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Moving Forward with Digital Disruption: What Big Data, IoT, Synthetic Biology, AI, Blockchain, and Platform Businesses Mean to Libraries

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ALA American Library Association

MOVING FORWARD WITH DIGITAL DISRUPTION

WHAT BIG DATA, IOT, SYNTHETIC BIOLOGY, AI, BLOCKCHAIN, AND PLATFORM BUSINESSES MEAN TO LIBRARIES

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Abstract

Digital disruption, also known as “the fourth industrial revolution,” is blurring the lines between the physical, digital, and biological spheres. This issue of *Library Technology Reports* (vol. 56, no. 2), “Moving Forward with Digital Disruption: What Big Data, IoT, Synthetic Biology, AI, Blockchain, and Platform Businesses Mean to Libraries,” examines today’s leading-edge technologies and their disruptive impacts on our society through examples such as extended reality, Big Data, the Internet of Things (IoT), synthetic biology, 3-D bio-printing, artificial intelligence (AI), blockchain, and platform businesses in the sharing economy. This report explains (1) how new digital technologies are merging the physical and the biological with the digital; (2) what kind of transformations are taking place as a result in production, management, and governance; and (3) how libraries can continue to innovate with new technologies while keeping a critical distance from the rising ideology of techno-utopianism and at the same time contributing to social good.

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Digital Disruption and the Fourth Industrial Revolution

The Evolution of Digital Technologies

We are living in an era defined by remarkable technological advances. Since the mass adoption of the personal computer in the 1980s, we have seen and lived through many changes in our work and leisure activities. Significant shifts have taken place in the economy, finance, businesses, education, government, health care, manufacturing, charity, and even art as the result of developments in digital technologies. Particularly notable is how quickly those digital technologies have evolved. To name a few examples, while floppy disks sound archaic, they were widely used throughout the 1990s, only three decades ago. Their storage capacity of the 3.5-inch floppy disk was 1.44 MB. Today's much smaller USB drive holds 128 GB or more. It was less than thirty years ago, in August 1991, that the very first web page on the World Wide Web by Tim-Berners Lee went live.[1] Now, we can no longer imagine the world without the World Wide Web. It has become a platform for almost every human activity. It was in 2007 that Apple's iPhone, the first smartphone that enabled people to fully access and navigate the World Wide Web, was released. Less than a decade later, the smartphone became ubiquitous.

With the exponential increase in computing power, digital technologies are continuing to advance at a rapid pace. Recent breakthroughs in machine learning techniques of artificial intelligence (AI) have enabled machines to take on tasks that had been regarded as things only humans could perform. Such tasks include image classification, translation, speech recognition, and medical diagnosis. Virtual reality systems, such as HTC Vive and Oculus Rift, have become affordable for the consumer electronics market. A drone, which used to be an obscure military technology, is now widely used for recreational and commercial purposes. Synthetic biologists are building genetic circuits and biological parts to assemble organisms, hoping to make biology and electronics fungible.[2]

Digital Disruption

These technological advances have brought significant changes in many fields. The term *digital disruption* tries to capture this all-encompassing impact of today's fast-advancing digital technologies on our society. It refers to "an effect that changes the fundamental expectations and behaviors in a culture, market, industry, or process that is caused by, or expressed through, digital capabilities, channels, or assets."[3] The emphasis is placed on the nature of the change. Digital technologies are disruptive in that they drive changes in the expectations and behaviors of both consumers and businesses, which are fundamentally different from those in the past. There is no shortage of examples of digital disruption around us.

Amazon Go, Amazon's brick-and-mortar store, is a good example. The first Amazon Go store opened in 2018. In appearance, an Amazon Go store is not much different from many other physical stores where food items are stocked on shelves for shoppers to browse and purchase. But it has neither a cashier nor a checkout line. Shoppers at an Amazon Go store simply grab the items that they want to buy, and Amazon automatically charges their credit cards when they leave the store. How is that possible?

Leading-edge digital technologies, such as sensor fusion, computer vision, and deep learning algorithms, are brought together to make this "Just Walk Out Technology" a reality.[4] An Amazon Go store is fitted with many cameras and sensors that track an item's location, weight, temperature, and so on, and with computing devices that process the data from those sensors and cameras.[5] These electronics detect changes when a shopper takes a product from the shelf or returns it and keep track of the picked-up item in a virtual cart. When shoppers enter or exit the store, they scan a QR code with the Amazon Go app on their smartphones. This allows the store to identify shoppers and mark the beginning and end of each shopping trip. When a shopper leaves the store, Amazon automatically charges their credit card for the items taken and sends a receipt. At the time of this writing, there are seventeen Amazon Go stores, and six more are planned in Chicago, New York City, San Francisco, and Seattle. Amazon intends to open as many as three thousand stores by 2021.[6]

The Amazon Go store offers advantages to both shoppers and Amazon. Time-constrained shoppers will no doubt welcome the fast shopping experience without having to wait in a long line to check out. Shoppers also no longer need to carry a means of payment, such as cash or a credit card. The Amazon Go app on a smartphone is all that is needed. This will be quite convenient for those who have not planned to shop but have a few things to buy. If they happen to pass an Amazon Go store, they may drop in for a short visit. To Amazon, an Amazon Go store also presents a clear value proposition. With everything automated and handled by sensors and computing devices including the checkout process, Amazon does not have to hire cashiers nor many store clerks, thereby saving on wages. Since the store needs much less labor to operate, it can stay open for longer hours at a much lower cost, which is likely to increase the revenue. In addition, the store requires much less space since it does not need checkout stands and space for lines, yet it can handle a large number of shoppers because their shopping trips will be completed much more quickly without the separate checkout process.

It would not have been possible to realize these benefits without the necessary digital technologies. In that sense, technology has been pivotal in creating this type of new business opportunity and customer experience. Thus, digital technologies can make businesses operate differently than they had in the past. An Amazon Go store's everyday operation depends on the performance of the software and hardware components of the store. Without them, it cannot function as a store at all. By contrast, store clerks and managers are much less important because sensors and data analytics can generate needed information to optimize the store operation without requiring much input or help from those store clerks and managers. Naturally, Amazon will invest heavily in the IT side of the Amazon Go store and prioritize it over the HR side.

New types of businesses, such as Amazon Go, may also lead to different expectations from customers. People will no longer care much about the cheerful attitude and the helpfulness of store clerks. While those have been traditionally important factors for customer satisfaction, a store that does not require a separate checkout process makes them simply irrelevant. Instead, the smooth functioning of the Amazon Go app and the accurate and fast tracking of picked-up items become crucial to a good shopping experience. Shoppers at an Amazon Go store will also spend much less time than at other physical stores. For this reason, they are likely to be less interested in how spacious or nice the store is.

Right now, not many people shop at an Amazon Go store, so their experience is not the typical shopping experience. But imagine a future in which all stores would work like the Amazon Go store. We can immediately see how this would change the way we live our lives and organize our daily activities. A smartphone would be a must-carry item since it would function as a de facto wallet. There would be no more anonymous purchases because all shopping activities and purchased items would be associated with the person who picked up and paid for them. Since the store would track every item's location on the shelf in real time, shoppers would be instantly able to check if an item was in stock, and if so, exactly where in the store it was placed. Even at peak times, stores would be much less crowded since people would not have to wait to check out. Stores would become very computing-heavy as they would be fitted with a large number of sensors, cameras, and other electronics to detect purchases. They would also no longer be designed as spaces where people roam around and explore. Stores would be used more and more like large vending machines, where few store staff would be around and shoppers would be quick to arrive and leave with the items that they needed.

The Fourth Industrial Revolution

What the Amazon Go store accomplishes may appear to be simply reducing shopping time. But we need to observe a more important trend here. For the first time in human history, machines are starting to perform not only physical and mechanical but also cognitive tasks. Digital technologies have been increasing automation in many areas. But now, with the recent breakthroughs in AI, automation is spreading to areas that used to be seen as the exclusive domain of humans.

Two MIT economists, Erik Brynjolfsson and Andrew McAfee, named this phenomenon "the second machine age" in the book of that title published in 2014.[7] In the book, they stated that the industrial revolution was the first machine age, in which machines complemented humans by performing physical labor; now we have entered the second machine age, in which the automation of cognitive tasks substitutes for rather than complements humans. In their more recent 2017 book, *Machine, Platform, and Crowd*, McAfee and Brynjolfsson argued that many decisions, judgments, and forecasts currently made by humans should be turned over to algorithms, with humans sometimes in the loop and other times completely out of the loop.[8] They acknowledged that incomplete or biased data can produce faulty algorithms whose use generates erroneous or unfair results. But they also see intelligent machines complementing the weaknesses of inaccurate and irrational human decisions and judgments often resulting from the so-called "System 1," the fast and intuitive part of the human brain that operates automatically but cannot be logically scrutinized or turned off at will.[9]

The fourth industrial revolution is another concept that attempts to capture this phenomenon of the all-encompassing and fundamental changes brought on by digital technologies. The advocates of the term *fourth industrial revolution* distinguish today's era from the computer or digital revolution, which began with the developments of semiconductors in the 1960s and was further catalyzed by the spread of mainframe computing, personal computers, and the Internet in the 1970s, 1980s, and 1990s respectively. They observe that the first industrial revolution mechanized production, using water and steam power; the second industrial revolution created mass production with electricity and the assembly line; the third industrial revolution automated production with electronics and information technology.[10] The fourth industrial revolution began at the turn of the twenty-first century and is characterized by a much more ubiquitous and mobile internet; smaller, more powerful, and cheaper sensors; and AI, particularly machine learning.[11] Klaus Schwab, author of the 2016 book, *The Fourth Industrial Revolution*, emphasized that what differentiates the fourth industrial revolution from the previous digital revolution is not simply a multitude of novel technologies—such as 3-D printing, gene sequencing, nanotechnology, renewable energy, and quantum computing—but the fusion of these technologies and their interaction across the physical, digital, and biological domains.[12]

The idea that the recent advancement in digital technologies has reached a qualitatively distinct stage of digital revolution is becoming more widely accepted as new digital technologies bring changes that are much more rapid and comprehensive than in the past to the way we live, work, and interact with one another. As Schwab argued, the newest technologies are indeed blurring the lines between the physical, digital, and biological spheres. They are also disrupting almost every industry in every corner of the world, transforming entire systems of production, management, and governance.[13]

In the following chapters, I will highlight some of the areas where such digital disruption is already blurring the lines between the physical, digital, and biological spheres. I will also examine what kind of transformations today's digital technologies are enabling in production, management, and governance. Lastly, I will discuss how those changes, disruptions, and transformations will impact libraries. How can libraries and library professionals prepare for the digital disruption? How can libraries adopt and utilize new technologies to make library services, programs, and operation more successful and innovative and at the same time contribute to social progress? If we are indeed at the dawn of the fourth industrial revolution as some argue, then now is certainly a good time to ask these questions.

