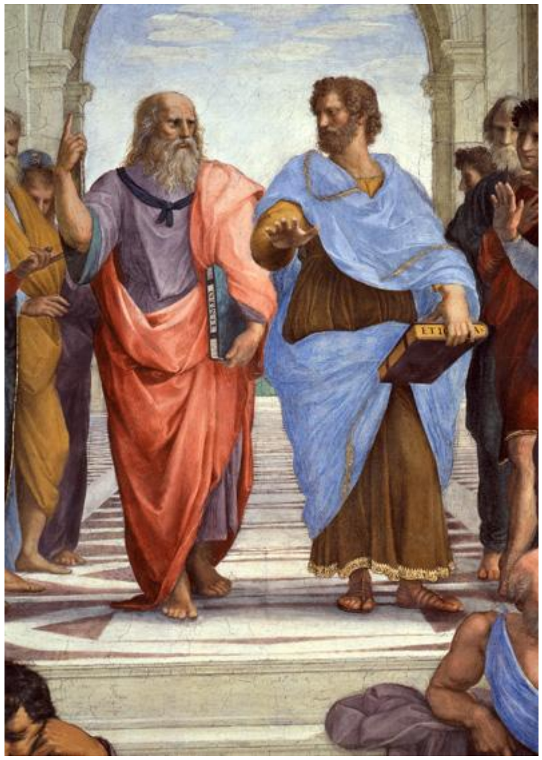
Technology and the Laws of Thought



Gopi Krishna Vijaya

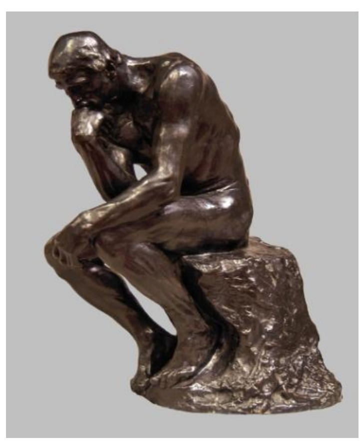
Spring 2015

Technology

Greek

τέχνη (techne): art, craftsmanship, skill

λογική (logike): reason, rational thought



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The Sanctuary Project

Preface

In the past couple of decades, the globe has been encircled by the web of technology. Devices have become obsolete so blindingly fast, that coming to grips with the pace of development has become tougher with time. It is not uncommon to feel as if one is on a roller coaster ride, hanging on to the seat by the tips of the fingers. From around the time *Futureshock* of Alvin Toffler became popular in the 1970's, several hundreds of books have been written, talks have been arranged, conferences organized under the theme of technology, especially about computing technology that has come to influence our lives so penetratingly. However, the glare of new technology has grown so strong that most descriptions restrict themselves to the past 50 years or so, as it is not worthwhile to describe and study an obsolete technology in full working detail. Even if the earlier history is mapped out, the corresponding conceptual development, particularly the philosophical development is not generally addressed.

Additionally, innovation has been a goal much stressed upon in recent years. In a rapidly changing environment, it is doubly difficult to identify what is really new, making it a tricky goal to work with. Hence what is most needed is an analysis of the way we came to be where we are today in terms of technology, and a clear understanding of what the effect of technology is on the human mind. Only this can show where we are headed.

These two aspects are addressed in this work: how the technology was created, and how it is related to the thinking process. Not only is a historical overview provided, but the conceptual developments which came into being along the way are highlighted as well. This is seen to lead right back into the time of the Renaissance and the Age of Enlightenment, and by suitably arranging the different streams of thought so that their effect on each other can be seen, a way is found into the much distant past−to the origin of the ideas guiding technology today. This path can get winding at times, but is by no means random. The aim of the process is to see if the way technology has developed was the only way possible, and if there are any ideas that can give a different orientation for it. At the same time, by studying the effect of machines on the human mind, ways to understand and compensate for these effects are suggested. It is hoped that this helps to not only tackle technology in the right way, but also enable new ideas to enter into this field that can prove fruitful for every free thinking person.

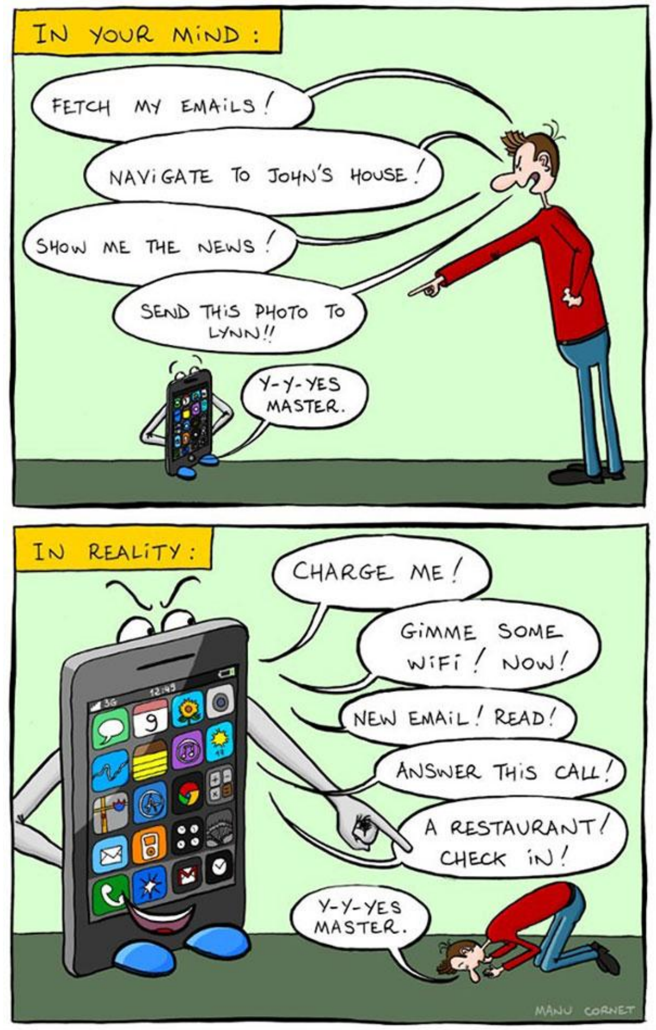
Gopi Krishna Vijaya

May 2015.

The real question is not whether machines think but whether men do. The mystery which surrounds a thinking machine already surrounds a thinking man.

- B. F. Skinner

Chapter 1: The Situation Today



(courtesy: Manu Cornet)

One of the distinguishing features of the world today is the sheer number of distractions one is subjected to day in and day out. Every aisle in the supermarket has a thousand options, every street in the city has a thousand boards and advertisements, and every click of the button pours out a million options for pursuit. The sights and sounds that blare forth from all directions, especially in the midst of a big city have reached unprecedented levels, especially if all the earphones and small-screens are included. This development is noticed not only by the experts in psychology or students of anthropology, but by the general public. The sudden rise of computers, internet, smartphones and its consequences can hardly be missed by anyone. This transition into the world of distraction is being experienced by a larger section of the population today than ever before, and quicker than ever before.

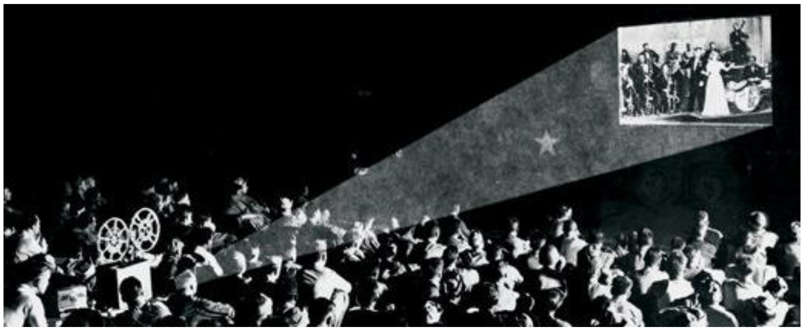
As the things that demand our attention have proliferated, attention-spans appear to have gone the other way. In the span of just fifteen years, it can be observed that it is much harder to concentrate on one topic today, in any field of life. In order to accommodate, and to somehow work with this limitation, the fields of knowledge have gradually splintered into innumerable tiny boxes. Observe the number of specialists that have arisen in the various fields of knowledge e.g. “a doctor” is not to be found easily, but rather an “ologist”, whose specialty is one specific part of one specific organ of the body. It is hard for a scientific investigator to even understand the vocabulary of another field of science, let alone communicate the thoughts accurately. It is actually easier to be “the expert” of a small topic than to have an in-depth grasp of a wide array of knowledge. This appears to be one of the side-effects of the Information Age: a fracturing of knowledge and attention. So on one hand, the ability to access information has increased enormously, and on the other hand, the ability to remember, assimilate and work with that information is getting difficult.

Noticing this change is one thing, coming to terms with it is quite another. It is clear that with time, these effects of technology can only increase. This brings up several questions. How did this technology arise? Where did it originate, and where is it headed? How to distinguish the harmful and useful effects of technology? Where is it possible to draw the line, if at all such a line exists?

It is possible to think about technology in simple terms, for example: the knife that is in the hands of a surgeon and the knife that is in the hands of a robber. If so, then it is not the knife that is the issue at hand, but the person and his motives, in which case all worrying about technology becomes irrelevant. However, things are not as simple as all that when comparing a knife with the effects of modern computing technology. The effects of a knife are clear and visible to all while the effect of technology on the workings of the innermost aspects of the mind is not easily visible. The cooperation with the machine remains out of sight. Studying the *visible* effects of technology is easier than understanding the *invisible* effects on something as internal as thinking and focusing. Computing technology is, as the saying goes, a whole other animal.

It is therefore important to identify what the relationship is between thinking capacities and our current technology-filled life, and what can be done about it. This is a vast field, and it would involve delving into an obstacle course of sorts to trace the origin of the relevant ideas. Since these changes are not easily visible to the eye, it requires some patience to identify the path to trace. Hence, a good approach would be to consider the changes themselves in greater detail, and try to get a clear image to work with. This way the right questions can reveal themselves along the way, instead of trying to force-fit the situation into specific questions. Since the topic is about the recent changes in thinking capacities, it is best to begin with the present day and work backwards, which will be done in the following chapter.

Chapter 2: Patterns of Thought

Since the path of approach is not easily visualized in case of internal thought processes, the first thing to do is to study the current scenario in a bit more detail. This would help visualize the process more clearly. The ideal place to start the enquiries is with what is right “in our face” i.e. the screen on which you are reading this. It could be either a paper or (more likely) the computer screen. If it is being read on a paper, then it was probably printed by a computer after seeing it on the screen, leading back again into the computer screen: a good starting point.

In general, what would the response be if a person is asked today: “How does this screen work?” The chances are that “how computer screens work” would be typed in Google, Wikipedia, or perhaps, in “howstuffworks.com.” Within a few minutes, everything related to the computer screen will be available, right from the pigments on the sheets that make up the screen to the way the screen is refreshed. A YouTube video might even provide a look into the cross section of the screen. Everything appears very straightforward. However, imagine the situation after a week. If the same question is asked, what would be the likely result? Of course, a person might remember “googling” it, but only vaguely remember the details, and would probably do a quick search again to give the answers. Similarly, after a month… it is likely that the person would be halfway through an article on screens, and then realize: “Hey, I have read this before! Some time recently…” Hence, there is a definite observable variation in both memory and understanding.

Now, let it be further assumed that a project report is required for the same topic, as to “How Display-Screens Work.” What would be the likely method of approach? It would most likely involve clicking on a lot more links, and perhaps a visit to the library. Discussion with others would occur through email, online forums and social media. The report would be typed up on a computer, reorganized, edited, proofread, and submitted via email. It is possible to imagine a student completing the entire project on a laptop without even leaving the bed. In other words, it might not even be necessary to move away from the computer screen, in order to understand how a computer screen works! At the end of it all, if there are 200 people completing such a project today, how many would have involved actually taking apart an old computer screen? And how many would involve links picked from the first page of results in Google? It is worth pondering that for a moment.

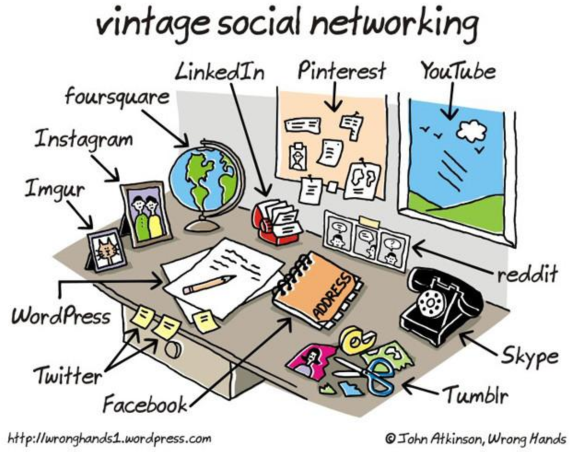
Now, consider taking a few steps back, about 30 years in the past, in order to compare it with the situation today. Imagine the results of the previous project as written by 200 young students in the 1980's, who embark on such a project like their modern counterparts. To stay true to the different time periods, assume that the students of the 80's have a project to submit on the *television* screen. When in the library, if the movements of the students are imagined, it is easy to see several different starting points from different books, involving a lot of physical movement to and from bookshelves, to study desks and perhaps coffee shops. Possibly a good number of the students would be in the junkyard which had spare parts of the television. A typical student would have at least travelled from the house to the library to look up references. In the writing process, from one sentence to the other, there would have been a lot of time involved. Every sentence would have had to be first thought out, discussed, and then written or typed out, with little erasing (save for typos). The sentences spent a lot more time in the mind before getting transferred to paper. In addition, a considerable amount of activity, both mental and physical muscular activity, was involved in the process. It is quite a big difference between the push of a button and planning a bus ride to the library between several other chores. Hence, these two aspects can be seen to clearly distinguish between the two eras: the element of *time*, and the element of *effort*.

The next step is to confirm this development by considering an earlier time period. By moving back 50 more years into the past, somewhere in the 1930's, a different scenario can be visualized. Consider a slightly different project for the student of 1930: to identify how the cinema worked, for example (keeping the theme of screens alive.) At this point, there were virtually no technical aids to the thinking process itself, except one's own capacities, books and slow communication with other people. There were only a few machines that the common student could use to help him, such as perhaps the local printing press and the radio. The practical side would have likely involved actual protracted work with cinematic equipment and projectors, which was not owned by a lot of people at the time. It would have been necessary to learn to operate the instruments related to projecting an image on the screen in the cinema hall itself. The effort and scope of the project is magnified, and the time taken for it is similarly lengthened.

Thus, time and effort involved in any mental activity are seen to increase for every decade traveled into the past. It is a common experience for those who communicate with their grandparents to marvel at the amount of effort even simple tasks took, in their time. Of course, this is no great revelation, because a machine is an object that saves human time and effort, after all. But the important point here is to have a clear visual of the inner *mental* situation with regard to this necessary time and effort, as this is the part that is not readily visible.

At the same time, observing other devices other than computing devices shows a comparatively slower evolutionary process. For example, the shape of the knife has not really changed in several centuries. Even automobiles, airplanes, bikes and ships have all sustained their basic structure for nearly a century. It is mainly with the start of computing technology that the pace of change has accelerated so tremendously. Since all technology before the computers helped to assist bodily work, the possible reason for this accelerated speed has to be related to its connection to the human thinking process. That is the conclusion one is led to when comparing rates of change of technology: the speed of evolution of technology that is related to mental activity far outstrips the evolution of other forms of technology.

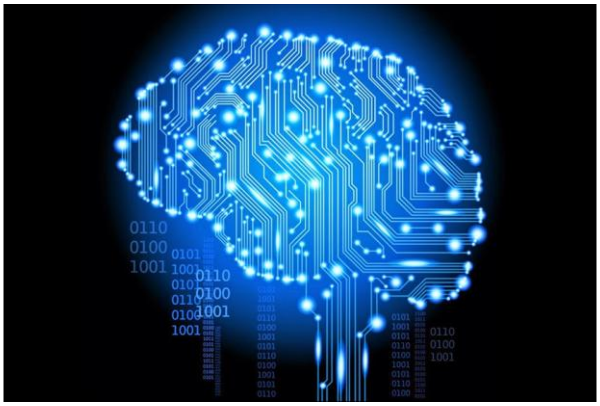
In addition to changing much quicker than conventional “visible” technologies, computing technology has also absorbed the activity of older devices into itself. For example, a good comparison between the situation before and after the early 2000’s can be seen in this picture:



It can be observed that the working office or study desk has become “virtualized” and sucked into the computer and the internet. This is the major difference between the tools used in the middle of the 20th century and the tools used today: most of the tools have been absorbed into the computer. For most projects involving mainly analytical thinking, in place of the library, the office desk, the telephone (and perhaps even the television), there is one instrument: the computer. Thus, the focus would have to be on computing technology, with other forms of technology remaining in the background.

It is important to visualize this entire process clearly: as to how a project is approached, started and finished in today’s world. The patterns of thought seen in the use of this technology leads to the central issue: How exactly does a computing machine affect the human thinking process? And how is this effect different from other machines?

