Passages To Innovation Acceleration

Authors

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Summary

The transition between the 20th and 21st centuries, the years between 1975 to 2025 to be exact, will forever mark the confluence of a series of innovations that are intimately and symbiotically related, which led to a greater interconnectedness between the digital and physical worlds.

In the digital world, one of these innovations is the advent of the Big Data, the arrival of new types and sets of data that have never before been observed, collected or analyzed. What we refer to as Big Data spans a broad spectrum of subjects and industries. In life sciences, we decode the big data of our DNA. In business, enterprises collect and monitor the big data of customer activity, compiling and evaluating each mouse click performed during every customer web site visit, identifying the various patterns that lie behind transactional success and failure. In the social sphere, big data analysts study mobile application data, tracking millions of geographical patterns and positions in order to guide us toward targeted social encounters.

All this Big Data can now be generated and collected thanks to the pervasive use of technologies, such as mobile devices and electronic sensors; shared through the rapid adoption of social media and other user-friendly and intuitive applications; and analyzed on a massive scale using the enormous processing and storage capacities enabled by cloud computing.

At the same time, in the physical world, a similar revolution is underway. The introduction of nanotechnologies and atomic precision manufacturing is redefining the production of physical goods– in terms of the exactness achieved in product creation, changes to the types of raw materials used, and a drastic restructuring of the supply chain as we know it.

In this paper, we will analyze the way the virtual and physical forces of Big Data, Cloud computing, Social, Mobile, and Nanotechnologies are highly inter-dependent and how, in a never ending cycle, advancements in one helps catapult advancements in the others. We will examine how the speed of innovation in the digital world is becoming achievable in the physical world– and how these large-scale technological disruptions affect global attitudes and behaviors.

Introduction

From a sociological, economic, and scientific perspective, we are at a momentous point in world history. This quantum leap forward in technology and the subsequent scientific, social and business knowledge are the result of a convergence of forces that will usher in a new era of scientific enlightenment, social revolution, and business Darwinism. All of which will happen simultaneously, challenging our capacity as humans and as a society to absorb and adapt to such an avalanche of change.

These fundamental transformations in how we see and do things are the direct result of certain ideas that lived long enough to become innovations. These innovations were introduced to the world, embraced, adopted, shared, spread, adapted, re-adopted, spread some more, adjusted, adopted again, and spread even further, in an ever-evolving cycle. One crucial element in this evolution is the speed at which innovation occurs, evolves, and crosses boundaries - geographic, cultural, social, economic, and many others - because it is when innovation transcends borders that it spreads broadly and gains the force and momentum needed to truly change the world.

Over the past few decades, we have experienced not one, but several phenomena that are fundamentally re-defining the speed at which innovation is introduced, evolved and spread across the globe. These phenomena are profoundly changing the way products are manufactured, supply chains are assembled, and distribution channels established.

Similar to the changes that occurred during the Industrial Revolution, these phenomena will lead many industries to cease to exist, the creation of new ones, and the reinvention of others. Those at the forefront of technology will want to be more than passive observers in this transformation; they will want to be thoughtful leaders who actively forge the way toward innovation.

Immersed In Data

Over the past decade, a persistent narrative has developed around rapid data growth– and for good reason. In 2001, it seemed incomprehensible that the world could produce one Exabyte (1 billion gigabyes) of data in a calendar year. Today, that much data is produced in a little more than a day. New business models, tools and skill sets are beginning to uncover tremendous value in this collected data.

New classes of companies are searching and finding ways to divine understanding, predict behavior and out-think their competitors, using newly learned analytical techniques that are known as Big Data. When computers first emerged, digital data was confined to information analyzed at a capacity, speed and level of accuracy that superseded human abilities, such as sensor information at a national or global scale. The scope of digital data collection has broadened from transactional data generated by the automation of business processes, to scientific data involving the geophysical landscape of an oil and gas reservoir, and to social data involving the innumerable interactions between friends.

But while the “bigness” of Big Data captures much focus, the size of data sets is but one dimension that challenges this new technology discipline. Another essential dimension is how ***fast data*** is created. Machine-to-machine interactions and a vast variety of data-generating sensors – temperature, timing, position, and acceleration - can generate staggering amounts of data in seconds. The Large Hadron Collider at CERN on the Franco-Swiss border generates one petabyte (1 million gigabytes) *per second.* At this size and speed, the volume of the data set must be reduced by a factor of 40,000 in order to be manageable by the 11,000 scientists across the globe who run experiments the data.

