Living in a Sudoku World: The Societal Shift Caused by Technology's Integration Into Our Every Day Lives

Christina Hu

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Advisor: John Tresch

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Chapter I: The shifting puzzle landscape

What puzzles tell us about ourselves

Popular culture has traditionally been an important sociological and anthropological tool. While 'pop culture' has sometimes been a contentious term, it generally refers to "beliefs and practices, and the objects through which they are organized, [which] is widely shared among a population."[1] Many studies have been devoted to examining what constitutes popular culture – what items or ideas have pervaded mainstream society? How have they been produced, consumed or understood? More importantly, how can we understand the "characteristics of the industries that produce [them]"?[2] Artifacts of popular culture dovetail nicely with cultural emphases; they are shaped by contemporary values and as such, reflect societal movements over time as illustrated through what we find interesting, entertaining or funny. They have the potential to generate tremendous insight into what we think, and why we think what we do.

Puzzles play an interesting role as an occasionally overlooked, but significant, part of popular culture. They have long captured the fascination of human beings; since the dawn of ancient times, people have been instinctively drawn to mysteries and the unknown. One of the oldest surviving manuscripts, the *Rhind Papyrus,* is an ancient collection of puzzles dating back to the Egyptian Hyskos dynasty, which was in power around 1650 BC[3]. This manuscript was copied by the Egyptian scribe A'h-mose, or Ahmes, who wrote that puzzles grant "entrance into the knowledge of all existing things and all obscure secrets."[4] His words suggest a deeper meaning to puzzles, an indication that our penchant for consuming puzzles extends beyond a human need for entertainment. There is a more powerful force driving our interest, whether that is a natural compulsion to solve things or an unconscious embrace of larger social trends.

There is no question that puzzles are once again enjoying their moment in the sun; the twentieth century saw the creation of a number of popular puzzles, which have inspired the formation of dozens of associations, competitions and publications. Hundreds of thousands of puzzle books are sold annually and puzzles of all sorts fly off the shelves at Christmastime. Yet, the puzzle landscape has begun to shift within recent years. Puzzles exploring mathematical concepts and logic, as exemplified by the seemingly overnight success of Sudoku, are experiencing resurgence in attention over literary ones such as crossword puzzles, which have enjoyed immense popularity since their invention in 1913. The changes within the puzzle landscape is reflective of a larger societal shift; as a result of modern technologies, an increased value has been placed on the ability to exercise quantitative and logical thinking, rather than argumentative and critical thinking.

While Sudoku puzzles were not presented in their modern form until 1979, they are a derivation of Magic Squares, which first appeared nearly 4000 years ago in China. A magic square is a square that is divided up into little cells. Each of the rows, columns and diagonals, when filled with consecutive numbers, sums to a magic number. Magic squares originated in ancient China circa 2200-3000 BC; as legend has it, the mythical Emperor Yu noticed a three-by-three magic square marked on the underside of a sacred tortoise emerging from the Lo River. These magic squares were thought to have supernatural powers by the Chinese and were often inscribed in talismans and amulets to bring good fortune and protect against evil.[5]

Magic squares quickly spread to the Arab world and Europe, where they continued to be treated as mystical symbols. They surfaced in India by the first century AD, where they were strongly associated with astrology and the "great mysteries of the universe"[6]; each of the planets was represented with magic squares of different orders, and as magic squares continued to spread, they became filled not only with Arabic numerals, but also Christian words and Hebrew letters. As they spread throughout the medieval world, magic squares were considered to be "reifications of hidden…patterns that governed the universe."[7] They continued to capture the imaginations of philosophers and artists everywhere as people were mesmerized by the patterns that existed among the numbers and considered them to be representations of supernatural forces at work.

These magic squares eventually came to be treated as mathematical and logical tools, particularly after the invention of Latin Squares. Latin squares are an offshoot of magic squares created in the eighteenth century by Leonhard Euler, a prolific Swiss mathematician. A Latin square has the same square design as a magic square; it is filled in such that each number (or Latin letter, as Euler used) appears once in every row and column:

A	B	C
B	C	A
C	A	B

B	C	A
C	A	B
A	B	C

C	A	B
A	B	C
B	C	A

Latin squares have a multitude of real-life applications; for example, since the 1930s, they have been heavily incorporated into combinatorics and the statistical design of experiments.[8] To illustrate the idea, say that you would like to bake a cake for a friend's birthday celebration. After doing some research, you have concluded there are three different flavors of cake (fudge, vanilla and lemon) that you think your friend would like. However, you own three toaster ovens, which have been permanently set to three different temperatures (350°F, 400°F and 450°F.) In order to properly design your experiment and bake the best possible cake, a Latin square can be interpreted as a baking schedule:

Fudge 350°F	Vanilla 450°F	Lemon 400°F
Vanilla 400°F	Lemon 350°F	Fudge 450°F
Lemon 450°F	Fudge 400°F	Vanilla 350°F

While the cake example was rather simple, its use of Latin Squares can be easily expanded to experimental planning in any number of real-life industries: testing pesticides on a variety of crops by carving up the field into a physical Latin Square, for example, or running clinical drug trials on sick patients to determine the most effective dosage and frequency combinations. More complicated problems can be properly analyzed by stacking sets of mutually orthogonal Latin squares or by simply building larger squares.

What most people know Latin Squares for, however, is their use as the basis of the modern Sudoku puzzle. Let's begin by looking at an easy Sudoku puzzle.[9] A starting grid might look something like this:

		9		6	2		1	
7		1		3			6	
5							7	8
8	3			5	1	9	4	2
4	6	5	2	7			8	3
2	1							6
	5		8			7		4
	7		3	2		8		

Look familiar? Each beginning Sudoku clue is simply an incomplete Latin Square of order 9. The rules are simple: complete the Latin Square, with the added restriction that each sub-square also only contains each number once. In other words, fill out the grid such that each row, column and 3x3 sub-square contains the numbers 1 through 9 without repetition.

Let's go back to the puzzle, and start by picking an empty square on the grid, such as the one denoted by the X:

		9		6	2		1	
7		1		3			6	
5							7	8
8	3	X		5	1	9	4	2
4	6	5	2	7			8	3
2	1							6
	5		8			7		4
	7		3	2		8		

What number could go in the box? We know that each row, column and sub-square can only contain the digits 1 through 9 once.

		9		6	2		1	
7		1		3			6	
5							7	8
8	3	X		5	1	9	4	2
4	6	5	2	7			8	3
2	1							6
	5		8			7		4
	7		3	2		8		

		9		6	2		1	
7		1		3			6	
5							7	8
8	3	X		5	1	9	4	2
4	6	5	2	7			8	3
2	1							6
	5		8			7		4
	7		3	2		8		

The sub-square already contains the digits 3, 4, 5, 6 and 8; similarly, its row already contains the digits 1, 2, 3, 4, 5, 8, and 9. Thus, there is only one possible value left to go in the box:

		9		6	2		1	
7		1		3			6	
5							7	8
8	3	7		5	1	9	4	2
4	6	5	2	7			8	3
2	1							6
	5		8			7		4
	7		3	2		8		

Sudoku is often touted as a puzzle that requires no math. "Don't be fooled by the presence of numbers," newspapers assure their readers. "No math needed here." Yet, Sudoku is absolutely a math problem – although no counting, arithmetic or algebra is required (no need to add or subtract any of those pesky numbers!), Sudoku puzzles are solved through pure logic, the true foundation of math. The core of the mathematical discipline (and really, every field of science) is grounded in the use of deductive reasoning; arithmetic and algebra are simply the tools to get us there.

