Stanford SILICON VALLEY NEW JAPAN PROJECT

Stanford | Shorenstein APARC | Japan Program

SVNJ Memo
2015-6

The Algorithmic Revolution Driving Business Disruptions: Beyond the Buzzwords

Kenji Kushida, Stanford University

The Algorithmic Revolution Driving Business Disruptions: Beyond the Buzzwords

Kenji Kushida*
Stanford University

Prepared for the Trilateral Commission Plenary, Rome 2016.

The Business Disruptions:

Over the past few years, business disruptions utilizing information technology (IT) tools have hit a wide variety of sectors. For example, Apple's iPhone and Google's Android—the **"smartphone" revolution**—*disrupted a wide variety of previously distinct product and service areas, each which had discrete sets of firms*: cellular handsets (Nokia, Ericsson, cameras (Canon, Nikon, Pentax, etc); camcorders (Sony, JVC); portable gaming devices (Nintendo, Sony); personal digital assistants (Palm, HP); watches (Casio, Seiko, etc); scanners (HP, Canon); barcode readers, point of sale terminals in stores, specialized display panels, and even metronomes, flashlights, consumer microscopes, and a variety of specialized devices that are now replaced by smartphones and apps.

Artificial Intelligence (AI) is an area that has recently crossed the threshold from basic research to a burst of commercial interest. This has led to vigorous debates about AI that replaces existing labor, versus augmenting human activities and capabilities—Google's fully autonomous car versus Tesla's Auto Pilot, for example. At first glance it seemed as though AI would replace simple tasks, leaving highly skilled tasks and areas requiring creativity intact, but it is now clear that a wide array of highly skilled tasks may be performed by algorithms that augment human activities (such as making diagnoses through MRIs, operating complex construction machinery, etc.) Firms at the forefront of AI are rapidly gathering top notch researchers from academia and industry all over the world—most notably Silicon Valley firms such as Google have been hiring aggressively, and Uber made headlines when it hired a core group of several faculty and numerous researchers and from Carnegie Mellon's computer science department and robotics lab.[i] Developments in AI, as well as robotics, will hit a wide variety of industries.

One of the major industries facing potential disruption, **automobile** manufacturers are now scrambling to pour resources into R&D as Google and Apple are developing autonomous driving vehicles—indeed, Google's self-driving vehicles on test runs is a common sight in Silicon Valley. Tesla Motors not only developed an electric car that initially topped the US *Consumer Reports* magazine's rankings, but also suddenly announced in October 2015 that its Auto Pilot could be downloaded by cars sold for a year

* Research Associate, Stanford University; Project Leader Stanford Silicon Valley – New Japan Project, International Research Fellow, Canon Institute for Global Studies.

and a half before that, literally transforming the core functionality of the product, and the human activity of driving, overnight.

Services such as Uber and Lyft have not only disrupted transportation services, but they also threaten automobile manufacturers as waves of urban consumers find even less need to own cars. Incumbent automobile firms are working hard to harness the growth of car-sharing services, such as GM's agreement with Lyft to lease vehicles to Lyft drivers—covering the entire cost of the car for full time drivers and along a scale of monthly payments of Lyft driving hours. Around the world, policymakers are pressured to find effective solutions on how to appropriately regulate firms such as Uber and Lyft and their local competitors that do not fit in the traditional taxi category.

Services such as AirBnB, which allow owners of accommodations to rent them out through an online service, are also causing policymakers to scramble as they weigh various interests and formulate how to extend regulatory frameworks.

In **finance**, **Fintech**, an area which includes startup firms using IT tools to offer niche solutions and services that large-scale financial institutions do not, are causing existing financial institutions to buy startups and services in order to avoid becoming disrupted. A core motivation for Fintech startups is to unbundle various services that incumbent financial institutions offer, but utilize IT to offer greater automation (such as investment advising) and therefore far lower overhead, better ways to measure things (such as credit risk for loans or driving patterns for auto insurance), better ease of use for services with tablets and mobile devices, and new services such as crowd-funding or services surrounding virtual currencies. The virtual currency **Bitcoin** has now emerged from a niche realm into a more accepted form of currency, with several legal framework recognizing it as currency. The underlying technology that decentralizes the log of activities, known as **Blockchain**, is also being examined for its potential to offer authentication at low cost compared to traditional centralized methods of authentication; the applications of blockchain transcend finance.

