The Digital Gesture

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It is difficult to find a domain of human experience that has not been affected, altered, or augmented by digital technology. From commerce and the pursuit of science, to entertainment and everyday tasks, devices built on digital technology now constitute the most prevalent means for working in the world.

But what is digital technology? How do the concepts signified by the word *digital* serve as the basis for the computer that I am now typing on? In this first article in a series of three, I will explore the historical origins of digital technology and how a few relatively simple concepts have led to the development of tools of an ever-increasing level of sophistication. By bringing the ideas that are at the center of digital technology into sharper focus, it is my hope that a kind of "digital gesture" will reveal itself, a gesture whose attributes remain remarkably consistent against a seemingly bewildering avalanche of new innovations. Subsequent articles will explore some of the more subtle ramifications of the digital revolution[1] as well as recent developments—including virtual and augmented reality (Pokémon Go anyone?)—with potentially far-reaching implications for the future of human consciousness.

Whence digital?

In the 17th century, long before the word "digital" came to be associated with modern technology, the word "digit" became an English word referring to the divisions at the end of a limb (a finger or toe) or to the individual, discrete units of a numeral system (e.g., the numerals 0–9).[2] Both of these meanings open perspectives from which the digital gesture may be glimpsed.

Consider the significance of how individual digits—fingers—can be moved and brought into a specific form while gesturing with the hand. The configuration of one's digits could be understood by an onlooker as an invitation, a warning, or an insult, depending on the observer's cultural background. A hand gesture composed of digits is a sign or symbol capable of conveying something that may be living in one's inner life out into the world.

Conversely, the language of hand gestures and the dexterous use of tools have played a pivotal role in how human beings have come to develop worldly intelligence. In the remarkable book *The Hand*, neurologist Frank Wilson uses the heading "hand-thought-language nexus" for a chapter exploring the close relationship between the human hand and brain and the evolution of an intelligence that has allowed humanity to gain "dominion over the rest of the natural world." So much for one type of digital intelligence.

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The second meaning of the word *digit* refers not to mobile appendages but to mathematical concepts. In the context of mathematics, however, the word loses most of its cultural significance and refers to the most basic form of representation within a numeral system. Most people are familiar with the numeral system called base 10 (also known as the decimal system) even if the term itself is unfamiliar. In base 10—which has ten discrete digits associated with it: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9—any number over nine is represented by more than one digit (e.g., the number forty-nine has two digits: 4 and 9).

But, despite its seeming ubiquity, base 10 is only one of a wide range of numeral systems. Some cultures, for example, use base 12 as the basis for their system of counting.[3] The signature of what has come to be known as digital technology is written in the numeral system with the least possible number of digits, namely, base 2, otherwise known as binary. In binary the digits 0 and 1 suffice to represent any number. And, unlike the intelligence developed through the movements made by human digits, the digits of binary represent an entirely different variety of intelligence, an intelligence independent of any external movement.

The birth of binary

Around the same time as the word "digit" crept into the English language, the concept of binary was dawning in more than one English mind. Although the binary system was first defined as such by Gottfried Leibniz in 1679, it was already substantially established 74 years earlier by Francis Bacon of Verulam in what has come to be known as Bacon's Cipher.[4] Conceived as a method for encrypting any kind of communication, the cipher allowed for the open transmission of a coded message whose meaning remained concealed to anyone lacking knowledge of the pattern behind the encoding.

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The intrinsic simplicity of the scheme allowed any message that could be put into language to be conveyed through nearly any means or apparatus. (Although tedious in actual execution, a lantern or bell would suffice to convey an encoded message.) Concealment and a claim to universality are both hallmarks of the digital gesture, attributes that characterize equally well the paradox at the center of Bacon's life. As part of the courtly machinations of his time, Bacon, like Machiavelli before him, recognized the need for secrecy, guile, and "serpentine wisdom." On the other hand, Bacon also aspired to discover a "universal key" to the laws of nature and considered not less than "all knowledge" to be within his domain of research. He laid great emphasis in his writings on the need for a "universal language" that could be based on "signs." He writes that

> …whatever can be *divided into differences sufficiently numerous* to explain the variety of notions…may be made a vehicle to convey the thoughts of one man to another.[5] [emphasis added]

Two hundred years after Leibniz codified base 2 into a formal mathematical system, effectively through a merger of arithmetic and logic (true=1; false=0), George Boole provided the mathematics necessary for making binary calculations. Then, a mere one hundred years after the establishment of "Boolean algebra," and closely following Turing's description of a Universal Machine,[6] the invention of the silicon-based transistor in 1954 opened the door to the type of electronic machine calculation that remains the basis for every digital device produced today.[7]

Due to the steady, decades-long stream of innovations predictably following Moore's Law,[8] a modern computer's central processing unit may now contain over seven billion transistors. Yet, despite their astronomical numbers and miniscule size, individual transistors in any digital circuit amount to what they were the day they were invented: on/off switches unreliant on a human digit for their actuation.