Chapter 3: Internal and External Effort



> For it is unworthy of excellent men to lose hours like slaves in the labor of calculation which could safely be relegated to anyone else if the machine were used.
>
> − G. W. Leibniz

Before the age of machines, it was the animals that provided the motive force for all of mankind's activities. Once the machines took over, the burden of generating power fell on inanimate processes. This meant that what would once have taken many people months of back-breaking repetitive work could be accomplished with the help of moving a few levers and buttons. In addition, up to about a century ago, what the machines took over was almost always related to some skeletal or muscular movement of the human body. The six simple machines, as most of us were taught in grade school, all replace movements of one kind or another executed by the muscular-bone system of man.

Wedge (fingers)

Pulley (joint movement)

Inclined Plane (tilting)

Lever (arm, knee)

Screw (wrist)

Wheel and axle (rotating joint)

So, it can be said that movements of the hands and legs are "outsourced" to the machines, and multiplied. This is the origin of technology in its conventional form, as it existed until the 19^{th} century.

However, manual effort is not the only kind of effort that exists in this world, as anyone who has struggled for hours on end with a mathematics problem will gladly attest. This was also seen in the comparison of the TV-screen project report from decade to decade. In this case, effort belongs to the thought process alone, which does not pass over to the limbs. It is here that the apparent difference between a thought process and a mechanical movement of the skeleton and muscles can be observed: one is *internal*, the other *external*. For the time being, the words "internal" and "external" will only be used to indicate their general nature as a matter of experience, and whether or not the two are strictly distinct will be examined later in chapter 6. In terms of experience, most analytical, scientific or meditative effort is directed at the cultivation of internal effort for producing results, while athletic and gymnastic efforts are directed at the cultivation of external effort.

Humanity spent large periods of time when bodily effort determined daily life to a great extent. However, skills were developed over a period of time which prepared the way for the rise of technology and the formulation of the laws of mechanics. This indicates that just as the laws of mechanics were formulated after several generations of men and women had steeped themselves in the work of building various structures, what is external work at one point of time evolves into capacity for internal effort at a later point of time. It is quite possible that Galileo has never had his hand crushed by a boulder or spent years building a tower, but that did not prevent him from observing the laws of falling bodies. This indicates the important transformation that occurs from age to age: external bodily effort of one era transforms into the capacity for inner effort of a later era. (It is important to note at the point: external effort only develops the *capacity* for inner effort, not the effort itself! It is up to the individuals to develop that, a fact which will be examined in the later sections while expanding on the vague term "inner effort.")

As the external work got outsourced to the machines as technology, Mathematics and Natural Science bloomed parallel to it. This period continued from 16^{th} century until the end of the 19^{th} century, when a new idea entered mankind: Is it possible to outsource the inner effort of *thought* to the machines as well? Side by side, another idea was also taken seriously: What if my so called "inner effort" or willpower is nothing but a mechanical effort of my own mind? In other words, what if my mind is a machine?

While pursuing these questions, the outsourcing process of thinking must be analyzed. An overview of this process can be described. First, they were used purely as calculating machines or calculators, to supplant the rote calculation that was done before then. What followed this was the creation of calculating machines whose rules of calculation could also be included within their operation i.e. programmable machines or computers. In addition, the programmable machine has served to be the "nervous system" of all other machines, helping to interface several of them at once. It has thus been possible to merge the functionalities of several devices into one device, as shown in the picture about social media. Ever since then a great controversy has been raging as to whether human mental capacities are comparable to the mental capacities of a machine, or not. Currently, the computer leads technological revolutions, as every process in the world is reproduced within the computer, and the computer also generates new data never generated before.

This phenomenal success of computing has also given rise to the notions of computers "becoming conscious/self-aware" or even coming to life. In other words, life processes are seen as a combination of extremely complex mechanical interactions, and since computers perform these calculations in a fraction of a second, would it not be feasible to call a computer *alive*? These, and many other related questions have cropped up in the past few decades with increasing intensity.

Essentially, the key question is regarding the thinking process itself. How *does* a human being think? Once the process is understood, it is only then that a comparison with the computer can be correctly made.

It is hence necessary to trace the idea of computers or “thinking machines” as they were called earlier, until a clear view is obtained of the thought process itself. The route can be taken backwards in time as follows: starting with social media (2000’s), which involves interfacing several profiles over the internet, one can work back to the idea of the internet, which was first developed (from the late 1960’s, to early 1990’s) by several computer engineers in order to connect the data between universities. Since this interconnection duplicated the single computer, it is necessary to trace the development back to the ideas inspiring the computer. Prior to 1960’s, the milestones in this development can be outlined thus:

Year (approximate)	Concept	Pioneers
1945	Computer architecture, Programming	John von Neumann, Grace Hopper
1937	Switching Theory	Claude Shannon
1936	Computability of Numbers	Alan Turing
1931	Incompleteness Theorems	Kurt Gödel
1879	Symbolic Logic	Gottlob Frege, Charles Peirce
1847	Digital Logic	George Boole
1670	Mathematical Logic, Binary numbers	Gottfried Leibniz
1642	Calculating Machine	Blaise Pascal
1641	Mechanics, Coordinate Geometry	René Descartes
1601	Binary Codes	Francis Bacon (Lord of Verulam)

There is a gap of 200 years that leads into the Enlightenment Era, when mechanical calculators were first developed. In the same period, philosophy played a strong role in generating these ideas, involving for example the beginning of mathematical logic. This means that the Enlightenment Era is a good place to start the analysis, where the first seeds for today’s technology were laid. Starting from this time period, one can progress back to the present, paying attention to the developments and the pioneers who developed them. A description of this path, as well as the contribution of each pioneer will now be analyzed, keeping in mind the relationship with the thinking process throughout the analysis.

Chapter 4: Ideas Behind ‘Thinking’ Machines

Example 3. Of a Bi-literary Alphabet.

Aaaaa,	aaaab,	aaaba,	aaabb,	aabaa,	aabab,
A,	B,	C,	D,	E,	F,
aabba,	aabbb,	abaaa,	abaab,	ababa,	ababb,
G,	H,	I,	K,	L,	M,
abbaa,	abbab,	abbba,	abbbb,	baaaa,	baaab,
N,	O,	P,	Q,	R,	S,
baaba,	baabb,	babaa,	babab,	babba,	babbb.
T,	V,	W,	X,	Y,	Z.

For by this Art a way is opened, whereby a man may expresse and signifie the intentions of his minde, at any distance of place, by objects which may be presented to the eye, and accommodated to the eare: provided those objects be capable of a twofold difference onely; as by Bells, by Trumpets, by Lights and Torches, by the report of Muskets, and any instruments of like nature. But to pursue our enterprise, when you addresse your selfe to write, resolve your inward-infolded Letter into this Bi-literarie Alphabet.

−Francis Bacon, 1623

Language is the mode used to communicate human thoughts. Hence it is essential, while studying the development of thinking processes, to study the mode of their communication in every time period.

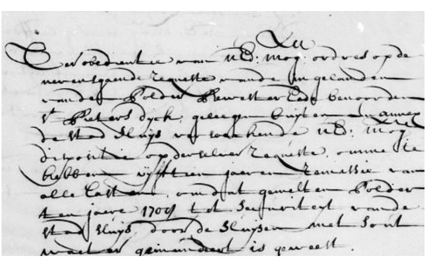
The foundation for the modern day communication device – the computer – is the binary code system, which originated in the methods for passing secrets and codes i.e. in cryptography of the 17th century. Binary numbers as a mathematical system were explored in ancient cultures and even tribal societies while using different “bases” for a number system, such as 2, 10, 12, 16 and 60. However, it was the idea of Lord Bacon of Verulam to associate an alphabetical character to a binary code, thus bringing mathematical application into language. Base 2 was the most natural base to use, as most physical objects can be affected in that fashion e.g. “by trumpets, by lights and torches.”

The researches of Bacon into cryptography brought into culmination something that had begun in several old cultures like China, Meso-America and Sumeria: the art of writing. What was formerly transferred only via the human voice from generation to generation (before 3rd millennium BC according to historians, which marks the start of Sumeria) was engraved in tablets during this ancient period. This occurred in several stages. Following the early stylus marks and hieroglyphs, for centuries mankind used *writing* for keeping record. In its earliest stage there was still an imprint of the writer of the particular record: the *handwriting*. It is possible to bring out a considerable amount of variation within the way something was written down, not in content, but in form, giving rise to various styles of writing each with their own nuance. Beauty and art played a major role in much of the earlier writing styles, as is evident when calligraphy or even hieroglyphics are studied. This can be called Stage I: the transfer from voice to script. In this stage, as one writer copied down what was written down by his predecessor, individual variations in the style of writing (which was predominantly cursive) were naturally present for any particular written content.

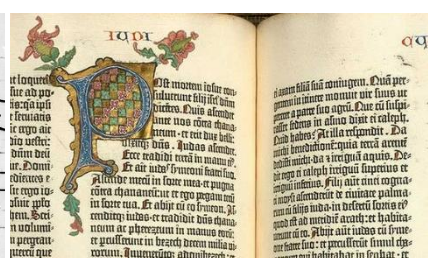
This prevailed until the 14th century AD. The next massive variation in communication occurred at the beginning of the 15th century with the invention of the printing press. Now, the "style" of handwriting was frozen into the machine, and letters were split up into blocks, which could then be used to produce and infinitely reproduce a particular page. Thus, in this Stage II, individual handwriting no longer mattered, however there was still a considerable variation between book to book, language to language, ink to ink, and paper to paper. In spite of the mass production, these aspects made it through.

It is well known that the printing press revolutionized culture, as knowledge penetrated to the masses in a way never possible before, and "literacy" as a social concept came into being. About two centuries after the invention of the press, with the advent of Bacon's cipher, all personality is driven away from the expression of writing as each character is reduced to "on" and "off", so to speak. There can be no individual variation possible in the transfer of this code, even if a wide variety of physical objects are used for the transmission. One can light fires, shine mirrors, or bang on drums, and the net effect is the transfer of the same character across from one place to another. The "paper" could vary, but there was no leeway for variation in binary code. This is Stage III, which developed later into various forms such as Morse code and even Braille.

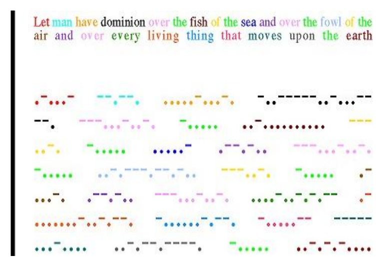
Hence, the transformation can be represented as follows:



Stage I – Cursive Handwriting



Stage II – Printed Letter

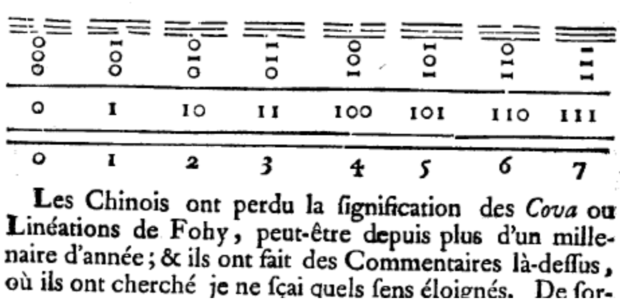


Stage III – Binary Code

Hence, mathematics and language intertwined, with a mathematical construct *replacing* a letter of the language. The full effect of the individual was diluted in stages: from the unique human voice, to the varied handwriting, to the standardized letter, to the universal code.

What rose up as the art of printing in the 15th century in Europe happened to be a reflection of an art developed in China in as early as the 3rd century AD. Chinese printing had advanced considerably, but was restricted in its use of movable type because of the immense complexity of its language, which was entirely unsuited for developing a large scale process. It was in Greek, Latin and Anglo-Saxon languages where the phonetic script allowed the best possible application of printing. Another idea of Ancient China was, however, much more amenable to a complete adaptation, which was done by the famous German philosopher: Gottfried Wilhelm Leibniz (1646-1716).

Leibniz is famous today mainly for developing Calculus along with his contemporary Newton, and for developing the binary representation of digits which he was studying for application in computing. He had a deep interest in Ancient China. He studied Chinese writings extensively, and is said to have remarked to a friend in a letter that “I shall have to post a notice on my door: Bureau of Information for Chinese Knowledge.” This fascination with China increased when he encountered the Hexagram arrangement of Fu Xi, which closely mirrored the binary system. Thus, he was deeply influenced by Chinese philosophy in the very work that laid the foundation for modern binary computing.



000	001	010	011	100	101	110	111
0	1	10	11	100	101	110	111
0	1	2	3	4	5	6	7

Les Chinois ont perdu la ſignification des *Cova* ou Linéations de Fohy, peut-être depuis plus d'un millenaire d'année ; & ils ont fait des Commentaires là-deſſus, où ils ont cherché je ne ſçai quels ſens éloignés. De for-

(Left) From Leibniz’ *Explication de l'arithmetique binaire (1703)* and (right) Bagua of Fu Xi

Of course, Leibniz was also interested in fully functional calculating machines and had even constructed one, much like Blaise Pascal, who had designed one such machine in 1642. These machines used the well known system of interlocking gears to add, subtract, multiply and divide. While Pascal’s machine utilized the decimal system, Leibniz also outlined a method for a binary calculating machine:

> This type of calculation could also be carried out using a machine. The following method would certainly be very easy and without effort: a container should be provided with holes in such a way that they can be opened and closed. They are to be open at those positions that correspond to a 1 and closed at those positions that correspond to a 0. The open gates permit small cubes or marbles to fall through into a channel; the closed gates permit nothing to fall through. They are moved and displaced from column to column as called for by the multiplication. The channels should represent the columns, and no ball should be able to get from one channel to another except when the machine is put into motion. (Leibniz, *De Progressione Dyadica*, 1679)

While calculation with machines was mainly seen at the time to be an aid to repetitive mathematical work, what is more interesting is the relation to thinking that was beginning to be formed at the time. Leibniz was very interested in showing that all statements that express human thought can be represented using a symbolic method, hence forming an “alphabet of thought.” He states his ideal as follows:

> … if one could find the characters or symbols to express all our thoughts as cleanly and exactly as arithmetics expresses numbers, or as analytic geometry expresses lines, one could do the same as one can do with arithmetics and geometry, as much as they are subject to reasoning. This is because all investigations that depend on reasoning would take place through the transposition of

> these characters, and by a kind of calculus. This would make the invention of very nice things very easy...
>
> And the characters which express all our thoughts would constitute a new language which might be written or pronounced. This language will be very difficult to make, but very easy to learn. This language would be the most powerful instrument of reason. I daresay that this would be the last effort of the human spirit, and when the project will be executed, humans will only care about being happy because they will have an instrument which will serve as much to amplify reason, as much as the telescope serves to improve the vision. (Leibniz, *Characterica Universalis*, 1677)
>
> The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate [*calculemus*], without further ado, to see who is right. (Leibniz, *The Art of Discovery* Wiener 51, 1685)

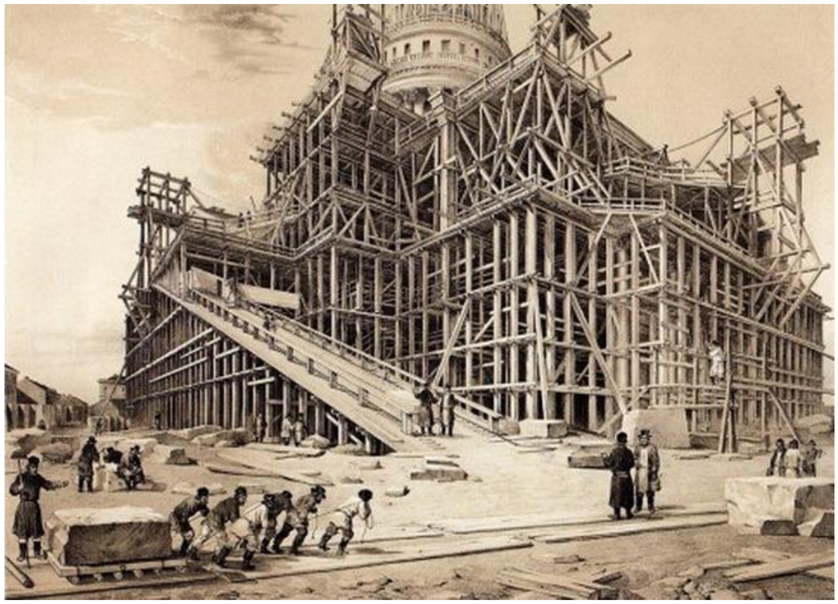
It can be observed that this is the origin of a second stream of thought, one which strives to convert the reasoning or logical process into a mathematical process. These ideas indicate the interest in representing thoughts as mathematical expressions, and also indicate the ideal of a machine that enhances reasoning "as much as the telescope serves to improve the vision." Here, thinking and mechanism are closely interlinked as an ideal.

René Descartes, the great French philosopher, was meanwhile convinced that the world was a mechanism, and everything in it followed the same laws that are to be found in a machine. This view saw the material Universe as a gigantic clockwork mechanism, set in motion by the Creator and continuing forever in that fashion. The laws constituted the rules of coordinate geometry and mechanics. However, Descartes believed the mind to be distinct and separate from matter, superior to the mathematical mechanism of the world, while Leibniz considered the processes of the mind itself (reasoning) as a mathematical process. Here the two views of relationship of thinking to mathematics are revealed: one which views the thinking as distinct from mathematics, and one which views them as being identical for all practical purposes.