Since the introduction of Sudoku puzzles, they have achieved widespread popularity around the world. Howard Garns, an American architect, "invented" Sudoku in 1979, where it was published under the name "Number Places" in Dell magazine. There, the puzzles went virtually unnoticed until they were discovered by Nikoli, a Japanese puzzle publishing firm. After making some adjustments, such as decreasing the number of clues in the grid, Nikoli included the puzzle in one of its magazines. It quickly became the best-selling puzzle in Japan under the name *Suji wa dokushin ni kagiru* ("the numbers must be single"), which was eventually shortened to the familiar *Su-doku* ("single numbers.")[10] Sudoku remained largely sequestered in Japan until 2004, when retired judge Wayne Gould persuaded the *Times of London* to publish Sudoku puzzles. Within months, every British paper was running these now-wildly popular games. Under the influence of British pop culture, and in a fascinating case of transcultural transmission coming full circle, Sudoku rapidly returned back to the United States, where it was picked up by the New York Post in 2005. Its meteoric rise led to dozens of Sudoku books, the formation of both

U.S. and world Sudoku championships, the manifestation of countless variations and amusingly, a 700% increase in pencil sales.[11] The wildfire spread of Sudoku was the fastest introduction of any puzzle in newspapers since the crossword gained popularity in the mid 1920s.[12]

In fact, Sudoku gained so much traction that it caused many crossword enthusiasts to worry that their favored puzzle would be nearly eliminated. As newspapers scrambled to find space to accommodate these puzzles, some ambitiously publishing Sudoku puzzles on every page, crosswords were often pushed to the side. In bookstores, shelves were cleared of crossword books to make room for Sudoku anthologies, which were being snapped up like hotcakes. Will Shortz, the well-known editor of the New York Times crossword puzzle, released a series of Sudoku puzzles that sold millions of copies; in contrast, his "crossword titles were deemed rocketing success stories if they sold 150,000 copies in four years."[13]

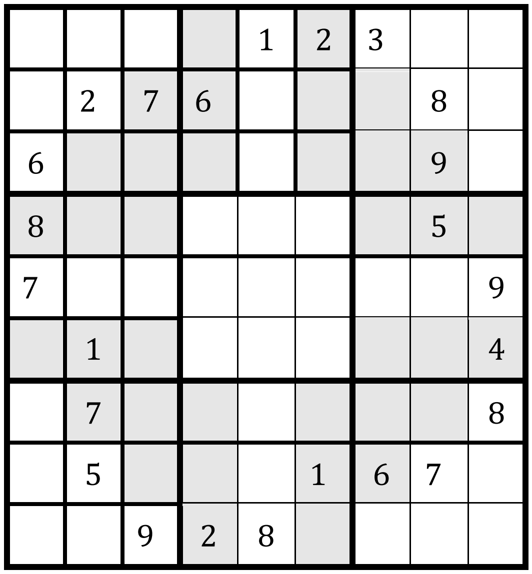
There are many theories as to why the Sudoku craze spread so rapidly; its allure may be at least partially attributed to the fact that it contains an element of universality that crossword puzzles lack. Crossword puzzles rely heavily on popular culture and literary quirks for their resolution. This "cultural specificity"[14] makes it difficult for someone who easily solves *New York Times* crosswords, for example, to solve a puzzle from the *Daily Telegraph*. It also generates a temporal gap, which although "infinitely easier to overcome," severely restricts how people of varying ages can interact with puzzle clues together. Different generations possess entirely distinct subsets of pop culture and trivia knowledge, which limits their opportunities to share a special eureka moment of enlightenment.

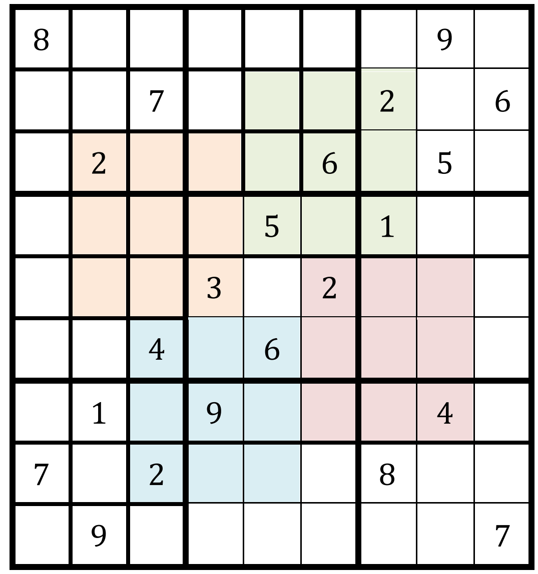
This, of course, speaks nothing of the inherent lingual barriers posed by crossword puzzles. The key to solving crosswords often lies in the ability to pick apart linguistic and grammatical cues embedded within the clues; the art of puns is entirely lost in translation. In contrast, Sudoku's numeric nature allows it to transcend boundaries. Sudoku puzzles can be written anywhere, played anywhere and enjoyed by people of all backgrounds, ages and cultures. As its own transcultural ascent to stardom can attest to, Sudoku is truly an international experience, one that can be shared, understood and appreciated by a diverse spectrum of audiences.

Critics might consider Sudoku's universality to pander to the lowest common denominator. There is something to be said for the resulting loss associated with a simplistic game; crossword enthusiasts have built a remarkable culture around people who "cherish vocabulary and wit, prize precision and accuracy, and who believe it is a moral good to read widely."[15] As Jack Rosenthal, an editor at the New York Times put it, crossword culture offers "a slice of the intelligentsia,"[16] and perhaps a hint of elitism. To excel at solving crosswords, one must often be well versed in literature, history and trivia; crosswords test the bounds of the English language by crafting tricky puns and utilizing language in novel ways. In contrast, critics lampoon Sudoku for being generic or downright boring.

Admittedly, Sudoku puzzles can often seem plain, largely due to the fact that most of them are written by computer programs; as all fads are, Sudoku is heavily dependent on new technologies. As Will Shortz wrote, “Every puzzle craze in history has come along at an opportune time, and the same is true of Sudoku.”[17] The popularization of Rubik’s Cube, for instance, in the early 1980s involved a new manufacturing process that allowed the puzzles to be made. Similarly, crosswords required not only an educated audience, but also the ability for newspapers to print these grids easily; this did not occur until the 1920s, which allowed crosswords to gain significant traction. The rapid mass-production of Sudoku puzzles requires intricate computer algorithms to verify that they each have a unique solution, provide the right clues and are rated accurately for difficulty. All of these things would be tedious and time-consuming to do by hand; however, with a simple click of a button, dozens of puzzles can be generated instantaneously.

Yet, these critics overlook the beauty hidden within Sudoku’s gridded lines. Sudoku requires no prior knowledge or training; its strength lies in that it opens up a world of logic to anyone who is interested. All that is required is willingness – a willingness to tinker with the puzzle, to experiment and even to take intuitive leaps. While critics often mistake its simple structure as dull and limiting, Sudoku puzzles can be beautifully crafted. Many puzzles have ben carefully designed, with starter clues arranged in an array of patterns; other puzzles delight in their simplicity, requiring a particularly clever flash of insight to complete a minimalist grid:[18]





This seemingly simple grid holds endless possibilities for permutation. Nearly 5.5 billion unique grids are possible, [19] many of which require just as much thought as a well-designed crossword puzzle. When compounded with the option of adding new rules (to mandate, for example, that the board is further divided into different jigsaw or pyramid shaped regions which also must contain the numbers 1-9 only once, as shown in the two examples above), it is clear that Sudoku can transform into a complex beast.