But where are the ones and zeros?

Behind WiFi, video games, virtual reality, the Internet, GPS, self-driving cars, and all other machines based on digital technology, there must exist, inevitably, a series of representations of the concept “one” and the concept “zero.” No matter how complicated, every digital device ultimately requires access to at least one such series of representations. Hidden from view on the hard drive in your computer, in the Cloud, on music CDs, or the memory card in your cellphone, a representation of a sequence of ones and zeros must exist somewhere in some form of media.

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A music CD can serve as a representative example. The shiny, reflective side of a typical music CD consists of a single spiral track—too small to been seen with the naked eye—that begins near the center hole and ends toward the outside edge of the disc. If this spiral would be unwound into a straight line, it would measure more than three miles long. Impressed throughout the length of this spiral track are tiny indentations called “pits” that are interspersed with areas containing no indentations called “lands.” The transitions from pit to land and from land to pit represent “one” and areas of no transition represent “zero.” As the disc spins, a laser shines onto a single point that tracks along the spiral’s axis, and the reflections cast by the passing pits and lands are progressively “read” by a light-sensitive detector. The series of ones and zeroes then undergoes a number of mathematical operations in order to create an electrical signal capable of driving a speaker.

A nearly identical process, only in reverse, created the pits and lands on the CD in the first place: a microphone—which is, basically, a speaker wired backwards—translates the movements of the surrounding air into an electrical signal; the signal is subjected to a series of mathematical operations; the results are stored in memory as a series of ones and zeros; a representation of the series is stamped or progressively burned via laser into the spiral of a blank CD.

Creating a representative series of ones and zeroes—called digital data—requires certain information to be extracted or “digitized” from some detectable phenomenon, a phenomenon that is otherwise experienced as continuous with other surrounding phenomena. Such a process occurs, for instance, when a digital image is recorded by a digital camera.

Imagine gazing at distant mountain peaks set against a bright sky. Now hold before your mind’s eye a grid or net so that the image beyond is framed by each delineated hole of the net. By numbering each hole of the net in sequence and noting if the image in each hole is light (sky) or dark (mountain), you have effectively digitized the view, albeit at a very low resolution. You could now produce a digital image by filling a piece of graph paper having a number of squares equal to the original net with the data from the digitization process.

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As the “size” of the holes in the net decreases, the resolution of the resulting image increases. The camera in the average smartphone is capable of digitizing from its 3264 x 2448 “holes” enough data to produce an image of “photo quality.” Regardless of the context, each instance of digitization—one could also call it discretization—results in exactly the same outcome: A series of ones and zeros comes to be represented in some medium, physically, magnetically, or otherwise.

A clock that binds, not unwinds

Having answered the *where* of digital data, the question of *when* remains. How digital data becomes useful again once it has been frozen somewhere ("saved"), touches on a theme at the very core of digital technology: the clock. Before any digital device can begin reading, processing, or producing ones and zeroes, there must be some method of separating one moment from the next so that one calculation can follow another in an orderly fashion. Since a machine is not able to execute an operation outside the programming to which it has access, once it is powered on, it must follow a protocol or set of instructions: If this, then that, otherwise do something else. But everything can't happen at once.

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For this reason, each digital device requires some way of "keeping time." It is here that the digital gesture finds its most apt expression, for a digital clock is not something that ticks, trickles sand, or tracks the sun, but is, rather, a shard of quartz made to vibrate at a fantastic frequency. Certain properties of shape combined with the piezoelectric effect make it possible for a quartz crystal to generate an electrical signal that oscillates between the states "on" and "off." Back in the ancient 1990s, a reference to the vibrational frequency of the crystal in a computer's main processing unit was used as a kind of shorthand for the overall speed of its calculating capability. In terms of speed, the edge of what was then considered to be the state of the art moved from hertz to megahertz to gigahertz.