This intersection of mechanism, thought, language and its representation is seen to be the determining factor with regard to all computations of the later years. Just as Bacon's ideas were instrumental in making all writing universal and mathematical, Leibniz and Descartes concerned themselves with universal logic and universal mechanism respectively. This theme of Universality, or removal of the expression of human thoughts from the personal sphere to one governed by mathematical laws, guided the development of ideas for technology until the end of the 17th century.

In terms of philosophy, there is a substantial gap from these preliminary investigations of Bacon, Leibniz and Descartes to the developments of Boolean algebra and mathematical logic of the 19th century. While this might give the *appearance* of a gap, it points once more to the aspect of *internal* development hinted at previously, where the thinking itself undergoes a gradual change. To trace this internal development accurately, the thought process has to be understood in all its aspects i.e. thought construction has to be studied.

Chapter 5: Thought Construction

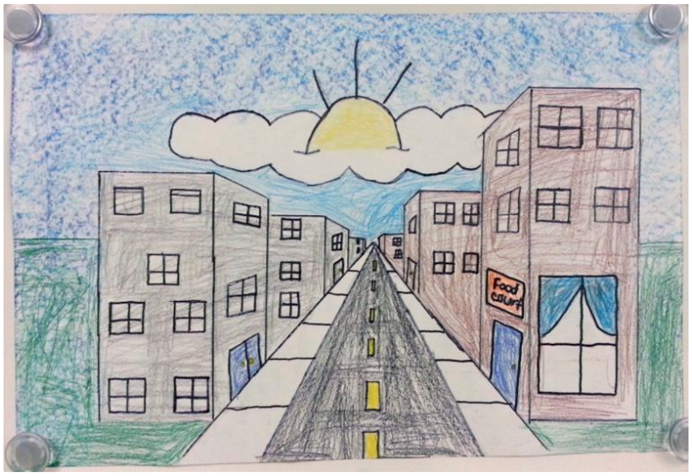


> Un tas de pierres cesse d'être un tas de pierres, dès qu'un seul homme le contemple avec, en lui, l'image d'une cathédrale. (A rock pile ceases to be a rock pile the moment a single man contemplates it, bearing within him the image of a cathedral.)
>
> −Antoine de Saint Exupéry

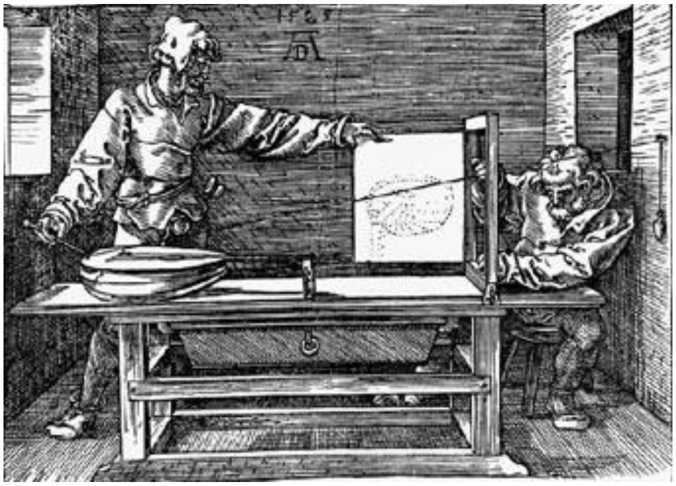
The previous chapter described the transitions that occurred at the end of the 17^{th} century, which served to combine logic and mechanisms into an intertwined system. The question naturally arises: is thought a form of mechanism? In the case of the calculations necessary to generate extensive mathematical tables, it is clear that a mechanism certainly helps the thought process. Does this however mean that a thought process is *identical* to a mechanism? This is the central core of the problem, and hence has to be addressed carefully.

When considering any topic, particularly the issue of thought, it is important to realize how quickly worldviews transform. A fact taken for granted today might not even be conceivable two centuries ago, and this is even more so when a *concept* or idea taken for granted today. Most historical overviews find it difficult to make this transition: to not only describe events of a bygone era but also to really *think* as the people thought at that point in time. This aspect has to be cleared up before trying to understand the thinking process itself.

It is useful to begin with some illustrations. Consider the solution of a straight forward problem: How must a drawing be created on a sheet in order to represent a 3D image? It is clear to anyone today with the slightest artistic training that it is a simple matter of drawing the farther objects proportionately smaller. It is called the use of perspective in drawing, where parallel lines appear to be meeting at a point on the horizon called the *vanishing point*. Anybody who has drawn a row of houses in their childhood knows that it is perhaps the most straightforward rule to identify and follow with respect to drawing.



However, studying the history of art reveals something astonishing, that it was not until the 15th century that artists even discovered this rule, which until then had used rough approximations of sizes in order to achieve the 3D effect. For millennia, *the mathematical laws of perspective were unknown*. In fact, once discovered, a machine with strings and weights was utilized for practicing this technique as shown in the image below:



Albrecht Dürer, *Instruction How to Measure with Compass and Straight Edge* (1525)

Numerous descriptions of perspective in art and renaissance art include these technical descriptions, but an important question is missed. How is this enormous discrepancy possible, in something as "normal" as watching train tracks or road lines meeting at a vanishing point? Even though geometry of lines had been known and well-studied for millennia, why did one have to wait until the 15th century for artists to catch on to something that even a young child, with his eyes open, can identify? This is one question to keep in mind, as it prevents a projection of today's ideas backwards indiscriminately, and shows that different time periods can have entirely different points of view (literally).

What this means that just as worldviews change, thinking process also changes along with it, and it is hence necessary to know how thought evolved, or how it was constructed over a period of time. This change in thought process over time can be tackled by observing how the change occurs in an everyday situation. For example, consider a scenario where a logical mathematical proof is being taught to students: that the solution to quadratic equations gives two roots. Even with adult students, it is clear from the learning process that there is a big difference in solving equations before and after proving this rule. Seeing something solved is different from solving it oneself. Something that appears insurmountable at one time appears easy, straightforward and logical after learning it. Similarly, mathematical rules taught in high schools today required, in the past, the best minds in mathematics to design and identify them, because they had to be formulated, or constructed, for the *first* time.

In these examples, it can be identified that there is a lot more to the thinking process than mere logic, and that is the same concept that was earlier hinted as "inner effort." This defines the difference between something that has been already discovered and something that has to be discovered anew. It also shows that discovery is by no means a simple process of logical extension, else many of these discoveries would have been as straightforward as drawing two straight lines to identify where they intersect. By observing numerous instances of the thinking and learning process in people, it can be confirmed that there is a significant difference before and after a thought structure has been built up. *Before the construction of a logical sequence, effort of will is paramount, while after its construction, one can simply observe the process and find it to be logical.*

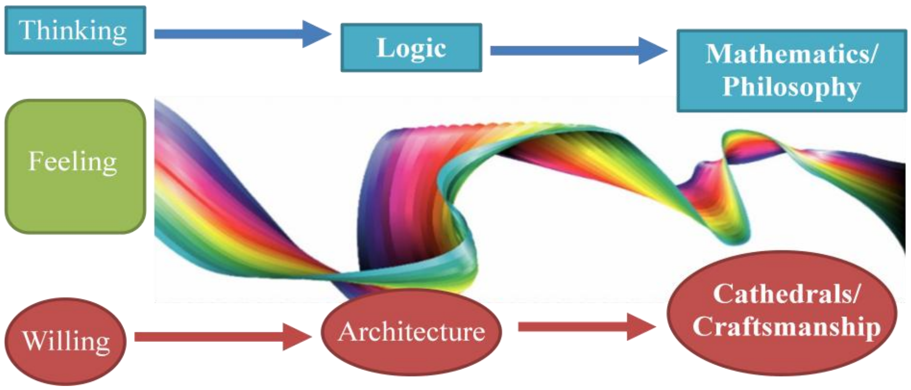
We will identify this process of inner effort as "willing," which is something joined to the activity of "thinking." It must be emphasized that these concepts are not arrived at in a theoretical fashion, but directly from the observation of the thinking process itself; something that every thinking person can verify from experience. An objection can be raised that this element of internal effort might not be real, and just a figment of imagination caused due to the situation. However, the criteria being used to determine its validity is the same as that used by logic: an internal observation of truth and its external verification. As long as it can be verified that there is a difference between memorizing a concept and understanding a concept, this fact of internal effort stands on solid ground. Just as the builders of a mansion must spend an enormous amount of physical effort in constructing all the staircases and interconnected rooms, which the occupiers can then simply walk over, in the same fashion the structures of thought built by the great thinkers of one era are simply "walked over" by their descendants. If thinking was a matter of logical/intellectual connections alone, then it must be as simple to *make* a road as to *walk* on it. Reality shows otherwise, and there is a large difference between the two. This factor that comes into play from beyond logic is the effort, or will.

However, application of effort and knowledge of logic are necessary but not really sufficient in order to lay down the pathway from one idea to another. Continuing the analogy of construction, consider a railroad builder who cannot see past a mountain. In other words, he knows the laws of mechanics to dig a tunnel, and has the necessary manpower to get the job done, however, whether the job can really be accomplished or not cannot be determined with both these conditions, and something else more mysterious comes into play: *skill* or *feeling*. Whether gained by long experience or due to innate talent and genius, this realm of feeling is that from which the mysterious nature of *skill* manifests itself, and actually completes the entire process. In the above example, a skilled builder would have developed a *feel* for the terrain (please note that the word is used here in a sense different from that denoting emotions alone) that would indicate whether or not the task can be done in a satisfactory way. This same skill is observed by mathematicians and engineers as well, who speak of the beauty of certain theorems and the artful way in which proofs or even machines are constructed. Thus, while the thinking process might superficially appear to be a straightforward matter of logically connecting one concept to another, the actual process is similar to the building of a cathedral. Laying one brick on another does not a cathedral make. A complete idea of the entire building (the layout), the effort necessary to build it (the manpower) and the artistic flourishes that give each cathedral its individual stamp (skill of the workers) are all necessary for the structure to stand and function.

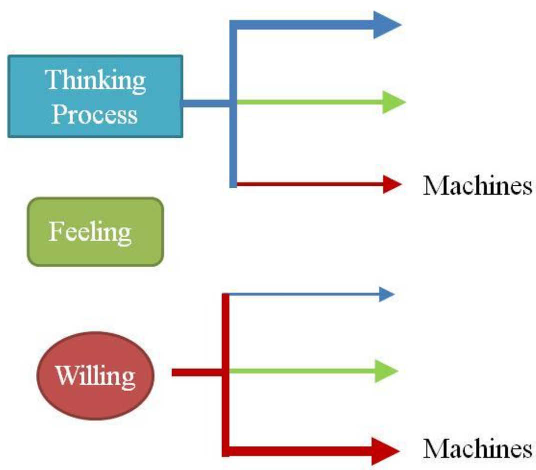
These are hence the distinctions within the process of thinking: thinking itself, thinking colored by willing (inner effort) and thinking colored by feeling (individual skill). Just as the strength of a building lies in its framework, and the strength of a limb is determined by the skeletal bones, the strength of a thought process lies in how well it stands up to scrutiny and verification i.e. how it leads to a better understanding of the world. When there are inconsistencies within a structure, it has the same effect as that of a broken pillar, which cannot support the building any more. This was why it was necessary for the most vigorous efforts to be applied by many individuals in order to create a theory or a philosophy, as the thought framework had to be built. An individual who works on developing this internally consistent thought structure can be called the *Philosopher*.

This differentiation of the thinking process also sheds light on a different approach in the development of civilization. Just as it was observed that thinking involved a feeling or nuance, and also of inner effort or willing, the same can be observed in the domain of actual physical toil: the domain of willing. Someone who spends the entire day working at a construction while obeying the orders of an architect, can be described as living in the action or willing alone. However, when the construction worker not only piles stone upon stone, but also has a say in the design underlying the construction, the element of thinking enters into the physical actions, which ultimately leads to the development of skill. This person transforms things by starting with actual building experience, instead of starting with the concept or idea, and can be referred to as the *Craftsman*.

The Philosopher and the Craftsman, are thus the essential actors on the world stage, with the Artisan or Artist serving as a mediator between them. A Philosopher begins with thinking, and merges the other aspects into it. The Craftsman begins with something tangible, with the actual building process, and merges the other aspects into this activity. They both utilize skill: an artistic Philosopher sculpts one thought with another with the same skill that an artistic Craftsman brings to the buildings. The Artisan is hence active in both the approaches. Thus, thinking, feeling and willing are observed to be concepts which intermingle with one another, and whichever is dominant generates the mode of activity. These two parallel streams, one which took the route of philosophy and development of thought structures (Philosopher), and the other which dealt with the building of devices, cathedrals and temples (Craftsman), ran parallel for several centuries, with some mediation due to art. One culminated in the knowledge of mathematics, while the other in practical expertise of architecture and technology. The threefold nature can be represented thus:



After the Renaissance, the two streams of Philosopher and Craftsman started merging, from which the resultant "offspring" is obtained: Natural Science/Physics/Technology. Thinking and willing merged together gradually, creating new machines. Now, the three divisions expressed above are not airtight boxes, but indicate the biases within the activity of man. There is hence an overlap of each quality with the other two, i.e. thinking has aspects of feeling and willing, willing has aspects of thinking and feeling, etc. Since it is the element of physical toil i.e. the *external effort* or physical will that gets out-sourced to the machines, a similar process is to be expected for the thinking process too: the *internal effort* of thought (the will-element of thought) is likely to be outsourced to the calculating machines. This can be indicated like this:



The aspect of feeling contributes to both extremes, and for the purpose of understanding the extremes better, it is kept aside for the time being. Both an aspect of thought and physical action have the potential of getting outsourced. Just as various tools and devices help with external construction by multiplying the physical effort of man, there is an element of inner effort that machines, when suitably designed, may multiply as well. This was the situation at the end of the 17th century Enlightenment era when the first "aids to thought" were being constructed.

While the differentiations of thought into the willing and feeling element were perhaps not addressed clearly, thought was still not restricted to a mechanical process in this time period. Other aspects of thought life were still seen, and in fact, the ethical motivation for will power was still very clearly emphasized. For example:

> I found it appropriate to insist a bit on these considerations of final causes, incorporeal natures, and an intelligent cause with respect to bodies, in order to show their use even in physics and mathematics: on the one hand, to purge the mechanical philosophy of the impiety with which it is charged and, on the other hand, to elevate the minds of our philosophers from material considerations alone to nobler meditations. (Leibniz, *Discourse on Metaphysics*, 1686)

It is easily observed that the lives of many philosophers and mathematicians of this era were also steeped in a life of arts, devotion and religious works (feeling and willing), which are generally discounted as irrelevant or mistaken by modern scientific researchers. For example, Newton considered his Theological works to be of more importance than his scientific ones. Leonhard Euler, one of the most prolific mathematicians of all time, wrote the *Defense of the Divine Revelation against the Objections of the Freethinkers*. Blaise Pascal, discoverer of projective geometry and child prodigy in mathematics, underwent a religious conversion when he was 31 and produced works on Theology. Leonardo Da Vinci was the epitome of the Artist-Craftsman, whose feats are perhaps unparalleled by any individual today.

Modern research has great difficulty in accepting that there is more to the thinking process than is commonly believed today, and is especially confused with the firing of inner effort by religion. The following passage shows this clearly:

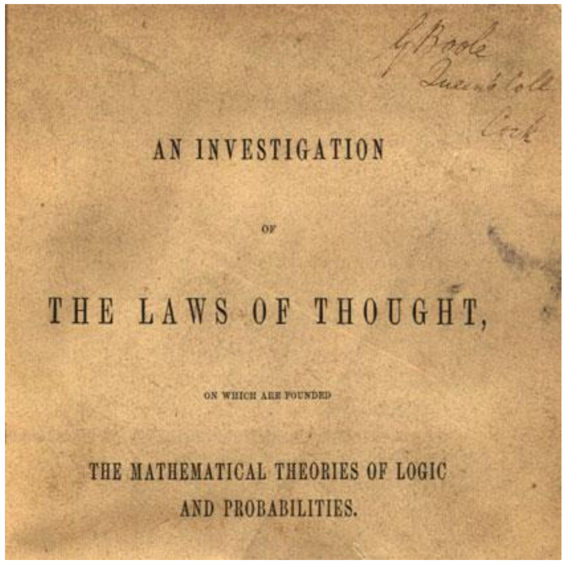
> This combination of fanatical devotion and original scientific thinking was not uncommon during the period. And such obsessive faith was no self-protective affectations of genius either. Van Helmont, Pascal, Spinoza and Newton all considered that their religious thought was their major contribution. A curious aberration… (Paul Strathern, *Mendeleyev's Dream* pg 171, 2000)

It is neither a curious aberration nor a weird obsession, but a necessary component of the complete thinking process. It is straightforward evidence of the fact that the inspiration for inner effort−the will element−has a major role to play in the production of mathematical and philosophical works. The feeling element as well as the inner effort enhance and help complete the thought process. A study of the lives of scientists reveals this working together of the Philosopher and the Craftsman to various degrees. It also reveals mistakes in thought processes clearly through their life experiences. For example, Francis Bacon has had an enormous influence on the experimental method followed in the past two centuries, and his methods of coming to generalities by way of individual instances has become famous as the Inductive Method in science. His writings on *The New Atlantis* and his descriptions of Solomon House inspired the foundation of the Royal Society. Yet, in spite of all the descriptions of experimental methods to be followed, the only experiment that Bacon ever personally carried out had unexpected results: Wondering if flesh can be preserved by refrigeration, he got out of his carriage in the snow, borrowed a chicken and stuffed it with snow–a feat that led to an infection of pneumonia and death barely two weeks later. It is ironic indeed that the only experiment conducted by the person who taught the entire world about the "experimental method" lead only to his death. Once more, it shows the fallacy in the philosophy that neglects the thinking capacity of the human being and emphasizes the repetitive experimentation exclusively. The willing element of thinking–especially that related to only to repetition–dominates everything else, and hence leads to a dead end.

