-time transaction (September 1, 2020).

example, in the Bitcoin protocol, mining involves solving a hash algorithm, the SHA-256, which turns any arbitrary input into a 256-bit string. In practice, the mining process involves iteratively hashing a block until a specific target is met. Thus, the block does not become valid until after the target is reached, when a miner solves the SHA-256, producing a proof-of-work.

Mining may be further defined as a search problem requiring miners to find an input, the nonce, less than a target value T, which is considered a valid hash. Classically, the success probability of mining a block with guesses is given by $Trt/2^{256}$, where r is the hash rate – guesses per second, and t is the time in seconds. Currently, there is no known efficient algorithm, which can invert SHA-256. As a result, the only way to solve the SHA-256 is brute force search. In other words, trying different inputs until a satisfactory solution is found. Indeed, miners who solve the SHA-256 for a particular block are rewarded with digital coins.

For example, the Bitcoin mining system involves scanning for a value that when hashed produces a hash, h such that $h < T$, resulting in a valid proof-of-work. The proof-of-work scheme ensures transactions are validated by those who are willing to expend enough physical energy and time to do so, while introducing an incentive to induce market competition. In the bitcoin protocol, for the first four years each block issued fifty Bitcoins. However, the number of Bitcoins awarded for solving a block halves every four years. So, in 2012, the Bitcoin issuance rate dropped to 25 Bitcoins; in 2016, the Bitcoin issuance rate dropped to 12.5 Bitcoins; and in 2020, the Bitcoin issuance rate dropped to 6.25 Bitcoins. The number continues to halve until 21 million Bitcoins have been issued, which is approximated to occur in 2140.

In sum, blockchains are adaptable systems with evolving rules. However, the reward comes at a cost to miners. Because the SHA-256 is only solvable by brute force methods, mining requires substantial electricity and computing power. As a result, miners join to form mining pools, where participants work together towards finding the next block and share rewards based on each miner's respective contribution. Competition amongst mining pools is fierce, producing adversarial strategies favoring the pools with the most computing power. As a result, the fraction of blocks solved by solo miners has steadily declined and is widely considered impossible today. In fact, one reason competition is so stiff is because there is a strong economic motive for miners to win rewards in the form of new coins. Since its inception, blockchain technology is immediately finding utility as a digital currency.

Cryptocurrency

Cryptocurrency is a digital token, created with blockchain technology. In the Bitcoin White Paper, Satoshi Nakamoto defines an electronic coin as "a chain of digital signatures."[291] Additionally, in The Bitcoin Standard, Saifedean Ammous argues, "Bitcoin is the newest technology to serve the function of money, solving the problem: how to move economic value across time and space."[292] According to Ammous, at its core, money is a good assuming the role

[291] Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System 2 (2008).
[292] SAIFEDEAN AMMOUS, THE BITCOIN STANDARD 1 (2018).

of an accepted medium of exchange. In short, cryptocurrencies may be defined as a collection of concepts and technologies forming the basis for a digital money ecosystem. In February 2021, the cryptocurrency market exceeded $1.5 trillion.

Bitcoin is the first and largest cryptocurrency.[293] Perhaps peripheral, Bitcoin has a dominant market share in the cryptocurrency market, with a market capitalization reaching $1.2 trillion in February 2021.

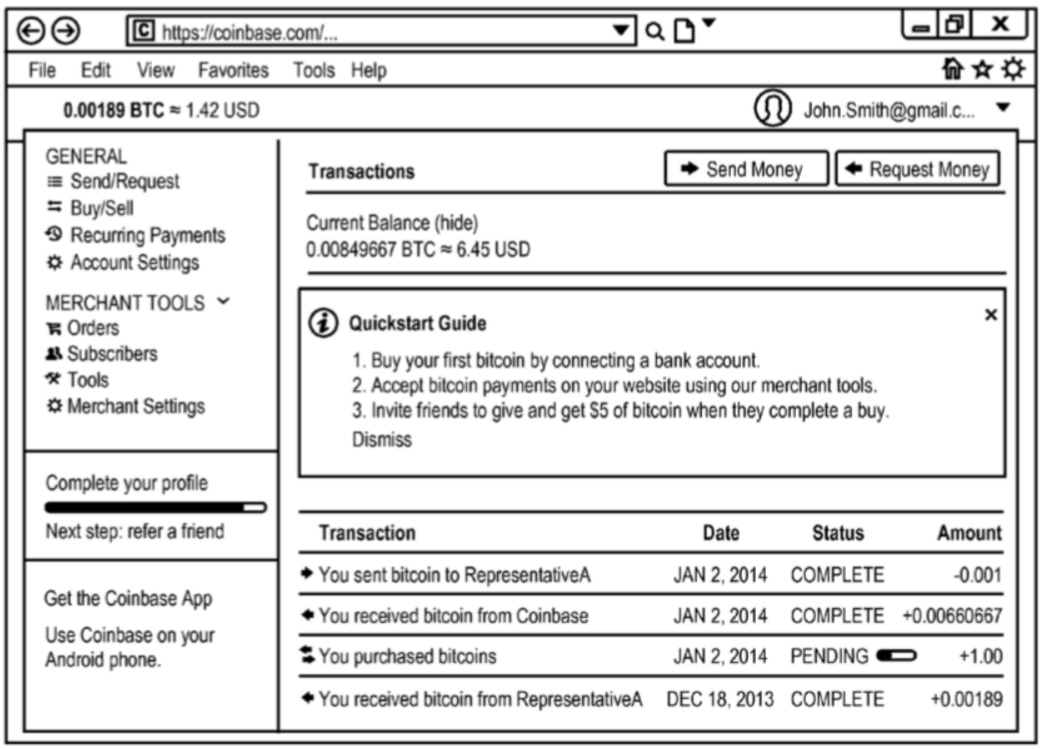

Figure 54[294]

Figure 54 is an internet browser view for Bitcoin transfer on Coinbase, which offers a cryptocurrency exchange and marketplace. Some suggest Bitcoin's market dominance will continue in line with the power law, to those who have abundance flows.

Consider on September 17, 2014, one Bitcoin was worth $457.33 and on September 17, 2020, one Bitcoin was worth $10,774.63. Figure 55 graphs the price of one Bitcoin in United States Dollars over five years.

[293] U.S. Patent No. 10,229,396, to Shtylman et al., Bitcoin exchange (March 12, 2019).
[294] U.S. patent No. 9,436,935 to Hudon, Computer system for making a payment using a tip button (September 6, 2016).

Figure 55

Interestingly, the world's largest automotive manufacture, Tesla, announced in January 2021 plans to process Bitcoin as payment. Then, on February 16, 2021 Bitcoin's price exceeded $50,000.00 for the first time. The highest price ever paid for a bitcoin on Coinbase's exchange was $58,367.00 in February 2021. In the same year, large financial institutions publicly announced plans to service Bitcoin transactions, including J.P. Morgan, BNY Mellon, and Goldman Sachs. The institutionalized financial focus on Bitcoin as opposed to cryptocurrency more generally may continue given Bitcoin accounts for approximately 72.64% of the total cryptocurrency market.

Created by Vitalik Buterin in the year 2014, Ethereum is the second blockchain, which uses its own cryptocurrency to reward miners called Ether. Moreover, Ethereum includes a platform for application development which is becoming increasingly popular. The major difference between Bitcoin and Ethereum is that the total supply for Bitcoin is finite with 21 million coins, but the Ethereum Blockchain is not finite. Thus, some argue from a supply and demand economics perspective, this makes Bitcoin far more valuable. On the other hand, without rewards left for miners, some speculate Bitcoin will die out completely.

Litecoin is the largest alt coin, which refers to all coins after Bitcoin and Ethereum. On GitHub, the Litecoin repository is identifiably forked from Bitcoin. Like Bitcoin and Ethereum, Litecoin is based on a computational proof-of-work. However, other alt coins are developing based on a different validation mechanism called a proof-of-stake.[295] For example, Algorand is a proof-of-

[295] U.S. Patent No. 10,841,100 to Lam et al., Dynamically managing exchanges of data using a distributed ledger and homomorphic commitments (November 17, 2020).

stake blockchain, which evolved to improve security and power efficiency across the network by limiting miners to validating transactions proportional to an ownership share.[296]

Often times, users interact with a network via a wallet, serving as a primary user interface. A wallet is software holding cryptocurrency, addresses, and keys. Said another way, a wallet is a computer program for storing the public-private key pairs for cryptocurrency transactions.

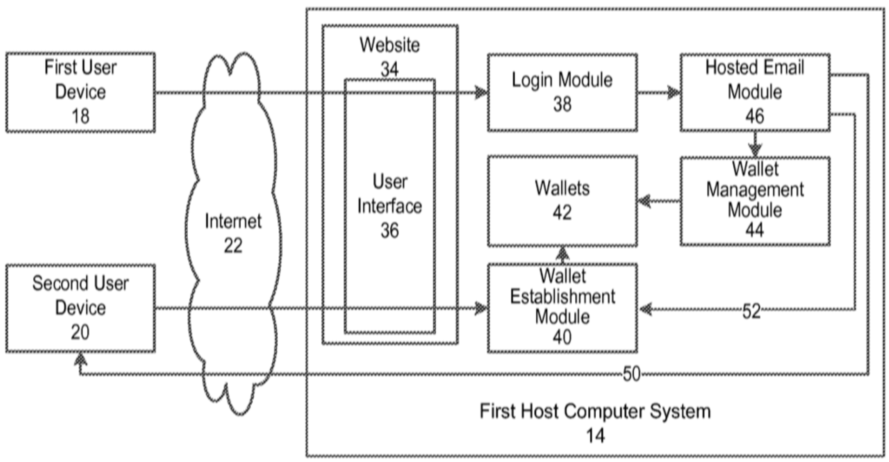

Figure 56[297]

Figure 56 is a patent drawing for a Bitcoin wallet from a Coinbase patent for a host computer with a wallet which is made accessible to users via the internet. The critical value added by wallets is that they allow users to exchange and store cryptocurrencies in a centralized platform. Importantly, wallets hold digital money. So, without wallets to secure value, some suggest cryptocurrency may take the form of a security instead of a currency.

There are robust regulatory restraints relating to cryptocurrency, including securities regulation, taxation considerations, and criminal activity and uses. Indeed, the Federal Reserve states compliance with the Bank Secrecy Act and anti-money-laundering requirements as two of its chief concerns relating to blockchain regulation.[298] Additionally, the scope of cryptocurrency as an investment poses regulatory questions from a securities perspective.

[296] Yossi Gilad, et al., Algorand: Scaling Byzantine Agreements for Cryptocurrencies, 53 (2017).
[297] U.S. Patent No. 10,755,241 to Langschaedel, Hot wallet for holding bitcoin (August 25, 2020).
[298] David Mills et al., Distributed Ledger Technology in Payments, Clearing, and Settlement Fed. Reserve Bd. Fin. & Econ. Discussion Series, Working Paper No. 95, 30 (2016).

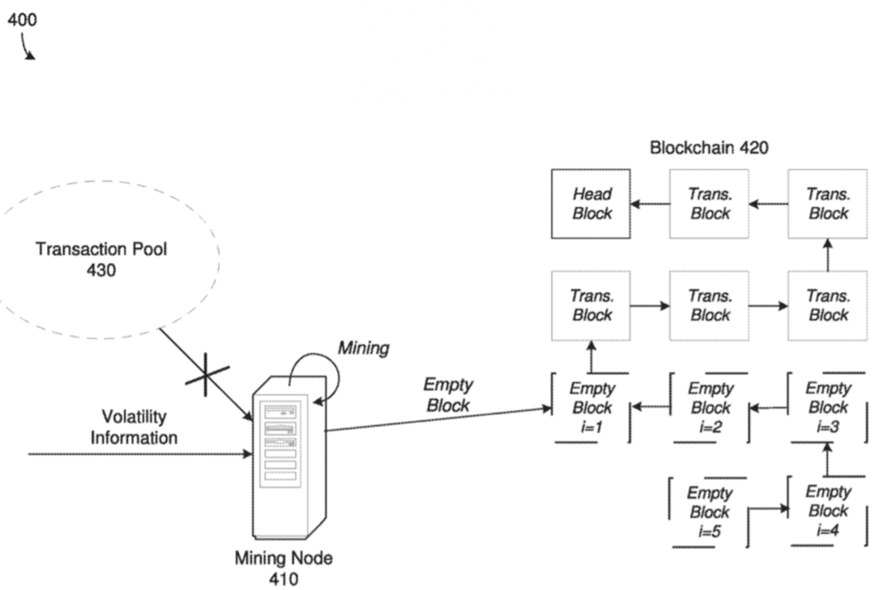

Figure 57[299]

Figure 57 illustrates a process by which cryptocurrency volatility is controlled. For example, the Securities Act of 1933 and the Securities Exchange Act of 1934 collectively regulate the disclosure of securities information to investors.[300] As such, corporate financial compliance with regulatory oversight will be critical for firms using blockchain technology.[301]

For example, Ripple is a blockchain created in the year 2014.[302] However, in December 2020, the United States Securities Exchange Commission (SEC), brought a lawsuit against Ripple's creators for selling the asset without first registering to sell securities.[303] Interestingly, Ripple was sold on the Coinbase cryptocurrency exchange throughout that period, but Coinbase was not party to the lawsuit.[304] Moreover, the driverless car maker, Tesla reported purchasing $1.50 billion in Bitcoin to the SEC in January 2021.[305] Tesla further stated the laws regulating cryptocurrencies are unclear, so it plans to begin accepting Bitcoin as a form of payment in the near future.

The marketplace for cryptocurrencies is extremely volatile. The laws surrounding cryptocurrencies are likely unclear by design because it gives the SEC the ability to pick and choose their targets, like Ripple. As a policy matter, using unclear laws to exercise political

[299] U.S. Patent No. 10,691,648 to Deshpande, et al., Controlling volatility via blockchain (June 23, 2020).
[300] 15 U.S.C.A § 77-78.
[301] Veronica Root, Coordinating Compliance Incentives, 102 CORNELL L. REV. 1003, 1010 (2017).
[302] David Schwartz, et al., The Ripple Protocol Consensus Algorithm (2014).
[303] Securities and Exchange Commission v. Ripple Labs, Inc., et al., United States District Court, 20 Civ. 10832, Complaint (December 22, 2020).
[304] U.S. Patent 10,878,389 to Shtylman et al., Cryptographic currency exchange (December 29, 2020).
[305] Tesla, Inc., United States Securities and Exchange Commission, Form 10-K, 23 (February 8, 2021).

authority is unconstitutional, but the SEC may still seek to seize cryptocurrencies, penalizing owners. As a result, establishing an ownership interest in cryptocurrencies may be risky. However, owning patents in the blockchain market promises high reward.