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This last designation is reserved for any chip whose clock speed exceeds one billion vibrations per second. With each on/off cycle of the clock, a simple mathematical operation can be made: adding together one and zero, for instance. That is not particularly useful. But when billions of transistors are driven to produce billions of calculations billions of times each second, an astonishing world of possibilities opens up. It is the blinding speed of sequential calculation that makes every manifestation of digital technology possible.

It is a feature of the digital gesture that it works back onto the world conception that produced it in the first place. The Standard International unit of time defines one second as the period that elapses during "9,192,631,770 cycles of the radiation produced by the transition between two levels of the cesium 133 atom." Atomic clocks based on this definition now gain or lose one second in fifteen billion years, a timeframe that eclipses by more than one billion years the age of the known universe as proposed by the Big Bang theory. Time is now, by definition, synonymous with an oscillation between two discrete, fixed poles. It has itself been digitized.

Digital idol

As the digital gesture facilitates devices that are ever-smaller and more compact while simultaneously allowing for an ever-increasing speed of calculation, what becomes of the data produced, stored, and processed via these capacities? What happens to all the digitized libraries, discographies, maps, images, financial information, et cetera ad infinitum, that comprise the ever-expanding trove of an era already long under the influence of Big Data? Sophisticated algorithms make it possible to discern apparently meaningful patterns within the worlds of data that have been built out of binary "atoms," the seemingly endless representations of ones and zeros. But, what do such representations amount to outside the digital realm?

Before considering the relative merit of the binary representation of something, at least three assumptions must be made. First, that sufficient data corresponding to the "something" can be captured in the first place. (How many pixels does one need to be able to recognize one's mother in a digital photo?) Second, that there is a mechanism by which the data can be reconstituted or "read" in the future. (What happens when a long-forgotten CD containing family photos resurfaces in a world that no longer contains a corresponding CD reader?) Third, that the recovered data can be displayed or otherwise reproduced in some meaningful way. (Of what use is the data read successfully from a CD if it produces "pixel" information for a display that can reproduce only "polygon" information?) It is possibly an example of poetic justice that the binary system, as implemented in digital technology—to all appearances capable of representing some version of reality in the most objective, unbiased, quantitative manner yet conceived—is useless without the layers of context by which it can be interpreted. Just as a language cannot be truly meaningful without someone who is able to speak and understand it, a string of 1s and 0s is inherently meaningless without a machine capable of recontextualizing it.

From this point of view, binary data, no matter how well it is outwardly represented, can only ever be an artificially produced image of something else. The digital gesture, shrouded by the binary data that it produces, closely resembles what Owen Barfield refers to as an idol. He asserts that, "when the nature and limitations of artificial images are forgotten, they become idols." (Barfield 1988, p. 39) When seeing an image on a computer monitor or reading an email or hearing a voice through a cell phone, it is very difficult to keep in mind that each of these is an artificial image that is necessarily limited by the very data that comprises it. The Psalmist, in describing the creations of forgetful idolaters, puts it this way:

Their idols are silver and gold:
even the work of men's hands.
They have mouths, and speak not:
eyes have they, and see not.
They have ears, and hear not:
noses have they, and smell not.
They have hands, and handle not:
feet have they, and walk not:
neither speak they through their throat.

Building a better batoid (any cartilaginous fish in the superorder *Batoidea*)

Despite being haunted by the spectre of an overwhelming number of artificial images, digital technology taken as a whole constitutes the most powerful instrument that modern civilization has been able to produce. A paper recently published in the journal *Science* documents the real-world efficacy of the digital gesture. A diverse group of researchers working across several scientific domains was able to create a 1:10 scale artificial skate with a skeleton of gold capable of swimming using muscle cells grown from rat heart tissue genetically engineered to react to specific frequencies of light.

After pausing to admire the sheer audacity of such a feat, one might initially struggle to identify ways in which digital technology as such played any role in the development of this "living, biohybrid system." But, as the dazzling effect of scientific heroism fades, the digital gesture lying behind each idea and piece of equipment used to construct such an animal-machine becomes apparent. To micro-fabricate the gold skeleton, genetically engineer the light-sensitive muscle using a technique to precisely "edit" DNA, and even to record and present the images of the finished project, each step required the use of digitally-derived tools.

The coordination of the diverse international team also required the use of digital communication technology, as did access to digital archives and the experimental data of other relevant projects. Despite any appearances to the contrary, the digital gesture is the foundation for all such technical virtuosity. It is perhaps due only to the circumstance of many of these techniques and technologies having already become passé that they do not shine out as brightly to one's attention as does a shimmering skeleton of gold.