However, with the entrance of the first calculators, this inner effort of repetitive thinking was outsourced to a mechanical device. Just as huge engines multiplied the efforts of men in industry, the possibility of multiplying calculating capacities also arose. Hence, the thinking process does contain an element that involves effort, and all repetitive effort can be outsourced to a machine. However, this does not exhaust all that thinking can accomplish in the world. This is how the question posed at the beginning of this chapter can be answered: Thinking is not identical to a mechanism, but does contain elements which can be mechanized. That is the crucial idea.

As the streams of the Philosopher and the Craftsman started intersecting one another, several philosophical issues regarding the free will of man, thoughts and his relationship to machines arose. The first time the streams intersected, it gave rise to the works of Leibniz and Pascal in the area of ‘thinking machines’, and the work of Newton in the area of natural science. After this era of Enlightenment, the streams diverged slightly again for another two hundred years, when both the Philosopher and the Craftsman worked more in their own domains. The 200 year gap was filled with the discovery of numerous technological devices, and philosophy took the center stage in most of Europe of the time. When the two streams intermixed again in the second half of the 19th century, it gave rise to the field of mathematical logic for the Philosopher, and that of numerous calculating machines for the Craftsman. These subjects need to be studied further, to determine the transformation of the thought process over the next two centuries.

Chapter 6: The Laws of Thought



> No matter how correct a mathematical theorem may appear to be, one ought never to be satisfied that there was not something imperfect about it until it also gives the impression of being beautiful.
>
> – George Boole

The dawn of the 19th century saw a rapid development of natural science, leading to the rise of new ideas in physics and mathematics. Industries were in full swing, laws of electricity and magnetism began to be investigated (by the likes Faraday, Volta and Ampere), and non-Euclidean geometry was developed by many mathematicians, including the "Prince of Mathematics" Carl Gauss. Devotion to architecture of buildings was now transferred either to technology, or to a study of the architecture of the human body, leading to large strides in anatomy and physiology. Cell theory took shape, and the possibility of different functions of the body being localized in different parts of the brain began to be investigated.

It was precisely in the midst of this environment that George Boole (1815-1864) lived, and his life shows the indications of the struggle between the different aspects of the thinking process. Deeply religious by nature, Boole had a mystical experience in 1833 which was later described by his wife Mary Everest Boole:

> My husband told me that when he was a lad of seventeen a thought struck him suddenly, which became the foundation of all his future discoveries. It was a flash of psychological insight into the conditions under which a mind most readily accumulates knowledge [...] For a few years he supposed himself to be convinced of the truth of "the Bible" as a whole, and even intended to take orders as a clergyman of the English Church. But by the help of a learned Jew in Lincoln he found out the true nature of the discovery which had dawned on him. This was that man's mind works by means of some mechanism which functions normally towards Monism. (M E Boole, *Indian Thought and Western Science in the Nineteenth Century*, 1931)

The inspiration for inner effort is once more seen to originate in the sphere of religion, as borne out by Boole's deep interest in all religions and his desire to work in the cause of "pure religion." Studying his life and conceptual development must hence necessarily include the logical precision, the aesthetic sense, as well as religious devotion simultaneously, as it existed in the individual. This is not usually done today, and there is a recurring tendency to pick and choose. Only one part of the story is valued and the rest discarded as being irrelevant (quite against the spirit of scientific investigation):

> The father of pure mathematics, as Bertrand Russell would later refer to Boole, had not been purely interested in mathematics, nor was his mathematics free of the "impurities" of extradisciplinary concerns, in particular, religious ones. The symbolic logic that is now the essential tool for secular philosophers and that forms the basis for dispassionate computers began in the mind of a warm-blooded, religiously concerned idealist (Dan Cohen, *Equations from God*, Ch. 3, 2007)

In other words, the assumption is made that mathematics is "disciplinary" and everything else is necessarily a separate box or an "impurity." This assumption is one of the primary reasons why this aspect of Boole's life and work is hardly known or even realized today, making it a fact worthy of mention.

As already described, Bacon pioneered the use of binary to represent letters and language. Leibniz developed the use of binary numbers in mathematics and suggested their use in calculating machines. He also suggested that logic might be represented mathematically. Boole took the first steps to accomplish that by trying to represent thought and logic itself in a binary form. Language, Mathematics and Logic: these were the domains that could now be represented in a binary form, as a work of the Philosophers. It is clear that there are a finite number of letters in the alphabet, and a finite representation of numbers, Thus, letters and numbers can be represented in binary, a feat which does not alter the very content of thought itself. For instance, I can express a number in any base, and I can also write a certain word in any script. The form of the letter is not crucial to understanding the meaning of the communication. However, with Boole, the notion of "meaning" and logical thinking itself is expressed in the form of binary algebra, which has to be analyzed further.

Boole considered his work a natural extension of the works of Aristotle. Prior to Boole's analyses, logic was developed as an interrelationship of concepts or propositions, which were then differentiated. Qualifiers such as "All objects," "some objects" and "no objects" were referred to as *subjects*, while their qualities e.g. "round," "white" etc. are called *predicates*. The verb forms the link or *copula*. The copula was seen as a logical connecting link, and it is normally a verb. In other words, the bridge between the subject and predicate involved either an existence (is) or lack of existence (is not).

Together, different kinds of propositions were created, such as:

All diamonds are solid.

Some stones are soft.

Some pebbles are not black.

No rocks are liquid.

Logical propositions were studied, discussed, debated and elaborated by the Greeks of the same period, the Arabs of the 7th-10th century, and the Scholastics of the 13th century. Thus, the works of Aristotle on logic have had an immense role in the development of further thought for nearly two millennia. Nevertheless, the development of a logical train of thought itself was not altered, and everything was still expressible in terms of basic “syllogisms” like this one:

All diamonds are solid.

Kohinoor is a diamond.

⇨ Kohinoor is solid.

This is essentially the crux of the development of logic, and is also called a syllogism or deduction. A logical deduction was therefore at the root of all philosophy for many centuries, as workers in this field strove to build thought itself and also the relationship between man and the world. Rules were derived for these logical deductions and for determining validity and invalidity of propositions. The laws of thought according to this system are:

A is A	(*Law of Identity – A concept is equal to itself*)
A is not (not A)	(*Law of non-contradiction – A concept is not the same as its opposite*)
All A is either A or not A	(*Law of excluded middle – A concept is either true or false*)

These were followed quite strictly by medieval logicians. For example, Avicenna (10th century) is said to have declared that: “Anyone who denies the law of non-contradiction should be beaten and burned until he admits that to be beaten is not the same as not to be beaten, and to be burned is not the same as not to be burned.” A dry sense of humor indeed, but it is hard to imagine today how central these debates were to the intellectual life of the time, when the ideas one held to be true had life-or-death repercussions.

It can be seen in the form of the copula that the laws of logic denote *static* situations, i.e. either something *is* or *is not*. There is no other possibility. It is interesting to probe the origins of these statements in logic and ask why the Greeks posed a statement in that particular fashion. Since the experience of one era determines the concepts woven out in the following period, the natural question to ask is: What motivated the laws of thought? What was the experience on which these laws were based?

A study of the thought life and pursuit of Truth of the ancient Greeks shows that geometry was revered, as was music (*Harmony of the Spheres*). It was understood that in geometry man could really grasp the structure of the world, and man’s place within it. This is indicated by the Platonic saying “God geometrizes” which was said to be written at the entrance of his school at Athens. In fact, Aristotle was a student of this school itself, and geometry formed the soil for the seeds of logic to be sown. For example, a shape is either a triangle or not a triangle: the same spatial experience could not take two separate forms at the same time. A triangle as a concept remained something static and did not change with time, giving an assurance of a firm foundation to think. This clarity of thought in geometry guided the early development of logic as well, resulting in a twofold copula: *is* or *is not*. The origin of the copula can be indicated as:

School of Athens => Geometry => Copula *is* / *is not*.

Similarly, it can be observed that there are *quantifiers* in the statements: **all**, **some**, and **none**. Here, it is a matter of encompassing the element through number, which is necessarily what our notions of quantity are tied to. Whether or not an actual count is performed, **all** is necessarily more encompassing than **some**, and some is more encompassing than **none**. The origin of these relationships can be traced to the domain of arithmetic, or the positive real line. This was the development that had its roots in musical ratios and numbers. It is important to keep in mind that it is the form of the quantifier itself that is of interest here, and not the concept that it is referring to. For example, consider:

All ideas are wonderful.

It is not important whether or not the *ideas* are quantities, but that the notion of **all** itself is derived from the notion of a quantity. Quantities owe their origin to arithmetic. Origin of the laws of arithmetic can be traced back to a much earlier School: The Pythagorean. The Pythagoreans revered numbers above all as the guiding principles of the Universe, and their ideas had taken strong root by the time of Plato and the School of Athens. Geometry was also seen as being derived *from* arithmetic, paralleling their natural developments in the Schools of Pythagoras and Plato. Hence, the derivation of logical terms is:

School of Pythagoras => Arithmetic => **Quantifier *All* / *some* / *none***.

School of Athens => Geometry => Copula *is* / *is not*.

It is well known that the Greeks were quite skilled in the development of both, and it comes as no surprise that logic owes its origins and internal structure to ideas from geometry and arithmetic. There is yet another aspect of this logic that has to be addressed. This is the subject and predicate, which can be called "class" in general. Conventional understanding simply takes "class" as "collection of objects" or a sack of goods, plainly speaking. However, meanings for the same words can be quite different in different periods (refer to earlier example of perspective drawing.) Hence, this does not take into account that in the Greek era, even ideas were treated as real "objects." Indeed, Plato's philosophical work involved the notion that true reality consists of ideas. In stark opposition to Plato, the Stoics of a later era considered the entire world including ideas as being corporeal, or physical. This also mirrored the different motivations of Platonists and Stoics: Platonists were concerned with concepts from the ideal world (metaphysical realities), while the Stoics focused on actual application within a deterministic physical world. These polar opposites must be taken into account, as they are central to the operations of logic that developed later. If the name of a class of object or ideas is called "concept," the summary of Aristotelian logical forms can be written as:

Quantifiers: Arithmetic

Copulas: Geometry

Class: Concepts (objects/ideas)

The Stoics were more interested in the utility of the laws of thought to living a moral life than in deriving implications of the laws themselves. This meant that they focused on the class alone, and developed consequences. Naturally, Aristotelian logic involved these derivations of consequences, but they were not studied exclusively as done by the Stoics. It is therefore from the Stoics that sentences of this form are derived:

If A then B

Not both A and B

This is perfectly suited not only to develop consequences, but to determine actions. A and B can thus denote *actions*, in addition to ideas or objects. It also rests on a condition: “if,” which separates the true from the false, the “is” from the “is not.” Since A and B can denote actions, the following statement is also possible.

If A then *do* B.

This then adds to the list of copulas, in a different form – not only can B *exist* or *not exist*, be true or false, but it can also be *done*. It is particularly well suited to applications. The updated summary becomes:

Quantifiers:	Arithmetic
Copulas:	Geometry (is / is not), *Actions (do)*
Class:	Concepts (physical/metaphysical)

This brings the discussion from the realm of the Philosopher back to the realm of the Craftsman, and it is worthwhile to see that the logic of the Greeks had their renaissance only in the 19th century: the age of the Engineer/Scientist. In this era, Boole developed a logic which expressed only one particular form of the four Aristotelian copulas viz. *equality*, represented by *equations*. The four statements of the Greeks are reduced to one expression relating to concepts.

All diamonds are solid.	1	
Some stones are soft.	2	=> Coal = Black
Some pebbles are not black.	3	
No rocks are liquid.	4	

Since equations with variables are nothing but the formulation of *algebra*, for the first time logic is expressed through algebra, a branch of mathematics. Logic gets ‘mathematized’ for the first time. This conversion of logical copulas to equality has been addressed in recent works:

> Where Aristotle saw predications Boole saw equations. Boole realised that his theory of logical form was in radical opposition to Aristotle’s, but he seems to have thought that Aristotle had just not gone deep enough, not that Aristotle was fundamentally mistaken. Boole’s pattern was S–is–P, Subject–is–Predicate, or S=P, Subject equals Predicate. (Corcoran, THPL 24 p 261, 2003)

This conversion of four possible expressions into the single expression of equality had its consequences:

> What was immediate for Aristotle required mediation for Boole. Again, Aristotelian simplicity becomes Boolean complexity. For example, Aristotle would go from the two premises “Every square is a rectangle” and “Every rectangle is a polygon” immediately—in one step—to the conclusion “Every square is a polygon.” Boole broke this down into eight tediously meticulous equational steps. The first step is going from the second premise, “Every rectangle is a polygon”

> to an intermediate conclusion gotten by something analogous to multiplying equals by equals, namely “Every square that is a rectangle is a square that is a polygon,” “multiplying” both sides of the equation by “square.” (Corcoran, ibid.)

In other words, conversion of all the copulas into a single one (*is* or *equals*) made the representation of statements cumbersome. If only *equality* is included as a copula, there is naturally no inequality that can be expressed, leading to the complications just quoted. If Boole wanted to *extend* logic, a natural way forward would have been to study different copulas, which do not make sense in Aristotelian formulation. For example, compare these two sets of statements:

All men are mortal.	All children like candy
Socrates is a man.	The cat likes children
=> Socrates is mortal	=> The cat likes candy

The second “syllogism” on the right is not necessarily valid in real life, and it indicates that a different domain opens up when a different copula is used. Hence, a new form of logic can be determined for *likes* and *does not like* just as it was built up for *is* and *is not*. Instead, the set of copulas is reduced to just *is* by Boole.

This alteration had other effects as well. With the nature of the copula altered, the subjects, predicates and quantifiers changed. Boole reduced the quantifiers **all**, **some** and **none** to just two: **all (1)** and **none (0)**. Also the quantity, which stood by itself in the traditional system, was now inserted *with the class*. This means, that one no longer had **All** diamonds but instead just a single All-diamonds which became the same as just diamonds because **All** = 1. Similarly, instead of saying “**No** diamonds” one had to say All-diamonds. The quantifier gets attached to the class itself. Hence, just as the ancients had to create a number to represent zero, for the first time a new *class* or object also had to be created for the purpose of saying “nothing.” Nothing becomes a class of objects! For example, the standard logical statement transforms like this:

No A is B

⇨ (**No** A) is (B)

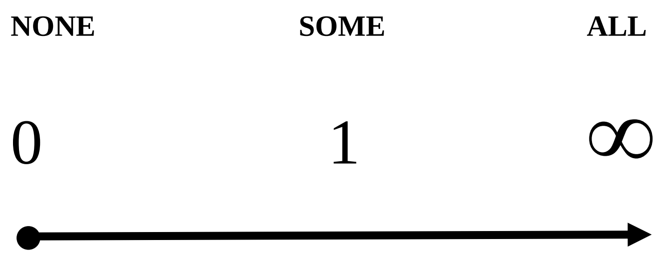
⇨ (All A) and (All B) is (nothing)

⇨ A.B = 0

This is a phenomenal transformation, as the variable “zero” or “nothing” has literally been created *ex nihilo* to fill in the function of *is not*. Since the copula is no longer available, the object itself must have “nothing.”

These laws developed by Boole were complemented and enlarged by Gottlob Frege (1848-1925). Like the Stoics before him, Frege concentrated on creating a system where all logical statements can be expressed symbolically, and also applied. He hence elaborated propositional logic in a mathematical form, making it possible not only to express equations mathematically, but also to include the application using propositional statements (if… then, and, or etc). This enabled logic to be expressed as a mechanism, as an *action*. What Boole did for Aristotle, Frege accomplished for the Stoics, and the works of these two thinkers and their contemporaries (such as C. S. Peirce) form the basis of what is known as Boolean algebra today.

If all the quantifiers of traditional logic had been included, it would have never been possible to indicate it by a machine, because of the quantifier **ALL**. As hinted earlier, these quantifiers bear a direct resemblance to arithmetic, represented like this:



No mechanism can generate infinity, so that had to be removed. The meaning of **ALL** is shifted onto "1," giving:

NONE	**ALL**
0	1

The quantifier **SOME** is no longer required: it is simply absorbed in the class name itself. Therefore, both the names of classes (subject/predicate) as well as the copula (*is not*) become *quantified*. This conversion of all logical statements into algebraic form is thus seen to remove everything that could not be quantified or mechanized and retain only that which could. It is not an extension, as Boole believed, but a reduction, or a filtration.