Ownership

Owning blockchain technologies promises the opportunity to capture an early stake in the millennium's most prolific and best performing financial asset. Ownership considerations for blockchain technologies arise according to an eclectic assortment. Each technology is unique and different, offering new features and capabilities, along with unique problems and challenges. More generally, considerations for owning blockchain technologies include software licenses, patent rights, government interests, and transfer via smart contracts.

A unique feature for blockchain technologies compared to other high technologies is blockchains are in theory all open source software. The reason blockchains are designed to be open source is because the technology is intended to decentralize economic transactions. As such, for distributed ledgers to be effective, they must be accessible by all nodes the network and thus public. For example, the Bitcoin network software stack, Bitcoin Core, is available as open source code and can be run on a wide array of computing devices.

Bitcoin Core is available on GitHub and is released under an MIT License.[306] Other cryptocurrencies including Algorand and Litecoin, use the MIT license as well. Typically, the code is protected under copyright law, which includes certain functional elements for the technology.[307] Then, the MIT License grants a license to use the technology, while limiting liability for the copyright holder.[308] As such, blockchain technology is said to be made open because anyone can use it, subject to the license, promoting arguments for a decentralized economy. However, not all blockchain technology is open, in fact there is an abundance in proprietary blockchain technologies evolving across the financial industry.

Patents for blockchain technology come in many forms. For example, IBM patented technology for controlling market volatilities using blockchain.[309] Another example is patents for software making blockchain technologies accessible to investors.[310]

[306] Bitcoin, Bitcoin Core integration/staging tree, Github (2019).
[307] 17 U.S.C. §102.
[308] The MIT License, Open Source Initiative (2021).
[309] U.S. Patent No. 10,691,648 to Deshpande et al., Controlling volatility via blockchain (June 23, 2020).
[310] U.S. Patent No. 10,839,377 to Scrivener, Syncing blockchain nodes with snapshots (November 17, 2020).

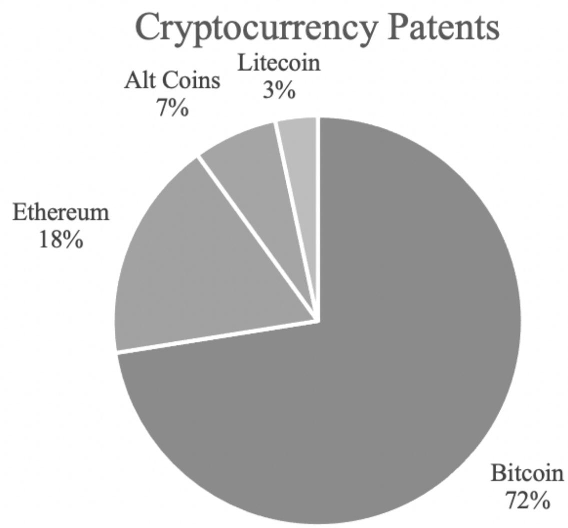

Figure 58[311]

Figure 58 charts patents with claim terms including cryptocurrencies. The graph relatively mirrors the market capitalization for the coins, with patents for Bitcoin technologies being the most prolific.

Patents for AI technologies incorporating into blockchain transactions are on the cutting edge. Figure 59 is a patent drawing for blockchain technology using deep learning.

[311] Data recorded on February 12, 2021.

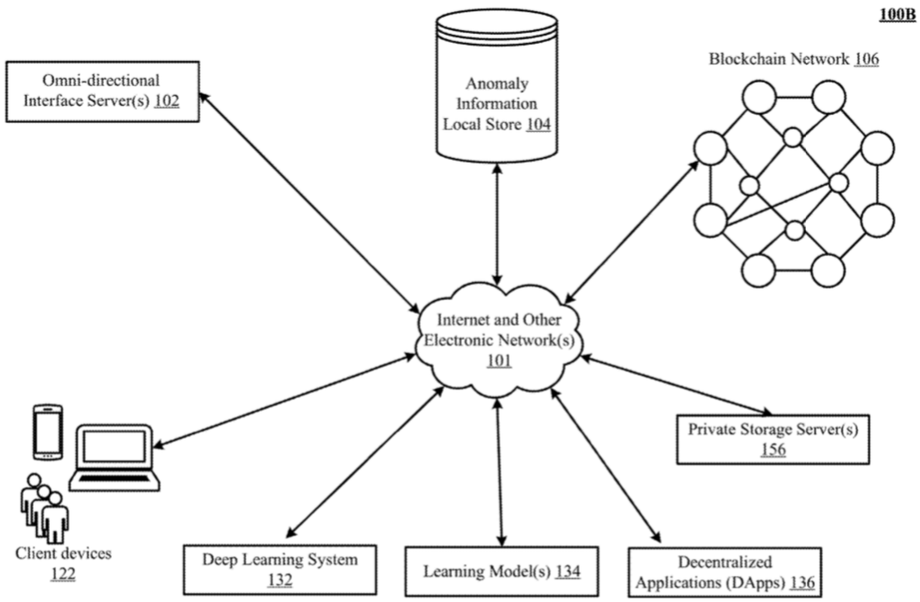

Figure 59[312]

Patents help to validate blockchain technologies because the Government approves the innovation to grant a patent, making it less likely to be deemed illegal. The U.S. Government owns significant interests in Bitcoin. For example, in the year 2017, the United States Government seized more than 150,000 Bitcoins in connection with Silk Road founder, Ross Ulbricht's arrest.[313] Today, the sum seized is worth more than $7 billion. In addition to criminal seizure, another reason for Government ownership in blockchain technologies is global economic competition. Indeed, recent reports explain most Bitcoin mining happens in China.[314] However, another possibility is to keep certain blockchain technologies secret altogether because disclosure may give away a competitive advantage in the marketplace.

A main advantage for blockchain technologies is the ability to transfer capital in a more economically efficient way.[315] A smart contract is a computer program which automatically executes, transferring cryptocurrency. In other words, smart contracts are programs that are logically executed on a blockchain without a central oversight.

[312] U.S. Patent No. 10,873,465 to Dods et al., Neural Network Classifiers for blockchain data structures (December 22, 2020).
[313] United States v. Ulbricht, 858 F. 3d. 71, 88 (2017).
[314] Ben Kaiser, et al., The Looming Threat of China: An Analysis of Chinese Influence on Bitcoin (October 5, 2018).
[315] U.S. Patent No. 10,769,600 to Chen et al., Cryptocurrency transactions using debit and credit values (September 8, 2020).

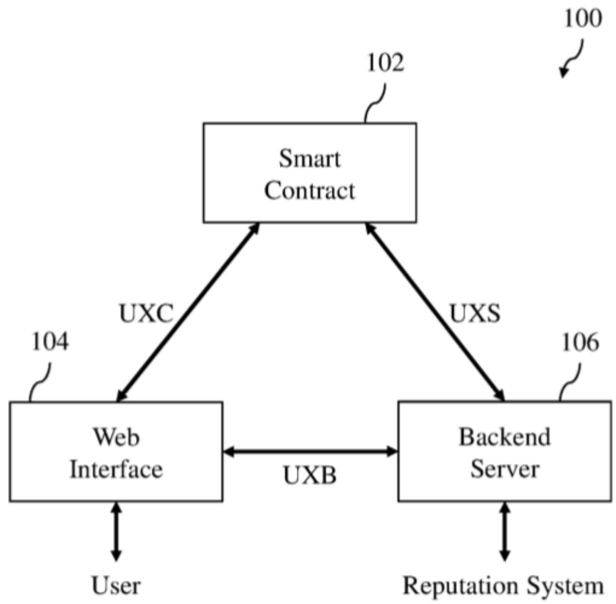

Figure 60[316]

Figure 60 is block diagram for an autonomous smart contract. In fact, a main purpose in developing Ethereum was to ensure a better method for transacting using smart contracts. Later, Tezos, a blockchain started in Isreal, created a more secure blockchain for smart contracts by reducing code complexity.[317] In sum, smart contracts are just regular contracts written in programming language.

Blockchain ownership comes in various forms for both intellectual property and software code. Moreover, cryptocurrency owners include governments, publicly traded companies, and institutional investors. Among these various owners, transferring economic value via smart contracts is improving efficiency in transactions. The most important aspect for owning blockchain technologies is the ability to secure the asset over time.

Security

Security is the most important feature for blockchains. In fact, if transactions are not secure, then users will not transact because the risk for loss will be too high. As such, various alt coins are developing specifically to address security concerns with the blockchain architecture. For example, Tezos sought to address security concerns in Bitcoin using a more decentralized ledger.[318] The Tezos blockchain uses a staking consensus mechanism to insulate against risk by limiting mining power based on ownership.

[316] U.S. Patent No. 10,635,471 to Davis et al., System and method for an autonomous entity (April 28, 2020).
[317] L.M. Goodman, Tezos: A Self-Amending Crypto-Ledger Position Paper, 9 (August 3, 2014).
[318] L.M. Goodman, Tezos: A Self-Amending Crypto-Ledger Position Paper, 2-5 (August 3, 2014).

Additionally, privacy is impossible without security. If information is not secure, then it can be accessed and thus taken. Across distributed ledgers, no transactions are private. Instead, all transactions are public.

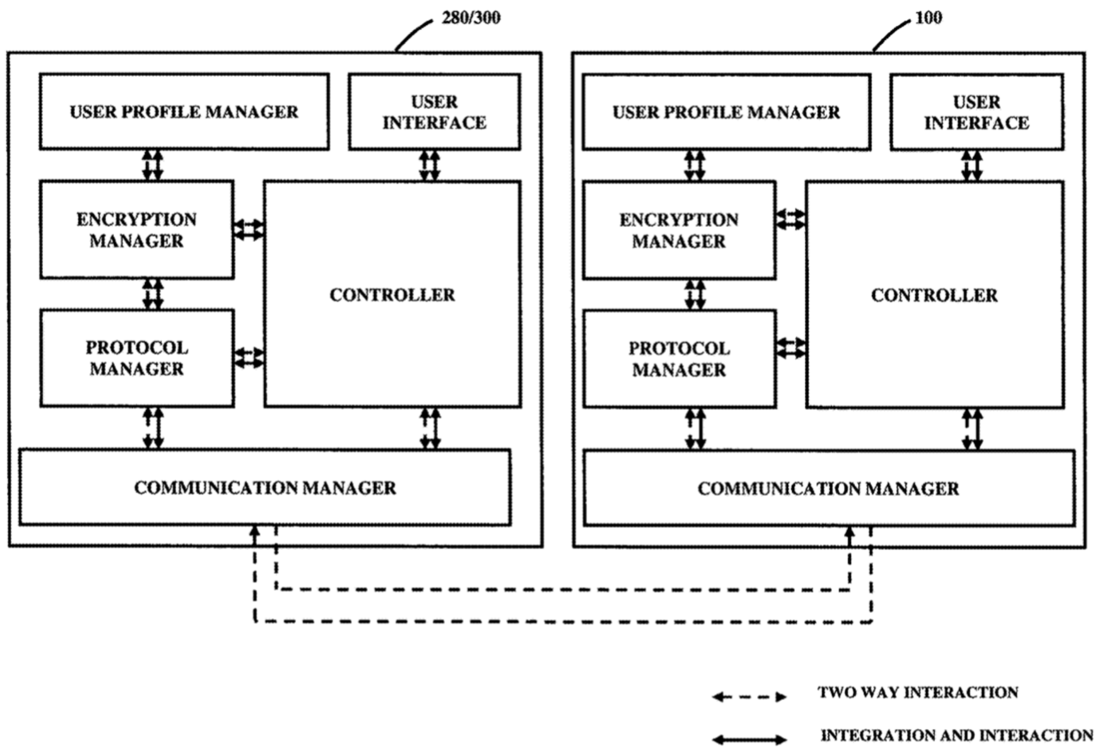

Figure 61[319]

Figure 61 is an illustration depicting a methodology for securing a digital wallet. In fact, companies and alt coins are working on problems preserving privacy across the blockchain networks.[320] For example, Zcash evolved specifically to create a more private cryptocurrency.[321]

Another risk for blockchain adoption is whether the technology will be used to advance criminal activity and money laundering. For example, Ross Ulbricht and Hugh Haney were both convicted on charges relating to using Bitcoin to traffic narcotics across the Silk Road. As such, some worry the technology serves implicitly illicit transactions and parties.

319 U.S. Patent No. 10,540,704 to Mazed et al., System and method for machine learning based user application (January 21, 2020).
320 U.S. Patent No. 10,341,121 to Androulaki et al., System, method, and computer program product for privacy-preserving transaction validation mechanisms for smart contracts that are included in a ledger (July 2, 2019).
321 Daira Hopwood, et al., Zcash Protocol Specification, 1 (July 13, 2020).

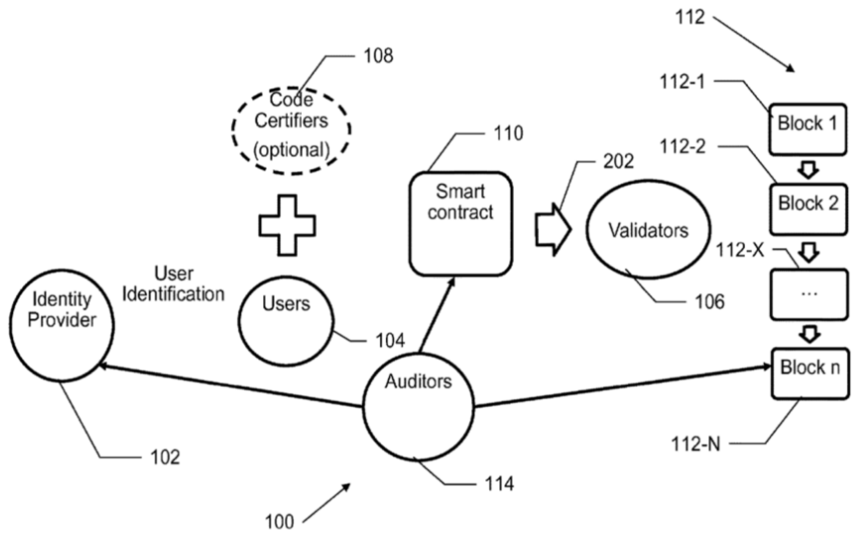

Figure 62[322]

Figure 62 is a drawing for a process by which smart contracts are created with user identification features. Consider instead, the technology will have the opposite effect because it will become more difficult to exchange value without a digital trace.