Notes

1. "History to Date," WWW Project History, CERN, accessed September 9, 2019, http://info.cern.ch/hypertext/WWW/History.html.
2. When these techniques of biological engineering sufficiently advance, biological matter can be programmed to perform specified functions and placed in different organisms. This is a vision of synthetic biology—that is, using living cells as substrates for general computation. See Joy Ito, "Why Bio Is the New Digital: Joy Ito Keynote," Solid Conference 2015, YouTube video, 11:45, posted by O'Reilly, June 25, 2015, https://www.youtube.com/watch?v=pnHD8gvccpI.
3. "Digital Disruption," Information Technology, Gartner Glossary, accessed September 9, 2019, https://www.gartner.com/it-glossary/digital-disruption.
4. *Sensor fusion* means the process of merging and improving data from multiple sensors to increase accuracy.
5. Amazon patented its "smart shelves" system in 2018. See Alan Boyle, "Fresh Patents Served Up for the Smart Shelf Technologies Seen in Amazon Go Stores," GeekWire, September 4, 2018, https://www.geekwire.com/2018/fresh-patents-served-smart-shelf-technologies-seen-amazon-go-stores.
6. "Amazon Go," Amazon, accessed November 9, 2019, https://www.amazon.com/b?ie=UTF8&node=16008589011.
7. Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton & Co., 2014).
8. Andrew McAfee and Erik Brynjolfsson, *Machine, Platform, Crowd: Harnessing Our Digital Future* (New York: W. W. Norton & Co., 2017), 64.
9. Daniel Kahneman, *Thinking, Fast and Slow* (New York: McMillan, 2011), 20–21, quoted in McAfee and Brynjolfsson, *Machine, Platform, Crowd*, 36.
10. Klaus Schwab, *The Fourth Industrial Revolution* (New York: Currency, 2017), 6–7.
11. Schwab, *Fourth Industrial Revolution*, 6–7.
12. Schwab, *Fourth Industrial Revolution*, 8.
13. Klaus Schwab, "The Fourth Industrial Revolution: What It Means, How to Respond," World Economic Forum, January 14, 2016, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond.

The Digital Meets the Physical and the Biological

New Developments in Extended Reality

Extended reality (XR) is one of the new digital technologies that illustrates how the physical gets infused with the digital. *Extended reality* refers to the environments and human-machine interactions "that either merge the physical and virtual worlds or create an entirely immersive experience for the user."[1] Such environments and interactions are generated by computer technology and wearables, which are computer-powered devices or equipment, such as a headset or a pair of glasses, that can be worn by a user. Augmented reality (AR), virtual reality (VR), and mixed reality (MR) are different types of XR.[2]

Virtual Reality

Virtual reality is an artificial three-dimensional environment that is created on a computer or captured by a video camera. It is presented through a head-mounted display and base stations that track the user's location. The head-mounted display and the base stations are both connected to a high-performance PC that runs VR apps. The user interacts with the virtual world by means of controllers. Oculus Rift and HTC Vive are two well-known VR systems, both released in 2016.[3] The price for these VR systems has gone down significantly. They can be purchased for as little as $400 to $500 at the time of writing. Microsoft also has a VR platform called Windows Mixed Reality.[4] While its name includes the term *mixed reality*, it is actually a VR platform.[5] Unlike HTC Vive or Oculus Rift, Windows Mixed Reality headsets have inside-out tracking, which allows them to track the user's movements and direction without external sensors. Many manufacturers, such as Samsung, Acer, and Dell, are selling this type of VR headset for the Windows Mixed Reality platform.

These VR systems enable individuals to immerse themselves in a simulated environment, which feels real to explore and manipulate. Gaming and entertainment are the areas where VR has become immediately popular. But VR can also bring benefits to a number of non-gaming activities. Its immersive power makes VR an effective tool for activities such as learning, job training, product design, and prototyping. For example, teachers are using VR apps such as Google Expeditions and DiscoveryVR in classrooms to take students on virtual field trips to faraway places.[6]

The three-dimensional VR environment also brings unique advantages in creating 3-D models.[7] VR applications for 3-D modeling—such as MakeVR Pro, Medium, ShapeLab, MasterpieceVR, Gravity Sketch Pro, and Google Blocks—allow people to create a 3-D object in the 3-D environment, review it, and export it in the .STL or .OBJ file format ready to be 3-D printed.[8] These applications enable users to import 3-D model files as well and modify them in the 3-D environment. The adoption of VR can bring interesting changes to product design. In 2016, BMW announced a plan to use HTC Vive VR headsets and mixed reality for vehicle development for greater flexibility, faster results, and lower costs.[9]

The current VR technology is limited in its support for social VR experiences, however. While it could be great to perform certain tasks in the VR environment, being unable to interact with others in the same VR environment is a shortcoming that will need to be overcome for VR to become fully mainstream. Two social VR platforms, VRChat and AltspaceVR, provide VR environments in which VR users can meet and interact with other VR users. But the experience on these platforms is not yet as smooth as one would expect.[10] Facebook, which acquired Oculus in 2014, introduced Facebook Spaces in 2017 and is now developing Facebook Horizon, which is to be launched in 2020. Mozilla also started its own browser-based social VR platform, Hubs in 2018.[11] Whether these experiments will eventually lead to a more refined social VR experience remains to be seen.

VRChat
https://www.vrchat.net

AltspaceVR
https://altvr.com

Facebook Horizon
https://www.oculus.com/facebookhorizon/

Hubs
https://hubs.mozilla.com

Augmented Reality

Unlike VR, which creates a completely separate reality from the real-life environment, AR and MR add information to the real world. AR is an overlay of digital content on real-life surroundings. The general public has become familiar with AR through Google Glass and Pokémon Go. Pokémon Go is an AR game played on a smartphone. It was released in July 2016 and became highly popular, earning a total of $1.2 billion and being downloaded 752 million times by 2017.[12] Two years later, the game is still popular and widely played across the world.

Google Glass is a device for AR. It debuted in 2013, and some libraries purchased and lent them to library users. Due to the widely raised privacy concerns, Google stopped selling the prototype Google Glass in 2015. However, its second-generation enterprise edition has been adopted and tested at several companies such as Boeing, GE, and DHL, reducing processing and training time and improving productivity and efficiency.[13] For example, a farm equipment manufacturer, AGCO, has about 100 employees using the custom Google Glass. With the Google Glass on, AGCO employees can get a reminder about the series of tasks they need to perform while assembling a tractor engine. They can also locate and access certain information related to the assembly of parts. They can scan the serial number of a part to bring up a manual, photos, or videos with Google Glass. AGCO reported that the addition of Google Glass made quality checks 20 percent faster and also helped training new employees on the job.[14] Google unveiled the Google Glass enterprise edition 2 in May 2019. This newer model does not look much different from plain eyeglasses. It costs $999 and is equipped with a faster quad-core 1.7 GHz CPU processor, an 8-megapixel camera, a 640 × 360 optical display, a microphone, a speaker, a multitouch gesture touchpad, 3 GB RAM, and 32 GB storage.[15] The new Google Glass enterprise edition 2 is sold for corporate users only.

AR is also being adopted in education. A system called zSpace provides a suite of AR applications developed specifically for learning.[16] It consists of a computer, a pair of 3-D glasses, and a pen. The educational applications available for zSpace help people to learn in categories of K–12 education, career and technical education, and medical education. zSpace provides a way for multiple people to experience AR at the same time, although the control is still limited to one person.

It is to be noted that many more smart glasses are now coming to the consumer electronics market. Some have only a few simple features and basically function as a combination of a fitness tracker, a notification display, an earphone, and a still and video camera.[17] But other smart glasses, such as Vuzix Blade and North Focals, are designed to be more like a smartwatch, closer to the way Google Glass works, allowing people to use functions and apps, which include instant messaging, maps and directions, Alexa, Google Assistant, Yelp, and Uber.[18]

Vuzix Blade
https://www.vuzix.com

North Focals
https://www.bynorth.com

Interesting developments in AR are also taking place with Google Lens. Google Lens is the camera-based AR technology that started supporting the Android smartphone's camera app in 2017. At the 2019 Google I/O conference, Google introduced AR search powered by Google Lens.[19] Using a compatible Android and iOS device, such as an iPhone or an Android smartphone, people can now see a 3-D object in their search results and view it as if it were in their immediate surroundings in real-life scale through the device's camera. It is not difficult to see that many businesses, such as furniture stores, will be motivated to provide 3-D files of their products to be available for AR search because such files can vastly improve their customers' shopping experience. Google Lens can also find and suggest similar items to buy when people see something they like, whether it is a shirt, a chair, or a handbag. Achieving the same result by running a conventional web search would be much slower.

Google Lens
https://lens.google.com

With the help of rapidly advancing research in artificial intelligence (AI) and computer vision, Google Lens is capable of performing real-time translation and object identification. It scans and translates texts, allows one to look up words and copy and paste them, adds events to one's calendar, and calls a phone number. These features can come in handy on many occasions. For example, at a restaurant, one can not only translate the menu but also look up dishes and even find out which ones are popular from the reviews and photos from Google Maps, using the Google Lens feature on a compatible smartphone. While traveling, one can point the camera of a smartphone at a popular landmark and find out its hours and historical facts associated with it. Buildings and other landmarks are not the only items that Google Lens can identify. It also identifies plants and animals.

As its name suggests, Google Lens provides a lens through which the world can be viewed augmented and enriched with digital information. This will make the physical and digital worlds more integrated and enmeshed with each other. Currently, Google Lens operates through the camera on a smartphone, but once integrated with the future models of smart glasses or other wearables, it will open up a whole new way for us to interact with the physical world.

Mixed Reality

Mixed reality (MR) is a combination of VR and AR. It allows one to view and interact with the real physical world and digital objects by mixing them together. *Mixed reality* is a term originally created to describe a digital environment named ProtoSpace developed by NASA's Jet Propulsion Laboratory in 2016. ProtoSpace is a multicolored CAD-rendering MR program that allows engineers to build an object that feels and acts like a real object. It is used to find flaws in the design before a physical part is built.[20] MR has been around for a while, but it is not yet as well known to the public as VR and AR.

