One thing we'd hoped to do while having you in Siegen was to explore the possibility of including you in an edited volume *Becoming Digital.* Me, Sebastian, and Valerie are the editors. Our intent is to target MIT Press, which we have strong relationships with. The idea is to look in parallel both at the rigorous historically grounded working through of digitality as an analytical category building form the original analog vs. digital ways of measuring/reading that come out of computing in the 1940s and the loosely coupled history of digitality as an actors' category in which it has often come to mean either "something to do with computers" or "something you can't see," The question in each chapter is "What's digital about X?" where X is something like digital media, digital humanities, digital storage, digital communication, digital packets, digital objects, etc. Some will focus more on developing the original sense of digitality as an analytical category, while others will be thinking about the things that have more recently been called digital in other senses. But the tension between those two approaches to understanding digitality historically is fundamental to the project.

What's digital about digital standards?

Valérie Schafer, C^{2}DH, University of Luxembourg & Francesca Musiani, CIS, CNRS

Analysis of digital standards as complex agencies and socio-technical processes, which are also inherited sometimes from the analogue time, although they have to deal with new actors and challenges.

1- Digital standards in not just about computing

Several actors are involved, may they be media companies, telecommunications, lawyers, companies involved in digital content, etc. An evolving process of standardization (a little about history) from standards de jure to standards de facto, from ISO to W3C, from the study of standardisation to the study of governance in the academic field, etc.

2- Digital standards is not just about techniques

Strong socio-technical processes / Arenas, governance issues, agencies, controversies (as heuristic tools for understanding standardization processes), etc. Informal vs formal standardization (this part is based on precise case studies).

3- Digital standards is not just about digital

Discussion on the materialities of standards (in the shadows: a civilization of papers, travels, social networking, etc.); the heritages of previous standardization processes, inherited from analogue times, such as the role of ITU; very material consequences (closed standards, compatibility and interoperability of materials, gateways, etc.)

What's digital about digital heritage?

Valérie Schafer, C²DH, University of Luxembourg

Digital heritage is a vast term that includes digitised and born-digital heritage as well as computing heritage (hardware, software, devices, etc).

It is difficult to fit this wide-reaching tangible and intangible heritage into a neat box, since the related stakeholders, media, approaches and audiences are so varied; it is also a complex socio-technical process that requires an exploration of stakeholders, politics and audiences; there are multiple agencies and governance models, and different visions at stake among fan communities, institutions, countries, etc. How best to reconcile computing and digital heritage – the former often centred on hardware and the latter more on content? How to open up the "black boxes" of both? How to reveal uses? How can we link both with the process of digitalisation, of "becoming digital"? Can we identify and define a "heritage of digitalisation" as a new approach that would hold all these strands together?

1- Several types of digital heritage

Typology: digitised vs born-digital / hardware vs software; born-digital or "reborn digital"? When it comes to born-digital resources there is a multitude of sources that has been treated in varying ways, from emails to e-books and Web archives, newsgroups, software heritage, etc. There are also different legal frameworks. What is the relevance of these categories in terms of technical challenges (for example differentiating between digitised and born-digital, which contain analogies and differences that will be discussed)?; questions regarding mining tools and the notion of exhibition – for example exhibiting hardware, or retro-gaming and machines that still work with associated software, the issue of emulation, etc.) will also be addressed.

2- The materialities of digital heritage

in terms of collection, curation, access, dissemination, exhibition, etc. Related environmental costs?

3- Digital heritage and heritage of digitalisation

How to contextualise and show a process ("becoming digital") and uses (fans, general public, researchers, conservation practices, etc.)? Issues associated with co-shaping, the role of communities and stakeholders in heritagisation.

Historicizing Digitality

Thomas Haigh

(Material from the original Early Digital effort not used in the *Exploring the Early Digital* Springer book introduction).