In fact, all transactions across blockchain networks are public. So, one need only discover the owner of a public address to discover the parties to any exchange. Moreover, new technologies are evolving to identify suspicious behavior across distributed ledgers.[323] Some argue, blockchains make it possible for a person to engage in transactions without revealing one's true identity. However, contextual information related to blockchain-based transactions can be analyzed to deanonymize individuals.

There are two ways to hack blockchains. The first is stealing a private key to siphon funds from a victim's wallet, which is probably criminal hacking.[324] For example, malicious hacking involves taking unauthorized control of private keys to secure protected funds.[325] To prevent this from happening, cryptocurrency exchanges develop robust software frameworks to ensure financial security.[326]

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[322] United States Patent No. 10,341,121 to Androulaki et al., System, method, and computer program product for privacy-preserving transaction validation mechanisms for smart contracts that are included in a ledger (July 2, 2019).
[323] United States Patent No. 10,380,594 to Bayer et al., Systems and methods for monitoring and analyzing financial transactions on public distributed ledgers for suspicious and/or criminal activity (August 13, 2019).
[324] United States Patent No. 10,891,600 to Rebernik, User private key control (January 12, 2021).
[325] U.S. Patent No. 10,354,236 to Wang, Methods for preventing front running in digital asset transactions (July 16, 2019).
[326] United States Patent No. 9,882,715 to Alness et al., API key generation of a security system forming part of a host computer for cryptographic transactions (January 30, 2018).

The second hack is a majority override, which results from competitive advantage in mining. To combat the majority override problem, Algorand developed a proof-of-stake chain.[327] Proof-of-stake chains differ from classical blockchains, which use a proof-of-work to validate transactions. Majority overrides should not be considered criminal hacking because they result from the legitimately described blockchain software code. In other words, you have to follow the rules to change the rules on the blockchain and new rules mean innovation.

In sum, without security, blockchains simply would not work. In fact, there would be no incentive to use or own digital assets which could be taken without regard for an owner's wishes. As blockchain technology evolves security will continue to be the most important software feature. Moreover, as new mechanisms evolve protecting digital assets provides enormous opportunity for new inventions and innovations.

Conclusion

Chapter 8 discussed blockchain technology in four parts. First, the Chapter explored fundamental architectures for blockchain computing. Next, the Chapter provided comparative critique for cryptocurrency markets, finance, and exchange. Third, decentralization was distilled with a focus on ownership and legal property rights to blockchain technologies. Finally, Chapter 8 examined security concerns relating to blockchain mining and transactions.

Even with companies like Tesla growing more than 200.00% in the year 2020, cryptocurrencies far outpaced the stock market. So, it isn't surprising Tesla bought $1.5 billion in Bitcoin in January 2021. In its 2021 Form 10-K filing, an annual report to the SEC, Tesla explains the reason for the investment is because of the SEC's selective enforcement scheme and a deeply volatile market. In fact, returns from blockchain technology are outpacing even the best investment firms, including Berkshire Hathaway. But as a system, for a while Warren Buffet's description that cryptocurrency is rat poison squared seemed significant.

However, now that Bitcoin is worth more than both Berkshire Hathaway and Tesla, blockchain is too big to fail. Still economically, not much has changed since Hamilton wrote in the late 18th century. Similar to the revolutionary period, in modern society, money remains the ultimate form of freedom. It enables the holder limitless power to cure disease, promote progress, and even explore space.

In many ways, blockchain is simply a new form of freedom. In fact, the largest lure for investors is that blockchain's create a currency not controlled by a central government. As such, blockchain has been a truly global technology since its inception. But the technology should not be considered truly decentralized because the economic system is being recentralized to those with the most computing power for mining. Moving forward, no technology stands to have a greater impact on the future of blockchain than quantum computers.

[327] Jing Chen, Silvio Micali, Algorand (May 26, 2017).

Chapter 9 Quantum Computing

Introduction

Quantum mechanics is the scientific discipline concerned with the motion and interaction of subatomic particles. Conceptually, Richard Feynman was the first person to discuss the intuition behind quantum computers, specifically to evolve computers from binary logic to a higher-order logic using quantum mechanical properties. The idea was based on the quantum mechanical principle, superposition. Superposition describes an instance where a subatomic particle occupies two independent spatial positions simultaneously. Feynman's greatest idea was to exploit this principle to improve computational systems.[328]

On the bleeding edge, quantum computing technologies are relatively new. Generally, quantum computing refers to a range of technologies harnessing the power of quantum mechanics to perform computation. In fact, quantum information technologies are actively advancing the art in both hardware and software, converging new systems and reinventing the most meticulous computational methods.

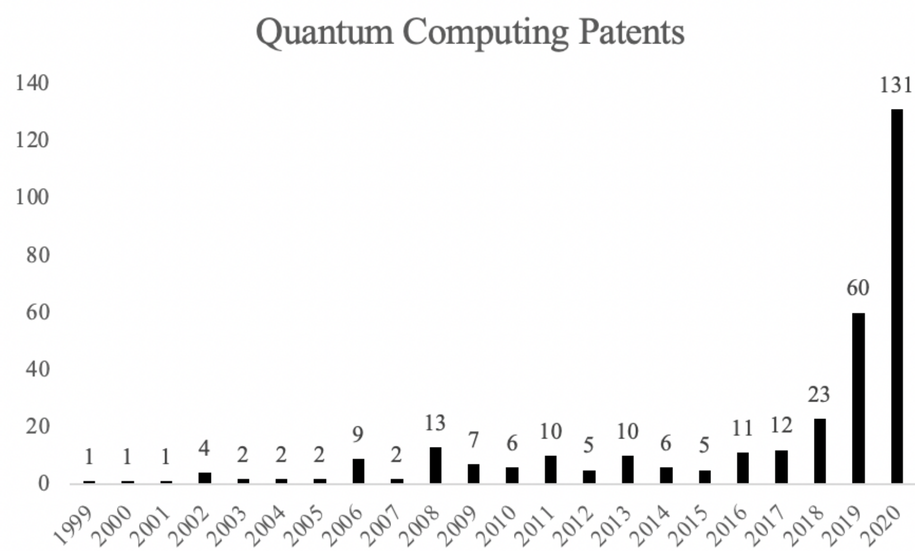

Figure 63

Figure 63 charts the number of quantum computing patents granted each year by the USPTO. By the end of the year 2020, there were a total 321 of quantum patents with active claims. The trend reflects the technologies increasing popularity in both research and industry.

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[328] R.P. Feynman, The Principle of Least Action in Quantum Mechanics, A Dissertation Presented to the Faculty of Princeton University in Candidacy for the Degree of Doctor of Philosophy at 1, 3 (May 1942).

Chapter 9 explores the technical art in quantum computing technologies. First this Chapter explores the various quantum architectures driving the edge computational hardware. Second, software structures and programs for applications including optimization and search are discussed. Third, quantum artificial intelligence is analyzed with a focus on machine learning.

Quantum Computers

A quantum computer is a physical system utilizing quantum effects during the computational process. Quantum computers differ from classical computers because of the way in which they process information. Classical computers process information with bits, which are a binary representation, but quantum computers process information with qubits, which represent information in a complex vector space.

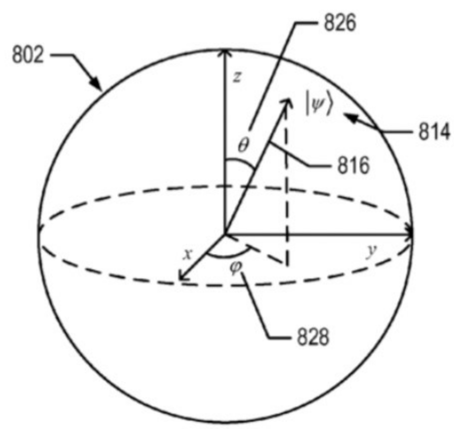

Figure 64[329]

To illustrate, Figure 64 is a patent drawing for a qubit, representing a single computational unit as a complex vector. The mathematical abstraction is intended to mirror the difference between classical and quantum states in physics.

In short, the qubit is an innovation advancing the goal to improve computing efficiency and power. Drawing on the laws of quantum mechanics, a qubit may represent a zero, one, or zero and one simultaneously in a state of superposition. As a result, the qubit allows for faster computing and less electrical power consumption compared to its classical counterpart. Generally, there are three types of quantum computers using qubits, adiabatic quantum computers (AQCs), gate-model quantum computers, (GMQCs) and photonic quantum computers (PQCs).

[329] United States Patent No. 9,836,698, to Bocharov, et al., Method and system for decomposing single-qubit quantum circuits into a discrete basis (December 5, 2017).

Adiabatic quantum computers (AQCs) are supercomputers harnessing natural quantum state evolution to perform computation.[330] Instead of using Silicon like traditional computer chips, the quantum chip uses a metal called Niobium. The Niobium is looped throughout the chip, connecting the qubits and acting as a superconducting metal where each loop models a quantum spin. The chip is cooled to the near zero Kelvin temperature and becomes a superconductor, a metal with properties including zero electrical resistance and magnetic flux fields. The superconducting properties allow the chip to manipulate quantum mechanical physics and eliminate noise during the computational process.

From a computational perspective, AQCs use the Adiabatic Theorem to perform computation. The Adiabatic Theorem comprises two parts, the Ising Model, and a traverse magnetic field.[331] The Ising Model is traditionally used in statistical mechanics, where variables are binary and the relationship between variables is represented by couplings, which connect qubits. The Ising Model uses a Hamiltonian energy measurement function to describe the total amount of energy in a quantum system. The input for the Hamiltonian function is a state of the system. The output is the energy measurement for the system. In other words, the Hamiltonian returns the energy measurement for the particular state in the system.

In addition to the Ising Model, the second essential element for AQCs is a traverse magnetic field, which can be manipulated to solve computational problems.[332] During the computational process, each qubit begins in a state of superposition encoded in a circular magnetic field. Then, a barrier is raised, and a magnetic field is applied to the qubits. As the magnetic field is applied, each qubit moves toward a classical state, ending as a zero or one. The qubits minimize their energy according to a bias which controls the magnetic field acting on the qubits. Additionally, the links between qubits and couplers, allow for the resulting states of multiple qubits to affect one another.

AQCs harnesses natural quantum state evolution to solve optimization and sampling problems. More specifically, AQCs measure quantum state evolution with a Hamiltonian function, manipulating a magnetic field to perform computation.[333] A major advantage of the AQC model is its scalability. As a result, AQCs are the first type of quantum computer capable of real-world application.

[330] U.S. Patent No. 7,135,701 to Amin, et al, Adiabatic quantum computation with superconducting qubits (November 14, 2006).
[331] U.S. Patent No. 7,418,283 to Amin, Adiabatic quantum computation with superconducting qubits (August 26, 2008).
[332] U.S. Patent 10,510,015 to Mohseni, et al. Constructing and programming quantum hardware for quantum annealing processes (December 17, 2019).
[333] U.S. Patent No. 7,788,192 to Amin, Method for adiabatic quantum computing comprising of Hamiltonian scaling (August 31, 2010).

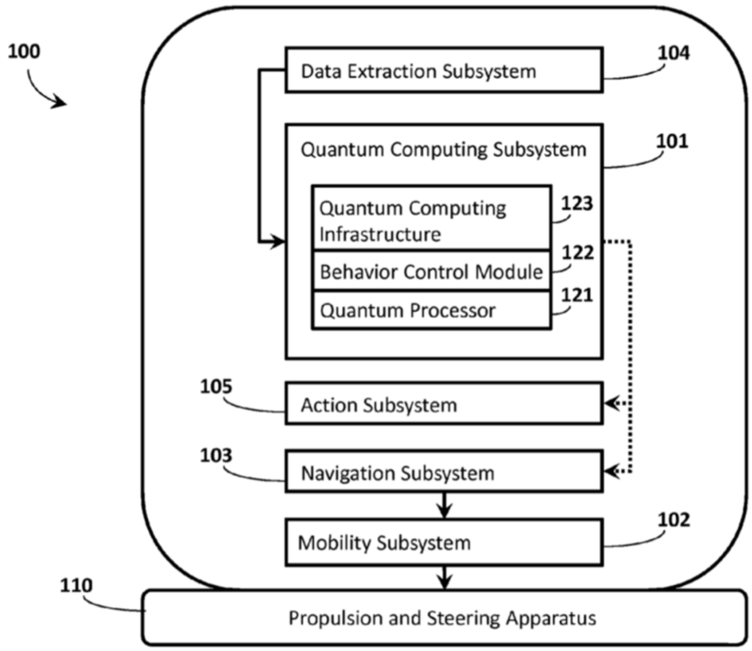

Figure 65[334]

For example, the Canadian quantum computing company D-Wave patented systems and methods for remote robotics control using an AQC. Figure 65 is a drawing form a D-Wave patent for a propulsion and steering control system using a quantum subsystem for navigation. However, a hotly disputed question regarding AQCs is whether they can scale to a universal quantum computer similar to the way in which other quantum computers may.[335]

The second type of quantum computer is the Gate Model Quantum Computer (GMQC).[336] In contrast to AQCs, which utilize a quantum state's natural evolution, GMQCs directly control quantum state evolution.[337] In this approach, quantum circuits are engineered from electrical and mechanical components to create a computational circuitry using qubits. Further, the qubits are acted upon by sequences of logical gates that are the compiled representation of an algorithm. The GMQC includes two key elements, the quantum circuit and gate transformation.

334 U.S. Patent No. 9,400,499 to Williams, et al. Systems and Methods for Real-Time Quantum Computer-Based Control of Mobile Systems, (July 26, 2016).
335 U.S. Patent No. 10,037,493 to Harris, et al., Universal adiabatic quantum computing with superconducting qubits (July 31, 2018).
336 U.S. Patent No. 10,347,605, to Sandberg, et al., System and method for routing signals in complex quantum systems (July 9, 2019).
337 United States Patent No. 10,417,574 to Babbush, et al., Embedding electronic structure in controllable quantum systems (September 17, 2019).

In essence, GMQCs uses a circuit, replacing classical gates with quantum equivalents.[338] However, a quantum circuit can process information in a manner significantly different from binary digital techniques based on transistors. In the circuit model, qubits remain coherent over time periods much longer than the single-gate time.[339]

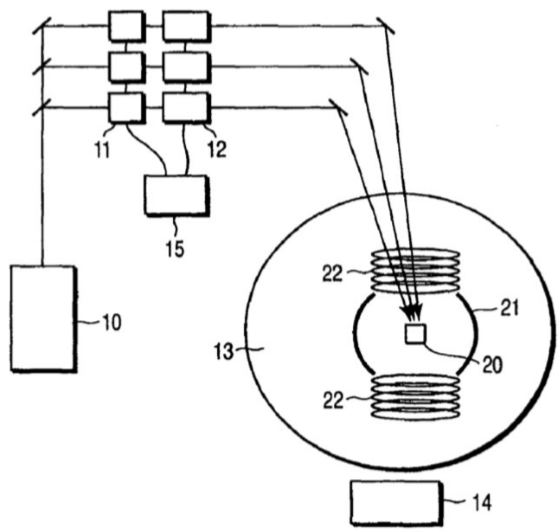

Figure 66[340]

Figure 66 is a schematic for coils applying a magnetic field to control quantum circuit evolution. A conventional approach to quantum circuit design can use a universal quantum computing circuit that can compute all types of algorithms. The universal quantum computing circuit typically can have qubits that can be connected to all of their neighbor qubits, and usually can run all or virtually all types of algorithms. For GMQCs, the main goal is to control and manipulate quantum state evolution over time with gate transformations.

