ABSTRACTING REALITY

Art, Communication, and Cognition in the Digital Age

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**This book is dedicated to
my parents**

Joseph Andrew Wolf

and

Dorothy Jane Wolf

Contents

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PREFACE

Digital technology is among the fastest-growing phenomena of recent decades, with the appearance of affordable computers and their integration into a wide range of technologies, most notably communications technology. The shift from analog technology to digital technology, however, has repercussions often left unacknowledged or unexplored in depth. These differences stem not only from the applications of the technology but their basic, inherent nature as well. A good place to begin, then, might be the differences between "digital" and "analog", and the concepts they represent.

While the concept of "digital" today often pertains to intangible abstractions, its origins lie in the realm of the tactile. "Digit" comes from the Latin *digitus*, meaning a finger or a toe, a definition which the *Oxford English Dictionary* tells us is "Now only *humorous* or *affected*."[1] Today, of course, the term refers mainly to the numerals zero through nine, the basic elements of the number system. The fourth and fifth definitions given by the *OED*, however, are relatively recent additions relating to computer terminology:

> **4.** Of, pertaining to, or using digits [DIGIT *sb.* 3]; *spec.* applied to a computer which operates on data in the form of digits or similar discrete elements (opp. *analogue computer*).
> **5. a.** Designating (a) recording in which the original waveform is digitally encoded and the information in it represented by the presence or absence of pulses of equal strength, making it less subject to degradation than a conventional analogue signal; of or pertaining to such a recording.[2]

In the past few decades, these new definitions have made the term "digital" almost synonymous with the computer, despite a long history of digital technologies preceding the computer.

The term "digital" has a number of other connotations. Conceptually, digitization is often connected with *quantization*, a process closely related but not synonymous to it. While digitization concerns the conversion of data into numeric form, to *quantize* something is to restrict the values or states of a system so that variables can only appear at discrete magnitudes which are multiples of a common unit. In other words, quantization sets a number of distinct levels or units which are used to measure something, and these are the *only* levels at which data can be represented. For example, when a student receives a grade in a class, the grade will be either A, A-, B+, B, B-, C+, C, C-, and so on; you can't get something in between (at least at most schools). A student's performance, then, is rounded off to the nearest grade level, to make the whole process of grading easier and simpler. The same thing happens when sound is quantized; the continuous sound wave is broken up into "samples", each of which is rounded off to one of the possible levels allowed by the machine which is quantizing it. Likewise, pictures are broken up into *pixels*, the tiny square elements that make up computer imagery. Quantizing, then, takes something analog with infinite detail or gradations, and simplifies it into something with a limited amount of detail, making it easier to work with or "store" as data in a limited amount of computer memory.

Once the data is broken up into pieces (like grades, samples, pixels, etc.), those pieces can be represented by numbers and encoded into numerical form; this is the basis of *digitizing*.[3] Thus, in an analog-to-digital conversion, some form of quantizing must occur before digitizing can occur. When "digitizing" is referred to as a process, it more often than not includes quantizing along with it, since the two processes are so closely related; but it still is important to see two processes as distinct, one preceding the other. Likewise, a societal trend towards digitization can only occur after a quantization of everyday life occurs —a process which is the subject of chapter one.

The effects of quantization and digitization are perhaps best described in two keys words, *discrete* and *representation*. The discrete nature of digital data is what separates digital and analog forms, and encoding changes the form of representation. This change is illustrated by the difference between analog and digital computers: analog computers use physically measurable quantities (length, weight, voltage, etc.) to represent numbers, while digital computers use symbolic representations of variables. Thus the conversion from analog to digital involves a semiotic shift from the indexical to the symbolic, a topic which will be examined in detail in the final chapter on indexicality.

Another difference between analog and digital is their connotative meaning in popular usage. In common parlance, "digital" has come to represent the modern, state-of-the-art technology, while "analog" refers to an older, outmoded and outdated form; this distinction is perhaps most obvious in the music industry where compact discs quickly replaced vinyl albums as the dominant commercial format. The term "digital" is also often associated with a high degree of quality, even though the term refers to a technology and not a specific application of it. What is usually not acknowledged is that all output devices, monitors, speakers, printers, and so on, are analog devices. To be of use, sound and image must reenter the domain of the physical world, and in doing so there is an inevitable shift back to analog form. This is similar to the idea that no one has ever seen a perfect circle. A circle is only perfect when it exists as a mathematical entity; once it is drawn up or printed out, imperfections in physical media, albeit small ones, render it imperfect. Thus "digital" can only refer to data represented or "stored" in digital form; as output it becomes analog again.

It would seem, then, that "digital image" is oxymoronic; if stored in numeric form, the image is not an image in the conventional physical sense; we cannot see it. And once it *is* in visible form, as output, it is no longer strictly digital. The term "digital image" does make sense if we refer to another definition of "image", that of a mental picture or representation of something. Thus, when "digital image" is used here, it will mean an image which has been stored in some digital format. In this sense, the digital image promotes a shift from the *perceptual* to the *conceptual*, a theme running throughout this book. With the widespread and full-scale integration of digital technology into daily life, "digital" has become more than a type of technology; it has come to stand for the fabric of the growing information society. It extends beyond a form of design into a way of thinking, an attitude towards the world and the future.

The first part of this book, *The Emergence of Digital Technology*, examines the frame of mind and ways of thinking from which digital technology arose, and the conditions which made it desirable. Chapter one looks at the quantization of everyday life that set the stage for digital technology, and chapter two looks at the development of digital technology and a variety of its precursors.