This discussion of Sudoku's appeal, of course, overlooks the most obvious explanation of all: it's fun. There is a psychological hook associated with the nearly euphoric rush of satisfaction as the solver experiences an a-ha! moment and is able to fill in a number of cells in rapid succession. On a deeper level, however, there is something intensely captivating about Sudoku's innate character. It gives the player a feeling of "being in control"[20] and provides a "powerful form of escapism from the ups and downs of every day life."[21] While life rarely provides a clear-cut, black and white solution, a Sudoku puzzle does – it allows us to wade through the confusing to impose a semblance of order, something that rarely happens in the larger real puzzles of life. Our rationality allows us to eliminate the false and strip away the numbers that don't fit, until we reach our solution. By thus proceeding methodically and thinking logically, Sudoku allows us to "distill complication into elemental clarity."[22]

Evgeny Morozov, a Russian writer and researcher, termed this new concept "solutionism": the idea that there exists a singular solution to every problem, and by thinking rationally, logically and algorithmically, we will be able to discover it. It is interesting that Sudoku captured the notion of solutionism so brilliantly; undeniably, there is a relation between the two. Just as Sudoku gained traction within the international community, so did the idea of solutionism. It has evolved into a major societal trend that pervades all corners of human society.

The rise in solutionism is caused, in large part, by the increased presence of technology into our everyday lives. Morozov claims that technology is the vehicle through which we realize our solutionism – through technology, we are able to come up with the solutions to fit our needs. Want to lose weight? Let's write an app for that. Want to measure chemical levels within the body? Let's code a machine to do that. For the puzzler, Sudoku brings the luxury of the same, logical procedure by which we can solve the problem – by methodically applying logic and rationality (indeed, by programming and thinking like a machine), we arrive at the solution. For many, it's a form of escapism, a way to impose order on the chaos and madness of our every day lives. Yet, it hints at a shifting attitude in society, one that is driven by technology and its motivations.

In Morozov's book *To Save Everything, Click Here: The Folly of Technological Solutionism*, he quotes Google executive chairman Eric Schmidt on the very first page: "Technology is not really about hardware and software any more. It's really about the mining and use of this enormous data to make the world a better place."[23] Schmidt isn't necessary introducing a revolutionary idea during his speech; rather, he is voicing something that has been filtering through society's subconscious. Whether this is driven by Silicon Valley or not, society is experiencing a shift towards quantification. There is a new value assigned to tracking behavior, quantifying information and mining the resulting data – information about our world is being boiled down into numbers and code. This is useful for not just coders, but for everyone – marketers, for example, can use this data to maximize profit despite marketing being a field traditionally dependent on creativity and other 'soft' skills. The ability afforded to us by coding and quantification is changing the way we look at and interact with the world beyond us, particularly as we recognize the huge Internet presence in our lives. The more time we spend online, the more our activities are noted and being fed into algorithms somewhere to the point where our activities are predictable. We have all become machines and Sudoku (whether by design or not) taps into that subconscious quality.

Chapter II: Data is the New Black

The Rise of Big Data in Our Sudoku World

The sheer amount of data in the world around us has been increasing exponentially in recent decades. Companies are constantly collecting trillions of data points about each of their customers, captured either through our online activity (in part facilitated by the explosive growth of social media) or through the millions of sensors embedded within our physical world today, which constantly stream information about us. Our entire world has been altered by the increased accessibility to mobile internet – it has changed the way we perceive, understand and interact with the world around us.

The collection and subsequent analysis of data has infused every part of our world today; it has fundamentally redefined the way each and every sector of the global economy functions today. The full utilization of Big Data is responsible for a substantial segment of modern growth and innovation and has become a highly relevant topic for everyone – not just leaders of industry – to consider going forward. Its infiltration of our world today, as facilitated by the improvement of computing technologies and mobile internet, has caused us to think differently not only about the world today, but also how we think about our future – most significantly, our children.

Big data is the latest global phenomenon. The proliferation and use of digital technology has increasingly allowed us to generate, share, access and analyze data from the world around us, and from each other. To fully appreciate the sheer scope of the situation, let's take a step back. For instance, out of the world's seven billion people, nearly six billion people have access to mobile phones.[24] This is more than the number of people who have access to basic sanitation, such as a working toilet.

The accessibility of networked technology is astonishing and thanks, in large part, to the amazing growth of computing capabilities. Technology has come an incredibly long way since the clunky days of Charles Babbage's Analytical Engine and the ENIAC – since then, our "computers" have morphed from large, unwieldy machines into sleek rectangles patterned in silver and white, easily slipped in pockets and purses.

The rate of improvement has been incredible. Consider the fact that the average cost of storing a gigabyte of information has decreased from the whopping $437,500 in 1980 to a mere $0.05 in 2013.[25] Or, perhaps the fact that the fastest supercomputer in 1975 cost $5 million to produce, nearly 125,000 times the cost of an iPhone 4 with equivalent processing power. [26] These new technologies have played a pivotal role in transforming the world around us. Our ability to generate and store digital information has caused a massive shift in how we interact with the world around us; in a sense, our worlds have become dominated by algorithms, quantification and the ability to analyze data.

The transformation of computing technology has been nothing short of impressive. Traditional histories of digital technology tend to begin in 1830, with the introduction of the Analytical Engine. The Analytical Engine was the brainchild of Charles Babbage and Ada Lovelace, and constituted one of the first general purpose computers ever produced. Although never fully finished, the Babbage's Engine provided two key features: (1) the "automatic storage and retrieval of information in coded form," and (2) "the automatic execution of a sequence of operations."[27] Importantly, his machine was able to handle the "[abstraction of] information away from its physical substrate."[28] Rather than simply manipulating numbers as many previous calculators did, Babbage's proposed engine could handle variables, the representation of numbers and of process. Its ability went beyond simple computation but, as Ada Lovelace explained, it performed operations – "any process which alters the relation of two or more things."[29] Lovelace's sequences of operations would later be called algorithms and, in more recent history, recognized as a computer program. She envisioned the Analytical Engine as an "engine of information" rather than a simple "engine of numbers". However, as Babbage admitted, the engine was ahead of its time; coupled with a number of technical difficulties in the production process, Babbage and Lovelace's Analytical Engine remained unfinished.

It wasn't until nearly a century later that Alan Turing described his theoretical device that would extend the relationship between arithmetic, binary logic and a computing machine. His Turing machine was the first theoretical discussion of "the fundamental quality of computers" – the idea that computers can process an infinite number of operations, if humans can properly program these actions. A computer, in many ways, is anything a programmer wants it to be; it's not just a machine, but also a universal machine with unlimited potential. As engineers began designing these machines in the mid 1930s, they took a renewed interest in Babbage's work. These concepts, however, remained solely theoretical until hardware was adequately developed decades later.

Early computers were excessively inaccessible to the common person. They were large, difficult to operate and prohibitively expensive for the average layman.

ENIAC, for example, was the first general purpose electronic computer. To say the least, ENIAC was sometimes affectionately referred to in the media as the "Great Brain." Certainly, it had an unprecedented amount of computing power, something that wildly excited scientists and engineers at the time. Yet, it was also a behemoth of a machine, clocking in at over 20 tons, taking up 1800 square feet and consuming 150 kilowatts of power. It cost $500,000 to produce, nearly $6,000,000 in contemporary dollars – something well out of the budget of the common person.

It wasn't until the invention of the transistor that computers could be popularized and fit for general public consumption. It was introduced in 1947 by John Bardeen, William Shockley, and Walter Brattain, three scientists working at Bell Laboratories. These men would go on to win the Nobel Prize for their work on the transistor, which has been considered a fundamental building block in modern computers. The transistor was a new semi-conductor device used to amplify electronic signals and power; it replaced the bulkier, fragile, inefficient and expensive vacuum tube as the semi conductor of choice.

Transistors have come to play an instrumental role in driving product research and technological innovation, allowing engineers to produce faster, cheaper and smaller products for the public consumption. They have paved the way for us to have portable computing devices, which has led to an enormous expansion of both the hardware and software industries. The computer systems industry is currently one of the fastest growing industries in the US.[30] The software industry is the largest recipient of venture capital in the U.S.; in the last quarter of 2011, it received $1.8 billion worth of funding.[31] Much of this growth is driven by demand for mobile software and applications, which has skyrocketed in recent years as more consumers use smartphones and tablet deices. The mobile applications segment is estimated to have generated worldwide revenue of $15-20 billion in 2011, and is expected to continue an upwards trajectory. Social technologies alone present an opportunity for uncapped potential, with projections of an additional $900 billion to $1.3 trillion of value annually.