The Microsoft HoloLens is likely the most widely known MR headset.[21] It is a self-contained holographic computer contained in a headset and can not only project virtual objects into the real world but also produce real-life-like interactions by mapping the user's environment as a three-dimensional mesh. Scopis, advertised as "a mixed-reality interface for surgeons," is a medical image guidance system that provides an MR overlay through the Microsoft HoloLens.[22] A surgeon wearing the HoloLens headset gets guidance from Scopis through spinal and other complex surgeries.[23] It improves the accuracy and speed of the surgery.[24]

Microsoft released the HoloLens 2 in November 2019 with a price of $3,500.[25] The HoloLens2 comes with a much larger field of view and better ability to detect physical objects in comparison to the HoloLens 1. It is also equipped with a multitude of sensors, speakers, and a camera. Just like the Google Glass enterprise edition, the HoloLens 2 is available for industrial use only.[26] It will not be available to general consumers. The development edition also requires a monthly subscription fee of $99.[27]

Magic Leap is another MR headset.[28] Unlike the HoloLens, it is connected to a small hip-mounted round computer that handles the primary data and graphics processing and comes with a controller. Its personal bundle version is sold for $2,295. Another MR device, Meta 2, is a headset tethered to a conventional computer. It was released in late 2016 to developers with a much lower price of $949, but is no longer produced because the company shut down in early 2019. [29]

The examples and new developments in VR, AR, and MR technologies described above show that, while still at an early stage, the adoption of XR has begun in a variety of areas including education, health care, manufacturing, aviation, engineering, shopping, and even search, blurring the lines between the physical and the digital. VR is becoming more and more common in entertainment and gaming. In the world of advanced MR, interacting with digital and physical objects would be nearly indistinguishable.

The early development of the AR Cloud, a real-time machine-readable three-dimensional map of the world, is also in progress.[30] The AR Cloud is to serve as a kind of shared spatial screen that enables multiuser engagement and collaboration in the AR environment. It is thought to be an important future software infrastructure in computing comparable to Google's PageRank index and Facebook's social graph.[31] By combining the digital and the physical world in a seamless manner, XR has the potential to transform people's activities both online and offline into something completely new. It will be a while until compelling XR applications and experiences become available, but today's XR is certainly moving beyond the stage of experimental prototyping.[32]

Currently, most libraries are focusing on providing VR equipment and space, so that library users can experience VR firsthand.[33] VR equipment and spaces are often placed in library makerspaces, but some academic libraries have a separate immersive VR environment as well as spaces and equipment optimized for visualization work that facilitate and enhance the learning, teaching, and research experiences of their students and faculty.[34] While most libraries that have adopted VR and AR currently allow users to experience commercially available VR or AR content, some libraries may begin to create their own VR or AR content in the future. When that happens, we may see library-specific VR and AR applications that enable library patrons to interact with the physical library environment for specific events, such as a summer reading challenge or a library scavenger hunt.

Big Data and the Internet of Things

Big Data

Another technology trend that is blurring the lines between the physical, digital, and biological spheres is Big Data and the Internet of Things (IoT). According to a report by Watson Marketing, approximately 2.5 exabytes (EB) of data are currently being created every day.[35] More than 17 billion connected devices are in use worldwide, and 7 billion of them are IoT devices.[36] International Data Corporation estimates that the number of those IoT devices will increase to 41.6 billion by 2025, which, in turn, will generate 79.4 zettabytes (ZB) of data.[37]

Big Data is often characterized by 3 *V*s: high-volume, high-velocity, and high-variety. Here, *high-volume* refers to the scale of petabytes, exabytes, yottabytes, and zettabytes.[38] An example of *high-velocity* is Twitter, an Internet service whose data is created by its users. Every second, an average of about 6,000 tweets are posted, amounting to more than 350,000 tweets per minute and 500 million tweets per day.[39] That is a lot of data generated in just one day. Big Data is also *high-variety*, meaning data of many different types, such as text, audio, video, and financial transactions, that originate from a variety of sources, including electronic health record systems, global position systems (GPS), fitness trackers, set-top cable boxes, social media, emails, and various kinds of self-reporting sensors.

Big Data isn't about data alone, however. No matter how much data one accumulates, that data would have no value unless it is analyzed to bring new insight. For this reason, Big Data is defined as "high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation."[40] The tools and technologies for storing, retrieving, and analyzing today's high-volume, high-velocity, and high-variety data are an indispensable component of the Big Data trend. As Dale Neef, author of the book *Digital Exhaust,* wrote, what makes Big Data different from just more data is the ability to apply sophisticated algorithms and powerful computers to large data sets to reveal correlations and insights previously inaccessible through conventional data warehousing or business intelligence tools.[41] To an organization, tapping into Big Data means capturing and collecting both human- and machine-generated data related to its activities; analyzing such data to identify correlations and patterns to discover new insights; and utilizing those correlations, patterns, and insights to benefit the organization.

The Internet of Things

The Internet of Things (IoT) is an important contributor to Big Data because it generates a large volume of machine-to-machine data. Simply put, IoT is the network of uniquely identifiable things—that is, objects virtually represented on the Internet. IoT consists of sensors and actuators embedded in physical objects connected to the Internet.[42] The network of those sensors and systems captures, reports, and communicates data about their environments as well as their own performances and interacts with those environments. A smartwatch, a smart thermostat, a Fitbit, and an Amazon Alexa are all examples of IoT devices.

Depending on their requirements, IoT devices fall into two categories: critical IoT and massive IoT. *Critical IoT* refers to sensor networks and systems that relate to critical infrastructure at a corporate or national level; it includes devices that require high network availability and low latency. On-board controls for an autonomous vehicle and the national energy and utility infrastructure are examples of such critical IoT.[43] Massive IoT, on the other hand, refers to systems and applications with a very large number of devices equipped with sensors and actuators, which send data to a cloud-based platform on the Internet. Those devices are less latency-sensitive and require low energy to operate. Wearables (e-health), asset tracking (logistics), smart city and smart home, environmental monitoring and smart metering (smart building), and smart manufacturing (monitoring, tracking, digital twins) are the areas where such massive IoT applications can be developed and deployed.[44]

Radio frequency identification (RFID) systems have been long viewed as a prerequisite for the IoT because they allow machines to identify and control things in the real world. In an RFID system, an object with an RFID tag can be identified, tracked, and monitored by the RFID reader. The activities of RFID tags and readers are initiated by an RFID application, which collects and processes data from RFID tags. An RFID system creates digital representations of physical objects, and as a result, it is a good example of an IoT system.

An IoT system usually has three layers: the perception layer, the network layer, and the service layer (or application layer).[45] In the perception layer, information about the physical world is captured and collected by sensors, wireless sensor networks, tags and reader-writers, RFID systems, cameras, GPS, and so on. The network layer provides data transmission capability. The service layer, also known as the application layer, processes complex data through restructuring, cleaning, and combining; provides services such as facility management and geomatics; and transforms information to content for enterprise application and end users in areas such as logistics and supply, disaster warning, environmental monitoring, agricultural management, production management, and so forth.[46]

The Impact of Big Data and the Internet of Things

How will Big Data and the IoT will change our lives? It is likely that the IoT infrastructure will be built slowly over many years. But the fully realized IoT can eventually connect all physical objects in the real world and allow us to detect, track, and control them digitally through their online representations. Furthermore, those connected physical objects will be able to communicate with one another to perform more sophisticated and complex tasks based upon the information received. This type of machine-to-machine communication and cooperation will significantly increase the degree of automation in the real world. In such a world, a smart refrigerator can alert you to buy milk when it runs out or even place an order to your predetermined grocery store, so that you can pick it up. A home entertainment system will automatically purchase movies that you would enjoy based upon your preferences and play them for you. Even energy grids will be kept at their optimal states thanks to a large amount of detailed sensor data collected, analyzed, and promptly acted upon.

The more physical objects are brought into the IoT, the more digital data they will generate. The Big Data phenomenon is likely to continue since such massive amounts of data need to be collected, stored, retrieved, analyzed, and acted upon on an ongoing basis. The quickly advancing Big Data tools and technologies related to data storage, retrieval, and analytics will help make the IoT infrastructure of the world more robust and complete.

Today's IoT adoption and utilization are not yet close to this full realization. But many researchers in library and information science have proposed a variety of IoT applications for libraries. Those proposals include location information and services inside a library, a system for managing study room seating and library resource utilization, an intelligent energy-saving lighting control system, a library data resource object model and the process of library personalized information service management, and a library noise information storage system.[47] But in the present at least, the most common type of IoT technology utilized at libraries is RFID. Many libraries now attach RFID tags to the materials in their collections. This allows them to implement self-checkout and to automate tasks such as shelf-reading, inventory, and handling of materials upon their return. RFID tags can, however, be used for purposes beyond inventory management.[48]

Along with the Big Data trend, academic libraries have been adding data-related services and support as part of research support. As government funding agencies, such as the NIH and NSF, have mandated data management plans in grant applications and public access to data from federally funded research projects, libraries started helping researchers with research data management plans and educating them about the need to make research data findable, accessible, interoperable, and reproducible (FAIR).[49] Many libraries also operate their own data repositories and provide data storage and archiving. Data services librarians assist faculty, students, and researchers with identifying relevant data sets for their projects, advise on appropriate data management practices, and perform tasks such as data set acquisition, data curation and dissemination, and data-related consultation and instructional support.[50]

As the Big Data and IoT trends mature, libraries and librarians will be asked to play a larger role in developing a variety of data-related support, services, programs, and other educational offerings, systems, and applications. Libraries may be asked to take on managing, storing, and preserving massive real-time data sets.[51] There will be an increasing demand for library professionals who are knowledgeable and skilled in data analytics. As more sensors and smart things are introduced to and integrated with the library in both its services and operation, innovative new ways to serve library patrons and to achieve a higher level of operational efficiency are also likely to emerge.[52]

It is easy to see how the IoT blurs the lines between the physical and the digital. The IoT aims to create a digital layer over our physical world. In the mature stage of the IoT, things in the world will be digital as much as physical. Full connected to the Internet and with one another, smart things will continuously engage in machine-to-machine communication and cooperation. This will enable them to operate much more intelligently, thereby reducing the need for human control or intervention. Naturally, all such smart objects, which would be basically everything in the world when the IoT is fully realized, will generate a massive amount of data. The infrastructure and the networking capability to capture, process, and store such a massive amount of data will be critical. This is how the IoT will accelerate the Big Data trend, and the massive amount of data from IoT devices will in return fuel future developments in artificial intelligence (AI), and machine learning in particular, where massive data sets are required to train algorithms.