A quantum gate is a computational state transformation acting on qubits. In quantum information processing, gates are mathematical abstractions useful for describing quantum algorithms. Indeed, quantum gates do not necessarily correspond to physical objects as they do in the classical case. Instead, they may represent the relationship between entangled electrons – as modeled by quantum mechanics. For example, the controlled-NOT (C_{not}) gate operates on two qubits, changing the second bit if the first bit is one, or leaving the bit unchanged otherwise.[341]

338 U.S. Patent No. 10,803,396, to Yoscovits, et al., Quantum circuit assemblies with Josephson junctions utilizing resistive switching materials (October 13, 2020).
339 U.S. Patent No. 9,892,365, to Rigetti, et al., Operating a multi-dimensional array of qubit devices (February 13, 2018).
340 U.S. Patent No. 7,826,115 to Goto, et al., Quantum computing method and quantum computer (November 2, 2010).
341 U.S. Patent No. 10,439,735, to Bishop, et al., Quantum communication link robust against photon loss (October 8, 2019).

Another important quantum gate representation is the Hadamard gate, which produces an equal superposition of states. Moreover, quantum gate arrays are quantum gates, which are bound together.

Some suggest the GMQC's main advantage is the potential to scale to a universal quantum computer. A Universal Quantum Computer is a quantum computer that can simulate any other quantum computer.[342] But, the GMQC has drawbacks as well. For example, GMQCs control explicit physical states as computational states, which makes the approach sensitive to decoherence and noise. Further, GMQCs are slower to scale than AQCs, meaning practically GMQCs have far less qubits. However, a new model for quantum computing is scaling faster than both GMQCs and AQCs.

Photonic Quantum Computers (PQCs) are the newest type of quantum computer. PQC hardware is developing on research demonstrating a qubit can be represented by polarized photonic spin.[343] A photon is a single light particle, which has no charge and zero rest mass. The relationship between electron spin and photonic polarization may be explained analogously.[344] For example, MIT researcher Mihika Prabhu, experimentally demonstrated success for quantum sampling on a PQC.[345]

In short, PQCs use a photonic circuit board for computation. Figure 67 illustrates current flow from a source through a semiconductor photodetector and superconducting component.

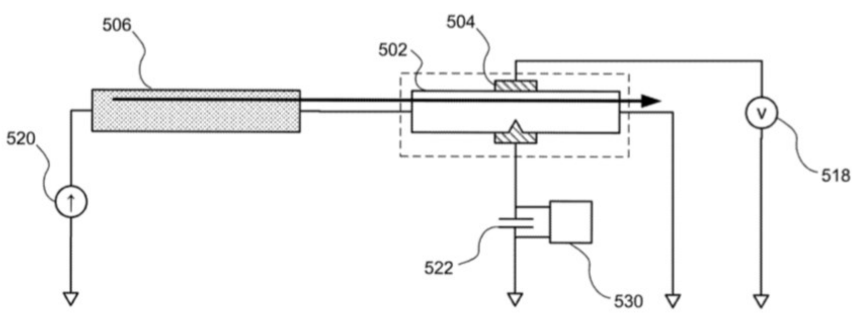

Figure 67[346]

PQCs are modeled on silicon chips and offer a more rapid ability to scale than AQCs and GMQCs. In fact, PsiQuantum, a quantum computing startup in Palo Alto, CA which

342 U.S. Patent No. 7,529,717 to Vala, et al., Universal quantum computing (May 5, 2009).
343 U.S. Patent No. 10,197,440 to Najafi, Niobium-germanium superconducting photon detector (February 5, 2019).
344 Chris Bernhardt, Quantum Computing for Everyone 46 (MIT Press 2019).
345 Mihika Prabhu, et al, A Recurrent Ising Machine in a Photonic Integrated Circuit (2019).
346 U.S. Patent No. 10,566,516 to Najafi, Photodetector with superconductor nanowire transistor based on interlayer heat transfer (February 18, 2020).

manufacturers PQCs, has raised more capital than any other private quantum computing company acquiring over $500 million by the year 2020.[347]

The quantum computer supports faster computing and less electrical power consumption compared to its classical counterpart. Generally, there are three types of quantum computers. First, AQCs harnesses natural quantum state evolution to solve optimization and sampling problems. Second, GMQCs manipulate quantum state evolution using quantum circuits. Third, PQCs use a photonic circuit board for computation. Each type has respective advantages and relative weakness. In addition to quantum hardware, quantum computing comprises great software innovations.

Quantum Software

Quantum software and algorithmic architectures are attractive for both academic researchers and industry professionals. In fact, quantum software systems provide speedups for computational processing when compared to classical computing techniques.[348] Moreover, quantum software provides a more powerful resource for conserving energy efficiency during the computational process. Indeed, industrial applications for quantum software technologies span sectors including transportation, information technology, and healthcare.[349] Two common quantum software systems are optimization applications and search algorithms.

Optimization refers to a computer program selecting the best element from a set of available alternatives.[350] Optimization problems arise in quantitative disciplines including computer science, engineering, and economics. For example, optimization software may be used for portfolio maximization or robotics control systems. In the simplest case, an optimization problem consists of maximizing or minimizing a function by systematically choosing input values from within an allowed set and computing the function's value.[351] The two most common quantum optimization algorithms are Quadratic Unconstrained Binary Optimization (QUBO) and Quantum Approximate Optimization Algorithm (QAOA).

Quadratic unconstrained binary optimization (QUBO) algorithms are a common quantum optimization algorithm.[352] QUBOs are used for solving a variety of optimization problems and lie at the heart of many experiments performed with AQCs. For example, QUBO models are being explored in initiatives by organizations such as IBM, Google, Amazon, Microsoft, D-

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[347] Vikas Hassija, et al., Present landscape of quantum computing, IET Quantum Communication (2020).
[348] U.S. Patent No. 9,875,215 to Macready, et al. Systems and methods that formulate problems for solving by a quantum processor using hardware graph decomposition (January 23, 2018).
[349] U.S. Patent No. 10,068,183 to van Rooyen, Bioinformatics systems, apparatuses, and methods executed on a quantum processing platform (September 4, 2018).
[350] United States Patent No. 10,095,981 to Garrison, et al., Multi-state quantum optimization engine (October 9, 2018).
[351] U.S Patent No. 10,176,433 to Hastings, et al., Training a quantum optimizer (2019).
[352] U.S Patent No. 10,275,422 to Isreal, et al., Systems and methods for finding quantum binary optimization problems (April 30, 2019).

Wave and Lockheed Martin, Los Alamos National Laboratory, Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, and NASA's Ames Research Center. In short, the QUBO algorithm minimizes binary Boolean variables to solve optimization problems.

To illustrate, scientists solve problems using AQCs by first expressing the problem as a QUBO. Then, the scientists embed the logical problem in the AQC's physical architecture by mapping logical variables and qubits. The mapping for QUBO problems utilizes the Boolean state variables, TRUE and FALSE, which are represented in a triangular matrix. In the triangular matrix, the diagonal terms are the linear coefficients, and the non-zero off-diagonal terms are the quadratic coefficients. Finally, the problem is sent to the AQC, which performs an annealing process and returns the computational results.

A second popular quantum optimization algorithm is the Quantum Approximate Optimization Algorithm (QAOA). QAOA models are being explored in initiatives at IBM, Google, D-Wave, Lockheed Martin, and NASA's Ames Research Center. In short, the QAOA produces approximate solutions for optimization problems. Some suggest QAOA provides a possibility for speedup compared to classical optimization algorithms.

First, scientists define an optimization problem's parameters and a cost function.[353] Then, the QAOA maps a cost function to a Hamiltonian function. In turn, this transforms the classical optimization problem to a quantum optimization problem because Hamiltonian energy measurement is a quantum problem, which can be processed with a quantum computer. Next, each state begins in a quantum superposition. Next, QAOA iteratively applies unitary operations to the state. The function's value gradually moves toward optimality and eventually converges with a global minimum. The global minimum corresponds to the problem's optimal solution. In addition to optimization problems, quantum search is also a promising area for quantum computing applications.

Search is the algorithmic process for finding something. The computational search problem is popular in many industries including finance, advertising, and telecommunications.[354] In fact, several software engineering tasks can be formalized as search problems. Perhaps the most notorious search algorithm is the Google page rank algorithm, which utilizes Markovian techniques to search the web and return optimal results to the user. Indeed, the Google page rank algorithm made Larry Page and Sergey Brin a fortune, promising high hopes and economic

[353] Zhihui Wang, et. al., The Quantum Approximation Optimization Algorithm for MaxCut: A Fermionic View, Quantum Artificial Intelligence Laboratory, NASA Ames Research Center, California 94035 (June 12, 2017).
[354] U.S. Patent No. 10,580,039, to Collins et al., Entity-based searching with content selection (March 3, 2020). *See also* U.S. Patent No. 10,565,262 to Lobo, et al., Methods for refining search results in an application (February 18, 2020).

incentives for superior quantum search algorithms.[355] As such, recently, there have been several attempts to develop quantum search algorithms, which offer a quantum speedup.[356]

Perhaps the most prominent quantum search system is Grover's Algorithm, a quantum search algorithm which is superior to all classical search algorithms. Some scholars and computer scientists focus research in quantum search on structured data forms. Thus, it is important to note that Grover's Algorithm only offers a speedup on unstructured search problems. Indeed, Grover's Algorithm uses amplitude amplification to search an unstructured set of elements. According to Grover, "The result in this paper is a subtle consequence of the fact that quantum mechanical amplitudes can be negative, whereas the associated classical quantities are probabilities which are required to be positive."[357] While Grover Search is limited to unstructured data, the underlying algorithm is used in many quantum search variants and descendants. In sum, Grover argues his algorithm is a demonstration of yet another way in which quantum computers can outperform their classical counterparts.

At this point, the scale at which quantum search algorithms provide speedups is promising. Some early attempts to implement Grover's Algorithm on D-Wave's AQC have been successful. Moreover, D-Wave's system is capable of effectively solving sampling problems. And, University of Texas Professor, Scott Aaronson, has mathematically proven search sample equivalence. According to Aaronson, "[I]f classical computers can efficiently solve any search problem that quantum computers can solve, then they can also approximately sample the output distribution of any quantum circuit."[358] According to Aaronson's proof, D-Wave's AQC can run any search algorithm by reframing the search problem as a sampling problem. Additionally, this is consistent with multiple D-Wave patents, which include claims for quantum search applications utilizing optimization algorithms.[359]

Perhaps one solution is an invention by Thomas Routt for a new quantum search software mechanism. More fundamentally, the synthesized mechanics behind Routt's invention is well illustrated in the art.

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[355] Sergey Brin and Lawrence Page, The Anatomy of a Large-Scale Hypertextual Web Search Engine (1998). *See also* U.S. Patent No. 8,667,037, to Jain, Identification and ranking of news stories of interest (March 4, 2014). *See also* U.S. Patent No. 8,145,623 to Mehta et al., Query ranking based on query clustering and categorization (March 27, 2012).
[356] U.S. Patent No. 9,697,252, to Hall, Methods, apparatus, and computer program products for quantum searching for multiple search targets (July 4, 2017)
[357] Lov K. Grover, Quantum Computers can Search Arbitrarily Large Databases by a Single Query, Vol. 79 Physical Review Letters No. 23, 4711 (1997).
[358] Scott Aaronson, The Equivalence of Sampling and Searching, 1 (September 26, 2010).
[359] U.S. Patent No. 10,346,508 to Amin, et al., Re-equilibrated quantum sampling (July 9, 2019).

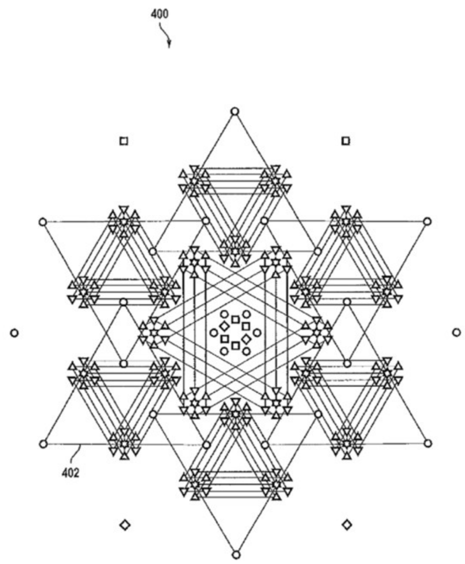

Figure 68[360]

For example, Figure 68 is a schematic view from a patent for quantum search technology using an E_8 root system, a mathematical field focusing on group theory. The E_8 root system uses a quantum memory fabric consisting of vectorized roots to map search problems in quantum space. The invention in U.S. Patent 553' offers an approach to search that can fully integrate with a quantum gate model computer to provide a speedup in performance.

As such, the future is auspicious for quantum search and quantum software more generally. In sum, quantum software is a strong tool for maximizing energy efficiency during the computational process for optimization and search problems. Early applications for quantum software range from portfolio optimization to robotics control for mobile systems.[361] Moving forward, the technical edge in quantum software is quantum artificial intelligence.

Quantum Artificial Intelligence

Quantum Artificial Intelligence (QAI) is software code converging artificial intelligence and quantum information technologies. The convergence manifests in many myriads. For example, machine learning software may be implemented on quantum hardware technology.[362] One application for QAI is image recognition using neural networks, or other machine learning architectures.[363] Alternatively, quantum search algorithms may be executed on classical

[360] U.S. Patent No. 8,190,553 to Routt, Methods and systems for quantum search, computation and memory (2012).
[361] U.S. Patent No. 9,400,499 Williams, et al., Systems and methods for real-time quantum computer-based control of mobile systems (July 26, 2016).
[362] U.S. Patent No. 10,268,232 to Harris, et al., Apparatus and methods for optical neural network (April 23, 2019).
[363] U.S. Patent No. 8,073,808, Systems, methods, and apparatus for automatic image recognition (December 6, 2011).

hardware.[364] Thus, as an industrial discipline and research focus QAI composes both quantum hardware and quantum software, as well as other methods for full stack software development.[365] At the edge in QAI technology, quantum machine learning allows computational matter to learn at the deepest levels in the physical universe.