Reductions of logical statements into mathematical expressions make them well suited to include both calculations as well as the rules of calculations into the mechanism of a device. Sure enough, this generated the possibility of replacing the will element of thinking, and to outsource it to the machines:

> With earlier sorts of logic, to determine whether the validity of an argument had been proved, we still needed to understand the meanings of words – at least *some* of the words – and this meant we still need to *think*. With symbolic logic, by contrast, we don't need to think at all, or rather the only thing we need to think about is whether the symbols appear in the order specified by the rules that govern them. In consequence, so long as the proof is sufficiently spelled out in a symbolic language, the task of verifying it is strictly clerical. What we look at is simply a matter of form – and *purely* form… In this respect, then, determining whether an argument's validity has been proved within the system is strictly mechanical, and in our age, it can certainly be done by machines. (Shenefelt and White, *If A then B, How Logic Shaped the World*, p 252 2013)

Thus, "formal" logic served to reduce the necessity for thought, and to increase the mechanization of concepts.

At this point, it is worth asking: Was this "mathematization" necessary? In other words, what prior reason could one have in order to insist that logic has to be mathematical, and more specifically, algebraic? What is the reasoning that motivated this logical development? A study of Boole's works gives a surprising answer to this:

> Whence it is that the ultimate laws of Logic are mathematical in their form; why they are, except in a single point, identical with the general laws of Number; and why in that particular point they differ;–are questions upon which it might not be very remote from presumption to endeavour to pronounce a positive judgment. Probably they lie beyond the reach of our limited faculties. (Boole, *Laws of Thought*, Ch.1)

Thus, there is no specific reason for insisting that logical rules have to correspond to mathematics, other than the general feeling of confidence that thinkers have in the methods of mathematics (perhaps due to the great success of the Industrial Revolution) as exemplified by Boole. It is a *claim* and not a deduction from previous circumstances, nor a solution to a specific problem. This fact is important to highlight as it shows that the factors motivating the *creation* of mathematical logic were *neither mathematics nor logic*.

Boolean algebra connected logic to algebra, in the process significantly altering the form of logic as it was practiced for centuries. Several features of logic were extended, but only in terms of their algebraic representations (logical gates such as AND, OR, NOT etc.) At the same time, quantifiers are reduced from three to two, copulas are reduced from two to one, and new categories of "everything" (1) and "nothing" (0) are introduced as classes. Language and verbal influences are removed entirely, and replaced by abstract symbols. Thus, while the theory itself was generated due to the *religious* will-temperament of its creator, the effect of it was to create *mechanical* (will) equivalents of logical statements. Religious will inspired mechanical will.

Traditional logic was guided by geometry and arithmetic, which were in turn guided by experience. Replacing this by an "algebra" of logic removes those restrictions of experience, giving it a free reign in terms of equations and combinations. Hence, Boolean algebra *appears* to show an extension of logic, even though it is a reduction of it to include only a subset of mathematical concepts.

Mathematics is logical. But now, since logic and algebra were combined as symbolic logic, this form of logic had an effect in turn on mathematics itself. Hence mathematics itself is changed, and seen differently. Since mathematics is at the core of science, this impacted all of natural science. This feature will be elaborated in the next chapter.

Chapter 7: Numbers and Neurons

> Music is the pleasure the human mind experiences from counting without being aware that it is counting.
>
> \- Gottfried Leibniz

So far, the transformations occurring in logic and their relationship to mathematics have been described. In particular, the key changes that occurred with Boolean algebra have been indicated viz. the transformation of quantifier "all" from infinity to one, the removal of copula "is not" and the addition of the concept "nothing" into the predicate or class name. Frege's work helped to make this logic practical by retaining the copula "do" and expressing a logical statement as a sequence of abstract operations. That which earlier required a knowledge of language and hence an evaluation of meaning, was converted into an automatic operation. In addition, the sequence of development of logic was now reversed:

Mathematics and Arithmetic => Geometrical understanding => Logic of Ancient Greek (ca 200 BC)

Logic of Ancient Greek => Algebraic expressions => Mechanical operations (ca 1900 AD)

In other words, instead of deriving logic *from* mathematical understanding, it was *equated* to a specific mathematical domain. This logic, called symbolic logic, now became identical with mathematics. It is but natural to go one step further, and that is precisely what happened: a new mathematics was derived from symbolic logic. Development of mathematics hence came full circle, from mathematics generating logic to symbolic logic generating formal mathematics.

Mathematics => Greek Logic => Algebraic Logic => Formal Mathematics (200 BC to 1900 AD)

As indicated earlier, while engaging the thinking process there is a direct perception of a force, or will element in the effort needed to form a thought. Without this will element there is no difference in thinking about something for the first time and thinking about something that has already been thought about. It has also been indicated that only the repetitive aspect of this force can be directed to a machine. An example can be used to study this process in some more detail.

Assume that you are asked to derive the surface area of a cone for the first time. The first struggle would probably be the hardest, as you wend your way using calculus to determine the right formula. Now, if the same question is given again, and asked to be demonstrated to a third party, the derivation flows more smoothly, and the effort involved is significantly lowered. After a few repetitions, there is minimal effort involved, and the process becomes automatic, and as a consequence, easier to repeat. Compare this with the effort involved in lifting, say, a heavy rock. The first time, there is a large effort involved. After several repetitions, involving perhaps weeks, months or even *years* of experience, it gets easier to lift. In the process, both the bones and the muscles are strengthened. Thus, mental effort appears to be a greatly accelerated analog of physical effort. Both have the quality that with repetition, inner strength increases, so as to match the resistance eventually. Once the strengths are matched, the task becomes easier, and in the end, becomes mechanical. Thus, mechanical process is seen to be the very minimal residual form of inner effort.

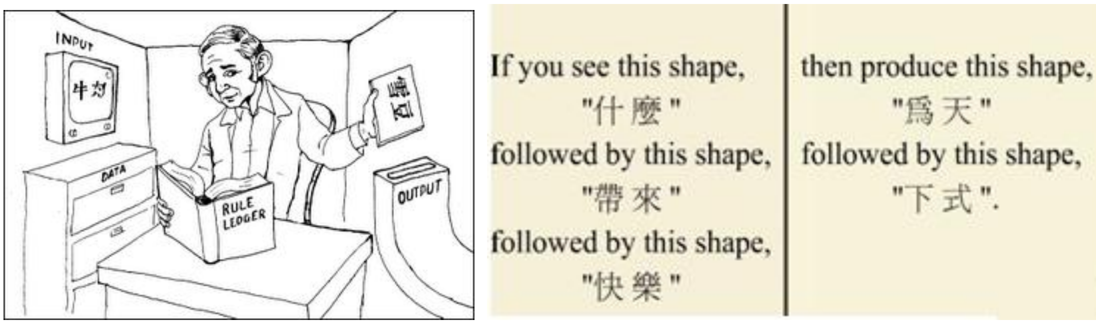
Secondly, after receiving the problem of a cone, assume that you are given a problem in properties of prime numbers. Naturally, this would refresh the will-element once again. After solving this second problem, suppose you declare that it took the same amount of effort to solve this problem as it took to solve the one on surface area. Nevertheless, doing the problem of surface area again would not involve the same effort, but doing a *new* problem requires roughly the same effort. This clarifies the process some more: *novelty* is the key criterion that demands effort each time, while *identical repetition* reduces effort over time. Therefore, in terms of the thinking process as a whole including these willing and feeling aspects, the capacity to understand involves the capacity to generate new ideas, as opposed to repeating existing ideas. This freshness of thinking is developed when trying to understand topics which are as different from each other as possible, or in generating new ideas for the same topic.

Hence, a healthy thought process necessarily involves creating new ideas. But, what is the result of ideas being restricted to those which are logical, algebraic, and hence mechanical? The natural consequence of that restriction is that ideas themselves are seen as being mechanisms! In a direct inheritance of Stoic Philosophy, whose *assumption* was that the whole world is corporeal, thoughts are seen as mechanisms. Here it is easy to observe how the cause and effect are inverted. The idea of mechanism is one arrived at through many centuries of effort of both Craftsmen and Philosophers, and now it is claimed that thought is a mechanism. It is easy to see how one gets into a knot when pursuing the topic like this, when one asks “What is a mechanism?” Answering this would require thinking once more, looping back to square one.

This is reminiscent of the old joke:

> *What is mind?* Does it matter?
>
> *What is matter?* Oh, never mind!

An illustration of the fact that mechanism is not the same as understanding a concept is shown by the “Chinese Room Argument,” described by John Searle in 1980.



Translator in the room, with his Translator (Picture courtesy: David L Anderson, CCSI)

In this argument, a person who has does not know the Chinese language is kept in an enclosed room and is asked to read off a certain set of characters on the input screen. He is given a big fat rule book, containing all the rules about what the output is for any specific input character set. It is possible for this "Translator" to generate a response for any string of shapes, and except for the fact that it would take him a while to provide the response, would be indistinguishable from someone who knows Chinese. Yet, in spite of the fact that he performs accurate pattern recognition, the Translator knows no Chinese and does not understand what any word means at the end of the day. Meaning is completely missing, as the pattern is *not* the *meaning*. This method of functioning is also seen historically with the first major computing machines: looms that weaved patterns of cloth.

This is a direct result of the application of Frege's rules for generating symbolic logic, which can be executed mechanically. As a matter of fact, instead of keeping an actual person inside the box, it is possible to replace it with an elaborate pattern of dominoes. All that would be required for repeated operation is that a fallen domino (or sets of fallen dominoes) can be made to stand again by pressing a lever outside the room, or by a falling domino inside the room. In this case, the "rules" are formed by the pattern in which the dominoes fall. By connecting each Chinese character to a specific set of dominoes, which either fall or do not fall, it is possible to generate a response at the output that once more corresponds to a specific character. As anyone who has arranged dominoes for entertainment knows, kicking a domino can hardly be called "thinking."

(Courtesy: Matt Parker's Domino demo)

Whether it is with dominoes or with gears and levers, the nature of mechanism is clearly seen as something that is necessarily deterministic and finite. The placement of the thinking process is also not clearly identified in the case of a mechanical device. Normally it is taken for granted that the machine helps to think once it is set into operation. This idea has also been suggested earlier, that the repetitive element of thinking might be outsourced to the machine. In reality, the situation is exactly reverse: Thinking is involved only in setting up the "rules" of the operation, or in preparing the rule book or the domino arrangement, and it *stops* the moment the machine is set in motion. Whether one sees dominos falling, gears churning, or electricity firing, the process is identical in essence. It is just like kicking a stone downhill and watching its progress according to gravity. Hence, the basic process underlying computation is mechanism, and not thought.

Another consequence of this restriction of logical form to mechanism, especially with the copula and quantifiers, is the effect on the notion of infinity. As already pointed out, geometry motivated the copula and arithmetic motivated the quantifiers in Greek logic. However, several changes occurred in these subjects towards the middle of the 19th century, simultaneous with the works of Boole. Just a year prior to Boole's *Laws of Thought*, William Hamilton discovered the algebra of quaternions (with one real and three complex quantities). This topic was added to the already existent serious debates among mathematicians as to the nature of numbers, particularly negative and complex numbers, which could not be grasped intuitively. Hence, as algebra was undergoing a massive change, geometry was also being revamped from the ground up: the Euclidean system which had stood for two millennia, just like logic, was called into question. The postulate that stated that parallel lines never meet, was found to be unnecessary for a consistent geometry, throwing open the door to Non-Euclidean geometry and Synthetic Geometry (also called Projective Geometry) that began to be developed as generalizations of Euclidean Geometry. In this form of Geometry, parallel lines did meet: at a point at infinity.

Frege was strictly against the replacing of the axioms of Euclid, and instead added *more* axioms to make the system stricter. He declared that "no man can serve two masters" i.e. either Euclidean or non-Euclidean systems were true (*On Euclidean Geometry*, p251, 1997.) Since the assumptions taken to be "self-evident truths" were no longer valid, the reaction was to abandon the idea and focus on setting up a set of abstract axioms, whose consequences are explored.

Around the same time of Frege's work (1879), irrational numbers were clearly defined by Richard Dedekind (1872) while Georg Cantor explored the fact that there are an infinite number of possible infinities (1874). However, the mathematization of logic was restricted to the Euclidean domain, giving rise to analog machines. Moreover, only whole numbers (zero and positive integers) could be represented in binary code, which led the way to digital machines. These were two immediate consequences of the rejection of both projective geometry, and of infinity–a fact that will be described more in the next chapter.

While infinity is not accessible to mathematical representation, one can still express it as a concept, as it is done in this very sentence. Hence, the logical domain extends beyond that of finite numbers. It is necessary to see that logic is also not restricted by the use of copulas *is* and *is not*. This opens the door to include non-mathematical ideas (or at least, the non-Euclidean) into logical form, and to alter the form of analyzing the possibilities in a situation. Hence thinking has a range that intrinsically exceeds that of mathematics and mechanics.

This fact is mostly overlooked by most comparisons of the mind and the machine. Consider one of the typical examples used for estimating the power of mind and machine: a game of chess. This game has highlighted the epitome of intellectual capacity for several centuries. It is possibly one of the few games today that are simple and yet represent strategy, combinatorics, and even elegance and intuition so well.

McGonagall's giant chess set

Traditionally, in order to investigate whether or not the machine can compete with the human mind, the number of possible moves are calculated, and probabilities weighed in order to determine outcomes. Orderly to begin with, a rough estimate of possible games that can ever be played on the chess-board, rises astronomically with every move: 400 board configurations after the first move, nearly 200,000 after the second move, up to 121 million after the third, and estimated to be nearly 10^{100000} in total (no precise calculations exist). This is just with 64 squares and 32 pieces. Since this appears to be a very large, yet finite number, it appears likely that inevitably, with the rise in sheer computing power of machines, a machine might beat a human player. This is the method followed when comparing the mind and the machine: the possible number of combinations is calculated in each case.

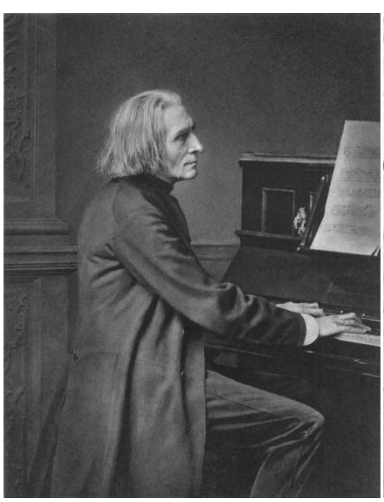
However, a second look at the game reveals an inherent assumption in this calculation: *that the rules of the game remain fixed*. Since all the rules are geometrical/arithmetic rules (directions and steps of movement) that can be quantified with just an array of integers, the logic used is precisely that which can be mechanized. What if, instead of restricting logic the way it is usually done, the numbers of possible rule-configurations are calculated? If rules are allowed to change, how would it alter the situation? In this case, one can easily see that the calculations are quite impossible to do, simply because there is *infinity* of rules to choose from. Just as young children make up rules and change them as they play along, rules can always be altered. This option opens the door to the full range of human mental capacities to act, and removes the barrier that existed for the "rules of the game." It does not matter if there are 64 squares and 32 pieces or 64 squares and 31 pieces–an infinite number of games are possible if the rules can be changed. As Georg Cantor rightly pointed out, there are an infinite number of infinite numbers. Regardless of the number of squares or pieces−"sky is the limit."

With just 26 letters of the alphabet, the English language has been growing and continues to grow with every added speaker. Countless number of books have been written, poems composed, reports described, with no end in sight. With a few notes of the musical scale, music is still being composed afresh each day. With a few colors, new paintings are created every day. Creativity, hence, is not limited by the tools of expression or number, but only by the capacities of the thinking and intuitive processes. In numerical terms, a sustained creativity occurs *ex nihilo, infinitum*.

This capacity of the rules to change completely alters the way in which calculations are done, and end up making the calculations irrelevant. As long as the rules for calculations are a constant, they can carry some meaning, but what meaning can be obtained when the rules themselves get changed? This explains the difficulty faced by the best of mathematicians when dealing with things like negative numbers and imaginary numbers, because the rules of mathematics changed.

This possibility of changing rules was missed almost completely by logicians of the 19th century. It is possible that many aspects can now be seen much better in hindsight due to greater familiarity with the nature of technology, while logicians and mathematicians of the 19th century still experienced the beginning of the Industrial Age. Biology had already reached a high level of development at the end of the 19th century, with the detailed study of cell structures and nervous system being done. With the advent of technology, cells were seen as tiny machines or tiny test tubes with chemical interchanges with the DNA. The brain itself, made up of neurons, was seen in a similar fashion to resemble a gigantic factory-like operations-control center. Biology was hence explored using the tools of physics and chemistry, where mechanism reigned supreme, and it began to be taken for granted that cell functions determined human behavior.