The second part, *Art*, is concerned with the effects of digital technology within art and culture. Chapter three looks at how digital technology has been integrated into the production, preservation, exhibition, and reproduction of art, and changes in the notion of "art" itself, and it explores the implications of digital artwork's lack of physicality, tracing its links to the physical world. Chapter four looks at how the technological basis of digital artwork results in biases which can occur at the cultural level, and chapter five looks at how digital technology has expanded the possibilities of composite imagery, and some of the implications of these changes.

The third part, *Communication / Media*, builds on second part and broadens its scope out from art to include all other forms of communication and media, and looks at how digital technology has been positioned among them. Chapter six examines the growth of machine mediation in social interaction and notions of interactivity, while chapter seven looks at the culmination of electronic communication with the forging of the conceptual, informational realm known as cyberspace.

The final part, *Perception / Representation / Cognition*, extends the scope of previous chapters to include the activities through which individuals perceive and understand the world around them. Chapter eight examines the effects of digital technology on the environment, and the way it recreates the user's environment. Chapter nine continues this theme and looks at notions of virtual reality, the fantasies surrounding them, and the idea of the substitute. Finally, chapter ten, on indexicality, traces how digital technology mediates and abstracts the indexical linkages between the observer and the observed, and how the notion of indexicality itself has been called into question. It looks at the implications of these changes for users, and the increasing degrees of abstraction brought about by digital technology and the media.

Throughout this book, I try to show how the effects of digital technology, and the concepts surrounding it, have subtly altered the fabric of society and culture in areas both the practical and theoretical. While many of these changes may appear, initially, to be small, insignificant, or even for the better, it is not so easy to determine the worth of their combined effects, arising from the implementation of the technology and the nature of the technology itself. It is my hope that this book will help to open up inquiry into these areas.

NOTES

1. *The Oxford English Dictionary, Second Edition, Volume IV: Creel-Duzepere*, prepared by John. A. Simpson and Edmund. S. C. Weiner, New York: Claredon Press, and Oxford, England: Oxford University Press, London, ©1993, page 653.
2. Ibid., page 654.
3. Occasionally, because "digital" is the adjective form of "digit", people mistakenly use "digitalize" in place of "digitize"; *digitalization* refers to the administration of medicine prepared from *digitalis*, a genus of plant including the foxglove, or *Fingerhut*, the German name for the plant.

I.

Digital Development

1.
The Quantization of Everyday Life

Consider how many numbers you use or see on a daily basis, and the important role they play in giving order to your life and the way in which you picture and think about the world. Even such activities as talking on the telephone or buying something at a supermarket involve digital technologies and the streams of numbers they produce. In the last century or so, numbers have taken on an important and often central role in people's lives, allowing digital technologies to flourish. Of course these technologies are partly responsible for the increase as well; but they could only come about in a world already obsessed with measuring and counting.

The concept of "digital", and technology based on it, required the idea of counting, the notion of *quantity*, and the ability to see things as distinct entities or separable into distinct parts. Being able to think of things as made up of component parts is immensely useful as a way of thinking, leading to new ways of seeing the world. But in recent times it has been taken to quite an extreme —and is encouraged by modern digital technology itself.

Digital technology promotes a quantized style of thinking that produces a limited, if not hazardous, way of looking at the world, changing the nature of cognition and the individual's link to lived experience and intersubjective reality. (When I use the word "quantizing" here, I mean it in a conceptual sense; how we think of things, not necessarily the things themselves; the *signifier*, not the *signified.*)

While widespread promotion and acceptance of a "quantized" way of thinking has been relatively recent, its roots precede the digital age, extending back through recorded history. Although quantization certainly is useful and has been essential in shaping much of Western culture (and to a degree Eastern culture), it also has limitations and disturbing side effects.

Divide and Conquer

In order to make sense of the world —or rather, our sensory impressions of it— we break it up perceptually into series of parts; through visual cues like color, focusing depth, motion, shape and texture, we distinguish individual objects in the visual field, separating foreground from background. In a similar fashion, we also break things up conceptually, in order to name them and refer to them. The color spectrum is continuous, yet it has been divided up into colors which are named; although people may not always agree on the boundaries (between 'red' and 'orange', for example) references to specific colors are generally understood.

Such boundaries are artificial ones, but are important in defining the objects of study in question. Historians are aware of the perils of periodization, which imposes an order the structure of which is determined by certain events at the expense of others. We might think of the 1940s, 1950s or 1960s as separate, distinct periods, even though more cumbersome divisions of 1951-1957, 1958-1962, and 1963-1971 might prove just as useful historically. The division by decade is merely a numerical one, with no reference whatsoever to the history being periodized.

Not only are things divided, but divisions tend to be of equal size or measure, standardized so that consistent and interchangeable units are created; unit multiples can be calculated quickly, and measurements made by one person will be consistent with those made by another. This is similar to the idea behind *quantization*, the process in which an analog range of values is made to fit into a finite number of discrete levels or units, usually equal in size, so as to be represented more simply. This simplification made understanding, representing, and remembering easier and communication more precise. Quantization, as a form of 'rounding off', is simplification at the expense of accuracy, and throughout history, as we shall see, attempts to regain accuracy have been made through the use of increasingly smaller units.