Synthetic Biology and 3-D Bio-Printing

So far, we have seen how extended reality and the Internet of Things blur the lines between the physical and the digital. Now, let's take a look at how biological processes are being transformed to be more digital with genetic circuits and biological parts.[53]

Synthetic Biology

Today's digital computer is an electronic device that stores, retrieves, and processes data. The data processing takes place in the CPU (central processing unit), a microchip usually made of silicon. A computer program is a set of instructions for the computer hardware to perform particular operations. These operations all boil down to manipulating bits, the smallest unit of digital data in a computer—namely 0s and 1s. Synthetic biologists are interested in making a biochemical process, such as DNA/gene synthesis and the creation of proteins, more akin to computer programming.

Synthetic biology studies how to program cells using synthetic genes. With that, synthetic biologists want to make biological parts, devices, sensors, and chemical factories, which in turn can be used to build pharmaceuticals, renewable chemicals, biofuels, and food. They view a ribosome, which creates proteins in a cell, as a molecular machine. Ribosomes read a set of synthetic genes, in which the amino acid sequences of a protein are encoded. The genes give ribosomes the instructions for how to build proteins. In that sense, genes and ribosomes are analogous to programs and a machine that together produce an output. Cells, where ribosomes reside, can be regarded as tiny factories equipped with molecular machinery that produces chemicals.

The first synthetic life form, JCVI-syn1.0, was created in 2010 by an American biotechnologist, J. Craig Venter, and his team.[54] The DNA code of the replica of the cattle bacterium *Mycoplasma mycoides* was written on a computer, assembled in a test tube, and inserted into the hollowed-out shell of a different bacterium. The genome assembly process required stitching together eleven 100,000 base-pair DNA segments into a complete synthetic genome and propagating as a single yeast artificial chromosome.[55] The synthetic genome then encoded all the proteins required for life, which means the DNA "software" built its own "hardware." This process of converting a digitized DNA sequence stored in a computer file into a living entity capable of growth and self-replication cost roughly $40 million and countless worker-hours. In 2019, a team of scientists at the Medical Research Council Laboratory of Molecular Biology, a research institute in Britain, succeeded in synthetizing the complete genome of *E. coli*, named Syn61. JCVI-syn1.0 had a total of approximately 1 million base pairs (1079 kb). Syn61 has a total of 4 million base pairs (4 Mb) of synthetic DNA sequence swapped in the native chromosome.[56] This is the largest synthetic genome created to date.

The speed and the cost of DNA sequencing and DNA synthesis are important factors in taking synthetic biology to a larger scale. Sequencing DNA allows researchers to, so to speak, read the instructions of how to construct a biological part, which is a building block of life. In turn, DNA synthesis enables them to write new genetic information by replicating, modifying, and creating genes. These are the most basic steps in synthetic biology. But DNA sequencing and synthesis are time-consuming and expensive.

In digital computing, Moore's Law—that the number of transistors on integrated circuits doubles about every two years while the cost halves—has been shown to be valid. This phenomenon has drastically lowered the cost of computing over the years. Some synthetic biologists are now hoping for a similar trend to surface in DNA sequencing and DNA synthesis.[57] While it remains to be seen if this hope will be realized in the near future, the ability to quickly read and write DNA at a lower cost will make it possible to identify and catalog standardized genomic parts. Those biological parts will be used and synthesized to quickly build novel biological systems, redesign existing biological parts and expand the set of natural protein functions for new processes, engineer microbes to produce enzymes and biological functions required to manufacture natural products, and go as far as designing and constructing a simple genome for a natural bacterium.[58]

The drop in the cost of DNA sequencing and DNA synthesis will facilitate and accelerate developments in synthetic biology, such as the manipulation of organisms into bio-factories for producing biofuels, the uptake of hazardous material in the environment, and the creation of biological circuits.[59] Since microorganisms are small and require only a small amount of energy to operate, the ability to program cells and biological processes to produce specific outputs with precision will usher in a truly new era of manufacturing.

3-D Bio-Printing

Synthetic biology is not limited to synthetizing DNA molecules and proteins. Today's researchers are using the novel bio-printing technology to build whole cells, tissues, and even organs. This brings biology even closer to the digital realm. In 2016, regenerative medicine scientists at Wake Forest Baptist Medical Center succeeded in printing living tissue structures using a specialized 3-D bio-printer. Researchers were able to bio-print ear, bone, and muscle structures that further matured into functional tissue, which developed a system of blood vessels when implanted in animals.[60] This means that in the future, patients with injured or diseased tissues can receive new living tissue structures that would replace the injured or diseased ones.

The way bio-printing works is not drastically different from the way a common 3-D printer works. Bio-printing is an additive manufacturing technology of a physical 3-D object. As such, it creates a three-dimensional object layer by layer. However, a bio-printer uses bio-ink, which is organic living material, while a common 3-D printer uses a thermoplastic filament or resin as its main material. Bio-ink is a combination of living cells and a compatible base, like collagen, gelatin, hyaluronan, silk, alginate, or nanocellulose. This base is a carrier material that envelops the cells. It provides nutrients for cells and serves as a 3-D molecular scaffold on which cells grow.[61]

Bio-printing can be done by different methods, such as extrusion, ink jet, acoustic, or laser. But regardless of the specific method used, a typical bio-printing process goes through the common steps of 3-D imaging, 3-D modeling, bio-ink preparation, printing, and solidification.[62] 3-D imaging uses the exact measurements of the tissues supplied by a CT or MRI scan. Based upon this information, a blueprint is created, which includes the layer-by-layer instructions for the bio-printer. Suitable bio-ink is prepared next. After that, this material is deposited layer by layer by the bio-printer and goes through the solidification process, producing functional tissue or even an organ. Researchers are currently working on ways to bio-print a human heart, kidney, and liver. In 2018, scientists at Newcastle University bio-printed the first human cornea.[63]

Synthetic biology's vision to repurpose living cells as substrates for general computation has so far manifested itself in genetic circuit designs that attempt to implement Boolean logic gates, digital memory, oscillators, and other circuits from electrical engineering.[64] Biological circuits and parts are not yet sufficiently modular or scalable. Nevertheless, synthetic biology holds a key to the potential future in which electronics and biology become fungible and matter becomes programmable.[65] When this happens, the function of a mechanical sensor, for example, may be performed by bacteria, and those bacteria may function in connection with electronics and computers. In such a future, living organisms and nonorganic matter will interface and interact with each other seamlessly. One day, we may well use living organisms to produce materials, and living organisms may serve as an interface for everyday electronics. When developments in the areas of computational design, additive manufacturing, materials engineering, and synthetic biology are combined, the result will truly blur the line between the physical, the digital, and the biological.

DIYbio, Citizen Science, and Libraries

Synthetic biology inspired the citizen science and the DIYbio movement, which resulted in many local DIYbio communities and biohackerspaces. At biohackerspaces, the public can learn about and pursue biotechnological solutions that solve everyday problems without being professional scientists or affiliated with a formal wet lab.

The DIYbio movement refers to the new trend of individuals and communities studying molecular and synthetic biology and biotechnology without being formally affiliated with an academic or corporate institution.[66] DIYbio enthusiasts pursue hobbyist biology projects, some of which may solve serious local or global problems. Those include testing for melamine contamination in milk and developing an affordable handheld thermal cycler that rapidly replicates DNA as an inexpensive diagnostic. A biohackerspace is a community laboratory that is open to the public where people are encouraged to learn about and experiment with biotechnology. A biohackerspace provides people with tools that are usually not available at home but often found in a wet lab, such as microscopes, Petri dishes, freezers, and PCR (polymerase chain reaction) machines that amplify a segment of DNA and create many copies of a particular DNA sequence.[67] Currently, the DIYbio website lists more than a hundred such DIYbio communities and biohackerspaces.[68] A biohackerspace democratizes access to biotechnology equipment and space and enables users to share their findings with others. In this regard, a biohackerspace is comparable to a makerspace and the open-source movement in computer programming.

A biohackerspace that involves chemicals and biological matter is not something that existing libraries can adopt as easily as a makerspace. However, libraries can work together with local DIYbio communities and biohackerspaces to advocate for scientific literacy and educate the public. It is also possible for libraries to partner with local DIYbio communities and biohackerspaces to host talks about biotechnology or promote hands-on workshops where people can have the experience of doing science by participating in a project, such as building a gene.[69] A libraries' reading collection focused on biohacking could be introduced to interested library patrons. Libraries can contribute their expertise in grant writing or donate old computing equipment to biohackerspaces. Librarians can also offer their expertise in digital publishing and archiving to help biohackerspaces publish and archive their project outcomes and research findings. These are all relatively untapped areas for libraries, which nevertheless hold great potential to raise the level of overall science literacy in the communities that libraries serve.

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Chapter 3

Digital Disruption in Production, Governance, and Management

In the previous chapter, we saw the areas in which digital disruption is already blurring the lines between the physical, digital, and biological spheres. In this chapter, we will examine what kind of transformations today's digital technologies are enabling in production, management, and governance and discuss how those changes, disruptions, and transformations may impact libraries.

Fundamental Changes in Production

Platform Businesses and Network Effects

Today's World Wide Web is a platform for almost all types of human activities, ranging from broadcasting and education to gaming, dating, and so on, and commerce is a big part of those activities. As e-commerce matures over the years, a "platform" business has emerged as a new and successful business model. The term *platform business* may sound unfamiliar, but examples of platform businesses can be seen all around us. Uber, eBay, Airbnb, Alibaba, Amazon, and Facebook are all examples of platform businesses.

A platform business enables value-creating interactions between external producers and consumers, provides an infrastructure for those interactions, and sets governance conditions for them in order to find matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants.[1] The core activity of a platform business is enabling interactions between providers and consumers and facilitating value exchange between those two parties.[2] Digital technology and the World Wide Web have been key to the success of platform businesses. In contrast to traditional businesses, platform businesses' most crucial infrastructure is digital. Their technology infrastructure enables them not only to reach a large number of people at many different locations but also to rapidly scale up their operations over a short period of time.