Let that sink in for a moment. Social technologies (hereby defined as products and services that enable the formation of online networks and communities) have the potential to provide an additional trillion dollars worth of value annually to the world. Online activity has undergone a brilliant metamorphosis from its early days, when it was largely limited to solitary activities: checking one's email and the occasional online shopping spree. Today, social technologies have infused our popular culture and, for better or for worse, changed the way we live. They change the way we interact with friends, or even strangers; the level of intimate detail available about a tangential acquaintance, for example, or the degree to which we rely on online forums for advice or entertainment has literally changed the way we live. They provide invaluable tools to businesses who now, for perhaps the first time ever, are able to peer closely into the mind and habits of their consumer audience. Social media platforms provide everything from blatant unfiltered feedback (ranging from the obvious form of reviews posted on websites like Yelp to the less obvious form of status updates, or Tweets) to the more subtle form of tracking their online behavior. In short, these new social technologies provide copious amounts of data points, which has the opportunity to provide enormous insight for consumers and businesses alike.

In many ways, Sudoku puzzles serve as a microcosm for this change. From a given number of data points, we are able to draw new conclusions to fill in the grid, to discover the solutions that we seek to the questions we ask. New technologies, social and otherwise, allow us to have more numbers in our starting grid, ultimately facilitating our solutionistic view. The potential realized value, however, is limited in part by the talent available – the necessary analytical skills, entrenched in mathematical rigor, machine learning and statistics, take years to train and are just not being taught to enough people. The McKinsey Global Research Institute projects that demand for this “deep analytical talent” will be 50 to 60% greater than its supply by 2018.

This inefficiency begs the question – if this is the future, how can we best prepare our children for it? How can we teach our children the Sudoku skills that they need in order to adapt to an evolving reality? After all, the values that we perceive in the world around us are best applied to the education of our children. Whether people consciously recognize it or not, there is a growing need for our children to be educated in way that not only allows them to properly consume and analyze Big Data, but also allows them to be competitive in a technology-dominated world.

Chapter III: Math and Science – Not Just For Geeks Anymore

The Sudoku Shift in Our Educational Paradigm

"Worried about Alzheimer's disease? You may want to finish that game of Sudoku before you read this."[32]

That was the opening line of a January 2012 article published by ABC News. It referred to a new study that had concluded playing "brain-stimulating"[33] puzzles could provide a preventative measure against diseases such as Alzheimer's. In particular, Sudoku has taken a position in the spotlight; a number of articles and blog posts have been written about the growing belief that solving Sudoku puzzles is a way to "boost brain power,[34] "train their minds," and improve cognitive function. Whether this is true or not is beside the point. The point is that this is how society has come to view Sudoku. The skills involved in solving a Sudoku puzzle – the ability to think rationally and logically – are what's now important; the public has come to equate Sudoku skills with intelligence, cognition and raw brain power.

This belief is not entirely misplaced; as technology becomes increasingly involved in our every day lives, it is important that we are able to fully utilize our Sudoku skills to remain competitive. This manifests in two ways, which are intimately related. On one hand, being able to think like a machine has never been more important; the ability to think rationally is critical to developing a successful computer program, which has come to dominate the majority of contemporary technological innovation. On the other hand, another aspect of Sudoku puzzles has become increasingly relevant – the necessity of drawing conclusions from a set of given information. Sudoku puzzles require us "filtering… everything extraneous"[35] in order to infer the correct answer. The development of these skills through a new form of education has become newly relevant given the rise of Big Data and the evolving demands of society.

It would be erroneous to not acknowledge the inherent economic viability of pursuing this type of education. For many, we live in a dual labor market – that is, one with "good jobs" and one with "bad jobs."[36] There is limited opportunity to move between the two, and placement into either sector is not only determined by structural inequalities, but also by education. While earlier some may have believed that any higher level education might have been sufficient, there is a growing contingent of people that believe a strong background in mathematics is increasingly in demand[37] and in fact, is essential for college success and career opportunity.[38]

For many, this manifests into the debate of the benefits of a humanities-based, liberal arts education as opposed to pursuing a STEM-based college degree. A study released by the Georgetown University Center on Education and the Workforce show that the top earning fields are STEM-based industries, with petroleum engineers, pharmaceutical scientists, and those studying math and computer sciences earning a median of $120,000, $105,000 and $98,000 respectively. At the other end of the spectrum lie those who studied psychology, early childhood education and theology, earning a paltry $29,000, $36,000 and $38,000.[39] [40]As the cost of a four year college education climbs higher and the nation suffers from economic turmoil, many ask – is a liberal arts education worth it?

The answer to that depends on who you ask. The value of the 'humanities' education is that it traditionally serves "as a prerequisite for personal growth and participation in a free democracy, regardless of career choice."[41] Through the pursuit of fields such as language, literature, the arts, culture, history or philosophy (to name a few), the humanities seek to investigate what it means to be human, to understand who we are, what we value and why we value it. It can have enriching effects on peoples' lives and provide a fundamental basis for how we interpret the world around us.

Yet, for many, that is not enough. Florida governor Rick Scott, for example, believes in charging higher tuition to students who pursue liberal arts and social sciences at the public universities,[42] citing his belief that they aren't practical: "You know, we don't need a lot more anthroplogists…it's a great degree if people want to get it, but we don't need them here. I want to spend our dollars giving people science, technology, engineering math degrees. That's what our kids need to focus…on."[43] Much of his rhetoric focused on the need to get a job and to have a 'marketable' education. After all, students face enormous pressure from their parents and those around them to focus on degrees that will allow them to pay off their often crushing student debt, and to get an education that will allow them to get a job.

Regardless of the merits of each side of the argument, the numbers speak for themselves – the study of humanities and the social sciences is becoming less popular among undergraduates. From 1966 to 2010, the number of bachelor degrees awarded in the humanities dropped from 14% to 7% of total degress awarded nationally.[44] For many elite schools, humanities degrees are no longer in the top five most popular degrees pursued and the number of humanities based faculty vastly outstrips relevant student population. At Stanford, for example, roughly 45% of total faculty is based in humanities departments, even though only 15% of the student body is focused on those degrees.[45]

Part of this decline may be driven by a national focus on increasing STEM education. While some have considered it to be an "obsession",[46] President Obama has been determined to increase STEM education through national initiatives. Arguably, initial pushes toward increasing STEM education began in the early 20th century saw significant advancements in science and technology; mirroring the blossoming technology industry now, scientists and other skilled workers became highly sought after to work in these at the time, newly innovative industries. This industrialization led to a need for a more rigorous type of scientific education, particularly in conjunction with technology. In 1945, a Harvard report argued, "science and technology develop in parallel, each fructifying the other."[47] Following the end of World War II, President Franklin D. Roosevelt defined a policy that "required the continuous deployment of new scientific knowledge to assure social progress," even in times of peace.

These sentiments were amplified after the advent of the Cold War in the late 1950s and the Sputnik crisis. The Sputnik crisis unleashed a frenzy of support for increased support for STEM efforts and a wave of education reform directed at strengthening STEM based programs. For one of the first times, there was a major push to teaching science in the lower grades[48] as the nation set to accelerate the rate of scientific education. Teachers, politicians and scientists alike came together to push through a variety of reform measures. Since the Sputnik challenge ended and the United States successfully sent men to the moon, however, these efforts to increase STEM education largely subsided, or were rendered less visible in the context of huge expansion of national education and universities, across all fields, in the 1960s.