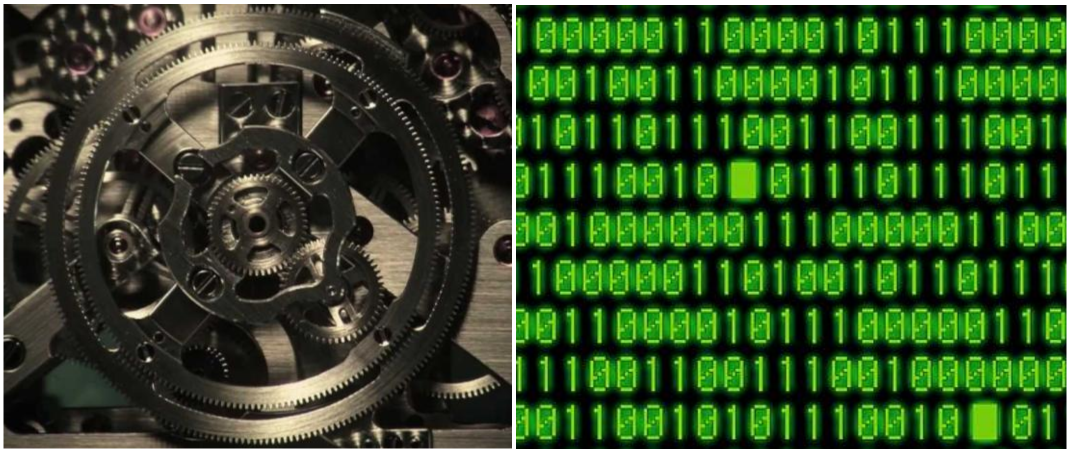
Removing the restrictions of number gives a much clearer look at the activity of the brain. Just as the piano can be broken or a string of a violin can go missing, it is indeed possible that physical variations in the brain cause intellectual capacities to vary. Snapping a few keys or over-tightening a few strings affects the sort of sounds the piano can produce. Thus there is definitely a connection to the physical instrument and its expression. But the possible tunes that can be created on the broken piano is once more infinite, hence there can be no calculable difference between the working piano and the broken one, in terms of its music. In addition, the piano works due to the laws of mechanics: vibration, lever action, pushes and pulls, pressing of keys, etc. Everything can be calculated, as to how each key can be pressed and each sound produced. *It is the number of possible tunes that is not calculable*. Modern biology focuses entirely on electrical actions and cell behavior, just as if a person who wanted to learn music were to take the piano apart piece by piece to determine how the sound is created. This would naturally lead nowhere as far as music is concerned, since music lies in the combinations of sounds, not in their mechanisms. Similarly, creative thought lies in its capacity to generate fresh ideas, and not in amino acids, neurotransmitters and network interconnections. This shows the key difference that takes place in calculating the capacity of human thought and that of machines.




It might be argued that the piano has a player who affects it from outside, and there is none who can be observed to act as the "player" for the brain. Here is where internal observation comes into play, the very same observation that enables one to observe one's own thought processes and define notions such as "consistency," "logical" and "internal effort." Ideas of logic and concepts do not occur through peering through a microscope, but directly from an individual's experience of them, which are later confirmed by looking through any instrument. Hence, there is indeed a player, *the human individual*, whose thoughts leave an impression on the brain via electrical impulses in the same way a piano player leaves his impressions on the piano via the keys.

If numbers *have* to be used to get an idea of the difference between musical instruments and the human brain, consider this: Music consists of a few basic notes, and there are new tunes being produced even today. Calculating the number of songs ever sung would literally take forever, and is infinite. If a few octaves of notes have been the basis of all the infinite music ever played and will be played on instruments, what indeed could be the capacity of 100 *billion* neurons? That gives the real qualitative comparison of human creative capacity, as a quantitative one is not possible.

Chapter 8: The Digital Transition



Before Turing, things were done to numbers. After Turing, numbers began doing things.

−George Dyson, *Turing's Cathedral*

Mathematics and logic form the mold into which technological applications are cast. As brought out in the previous chapter, far-reaching modifications were made to logic, and this effect carried through into mathematics as well. The way in which this change in logic, and the corresponding change in mathematics, determined the range and capacity of further technological development will be the focus of this chapter.

As the 20th century dawned, mathematicians in Europe continued work on formal mathematics, attempting to define a fully consistent set of axioms based on the rules of symbolic logic. This transition from self-evident truths to axioms as a basis for mathematics was completed with the monumental work by Bertrand Russell and A N Whitehead: *Principia Mathematica* (1910). At the precise point that mathematics transitioned into the abstract realm, technology came to the fore in a very real and powerful way, via the First World War.

The Great War, as it was called, was the first one in recorded history that relied so heavily on technology. Trench warfare led nowhere, shifting the emphasis onto bigger and better guns. The use of mechanical calculators received a huge boost due to the need for calculating accurate firing ranges of missiles and cannons. Even though digital machines like Herman Hollerith's mechanical census tabulator had performed well enough to be recognized in the mainstream, analog machines (with continuous motion) dominated the calculations during the war. If there was any aspect of art or aesthetics being involved in the design of earlier mechanisms, it was crushed out by the war and replaced by the aspect of utility. Deadly accuracy was the need of the time. Similarly, inner effort was almost entirely devoted to formulating strategies. It was in the middle of this upheaval that a small circle was pulled together that would have a major role in the rest of the century: Veblen's circle.

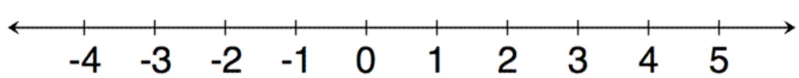
As described in George Dyson's books *Turing's Cathedral*, this small collection of mathematicians employed by Oswald Veblen for calculating gun trajectories consisted of people who went on to make significant contributions to the development of computers:

> Veblen organized the teams of human computers who were placed under his command, introducing mimeographed computing sheets that formalized the execution of step-by-step algorithms for processing the results of the firing range tests. It took the entire month of February to fire the first forty shots, yet by May his group was firing forty shots each day, and the growing force of human computers was keeping up. Veblen recruited widely, with a knack for discovering future mathematicians and making the best use of their talents during the war. (*Turing's Cathedral*, p40 2012)

In addition, Veblen later helped set up the Institute for Advanced Study at Princeton in 1930, which became the Mecca for many talented mathematicians and physicists like Albert Einstein, John von Neumann, Kurt Gödel, Alan Turing, Claude Shannon, and Robert Oppenheimer. It was mainly in this Institute (and nearby Princeton University where Alan Turing worked) that the achievements of computing theory and technology were concentrated. The IAS was to computers what the School of Athens was for logic. It is hence quite illuminating to study this development in some detail, with attention to the concepts introduced by some of these workers.

Even though the mathematics for digital circuits was available since the late 1880's with the works of Boole, Frege, Peirce and others, it was only in 1937 that they were actually applied. Claude Shannon, who was aware of the works of Boole, realized that the algebra lent itself for use in switching circuits for telephone networks. Thus, for the first time, a practical application of symbolic logic was determined. The effect of this discovery has been so influential that Shannon's thesis has been called "possibly the most important, and also the most famous, master's thesis of the century." Until the time of Shannon, computing was carried out only with analog machines e.g. the Differential Analyzer which was used to integrate differential equations necessary for missile and bomb trajectory determination. It was only after the application to switching and logical circuitry was it possible to build a practical digital computer, marking the birth of the digital era.

This transition from analog to digital has a parallel in mathematics as well. As pointed out previously, the transition from Logic in general to Boolean Logic involved the sacrifice of infinite quantities, which cannot be represented either mathematically in an equation or mechanically. Even though all mathematical operations could be encoded, the numbers themselves had physical restrictions. This meant that all signatures of the concept of infinity had to disappear from the number line. Consider the number line below:



What are the categories of numbers possible? If a, b, c represent the digits, they can be classified as:

- Integers (a, b, c, -a, -b, -c etc.)
- Rational numbers (of the form a/b)
- Irrational numbers ($\sqrt[5]{a}$, $\sqrt[3]{b}$ etc. with a and b prime)
- Transcendental numbers (π, e, π^a, e^b, etc.)

Of these, only the first two can be measured exactly, and also constructed by ruler and compass. Most of the irrationals and all of the transcendentals cannot be calculated. Even though all these numbers exist on a number line one draws with the sweep of a pencil, only the first two sets allow manipulations and calculations. For example, there is no way to indicate "$\sqrt[7]{7}$" (7^{th} root of 7) or "π" exactly on a number line, even though one can easily draw a continuous line from 1 to 2 or 3 to 4. This is the key principle which defines whether or not a number can be utilized in a mechanical process.

Machines can hence be used to conduct operations on integers and rational numbers only, while for the other two, approximations are naturally involved. Hence, one can add, subtract, multiply and divide only using the integers and rational numbers, and the mechanisms which generate these functions together constitute an *analog computer*. Even ruler and compass, or folding in origami, is something that shows an analog operation.

Since irrationals, trigonometric functions and logarithms are not constructible in general, for centuries the only possible way to obtain them has been through tabulating them empirically and looking them up when required. This meant that mathematicians spent considerable time in creating these tables for later use. These are not accessible to any known machine, and are beyond the domain of *exact* calculation. Hence, the limits of analog computers are reached with rational numbers.

What are the numbers that can be represented digitally? As the name suggests, only those using the digits (fingers), namely the countable numbers. Negative numbers and decimal fractions cannot be represented directly in terms of 1's and 0's, they can only be encoded so that the sign of the number or the placement of the decimal is added as an additional string of digits. Nor can recurring decimals be represented, e.g. 1/3 can only be approximated as 0.3333333. All irrational numbers are impossible to calculate in finite time, hence this ultimately restricts the set of numbers to whole numbers i.e. 0, 1, 2, … n, where "n" is as large a number as is physically possible to represent. This forms the range of a digital system, as a direct consequence of Boolean algebra. A digital computer can hence be 100% accurate only with integer addition, subtraction, and multiplication. Any other operation involves approximations.

This means that the range is reduced when one transitions from the ideal analog computer to the ideal digital computer. This mirrors the development of Boolean logic, which jettisons most of the comparisons except equality, and hence reduces the range of the copulas previously in use. Logic and Mechanism hence move in step with each other. The fields of mathematics generate the corresponding mechanical operations thus:

Geometry => Construction with compass/ruler => Analog machines

Arithmetic => Integer number operations => Digital Machines

It was important to go into this much detail regarding this transition because, in addition to the discovery of the use of Boolean algebra in circuitry, several mathematical and logical identifications were made at this time with regard to computation. These were intimately connected to this transition into the digital world, since the focus now shifted from *geometric analog construction* to *arithmetical digital computation*. While the Greeks focused on finding out if a certain statement was *true*, developers of symbolic logic focused on finding out if a certain statement was *provable*, and formal mathematicians focused on finding out if a statement is *computable* or not. Concomitant with this, all the struggles of the Greeks with paradoxes in logic were recast as problems of proofs or problems in computability.

The early problems with logic can be shown with a classic example: the Liar's paradox. This paradox (attributed, among others, to Epimenides) is generally stated as:

Epimenides (a Cretan) says: All Cretans are liars.

Is this a true or a false statement? If it is true, it implies that it is false, and if it is false, it becomes true. A stricter example is a sentence like this: *This sentence is false* (Hehner 2014). Thus, right at the core of logic, a self-referential statement generates an absurdity, bringing into question the very ideas of true and false. This has been tackled in numerous ways for a long time by logicians. However, in the 20th century, two mathematicians recast the resolution of this problem into the modern form, and shifted focus from "truth" to "provability" and "computability." They were Kurt Gödel and Alan Turing, whose work appeared at the same time as Shannon's.

Kurt Gödel directed his attention to one of the questions posed by David Hilbert regarding formal systems of mathematics in 1928, where Hilbert asked whether such a formal description can ever have a complete and consistent set of rules. Since formal mathematics added several axioms, it was of primary importance for this system to be fully consistent if it has to be valid. Gödel found out in 1931 that this was not possible and one could always find a statement that could not be proved within the system, making the system incomplete. This is the precise analogue of the Liar's Paradox cropping up once again because the Paradox was not resolved, but shunted from one domain to the other.

The meaning of Gödel's Incompleteness Theorem, as this came to be called, is clearly described in this warehouse analogy by David Black:

> To understand the consternation experienced by mathematicians as a result of Gödel's discovery of the essential incompleteness of mathematical systems, imagine that a mathematical system is a large warehouse, and that each true statement in the system is a box stored in the warehouse. Naturally, boxes are counted when they enter or leave the warehouse, and records are kept of the number of boxes and their locations in the warehouse. Now imagine taking a physical inventory of the contents of the warehouse; the point of such an inventory is to record the existence and location of every box contained by the warehouse. The people taking the inventory must devise a path through the warehouse so that they can count every box, missing none and counting none twice. Physical inventories involve no magic; they must simply be carefully planned and meticulously executed. Imagine that the inventory is now complete, and the records on the warehouse's contents are now available for inspection. Gödel's proof demonstrates a method whereby any wise-guy warehouse man, upon looking over the results of the physical inventory, can enter the warehouse and turn up a box which does not appear on the records. Suppose the inventory records are corrected to include the newly discovered box; after looking over the corrected records, the wise-guy can produce another unrecorded box, and can keep doing so without limit. lf you were the manager of the warehouse, how would this make you feel about your operation? Gödel's incompleteness proof engendered similar feelings in mathematicians about their knowledge of their own mathematical systems. (*Context and Significance of Gödel's Proof*, David B Black, Shoreline Vol. 4 pg 55, 1991)

This description is seen to describe the behavior of points on the number line exactly. Just as between any two numbers one can always find another number which wasn't counted before, in the set of algorithms one can find one which wasn't recognized before.

While Gödel concentrated on whether a system of formal mathematics was complete and consistent, Alan Turing tried to find out if it was possible to say beforehand whether or not a certain statement could be proved (1937). Since a proof was intricately tied to mathematical mechanism, as shown earlier, generating a proof depended on whether a number was computable or not. And what did he mean by "computable"? "*According to my definition, a number is computable if its decimal can be written down by a machine.*" For example, a recurring decimal is called computable because the rule to calculate it can be encoded into the machine. Similarly π and *e* can be expanded in terms of series expansions, and are called computable by Turing.

$\pi = 4\ (1 - 1/3 + 1/5 - 1/7 \ldots \infty)$

It is at this juncture that the classic "bait-and-switch" can be identified: The computable number π is something that can be computed, as long as *infinite* time and memory are provided! This is really as meaningless as saying that it is possible to do something, with the minor problem that it would literally take forever to do. The very definition of computable numbers is fundamentally flawed, as they are by definition not computable. One can find a pattern to them, just as π generates a circular pattern, but that is a far cry from actually constructing a length π units long, which is not possible by calculation. Turing's concept of computable numbers does not address this issue (numbers that go to an infinite number of decimal places) but instead pushes it under the rug.

Secondly, the entire exercise of provability, paradoxes, computability etc. can be illustrated by a simple example. Consider a group of people, say a dozen, and assume their talk is being studied by one interested researcher. There would be several statements which might be true, several lies, and several mixtures in their speech. If one among them declares aloud "I am lying right now" he or she has uttered the Liar's Paradox. If the sentence is true, it is false (a lie), and if it is false, it is true, making it stuck in a loop. In a second scenario, assume that all the people are saying the exact same sentence. There is no way of saying if all of them are lying or if all of them are telling the truth. These two situations exist, and the only way the truth of the matter can be adjudged is if there is a real event corresponding to what is being told by all of them, which was experienced also by the researcher. Since this depends on experience of the researcher, logic necessarily has its limitations. This is the limit all logicians come up against.

However, Gödel converted the question of truth into one of provability, and restated the Liar paradox in the language of formal logic with his "Incompleteness Theorem." Turing's notion of computability was flawed, but nevertheless his attempt to reduce a system into computable and non-computable faced the same barrier, leading to his descriptions of the *Halting Problem,* which is "just the Liar's Paradox in fancy clothing" (Hehner, 2014). In addition, he also hit upon the same problem of verifying the truth of a statement, which cannot be done by staying within the logical system, be it by computing or by anything else. He therefore concluded that there was no way one could say beforehand by any method if a certain statement was computable or not.

Hence, this entire development had the effect of hiding the irrationals and transcendental under the guise of computability, while the actual problems with logic were not resolved, but simply recast in a new language. The reason for the persistence of these logical problems was that the logic developed by the Greeks was still being used, only with more axioms and a smaller set of interrelationships (symbolic logic). The child inherited the defects of the parent, so to speak.