The ability to process large streams of fast data in a business setting requires a real-time analytical capability to complement the tools that collect and analyze large pools of historical data from a data warehouse. Once that capability is established, the practical implication of real-time analytics is responsiveness to change in market conditions, customer behavior, and traffic patterns; the possibilities continue to multiply.

Perhaps the most overlooked (or presumed) aspect of the potential of Big Data is that much of the data being analyzed is *new data*: new data from cloud or consumer applications, social interactions, location information from mobile devices, telemetry from smart machines and sensors. Not only is much of this data new in and of itself, but the permutations of its use can add a new dimension to historical data, such as combining buying patterns with climate trends or political activity.

The influence of this new data is two-fold. First, it allows us to improve the process of how innovation spreads. Consider, for example, the visibility in which our social fabric can now be obtained by analyzing Big Data collected by Facebook and Twitter interactions. By harvesting this data, we can easily devise social media techniques to spread ideas at a very fast pace and on a global scale. For example, a single video introducing an idea or a product, when targeted at the right channels and influencers, has the potential for going viral, gaining millions or even billions of views within a matter of days.

Second, this new data is technology's natural resource, giving us raw material that now makes many technology-driven decisions and innovations possible. Consider, for example, the field of personalized medicine that intends to shift cancer treatment away from chemotherapy, which affects all cells in the human body, toward a more precise treatment that targets only the mutated cells. With the availability of such new technologies, scientists have access to a representative sample of genes, from healthy individuals--or the control group-- and from individuals affected by a particular disease; they then use massive amounts of computations to perform the comparisons and identify the specific mutations and to understand their side effects.

Global Nervous System

Big Data is not the only disruptive technology trend occurring. Cloud computing refers to the astronomical quantities of processing power, storage capacity, and networking connectivity that major enterprises, universities, communities and Cloud providers are building and aggregating. These providers typically assemble massive infrastructures and offer compute- and storage-as-a-service, where consumers pay per-usage, on demand, with zero up-front capital investment.

Consider Netflix, for example, as it accounts for nearly one third of the internet traffic in the United States. Yet Netflix owns no data centers and runs its entire operation in the Cloud. The wasteful approach to funding high tech startups in the early 2000s included outsized capital investments in data centers, hardware and software. This significantly contributed both to the many failures of the era, but also to the economic bubble and subsequent bust of the high tech economy. Today, the cost of entry into the *lean startup* world – be it high tech, life sciences, or pharmaceuticals – is far lower and vastly more predictable, which is a major enabler of innovations across industries.

The creation, collection, aggregation, analysis and storage of Big Data are propelled by the Cloud technologies and Big Data's pervasive presence has become cost effective by the economies of Cloud. In fact, there is a strong symbiotic relationship between Cloud and Big Data where Cloud enables and accelerates the creation of Big Data. The exponential increases in Big Data force the expansion of Cloud, where the heightened demand for processing and storage capacity accelerates technology development and hastens commoditization of technology components.

Today, Big Data and Cloud are accessible to the masses by the global use of Mobile devices, and the emergence of social networks. Both trends have facilitated a more intuitive and seamless interaction among people on a worldwide scale. Advances in digital technology create an environment in which technology is ubiquitous, encouraging society to re-learn how it lives, communicates and works. Society is becoming progressively more dependent upon mobile and social networks that are enabled by the advances in Cloud computing.

To put this in perspective, there are 6.8 billion mobile-cellular subscriptions worldwide, accounting for 96% of the human population. As more and more individuals worldwide attain mobile access, social networks continue to expand their reach as well. Facebook, for example, reached 1.15 billion users as of June 2013, an year over year increase of 21% . LinkedIn and Twitter are both growing by more than 30% year over year.

Developing nations, such as Brazil and India, account for much of the recent growth in these social networks. The rapid adoption of mobile devices on a global scale, is rapidly obviating distribution channels of the past, as social networks expand their worldwide influence. This has created a new generation of digital distribution channels that deliver everything in real time with an unprecedented reach.