Introduction (Will change depending on whether this is book introduction or a chapter)

People talk a lot about “digital” things these days. That’s true particularly in departments of humanities and social sciences in universities. The “digital humanities,” whatever they are, have been the most discussed, best funded, least unemployable new area of humanities scholarship of the current century. There are chairs in the study of “digital practices” and centers for research into “digital cultures.” Talk of the “digital society” is beginning to edge out the old new discourse of an “information society.”

Scholarly discourse can go in odd directions sometimes, but in this case it largely mirrors some much more broadly based and consequential changes. SAP, the software company around whose projects most large companies have rebuilt themselves, is selling a “digital transformation” to its customers as the next big thing. The recording industry is struggling to survive a transition to “digital formats.” Young people, who as always are assumed to have mentally adapted to new technology, are called “digital natives” in the popular press.

Like almost everything else to do with computer technology the digital discourse tells a story about the future. Specifically a ruptured future, in which technology has made the past irrelevant. It’s no accident that embrace of “the digital” has been accompanied with a crisis in the position of historical scholarship, within universities generally but particularly within fields such as media studies, communications, and library/information science where historical work was until recently seen as a core research area.

Our aim here is to tackle this assumption head on, by demonstrating that historical scholarship has unique value in understanding what the “digital” in digital practices, digital humanities, digital transformation, etc. actually means. To do this, we must make explicit and well-supported what is often left implicit or merely asserted. For example, I have a personal faith that my understanding of the technical history of computing in the 1940s. an area seen as esoteric even by self-identified historians of computing, has something important to offer any discussion of digital practices or transformations. Yet I have not, until now, made a concerted effort to explain what that something actually is.

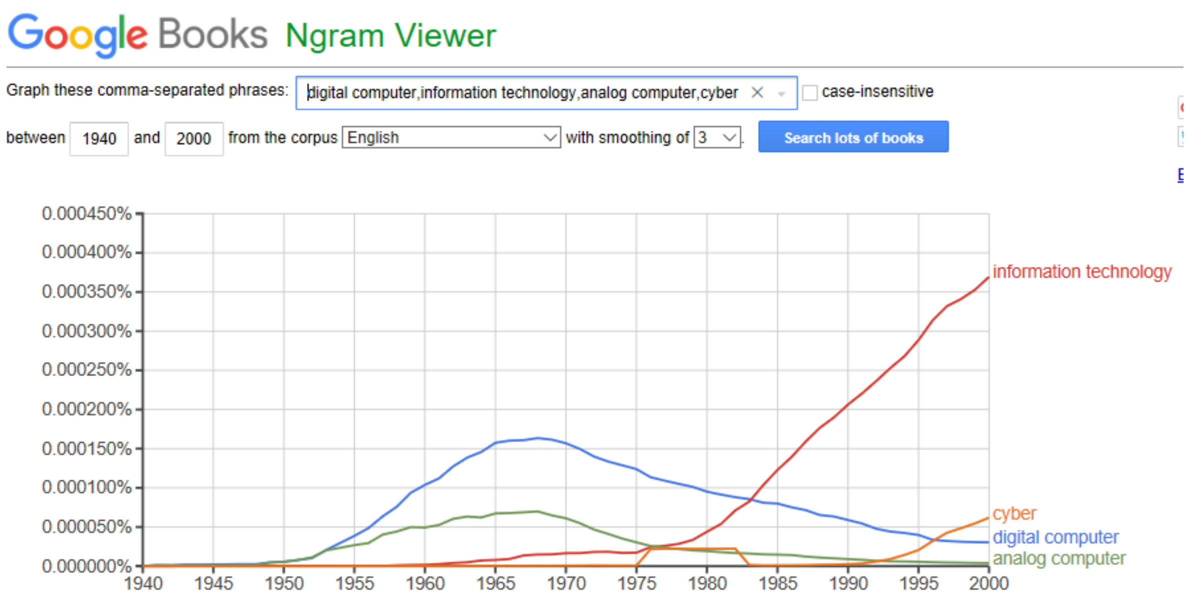
From “Digital Computer” to Digital Everything