Quantization, then, arose out of the 'divide and conquer' thinking that successfully had allowed people to break down and reconstruct the world conceptually, and communicate ideas about the world and the objects in it. Archaeologists suggest that written communication itself may have arisen from mathematical representation when thousands of years ago, tally marks used for measuring amounts grew into more expressive forms.[1] The invention of mathematics was the first step towards quantization, because it allowed *quantification*, the expression of things as quantities, in amounts or numbers. Since many things being measured were not conveniently or consistently divided by nature into individual objects, arbitrary units and measures came into being which were first based on nature but which gradually tended towards complete abstraction. The contents of everyday life were broken up and rounded off into these units, to make life in general a more orderly experience.

The quantization of everyday life can be seen in four conceptual areas which have been broken up into units and continuously subdivided and abstracted into increasingly smaller units for greater manipulation and interchangeability. These concepts, *Time*, *Space*, *Value*, and *Information*, are four constructs we use to mentally reconstruct and order the way we think of the world; changes in the way we conceptualize them become changes in cognition itself.

Time

Without reliably regular intervals produced by natural events such as sunrise and sunset or the phases of the moon, how could one consistently measure the passage of time? What can be relied upon to measure time, apart from consistencies found in nature? And how can we be sure that they really are consistent, if they are the basis of the measuring devices themselves? These are some of the questions that had to be overcome in time measurement, and measures of space relying on time measurement.

Timekeeping began at the dawn of history, and the desire for consistency and precision has driven timekeeping developments ever since. Technological advancements have allowed for increasingly finer units of time to be measured, and have worked in tandem with people's desire or need to keep track of smaller and smaller units. As A. J. Turner writes in *Of Time and Measurement: Studies in the History of Horology and Fine Technology*;

> ... smaller units had to be imagined, and ways to determine them devised. Such active time-measurement involved the development of tools and machines. It also involved a change of relationship with time. Gradually time became more manipulable. Time as a given element of the world gave way to a time which was created by the machines which measured it. In the process man became increasingly independent of nature. Whether this be seen as a liberation or denaturisation, it was an important consequence of the development of time-measuring devices and is apparently irreversible.[2]

The earliest measurements of time arose from the observation of cyclical or regular phenomena in Nature. Sunrise, sunset, full moon, new moon, and the positions of constellations were based on celestial mechanics, while the flooding of the Nile helped the ancient Egyptians determine the length of the year. The combination of the two natural units of time, the day and the year, resulted in the calendar, which the Egyptians set at 365 days, possibly as early as 4228 BC.[3]

The next division of time was the marking of noon —the sun's zenith— and the division of the day into hours. Although the earliest evidence of sundials dates from around 2000 BC, divisions of the day into hours of equal length were first used by astronomers and the physicians and astrologers who relied on the astronomer's work, and it was around the 14th century that hours finally became more commonly used in social life. Turner points out that there was even some resistance to hourly divisions, due to the

> ...clash between biological time and the artificial time of the sundial when this was adopted in social life. That the tiresomeness of waiting for the sundial to give one leave to eat furnished matter for the comic poets Plautus (3rd century BC) and Alciphron (1st century AD) is suggestive of a more widely spread reaction.[4]

Eventually the division into hours became accepted, especially in regulated communities like Christian monasteries, and new technologies such as the weight-driven clock and later the pendulum clock lent timekeeping greater precision. During this time of public acceptance, craftsmen made clockmaking into an art, and the clock took on greater importance in daily life, and even a town's self image.[5]

During the Renaissance, clock movements became smaller, and the clock moved indoors and entered into family life. In the early 16th century, further miniaturization brought about the carriage-clock, and finally the pocket-watch. Mechanical accuracy and the recognition of the importance of time had increased to the point where minute hands came into use and were seen as necessary. [6] The next division of time divided minutes into seconds. Although clocks with a second hand appeared during the 16th century, their accuracy was still far from being good enough to warrant having one, nor was there any societal need for one. Even in contemporary life, there is scarcely little need for a second hand, except to indicate that the clock or watch is still running and has not stopped; most digital light-emitting diode clocks do not even display seconds. Why then, were timepieces with second hands produced in an era that did not have the technology for the needed precision? Historian Carlo M. Cipolla suggests an answer;

> The most striking occurrence in the early history of clocks is that while medieval craftsmen did not improve noticeably in precision, they soon succeeded in constructing clocks with curious and very complicated movements. It was easier to add wheels to wheels than to find better ways to regulate the escapement. On the other hand complicated movements had quite a popular appeal and most people believed that a correct knowledge of the conjunction of the heavenly bodies was essential for the success of human enterprises.[7]

Already, technology was beginning to outstrip the public's ability to understand it. It had become something of a novelty, and an aid to growing astrological superstitions.