Many of today's platform businesses thrive because they succeeded at realizing what economists call *network effects*. Hal Varian, the chief economist at Google, describes network effects as follows: "A good exhibits network effects if the value to a new user from adopting the good is increasing in the number of users who have already adopted it. This generates a positive feedback loop: the more users who adopt the good, the more valuable it becomes to potential adopters. This positive feedback loop also works in reverse: if adoption fails to reach a critical mass of users, the good or service may fall into a 'death spiral' and ultimately disappear."[3]

A good example of positive network effects is the World Wide Web.[4] When it was first created, there were only a small number of web pages and users. The value of those web pages and of the World Wide Web was accordingly small. However, as more people access the Web, use the content, and engage in activities with one another on the Web, the value of the content and businesses on the Web increases to new users. This draws more people to the Web, thereby driving its growth and drawing even more users. The network effects apply to today's platform companies. The more users join and use platform businesses such as Facebook and Twitter, the more value their services have for new users. Note that network effects can also be negative. In the case of negative network effects, the value of a good or service mediated by the platform business decreases as more users adopt the good or service.

Varian distinguishes "network effects" from "increasing returns to scale" on the grounds that network effects are a demand-side phenomenon while the latter is a supply-side phenomenon.[5] What he means by this is that network effects have to do with value increasing with the number of units sold, while increasing returns to scale have to do with the cost declining or the quality improving with the number of units produced. In platforms that achieve positive network effects, the value of adopting a service to an incremental user is larger when more users have already adopted the service. Here, value rises based upon how widely the service is already shared.

Platform businesses benefit from both (a) "increasing returns to scale" and (b) "learning by doing."

a. Airbnb and Uber present an opportunity to generate new revenue with very little up-front cost for those who have spare bedrooms and cars that are underused. With those providers on board, Airbnb and Uber can increase the number of new accommodation and ride options for consumers. The more suppliers join these platform businesses, the more value consumers get to derive from booking accommodations and rides through those businesses. That is, platform businesses increase their returns as they scale up their operations.
b. These businesses also improve their performance and lower the business cost by learning and applying new strategies, such as predictive analytics and machine learning algorithms. Airbnb, for example, makes use of deep learning techniques to enhance search ranking, listing categories, and amenities detection.[6] Uber relies on artificial intelligence (AI) for many things such as fraud detection, risk assessment, safety processes, marketing spend and allocation, matching drivers and riders, route optimization, and driver onboarding.[7] Just like any other type of business, platform businesses improve their productivity through practice and innovation over time, that is, learning by doing.

Connections as a Means to Generate New Value

New online platform businesses certainly follow a different business model than the traditional one. Almost all successful traditional businesses own and maintain large physical infrastructure and assets to process raw materials, produce goods or services, and hire a number of employees. Today's platform businesses, however, do not produce particular goods or services. They may not own any physical assets to operate. Unlike the more traditional linear type, platform businesses do not own the means of production. Rather, they create and maintain the means of connection.[8]

For example, Airbnb facilitates people's lodging arrangements by connecting those who are willing to rent their rooms or houses with those who are looking to stay at such places while traveling. Airbnb has over four million property listings in 6,500 cities across 191 countries. It is valued at approximately $30 billion, the third most valuable private business in the world.[9] But Airbnb does not own or maintain any of the real estate properties that it lists. It simply acts as a broker of the lodging arrangement transactions and makes money from charging transaction fees.

Platform businesses produce connections at an unprecedentedly large scale with the help of digital technologies. This is the kind of change that digital disruption is bringing to the area of production. The idea of platform businesses is not new. Marketplaces and shopping malls played a similar role in the past, albeit in the brick-and-mortar form. What distinguishes today's platform businesses is the fact that their activities take place more quickly with greater precision at a global scale, meaning they connect providers and consumers beyond the restrictions of time and space with more details factored into final transactions. All of us have had the experience of buying something on Amazon to later find out that its seller is shipping the item from a country on the other side of the globe, such as China and India. Amazon and other online platform businesses enable and facilitate such global-scale matches in astronomical volume. eBay, for example, enables interactions between over 170 million buyers and 25 million sellers all over the world.[10]

Artificial Intelligence as a Tool for Production

I showed above how digital technologies are bringing disruption in the world of business, where a traditional company's core activities are producing and delivering goods and services directly to its customers. Unlike those traditional businesses, platform businesses generate value by brokering connections between suppliers and consumers at a large scale and achieving positive network effects. Brokering the match between suppliers and consumers is one way in which digital technologies generate value. But digital technologies can also be used for the production of goods and services in a more direct way.

Artificial intelligence (AI) is the technology behind the new phenomenon of machine-generated content and services. AI is a discipline pioneered by British mathematician Alan Turing. Its goal is to create an artificial being that is as intelligent as a human, whether it is a piece of computer software or a machine.[11] John McCarthy, professor emeritus of computer science at Stanford University, came up with the term *artificial intelligence* to describe the topic of the Dartmouth Conference in 1956.[12]

The early AI systems followed the symbolic AI approach, which attempted to approximate human intelligence by mapping rules and programming logic into AI applications. The symbolic AI approach produced many expert systems. An expert system is a computer program that mimics a human expert's decision-making process by following explicit rules and instructions that were fully understood and articulated by humans in advance. The impact of the so-called expert system in the early 1970s was mostly confined to academia. By contrast, recent breakthroughs in AI are changing the world. Those breakthroughs were enabled by the adoption of machine learning techniques, particularly deep learning, a subfield of machine learning that uses a neural network with many layers.[13]

Unlike an expert system, a machine learning system is not built with a comprehensive set of rules. Instead, it is given a large amount of data and a preliminary mathematical formula, which allow the machine learning system to gradually learn to classify or analyze that data in order to make accurate predictions over time through training. Deep learning, a subfield of machine learning, utilizes an artificial neural network (ANN) with multiple hidden layers between the input and the output layers, which refines and produces a learning algorithm that best represents the result in the output. Computer vision, facial and speech recognition, natural language processing, machine translation, and customized recommendations are all areas where the application of deep learning produced impressive results. This novel machine learning approach enabled AI researchers to build programs whose performance is close to or even exceeds that of humans. Research in machine learning and deep learning is continuing to advance at a rapid pace. In 2016, AlphaGo, an AI program designed with deep learning techniques to play Go, a very complex strategy game, won four out of five Go matches against the eighteen-time world champion Sedol Lee.[14] And this formidable AlphaGo was defeated by another AI program, AlphaGo Zero, only one year later.[15]

The greatest difference between a symbolic AI system and a machine learning AI system is that while the former is deterministic, the latter is not. In comparison to past AI systems that followed the symbolic approach, machine learning AI systems showed huge improvements in their performance. But they also present the new problem of opacity, which is often referred to as the "black-box AI" problem.[16] A machine learning system develops its own rules based upon a massive amount of data, and those rules often involve a very large number of parameters, ranging from hundreds to thousands or more. This makes it difficult for even the developers of such machine learning programs to tell exactly how those programs produce particular outputs or to fully explain the process. For example, AlphaGo learned how to play Go by playing millions of Go games against itself, and Deep Face, a deep learning facial recognition system developed by Facebook, operates with more than 120 million parameters.[17] Clearly, the level of complexity commonly seen in deep learning applications makes the use of advanced AI algorithms controversial, particularly in areas where transparency and accountability are of critical importance, such as in court.[18]

Nevertheless, the impressive results of machine learning and deep learning prompted many industries to adopt AI in areas traditionally viewed as exclusively human domains. Journalism is one such area. The *Washington Post, USA Today,* Reuters, and BuzzFeed are all experimenting with AI technology in news writing.[19] Heliograf, the *Washington Post*'s AI-powered software, produced news stories about the Olympics and elections based upon given narrative templates and a set of structured data provided. Wibbitz, the AI software of *USA Today,* creates short news videos that condense news articles. Bloomberg News uses similar AI technology to produce as much as a third of the content that it publishes.[20] Its AI tool, Cyborg, helps reporters produce thousands of articles on the quarterly earnings reports of businesses. AI applications are also used to generate many news articles on baseball, football, and earthquakes at the Associated Press, the *Washington Post,* and the *Los Angeles Times,* respectively.[21]

That computer programs are creating content for humans to read sounds like a sci-fi story, but it is most certainly happening now. By generating news content with AI, media companies can lower the cost of content creation and target many small audiences on local or niche topics with a much larger number of stories quickly created, at the same time.

The subfield of AI that deals with language is referred to as natural language processing (NLP). AI is not used only to produce news articles and other types of stories but also to perform translation. Google has been long applying machine learning and deep learning techniques to improve the performance of Google Translate.[22] In 2017, it released the Pixel Buds, a pair of wireless earphones that provide real-time translation for forty different languages by connecting to Google Translate. Google has introduced this real-time translation feature to Google Assistant-enabled Android and iOS phones in December 2019.[23] In 2018, Google also announced a new feature of Google Assistant called "duplex." With this duplex feature, Google demoed Google Assistant successfully making a restaurant reservation by carrying out a phone call with a person at the other end of the line.[24] These developments indicate that more language-involving tasks will be automated by AI to a significant degree in the near future. There is even a company that provides the service of AI in design, which many consider to be an area reserved for human creativity.[25]

News creation, translation, and a personal intelligent assistant are not the only new services whose production is being led by digital technologies, specifically AI. Autonomous driving technology pursued by Apple, Google, Tesla, Uber, General Motors, Mercedes-Benz, Ford, and many other companies is another example of such machine-produced services to come.[26] From new ways to generate value in e-commerce through brokering connections at a massive scale to partly or fully machine-created services and content, digital technologies are certainly disrupting the area of production. In the next section, we will take a look at what kind of transformative changes digital technologies are ushering into the area of governance.

Challenges to Governance

Digital Technologies and Governance

Today's digital technologies are suggesting new ways of governance that rely less on traditional third-party authorities. *Governance* refers to establishing, monitoring, and implementing the rules and procedures for an organization to properly function. An organization is often run by people with conflicting interests who support different decisions. Governance activities manage such situations of disagreement and conflict by following a set of rules and procedures and steer the organization to adopt a decision that helps its prosperity in the long run. A government is the most prominent example of a governing agency; its operation is dedicated to governing an area or a country. What kind of role do digital technologies play in governance?

Digital technologies excel at connecting a large number of people on the Web and facilitating activities or transactions among them. This ability of digital technologies creates the potential to decentralize the governance role of a third-party authority or even eliminate it altogether. Blockchain is the technology that is in the center of this new possibility.