The accepted antonym of digital is not “physical” but “analog.” As Ronald Kline has explained, this distinction arose during the 1940s, with the spread of automatic computers.[1] He locates it precisely in discussions between two pioneering creators of digital computers. Both kinds of machine could automate the solution of mathematical problems, whether at the desk, in the laboratory, or, as control equipment, in the field. The two kinds of computer represented the quantitates they worked on in fundamentally different ways. Digital machines represented each quantity as a series of digits. mechanisms automated the arithmetic operations carried out by humans, such as addition and multiplication, mechanizing the same arithmetic tricks used by humans such as carrying from less

[1] Cite chapter in the Springer book, and his broader work.

significant digits to more significant digits or multiplying by repeated addition. Within the limits imposed by their numerical capabilities the machines could be relied upon (when properly serviced, which as not a trivial task) to be accurate and to give reproducible results. Machines with more digits provided answers with more precision.

Analog computers represented quantities quite differently. Each quantity being manipulated was represented by a distinct part of the machine such as a shaft, a reservoir, or an electrical circuit. As the quantity represented grew or diminished the component representing it would change likewise. The shaft would spin more or less rapidly, the reservoir empty or fill, the voltage across the circuit rise or fall. Connections between these components were engineered to mimic those between the real world quantities being modelled. A wheel and disc linked one shaft's rotation to another's, a pipe dripped fluid from one reservoir to another, an amplifier tied together the currents flowing in two circuits. This explains the name "analog computer." An analogy captures the relationship between things in the world, defining a specific correspondence between each element of the analogy and something in the system being modelled. Analog computers work continuously, and each element does the same thing again and again.



By the 1970s digital computer technology was replacing analog technology in its remaining niches, as digital computers got cheaper, faster, and more robust. As a result, the qualified "digital" was usually dropped. "Information technology" rather than anything "digital" emerged as the most-frequently used description of the convergence of the technologies (and industries) of computing and communications.

As the Internet spread rapidly in the mid-1990s the word digital was rarely attached to it in popular discourse. Early discussion framed network-mediated interactions as happening "online" or in "cyberspace." The latter is itself a revival, via science fiction, of the 1950s vogue for cybernetics. "Cyber" has endured in a few specific areas, such as "cybersecurity" and "cyberinfrastructure" but coinages such as "cyberculture" once popular to describe features of network-mediated communities have faded in recent years. The technical term "virtual" was appropriated in the 1980s to describe computer-visualized spaces ("virtual reality") and, more indirectly, computer-mediated communities (“virtual communities”). The letter “e,” standing for electronic, was appended to things like mail, business, and government.

In recent usage digital is often taken to mean “immaterial.” When, for example, entertainment industry executives discuss the shift of consumers towards “digital formats” and away from physical disks their statements make sense only if one adopts some new definition of “digital” that excludes CDs and DVDs. That is a stretch, particularly as the D in DVD stands for Digital. Likewise the software giant SAP has been touting its new “digital native” platform, SAP Digital. This would suggest that the mainframes, client-server systems, and web platforms on which previous generations of enterprise software have been running since the 1970s were not digital. My linguistic inclinations are usually descriptive rather than proscriptive: the meanings of words evolve. Yet it is hard for me to see the false oppositions this usage creates as anything more than the flaunting of technological ignorance.

“digital” [illegible]

In other areas “digital” has taken on a broader meaning: not just things that are downloaded but anything to do with computers. This is the meaning of “digital” in the “digital humanities” and in various calls for digital media studies, digital STS, and the like.

All that is to say that there is something historically contingent, and perhaps arbitrary, about the recent of the word “digital” rather than “electronic,” “virtual,” “cyber,” or “information” to describe the agglomeration of computer-based technologies and applications that structure ever more of our human interactions. Standardization on those words in particular areas seems to be almost random, certainly path dependent and driven by the word choices of particular authors or the whims of granting agencies. As I’ve written elsewhere, Nicholas Negroponte’s book *Being Digital* seems to have something to do with the shift, and particularly with the misleading idea that digital information is immaterial. So does the rise of the “digital humanities.” But these is a lot more history, so far unstudied, to explain why digital edged out its rivals.