By 1896, the year of the return of the Olympic Games, Olympic records were being recorded with an accuracy that included tenths of a second, and by 1968 they were recorded in hundredths of a second. Science, too, had grown in complexity, requiring ever finer measurements of time, space, and mass. In the late 1920s, Joseph W. Horton and Warren A. Marrison of Bell Labs attained a new level of accuracy with the first quartz-crystal clock, which became the primary laboratory standard by the 1940s. But physics demanded even greater precision, for example, in experiments testing for relativistic time dilation, in which a clock aboard an airplane was predicted to run billionths of a second faster than one on the ground. Atomic clocks, based on the oscillations of atoms, provided the answer. In 1967, the second was redefined atomically as being equal to 9,192,631,770 oscillations of the cesium-133 atom.[8]

Just as the calendar regulated life, advances in timekeeping precision led to adjustments made to the calendar. The year is slightly longer than the 365 days the Egyptians measured, and Hellenistic astronomers added a leap day to make up for the missing quarter day every year. The leap day was officially adopted into the calendar in 46 BC, in Rome under the reign of Julius Caesar. In 1582, Pope Gregory XIII's advisors persuaded him to drop the leap day in years ending with two zeroes, since the year was not quite 365.25 days either. And more recently, in 1987 and 1992, timekeepers have added "leap seconds" to restore accuracy; the earth's spin on its axis has been slowing down by about one millisecond (a thousandth of a second) per day, and leap seconds help the earth to catch up to humanity's clocks.[9]

But the quantization of time does not end there; theoretical physics went further still, speculating on what the shortest spans of time possible might be. One proposal was the *chronon*, described as the time taken for a photon to traverse the diameter of an electron, which is approximately equal to 10^{-24} seconds. And finally, the smallest unit of time ever conceived is the unit known as *Planck-time*, which is the amount of time it takes for a photon to move through a distance equal to one unit of *Planck-length* (equal to 10^{-35} meters). One unit of Planck-time is equal to 10^{-43} seconds, an unimaginably small amount of time; there are more units of Planck-time in one second than there are seconds in the current age of the universe —more, in fact, than if the universe was 21,125,500 *billion billion* times the age it is now!

Clearly time, our experience of it, and its value to us, have changed the way we think of the world. Time has ceased to be a continuous flow, and become fragmented and segmented; most public events in daily life are set to begin on the hour or half-hour, and private ones often are as well. We think of time as having arbitrary units of equal length, subdividing them and grouping them into larger units as well. Conceptually, our temporal life has become discontinuous and departmentalized; the irony is that the more divisions we make in our day, the less time we seem to have.

Space

The quantization of time has always been closely related with the measurement of distance; in early societies day and night and the phases of the moon may have been the only ways of expressing distances. Astrolabes, invented during the Middle Ages, provided a means of measuring large distances or heights using celestial bodies as a guide. The sun, moon, and stars were used for navigation and aided cartographers in mapping land and sea; they even allowed Eratosthenes, a Greek astronomer, to estimate the circumference of the earth in 200 BC. Measurements of smaller distances were also based on nature, and often on the human body, which was always available for use and easy to understand. But the disadvantages of such a system were the lack of common multiples or divisions of units, as well as the varying size of the body from one person to another.

Like time measurement, the need for standards took linear measurement into abstraction and the devising of more arbitrary units. At first, attempts were made to keep the older system; around the beginning of the 12th century, the yard was set as the distance between King Henry I's nose and the middle fingertip of his outstretched arm. This brought some interchangeability between units, albeit a complicated and convoluted one;

> In England the digit-- later standardized at 3/4 inch (1.905 cm) --was originally a finger's breadth, equal to 1/4 palm, 1/12 span, 1/16 foot, 1/24 cubit, 1/40 step, and 1/80 pace. The palm or hand's breadth was equal to 1/3 span or 1/6 cubit. Based on the foot of 12 inches, it was made equal to 3 inches (7.62 cm). A span was equal to the distance from the tip of the thumb on the outstretched hand, and based on the foot it was made equal to 9 inches (2.286 dm). The cubit was the distance from the elbow to the extremity of the middle finger, which was generally reckoned as 18 inches (4.572 dm), or 6 palms or 2 spans. A step was 1/2 pace or approximately 2 1/2 feet (ca. o.76 m), while a pace equaled 2 steps or approximately 5 feet (ca. 1.52 m). Other body measurements were the shaftment of 6 inches (ca. 15.24 cm) or the distance from the tip of the extended thumb across the breadth of the palm; the nail, used principally for cloth, that represented the last two joints of the middle finger, equal to 1/2 finger, 1/4 span, and 1/8 cubit, and standardized at 2 1/4 inches (5.715 cm); the hand of 4 inches (10.16 cm); the finger for cloth equal to 2 nails or 1/2 span, and generally expressed as 4 1/2 inches (1.143 dm), and the fathom, the length of a man's outstretched arms containing generally 6 feet (1.829 m).[10]

In Ronald Edward Zupko's book, *Revolution in Measurement: Western European Weights and Measures Since the Age of Science*, from which the above quote is taken, he recounts the history of British measurement systems and reforms, the coming of the first metric system in France in 1795 and its rapid international spread afterwards, and the reluctant acceptance of the metric system in Britain and the United States after great resistance. The spread of the metric system and its victory over systems in use for centuries was due to its usefulness in science. Metric units are all base 10 and easily convertible, and distance, volume, and weight are all interrelated.