Quantum Machine Learning (QML) refers to a specific type of QAI software application, which most often uses quantum hardware architectures with both classical and quantum algorithms for machine learning. QML is a process by which quantum computational matter statistically rearranges itself according to logical rules. More generally, the purpose for QML technology is to create machines that perform certain functions better than humans and classical machine learning software. According to quantum machine learning scholar, Maria Schuld, “The new research field of quantum machine learning might offer the potential to revolutionize future ways of intelligent data processing.”[366]

One common software structure for QAI technology is the quantum neural network (QNN), which performs structured and unstructured learning.[367] A QNN is an organized structure of interconnected neurons, capable of association as a graph with nodes and edges.

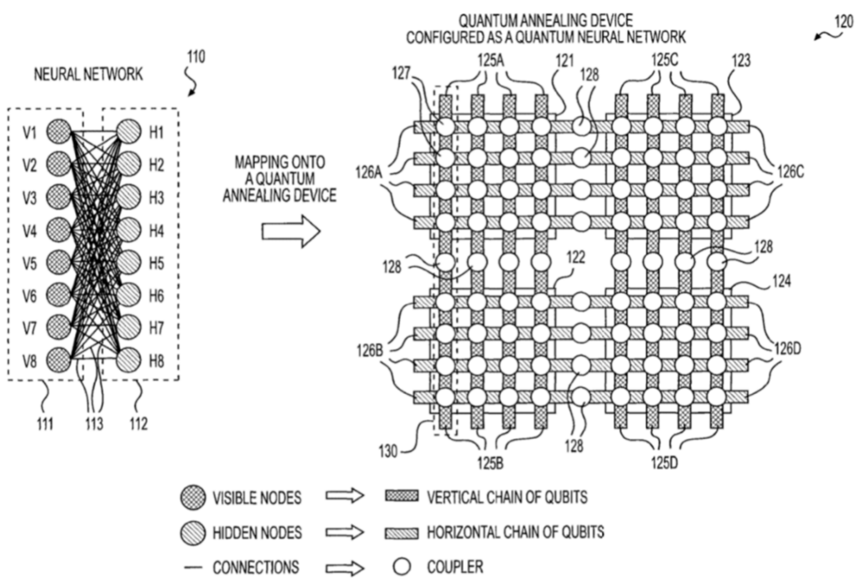

Figure 69[368]

364 U.S. Patent No. 10,339,466 to Ding, et al., Probabilistic inference in machine learning using a quantum oracle (July 2, 2019).
365 U.S. Patent No. 10,402,743, to Rigetti, et al., Operating a quantum processor in a heterogeneous computing architecture (September 3, 2019).
366 Maria Schuld, et al., An introduction to quantum machine learning, 2 (2014).
367 U.S. Patent No. 10,229,355 to Ronagh, et al., Quantum processor and its use for implementing a neural network (March 12, 2019).
368 U.S. Patent No. 10,417,553 to Adachi, et al., Quantum-assisted training of neural networks (September 17, 2019).

Figure 69 illustrates a process for mapping neural networks to a quantum computer. Additionally, Figure 69 is from a patent owned by Lockheed Martin, the American defense contractor. The network's interconnected neurons are modeled with weight coefficients, which are adjusted through a learning process until a model is optimized for performance. Importantly, QNNs are universal function approximators, meaning they can approximate any function with desired accuracy given enough neurons and qubits.

A second quantum machine learning software architecture is the quantum Boltzmann machine (QBM). Architecturally similar to the QNN, a QBM is a network of symmetrically coupled stochastic binary units. In other words, a QBM is a model representing a probability distribution over a set of binary variables. QBMs use two types of binary variables – visible variables, *v*, and hidden variables, *h*.

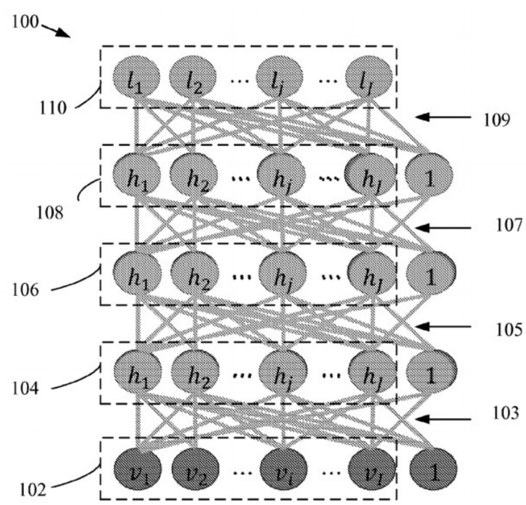

Figure 70[369]

Figure 70 illustrates a deep Boltzmann machine, with an input layer, three hidden layers, and a visible layer. The visible variables correspond to the important variables of a system – for example, the inputs and outputs. The hidden variables enable the encoding more complex relationships among the visible variables.

There are several QBM variations, for example Restricted Boltzmann Machines (RBMs) and Semi-Restricted Boltzmann Machines (SRBMs).[370] An RBM is a neural network, where the hidden units are conditionally independent given the visible states.[371] Further, the RBM has no

[369] U.S. Patent Application Publication US 2017/0364796, to Wiebe, et al., Quantum Deep Learning (December 21, 2017).
[370] U.S. Patent Application 10,368,846 to Venkataramani, et al., Classifying hormone receptor status of malignant tumorous tissue from breast thermographic images (August 6, 2019).
[371] U.S. Patent Application 10,817,778 to Baughman et al., Customized cooking utilizing deep learning neuromorphic computing of hyperspectral input (October 27, 2020).

lateral edges with its visible or hidden variables and is modeled as a bigraph graph. A bigraph is a set of graph vertices with two distinct sets. In the RBM, the hidden nodes are not connected to one another and the visible nodes are also not connected to one another. By contrast, in the SRBM, the hidden nodes are connected to one another, but the visible nodes are not. In other words, SRBMs have connections between the hidden variables, but not the visible variables.

However, both RBMs and SRBMs are shallow networks, with only two layers. Therefore, the most powerful QBM model variant is the Deep Boltzmann Machine (DMB). The DBM is a QBM integrated with a QNN in which each layer captures an abstraction of information.[372] In the DBM, additional hidden nodes are added to create a multi-layered network, deriving deeper abstractions for statistical inference and meaning. As such, deep learning algorithms can be run on quantum hardware by reframing neural network architectures through a Boltzmann computational formalism. In addition to quantum deep learning architectures, quantum reinforcement learning architectures are driving the technical edge.

A third common quantum machine learning software architecture is the quantum observable Markov decision process (QOMDP), which is used for quantum reinforcement learning.[373] Again, classical reinforcement learning algorithms contain three elements: (1) model: the description of the agent-environment relationship; (2) reward: the agent's goal; and (3) policy: the way in which the agent takes actions.[374]

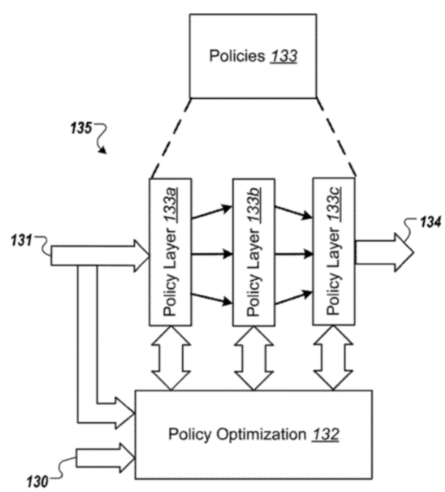

Figure 71[375]

[372] U.S. Patent Application 10,602,940 to Muchhala et al., Systems, devices, software, and methods for diagnosis of cardiac ischemia and coronary artery disease (March 31, 2020).
[373] U.S. Patent No. 10,666,462 to Shin, et al., Quantum system performing quantum channel estimation and method of modeling quantum channel (May 26, 2020).
[374] U.S. Patent No. 10,423,129 to Huynh, et al. Controlling dynamical systems with bounded probability failure (September 24, 2019).
[375] U.S. Patent No. 10,396,919 to O'Shea, et al., Processing of communications signals using machine learning (August 27, 2019).

Figure 71 is a schematic for policy iteration network for a quantum reinforcement learning algorithm. In the quantum context, the environment is a QOMDP, allowing more particular precision in state estimation. In other words, the state-space is described with a Hamiltonian, rather than a classical state measurement.

Similar to classical reinforcement learning, in a QOMDP, the interaction begins when an agent chooses an action in the environment's initial quantum state. The model continues to the next quantum state, where the agent receives a reward and a set of actions from which to choose, the agent selects an action, the environment returns a reward and the next quantum state. Ultimately, a quantum agent learns to take goal-oriented actions in the quantum state space. Like classical reinforcement learning, the goal for the agent in a QOMDP is to maximize its expected reward during the episode. In other words, the agent's goal is to maximize its total reward, rather than the reward for its immediate state.

In short, QAI is the technical edge information technology. However, the edge may not realize industrial value for decades to come. Yet some quantum algorithms and architectures certainly demand attention, particularly for application in cybersecurity. In sum, three common QAI software structures are QNNs, QBMs, and QOMDPs. QNNs and QBMs are most commonly used for quantum deep learning applications, where QOMDPs are used for quantum reinforcement learning. But more QAI architectures are developing on a daily basis for new applications, driving the edge forward through the twenty-first century.

Conclusion

Chapter 9 processed the technical art in quantum computing technologies. First, this Chapter explored the various quantum architectures driving the edge computational hardware. Three particular architectures evolving in the art were dissected, AQCs, GMQCs, and PQCs. Second, software structures and programs for applications including optimization and search were discussed. Third, quantum artificial intelligence was analyzed with a focus on machine learning. Particularly, quantum deep learning and reinforcement learning architectures were examined, including QBMs and QOMDPs, among others. Importantly, both quantum hardware and software innovations are driving the edge in computational processing

Moving forward, quantum computing offers to provide applications across industry. Specifically, quantum computers are being applied most in cybersecurity and finance. Cybersecurity is the most immediate application for quantum computing because most internet transactions are based on elliptic curve cryptography. However, in 1994 MIT Professor Peter Shor developed an algorithm solving the DLP in polynomial time. In his seminal paper, *Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer*, Shor describes a solution to the DLP on a QGMC.[376] Shor proposes, given prime number p and a generator g; the discrete logarithm of a number x is the integer r with $0 \leq r < p - 1$ such that

[376] Peter W. Shor, *Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer* 20 (1995) https://arxiv.org/abs/quant-ph/9508027.

$g^r \equiv x(mod\ p)$. Shor explains a method for solving DLPs on a quantum computer with two modular exponentiations and two Quantum Fourier Transforms, which are linear operations on qubits.

According to Shor, all that's needed to solve the DLP on a quantum computer is the order of the generator, so that it can be multiplied and inverted in polynomial time. The crucial ingredient for Shor's Algorithm is the Quantum Fourier Transform.[377] The Quantum Fourier Transform is a unitary transformation mapping one vector of complex numbers to another vector of complex numbers.[378] The result is a linear transformation that maps a quantum state encoding a periodic sequence, to a quantum state encoding the period of that sequence. In fact, given Shor's Quantum Fourier Transform in addition to the equations for modular exponentiation, some suggest hackers may be able to compromise the integrity of nearly all online financial transactions. As a result, quantum computing applications for cybersecurity directly bleed into application for financial technologies.

In finance, quantum computing not only demands attention for securing transactions, but also provides the possibility for changing the way in which blockchains operate. For example, due to the pseudo-random nature of solving mining blocks, Grover's Algorithm provides a method to speed up the mining process. Classically, the success probability for mining a block with pseudo-random guesses is given by $Trt/2^{256}$, where *r* is the hash rate – guesses per second, and *t* is the time in seconds. But, for a quantum miner running Grover's Algorithm the success probability is better than classical search algorithms. In fact, Grover Search provides a quadratic speedup compared to classical search algorithms. Still, some argue while quantum computing may offer a speedup for hashing, current quantum computational architectures are incapable of running such an algorithm.[379] However, others contend, in a post-quantum world, miners could gain an unfair advantage by mining blocks using Grover's Algorithm.

Perhaps the future is full of paradox for quantum computing technologies. In *Paradox*, Margaret Cuonzo asks "Should we consider quantum mechanics a progressive or degenerating research program?"[380] Considering Cuonzo's question is critical. If the answer is degenerating, then massive public waste will continue being spent on quantum research and development. If the answer is progressive, it may very well lead to a great human achievement. As we proceed, we should also consider the proposition that quantum mechanics will be our civilization's greatest accomplishment. In the end, time will tell.

[377] ELEANOR RIEFFEL, WOLFGANG POLAK, QUANTUM COMPUTING 175 (2014).
[378] Scott Aaronson, Shor, I'll do it, Shtetl-Optimized, The Blog of Scott Aaronson (2007).
[379] Craig Wright, Bitcoin and Quantum Computing, SSRN 3152419 (June 29, 2017).
[380] Margaret Cuonzo, Paradox 206 (2014).

Chapter 10 Reverse Engineering

Introduction

Reverse engineering is a process by which inventions are deconstructed to fundamental principles and reimagined anew. Start from the principle that all inventions can be reverse engineered, spawning new patentable creations. Now consider counter examples to the proposition. For example, most people contend patentable molecular discoveries are not capable of reverse engineering. But the truth is, a thesaurus often does the trick, providing new words for innovation.

In competitive technology markets, the edge matters. As such, technology firms are highly protective of their intellectual property (IP). Additionally, they are also eager to gain insights into their competitor's IP. There are several strategies for evolving and responding to competing technologies for emulous enterprises including reverse engineering and design around. Design around refers to a process by which technology is replicated outside the bounds of a competing patent, but without making any substantive improvements.

Importantly, both reverse engineering and design around are legal. However, both practices require meticulous focus on detail with reference to hurdling and evading the prior art. As such, reverse engineering is both a technical and legal skill, requiring the marriage of minds of inventors and patent lawyers. Indeed, to most successfully reverse engineer a technology one must be skilled in both the art and the law. These skills create a flexible leverage which exploits the attenuating bonds between logical syntax and linguistic semantics.

The thesis throughout this Chapter is that while any technology can be reverse engineered, in most cases once a technology is reverse engineered, it is better to innovate than design around. First, Chapter 10 will provide redesign thinking principles for reverse engineering any technology. Then, the principles will be applied to reverse engineer semiconductor sensors. Next, the principles will be applied to reverse engineer driverless cars. In sum, purpose for Chapter 10 is illustrating methodologies for reverse engineering any technology.