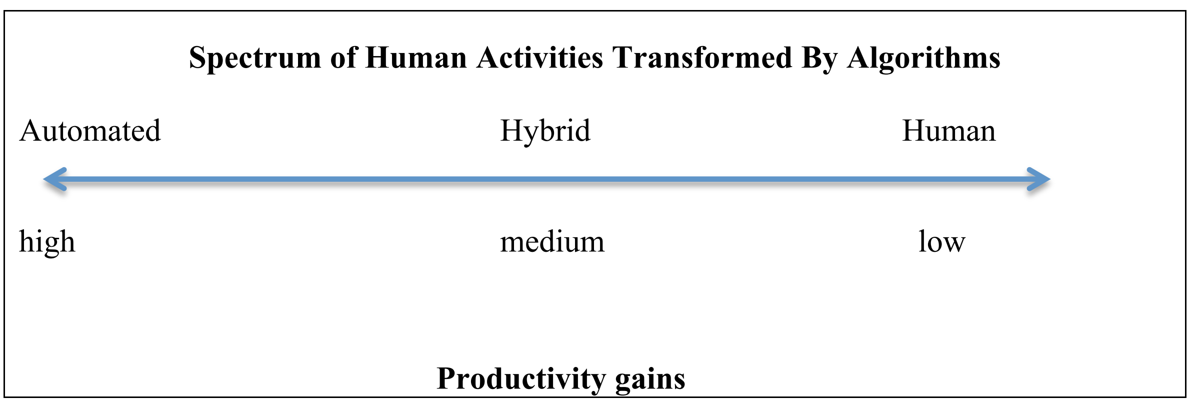
The coming era of **Internet of Things (IoT)** or Internet of Everything, is a world in which low cost sensors can be embedded in a vast array of objects and areas, to be connected by networks, enabling new levels of configurability, data collection, and new areas of possibility. We are rapidly entering an era in which one's imagination rather than cost constraints are now the upper bound of what can be measured and processed. Tesla Motors, for example, installed sensors and extra processing capability a year and a half before it rolled out its Auto Pilot—a fundamentally different paradigm of how to design automobiles entailing transforming the core functionality of the object later through a software download. Rather than optimizing for current needs like good traditional automotive engineers, Tesla chose to far exceed the current capabilities in terms of installing sensors and processing power, with a strategy to figure out how to fully utilize them later. This exemplifies much of IoT paradigm.

Big Data is a term now often used to refer to relatively small data combined with some analytics. Truly Big Data is now captured and analyzed by a small number of global-scale firms. These include Amazon, Google, and Microsoft, which have an array of billion dollar-scale datacenters that handle Exabytes of data (1000 Gigabytes = 1 Terabyte, 1000 Terabytes = 1 Petabyte, 1000 Petabytes = 1 Exabyte). The advantages of having massive scale that radically bring down the cost of data processing and storage are essentially infrastructure elements of today's IT innovation ecosystem.

Driving the Disruption: the Algorithmic Revolution

The Algorithmic Revolution: A basic driver behind many of the recent business disruptions in a wide range of industries is the transformation of computing resources from a scarce to an abundant resource. This allows an increasing swath of human activity to be captured by algorithms, which allows it to be split apart, transformed, altered, and recombined.[ii] Throughout human history, computing power was a scarce resource, and until the past few years, high-end computer processing and storage offerings were optimized to efficiently make use of scarce resource. Now, however, with the advent of global scale **Cloud computing**, which is essentially arrays of billion-dollar scale datacenters owned and operated by Amazon, Google, and Microsoft, computing resources do not have to be optimized. They operate at such large scale that the marginal cost of extra processing is essentially zero. Processing resources can be "wasted" on collecting and storing extra data whose use is not clear yet, linking various sources of data, running experiments, and the like.[iii]

Human activities can be placed along a spectrum of how they are transformed by algorithms. On the one hand is fully automated activities. Data searches, communications, and routine accounting, for example. On the other end of the spectrum are human activities that cannot (yet) be fully replaced by algorithms. In between are hybrid activities, in which human activities are substantially enhanced by algorithms.[iv]



Source: Zysman et al (2013)

The range of activities that are moving from human to hybrid and automated activities is growing quickly as the Algorithmic Revolution proceeds with ever-increasingly availability of processing power and storage. Driving, for example, is still largely a human activity requiring a driver to operate a vehicle for the same amount of time, even if services such as Uber make taxi-like services more efficient to find passengers and destinations. So is haircutting, where machines have not replaced humans, although booking appointments

can be potentially far more efficient through online platforms. Yet, auto pilot driving puts the activity in the
realm of hybrid, and automated driving (already a reality since 2008 for Komatsu's large-scale mining dump trucks, for example), has transformed the activity entirely.