They have only begun to pick up in reason years as, once more, the US experiences an international threat – the fear that American students lag behind those from other countries with respect to STEM capabilities and focus. In a 2003 "Trends in Mathematics and Science Study" conducted by the International Association for the Evaluation of International Achievement, the United States scored below many other developed nations for a variety of international benchmarks, despite improving from previous years of the study and performing above the international average.[49] These findings were echoed in the 2006 "Program for International Student Assessment," which assessed students for their problem solving abilities and knowledge. In PISA, US students scored below the international average among industrialized nations, calling into "serious question the depth of scientific understanding"[50] of US students. This has made STEM education a national priority – appropriately so, as the world continues to experience a cultural shift, revolving around "an epicenter"[51] of science and technology. Science, technology and mathematics drives change, making learning about these topics ever the more critical.

In 2009, President Obama launched his "Educate to Innovate" campaign; recognizing that STEM education is critical to America's "success as a nation,"[52] President Obama's campaign sought to (1) increase STEM literacy, (2) increase quality of STEM education in schools, (3) increase STEM opportunities for underrepresented groups. All of this, he declared, would go towards "strengthening America's role as the world's engine of discovery and innovation."[53] Since then, the campaign has raised over $700 million, increased federal investment and significantly broadened student participation within the STEM talent pool through initiatives such as robotics teams, chess teams and programming competitions.

President Obama's thoughts on the importance of science education sum up a sentiment that has been expressed since modern science was first introduced to western civilization in the 1500s. Great thinkers have always commented on the significance of science to our national prowess. Thomas Jefferson, for example, viewed "the sciences as keys to the treasures of nature…[and that] hands must be trained to use them wisely," and spoke critically against the lack of practical scientific education in the US. However, his petition to write and fully utilize a set of practical science textbooks – the first effort to create a science and technology curriculum – was denied by Congress. A science curriculum was not federally mandated for lower education until 1892. As the 1890s saw the shift from an agricultural to an industrial society and large-scale immigration, a Committee of Ten was appointed by the National Education Association to enact massive education reform. This committee recommended two years of science education to best prepare high school students “for the duties of life” and “[develop skills] in reasoning and logical investigation.”[54]

Reasoning and logical investigation, after all, has become all the more important to modernity. They are the necessary building blocks to take full advantage of the resources we have around us. Our ability to think logically and like machines will continue to spur technological innovation in every sense of the word – it will allow us to make the most of big data (either through its collection or analyzation) and the available internet (through new applications, new methods of social media and the improvement of existing software and hardware.)

There has been a significant call to arms in recent years for everyone to learn how to code. Part of this is driven by the overwhelming demand from Silicon Valley for more programmers and more innovators, to fuel the public appetite for new apps. However, current programmers aren’t the only ones advocating for programming education. People ranging from celebrities like Ashton Kutcher (“I'd like to advocate for computer coding to be an institution in the public school systems right next to biology, chemistry, physics, etc. If we want to spur job growth in the US we have to educate ourselves in the disciplines where jobs are available and where economic growth is feasible.“) to athletes like Chris Bosh (“Coding is very important when you think about the future, where everything is going. With more phones and tablets and computers being made, and more people having access to every thing and information being shared, I think it's very important to be able to learn the language of coding and programming.“) to politicians like former NYC

Mayor Michael Bloomberg ("We salute the coders, designers, and programmers already hard at work at their desks, and we encourage every student who can't decide whether to take that computer science class to give it a try. New York City's economic future depends on it, and while we're already giving thousands of our students the opportunity to learn how to code, much more can and should be done.") and former President Bill Clinton ("At a time when people are saying "I want a good job - I got out of college and I couldnt find one," every single year in America there is a standing demand for 120,000 people who are training in computer science.") have all spoken up in support of not only increasing STEM education overall, but also in support of an increased emphasis on computer science.

As Arianna Huffington, founder of the Huffington Post, put it, "learning to code is useful no matter what your career ambitions are." The latest wave of technology and its surrounding implications means that the importance of coding is not limited to economic efficiency and finding a job. Learning how to code is now crucial to becoming an educated citizen of the world – it is as essential as learning how to read or write, given the scale on which we interact with its products. It is somewhat frightening to think that we all walk around with these small machines in our pockets and yet, have no idea how they work or how to modify them or how to create them. To be fully prepared for the 21st century and to take full advantage of its opportunities, coding has become a necessity. Algorithmic literacy is needed simply to understand how the world is run these days, and how our options (economic, political, financial or otherwise) are shaped by these invisible forces.

The importance of technology and its ubiquitous application on both a micro and a macro level necessitate a push for STEM, and notably programming, education. Yet, underlying the push is the unspoken sentiment that something has to change. Not just in the way we act and interact with things around us, but an intangible change in the way we think. There has been an incredible shift in what we value as a society. Even as economic motivators remain the same, there is now a pervasive belief that to be successful, the path there is through logical, rational, and analytical thinking. There is a new emphasis on the quantifiable and the measurable. A shadow of a doubt has been cast over what we view as important, even what we view as intelligent. As Steve Jobs said in *The Lost Interview*, "Everybody should learn how to code. It teaches you how to think."

Yes, how to think. Technology has not only called into question how we act and what we teach our children, but also a larger shift in value of how we understand intelligence and critical thinking. The reality of our present and our future demands a new intellectual and educational framework and context for understanding (and thriving in) the world around us. Intelligence, then, has become defined by our Sudoku skills, and our ability to apply them to new challenges, such as the one posed by Big Data; this manifests in a huge push for STEM and programming education. The importance of learning how to code and utilizing data to examine the quantifiable is more than finding a job or making money. Rather, it has become about innovation, competition and being an educated global citizen.

Chapter IV: Finance – A Case Study in the Crisis of Automation

The Dangers of Our Sudoku World

5,472,730,538[55] – if one were to write out a complete list of every single unique, rotation-invariant Sudoku grid that could potentially exist, that's how many entries would be within the (presumably thick) tome. Who would have thought that a simple nine by nine grid could have so many arrangements? More importantly, who could even come up with that many different puzzles?

The answer is no one, or at least no one on his own. The creation (and subsequent enumeration) of a Sudoku puzzle relies heavily on the use of complex computer programs, which verifies its uniqueness and validity as a complete grid. The process would be incredibly time-consuming to do by hand, requiring hours or even days to complete a single puzzle. Yet, the key to writing lots and lots of puzzles is to automate the process. An algorithm can move through a puzzle, running through thousands of logical processes to reduce production time from hours to a few seconds. As technology and coding continue to develop, we are able to write programs that allow us to do things exponentially faster, and on a much larger magnitude, than ever before. The scale on which we are now able to operate is dizzying, yet exciting – technology and algorithms have transformed the world we live in.

Truly, technology drives global change. Each and every industry in the world around us has been touched by innovations in technology; after all, technology is the vehicle by which we create progress, enable development and present new opportunities for investigation. Technology has changed the way that we are able to operate, whether that is how we handle data (as illustrated by the introduction of Big Data, as facilitated by modern accessibility to the internet and our perpetual connection to networked sensors), or what we value (as illustrated, in part, by the growing emphasis on STEM-based education.) It has caused a fundamental shift across nearly every industry in the United States today, for better or for worse.

Of particular interest is the financial industry. The financial industry presents a fascinating opportunity for investigation simply because the finance is really not just about finance. Like the Sudoku puzzle, the financial industry has a certain universal quality. Finance affects every firm and industry out there today; without sufficient access to capital, companies would be hard-pressed to continue growing, innovating and changing. The existence of the financial industry is crucial to the development and maintenance of not only a well-functioning economy, but also a well-functioning society.

Its ubiquity, however, gives the financial industry immense power. Anything that happens in finance has serious consequences, which ripple out to impact other industries. Witness, for example, the economic bubbles (housing, Internet, telecom, etc.) of the late 1990s, or events such as the recent Great Recession. The "asymmetrical" boom and bust sequences of the financial industry (where it slowly accelerates before "culminating in a catastrophic reversal,"[56]) has riveting implications for each and every one of us – which is precisely what makes it such an interesting lens through which to view the world and to explore the effects that automation and our increasingly algorithmic ways of thinking has on the world.