Redesign Thinking

Design thinking is a user-oriented approach to innovation, focusing on coordinating collaboration between technologists and salesmen to create user friendly products.[381] In fact, conventional wisdom suggests progressive permutation often requires teams of people working together to create meaningful products. Recent developments in design thinking are focusing

[381] United States Patent No. 9,996,511 to Hansmann et al., Free form website structure design (June 12, 2018).

more specifically on empathizing with users, meaning encouraging engineers to take the users perspective while developing new technologies.[382]

An approach which appreciates the value in tactfully empathizing with users is targeted toward creating addictive products, which is usually a good thing for innovators. But some speculate is driving stagnation across technical markets, offering more of the same. Still too often, the term design thinking is used for buzz word effects, removing ownership and financial considerations from the equation. Recognizing this problem, redesign thinking does just the opposite.

Focusing on ownership and economics, redesign thinking is a framework for building anything because all technology can be reduced to functions, which are operations on information. The process by which fundamental functions are engineered in software and hardware technology is largely driven by economic incentives, motivating innovators to meet capital demand. But capital demand and user demand don't always coincide. When such conflicts arise, capital demand almost always wins. By forcing attention to the underlying problem technologies seek to solve, rather than the user experience, redesign thinking enables a process for inventing or recreating a function to solve any problem.

For example, Google users typically prefer search results which are returned without financial motive, which might distract them for more useful returns.[383] But Google customers, which are mostly businesses buying advertisement services, want ads targeted at Google users specifically for financial motivations.[384] Here, the capital demand trumps the user demand because Google is a business which needs to return revenue acquired from advertising sales, not users.[385] As such, instead of focusing on the user experience, like design thinking, redesign thinking focuses on the problem the technology sets out to solve. For example, to reverse engineer Google's search engine, start with the problem the technology solves, which is information on the internet is disorganized.[386]

Redesign thinking focuses on taking technology by making existing things better and solving existing problems from nothing. As such, the school of thought behind redesign thinking proposes any technology can be engineered anew or recreated from nihility, given sufficient temporal and financial resources. Perhaps more fundamentally, all technology can be reduced to binary – even quantum computers assume a binary world based on suspected ion polarization

[382] United States Patent No. 10,322,338 to Cozad et al., Adapting operation of a computing device based on intrinsic motivators (June 18, 2019).
[383] U.S. Patent No. 10,332,019 to Yang, et al., Ranking nearby destinations based on visit likelihoods and predicting future visits to places from location history (June 25, 2019).
[384] U.S. Patent No. 8,682,892, to Panda, et al., Ranking search results (March 25, 2014).
[385] U.S. Patent No. 10,580,039, to Collins et al., Entity-based searching with content selection (March 3, 2020).
[386] Sergey Brin, Lawrence Page, The anatomy of a large-scale hypertextual Web search engine, Computer Networks and ISDN Systems 30, 107 (1998).

and electromagnetism.[387] But the solution to hard technical problems, like reverse engineering Google's search engine, is not always so simple as a one or zero.

Consider the countless ways in which information on the internet could be organized using several search systems based of different methods like text tagging and content containers. Even more, countless algorithmic search strategies may be employed across various software languages and hardware processors, with each resulting in differing performance levels, user experiences, and financial returns. Unquestionably, the path to great inventions is most often paved with failure. So, it is best to build and implement a new solution that works, iteratively making it better according to three steps.

There are three steps to reverse engineer any technology. When reverse engineering a technology, the first step is to start by identifying the problem solved in the prior art. For example, Google's problem was organizing the world's information. Second, model the solution in the existing the existing art. One way to model solutions is to develop information flow models tracking the technologies digital evolution. Third, recreate the technology with technical documentation and computer code. Once the technology is reverse engineered to a working prototype, make it better.

There are at least two ways to improve the prior art, to innovate in solving a given problem. The first way is to simplify the existing art. For example, Google simplified the user interface for search engine technologies, so anyone could explore the web with the push of a button. The second method for innovation is convoluting existing solutions. Increasing complexity in the art often drives the edge in short term innovation. An example for a more complex improvement would be using a reinforcement learning algorithm to search and return results users find more valuable. Even more complexity may be added by using neural networks to predict user response, iteratively learning to improve accuracy and drive revenue.

So, the key to reverse engineering any technology is to start from fundamental principles and reason up. Some technology companies have started inventing ways to prevent reverse engineering. For example, Microsoft is developing methods for preventing software from being reverse engineered by layering levels of code between the user and machine.

[387] U.S. Patent No. 10,510,523 to Kim, et al., Surface ion trap having a trapping location whose position is controllable in three dimensions with high precision (December 17, 2019).

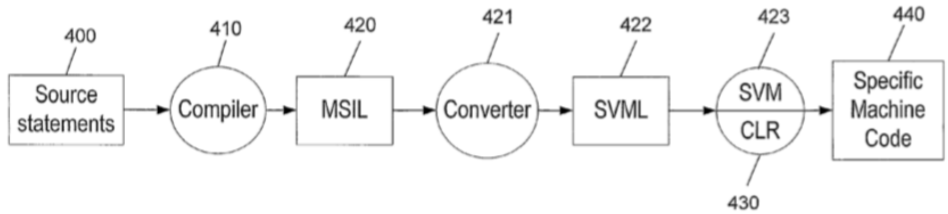

Figure 72[388]

Figure 72 is an illustration of a method invented by researchers at Microsoft for preventing reverse engineering. But reasoning from fundamental principles, inception occurs, even methods for reverse engineering can be reverse engineered.

Convoluted code can't cancel clarity. Distilling Microsoft's design to fundamental principles, the invention may be considered to have three steps. First, a software engineer writes logical statements. Next, those statements are compressed and converted to a machine-readable format. Microsoft's technology provides methods for encrypting the code during the second step according to various software structures. Third, a computer processes the machine code. While these methods may help prevent reverse engineering specific software by making it more difficult for the masses to simply copy code as written, the invention isn't full proof. Starting from scratch and reasoning up from machine code would allow any developer to redesign any Microsoft technology and make it better.

Similar to Microsoft, other software companies including Google and Facebook provide open source code on GitHub, but also take steps to prevent reverse engineering by limiting public disclosures to higher level software stacks. This allows the companies to retain the deeper architectures for lower level code, which are frequently updated. So, the foundational principle for redesign thinking is to solve problems from nothing, so the invention doesn't rely on corporate code for performance. With this approach, any technology can not only be surpassed, but improved to spawn future innovation. Two examples to which redesign thinking can be applied are semiconductors and driverless cars.

Semiconductors

To apply redesign thinking and test the theory that redesign thinking principles can be applied to reverse engineer any technology, we start by reverse engineering the hardest patents in the world. Two of the world's most valuable patents, Carnegie Mellon University's (CMU's) 180' patent

[388] U.S. Patent No. 8,352,929, to Asipov et al., Method for preventing software reverse engineering, unauthorized modification, and runtime data interception (January 8, 2013).

and 839' patent, protect CMU's semiconductor sequence signal technology.[389] A lawsuit on the technology resulted in one of the largest jury verdicts ever recorded, $1.5 billion in favor of the Plaintiff, CMU. The 180' patent and the 839' patent provide two of the most mathematically meticulous descriptions ever disclosed for an invention with a combined sixty-three mathematical equations. As a result, the technology is infamously thought impossible to reverse engineer.

Consider simplicity is truth. In a sentence, the invention disclosed in the CMU patents is signal sequence detectors for semiconductor circuits. The CMU signal sequence patents protected technology enabling processors to transfer information at a smaller scale. In other words, the problem the technology solved was that computers were too big. Despite the invention's novelty and utility, there are many ways for signals to proliferate throughout electronic devices. So, there are many ways to solve the problem. In fact, throughout the 20th Century scientists had been fostering solutions.

The late Physicist, Julius Lilienfeld, first patented microprocessor technology in the year 1930 and is largely considered the inventor of the field-effect transistor.[390] However, at the time, semiconductor materials were not integrated into circuits. A semiconductor is a solid substance that has a conductivity between an insulator and most other metals. Three decades later, the semiconductor circuit was invented in the year 1960 to provide a way to vary voltage across electrical circuitry.[391] Then, the microprocessor was patented in the year 1974 to enable the reduction of size and cost for computer production, using metal oxide semiconductors.[392] Semiconductors are still essential components of most electronic circuits because they enable digital information transfer at small scales.

The essential technology patented by CMU maps a data source flowing to a magnetic medium, producing data output. In other words, the protected invention solves the problem by providing a small-scale system for data transfer using a magnetic medium. Figure 73 is a magnetic recording system from the 839' patent.

[389] U.S. Patent No. 6,438,180 to Kavcic et al., Soft and hard sequence detection in ISI memory channels (August 20, 2002). *See also* U.S. Patent No. 6,201,839 to Kavcic et al., Method and apparatus for correlation-sensitive adaptive sequence detection (March 3, 2001).
[390] U.S. Patent No. 1,745,175 to J.E. Lilienfeld, Method and apparatus for controlling electric circuits (January 28, 1930).
[391] U.S. Patent No. 3,102,230 to Dawon Kahng, Electric field controlled semiconductor device (May 31, 1960).
[392] U.S. Patent No. 3,821,715 to Hoff, Jr., et al., Memory System for a Multi-Chip Digital Computer (June 28, 1974).

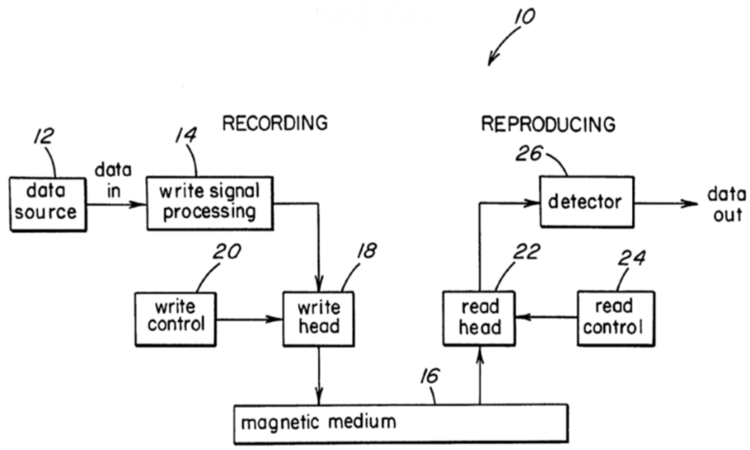

Figure 73[393]

The technology could be described in as little as three signaling steps, receiving, storing, and reproducing. As such, the technology receives a signal, then stores the received signal in memory, and finally reproduces the signal as an output. Unquestionably brilliant, the broader technology depicted has become a vital component for most modern computing systems. However, it is important to examine the invention in narrow detail to effectively reverse engineer the underlying technology.

Collectively, the 839' and 180' patents protect the invention, describing nearly identical technical architectures in their specification. Figure 74 is an illustration for a detector circuit from the 180' patent.

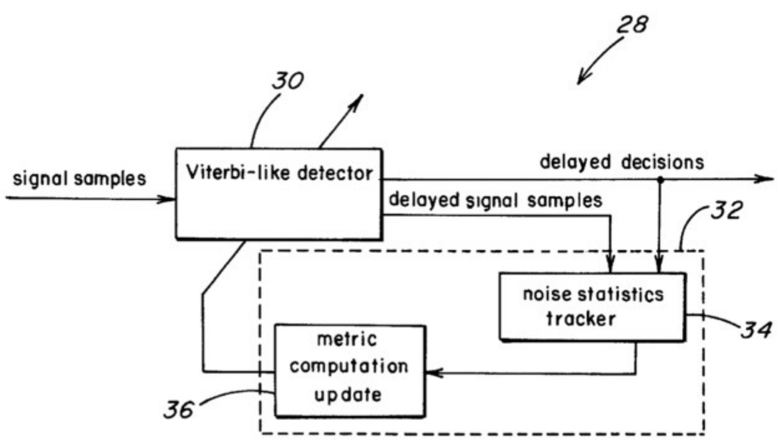

Figure 74[394]

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[393] U.S. Patent No. 6,201,839 to Kavcic et al., Method and apparatus for correlation-sensitive adaptive sequence detection (March 3, 2001).

[394] U.S. Patent No. 6,438,180 to Kavcic et al., Soft and hard sequence detection in ISI memory channels (August 20, 2002).

An interesting feature in both patents is the claim to a Viterbi-like detector. Viterbi mathematics is a common statistical sequence detection series for dynamic programming.[395] However, Viterbi mathematics came about in the year 1967, and Viterbi-like algorithms are outdated for use in industry. In large part, the reason Viterbi mathematics has been largely abandoned is because machine learning mathematics is better and more effective for large scale data processing. Given the art described in the 839' and 180' patent, there are at least two ways to invent forward.

The first way to invent forward is to innovate, meaning creating something better, something simpler. Figure 75 is a drawing for an invention advancing the art, by simplifying the system and integrating an intelligent noise cancellation device, making something better by improving performance and reducing error.

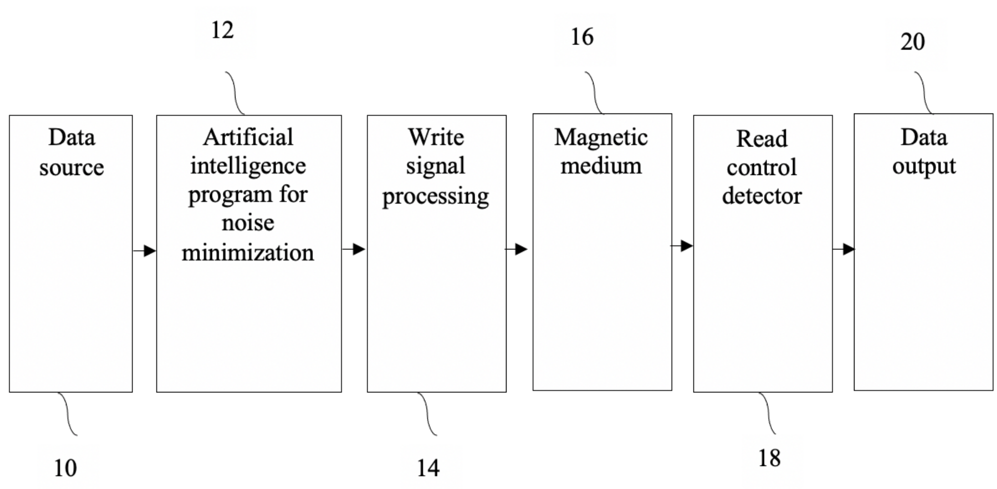

Figure 75

Another way, Figure 75 is an information flow model including a data source (10); an artificial intelligence program for cancelling noise (12); a write signal processing system, writing (14); to a magnetic medium (16); a read control detector, reading the data and controlling (18); data output (20). Moreover, the invention depicted is useful because artificial intelligence for noise cancellation, automates the reductive process with a learning algorithm instead of a standard statistical model, like the one described in the CMU patents as a Viterbi-like detector.