Blockchain

Blockchain refers to the distributed ledger technology. While it was originally developed for Bitcoin, the cryptocurrency that debuted in January 2009, blockchain can be used not just for financial but for any type of record keeping. What distinguishes blockchain from other record-keeping methods is its capability to encrypt a record of a transaction in a secure and tamperproof manner. Entries in a blockchain ledger are created by a distributed network of computers that participate in the blockchain-mining process, which makes the resulting records immutable and irreversible. Due to the security and the speed of the transaction it offers and its fully decentralized nature, blockchain is an exciting development for a wide array of industries, such as finance, insurance, digital content providers, supply chain management, and venture capital, as well as charities and even humanitarian NGOs.

How does blockchain manage to create and keep records tamperproof? This requires some explanation. Blockchain is basically a ledger, a list of transaction records, similar to a spreadsheet or a database. However, a blockchain database is distributed and decentralized. This means that a copy of each blockchain database resides in every single node of a network of computers. Each blockchain database in those nodes is identical, and all of them are kept in sync. The fact that there are so many copies makes it very difficult to forge a blockchain record. It is easy to forge a transaction record when there is only one database. It is much harder to do so when there are hundreds of thousands of them. Furthermore, in blockchain, each record is stored in a particular block, and each block is chained to the previous and the next block. If one changes a record in one block, it will make the entire block invalid because that particular instance of the block will now no longer match those blocks in other copies of the blockchain kept in other nodes of the network. This is how blockchain keeps its records immutable and irreversible.

The key components of blockchain technology are public key cryptography, hashing, nonce, and mining. Let's take a look at these one by one. First, public key cryptography works with the public and the private key pair. The public key is like one's address for a mailbox. The public key is given to others, so that they can find and send things. Once one receives something in the mailbox, the private key is used to unlock the mailbox.[27] The next component is a hash. A hash is data of a fixed size created by a mathematical algorithm. Each record in the Bitcoin blockchain, for example, is kept as a hash encrypted with the algorithm called SHA-256. For a hash function to work effectively in cryptography, it should be quick and easy to transform data to a hash, and at the same time nearly impossible to break the hash back into the original data. If a hash function takes too long to encrypt data or is easily decrypted, it is not practically useful.

Each block in a blockchain ledger includes multiple transactions. In the Bitcoin blockchain, for example, one block is capped at 1 MB, which contains approximately 1,400 Bitcoin transactions.[28] Each block includes the block header, nonce, the hash of the Merkle tree containing transaction records, the current time stamp, and the current block version number.[29] The block header includes the hash of the previous block. Nonce is a random string that satisfies the difficulty level set for the block to be accepted in the blockchain.[30] Finding the right nonce value is what is called "mining." Mining is a process of solving the mathematical puzzle of finding the needed nonce by the brute-force trial-and-error process. A transaction gets recorded into a blockchain through the following process.[31] Transactions in the block go through a hash function and get encrypted. The resulting hash values from those transactions are combined into what is called a Merkle Tree, which makes it easy for one to look up a transaction in a blockchain ledger.[32] Then, the hash of the Merkle Tree, combined with the hash of the previous block, nonce, the current time stamp, and the current block version number go through the hashing process again. Any change to any of this block data will make the block hash completely different.

With all these components together, the process from the creation of a new record to the recordation of that record into a blockchain can be summarized as follows.

1. A transaction is transformed into a hash.
2. The hash of a whole block is created.
3. A nonce is appended to the hash and hashed again.
4. The resulting hash is compared to the difficulty level required by a blockchain.
5. If it is less than the required difficulty level, other nodes on the network check and confirm the solution and update their instances of the blockchain. Otherwise, the nonce is changed and the trial-and-error process repeats until it finds the satisfactory nonce.
6. The hash of the header becomes the new block's identifying string, and the addition is propagated through the network. That block is now part of the ledger.
7. The miners responsible for this are rewarded (if there is a reward associated with mining).

Since the blockchain's recording process takes place in a distributed network of many computers—that is, nodes—it is not possible to predict when and which node will get to find the right nonce. It is also not possible to predict which nodes will check and confirm the block, thereby lengthening the chain. And by each block referring back to the previous block and the previous block referring back to the one before, this chaining mechanism makes each block and the records in it irreversible and immutable—that is, tamperproof. This feature makes blockchain a very promising new technology with the potential of great disruption.

Technology as a Trust Protocol

Traditionally, a third-party authority is brought into important transactions, such as fund transfer, real estate purchase and sales, insurance, and any type of credentialing, from school graduation to marriage certification. The role of a third-party authority in those cases is to guarantee the authenticity of the transaction and the integrity of the recordation process. However, the technological implementation of blockchain can now provide such a guarantee without relying on any outside party with existing authority. In this sense, blockchain is a trust protocol that enables transactions on the Web to be validated, authorized, and recorded in a secure manner using the distributed network and the hashing process only. This capability of blockchain can make the authorizing and recording role of a third party obsolete.

As a trust protocol, blockchain provides privacy and transparency. It can be used for a wide range of purposes, such as recording and confirming ownership, provenance, credentials, identity, or a financial transaction, separately or in combination. Without the need for a mediating third party, a transaction becomes immediate, and its cost becomes much lower, while it still remains secure. Imagine one does not need to go through a bank for a financial transaction or a county clerk's office to officially record the purchase or the sale of a piece of real estate. You can imagine the scale and the impact of the blockchain technology when fully implemented.

While certainly experimental, blockchain is already being adopted in many areas. The Washoe County Recorder's Office in Nevada recently announced that it will make marriage certificates recorded on the Ethereum blockchain platform.[33] Officially recording a marriage and getting an official copy of the marriage certificate usually takes a week or longer. But if the blockchain technology is used, the certification can be done almost immediately. In addition, making a false claim about any marriage will be detected much more quickly. Blockchain is also being used for humanitarian aid. The World Food Programme (WFP), the UN's food-assistance branch and the world's largest humanitarian organization, set up a program called Building Blocks in early 2017 in order to distribute its cash-for-food aid to over 100,000 Syrian refugees in Jordan. Before this program, transferring money to refugees who needed food required working with local banks in the affected area. This incurred large transaction fees that can be as high as 30 percent of the total food aid fund. The adoption of blockchain resulted in a 98 percent reduction in those fees.[34] It was estimated that by the end of 2018, the Building Blocks program would cover all 500,000 refugees in Jordan. [35] In the future, blockchain may be used for providing not only food aid for refugees, but also proof of their identities, thereby allowing refugees to start new lives in a place to which they are completely new with less friction.[36]

In Estonia, a country that gained independence from the former Soviet Union in 1991, there exists a national blockchain that registers every Estonian citizen's identity. Estonia has been using blockchain since

2012 for national data registries such as the national health, judicial, legislative, security, and commercial code systems. Estonia backs up its data in other countries for further security, and this is called *digital embassy*.[37] Estonia also incentivizes entrepreneurs through its E-Residency program.[38] This program helps people from other countries to establish an EU company based in Estonia. Since all government services in Estonia are fully online, a business's residency in Estonia can be fully established via the Internet. As of November 2019, Estonia has over 60,000 e-residents from more than 160 countries.[39]

Since blockchain is a set of code, other code can be embedded to trigger certain actions in a blockchain database. This is called a *smart contract*. It is how blockchain can not only fully automate but also go beyond the governance role of a third-party authority. As a piece of code, a smart contract is executed when specific conditions are met in a blockchain. It is a self-executing if-then statement on a blockchain and enables a transaction to be automatically performed without the mediation of a third party.

A smart contract adds to the disruptive potential of blockchain as it can provide more security than a conventional contract and lower the costs associated with the transaction. Perhaps to take advantage of those benefits, Arizona and Tennessee legally recognized smart contracts in 2018.[40] More examples of blockchain and smart contracts in use include Everledger, which stores information about over one million diamonds; Horizon State, a secure blockchain voting system; Augur, a prediction market platform for trading; EventChain, a blockchain-secured event ticketing system; and Livepeer, a peer-to-peer live-streaming platform.[41] Currently, most smart contracts take place in Ethereum, a prominent smart contract framework. Ethereum is an open software platform for decentralized blockchain applications.[42]

It is to be noted that issues remain in current blockchain technology. It is slow due to its decentralized nature, lacks standards, and for that reason has interoperability issues. The blockchain mining process consumes a huge amount of energy.[43] There is also a potential security risk, such as the *51% attack*. The 51% attack is a scenario in which someone gets control of more than 50 percent of the nodes of a blockchain ledger. If this happens, the attacker can reverse a transaction and also prevent any new transaction from being recorded into the blockchain.[44]

In spite of these issues, blockchain is expected to spread to many industries due to its unique benefits. As it is adopted more widely, it will have an impact on governance activities in all types of organizations from businesses to governments.

Technology Model of Employment

Changes in the Way We Work

So far, we have examined what kind of transformations are taking place in production and governance with today's digital technologies. Now, let's take a look at how digital technologies are changing the way we work as well as the way businesses manage their employees' work. In recent years, remote work away from physical offices has become a popular trend. Due to the increasing volatility in the labor market, freelancing has also become quite common. According to the report "Freelancing in America 2019" by the Freelancers Union and Upwork, an online freelancing platform company, 57 million Americans, approximately 35 percent of the US workforce, freelanced in 2019, and the share of full-time freelancers increased from 17 percent in 2014 to 28 percent in 2019.[45]

Jobs in today's economy no longer follow the pattern of steady growth. Due to the growing automation enabled by technology, many jobs that involve not just mechanical and manual but also more skilled work are at the risk of disappearing. In the previous section, we saw that advanced AI applications can generate news articles, for example. Autonomous vehicles can also take away a great number of driver jobs once they are fully developed. While it is uncertain when and at what level autonomous vehicles will be put to wide use, autonomous vehicles are already being tested on public roads in several countries at a large scale.[46] Imagine the day in which UPS and FedEx own fleets of self-driving trucks. There will be a drastic drop in the number of long-distance truck drivers needed in the shipping industry. What kind of workers will be retained by these companies, and what type of tasks will they be performing at that point? And how will those companies be managing their employees?

Earlier, we discussed blockchain as an example of how the third-party authority's governance role may be disrupted by digital technologies. Sony developed a blockchain technology that stores educational records such as test scores, degrees, and diplomas and filed a patent application for it in 2017.[47] Suppose that this new system is widely adopted, and schools and colleges all start storing their students' educational records in a blockchain ledger. Technologically, it is entirely possible to have such a system to handle on its own the payment of any associated fees and the instant delivery of transcripts and other educational records to those who request them. This means that schools and colleges will no longer need the staff to manage those processes. This type of increasing automation will add further volatility and uncertainty to the labor market and bring significant changes in the way businesses manage their workers.