For many, the story of American finance begins with the founding of the New York Stock Exchange. In its founding years, America represented new opportunities: opportunity for growth, opportunity for wealth and opportunity for investment. The promise of success seemed tangible for many, represented by the seemingly endless swaths of land stretching westward. Yet, the lack of financial institutions and national standardization in colonial America made doing business difficult. At any given moment, a financial transaction could be conducted in British pounds, French francs, gold or silver bullion, or any of the various currencies printed by the various colonial states. Moreover, the lack of an organized stock exchange made it extremely difficult to develop American commerce – there was no way for businesses and companies to procure investments. Even the American government found it difficult to raise money. Spearheaded by the efforts of Alexander Hamilton, the newly formed government issued $80 million in bonds in order to pay off their debts from the costly American Revolution. Despite offering a high interest rate to compensate form the still-pervasive distrust of federal governments, only part of the bonds were successfully sold;[57] nonetheless, this constituted the unofficial beginning of the American capital markets.

Although these government bonds were sold in a number of burgeoning centers of financial commerce (namely Philadelphia, Boston and New York,) New York began to pull ahead as a strong hub of financial services, such as banking. Perhaps lured by the "intoxicating" "scent of instant riches," men (both the "enlightened men" Hamilton envisioned and the "gambling scoundrels" Jefferson anxiously feared) flocked to the unofficial markets budding on the streets of New York. These "curbside markets" consisted of "auctioneers" and "dealers" who congregated at various points along Wall Street, either in coffee shops or on the curb; in a "crude approximation" of the sophisticated British and Dutch exchanges, auctioneers would set the prices while dealers speculated on positions, trading among themselves.

It quickly became clear, however, that an organized, regulated market was necessary. Without regulation, there were too many shady dealings going on. On one end of the spectrum, auctioneers would fix and rig prices. At the other end, speculators, like William Duer, played whatever cards they had to maximize their own personal gain. As Charles Geisst, author of <u>Wall Street: A History</u> characterized him, Duer was neither Hamilton's enlightened man nor Jefferson's gambling scoundrel; he was more of an "enlightened scoundrel" who single-handedly triggered the first panic of Wall Street. Duer was heavily involved in the government and quickly recognized that there was a significant stream of Dutch and English money coming into the States, as the two colonial powers searched for new areas of profit. In one of the first instances of insider trading, Duer (and some colleagues) took out speculative real estate and curbside positions. When charges were brought against him, his speculative positions collapsed, triggering a domino effect of other speculators who borrowed heavily to enlarge their own investments. The result? The first crash of Wall Street, which resonated through the entire marketplace.

Recognizing the need for a formal, organized market, a group of bankers founded what would later become recognized as the New York Stock Exchange. As legend has it, the men assembled under a buttonwood tree (located at what is currently 68 Wall Street) to enter the Buttonwood Agreement of 1792. The agreement established a structured, continuous market for trading; unlike the curbside dealing, this exchange was (1) subject to a membership fee and (2) subject to rules and regulations to promote integrity.

New York continued to establish itself as a dominant financial hub running up to the nineteenth century. Following closely on the heels of the Bank of North America, which was the first chartered American bank and located in Philadelphia, the Bank of New York attracted a substantial amount of investor attention after its founding in 1784. In part, this interest was driven by Alexander Hamilton, who founded the bank and commanded a great deal of respect and trust from financial investors. Moreover, New York attracted an increasing number of private banks – these were banks that didn't have state charters, which were highly difficult to obtain. After Pennsylvania passed a law making private banks illegal, private bankers gravitated towards New York as their new home.

Make no mistake, however: early antebellum America was largely ambivalent towards the financial services industry. Despite its own perceived self-importance, Wall Street was somewhat irrelevant to the American economy. The agrarian nature of America meant that for many, high finance was a distant concept. Businesses were largely locally funded and the true, moneymaking ideas centered on other issues of the time – the expansion of slavery, inventing machines and the constant push westwards. Wall Street itself experienced a significant slow in business; following the crash, Wall Street languished without a fresh influx of government bonds to keep itself busy. What press Wall Street did receive was typically negative, focusing on the barely balanced act of opulent, glitzy capitalism and the reckless, immoral (and shadier) dealings underneath.

For the first few decades of the nineteenth century, Wall Street remained "a still semi-rustic 'financial district', not far from open fields and masticating cows."[58] It slumbered even as New York developed into a major port city, energized by the Napoleonic Wars; it hardly batted an eye as the economy around it thrived, with annual real estate sales leaping from "100,000 acres in 1790 to half a million in 1800."[59] Wall Street did receive an electrostatic shock with a fresh issuance of government bonds during the War of 1812, which revitalized the business to the point where brokers established the New York Stock and Exchange Board, institutionalizing speculative activity. Even so, activity was limited (particularly compared to the modern stock exchange); in 1818, the exchange listed "only five US government issues, one New York State issue, ten bank issues, thirteen insurance companies and several exchange deals."[60] This comparatively small market faced a collapse during the panic of 1819, triggered by a combination of over-speculation and complications with the Second Bank of the United States (sometimes referred to as Biddle's Bank.) This financial collapse encompassed widespread bankruptcies and unemployment throughout the US, generating even more resentment towards Wall Street, criticizing what they perceived to be a "swarm of shavers and speculators, joking and drinking their way from one site of distress to the next."[61] It wasn't until the railroad boom of the 1840s and 1850s that the stock market truly received a huge boost, bringing trading to the New York Stock Exchange in its modern form.

America experienced a major railroad boom in the 1840'ss and '50s. Before that, preliminary railroads were typically less than fifty miles and existed mostly to supplement the existing system of canals and water transportation. However, the 1840's witnessed the "perfection" of railroad technology as demonstrated by the use of the iron T rail and the creation of standardized methods of constructing and grading the railroads. Railroads received support from seemingly sides. Early railroad advocates frequently pointed to railroads' military value stemming from their "all-weather, rapid-transport capabilities"; not only could they move troops and supplies quickly, but they could also protect against "foreign invasion, Native American unrest, and slave rebellion."[62]

These same capabilities made railroads the ideal choice for passengers, freight and bulky products alike – they were fast, comfortable and could travel even in the rain, the cold and during dry seasons. A trip that might have taken 4 weeks in 1800 by horseback or canal would have taken a mere 6 days on the railroads. Moreover, railroads were cheaper to build and maintain, and could go directly between two towns. The numbers speak for themselves: in the 1840's, only 400 miles of canals were built for a total of 4,000 miles of waterway. In contrast, 6,000 miles of railroad were laid in the 1840's and totaled over 9,000 miles by the 1850's. By the end of the 1850's, nearly 21,000 more miles of railroad track were built, creating a substantial transportation network east of the Mississippi River.[63]

Of course, this extraordinary type of exponential growth required a substantial amount of money. The capital requirements of the rapidly expanding railroad industry were substantial; railroad construction required intensive capital investment. To fund the almost frenzied railroad building efforts, railroad companies turned to Wall Street. These newly massive enterprises were some of the first businesses to raise capital outside of their local communities. Previous successful industries, such as the textile or iron industries, had been financed locally. Early railroads had been raised either through foreign investment or by directly appealing to those who would benefit most – farmers and merchants living along the railroad.