The basic unit of the metric system, the meter, was originally intended to represent one ten-millionth of the distance along the meridian running from the North pole to the equator through Dunkirk, France and Barcelona, Spain. Like many other arbitrarily set standards of measurement, the definitive meter was a metal bar kept as a physical replica. Such physical standards were in the safekeeping of the authorities, but still there was a need for an abstract or mathematical way of defining the standard which could not be destroyed, and which could be calculated anywhere without having to depend on a physical replica in a vault somewhere. Nor was the replica exactly the right length; increased precision measurement of the distance between pole and equator showed the error of the original surveyors to be off by about two miles.[11]

Over the years, technological advancements have continued to redefined the meter; "Up until 1893, the meter was defined as 1,650,764.73 wavelengths in vacuum of the orange-red line of the spectrum of krypton-86. Since then, it is equal to the distance traveled by light in a vacuum in 1/299,792,458 of a second."[12] As was the case with time measurement, science required increasingly finer units of measurement, and the metric system provided with a series of prefixes (1 decimeter= 10^{-1} m; 1 centimeter= 10^{-2} m; 1 millimeter= 10^{-3} m; 1 micrometer= 10^{-6} m; 1 nanometer= 10^{-9} m; 1 picometer= 10^{-12} m; 1 femtometer= 10^{-15} m; 1 attometer= 10^{-18} m). Finally, the smallest unit of length is that of *Planck-length* in theoretical physics, on which the unit of Planck-time is based. One unit of Planck-length is defined as

"The length scale at which a classical description of gravity ceases to be valid, and quantum mechanics must be taken into account... The value of Planck-length is of order 10^{-35} m (twenty orders of magnitude smaller than the size of a proton, 10^{-15} m)."[13] Such a unit is unimaginably small; to compare one unit of Planck-length to the thickness of a sheet of paper would be like comparing the thickness of a sheet of paper to a distance wider than the known universe. Likewise, other distances devised by astronomers are unimaginably large; one AU, or Astronomical Unit, is about 93 million miles, the distance from the earth to the sun; a light year, the distance that light travels in one year, is about 5880 billion miles, and a parsec (from *parallax second*) is 3.26 light years.

In the modern world, numerous factors have changed our sense of space and made us more conscious of its organization. Technological miniaturization, of everything from engines to microchips to household appliances, has changed the nature of the space around us and our relation to it. Microscopes and microphotography have shown us how enormous activity and complex structures can occur in a tiny space, and electrical and molecular engineering have shown how machines can be built at this scale. On the other hand, transportation and communication technologies have shrunk large distances and allowed us to form better and more detailed cognitive maps of the world; although they can sometimes be as distorted as those of ancient cartographers whose biases are often apparent in their maps (the Mercator projection, for example, emphasizes the north and de-emphasizes the south, and Germany, Mercator's homeland, is the projection's centerpoint). The way in which the land and space we occupy are divided can account for much of our experience of that space.

The earliest evidence we have of land division or landscaping is the remaining works and plans of the ancient Egyptians, who were fond of straight-ahead linear arrangements and bilateral symmetry. Straight lines and right angles are a natural product of surveying techniques, which measures distance in straight lines and area as the product of two lengths perpendicular to each other. Egyptian surveying was remarkably precise; the great Pyramid of Giza, for example, is extremely accurate in its dimensions and layout despite its enormous size. The ancient Greeks took the idea of landscape architecture further still, providing the foundation for city planning and land division in Western civilization. Their ancient cities also used the gridiron plan, in which rows of streets are laid out perpendicular to each other in a checkerboard pattern, indifferent to the shape of the land, shorelines, and changes in terrain.[14]

From ancient times onward, the grid pattern, breaking up space in units of equal size and shape, has been forcibly applied onto the land, and onto the surface of the earth in general. Latitude and longitude were introduced by the Greeks around 500 BC, and Eratosthenes, who estimated the earth's circumference, also devised a world map with lines of latitude and longitude, although the lines on these early maps were not evenly spaced; they were drawn to connect places that had the same length of daylight on the longest day of the year. The first uniform grid of parallels and meridians was developed in the second century BC, and is credited to the astronomer Hipparchus. From the stereographic projection of 130 BC and on through to the modern-day Peters projection and satellite mapping, cartographers have tried their hand at squaring the sphere, in their attempts to apply grids and develop flat projections of the earth's surface. In both the gridiron method and the system of longitude and latitude, mapmakers struggle to impose designs onto nature, even when the fit is a forced one due to land formations, terrain, or the curvature of the earth. Because of the earth's curvature, one degree of latitude can vary from 68.703 miles near the equator to 69.407 miles near the poles. Meridians of longitude converge at the poles, so one degree will vary, changing in length from 69.172 miles at the equator to 0 at the poles. The need for quantization again takes measurement and division away from the natural and into the abstract. And the units grow smaller; now that we live in a world where license plates on cars can be seen and read by satellites, degrees of latitude and longitude can be expressed in minutes and seconds of arc, amounting in global coordinate units that are less than a hundred feet wide.[15]

One would think that meridians would provide a convenient way to determine a time zone system, each zone covering an average of 15 degrees of longitude, but it is not as simple as that. Time zones were made necessary by high-speed travel and instantaneous communication during the era of the railroad and the telegraph. Each railroad developed its own time zones, and by the 1870s, 50 different ones were in use. An international conference to establish world time zones was held in 1884 in Washington D. C., but it was not until 1918 that the actual boundaries between the zones were established. Here again, irregularities of nature kept the boundary lines from being straight, and political divisions of land also determined where the boundaries should fall. As a result, there are areas on the globe (in the islands of the Pacific, for example) where, just by traveling north or south, one can change time zones by as much as three hours.