The Sharing Economy

The term *sharing economy* is often used to capture the character of the new type of economic activities that grew out of online platform businesses such as Uber and Airbnb. It refers to an economic model defined as a peer-to-peer activity of acquiring, providing, or sharing access to goods and services facilitated by those online platform businesses.[48] The sharing economy has certainly brought benefits and opportunities to people. It created flexible and short-term work options (also known as "gigs") and presented new ways for individuals to monetize their idle or underused assets by selling their short-term use-right to others. It also significantly lowered barriers to sales and purchase activities through online platforms.

The sale and purchase of services and goods between individuals are age-old activities. What is interesting about online platform businesses, however, is that they describe these age-old activities as "sharing" rather than "selling and buying." But this so-called sharing in *sharing economy* means short-term leasing or renting rather than sharing. And as such, it stands more in contrast with owning. A good example of this is buying and owning one's own car versus using the Zipcar service whenever one needs a car.

Sharing in its proper sense is something that takes place among friends and family with established connections. Such usual sharing activities do not involve monetary transactions, and their primary purpose lies in fostering connections and relationships, rather than making money or obtaining needed goods or services. By contrast, what is called "sharing" in the sharing economy is simply another type of market transaction for the short-term access to goods and services. For this reason, some have argued that a better term for this new type of market transaction is "the access economy."[49] Platform businesses in the sharing economy found a new way to create those short-term access offerings with more convenience and at a lower price point by mediating transactions online and attracting individuals rather than established businesses to provide services and goods.

Workers Reclassified as Consumers and Entrepreneurs

By enabling direct peer-to-peer (P2P) market transactions with technology, online platform businesses introduced much disruption to the established roles of a business as an employer and of a worker as an employee. In the traditional economic model, businesses hire employees to work for them and pay wages. Managing and supervising these workers is the responsibility of a business. While being placed under supervision for proper work performance, employees are entitled to fair labor practices from their employers. Employers are also to provide a level of support and direction for employees when disputes arise in their interactions with customers.

Online platform companies practically broke all of the well-established conventions in the employer-employee relationship. They claim to be technology companies that are no more than brokers in P2P transactions between individuals. This way, online platform businesses can distance themselves from their obligations as employers. For example, Uber does not regard its drivers as employees. Instead, it calls Uber drivers "Uber entrepreneurs."[50] It also argues that Uber entrepreneurs are the consumers of its platform.[51] With this new and confusing usage of the term *consumer*, Uber obscures the distinctly different roles of drivers and riders. Online platform companies prefer to conflate workers and consumers as simply "users" of their platform services and members of their so-called "community." But no matter which term is used, the role of one who works on a platform such as Uber to make a living is not so different from that of a traditional worker. Just like traditional workers, Uber drivers are also essential to Uber generating its revenue.

Let's take Uber drivers further as an example. Uber drivers can work on a flexible schedule. They also work on their own without a supervisor. These facts often count as the advantages of driving for Uber. But in comparison to the employees in a traditional company, Uber drivers also encounter disadvantages. Because Uber drivers are required to have a certain level of ratings, they are dependent on the ratings of their service by passengers even when those ratings are not fair or accurate. Since they have no formal supervisors or physical offices, they do not have a way to resolve these issues promptly, even when those ratings directly affect their earning.[52] Even in case of harassment or violence from passengers, which negatively affects their workplace conditions, Uber drivers can expect little meaningful support from the management.[53] Uber explicitly adopts a model of customer service communications in managing drivers and offshores and automates its main communications with them, which means that even urgent or important issues reported by Uber drivers that require a timely resolution will be often met with automated email replies.[54]

Uber drivers may be free from supervision by a human manager. But they are instead subject to surveillance-level algorithmic supervision by the Uber app, which they must use during their working hours. The app monitors drivers' performance in detail through the phone's accelerometer, GPS, and gyroscope and tracks each driver's ride acceptance and cancellation rates, hours spent logged in to the app, trips completed, and so on.[55] With its access to all drivers' real-time data, Uber has a huge advantage in morphing Uber drivers' behavior in the direction it needs at any moment. By contrast, Uber drivers have to rely on whatever information the Uber app supplies. For example, Uber uses a surge pricing notification to keep drivers working at locations where there is a high demand for rides. But when drivers get to those surge areas, they often find that the demand has already disappeared.[56] Unlike an ordinary employer, Uber does not provide drivers with explicit rules that apply to the important details of their work in advance because they are subject to constant change.[57] For example, pay rates for Uber drivers continually shift, and so do other policies and incentives.[58] Needless to say, working in an unstable workplace environment like this is likely to generate much stress.

It is apparent to many that Uber, Lyft, and other ride-sharing businesses are a new type of taxi-service company. As a matter of fact, these ride-sharing businesses, with their rating systems and the data they collect through the apps, actually hold much more power over individual drivers than any traditional taxi companies ever did. And yet, they use the rhetoric of "sharing" to refer to paid work and call their drivers "partners" and "entrepreneurs." This clearly does not match the reality experienced by those who drive for these ride-sharing services for a living. Alex Rosenblat, the author of the book, *Uberland*, observed that the sharing economy popularized wider changes to work culture by conflating work with altruistic contributions, bringing into question the identity of workers, and devaluing paid work itself and that Uber brought to light the power that technology platforms wield to disadvantage their workers even as the platforms shield themselves with the rhetoric of neutrality.[59]

Libraries in the Era of the Fourth Industrial Revolution

In this chapter, we looked at how today's digital technologies are disrupting and driving transformative changes in production, governance, and management with examples. I hope that these examples have shown that there are enough grounds in the claim that the fourth industrial revolution is well underway and digital technologies are now bringing much more rapid and comprehensive changes than in the past to the way we live, work, and interact with one another, disrupting almost every industry in every corner of the world and transforming entire systems of production, management, and governance.[60]

How do all these relate to libraries? Clearly, libraries are not online platform businesses. AI and blockchain are being discussed with interest by many library professionals, but they are not close to mainstream adoption yet.[61] Given this, one may dismiss the impact on libraries of these new technologies and the transformative changes that they are driving in the areas of production, governance, and management as less than significant. But this would be a mistake.

The success of online platform businesses demonstrates that in today's economy, digital connections themselves generate value. It also signals that we will be using and interacting with more and more technology platforms to obtain connections that we need for our personal and work lives. What do such technology platforms do well and not so well? Are there things that libraries can emulate in what those technology platform businesses do well? What are some of the things that technology platforms do poorly but libraries can do with excellence? In a way, today's libraries lead a double life, one as a physical building and the other as a digital platform of e-books and many other types of online resources. If well leveraged, this unique combination of the physical and the digital can become a point of strength for libraries.

There is no doubt that in order to adapt to and succeed in the times of digital disruption, libraries must continue to explore and evaluate emerging technologies and adopt them appropriately. AI may feel like a distant phenomenon to many library professionals right now. But it will bring fundamental changes to the information and knowledge industry as its capacity approaches the level of generating content and services whose value equals or surpasses that of those produced by humans. It will also most certainly have an impact on people's information-seeking, learning, and teaching activities. AI has the potential to automate the labor- and time-intensive cataloguing, abstracting, and indexing processes; improve information discovery and retrieval;[62] extract key information from a large number of documents;[63] and detect certain features from visual materials such as historical maps.[64] These are the aspects of AI particularly relevant to libraries.

Blockchain is still an experimental technology and has several drawbacks in its current stage, as noted earlier. But the immutable and tamperproof record keeping that it offers can benefit a certain set of data and records that libraries need to store and preserve exactly the way they were created. Libraries may also apply blockchain to securing information that is at great risk of being altered or compromised by changing circumstances.[65] Other ideas for utilizing blockchain for libraries currently under consideration include a library patron card and a library currency for interlibrary loan.[66] But blockchain implementation would be beneficial to libraries when it can serve as not only a novel but also a cost-effective solution.

Even if libraries do not get to make use of blockchain for their collections or services in the near future, blockchain and smart contracts are likely to present interesting and unique opportunities for libraries. For example, how may blockchain help with advancing the open science or the open access agenda that many libraries are strongly advocating?[67] Can blockchain be used to make the peer-review process in scholarly publishing more transparent?[68] How would these experiments relate to the overall trend of the role of governance and authority by a third party being challenged and replaced by technology, which I described earlier?

Lastly, libraries play a significant role in workforce development, helping with people's job searches and facilitating their job-related continuing education.[69] We have seen that digital technologies are likely to displace more jobs in the future. With their data-driven algorithmic supervision and management practices and the rhetoric of being a neutral broker, today's platform companies are already disrupting the traditional employment model while shunning their responsibility as employers. The clear understanding of how the platform economy redefines and reorganizes work and how technology enables this can help libraries best serve patrons who need help navigating the changing economy and the challenging job market.

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Libraries Facing Digital Disruption

In the previous chapters, we have seen how digital disruption is blurring the lines between the physical, digital, and biological spheres through the examples of extended reality, Big Data, the Internet of Things, synthetic biology, and 3-D bio-printing. We have also taken a look at what kind of transformations today's digital technologies are enabling in production, management, and governance. How can libraries and library professionals prepare for the digital disruption? How can libraries adopt and utilize new technologies to make library services, programs, and operations more successful and innovative and at the same time contribute to social progress? In this chapter, we will focus on these questions.

The Right Mindset for Innovating with Technology

Libraries have been embracing technology since the dawn of the Internet. It is thanks to public libraries that the public has a reliable place in their communities that provides free Internet connections and many educational offerings that teach people a variety of digital skills essential today. Many libraries also offer makerspaces, studios for multimedia creation, spaces that support entrepreneurship, and more.

There is no doubt that in order to stay relevant to the evolving needs of patrons, libraries must continue to invest in technology-related offerings and innovate their services and programs. This, however, is not something that is opposite to or competes with what some consider to be more traditional types of library services and programs, such as in-person reference consultation and the circulation of physical library materials. This is because technology is to help the library achieve its mission, not to change the mission itself. No matter what technology the library adopts and how it changes the library's services, programs, and other offerings, the library's mission—to empower people through knowledge and to facilitate and support their information-seeking and learning activities—does not change.

Given this, what kind of mindset would move forward the ability of library professionals facing digital disruption? Clearly, the ability to identify new technologies relevant to libraries, learn them quickly, and develop ways to adopt and utilize them to benefit library patrons is critical for library professionals to thrive in this environment. The mindset that helps cultivate this ability includes traits such as curiosity, open-mindedness, and confidence.