Yet, railroad companies seeking funds turned increasingly to New York City. In many ways, railroad capital activity cemented New York City's reputation as *the* financial center of the United States. After the fall of the Second Bank, Philadelphia had fallen to the wayside as a center of financial activity. Companies had originally turned to Boston as a source of capital; however, Boston had higher money rates than New York, due to a smaller surplus of funds. The railroad companies looked to Wall Street for funding and quickly, railroad securities came to dominate the market. By the mid 1830's, railroad securities outnumbered all other transactions on the NYSE; the railroad industry had pushed Wall Street from trading "as little as a hundred shares a day in the late 1820's…to 6,000" shares a day in the mid 1830's.[64] By the 1850's, hundreds of thousands of shares were traded weekly, with one particular four-week period totaling nearly a million shares traded.[65]

Simply by responding to the capital demands of the flourishing railroad industry, New York City had transformed into one of the largest capital markets in the world. Despite the influence of foreign money, a number of private banks opened in the 30's and 40's that were distinctly American. A visiting British businessman declared Wall Street to be "the most 'concentrated focus of commercial transactions in the world.'"[66] The sheer volume of business gave rise to a number of different speculative techniques: the use of puts and calls, the creation of selling long or short, and the introduction of convertible bonds, to name a few. By the time other industries and manufacturers had comparable financial needs, financial institutions were already fully developed in New York City.

The finance conducted in nineteenth century New York City, however, looks drastically different from the modern financial industry. As our Sudoku-ized world has become dominated by algorithmic dominance and a solutionistic view, so too has the financial industry. Wall Street has has been irrevocably transformed by the unprecedented application of rationality, logic, and the ensuing implications of automation. In order to fully understand the role that these factors play in modern financial markets, let us start once again at the beginning of the story: the New York Stock Exchange.

When people think of the stock market, many have historically associated it with gambling. It is not necessarily difficult to understand why this association exists; after all, investing in the stock market shares some basic similarities with the games we play on the casino floor. Both are situations in which we spend cash in the hope of making it big, whether that translate to an increase in share price or a good round at the poker table. Of course, you can do things to try and tip the scale in your favor. You could do research into the company, just as easily as you could apply any number of strategies in poker. Yet, at the end of the day, it really comes down to Lady Luck. Success is dependent on only a few factors: "your wits, your guts and your balls."[67]

These beliefs are backed by a number of financial theories, such as the "efficient markets hypothesis" and the "random walk hypothesis." Popularized by Burton Malkiel's 1973 book, *A Random Walk Down Wall Street*, the random walk theory proposes that stock prices move completely randomly and thus, cannot be predicted. This is consistent with the efficient markets theory (the origins of which can be found in Paul Samuelson's 1965 paper "Proof that Properly Anticipated Prices Fluctuate Randomly,"[68]), which argues that investors can never outperform the market given the amount of information available, because markets are perfectly efficient. In fact, randomness is a sign of a rational, perfectly functioning market.

Yet, as mathematics student Louis Bachelier began to realize in 1900, it is precisely this uncertainty that allows us to derive knowledge. Much as we can use statistical probability to analyze a game of roulette, we can use the same tools to describe the stock exchange. Similar thoughts were echoed by economist Irving Fisher, who made the radical proposal to incorporate uncertainty into calculation of investment valuation, allowing investors to calculate the present value of not only bonds, but also stocks. While "uncertainty could not be banished," Fisher sought to tame it with "enough data and the right mindset."[69] This melding of statistics, math and reason with economic theory marks the birth of a new breed of industry – *this* is what we understand to be modern finance.

The first wave of quantitative finance transformed risk from a "vague, unquantifiable menace that could be tamed only with judgment"[70] into a quantifiable property, which could be estimated by looking at volatility and variance, a measurement of how widely scattered data points are. Harry Markowitz, for instance, derived equations for portfolio optimization; portfolio selection, he argued, was all about the balance between risk and return. Other scholars (Bill Sharpe, Mike Jensen and Jack Treynor, to name a few) devised a number of investment performance measures; Merton Miller and Franco Modigliani followed up by devising a method to calculate a company's cost of capital. In this version of finance, risk could be manipulated, controlled and analyzed just as easily as any other variable. According to some, the right combination of securities could eliminate entirely.

The foundation left by these scientists leads us to the development of the Black-Scholes formula in 1969, sometimes referred to as the Black-Scholes-Merton formula. The Black-Scholes model is an equation that values an option given the price of the underlying stock, the exercise price of the option, the time until the option expired, the risk-free interest rate, and the variance (how widely scattered the data points are) of the stock. Its creation was brilliant – however, Black-Scholes wasn't adopted overnight; even if traders did happen to peruse academic journals in their spare time, Black-Scholes was difficult to understand and implement. Yet, those who could were handsomely rewarded. While Fischer Black and Myron Scholes received a Nobel Prize for their work, a number of investment managers (Ed Thorp, for example, or Henry Jarecki and Thomas Peterffy) were able to use their own algorithms to earn themselves hundreds of millions of dollars.

For traders who were ahead of the curve, Black-Scholes was a way to calculate the precise value of an option. Anyone who could calculate it in real time could compare the value with the real-time options price, creating an opportunity for arbitrage. If this was repeated enough times, with enough securities, a "healthy profit was virtually guaranteed."[71] For Peterffy, this posed an interesting question. After leaving Jarecki's investment firm Mocatta, he bought a seat on the American Stock Exchange, which had just begun to trade options. Originally a computer programmer, Peterffy used algorithms to calculate option values every night, which he then compiled into a miniature cheatsheet. Whenever he uncovered a pricing discrepancy, he could bark out an order in the stock pits. His problem, however, was that he was only one person operating. Even after hiring additional traders, Peterffy remained frustrated – after being deemed a market maker, it was too slow to communicate the prices to his traders, who needed to maintain constant pricing.

Thus, Peterffy devised a small, handheld computer that was issued to each of his traders. Each black box was pre-programmed with the appropriate algorithm, which spit out prices that his traders could quickly act on; his use of algorithms had transformed the trading pits into his own personal "cash machines"[72] with the first hint of electronic trading. The speed and precision afforded by Peterffy's automated system allowed his traders to "harvest not only large mispricings, but also smaller ones – and they almost always got to them before others."[73]

The speed and volume of trading rapidly increased as the rest of Wall Street caught onto Peterffy's game. Eager for a slice of the pie, larger investment banks began hiring programmers, scientists and engineers to enact their own algorithmic trading operations. Those who could think like computers and write the best programs were suddenly newly valuable to banks. Perhaps this contributes to the cultural prestige of banking; aside from the whispered promises of salary bonus and a glitzy lifestyle, bankers and traders were intelligent. They were the cream of the cream; the best and the brightest programmers often went to finance. The legacy of this decision is tangible, even today. Investment banks continue recruit not necessarily for financial know-how, but for analysts' abilities to think critically, rationally and intelligently.

This all became a somewhat moot point, however; as Black-Scholes and ensuing variations became nearly ubiquitous across investment firms and traders, it became apparent that there was a new value to algorithms: speed. As everyone employed algorithmic trading, any opportunity for arbitrage was quickly sniffed out by these computerized piranhas. What mattered most, then, was the ability to get to the trade the quickest. If the hedge fund was first to put in the trade, they could cash in. For those who were even a millisecond behind, there would often be nothing left. For those who still relied on human traders…forget about it.

The pressure was amplified when in 2001, the SEC mandated the decimalization of the market. This meant that all markets had to use decimals, instead of fractions, which meant that the spread on arbitrage could be as small as one penny. There was only one way to continue making these huge profits – by executing huge volumes of trades. Of course, the only way to get this sort of volume was through technology, and the human minds that could control it.

The computerization of trading strategies forever changed the world. Trades became entirely electronic, which were made trading much quicker and cheaper than when the "lumbering humans"[74] used to buy and sell stocks. As brilliant minds converged on the financial industry, they witnessed the innovation of new financial products. For a moment, it seemed as though finance was on a one-way road to stardom – for individuals in the field, the process of automation not only amplified the amount of money trading hands, but also amplified the amount of money going into their pockets. Many felt that it was deserved; the nearly instantaneous devouring of arbitrage meant that the market was continuously pushed towards equilibrium. The invention of new financial products meant more transactions to play with, and a more diverse portfolio for investors. To those in finance, life seemed good. All that would change, however, with the financial crisis of 2008.