The second way to advance the art, inventing anew is design around. The design around approach simply identifies the component parts of the invention, focuses on meticulous criticism, and improves the invention with incremental performance increase. Additionally, design around calls for more convoluted descriptions and illustrations to protect and insulate the invention at a

[395] A. J. Viterbi, Error bounds for convolutional codes and an asymptotically optimum decoding algorithm, IEEE Trans. Inform. Theory, vol. IT–13, 260–269 (April 1967).

deeper technical level. For example, Figure 76, is a drawing for a neural network for noise cancellation in signal sequence detectors.

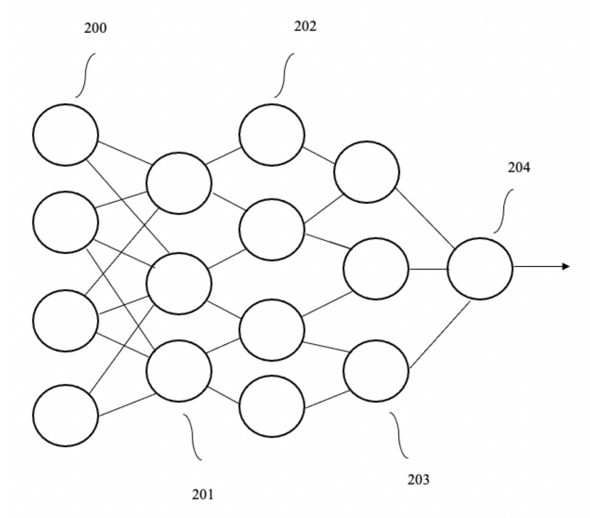

Figure 76

Another way, Figure 76 is an information flow model for a neural network including an input information layer, transferring information to (200); a hidden layer generalizing about the input data, transferring the data to (201); a second hidden layer, deriving abstractions from the second layer, and transferring to (202); a third layer where data is reduced, transferring to (203); a final output, cancelling noise, and transferring the data to a write processor (204). Compared to the innovation approach, the design around approach is more conscientious and detail oriented. By thinking narrow, innovation is easier because small differences can have a big impact.

In the year 2018, CMU filed a second lawsuit regarding the 839' and 810' patents against Avago Technologies, which is now Broadcom, an American semiconductor manufacturer. Carnegie Mellon is pursuing $750 million in damages in the United States District Court, in northern California for patent infringement. While the case is still pending, both CMU and Broadcom are represented by teams of attorneys arguing to ascertain the technologies meaning and value. As such, patents protecting similar semiconductor technologies are critically valuable – particularly as a shield for companies operating in flexible patent markets. In sum, both CMU semiconductor patents are capable of reverse engineering, further innovation, and design around using redesign thinking.

Driverless Cars

Over the past hundred years, the automobile has arguably changed Earth's landscape more than any other technology in the past two centuries. Consider in the middle of the 19^{th} Century during the California Gold Rush, the trip miners took to California from the East Coast could take as long as six months.[396] Less than 100 years later, early automobiles cut the trip time down to less than two days. Now, the quest to build driverless cars continues to reshape our world.

Today, there are 212 million drivers and 252 million vehicles in the United States. Collectively, these drivers and vehicles travel approximately 3.2 trillion miles each year. The emissions from automotive vehicles in the United States creates one fifth of the nation's total greenhouse gas emissions. And car accidents result in 2.4 million injuries each year in the United States. Even more, car crashes result in 1.3 million deaths globally each year.

In fact, driver error is the cause for the vast majority of automotive injuries and deaths, which take and destroy an unacceptable number of human lives each year. As such, a new transportation era is emerging, promising radical reshaping toward a safer, cleaner, and more efficient world. Founded in the year 2003, Tesla Motors is now the largest and most valuable auto manufacturer in the world. Regarding the company's robust patent portfolio, Tesla Motors CEO, Elon Musk stated, "we place a high priority on obtaining patents to provide the broadest and strongest possible protection to enable our freedom to operate our innovations and designs within our products and technologies in the electric vehicle market as well as to protect and defend our product portfolio."[397]

The secret to inventing on the cutting edge in autonomous vehicles is unity. Most professionals and academics analyze driverless car technology as consisting of two elements: perception and decision making. As such, there are two main problems for driverless cars. First, the car must be able to accurately sense the environment in which it operates. Second, the car must be able to process sensor data to accurately make decisions regarding control. Generally, reverse engineering a technology provides a way to reduce the existing technical art to fundamental principles. However, unity provides a way to recreate the technology anew by solving the safe driving problem from the ground up. As such, it makes more sense to innovate in driverless car technology than it does to design around existing solutions.

Perception refers to a car's ability to sense its environment and to be able to understand the meaning of the objects within that environment. The goal for perception technology is to most accurately and effectively observe and record data regarding the car's environment. Commonly used technologies that allow for autonomous car perception are LIDAR sensors and deep learning.

Light Detection and Ranging Device's ("LIDAR") are the most common sensor type for driverless cars, however other common sensor systems include RADAR and cameras. In fact, LIDAR sensors are often contained in the dome shaped structures on top of driverless cars.

[396] Karen Clay et al., Migrating to Riches? Evidence from the California Gold Rush, The Journal of Economic History, 6 (2008).
[397] Tesla, Inc., United States Securities and Exchange Commission, Form 10-K, 12 (February 8, 2021).

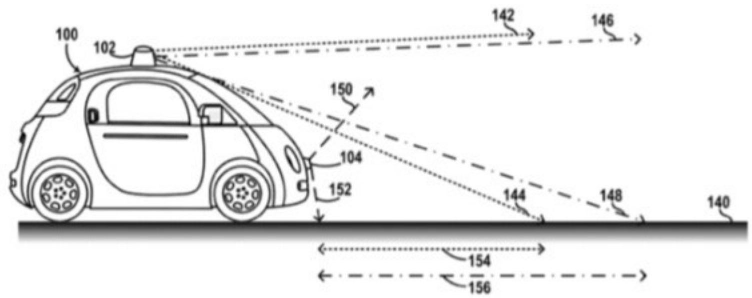

Figure 77[398]

Figure 77 represents a LIDAR sensor mounted on a vehicle, scanning the environment and receiving input. The data collected from the sensor is projected to a point-cloud, for intelligent processing.

LIDAR is a type of optical radar sensor with a transmitter and a receiver. The transmitter includes a laser and a beam expander to set the outgoing beam divergence. The receiver includes a telescope to collect backscattered signal, and appropriate optics to direct the return signal from the telescope to a detector, which records the signal. LIDAR sensors start by transmitting infrared light pulses. Then, the pulses travel to the nearest object and backscatter to the receiver. The time that it takes for the pulse to travel to the object and return to the receiver is multiplied by the speed of light and divided by two:

$$^{tc}/_{2} = d$$

where *t* is travel time, *c* is the speed of light, and *d* is the distance between the LIDAR sensor and the object. At its core, the input for a LIDAR system is backscattered laser light, while the output is a point cloud that models an environment.

In the context of driverless cars, LIDAR sensors record each data point collected in a point cloud.[399] A point cloud is a mapping of LIDAR data points that represents a model of a driving environment. Typically, multiple LIDAR sensors send information to a processor with several input sources to develop a robust and accurate point cloud, allowing cars to perceive their environment as accurately as possible.

For example, Tesla Motors invented technology allowing cars to perceive their environment with LiDAR and RADAR sensors. Figure 78 illustrates an invention for capturing sensor data for training a machine learning network.

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[398] U.S. Patent No. 9,880,263 to Droz, et al., Long range steerable LIDAR system (January 30, 2018).
[399] U.S. Patent No. RE48,042 to Pennecot et al., Devices and methods for a lidar platform with a shared transmit/receive path (June 9, 2020).

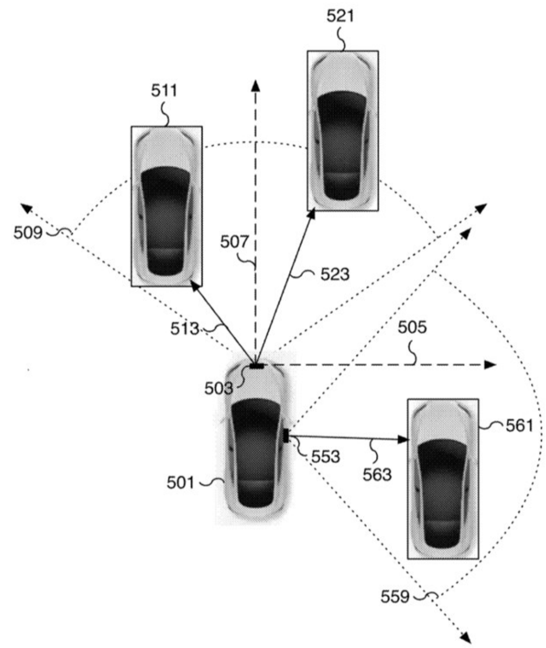

Figure 78[400]

The data is then further processed with various machine learning algorithms to map the car's environment. The environmental mapping, which updates in real-time, informs the car's control features and autonomous error minimization.

Decision making refers to a car's ability to calculate controls and appropriately interact with its environment. To this point, most manufactures ensure drivers have the ability to override any decision the car makes for safety reasons. In fact, Tesla Motors invented autonomous emergency signaling system to alert the driver when risks increase.[401] Tesla Motors' system receives data from sensors, including both RADAR and LiDAR sensors, for predictive processing with deep learning algorithms. As such, human attention is still important in driverless cars because lapse could be fatal, but some suggest better car control could come from reinforcement learning.

Reinforcement learning research for robotics control is ubiquitous among academic literature.[402] Moreover, the technology is now a prominent feature in industry, spurring innovation on the edge in driverless car technology. For example, one recent invention uses a reinforcement learning controller and computer vision model for autonomous driving.[403] Another invention

[400] U.S. Patent No. 10,956,755 to Musk, Estimating object properties using visual image data (March 23, 2021).
[401] U.S. Patent No. 10,831,206 to Cave, Autonomous driving system emergency signaling (November 10, 2020).
[402] Leslie Pack Kaelbling, et al., Reinforcement Learning: A Survey, J. of Artificial Intelligence Research (1996). *See also* Katerina Fragkiadaki et al., Grouping-Based Low-Rank Trajectory Completion and 3D Reconstruction (2014).
[403] European Patent 3564861A1, Vision-based sample-efficient reinforcement learning framework for autonomous driving (2019) (Assigned to Sony).

uses an actor-critic reinforcement learning method to control cars.[404] Thus, reinforcement learning is a decision making computer software that effectively minimizes dangerous collisions in obstacle avoidance tasks, which are often necessary to avoid car crashes.

By reframing the two fundamental driverless car problems as a single problem, innovation occurs. Instead of solving two problems for driverless cars, perception and decision making, inventors unifying the solution in singular systems will be most successful. So, the problem to attack is autonomy, in the most complete sense. Consider the formulation, how do you unify perception and decision making to optimize intelligent mobility?

Deep reinforcement learning systems have three capabilities that set them apart from all previous systems: (1) generalization; (2) learning; and (3) intelligence. As such, attention is rapidly turning to deep reinforcement learning as the hottest area in autonomous research. Figure X is an invention for a fully autonomous car, unifying the perception and decision making elements in a single system using deep reinforcement learning.

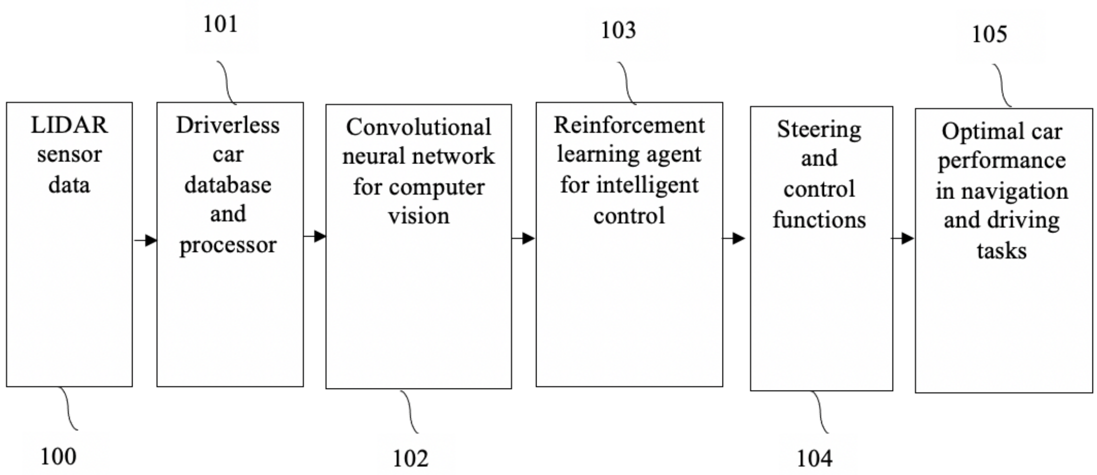

Figure 79

More technically, Figure 79 is an information flow model for an invention including a LIDAR sensor collecting data (**100**); transferring to a database and processor in a driverless car (**101**); processing the data with a convolutional neural network (**102**); visually processing the information for a reinforcement learning agent (**103**); taking actions to steer and control the car (**104**); to optimize performance in navigation and driving tasks (**105**). Convergent car code, integrating reinforcement learning and deep learning software, promises the possibility for remarkable breakthroughs in driverless vehicles. Both technically and economically, transportation systems throughout the world are moving toward full autonomy.

[404] U.S. Patent No. 10,061,316 to Nishi, Control policy learning and vehicle control method based on reinforcement learning without active exploration (August 28, 2018). (Assigned to Toyota)

Still, full scale autonomy is elusive because models using deep reinforcement learning have yet to be deployed at scale, so the technology presents enormous promise for the future. Indeed, deep reinforcement learning has been deployed in multiple successful control applications. However, concerns for safety, politics, and economics will likely continue to slow software advancements. Interestingly, Elon Musk was a founder of OpenAI, an AI company in California specializing in deep reinforcement learning control technologies for general applications.[405] However, Musk resigned from the OpenAI Board to avoid conflicts of interest with Tesla Motors.[406] As such, some speculate whether OpenAI's technology is also Tesla Motor's secret ingredient, the concealed keystone causing their rise from nothing to number one in a heavily regulated industry.