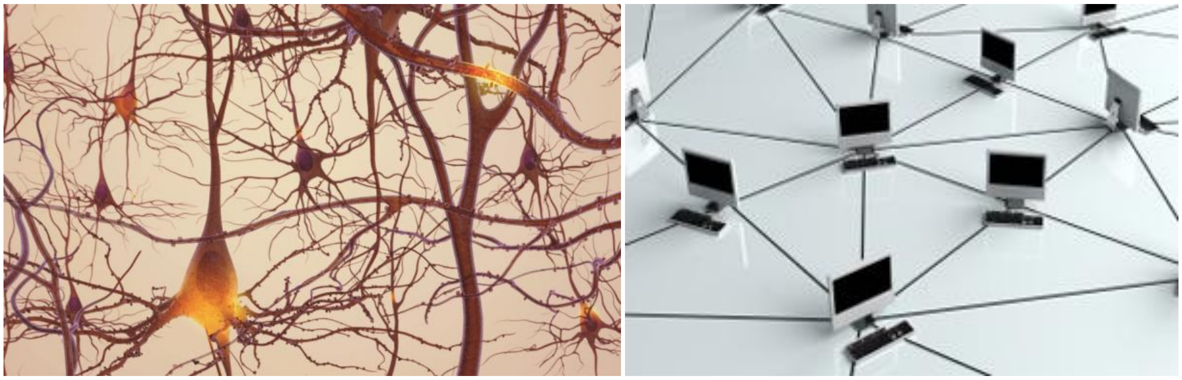
With the transition into digital machines, parallels with Greek development of logic are now mostly complete. They can be represented like this:

GREEK	MODERN
Aristotle	Boole
Stoics	Frege, Peirce
Epimenides	Gödel, Turing
Geometric Construction	Digital Computation
Euclidean Geometry	Boolean algebra
Logic	Symbolic Logic

It appears that this connection to Greek thought was missed by most people involved in the development of computers, who were really stimulated by Turing's work to build a machine that can compute anything. With the success of Shannon's circuits and Boolean logic, it was increasingly taken for granted that all thought processes can be expressed using Frege's symbolic logic, and that it can all be mechanized, even if it takes infinite time to arrive at the result (an illogical idea by all standards). Hence, the effects of irrationals and transcendentals were neglected and brushed to the side, while the essential problems that plagued Logic itself were not tackled directly, only reformulated.

Following the contributions of Shannon, Gödel and Turing, the task of making digital machines feasible was taken up very effectively by John Von Neumann and his collaborators. This last leg of historical development which continued up to the end of the century will be described in the next chapter.

Chapter 9: Repercussions



All stable processes we shall predict. All unstable processes we shall control.

- John von Neumann

As the new concepts of digital computing were taking root in the years following World War I, World War II arrived on the scene - the time when computing technology really came into its own. The focus of World War I was bigger and better guns, while the focus of World War II was bigger and better bombs. In this development, the basic structures of computers known today: memory, stored programs, subroutines etc. were developed during this period between 1941-1945. The person at the center of it all was John von Neumann.

Neumann had a knack for identifying ideas that could be implemented, and working next door to Alan Turing at Princeton, provided the impetus for the development of the programmable computer. The program and the *software* as it came to be called, was related to the machine or *hardware*, in this way (courtesy plyojump):

Hardware is the electrical circuits that make up a computer.

Software is a list of instructions for the order in which switches open and close.

Computer programs are a specific file holding these instructions.

Prior to his time, computers could mainly be programmed with one set of instructions. A different program required a physical reconfiguration of the machine. Neumann's interest was to transition to a machine that could alter its functioning depending only on the input instructions, a concept very similar to his collaborator Turing's Universal Machine. Taking an interest in modeling the shock-wave of a bomb, Neumann focused on the development of high-speed computers for the same purpose. Several electronic computers were being developed simultaneously in this time period, such as the ENIAC, Harvard's Mark I (where Grace Hopper, the first computer *programmer*, worked), Stibitz's Complex Number Calculator, the Selectron and the Stored Program computer at IAS. Neumann was the catalyzing factor between all of them:

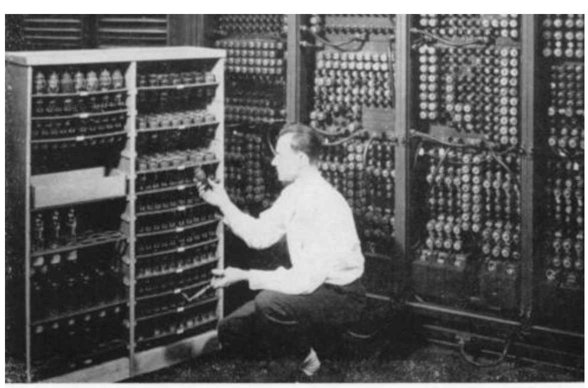
> Throughout the summer and fall of that year (1944), he shuttled by train between Harvard, Princeton, Bell Labs and Aberdeen, acting as an idea bee, pollinating and cross-pollinating various teams with the notions that had adhered to his mind as he buzzed around … von Neumann wandered around gathering elements and concepts that became part of the stored program computer architecture. (Walter Isaacson, *The Innovators*, pg 104, 2014)

This fact is quite important as it shows a transition in the nature of creativity, from the brilliant insights of a lone investigator or inventor to collaborative advancement of technology. If the will for the creative development of Boole's laws of thought came from his religious devotion, the will for the development for computers of this period came from waging wars, which is necessarily a group effort. Hence the transition in creativity is marked clearly:

> But the main lesson to draw from the birth of computers is that innovation is usually a group effort, involving collaboration between visionaries and engineers, and that creativity comes from drawing on many sources. Only in storybooks do inventions come like a thunderbolt, or a light bulb popping out of the head of a lone individual in a basement or garret or garage… The sparks come from ideas rubbing against each other rather than as bolts from the blue. (ibid. pg 85-110)

This is claimed in direct contradiction to the fact that virtually all major developments leading to the computer were done by individuals who received a "bolt from the blue" i.e. Leibniz (mathematical logic), Bacon (binary codes), Boole (binary logic), Pascal (mechanical calculator). Here, the fundamental repercussion of the development of mechanical symbolic logic can be identified: the denial of the very process of creativity. If the nature of thinking is deemed to be mechanical, and hence finite, the only way to make progress is to add up these finite chunks. It is hence a direct consequence of rejecting the notion of infinity in human thinking, a fact that was highlighted in Chapter 6. The main lesson to draw from this is instead that if one thinks only mechanically, then innovation is possible *only* by collaboration.

A second consequence of rejecting the infinite in logic is to make up for the same in terms of time and space i.e. to make computations *faster* (in time) and the computing elements *smaller* (in space). That is the only approach left open for this restricted form of creativity. These two themes, *faster* and *smaller*, reinforced each other and directed all computing innovations every decade since World War II. Switching had transitioned from the clunky electro-mechanical switches of the 1930's to the silent electronic vacuum tubes of 1940's (e.g. ENIAC). This increased the speed of operation, even though the tubes failed regularly:



Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

Speed increased every decade from this point onwards. The next shift was accomplished in the 1950's with the invention of the solid state transistor, which eliminated most problems of vacuum tubes, and was also smaller. Speeds increased, and sizes decreased again in the 1960's with the invention of the integrated circuit, which was smaller than a penny and had thousands of transistors. By the 1970's one had *millions* of transistors on a microprocessor chip. Nanotechnology, the science of the nanometer range, thus had a large influence on this process.

Vacuum tube to transistors to Integrated Circuits within 25 years (courtesy chipsetc.com)

This high computing capacity enabled the computer to link itself to display technology (television display). Edward Lorenz, who studied weather patterns on such a computer, realized that slight deviations in conditions for solving equations, when reiterated, cause enormous differences. This led to the development of Chaos Theory. Later Benoit Mandelbrot, who spent time both at the Institute of Advanced Studies as well as at the computer giant IBM, was able to study iterative systems of equations while studying noises on telephone networks. With computers it became possible to repeat iterations millions of times, which when combined with plotting complex number graphs produced the famous Mandelbrot set and opened the door to the study of fractals. Self-similarity was its key feature. Combining these two qualities, self-similarities and tiny deviations causing huge results one obtains the properties of *irrational numbers*. These are both self-similar (with infinite series or infinite fractional definitions) and cause large deviations under iteration ($(1.9999)^{20}$ can become very different from 2^{20}). Until the 1970's, the assumptions made nearly 50 years earlier to neglect irrationals and transcendental numbers could not have any effect as there was not sufficient number of calculations for those decimal positions to have an effect. But now, it was possible.

Hence these developments, which can only be studied with the help of a computer, resurrected the interest in the beauty of irrational numbers which had lain dormant since the extensive study of *phi*, the Golden Ratio $\left(\frac{1+\sqrt{5}}{2}\right)$. All the numbers that were neglected when considering symbolic logic and Boolean algebra made a reappearance in the 70's, but as approximations, in the study of fractals. Irrationals, complex numbers, and even quaternions made a comeback when computers were used for creating graphics. The very same ideas neglected a century ago resurface as approximations (as they are represented by 0's and 1's) within the digital world. What was eliminated in computing logic by removing the notions such as infinity was now being pursued by increasing iterations and computing speeds relentlessly.

Since the motto of *smaller and faster* has to deal with limitations of technology, the only possibility of enhancing the power of computers was to combine them with existing technologies. This happened in the reverse order i.e. the latest technology was incorporated first into the computer, and then the one before that, and so on. As already described, the most recent technological development before the computers was the cinema and television, which were incorporated by the rise of computer graphics and video games. The next available technology was the earlier development of the telephone. Hence computers were now linked together, like a telephone network. This culminated in the 1990's and determined the rise of the internet. When the internet connection was made wireless, it meant a connection to radio technology and therefore to wireless telegraphy. This determined the rise of Wi-Fi. It is possible to map out the developments in computing which, almost like clockwork, swallowed up the existent technology into themselves to generate a new gadget. The full development of each type of technology can be represented in waves, like this:

1960's-1970's:	Computer + Television	=	Computer graphics
1970's-1990's:	Computer + Telephone	=	Internet
1980's-2000's:	Computer + Radio	=	Wireless internet (Wi-Fi)
	Radio + Telephone	=	Mobile phone
2000's-2010's:	Computer + Radio + Telephone	=	Smartphone

As this trend continues, it is easy to see that the computer will increasingly be linked with all gadgets ever devised by man. Anything that can be operated upon can be automated by a computer: watches, calculators, light switches at home, cars, etc.

Meanwhile, the idea of the brain being similar to computers took a greater hold upon popular imagination, and the idea that computers can "learn" and "think" proved very attractive. Not realizing that no combination of standing or falling dominoes can ever "think," a type of animism has arisen in computer culture, where simply by using human words like "think," "learn," "understand" and "figure out" a sort of consciousness is attributed to the computing process itself. For example, consider this segment of an interview:

> *Omni Magazine (1987)*: Do you find it depressing that chess computers are getting so strong?
> *Claude Shannon:* I am not depressed by it. I am rooting for the machines! I have always been on the machines' side. Ha-ha!

This exchange highlights the anthropomorphic ideas attributed to the computer, which have gained in popularity with every successive decade and every successive rise in computing power. There has been very little focus on the fact that the actual thinking process is a far richer field than that which is described by rote repetition. Even the pioneers in computers who were right in the middle of developing the structure appear to have missed this connection. For example, Norbert Wiener was a member of Veblen's circle in the First World War who developed the ideas of *cybernetics*: that biological cells and electronic circuits have similar behavior when feedback loops are included. His theory formed the basis for not only computers but neuroscience as well for a large part of the 20th century. Yet, he made the following statements:

> The nervous system and the automatic machine are fundamentally alike in that they are devices, which make decisions on the basis of decisions they made in the past.
>
> Let us remember that the automatic machine is the precise economic equivalent of slave labor. Any labor which competes with slave labor must accept the economic consequences of slave labor.
>
> -Norbert Wiener

The logical conclusion from these two statements is that the working nervous system must accept the mental consequences of slave labor! It is interesting to see that Wiener never made this connection and reconsider his ideas on the thinking process, but remained convinced of the identity of the thinking and automatic machines.

However, consider this question from the ideas developed previously with regard to the will-element of human thinking. It is seen that the greatest application of inner effort is necessary for creating a *new* thought structure, and repetition has a role only so far as the necessary strength has to be developed. In addition, the inner effort applied by our mental process was seen to be a vastly accelerated version of physical bodily exertion. Hence, repetitions and mental calculations have their exact counterpart in gymnastics of the body, where a certain degree of repetition and effort is necessary to develop strength and flexibility.

However, restricting the body to only compulsory repetitive activities tires and wears out the body, as was done with slaves for many centuries. Consequently, all artistic and meaningful movement of the limbs gets neglected. At the same time, the opposite extreme of avoiding the repetitive strength-building activity in the prime of life is also harmful. For example, if a child never learns to walk as it is *always* helped by a walker, or if an adult *always* moves in a machine and never moves his legs, the legs atrophy and decay. Looking between these two extremes, it is possible to identify how to navigate between slavery and atrophy. It is to encourage strength-building activities, even repetitive ones, when the body is growing, in order to generate the strength to last a lifetime. Similarly, repetitive calculations and mental exertions are a necessary part of human education, and it is vital to develop the necessary strength of mind and inner effort before one begins to use any “aids to calculation.” It is also important to realize that further increase in mental effort can only be accomplished when creating new ideas. Hence, all technological aids to physical or mental activity will not have a detrimental effect, only if both the body and mind are engaged in activity which is entirely non-repetitive, fresh, and *creative*. Just as a modern day person may spend the entire day in a cubicle and yet keep the body fit by exercise, dance or social activity, the strength of the thinking capacity which uses computers and calculators all day long can only prevent atrophy if through focus, concentration and creativity an independent thinking process is developed.

Unfortunately it is precisely with regard to the development of will-element in thought, that there has been very little understanding. By the *belief* that thought is mechanical, inner shackles have been placed on the thought process which tend to direct it more and more towards atrophy. Even if a few people display a lot of ingenuity in making computers work, the net effect of using these machines are detrimental to the general populace as long as the will-element in thought goes unrecognized. This gives rise to several repercussions seen in the thought life of people today: unable to calculate without using a calculator, unable to write without using a word processor, unable to remember without using reminders, alarms and search engines, unable to navigate without using the GPS, a sharp rise in attention disorders, etc. Unless this fact is recognized, like the unused limb, our individual thinking capacity and ability to focus will degenerate. Just as the arm or leg loses strength when unused, the thinking process loses its strength as well. Since mental processes occur at a much faster time scale, the deterioration can be very rapid as compared to a physical atrophy.

It is not necessary to subscribe to any particular belief system, especially when dealing with technological matters. The belief of identity of mechanism and thought process, invoked by Boole and his contemporaries in the Industrial Era and virtually unchallenged until today, has had the powerful effect of crippling the will-element of thought. The Modern Olympics have the motto:

Higher, faster, and stronger

However, modern thinking has retained the first two and eliminated the need for strength, and is left only with higher density of mechanical components (*smaller*) and *faster* speeds of operation as its mode of expression. This cripples thought quite effectively.

It might be argued that development of computers in the past few decades have not hindered creativity, but helped develop it. For example, like the printing press of old, the internet allows every user to express thoughts in as many ways as possible. This, however, does not get to the root of the situation, because creativity by definition *cannot be bounded*. Creativity creates the rules of the game, alters and shapes them; not obey them. If creativity were truly included right at the very core of computing technology, then a large variation in the types of computers can be expected. But what is the situation in reality?

> According to Bigelow, "Von Neumann had one piece of advice for us: not to originate anything." This helped put the IAS project in the lead. "One of the reasons our group was successful, and got a big jump on others, was that we set up certain limited objectives, namely that we would not produce any new elementary components," adds Bigelow. "We would try and use the ones which were available for standard communications purposes. We chose vacuum tubes which were in mass production, and very common types, so that we could hope to get reliable components, and not have to go into component research." (George Dyson, *Turing's Cathedral*, pg 143, 2012)

> The basic architecture of the computer has remained unchanged for six decades since IBM developed the first mainframe computers…it was named after John von Neumann. (Darrel Ince, *The Computer*, pg 117, 2011)

> The basic functions of modern computers haven't really changed much since John von Neumann's "stored program concept" and Alan Turing's "universal machine" propositions of the 1930's. Although the technology functionality has increased exponentially, the process of binary computation (XOR, NAND, and so on) remain basically unchanged, as do the fundamental concepts of the architecture. (Russell D. Vines, *Wireless Security Essentials*, pg 4, 2002)

It is intriguing to see that in spite of the rapid changes in the world of computers, the basic architecture has remained the same for nearly half a century. In fact, that is the imbalance introduced into technological development, where the basic structure remains unchanged, while the surface structure changes much more rapidly than one could keep up with. Even if some variations in architecture are tried out, they do not challenge the digital basis of computing or the notion of counting neurons. Finally, even if there is some interest in analog computers, or a different architecture (e.g. parallel vs serial, or quantum architecture), the application of symbolic logic itself is not challenged. These developments are perfectly in line with the structure of the logic, and the notion of creativity and novelty being attached to number (*smaller and faster*), making that the only change possible within the rules of the system.

The connection between development of formal logic and physical exertion has been identified quite well by Shenefelt and White:

> In fact, one of the chief aims of logic in its systematic development is to render logical judgments as close to brute reflex as possible. This is why we study forms. Forms leap out at the eye. But once we spot them, the thought required is immediately reduced because we know what to do. We know which rules to apply. To say this isn't to say that logic makes us unthinking, but only that it saves our thinking for other matters – not for determining the mere cogency of arguments but for anticipating where the arguments are going or why they exist at all. In this respect, then, logic is like walking. The better at it we get, the less we need to think about it and the farther it takes us – to the contemplation of new vistas. (If A then B, pg 232, 2014)

However, what new vistas are possible if vision itself is impaired? The authors mention new vistas, but do not identify what those vistas might be, or how they can be accessed. This is the most important topic to be addressed at the end of this analysis: Where to go from here? Are there any alternative paths that could have been taken? How can the strength be brought back into the thought process? These are the questions that will be addressed in the final chapter.