I’ve been somewhat critical of this usage, going so far as to write an article titled “We Have Never Been Digital.” Using “digital” as a more exciting synonym for “computerized” is not wrong, exactly, as modern computers really are digital. But little work carried out under the banner of the “digital humanities” follows through on the implicit promise of probing what difference digital representations or the digitality of digital computers really make to the new social practices that grow up around them.

Characteristics of Digital Representations

The earliest digital computers were literally digital: their input and output consisted of sequences of numbers. But there is nothing to stop a collection of digits from representing a letter, or vice versa (consider, for example, 11 and eleven). In fact many early digital computers performed their input and output via paper tape of the kind used with teletype machines, providing a simple way of turning computer output into text whether or not any of the computer’s internal operations distinguished between bit patterns representing numbers and bit patterns representing text.

In the sense in which we use “digital” now (but not in the sense in which it was used in the 1940s) text has always been digital. Let me stress that distinction: it’s a matter of historical record that nobody called text “digital” before the invention of the modern computer. Thinking of characters as well as numbers as “digital” reflects both the influence of Shannon and the reality of digital computers that used numbers to encode and process text. Seeing all text as digital is thus a backward projection of categories. Yet once the categories are established there seems no plausible reason to deny that the alphabet was, in the modern sense, always digital.

Text is certainly is not analog in the post-1940s sense– an alphabet provides a fixed set of characters rather than a continuous range in which one letter blends into another. So if we accept the interchangeability of letters and numbers, something that was common in code making long before the digital computer, then we might consider a book to be a digital storage medium. This yields three important observations.

The first is that being “digital” does not necessarily mean that a medium is machine-readable, nor that it cannot be read by humans. Both texts, which are digital in the metaphorical sense, and printed mathematical tables (which are digital in the most literal sense) can be read easily by humans and only with difficulty and specialized hardware by machines. What is, or is not, machine readable will in any event change with time. Punched cards were often printed with the characters they represented, so that they could be read both by humans and by machines. Your smartphone comes a camera and a host of apps for optical character recognition are just a click away, so a typical modern computer would find it easier to read the text than the holes. 1

The second point is that the digital is not immaterial. The idea that “the digital” is defined by its immateriality is both ridiculous and common, a combination that calls out for substantial historical and philosophical analysis. Langdon Winner’s classic *Autonomous Technology* might provide a model in this respect. Some important work in that direction has been done by Jean Francoise Blanchette in his paper “A Material History of Bits.”[2] Yet there is something special about the relationship of bits to their material representations: different material representations are, from a certain viewpoint, interchangeable. Digital information can be copied from one medium to another without any loss of data, and the same sequence of bits can be recovered from each. Transcribe the text of the book into a text file, save that file, compress it, email it, download it, and print it out. One has the same series of characters. Discussion of “digital formats,” vague as it often is, gestures towards the truth of this experience: digital content can be downloaded over a network and, if sufficient bandwidth is available, experienced the same was as it had been accessed from a local disk. 2

The third point is that these different material representations of the same text are only interchangeable from certain viewpoints, and for certain purposes. A book is not the same thing as a text file stored in memory, which is not the same thing as a compressed file on a hard disk. The printed text would differ materially depending on whether one used a dot matrix printer or a modern laser copier. Neither would replicate the original book. For one thing, any illustrations would be lost. One might, as some manuscript preservation program do, deal with this by making an extremely high resolution scan of the book rather than transcribing the text. That would produce an entirely different digital representation of the same object, and one that might serve the needs of different users. But even that would not substitute for the all the uses of the original. Lovers of archives like to tell the story of a researcher who traced the spread of plague by sniffing letters, to see which had been perfumed with vinegar before sending (vinegar having, allegedly, been believed to prevent the spread of the 3

[2] Jean-François Blanchette, "A Material History of Bits," *Journal of the American Society for Information Science and Technology* 62, no. 6 (2011).

disease).[3] More prosaically, the printout would be more suitable than the disk file suitable for lighting a fire with, or substituting in an emergency in for toilet paper.