Mind the meme

No essential criticism can be leveled against the digital gesture in and of itself. It has enabled the sublime technical prowess lying behind all the relatively recent advances that have quickly come to be merely mundane for the most privileged parts of the world: celebrity-voiced driving assistants, personalized online shopping services, and an unwatchable number of digital media outlets, to name a choice few. Failing to keep the digital gesture firmly in one's consciousness, however, can lead to the acceptance of each new technological wonder as if it were inevitable, unavoidable, and hopelessly beyond one's ken, a magical happening created by way of a sufficiently advanced technicity.

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That the digital gesture is equal to the task of producing novel forms of life is an established fact. That the artificial lifeforms in question owe their existence to a flickering sea of artificial images is easily forgotten. The entire digital world is reminiscent of a mode of observation characterized by Ernst Lehrs as the "one-eyed color-blind approach." Should we, like Odysseus, hope to escape from the cave of a monochromatic, one-sided world outlook, it seems likely that such an endeavor will require the courage to forego the exclusive use of a correspondingly one-sided intelligence, no matter how powerful it may appear.

ENDNOTES

1. The industrial revolution that began in the late nineteenth century gave way to the digital revolution in the late 1950s, an impulse that continued to develop significantly in the 1960s and 1970s. Today in 2016, the fruits of the digital revolution have become central to a way of life in many parts of the world, and the use of digital technologies is now considered essential in almost every industry. (See the excellent 2013 study "Embracing Digital Technology" by *MIT Sloan Management Review*.)
2. The word *numeral* refers to an individual element in a system (e.g., "2") while the word *number* refers to the concept that is represented by the numeral (the idea of "two of something" or "twoness"). The words "numeral" and "digit" are not synonyms in the mathematical sense. A digit is always considered to be discrete, relating to a single element, whereas a numeral can refer to a number represented by several digits. For example, the concept "one hundred and two" can be represented by the numeral 102 which consists of the digits 1, 0, and 2.
3. Base 12 or the duodecimal system has twelve representative digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T, and E where T and E represent the equivalent of 10 and 11 in base 10. This means that base 12 can represent with one digit (e.g., the digit "E") what would take two digits in base 10 (i.e., "11"). Following the pattern further, the number twelve in base 12 is written as 10 and one gross—one hundred forty-four—as 100! There are several organizations that advocate for the general adoption of the duodecimal system as a replacement for base 10 due to the former's many advantages, the most significant of which is the ease with which fractions can be calculated (not to mention 12 signs of the zodiac, 12 months of the year, 12 hours of the clock, 12 finger bones of the hand, etc.).
4. Bacon's Cipher is a system of encryption whereby each letter of the alphabet is replaced by the characters "a" and "b," arranged in particular sequences. The letter "A," for instance, would be represented by the sequence "aaaaa," the letter "B" by "aaaab," "C" by "aaaba," and so on through to "Z" which would be "babbb." (In attempting to reconstruct the other letter sequences, particularly inquisitive readers may find themselves wondering

why "Z" isn't represented by the sequence "bbaab." Answer: The alphabet of Bacon's time consisted of only twenty-four letters.) This cipher was the precursor for what would later become the pattern for representing numbers in binary, with "1" and "0" replacing the characters "a" and "b."

5. "The Advancement of Learning," Book VI, *The Works of Francis Bacon*. James Spedding, Robert Ellis & Douglas Heath, eds., London, 1901, p. 439.
6. Alan Turing, famous for having helped to break German ciphers in World War II, was first to realize that it was "possible to invent a single machine which can be used to compute any computable sequence." This possibility—which he called a "universal machine"—laid much of the theoretical groundwork for the initial developments of computer science.
7. A transistor is simply the electronic version of a light switch: It either lets electricity flow or it doesn't. The switching of a transistor between its on and off states is controlled by electricity. By connecting transistors together in various arrangements, the resulting electronic circuits can be made to produce results that are consistent with Boolean algebra. All digital logic is built from these basic circuits.
8. Moore's Law, named after Intel co-founder Gordon Moore, predicts that the number of transistors that can fit into a square inch will double every 18 months. It is no exaggeration to say that faith in Moore's Law has fundamentally driven the digital revolution by allowing software and hardware companies to successfully plan well into the foreseeable future.

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