Divisions imposed by meridians and parallels can affect nations, particularly in times of war when territory is in question; for instance, the Mason-Dixon line, set at a latitude of 39° 43' 19.11", divided North and South, separating slave and free states; and the 38th parallel became the line separating North and South Korea during the Korean war. On a smaller scale, lines of longitude and latitude were used to determine much of the town and city planning of early America. On May 20, 1785, the United States Congress authorized the surveying of the western territories into six-mile-square townships, determined by lines of longitude and latitude. Each township was further subdivided into 36 square sections of 640 acres each. Around two-thirds of the present United States were sectioned off in this manner.[16]

The gridiron system was convenient for surveying and land speculation, as every section could be located by number, and deeds were often purchased and recorded that way. But the gridiron plan was not without its detractors, and was sometimes impractical due to the rigidity of the squaring of the land. As John Stilgoe notes in *Common Landscape of America, 1580 to 1845*;

> Roads followed section lines and section lines followed the compass. Surveyors gave no thought to avoiding natural obstacles or approaching natural resources, and as more than one anti-grid congressman had argued in the 1784 and 1796 debates, many settlers suffered permanently. Roads led deliberately and directly through swamps and over hilltops, tiring horses and infuriating drivers. Farmers discovered that some sections were well watered and that others were separated from useful ponds and springs by only several yards. Had the surveyors been allowed to modify the straight lines--even slightly--many sections would have been far more valuable.[17]

As it turned out, the straight lines had to be altered anyway. The use of meridians posed a further problem, because unlike parallels, they converged at the poles, and the distances between them changed about sixty yards per mile. According to Stilgoe,

> What evolved was the section correction, a common design solution to a most vexing geometrical problem. Every few score miles, surveyors shifted the meridian lines a hundred yards farther west and continuing platting. Hardly anyone on the ground noticed the irregularities scarcely visible as two right-angle turns separated by perhaps 300 or 400 yards, and readers of maps found them scarcely more obvious. . . . For all its shortcomings, the grid proved reasonably effective in ordering the land for sale and settlement. People grew accustomed to it, so accustomed in fact that had even the federal government wished to alter it or discard it for some better form, public opposition would have proved too strong. Phrases such as "a square deal" and "he's a four-square man" entered the national vocabulary as expressions of righteousness and fairness. By the 1860s the grid objectified national, not regional order, and no one wondered at rural space marked by urban rectilinearity.[18]

Land division grids still persist in the United States, in larger and larger scales, and with new construction technologies the land can be made to conform to it more than ever before. Because the grid design is used at so many different scales —globally, regionally, locally, and even at smaller scales like parking lots and tiled plazas— there is often a certain homogeneity to the look of things on vastly different scales. In the film *Koyaanisqatsi* (1983), extreme closeup shots of microchips are intercut with overhead satellite photos of cities at night, the colorful networks eerily resembling one another.

Within the land, there are further attempts at uniformity, as rows of identical highrises and places like Levittown can attest. Vertical space is also quantized, from the earliest terraced cultivation that turned a smooth slope into a series of steps, to the present day when even the airspace above buildings in downtown areas can be bought and sold. Most buildings are divided into numbered floors, and in urban residence towers, it is common for apartments to go up in price as they go up in floor.

In all of these cases, there is an increasing use of numbers as coordinates to locate a person within the grid of the city. Many U.S. cities have series of numbered streets or avenues (or both, like New York City), which are usually an index of a location's distance from City Hall or some natural boundary like a lake. Numbered streets also give some sense of the distance from one point to another; even if we don't know the city, we know that 9th Street is probably two miles away from 34th Street. On the streets themselves, there are house numbers, and even within a residence, an address will often have numbers to further specify a floor, suite, or apartment. As if that is not enough, there is the five-digit zip code, which in 1981 was expanded by an extra four digits tagged on after a hyphen, enabling automated equipment to sort mail down to a specific carrier, the person who makes the delivery.[19] Phone numbers likewise contain an area code, the prefix indicating a neighborhood area, and a country code if called internationally. Oddly enough, electronic mail addresses seem to be the only ones that occasionally get away with having all letters and no numbers in them.

The use of numbers for identification, location, and amount leads us into the areas of information and exchange value, two closely connected areas whose quantization has been slower than those of space and time, partly because what they measure is more abstracted from nature, more culturally variable, always in flux, and more difficult to standardize.

Value

What is value? It is not an inalienable or intrinsic property of matter, so how can it be quantified? Like space and time, the need to measure it exists only when there is a need to communicate it to someone else. Although value itself is always in flux, just as the values of currencies fluctuate, it is still quantized into numerically expressible amounts. The need to quantify value came about with trade and the need to insure that an equitable exchange had been made, since trade was an impetus for the development of mathematics itself. According to financial historian Ray B. Westerfield, the barter system, probably the first system of exchange, was inefficient;

> The dependence on chance coincidence makes barter an inadequate means of developing a market in which anyone can offer his goods with reasonable assurance of being able to trade for something else at least equal in utility to him. ... Occasionally he was forced, in order to make any trade at all, to accept some goods which he did not want for itself but which he knew someone else would be willing to accept in trade for something else he did want. A series of such three-party trades might well establish in each community the habit of looking on some particular goods as widely enough acceptable to act as a satisfactory medium for execution of any exchange. The money idea may also have taken root in a slightly different way. A particular goods may have become generally acceptable due to its basic value, not with the idea of receiving it and holding it between trades, but merely as a common denominator or standard against which to measure the value of both large (or intensely desired) things and small (or only slightly desired) things in working out the terms of a trade. . . . Traces of economic activity in the very earliest civilizations almost invariably show some commodity --cattle, grain, shells, trinkets and the like-- used as an exchange medium. With the passage of the centuries precious metals gained almost complete ascendancy over other commodities as a medium of exchange because they combined the attributes of portability, divisibility, durability, homogeneity, recognizability, and stability of value.[20]

Before value could be quantized, it had to be quantified, and precious metals had the attributes needed for a standard with consistency. Perhaps more than any other precious metal, gold has always been considered valuable, as far back at least as the ancient Egyptians and the Israelites of the Old Testament. Over time, most nations converted over to the gold standard, and in 1900, the United States passed the Currency Act, establishing gold as the currency standard. In *Capital*,

Karl Marx wrote of how one commodity (in this case, gold) becomes the socially-accepted *general equivalent* used to measure the value of all other commodities. The general equivalent, then, simplifies quality into a question of quantity; one bar of gold is as good as any other, as long as it contains the same *amount* of gold.