Nanotechnology

In 1981, K. Eric Drexler [2] introduced the concept of nanotechnology, a technology whose manufacturing is based on mechanical devices operating at nano-scale. To measure something in nano-scale is to measure it in the 10^{-9} of one atomic diameter, a unit named a nanometer, which is one billionth of a meter. Comparatively, a human hair is about 100,000 nanometers wide. Nanotechnology products are built with atomic precision by binding, positioning and combining atoms or molecules to form objects of amazing complexity, a process referred to as Atomic Precision Manufacturing [APM].

In [3], Drexler draws a parallel between the digital and the physical worlds, as illustrated in Figure 1. In the digital world, "digital *information* processing technologies employ nano-scale electronic devices that operate at high frequencies and produce patterns of *bits*." In the physical world, "APM-based *materials* processing technologies will employ nano-scale *mechanical* devices that operate at high frequencies and produce patterns of *atoms*." These atoms are combined or assembled together to form objects of an amazing complexity and of sizes varying from nano-scale objects, such as a replica of a racecar the size of a grain of sand, to actual size automotive parts.

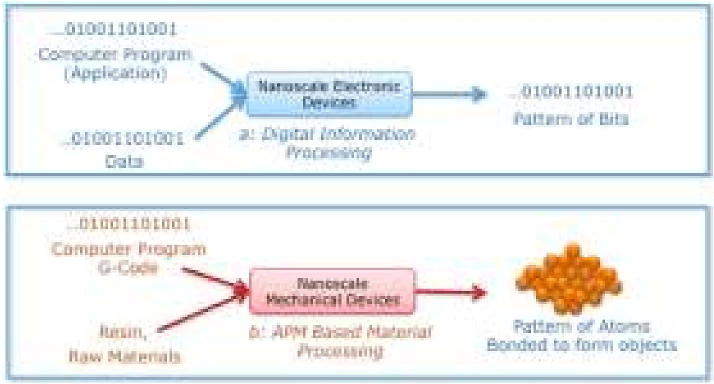

Figure 1: Digital Information Processing versus Material Processing Technologies

APM causes two major disruptions to the world we know today. First, through the rise of 3-D printers, APM has indirectly been introduced to the consumer market, as illustrated in Figure 2. 3-D printers are devices that use nanotechnology to print not the pictures of objects, but the objects themselves. 3-D printers typically deploy an additive manufacturing process whereby they generate, or *"print"*, molecules at atomically precise spots and bind these molecules together to form an object by creating and stacking each one of its layers from bottom to top. CAD software provides 3-D printers with information on what to make and how to make it, while "G-Code" is the fabrication language used, which commands the motors.

Second, the types of raw materials used in APM are abundant and inexpensive resources that are easily obtained. Common materials are resin and molten thermoplastics, such as ABS and PLA, due to the ease at which they melt and their ability to be reprocessed. For example, a shower head can be manufactured from PLA, at a cost of about $2.50. Other materials range from metals, such as steel, gold, silver, bronze, and titanium, to glass, nylon, chocolate, and even Bio-Ink.

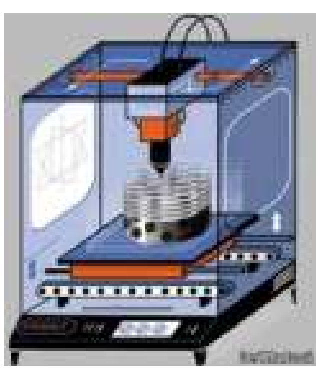

Figure 2: 3D Printer

With 3D printing, creating similar or different products costs the same and can be produced in varying unit sizes. As Anderson highlights in [1], features that are typically expensive in traditional manufacturing, such as variety, complexity, and flexibility, are free with digital fabrication. The computer is blind to the level of complexity and number of calculations it must undergo, and the calculations can be easily tweaked if the digital models need alteration. This renders specialized goods increasingly and easily accessible at more affordable prices.

Consumerization of Digital and Physical Innovation

Converging Elements of Transformation

Typically, production of goods follows a traditional sequence of steps, from the moment that raw materials are gathered, until the final product reaches the consumer, be it a business or an individual.

Figure 3.a illustrates a simplified view, whereby raw materials make their way into a manufacturing facility that transforms these materials into a product that is sent to distribution channels. The final product reaches retail outlets and the end consumer thereafter.