Of course, secrets are more fun than patents. Unfortunately, Tesla Motor's technology is no secret. In fact, the company is rightly named after Nikola Tesla, the second millennium's greatest inventor, because Nikola Tesla's inventions at the turn of 19th century are the foundation for Tesla Motor's electric vehicle technology, which is regarded as the best in the industry today. In fact, Tesla Motors encourages an open patent strategy. In a Tesla Motors blog post authored in the year 2014, Elon Musk wrote, "Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology."[407]

In sum, redesign thinking may also be applied to driverless cars to invent new methods and systems for autonomous mobility. First, start with the problem or problems in the prior art. For example, autonomy is a problem referring to engineering fully safe driverless cars. Next, start from scratch to reimagine a solution anew. Finally, create cars better than ever before. In distilling the creation to writing, let the pen be mightier than the sword, *calamus gladio fortior*.

Conclusion

In sum, any conceivable technology can be engineered given sufficient resources. First, Chapter 10 provided principles to reverse engineer any technology. The central idea in redesign thinking is to solve problems by reasoning from fundamental principles. This contrasts the conventional wisdom that the best technologies are born from teams working toward perfecting user experience. While people are necessary to bring ideas to life, the top inventions are often scaled from a single problem.

Second, redesign thinking was applied to reverse engineer semiconductor sensors and advance the art with neural networks for noise reduction. The Chapter tackled the toughest reverse engineering challenge to date, recreating and improving the CMU semiconductor signal sequence patents. The patented billion-dollar technology was distilled to fundamental principles,

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[405] Karen Hao, The messy secretive reality behind OpenAI's bid to save the world, The MIT Technology Review (February 17, 2020).
[406] OpenAI, OpenAI Supporters, OpenAI Blog (February 20, 2018).
[407] Elon Musk, All Our Patent Are Belong To You, Tesla Blog (June 12, 2014).

reimagined anew, and infused with AI technologies. All the while, the full potential for transistor technologies still rests nascently, waiting to rise more than nine decades after its invention.

Third, redesign thinking was applied to reverse engineer driverless cars and map the technical convergence toward unity fueling the cutting edge. Then, Chapter 10 provided a drawing for a novel invention unifying the perception and decision making elements in driverless cars. And still, the room for automotive innovation grows even greater with time. In other words, Tesla Motors's has been awarded more than 750 global patents, but all their patents have holes so big you could drive a truck through them! Either way, the best technology is always free.

Tremendous technologies take time. A common theme for great technologies in both discussed domains is delayed value capture. In other words, innovative computing technologies often take decades to realize and capture their full value in the economy. To get the ball rolling, start with the problem, then reason from fundamental principles to reimagine the solution anew. Frankly, in most situations reverse engineering is a waste of time because basic engineering is almost always a faster and more efficient way to solve problems, given equal resources to start. In other words, inventing is a much better strategy than trying to copy or modify existing solutions because it appreciates the uniqueness in every new technical challenge.

Chapter 11 Conclusion

Monopoly

Consider again the year 1851, when the Economist wrote, "Patents are like lotteries, in which there are a few prizes and a great many blanks." [408] More than fourteen decades later, Elon Musk stated, "I realized that receiving a patent really just meant that you bought a lottery ticket to a lawsuit, I avoided them whenever possible."[409] Although the dogma lasted more than two centuries in the social mind, erase the lottery ticket analogy because it is based on a false assumption of randomness.

Patents are not lotteries any more than any other game. For example, Musk spent a small fortune litigating over Blue Origin's patent for reusable rockets – the lead inventor of which was the company's founder Jeff Bezos. The patent wasn't randomly valuable. It was the result of over a decade of focus, vision, and hard work by its inventors. By comparison, litigation and value are less likely to be found in other patents or inventions, such as a urinal headrest[410] or pet ear protectors.[411] The value of a patent most often reflects the value of the underlying invention and inventing is a game of skill, not chance.

High technology patents are much more like diamonds than lotteries because high technologies are not invented by random chance, but instead result from thought, focus, and pressure which is applied to manifest a creation to being. Building blockchains, AI software, quantum hardware, rockets, and biotechnologies requires sustained and significant determination, resilience, and work. Moreover, drafting patents and obtaining legal rights for inventions in these fields is an arduous process with expensive regulatory fees and procedural requirements, often taking years to complete. So, while buying lottery tickets gives a random chance at a fortune, patents provide a way to write winning tickets.

Competition pervades the high technology industry, making patents all the more important for both offensive and defensive market strategies. Ultimately, patents are legal monopolies, providing a mechanism by which value may be captured for long term profit. Still most people think monopolies are illegal – but the truth is patents are a legal loophole, backed by the Constitution,[412] providing a legal path toward market exclusivity. Still patents are only as good as the inventions they protect.

Focus

[408] The Economist: Volume 9, Part 2, 811 (January 1, 1851).
[409] Elon Musk, All Our Patent Are Belong to You, Tesla Blog (June 12, 2014).
[410] U.S. Patent No. 6,681,419, Forehead support apparatus (January 27, 2004).
[411] U.S. Patent No. 4,233,942, Animal ear protectors (November 11, 2980).
[412] U.S. Const. art. I § 8, cl. 8.

At the time of his death in 1988, Nobel Prize-winning physicist Richard Feynman's blackboard contained the words "[w]hat I cannot create, I do not understand."[413] Feynman recognized a great paradox of the human mind – to fully understand an invention, the invention must first be created. Leading the way forward, inventors need to have a vision for tomorrow and the courage to distill an idea to life. The process by which ideas come to life, inventing, is about focus. Focus is the ability to concentrate on a singular motivation – isolating the mind on a single precept. This Book focused on three central pillars – the patent process, the state of the art in high technology, and the meticulous minutia by which inventing is done.

The first pillar is the patent process – strategy, value, and drafting. Chapter 2 explored the key principles and differences for each type of legal protection, as well as instances and scenarios in which they are typically applied. Chapter 3 discussed patent valuation strategies, providing methodologies to predict patent price based on financial data. Chapter 4 detailed strategies for writing patent applications and trade secret documentation for high technologies; the basic drafting requirements include drawings, claims, a detailed description, and an abstract.

The second pillar is the state of the art in high technologies – AI, biotechnology, space, blockchain, and quantum computing. Chapter 5 explored AI technology, with a focus on machine learning and NLP. Specifically, Chapter 6 examined biotechnologies with respect to healthcare economics, IP incentives, and future technical convergence with nanotechnologies. Chapter 7 explored space technology patents with a focus on radiation resistant hardware processors, satellites, and rocket technologies. Next, Chapter 8 discussed blockchain technology and IP, detailing the future of finance in a freer world. Finally, Chapter 9 explained the technical art in quantum computing technologies – the hardware changing computing forever.

The third pillar is inventing – reverse engineering. Chapter 10 provided a guide on how to reverse engineer, advance, and patent any technology. Most importantly, it advanced the thesis that any new or even conceivable technology may be reverse engineered with consideration to two variables – time and money.

Inventing is a dynamic process; it never really ends. And just as this book can never be complete, no invention or patent can ever be permanent. The perpetual path to perfection is about reduction, minimalism, and technology. Defined, technology is any new and better way of doing things. If a technology is new and useful, then it's an invention.

Inventing is most importantly about freedom, the ability to solve problems and overcome challenges. Everyone has great ideas that can make the world a better place. But most of those ideas never become inventions because significant legal and regulatory barriers blockade the path to progress. Still, humanity's greatest inventions won't be brought to life for years to come. Similar to the way in which the genius resulting from Edison and Tesla's rivalry at the turn of the

[413] Michael Way, "What I Cannot Create, I Do Not Understand," J. of Cell Science (2017).

19th Century has yet to bear its full effect on the world, today's breakthroughs will have a lasting effect for centuries to come.

Future

The future is just beginning and the opportunity for innovation is wide open. There are always opportunities to identify and solve problems, to innovate. Most people think the future has yet to be determined, but in many ways the future will be written by those who invent today. There's always a degree of chance and risk in creating something new. But that's nothing compared to the risk of never living life to the fullest or failing to push the mind to new limits. Indeed, inventions spawning from the present era will alter the course of human history for ages to come.

One invention to come is the singularity. Often AI researchers discuss the singularity as the time at which AI evolves to an unpredictable trajectory. This is usually associated with completely reverse engineering the human mind in a computational form. Thought to be the last necessary invention, the singularity will produce a machine which far exceeds human intelligence in all forms – including the ability to invent new machines and processes.

The time at which the singularity will come into being is estimated to be as early as the year 2029.[414] But others disagree. For example, the late Microsoft Co-Founder, Paul Allen, argued scientific progress is irregular and that the singularity is at least a century away.[415] As AI technology progresses, the future will be defined by initiatives aimed toward innovating in intelligence – toward a singular system replicating and surpassing the thoughtful processes of the human mind. Still science strives forward, toward space – and beyond.

Another invention coming in the future is new spaceships for interstellar travel, an exciting machine for pushing the bounds of human experience. The problem with existing spaceships is that they are not able to generate enough power to travel fast enough to escape our solar system. Despite the fact that there is near zero friction in space, because space is so massive – the trip to Mars alone would still take years with current spaceships.

Still, Earth will eventually look like Venus. So, becoming a space faring species is not a matter of choice – it's a question of when not if because traveling to new planets and places among the stars will be necessary for human survival. To make the journey to greater depths possible, nuclear rocket engines will propel a path forward. In fact, nuclear propulsion in deep space offers an opportunity for creating next generation interstellar spaceships.

Biotechnologies continue converging toward synthetic humans, or robots physically indistinguishable from humans. Synthetic humans will have all the same parts, features, and functionality as human beings, including emotions like hate and love – but will be meticulously and mechanically constructed. Yielding a new wave in medical advancement, synthetic

[414] Ray Kurzweil, How to Create a Mind 261 (2012).
[415] Paul G. Allen, The Singularity Isn't Near, MIT Technology Review (2011).

replications of the human condition promise progress and wonderous possibilities. The process by which humans reverse engineer themselves, will certainly yield synthetic versions of virtually every human organ, function, and conscious thought.

Humanity's greatest breakthroughs are born of our greatest challenges. For example, the atomic bomb was built from fear and necessity for survival, stemming from one of history's most bloody and brutal wars. Similarly, the best future technologies will result from the most significant struggles and problems faced in the present. The foresight to predict the future does not come from prophecy, but rather from focus, commitment, and dedication to solving hard problems. All people want the end result, but only inventors are willing to bear the cost of creation.

Present

At the twilight of technological tradition, maybe more of the same should be expected. Stagnation is becoming a real concern, given the relatively inconsequential innovations since the internet. Still the current software landscape strives forward, with specific software high technologies like AI and blockchain changing the fundamental nature of computing and finance respectively. In terms of hardware biotechnology, rockets, and quantum computers are driving the edge in high technology. New systems still involve the convergence of both hardware and software to facilitate complete system integration and usability to scale.

AI broadly refers to any machine capable of learning, remembering, and taking actions. Across the economy in industries including law, healthcare, and defense, new AI technologies are creating a better world. Although the technology is relatively new, AI systems have permeated the social mind since the early nineteenth century. Uniquely positioned at the intersection of several scientific disciplines including computer science, applied mathematics, and neuroscience, AI technology has the potential to be the era's greatest achievement.

Biotechnologies are changing medicine. Healthcare is the field having the most impact on humanity – every person on Earth is directly affected by healthcare and serves to benefit from new biotechnologies. Throughout the patent system, the technical art is evolving in diagnostics, neurotechnology, pharmaceuticals, and genetic editing. Inventing new biotechnologies is an opportunity to tackle the toughest problems. Moving forward, every human disease should be considered curable given sufficient resources – time and money.

Driven by a deep desire for adventuring toward new destinations, humanity's future is among the stars. Human space exploration, commercialization, and weaponization are being driven by new technologies developing at accelerating rates. The technologies supporting space exploration and advancement, such as reusable rockets and satellites continue to manifest throughout the patent system. Above all else, space is exciting – offering hope for a better future and perpetual possibilities to learn and explore.

Satoshi Nakamoto's vision for Bitcoin – to create a decentralized financial system – came to life at scale. As a result, many believe blockchain technology is the greatest financial innovation in human history. Indeed, blockchain is an open and transparent mechanism by which money may be managed. It is a fairer form of finance, offering opportunity previously absent to anyone with access to the Internet. Over time, blockchain will have wonderous impacts on creating a more equitable world.

Quantum computers are changing the way in which industrial computation happens. Perhaps the most secluded or the least known high technology discussed in this Book, quantum computing may have the most powerful impact. Capturing a fundamental physical truth, quantum computers promote powerful processing by directly manipulating and harnessing the power of sub-atomic particles. And the technical art surrounding quantum computing technology is flourishing in patent offices around the globe – both in terms of hardware like AQCs and QMQCs, but also in software such as quantum machine learning.

To invent a better future, it is most important to look to history. In fact, the more innovative the technology – the more history the invention must erase. In other words, an invention building on prior art from the 18th century is more likely to be profoundly innovative than a technology building on prior art from the 21st century. Even more, to know the future, it is necessary to learn from the failures of the past.

Past

Finally, we should seriously consider whether the greatest technology to come, is an object of the past. For example, two centuries later, Konstantin Tsiolkovsky is largely credited with inventing the rocket because of the famous rocket equation he formulated in *Reactive Devices*. But Tsiolkovsky describes so much more than the rocket equation in the work. He wrote:

> "Mathematical conclusions, validated by science, indicate the possibility of using such devices to explore heaven, establishing settlements outside the Earth's atmosphere. It will be hundreds of years before my thoughts find use. But then, people will use my ideas to settle not only Earth's face, but also the face of the Universe."[416]

To date, the world is still waiting for Tsiolkovsky's vision to fully come to life. As such, the final frontier will be conquered with meticulous mechanical manipulation, and breakthrough engineering for inventions conceived long ago.

Daring to be different comes at a cost. Tsiolkovsky wrote, "The whole universe known to us is zero and all our knowledge, present and future, is nothing in comparison to what we will never

[416] Константин Эдуардович Цколковский, Исследование Мировых пространств реактивными приборами (1903).

know."[417] A trillion stars in the night sky can't expose heaven's secrets. Against a backdrop of infinity, we realize our most vulnerable weaknesses. In doing so, we gain the knowledge necessary to conquer the Universe. The purpose for this Book is to create a roadmap for solving any problem, to paint a picture of both patents and inventing as a problem-solving process. Moving forward, time is our only obstacle.

[417] Константин Эдуардович Цколковский, Исследование Мировых пространств реактивными приборами (1903).