The interchangeability of digital representations, and their seeming immateriality, stems in part from the discovery of coding schemes that exploit redundancy to afford the automatic detection and correction of errors. Richard Hamming, a mathematician working for Bell Laboratories, did important work to formalize and generalize these schemes. There is nothing magical about digital representations, though they provide some inherent protection against error. This is true for human readers – with only ten numbers (or twenty six letters) to choose from our brains are adept at mapping odd squiggles to the nearest valid symbol. Binary representations in electronic systems are rarely represented materially as "presence or absence" but as, for example in CMOS logic, one volt as 0 or five volts as 1. Small fluctuations are ignored – two volts is also read as 0. In analog representations these small errors compound each time a signal is reproduced – such as the hiss that accumulated each time an audio cassette tape was copied. But all digital representations are ultimately material, and so electronic memories can be corrupted by cosmic rays, paper tapes mangled, or magnetic disks worn out.

Digital media, unlike analog ones, can be structured to support reading mechanisms that automatically overcome these corruptions. For example, compact disks incorporated enough redundancy to overcome small errors and detect large ones. They are likely to copy either perfectly or not at all. Digital systems can also exploit the detection of errors to ask for garbled information to be retransmitted. Over a bad link your emails may download more slowly, as your network software tried again and again to retrieve good copies, but once copies of the messages are obtained they are likely to be pristine.

[NB: I am sure a lot of media studies people have written about the characteristics of digital media and I should cite some – suggestions on work to engage with are welcome. Benjamin on mechanical reproduction, of course, but hopefully something less clichéd. Also Matt Kirschenbaum's work in Mechanisms is particularly relevant, and I should look for a quote].

Digital reading practices support, but do not mandate, these mechanical reading devices. Likewise the mechanization of digital reading enables, but does not mandate, the conditional control mechanisms needed to implement algorithms for error correction and detection. One might see these as a three level pyramid, in which each level sits on the one before.

Sense 1: Digital as a Reading Practice

There is no such thing as a digital object. Neither is digital information something immaterial. Digital information is read from material objects, but any object can be read in many different ways. So to me, digitality refers not to a kind of object but to a way of reading. Given a book one can read the text or admire the cover. A particular reader, whether human or mechanical, may or may not be able to extract a particular coded message from a particular medium. Claude Shannon's information theory is, in this sense, foundational to our sense of "the digital" and to the modern sense of "information."[4] Shannon's theory is often invoked in media and communications work as a kind of rhetorical garnish to lend an air of scientific respectability.

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[3] This is attributed to Anthony Grafton, which seems reasonable but I should verify. -> Bill Turkel!

[4] Ronald Kline, "Cybernetics, Management Science, and Technology Policy: The Emergence of 'Information Technology' as a Keyword," *Technology and Culture* 47, no. 3 (2006).

Round about the 1940s the word “information” acquired some new meanings. Whereas it had previously been inseparable from a process in which someone was informed of something (for example by action of an information office), it now became what Geoffrey Nunberg memorably called an “inert substance” that could be stored, retrieved, or processed. “Information” became, among other things, a synonym for facts or data – and in particular for digitally encoded, machine readable data.[5] This processes gained steam with the spread of the idea of “management information systems” within corporate computing during the 1960s, followed by the widespread discussion of “information technology” from the 1970s and the introduction of the job title “chief information officer” for corporate computing managers in the 1980s. I suspect that the root of this ever closer identification of information with computers lies in the digital engineering practices used to build computers and other devices during the 1950s. For the first time, Shannon-esque digital exchange of information was taking place between devices within a machine – memory tanks, tape drives, printers, and processing units were constantly exchanging digital codes with each other. This the context in which it became natural to think of a process of information occurring without human involvement and, with a slight linguistic and conceptual slippage, to think of the data itself as “information” regardless of whether or not anyone was being informed of anything by it – a new sense of information that Michael Buckland dubbed “information as a thing.”[6]

Why call digitality a way of reading, rather than way of writing? You might suggest that this deliberate encoding is the defining characteristic of the digital. This is a reasonable claim, and fits Shannon’s canonical and historically influential description of digital communication as the transmission in a particular code of a message from a sender to a receiver. When digital communication works the digits received are the same as those sent. So the intent of the sender is crucial for many methods of digital reading.