In order to identify and learn new things relevant to libraries, one must have a certain degree of curiosity. Only those who are curious enough will venture to learn new things. Open-mindedness is beneficial particularly in times of fast change since it is hard to predict the full impact of a new technology trend as it continues to develop and evolve. By keeping an open mind, library professionals can more easily spot what is relevant to libraries in today's continuously changing and evolving technology scenery. Lastly, a sense of confidence plays a key role in learning new things from the fields with which one is not previously acquainted. While some library professionals may already be well acquainted with a variety of technologies, many may not. Regardless, in comparison with those in other professions, those who work at libraries are in a much better position to learn new things due to their training and experience as information professionals and the wealth of resources available at their workplaces.

One way for managers and administrators to prepare their libraries for digital disruption is to provide their staff with time and resources needed to pursue appropriate professional development. They should also make intentional efforts to foster and cultivate the mindset of curiosity, open-mindedness, and confidence; encourage experimentation; and facilitate the exchange of ideas and further collaboration among the staff. This will increase the library's collective knowledge and skills over time and enable the library staff to develop new and innovative programs and services on an ongoing basis. Libraries are the embodiment of our belief that information and knowledge are to be shared for greater benefit. It would be only natural for this belief to be put into practice by library professionals themselves.

Keeping a Critical Distance from Techno-Utopianism

Having a sense of excitement about what new benefits technology may and can bring to libraries and library patrons is important. But equally important is to understand that technology does not always produce social good and can have negative social consequences. Libraries are institutions that aim to generate and increase social good in the communities that they serve. As a result, library professionals must be attuned not only to the benefits but also to the limitations of new technologies adopted by a society.

In 2015, a drone was hovering over the house of a man named William Merideth in Kentucky. Merideth was alarmed by its extremely loud noise and was not sure if it was a danger to his kids playing outside. He thought the drone was spying on his family and shot it down with his shotgun.[1] The owner of the drone turned out to be his neighbor, David Boggs. Upset over his expensive drone being completely destroyed, Boggs accused Merideth of property damage. Merideth argued that he had a right to privacy at his home. Not knowing what law exactly applied to a case like this, the police officers arrested Meredith because he was the one with a gun, and Boggs subsequently filed a claim for damages in federal court in Louisville.[2] The federal court dismissed Boggs' claim, however, leaving as to whether American federal law recognizes the concept of aerial trespass unresolved.[3]

Since drones didn't exist when the airspace law was made, the law itself does not address the question of whether a drone flying over private property counts as trespassing or not. While that question may be of interest mostly to legal scholars, the result of the adoption of a piece of commercial technology has much broader consequences. A loud flying robot in the air over people's houses is understandably alarming. In a rural area where many residents own a gun, a drone can easily trigger shooting. Of course, none of this would have occurred to the drone engineers and manufacturers. They probably thought that they were simply building a new and innovative tech gadget that is cheap enough for the consumer market and nothing beyond. They certainly wouldn't have associated their drones with potential gun violence in a residential area.

The story of William Merideth and the drone that he shot down aptly illustrates how a piece of technology whose use and design are not well thought out can cause an incident with potentially deadly consequences. According to Meredith Broussard, a data journalist and the author of the book *Artificial Unintelligence*, such lack of caution about how new technologies will be used and a reckless disregard for public safety and the public good are common in tech creators.[4] She draws our attention to the danger of techno-utopianism, the belief that technological advances can and will always lead us to a better and eventually ideal society.

Not surprisingly, this blind optimism about technology is getting more and more widely accepted, consciously or unconsciously, not only by tech creators but also by the general public, including library professionals. Since technology has brought so many benefits to our everyday lives, the mere idea that technology may cause harm rather than good can seem almost inconceivable. But no matter how powerful technology is, it is only a means to an end. Technology is not a panacea. Nor is it a goal to be sought out for its own sake. As institutions dedicated to educating the public and striving for continuous innovation to stay relevant to the public's changing needs in pursuit of knowledge and information, libraries should raise the public's awareness about the social consequences of new technologies adopted, in addition to their benefits.

Technology Is Not Value-Neutral

In early 2018, the ride-sharing company Uber announced a new service called Pool Express. This service puts together nearby riders heading out to destinations close to one another into one group and asks them to gather at one location. They then all take an Uber ride at that location, and Uber drops all of them off at the one destination.[5] This was advertised as another amazing innovation. Only it is not so innovative.

Grouping people together to take them to a common destination is what the bus and other modes of public transportation have been doing for a very long time. It is not at all a new idea, nor is it particularly innovative. It does not solve any new problem. Uber's Pool Express may lure those existing bus riders away with a fare lower than regular Uber rides. They are likely to be attracted to this new option because public transportation in many cities is not well managed or financed.

What is troubling about this type of so-called innovation is that those in many start-up technology companies often fail to see that the problem that they claim to solve with technology has a cause that has little to do with technology per se and a lot more to do with complex socioeconomic problems. The reason why many people do not find public transportation service appealing is in large part that such public transportation has not been sufficiently funded. If it were sufficiently funded and properly maintained to be frequent, on time, safe, and clean, then many more people would happily use public transportation. The currently unsatisfactory service condition of public transportation in many cities is not something that can be quickly fixed with some lines of code. Resolving this problem requires the political will of the people and a change in government spending. The problem is political, not technological.

But if Uber ends up fulfilling the majority of the public transportation needs, what is likely to follow? With fewer and fewer people using the existing public transportation options, such as city buses and the subway, public transportation will be given even less funding and lower priority. The conditions for the riders will worsen, and the bus and subway lines may be severely cut or even completely eliminated. This may not matter to those who can afford the private Uber service. But those who rely on public transportation options and cannot afford alternatives with a higher fare will be left without a means of transportation necessary for their everyday lives. Given this closer look, Uber's Pool Express is not just an old idea repurposed. It is a wrong fix that worsens an existing problem, which at the same time distracts people and diverts their attention from the real solution.

This is another case of techno-utopianism in action. It is also a good example of why technology does not always make things better. In her book *Artificial Unintelligence*, Broussard discusses the following characteristics of techno-utopianism.[6]

- blind optimism about technology
- lack of caution about how new technologies will be used
- disregard for social convention for the sake of building new things
- prioritization of efficient code above human interactions
- worship of the cult of genius that camouflages a range of structural discrimination
- techno-libertarianism and counterculture for radical individuality
- inability to reconcile the demands of being an individual with the demands of participating in a society, as if they were incompatible with each other

These characteristics can serve as a useful guide for library professionals in detecting and understanding the issues and shortcomings of approaches that claim to solve complex socioeconomic problems with technology alone and in educating the public about them.

Just as Uber's Pool Service has the potential to weaken our public transportation infrastructure and worsen the riding conditions of many who cannot afford more expensive private transportation services, the story of a drone marketed and sold to individual consumers illustrates a new technology's negative social consequence that could have been foreseen and prevented if sufficient thought were given to how people might react to a drone flying close to their houses with loud noise. It is not up to libraries to undo those negative social consequences and harm. But libraries can consciously try to adopt and utilize technology in the way that creates and contributes to social good.

Technology is not value-neutral. Technology affects and shapes our society, our behavior, and our social norms. It is a mistake to treat technology as if it were neutral, objective, and not colored by human beliefs, judgments, biases, and prejudices. Technology can certainly bring many amazing benefits to us and serve as an equalizer and democratizer for our society. But technology can also equally well function as a divider and the amplifier of existing discrimination. Technology is not inherently liberating. Nor does it solve every problem and automatically bring social progress.

Many times, I have seen a false dichotomy drawn in technology: makers vs. takers; creators vs. maintainers; developers vs. documentarians; hard skills such as coding and mathematics vs. soft skills such as project management, writing, coordination, and communication. In all these cases, makers, creators, and developers are considered to be superior to takers, maintainers, and documentarians. Hard skills are also often regarded to be somehow more valuable and harder to obtain than soft skills. No matter how prevalent, these ideas are not correct. All of us engage in some type of making activities. The fact that some people do not spend their time on 3-D printing or laser cutting or programming does not make them takers. There are a wide variety of making activities, from sewing and button making to screen printing, and everyone engages in some type of making activities. Without maintainers, new services, programs, and procedures do not last. Without documentarians, no application or system will be properly used and cared for over time. Without soft skills, hard skills will generate only products that are maladjusted to human needs. There is also no hard line between these two categories. One can be and should try to be both a maintainer and a developer, a maker and a taker, and skilled in both soft and hard skills.

These value-laden categorizations often arise from erroneous beliefs. But we rarely confront and question them. Why do Amazon's and Apple's virtual assistants both have female names, Alexa and Siri, while Hal 9000 in Arthur C. Clarke's *2001: A Space Odyssey* has a male name and a menacing red eye? Social anthropologist Kathleen Richardson wryly remarked on the blatant sexism in AI scientists and engineers: "I think that probably reflects what some men think about women. That they are not fully human beings. What is necessary about them can be replicated, but when it comes to more sophisticated robots, they have to be male."[7] It is easy to miss the hidden value judgement, such as this sexism embedded in new technologies, and to place unconditional trust in those technologies. But if we adopt those technologies without fully understanding their negative social consequences, we can end up with the world that is detached from and deprived of our own social values.[8] Our values should guide technology, not the other way around.

Since today's digital technologies continue to advance at a rapid pace, it is difficult to predict the future with precision. While we may try our best to guess how those changes, disruptions, and transformations will impact libraries, technology can always run ahead of us. But the rise of techno-utopianism—the belief that technological advances can and will always lead us to a better and eventually ideal society—is one unmistakable trend that can cause much social harm.

Libraries are in a unique position to educate the public to think critically about technology and the rising ideology of techno-utopianism in our society. To successfully play such a role, library professionals should be well versed in new technological developments and their applications. At the same time, they must be also fully aware of the fact that our unconscious value judgements and biases permeate both the technology we create and our discourse around it. I believe that this is the area where libraries in the era of the fourth industrial revolution can make a substantial positive impact and play a unique role. Technology is great at crunching a massive amount of data and at surfacing overlooked or unrecognized patterns in them. But technology knows no values. Social values and human interaction will be the two most important keystones that undergird tomorrow's tech-savvy libraries. Libraries should aspire to be the place that both digitally and physically reminds people that no technology can replace the value of human interaction.

Notes

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