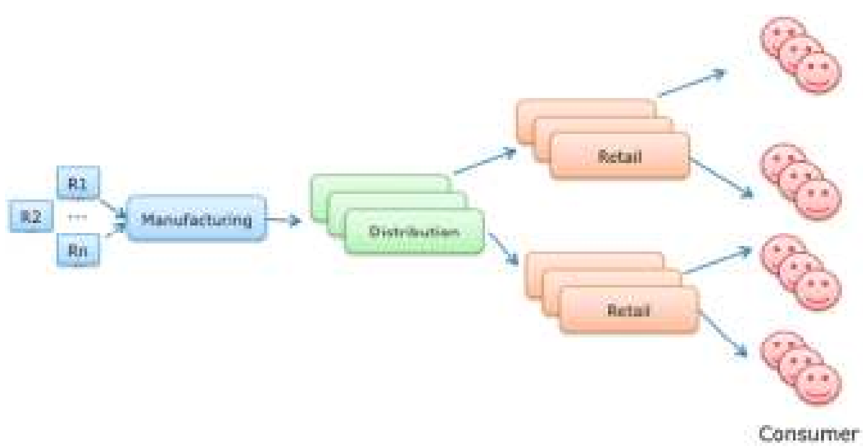

Figure 3.a: Traditional Production Chain

Figure 3.b illustrates a more complex process, whereby the output of a manufacturing process becomes the raw material for another manufacturing process, which can happen multiple times until it becomes a final product and reaches the end consumer. This process was used not only for the commercialization of physical products, but also digital products, as we previously purchased these software programs stored in compact disks (CDs) in retail stores and outlets.

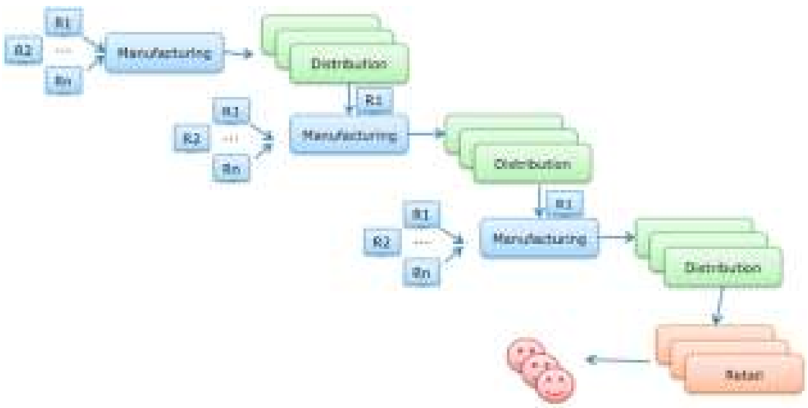

Figure 3.b: More Complex Production Chain

The advent of Big Data, Cloud, Mobile and Social networks has fundamentally changed the flow in the production of digital goods, as illustrated in Figure 3.c. Human capital acts as the most important resource in the production of digital goods, as it yields new ideas and the expertise and willingness for implementation.

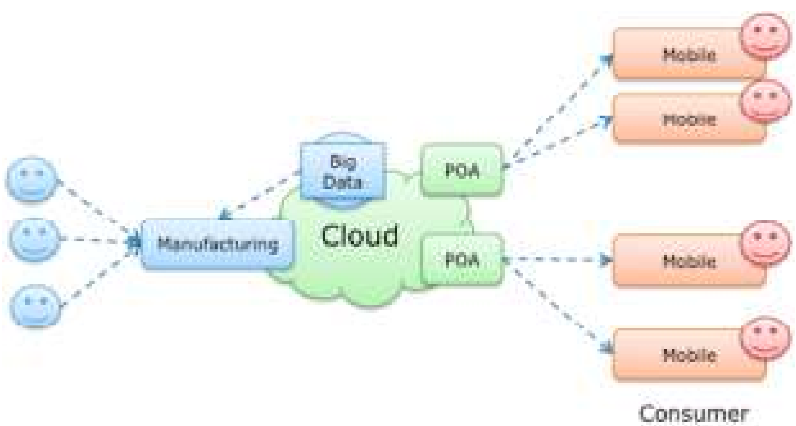

Figure 3.c: Production Chain Modified by Cloud, Big Data, Social and Mobile Events

The availability of Big Data has become a critical raw material in the manufacturing of digital goods. For example, in the scientific world, the availability of thousands of genomes has enabled individuals—not just major research departments in well known pharmaceutical companies—to analyze data and create applications to identify mutations in genes associated with the presence of certain types of cancer. Big Data has also given entrepreneurs access to tremendous amounts of data about consumers, their preferences, and their needs, allowing the entrepreneurs to segment the market in many different ways and specifically target their offerings.