Startup firms are often in a position to take advantage of IT resources, since one of the biggest constraints of large established firms is their legacy IT systems that are usually customized for particular uses. Since they were constructed in an era of computing resource scarcity, they do not offer the flexibility, scale potential, capacity, or cost advantages of utilizing global-scale cloud computing resources. For example, Uber is highly processing and storage intensive, delivering performance that does not degrade even as they grow rapidly—but they do not own their own datacenters, which would almost certainly guarantee that they would run into performance bottlenecks. Netflix is disrupting the broadcasting and cable industries, but it does not own its own datacenters either.

Silicon Valley has been an area optimized to produce high growth companies since it draws upon people from all over the world, enjoys a business ecosystem conducive to rapidly growing startups.[v] Critically, Silicon Valley's venture capitalists are under enormous pressure to find and facilitate the rapid growth of a couple winners in each portfolio that end up comprising the entire return of the portfolio, jettisoning the rest. These two factors: startups being more easily capable of utilizing the new paradigm of IT resources as abundant, and Silicon Valley being conducive to generating rapidly growing companies, has led to Silicon Valley being the producer of many of the IT-intensive innovations and disruptions forcing the rest of the world to adapt.

Of course, this potential has attracted more investments from around the world than opportunities, leading to a **bubble** of sorts. However, just as with the advent of the Internet in the mid-1990s, the fundamental changes underway today are real and will have long-lasting, transformative impact—but the uncertainty of which players will emerge victorious, and how to best make use of the Silicon Valley ecosystem, has led to the current situation where there is probably more funding than good opportunities. It must not be forgotten though that the aftermath of previous bubbles revealed the truly game-changing firms such as Google, Amazon, eBay, and Tesla, which survived and thrived after the bubbles burst (both the 2000 "dot-com" bubble burst and the 2008 "cleantech" burst during the global financial crisis), the current trajectory of Silicon Valley producing firms that are disrupting industries all over the world is likely to continue, even if the current bubble bursts.

The question for large firms is how to adapt to this new world of competition, in which previously distinct industrial boundaries collapse, and human activities move towards automated and hybrid activities.

The US "open innovation" model is worth putting into historical perspective. Open innovation is a paradigm in which large firms look beyond their own corporate borders to find new sources of technology and business models.[vi] This innovation model has been popularized by US firms, but it should be remembered that this model grew out of US competitive weaknesses of the 1970s and 1980s. After the oil shocks sparked a recession, coinciding with a surge of Japanese manufacturing in areas such as automobiles, consumer electronics, and semiconductors, large US firms essentially faced a situation in which they would go bankrupt (and many did), or adjust drastically. While many large incumbents went under and others adjusted, jettisoning practices such as implicit long term employment and a primary reliance on in-house R&D. As the computer industry took off, the US model of open innovation came of age, partly driven by a new paradigm of modular design.[vii] More recently, it should be noted that Apple bought the core technologies behind its iTunes music store, as well as Siri, the voice command system, from outside. Google bought Android, its smartphone operating system, along with a wide variety of other services it eventually integrated into its own.

If startups firms are finding new ways to make use of IT tools, harnessing the power of startups into the activities of large firms will undoubtedly be critical moving forward. Large firms offer a variety of resource advantages over startups, and "disruptive technologies" are not disruptive if the incumbent large firms can adapt to them,[viii] so the challenge is how to adapt rapidly.

Massive productivity increases and radical social change often occurs only after large firms understand and make use of new technologies available. Historically, this took a long time—75 years for electrification from steam power, for example, and a couple decades for computers.[ix] This round will almost undoubtedly be faster, and new players may displace older players.

The question for places, such as regional institutions and national and local governments, is how to harness these new developments given that something like Silicon Valley is difficult to duplicate. As new uses for IT tools will continue to be discovered as processing power continues to increase with lowering costs, it is likely that startups will continue to capture many of the new uses of IT tools in ways that we do not yet foresee. Offices of 40 years ago had a vast array of workers who were specialized in tasks that can now easily be done by a single individual with a computer or mobile device—scouring file cabinets for data, manually writing numbers in large spreadsheets, typing up documents, connecting phone calls, decoding telex messages for international communications, using protractors and rulers to calculate and draw graphs, scheduling travel or making hotel bookings, et cetra. These jobs never came back. However, even relatively unskilled workers that can use computers or smartphones can tap into the vast power of IT tools to perform many of these tasks that once needed higher levels of skill. A similar wave is likely to hit with the widespread diffusion of sophisticated AI. Therefore, a question for places is how to educate and train works to equip them will general, more malleable skills to be effective users of the technology. Not everywhere can be a leader in producing the IT infrastructure, tools, or platforms that will become commonplace, and here too, the question may be how to become effective users that can adjust quickly.