Chapter 10: The Road Less Taken

But small is the gate and narrow the road that leads to life, and only a few find it.

−Matthew 7:14

A recap of the full sequence of developments up to this point is now in order. In the first place, thinking was seen to have an aspect of pure thinking (such as logic), an aspect of skill (feeling) and an aspect of willing, involving internal effort. The inner effort involved in repetitive mental tasks could be done mechanically as well, which led to interest in calculating machines. In the second place, the idea that thinking and logic could also be mechanical processes started gaining ground, leading to the works of Boole and his contemporaries. The difference between the logic of the Greeks, which had its roots in geometry and arithmetic, and the logic of Boole, which had its root in algebra, was identified. It was also mentioned that a re-evaluation of Euclidean Geometry which was happening at the time, made all mathematicians and geometers question their assumptions. The path taken by some of them was to abandon assumptions and axioms based on real life experience (as was the case with Euclidean) and to construct an entire consistent system of abstract axioms. They reasoned that, since "common sense" had turned out to be misleading to justify the axioms of Geometry, the best course was to abandon the common-sense axioms and to allow abstract axioms to form the basis, and shift the focus to the mathematical consistency of this abstract system. As a result, logic was restricted by mathematics.

In this process, a different "common sense" could have been identified, that of the *eye*. While it is true that parallel lines never touch one another as far as the sense of touch goes, they *do* meet as far as the visual sense is concerned. Two railway lines do meet, according to the eye. However, as already pointed out, understanding the visual process and the mathematics associated with it (laws of perspective and projective geometry) had been a newcomer on the scene, as opposed to Euclidean geometry and solid laws of construction and geometry. This led to an abandonment of this line of thought, and logic was instead guarded from the intrusion of non-Euclidean or non-algebraic ideas.

Abandonment of non-mathematical ideas, as well as "infinity" within mathematical ideas, enabled the development of logic that could be mechanized. And finally, it was shown that mechanization using only digital changes also restricted the mathematical scope to the integers instead of the continuous geometric line. This had an effect, which was even predicted:

> Banish the infinite process, and mathematics pure and applied is reduced to the state in which it was known to the pre-Pythagoreans. (Tobias Dantzig, *Number: The Language of Science*, p139, 1930)

This is found to be an exact prediction, as the digital design of the computer has more in common with an elaborate and intricate abacus than any other prior machine. The effect of this development on the thinking faculty was described, and it was found that the restriction of the logic, as well as neglect of the element of inner effort (willing) have led to a decline in thinking capacity.

If a different alternative is to be found, the threads of thought must be traced backwards to find the fork in the road. Backtracking to this point in the 1850's when *The Laws of Thought* was first published; a different path can be identified: non-Euclidean Geometry. This subject was born during the time of Renaissance with the introduction of perspective in painting, and treated mathematically for the first time by Girard Desargues and Blaise Pascal (contemporaries of Descartes and Leibniz in the 17^{th} century). Carl Friedrich Gauss, who coined the term "non-Euclidean," actually downplayed the effect of this geometry, as it contradicted Immanuel Kant's dictum in *Critique of Pure Reason* that Euclidean geometry was the only valid path. Nevertheless, talented mathematicians like Gauss, Janos Bolyai, Nikolai Lobachevsky and Jakob Steiner investigated the new geometry and helped non-Euclidean Geometry come to the foreground in the beginning of the 19^{th} century.

What is the essence of these investigations? It was Euclid's postulate that parallel lines never meet. However, in non-Euclidean geometry, parallel lines were said to meet: at *infinity*. While at first glance this might seem as absurd as saying that one can calculate something provided infinite time is allowed, non-Euclidean geometry went one more step ahead. With a series of transformations, it was possible to map this point at infinity onto any other point, thus making it have as solid a foundation as Euclidean Geometry. Hence, non-Euclidean geometry was the first attempt to grapple with infinity and treat it mathematically, since the time of Euclid.

Around the same time, what non-Euclidean geometry did to geometry, imaginary numbers did to arithmetic. Introduction of complex numbers, such as "i" (and later "j" and "k" by William Hamilton, in "quaternions") proved extremely confusing for mathematical thinking, as one could no longer attribute qualities of "greater than" or "lesser than" to imaginary numbers. It was one thing to deal with irrational and transcendental numbers, which could still be identified on a number line, and quite another to deal with $i=\sqrt{-1}$. Arithmetic and Algebra were completely altered.

This is hence, the transformation that occurred in the middle of the 19^{th} century:

Geometry => Non-Euclidean Geometry

Arithmetic => Imaginary (complex) numbers

Both these transitions met with violent opposition at the time. Non-Euclidean Geometry was involved in "Textbook Wars" (whether or not Euclidean geometry was fundamental), while Hamilton's introduction of multiple complex numbers was embroiled in the "Quaternion Controversy" (whether or not complex numbers were practical). However, if that thicket is crossed somehow, a new question opens up. Since Greek Logic was founded on geometry and arithmetic, the natural question to ask is "What happens to logic now?" As identified earlier:

Quantifiers: Arithmetic (All, some, none)

Copulas: Geometry (is, is not)

Reversing this for the 19th century:

Complex Arithmetic: **New Quantifiers?**

Non-Euclidean Geometry: New Copulas?

This is the fork in the road that has not been well recognized conceptually, even though there was a lot of controversy surrounding these ideas. The road taken has been the one that abandons both these developments, and introduces more axioms into the logical structure, while limiting the existing copulas to just one. However, what if that is not done, and the other path is pursued?

Naturally, one will have to consider that other verbs can serve in place of "is" and "is not." This means that the law of contradiction can be overcome, and is not something absolute for all things in the world. While this statement, that contradiction is possible in the newer avenues for logic, may seem heretical to mathematicians and philosophers today, it is nevertheless the natural next step in the development of logic. The consequences of this are elaborated in a little-known essay by Carl Unger: *The Philosophy of Contradiction* (written in the 1920's). In this he systematically considers what is obtained by overcoming this contradiction, i.e. it gives rise to *logic of becoming* instead of logic of *being*, thus generating a new copula "becomes":

A is not (not A) => A *becomes* not A

As described further in the essay:

> The concept "seed" involves what is other than it is – that is, it should form roots and a stalk; equally is it part of the concept "stalk," that it should issue in leaves and a blossom. The contradiction in a concept, including what is other than it, is justified when we figure the time relationship as an essential part of the concept. The true concept of a seed is not that it should be equal to itself… The emergence of a contradiction is not, in itself, evidence of a false enquiry.

If A is a finite set, not-A is necessarily everything else i.e. infinite. Hence, this "logic of becoming" *includes* infinity in the same way that projective geometry includes the points at infinity.

This insight is a completely different approach, as it actually modifies the way in which thought is structured, giving a new fruitful basis for logic. As seen with the example of the seed, this opens the door for thinking with concepts which are not repetitive like calculations, and hence require a fresh infusion of inner effort in order to sustain them. This can be contrasted with the current attempts at creating "living automata" under the assumption that with enough complexity, networks, rapid calculations and feedback loops, life would spontaneously manifest. Unless the very form of thinking is altered, there is no way to get out of this dead-end path and understand living phenomena.

Unger continues this analysis further, which need not be elaborated at this point (but is definitely worth studying), except to emphasize that this understanding passed by virtually unnoticed by the logicians of the period. All the attention was focused on making the fortress of axioms impregnable. Even the eventual discovery of paradoxes by Gödel and Turing, coming as it did in the middle of World Wars, did not deter the use of this logic but rather made it more rigid.

Taking a different turn opens up worlds of possibilities. To get an idea of it, consider all the verbs that could have taken the place of “is/is not”! All of these form possible alternatives to the copula in logic, enabling a real extension of it. It also provides the vital clue in order to solve the problem posed in the beginning of this work: Does a machine affect the way one thinks, and if so, how to tackle the problem? This can now be addressed properly. Thinking has an aspect that has to do with inner effort, and this grows strong with novelty and originality. Rote repetition alone does not allow this, and can hence be safely outsourced to the machine. Thinking using symbolic logic alone requires some effort, but it does not allow one to change the rules of the game, crippling its limits. Thus, the only option is to proceed to strengthen thinking by contemplation of new forms of logic, so that one can treat every event as a fresh situation instead of trying to force-fit situations into a mechanizable model.

It also provides a guideline for providing access to technology while learning. Just as a toddler is not given outer support at the moment it is learning to walk, but instead is provided with encouragement to walk on its own, no technological aids to calculation must be used until one knows how to calculate on one’s own. Just as no harm is done when a physically fit person uses a motorbike, it is safe to use calculators, for example, only when one can conveniently calculate in one’s own mind. There can be individual variations in the process, but the principle holds. If technological aids are introduced before the corresponding strength is built up in the thought process, it would act as a permanent crippling factor, and be very hard to overcome in later life. While particular care is to be taken with all aids to the thinking process while a young adult is growing up, a similar principle holds for adult life as well. For example, if memory is not cultivated inwardly by taking an interest in events and retaining them in the mind due to the force of will, all aids to memory would have a crippling effect on individual memory. If there is a tendency to simply search for answers to questions, then it would become apparent that not only memory, but logic suffers as well, and it would become more and more difficult to actually engage in thinking, and easier to simply “play by the rules.” Additionally, if the fact is missed that true creativity and originality involves thinking that is not mechanical or repetitive, then it is possible for thought itself to become automatic, making man more machine-like in nature.

Thus, following this path from the fork offers a way to not only come to terms with logic and thinking in general, but provides the knowledge based on which safeguards can be identified for the use of computing technology. It is also possible for the Craftsman to embark on technology of a different sort than the ones generally used, and to consider entirely different architectures for machines. So far, the early pioneers in computer technology had obtained their motivation either from religious impulses, or from greed and war impulses. The identification that inner effort can be cultivated independently, and that it can be strengthened along specific ways, offers a new route: the impulse born of the desire to help, which is a human trait worthy of cultivation. The path which had been blocked so far, due to the rigid nature of the assumptions that the Philosophers had inculcated into technology, can be cleared for Craftsmen having this motivation behind their work.

Strengthening the thinking process also provides a balance between thinking and willing, so that skill and art from the realm of *feeling* can once more enter into the thought process. Individual and cultural differences can enter once more both into technology and ideas, rather than one uniform pattern being applied over the entire world (an inevitable consequence of adherence to mechanical logic alone). This would allow individuals to build on the successes of their predecessors, by remembering, understanding, and carrying forward the impulses of the older cultures in a *new* form. It is time that “novelty” no longer means simply a smaller, faster, or more powerful re-packaged version of the old, but is genuinely new. It is only then that instead of facing a future shock, one can look the future in the eye, go forward and *create* it.

Conclusion

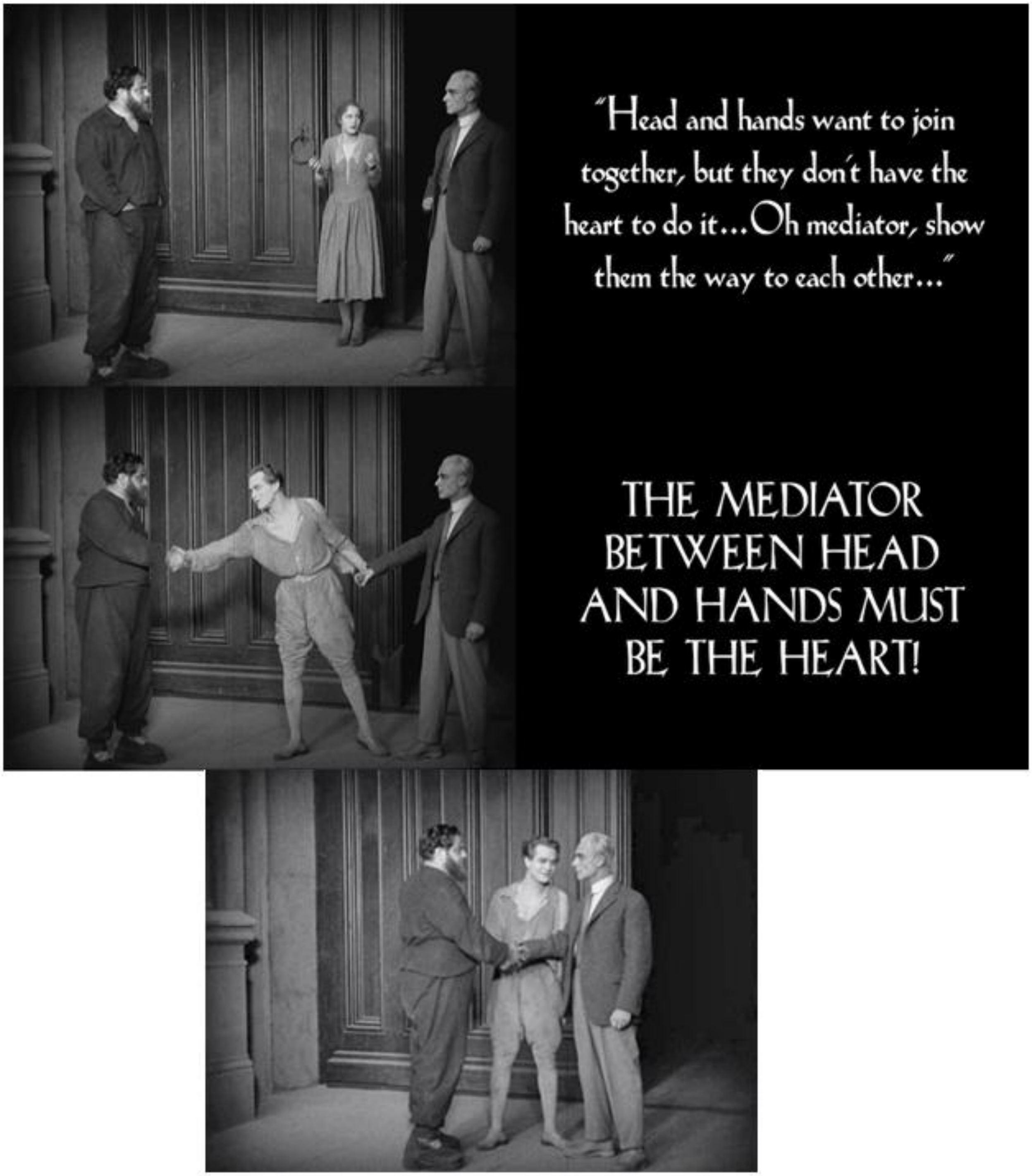
It has been shown that the central theme underlying the analysis of computing and thought is the notion that thought contains an element beyond logic alone in the internal effort or will. This opened the door to identify that the developments in logic and computations of the past century have focused entirely on the logic itself, rather than seeking for the origins of it or elements beyond it. It has also been shown that the major transformation that occurred at the end of the 19th century served to restrict logic to that which can be mechanized; a decision that has had massive repercussions in the way one understands thinking, and consequently, the way one views the human being.

A look at the origins of logic showed its dependence on physical experience and mathematics, as elaborated for nearly two thousand years since the Greek era. When the basic tenets of Euclidean geometry came to be questioned, it was time to revamp logic as well to remain true to this way of organizing thought. However, the opposite course of action, that of restricting logic even further to only that which can be mechanized was carried out, leading to the phenomenal importance given to computing in today’s world, over and above that given to new ways of thinking. This caused a sort of “re-inventing the wheel,” where all the paradoxes of the Greek logic came back to haunt developments in symbolic logic and computation as well.

Once it is *assumed* that thinking is identical to a mechanism, it leads to several repercussions, the first of which was already mentioned as a marked decrease in mental will power, and a resultant drop in memory, attention spans, focusing ability and creativity. However, this is not the only effect of mechanical logic over-reaching its boundaries. Human nature becomes increasingly rigid, as phrases like “I can’t help it, this is the way I am wired” or “It is in his DNA” become prevalent. This undercurrent of belief, that a human is as programmable as a computer, changes the personalities of people making them increasingly resistant to new ideas at a rate greater than ever before. At no point in history has mankind’s thought been linked with machines to the extent it occurs today, and there is a very real danger of jettisoning the very essence of thought from everyday behavior.

When symbolic logic, which is at home in the domain of logistics, penetrates thoughts relating to human relationships, it would have the natural effect of determining if people “fit together” like cogs in a machine or not. Relationships are retained only as long as the gears and hooks connect, and abandoned and replaced when they are not. This is the only type of thinking possible with this logic, and naturally, as relationships do not fit the box of symbolic logic, either the logic has to be abandoned or the relationship. Thus, misplaced application of this form of thinking can lead to significant tearing of relationships, and devaluing of human worth.

However, when it is accepted that this form of machine-logic is a small subset of the full range of capacities of the thought process, then it would be possible to prevent harm and actually use it for relieving the mind of rote repetitive work. In addition, the independent development of internal effort of thinking can take up its rightful role in preventing the atrophy of thinking and invigorating it in new artistic and creative directions, rather than a making a smaller and faster version of the old. The Philosopher can once more shake hands with the Craftsman, with the Artist bringing the two together.



Metropolis (1927)