Cloud platforms have become the manufacturing facilities and distribution channels for the digital world. Applications deployed in the Cloud, such as the Apple Store and Amazon, have assumed the role of eRetail, becoming points of access (PoA), and connecting consumers to digital goods. The collaborative environment of the social, mobile, and cloud have enabled people all over the world to collaborate on elaborate and highly customized product designs. Nanotechnology, APM, and 3-D printing are now changing the production process in the physical world.

Traditionally, computer innovations were rendered solely in the digital world in the form of digital applications, reports and visualizations. To create physical goods, manufacturers created factories run by proprietary teams with proprietary tools and techniques who maintained control over the production process. In this model, the largest shareholders, who provided the most capital, retained the largest control and profitability of the product. Control was retained due to either barriers to entry in terms of capital or location of raw materials, or expertise in the process of transforming raw materials into the final product. Not anymore.

The efficiencies of production gained in the digital world can increasingly be realized in the physical world through nanotechnology. The inverse economies of scale of nanotechnology and the consumerization of the manufacturing process promote a more democratized, self-manufacturing ethos. Individuals can either buy a 3-D printer or utilize manufacturing brokers in order to transform their digital designs into physical objects, forever changing and re-shaping the manufacturing world, as illustrated in Figure 3.d.

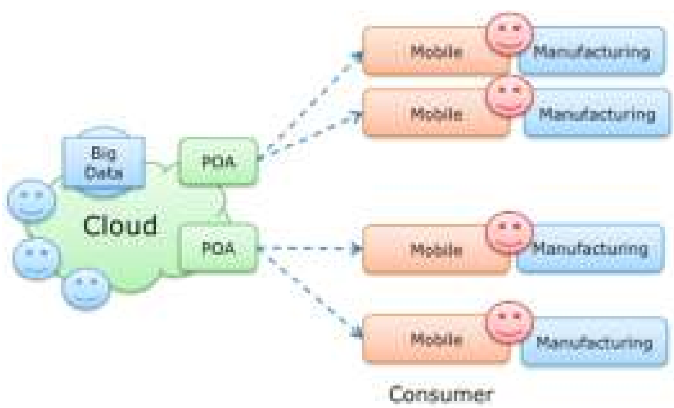

Figure 3.d: Production Chain Modified by Nanotechnology and 3-D Printing

The significant increase in the number of participants manufacturing their ideas and utilizing their expertise will promote specialization and begin to realize the notion of mass customization. The combination of abundant and inexpensive raw materials, together with the consumerization of 3-D printing, will rapidly reshape the role of manufacturing, the supply chain, and distribution channels.

The digital world has increased variation among products by overcoming distribution constraints with its unlimited capacity and possibilities for truly meeting individual needs and tastes. The Web’s ability to tap global markets has allowed “niche products”—as Chris Anderson calls them—to surface as it creates sufficient demand. Manufacturing will no longer be restricted to regions with ample raw material.

Furthermore, burdensome financial and capital investments will no longer stand as barriers when entering the manufacturing business. APM will ultimately cause a long tail of small niche manufacturing facilities, where big data analytics-driven design will retain most of the value in the production chain.

Three-D printers enable individuals to create customized products for themselves, and produce their digital designs through factories with the on-demand service of web-based manufacturing [1]. Those with innovative ideas no longer need a company or factory to bring them to fruition, only the right vision and software.

The economies of Cloud have enabled the development of global-scale applications, such as YouTube and Facebook, that can connect millions of people. For a great percentage of the population, these platforms provide a simple way to consume and share data, and provide an easier way to communicate than through reading and writing alone. Consequently, we become producers and consumers of Big Data in huge masses.