Many books have been written on the events leading up to the Great Recession of 2008, all of which are more thorough than anything that could be produced for the purposes of this paper. In a brief, and highly oversimplified summary, home mortgage payments became “securitized” – that is, rather than keep the risk on their books, lenders sold the mortgages to people who packaged these individual loans onto larger “tranches” of bonds. These were, in turn, sold to investors. As time passed, these packages grew significantly risker – not only because the tranches became more intricate and complex in nature, but also because the quality of the underlying mortgages deteriorated. As reality caught up to homeowners and they began to default on their payments en masse, these deals quickly went south and many firms found themselves needing to cough up money that they simply didn’t have on hand.

This, then, is the ultimate crisis of automation. Algorithms allowed traders to devise these increasingly complicated products and trade massive amounts of them; they were swapping hands so quickly that no bank fully understood the risk that they took on by accepting these deals. By removing the human element, algorithms transformed banking into a black box of sorts – a mystery item that only certain quants understood, that had the potential for rogue algorithms to go out of control. Whereas before a banker's success depended on his ability to "develop a gut feel of the client"[75] before embarking on a deal, computer programs cannot conduct the same intuitive check of the health and sanity of the system. What's worse is that just as computers allowed transactions to be conducted on an unprecedented scale, they also had an amplifying effect on the feelings and the thoughts of the human driving the process and pulling the strings. What starts off as confidence in algorithmic superiority rewarded with substantial financial success becomes magnified into a toxic cocktail of greed, hubris and arrogance; even if they stared into the black box and understood what was going on, would they even have done anything about it?

Chapter V: Conclusion
Living in A Sudoku World

Sudoku is pitched as a puzzle that involves solely logic; despite the numbers on the page, newspapers cheerfully proclaim, there's no math required. What they mean to say is that there's no arithmetic involved – unlike other puzzles such as the KenKen (another puzzle that is currently run daily by the New York Times), one is not required to add, subtract, multiply or divide any numbers. Mathematics is "characterized by the use of deductive logic,"[76] and nothing more.

Mathematicians are not the only ones who rely on logic; logic plays a central role in every branch of science. Scientists used to refer to Hypothetico-Deductive reasoning, as initially coined by William Whewell. They start with a hypothesis ("If…"), gather observations and test data ("And…" or "But…") and then draw logical conclusions appropriately ("Therefore…").[77] Since then, they mostly utilize the scientific method, which is has fleshed out the principles of Hypothetico-Deductive reasoning and has since guided the vast majority of modern scientific research.

Modern scientific research has been characterized by an increased emphasis placed on objectivity and quantification. The term "scientist" itself was not used until the 1800s, when William Whewell, the same man who named the Hypothetico-Deductive method, used it. Prior to that, science referred to any well-established field of knowledge and men who studied the sciences were called natural philosophers. Natural philosophers explored the universe through philosophical speculation and scholasticism; many of them never fully utilized empirical methods in their work. Since then, scientists have conducted experiments that increasingly rely on quantification. The validity and verifiability of their work rests heavily on the standardization of measurements, methods and procedures. Whatever cannot be “brought under experimental control” is not always considered “knowledge.” Science depends on evidence and the logical testing of observable data.

This type of objectivity not only has implications for natural science, but also for the social sciences and matters of public policy. As Theodore Porter suggests, “To quantify is to change society.” In the preindustrial world, the qualitative dominated over the quantitative. However, democratic societies have looked to those methods as a foundation for their choices; with quantification coms a subtle implication of fairness and equity.[78] These decisions carry more authority, as they seem to detach themselves from the biases and personal interests that pervade political debate and provide indisputable proof that this choice is the right choice. This draws a parallel to an idea that Morozov termed “solutionism” – the perspective that there is a solution to all of the world’s problems and inefficiencies, and that technology (or in this particular case, logic and quantification) will get you there.

Certainly, the importance now assigned to math and science through logic has caused them to become more prestigious; this has manifested in other areas as well, such as an increased presence in pop culture. Mathematics, in particular, has experienced numerous intersections with mainstream culture. The hit science fiction television show *Lost*, for example, makes it clear that there is a power to mathematics like no other; numbers and equations hold particular significance for the characters themselves, who are stranded on a mysterious island following a place crash.[79] Another example would be the popular movie trilogy of *The Matrix*, which relies on the linear algebra, the science of network theory and many references to new technologies.[80] Mathematical modeling has also gained prominence within video games; "quantification is nearly omnipresent in [role-playing games] design."[81] And, of course, mathematics has experienced a heightened presence within the puzzle landscape.

The newly heightened presence of math within the puzzle landscape is not simply restricted to the new importance of Sudoku; mathematics has also begun to integrate itself within crossword puzzles. In 2009, a number of the Sunday New York Times crossword puzzles all contained mathematically oriented clues, solutions and themes. A major factor that drives the pervasiveness of science/math clues is that the very constructors themselves all have a close relationship with math and use crosswords as an outlet. One puzzle constructor wrote, "[puzzle construction] is often a degree-of-freedom problem…filling the grid…is like solving, semi-simultaneously, a set of 70+ equations."[82]Another wrote, "All puzzlemaking is based on specific mathematical principles of symmetry and percentages."[83] Math is much more heavily utilized in crosswords than would initially meet the eye.

Ultimately, all puzzles are rooted in math, and by of extension, logic, in some way. They all involve the ability to pick out patterns within the chaos, to wade through the jumble to clues to decipher an answer. The human impulse to write or solve puzzles is a curious one; nothing in particular identifies someone who is more likely to enjoy puzzles than another. Perhaps this speaks to an innate attraction to mystery and the unknown. Perhaps this speaks to an innate desire to gain control and impose order in a microcosm of our life. Perhaps it's a survival instinct – those who can "see the tiger lurking"[84] at the edge of the forest and pick out a pattern among the randomness are more likely to survive. Or perhaps, simply, it's fun.

Puzzles are truly fascinating; Sudoku, for instance, is “math in the small.”[85] By asking a few questions about the puzzle (“How many puzzles are there? What’s the minimum number of clues needed to solve a Sudoku?”), one is invariably led to number theory, combinatorics and other areas of mathematical interest.

The rise in popularity of Sudoku parallels the rising role of technology in society. As computers and technology have become increasingly central to daily life, it has also changed how individuals live. More than ever before, our world is driven by math and quantification. The superstars we see around us today are not great philosophers, but great innovators who have pioneered new technologies to build products and companies that improve our wellbeing. This cultural shift in values is reflected in the types of puzzles that we choose to solve. The problems that concern us today aren’t about books and history; they have to do with machines, logic and breaking down a complex issue into small, manageable bites. The universality of technology applies as well; while not everyone feeds into the “intelligentsia” culture of crossword solving, everybody does have a smartphone or a computer. The issues associated with technology touch the lives of every citizen of the world, and will continue to do so.

Yet, one last word of caution. The story of the financial industry highlights some of the wonders and the dangers associated with a reliance on rationality and a belief in the random walk hypothesis. The random walk hypothesis is sometimes called a drunkard’s walk – imagine a drunk man stumbling around, completely lost. For the most part, he’ll wander randomly; maybe he’ll turn left, maybe he’ll turn right. But once in a while, a statistical black swan will occur, and he will bolt in a particular direction for no apparent reason. Without a human check in place, there could be dangerous consequences for him, and those around him.

Even if it may seem that way, technology is not enough. Honing our skills of reasoning and logic through STEM education is useful but is not sufficient for the development of a stable society. True success comes at the intersection of technology and humanities, of science and art, of Sudoku and crossword puzzles. The marriage of two different skillsets is what is important – and the combination of the two will help us thrive in our Sudoku world today.

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