While measures of weight like the ancient system of shekels, minas, and talents (there were 60 shekels to a mina, and 60 minas to a talent; the shekel was 0.497 ounces or 14.1 grams) were used to regulate amount, a more practical means of quantizing value came around 770-670 BC, when the coin, as a regular and standardized amount of a precious metal, came into being.[21] Each coin was considered equal to every coin of its kind, and all were stamped by the government who vouched for them. All values encountered in trade were expressed in multiples of the coin of lowest denomination; these then, were the discrete levels at which value could appear. Currently in the United States, the smallest unit of value would be the penny, or one-cent piece (although prices at gas stations are still measured out to the mill, or one-tenth of a cent, and then rounded off).

Unlike the units of space and time, the value of any currency or metal standard varies with the economy it exists in. This variation was also aided by the further abstraction of value from gold to less precious metals and to paper money, which first appeared in China around the 9th century AD. The abstraction of money into a more easily reproducible form allowed for greater convenience in transactions and portability, greater control by the government, but also a greater threat of forgery. The changeover from gold to paper money was an abstraction which separated the monetary value from the material value of the currency itself, a shift also noted by Marx in *Capital* (he even indirectly addressed the problem of the coin as a quantized unit, noting that wear and tear gradually reduces the weight of the coin). This shift allowed for a greater variation in value, with the strange result that the monetary value of the currency could actually become *less* than the material value of the money. In Hungary of June 1946, during some of the worst inflation in history, the 1931 gold pengö was valued at 130 million trillion paper pengös, and in 1923 Germany, the German mark was quoted at four trillion to the dollar; for smaller denominations, neither currency could have been worth the paper it was printed on. The United States Government found itself with a similar problem around 1981, when it decided to use a zinc-copper alloy in the production of pennies instead using all copper, because the price of copper had risen to the point where the penny was worth more as copper than as currency.

The monetary system turned use value into exchange value; with it you *can* compare apples and oranges, or at least their exchange value. The kind of thinking that developed along with quantized value allowed for people to measure and compare someone's "net worth" and use aphorisms like "Time is money". The development of valuation expressed in numerical form became a shorthand for communicating worth, and while it was convenient for purposes of trade, it also promoted a more narrow definition of what "value" was, limiting it to societal norms, and turning whatever it touched into a commodity.

Following the shift to paper money, further abstraction occurred with the use of checks, money orders, and credit cards; these were issued by institutions outside of government, and safer and often more convenient to use than the actual currency backing it up (or supposedly backing it up). This paved the way for the next abstraction, which money is still undergoing; the shift from paper to electronic funds transfer systems. Although it has yet to become the dominant form of common everyday usage, government and business have been using it since 1965.

In his 1968 book *Money in the Computer Age*, F. P. Thomson points out that physical money is easily damaged, destroyed, lost or stolen, subject to counterfeiting, and expensive for governments to manufacture, distribute, keep track of, and eventually replace. The paperwork, administrative staff, security precautions, and other overhead involved in money transfers, as well as postage or other forms of delivery, add to the cost of every monetary transaction. According to Thomson, these transactions are also more cumbersome, more time-consuming and less efficient than electronic versions of funds transfer.[22] Of course, the conversion over to electronic systems is also costly, and is one of the reasons why the changeover is so gradual, and why government and business lead the way.

The replacement of physical forms of money is only one function of electronic money; a more important function is the creation of new forms of money or value on electronic systems, like *electronic daylight money*. These "intraday overdrafts" are electronic interest-free loans given out by the Federal Reserve, which are loaned out in the morning and must be paid back before the end of the day. The speeds at which electronic transactions occur allow huge numbers of transactions to occur in the few hours these loans are available, and hundreds of billions of dollars are lent out in this manner every business day.[23]

Other types of electronic money include bank-linked money flows and corporate barter flows. The bank-linked money flows are not deposit money, but their settlement is in deposit money or cash (credit, cash, or ATM transactions). Although performed electronically, there is still a link to bank deposits. Corporate barter forms, however, are sent electronically between corporations, or internally within a corporation and its various offices around the world. Such transactions are private, do not involve the Federal Reserve or the government, and are difficult even to track. Since they are often not even bank-linked, they abstract money further still.[24] This form of money is so abstracted that it is difficult to separate out from other data. According to Elinor Harris Solomon;