Rules and Regulations will undoubtedly affect how the technologies develop and diffuse around the world. For a more detailed discussion on policy, please see:

Kenji E. Kushida, "The Impact of Digital Technologies on Innovation Policy" (forthcoming in the Handbook of Digital Transformations). PDF sent upon request. kkushida@stanford.edu

Appendix: The Radical Rise in Computing Power

A common measure of computing performance, floating operations per second (FLOPS), reveals at least a trillion-fold increase in computing power over the past fifty years. Compared to the Apollo Guidance Computer that performed the core calculations to bring astronauts to the moon in 1965, the 1985 Nintendo Entertainment System (NES), a home entertainment system marketed primarily to school-age children, had double the processing power. Compared to the world's fastest computer in 1985, the Cray-2 supercomputer, the 2014 Apple iPhone 6 has an estimated six times the amount of processing power.[1] The radically lower prices of computing power have enabled its diffusion at an incredible scale—compare the two or three Cray-2 supercomputers in the world in 1985, used largely by the government for nuclear weapons research, with the over one billion smartphones and tablets in 2015 with equivalent or greater processing power, owned by ordinary individuals around the world.

The Radical Rise in Computer Processing power
Computing power has increased a trillion-fold over the past 50 years. 1969 Apollo Guidance Computer (man to moon) = 1983 Nintendo Entertainment System 1985 Cray-2 supercomputer (world's fastest computer) = 1/6 of 2014 Apple iPhone 6 Only a few Cray-2 supercomputers existed → over a billion smartphones and tablets in 2015

The increase in processing power has been nothing short of breathtaking; Nordhaus estimates that, in constant dollars, computer performance during the twentieth century improved by a factor of 2 trillion. If calculated differently and compared to manual calculations, the improvement was up to a multiple of 76 trillion (Nordhaus, 2007). Nordhaus' data reveals the particularly rapid acceleration in the latter half of the twentieth century, corresponding with the advent of transistors and Moore's law.

---

[i] http://www.nytimes.com/2015/09/13/magazine/uber-would-like-to-buy-your-robotics-department.html?_r=0

[ii] Zysman, John, Stuart Feldman, Kenji E. Kushida, Jonathan Murray, and Niels Christian Nielsen. "Services with Everything: The ICT-Enabled Digital Transformation of Services." Chapter 4 in The Third Globalization: Can Wealthy Nations Stay Rich in the Twenty-First Century? edited by Dan Breznitz and John Zysman. 99-129. New York, NY: Oxford University Press, 2013. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1863550

[iii] Kushida, Kenji E., Jonathan Murray, and John Zysman. 2015. "Cloud Computing: From Scarcity to Abundance." Journal of Industry, Competition and Trade. doi: 10.1007/s10842-014-0188-y.

[iv] Zysman, et al 2013.

[v] Kushida, Kenji E. 2015. "A Strategic Overview of the Silicon Valley Ecosystem: Toward Effectively "Harnessing" Silicon Valley." Stanford Silicon Valley – New Japan Project. http://www.stanford-svnj.org/s/Silicon-Valley-Ecosystem-Overview-2015-m8b8.pdf

---

[1] Data from Experts Exchange: http://pages.experts-exchange.com/processing-power-compared/

[vi] Chesbrough, H. W. (2003). Open innovation : the new imperative for creating and profiting from technology. Boston, Mass., Harvard Business School Press.

[vii] Baldwin, C. Y. and K. B. Clark (2000). Design rules. Cambridge, Mass., MIT Press.; Lazonick, W. (2009). "The new economy business model and the crisis of US capitalism." Capitalism and Society **4**(2).

[viii] Kushida, K. E. and M. Ogata (2007). "When Innovators are not Implementors: The Political Economies of VoIP in the US and Japan." BRIE Working Paper(180). http://www.brie.berkeley.edu/publications/wp180a.pdf

[ix] Cohen, S., J. B. DeLong and J. Zysman (2000). Tools for Thought: What is New and Important about the "E-conomy". Berkeley, CA, Berkeley Roundtable on the International Economy, University of California at Berkeley. http://www.brie.berkeley.edu/publications/WP138.pdf