The digital era and the pervasive presence of the Cloud also eliminate the limitations of place and time, allowing content produced anywhere to be accessed anywhere, which results in Big Data being shared and disseminated everywhere. The introduction of inverse scale, as well as the affordability and wide availability of 3-D printers, is rapidly leading to self-manufacturing of highly customized items that will cost approximately the same if produced in one unit or in thousands of units. The cost of 3-D printers range from $200 dollars to a few thousand dollars.

The innovation accelerators identified here connect the innovations in the digital world with innovations in the physical world, fundamentally affecting the speed at which society propels forward, as illustrated in Figure 3.e.

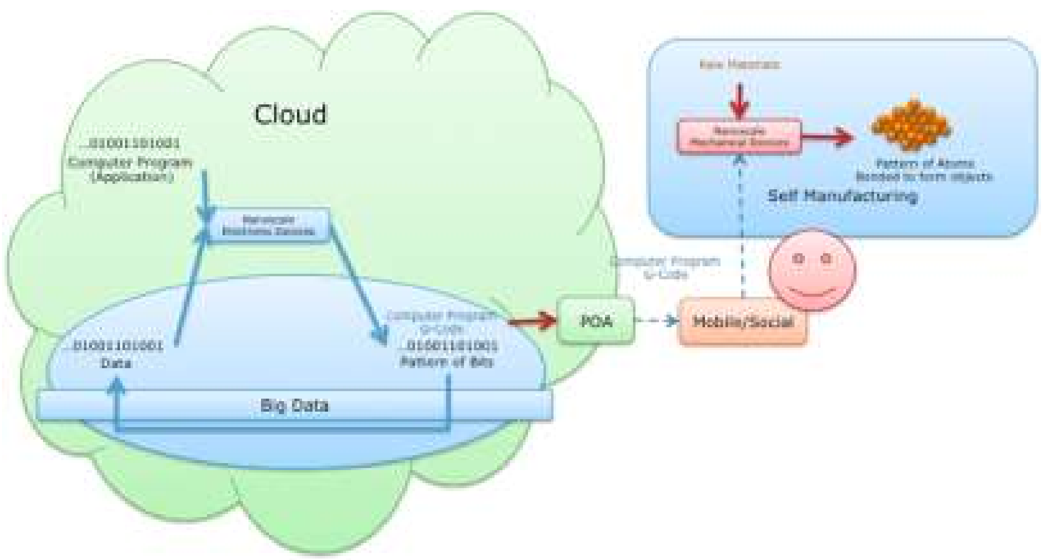

Figure 3.e: Connectedness of Innovations in the Digital and Physical Worlds

In this new world, Big Data provides a mechanism for collecting and assembling data that will allow us to understand customer preferences, have ideas, segment the market, and best design the appropriate solution in an educated, informed manner. Cloud will function as a means to process and digest all the data in a cost-effective manner, while social and mobile applications will provide the means for collaborating effectively, while also serving as both promotional and distribution channels for the resulting new products and ideas.

APM and 3-D printing have enabled inversed scale manufacturing [1] where products are designed and produced to meet the personal needs, habits, and other preferences of individuals, at no extra cost. Individuals can create their ideas or inventions by designing 3-D objects onscreen through the use of desktop CAD tools, which can be printed locally with their own 3-D printers or desktop fabricators, or they can send their files to a service bureau to manufacture their product in any desired volume.

Companies, such as Autodesk, PTC, 3D Systems, and service bureaus provide free design software that enables people to materialize digital designs through the means of 3-D printers or Laser Cutters. For example, Autodesk has a free 123D CAD program that provides two options in the "Make" menu option: individuals can "print local" through their own 3-D printers, or "print global" by sending their designs to a service bureau. Ponoko allows individuals to customize digital designs, upload them, and choose the materials and hardware used in the manufacturing process. Ponoko subsequently prints or laser cuts the digital design at the time of purchase. Individuals can sell their products on the Ponoko website or in their own retail stores.

Conclusion

As Cloud, Big Data, Social and Mobile focused innovations become more pervasive and influence disruptions in the digital world, we often divert our attention away from major technology-driven disruptions occurring in the physical world, and fail to see the connectivity between the two. The confluence of all these accelerators happening concurrently is creating a unique, historic momentum leading to the consumerization of innovation introduced in the digital world, via applications on mobile phones, for example, and the consumerization of innovation introduced in the form of physical objects, via APM and 3-D printing, as illustrated in Figure 4.