> The electronic money flows can be a part of broader kinds of confidential and proprietary corporate information all "bundled together." There is no way to unbundle the money-like information from that sent along within corporate message flows on a transponder portion of the satellite; and neither the Fed nor public would have any right to obtain the private information if such unraveling of data skeins were possible.
>
> Such money is continuous, not intermittent, and less predictable than daylight money in creation, timing and future scope. Unlike the daylight group we have little information on amount or flow. The size of flows is private information, published infrequently (say, once a year) and without any mandatory requirements or surveillance. The money exists as quite intangible information flows. Much of it moves on private satellite or nonbank links outside the banking system altogether.
>
> Yet messages transmitting such information-based "value" are used just like any other money in payment for goods and services. They can contribute to the volatility of financial asset prices. Such money "buys" financial assets at wholesale, futures, and options of financial assets and commodities; it hedges private traders and investors against risk, flows around the world on private wires currently built and in the process of construction and expansion.[25]

Ironically, in the digital age, we have come full circle and returned to a moneyless barter system. But this barter system has been abstracted far from nature; transactions occur at nearly the speed of light, trades need not refer to physical objects, strongboxes and vaults become data sets, and money becomes information.

Information

Unlike time or space, information is not a continuum that can easily be divided into units. The definition of "information" has changed over time, and it is only in the 20th century that it has become thought of as a precisely measurable entity that can be separated into discrete and indivisible units. In order for this to occur, there had to first be a way to express information numerically, so information (as we know it) made its first steps towards quantization with the development of quantitative thinking.

As counting became important, number systems developed, including the decimal system which has become the basis for almost all modern quantitative thinking. The base ten system, however, is only one possibility; the Yuki of California use cycles of eight, a sexagesimal system once existed in Babylonia and ancient Greece, a quadragesimal system in Latvia, and a vigesimal system in France.[26] And, of course, computers uses base two, or binary, for their operations.

Besides their role as data, numbers were also used to keep track of nonnumeric information. As printed information moved from the clay tablet to the papyrus roll, to the parchment codex and finally to the printed book, page numbers became increasingly important for the locating of printed matter (paragraph numbering had been tried, but was not successful). Certain documents, like the books of the Bible, go even farther and have numbered lines and verses because page numbering would not be consistent between translations. Page numbering, as the most convenient system, continues to be important for academic citing; and in the publishing business, page numbers have even become copyrightable and a source of profit and controversy.[27]

As pages were numbered in books, so collections of books were numbered in libraries. The library began as a record of land ownership, the decrees of kings, laws, genealogies, and religious writings, but in the Middle Ages the book and library came to be seen as valuable, along with the printing press that made many of them possible. For a library to be of use, there had to be a way of locating a desired text; thus indexing and cataloging alphabetically by subject and author began, though not without resistance.[28] Printed library catalogs which gave shelf numbers of books gave way to card catalogs when Melvil Dewey submitted his Dewey Decimal Classification system at Amherst in 1873; other systems like Charles Cutter's rival 35 base Expansive Classification system (using letters and numbers) existed before Dewey's, but Dewey's system won out in the United States. In 1903, the Library of Congress began its classification system, and many libraries subscribed. And now, in addition to call numbers, many libraries use bar coding numbers to keep track of their inventories.

As the number of libraries grew, so did the desire for an international standard of book-numbering, and in 1970 the International Standard Book Numbering (ISBN) system was started. This ten-digit number includes a group identifier indicating the national, language, geographic or other area where the book was published, a publisher prefix indicating a specific publisher, a title number, and a check digit. And since the late 1980s, libraries have used on-line catalog systems which

may one day be used to retrieve the texts of whole books. The computer, using an ASCII or Unicode number to represent every letter and punctuation symbol, seems the logical tool for library numbering.

Information and its quantization, however, was not limited to the library. Renaissance thinkers including Galileo, Descartes, Kepler, Huygens, Newton, and others contributed to a mathematicization of science, beginning with physics and astronomy, which became an attempt to mathematize all natural phenomenon. This dream continues today, in such projects as Benoit Mandlebrot's fractal geometry and the field of biomathematics. In the early 19th century, atomic numbers were devised and the periodic table of elements was created, and in the early 20th century, Bohr orbitals described the limited number of possible orbits available to electrons. Max Planck developed the notion of quanta, the indivisible and smallest possible units of energy (along with the supposedly smallest possible units of space and time, mentioned in the preceding sections). To many, it seemed that nature was already quantized, and science was finally able to study and measure its units; all matter and energy were divided into fundamental particles and forces. But the number of discovered and expected particles kept growing, and Heisenberg's Uncertainty Principle revealed the limits of measurability. Einstein's theories of relativity brought an end to notions of absolute space and time. More recent theories, like those of superstrings and Penrose twistors, have moved into dizzying mathematical abstraction. Although newer theories of contemporary physics are less bent on quantizing nature, they still are heavily mathematical and represent things purely numerically, and seem far removed from descriptions of everyday experience.

The success of the hard sciences in mathematizing their fields of study prompted the social sciences to do likewise. In the early 19th century, the English Utilitarians, under the leadership of philosopher Jeremy Bentham, began a series of commissions that collected social statistics regarding public life. These were complied into the Victorian Blue Books, which Karl Marx used to write his indictment of capitalism. Gradually politics came to rely more and more on statistic reports, and were largely reshaped by them.[29] And once politicians found uses for information collection, it was inevitable that the information age would get government support just as science had.

The success of science has largely been a force behind the quantization of everyday life in this century, and scientific method has been used to attempt to quantize and mathematize everything into numbers in a scientific study. The 1890 census was the first census to be tabulated by machine; Hollerith punch cards (discussed in the following chapter) made working with vast amounts of data and