Nanotechnology enables massive amounts of data to be generated through nano-scale devices. These nano-scale devices can be inserted anywhere and measure anything, such as in nano-medicine, where nanobots are injected into our bodies to measure and collect vital signs and other aspects of our health.

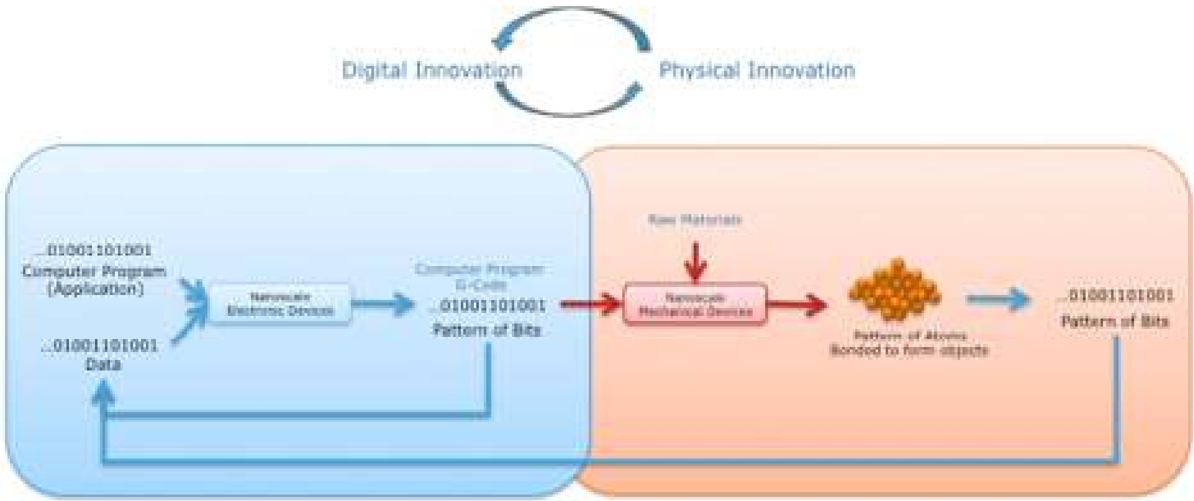

Figure 4.b: Symbiotic Relationship Between The Digital and Physical Worlds

In this new age of accelerated innovation, we are experiencing the democratization of knowledge and creativity with the ability to manifest innovation in both the digital and the physical world. It is the democratization of both innovation and entrepreneurship, largely due to the democratization of the means of production. These converging phenomena mean that, unlike any other time in human history, literally anyone, anywhere can be an inventor, because the age-old barriers to entry no longer exist in this new world.

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Short Biographies.

Patricia Florissi holds a PhD in Computer Science from Columbia University and is an EMC Corporation Distinguished Engineer. She graduated valedictorian with an MBA from New York University's Stern Business School and earned both MS and BS degrees in computer science from the Universidade Federal de Pernambuco in Brazil. She holds multiple patents and has been published in periodicals such as *Computer Networks* and *IEEE Proceedings*. Patricia Florissi is the author and narrator of the EMC Big Ideas series of educational animated videos that can be found be found at http://bit.ly/EMCBigIdeas and has more than 200,000 views all together. Several of her videos are on the topic of Big Data.

George Demarest is a 25-year veteran of the high-tech industry, with a tenure that has included software development and marketing roles at AT&T Bell Laboratories, UNIX System Laboratories, Oracle, and EMC. Most recently, he has focused on cross-product marketing and technology architecture, including operating systems, relational databases, clustering technology, grid/cloud computing, and BI/analytics.
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Jessica Rabe will graduate from Gordon College with a BS in Economics in December of 2013, aggregately finishing in two and a half years. She participated in Gordon's honors program, and will graduate summa cum laude. She recently interned at EMC Brazil's Big Data Research and Development Center in Rio de Janeiro, Brazil, and previously for U.S. Congressman Rodney Frelinghuysen. Jessica Rabe currently blogs for The American Enterprise Institute's Values and Capitalism initiative, has contributed articles to The Center for Public Justice's online journal, "Shared Justice," and founded the Global Perspectives column in the Gordon College newspaper.