Yet the idea that reading the digital involves determining the intent of a sender still seems problematic, not merely because of the difficulties in attributing meaning to intent. For example digital thermometers produce a series of coded values recording fluctuations in temperature. This is one of many applications of digital to analog conversion circuits, which reduce continuous quantities captured by instruments to digital data sequences. The digital encoding used is determined by the machinery, but the content of message comes from nature.

Nature holds at least one example of organically produced digital codes. Historians of science have written about the use of information theory by researchers investigating DNA in the 1950s. The very phrase “genetic code” makes assumptions tied to information theory and digital communication. Attempts were made, without much success, to use analysis of this kind to make predictions about how genetic information was stored and, once the role of DNA was clear, how base sequences coded for particular amino acids. Suddenly chemical sequences without a human author were being treated as a medium, holding a digital message. The title of Lilly Kay’s book *Who Wrote the Book of Life* captures her objection to this: researchers viewed themselves as reading a text but were in fact constructing one,

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[5] Geoffrey Nunberg, "Farewell to the Information Age," in *The Future of the Book* (Berkeley: University of California Press, 1997).
[6] Michael Buckland, "Information as Thing," *Journal of the American Society of Information Science* 42, no. 5 (1991)

bring ideas from information theory that hindered more than they helped.[7] The point is an interesting one, but subsequent developments in gene sequencing and manipulation suggest that the digital information perspective on the genome eventually became a source of leverage. The six billion nucleotides genome can be read and transcribed into a data file that fits comfortably inside a modern smartphone. While the connection between that data and human life is not fully understood it can nevertheless be searched for informational markers signaling traits and disease tendencies.[8] In this case there is a message without an author.

Sense 2: Digital Reading By Machines

So far I have spoken of digitally encoded sequences only as information. Messages can, of course, control as well as inform – an idea at the heart of cybernetics ("control and communication in the animal and machine" was the subtitle of Weiner's book). This idea is just as familiar to humanists and media scholars, given the prominence of approaches such as speech act theory, the postmodern insistence on culture as a means by which power is exercised, and a general emphasis on performativity.[9] Because digital encodings can be read reliably and precisely they are exceptionally well suited for control purposes.

In this broadest sense machines have been reading digitally for quite a while. Player pianos, jacquard looms, musical boxes, punched card machines, and similar mechanisms sensed and acted upon particular encodings. These were not, at the time, called "digital" but can plausibly be recognized as such in retrospect.

It does not make sense, in this context, to distinguish between mechanisms that read for information or read for control. In each case, the medium is read to control a mechanism. That is true whether the mechanism in question directs a loom, increments an accumulator, or transmits an encoding of the information just read.

The fundamental characteristic of digital control is that the machine being controlled carries out a series of distinct operations over time. A computer, or to use the vocabulary of the 1940s an automatic digital computer, is a device that performs a series of mathematical operations over time.

As an automatic computer begins work its instructions, in some medium or another, are present within it. Otherwise it could not shift automatically from each to its successor. As von Neumann put it, "These instructions must be given in some form which the device can sense." While he referred to this storage as involving "the use of some code" he applied the concept broadly, to include punched cards, paper tape, magnetic storage, photographic film, and wires arranged in a plug board. The modern computer, then, was first conceived with a full panoply of digital media usable for control purposes: optical, magnetic, wired, and physically sensed.

In fact, my work with Mark Priestley on the invention of the modern computer tells a story something like this: during the ENIAC project Presper Eckert invented delay line memory, a digitally readable and

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[7] Lily E Kay, *Who Wrote the Book of Life: A History of the Genetic Code* (Stanford: Stanford University Press, 2000), . I should also look at Evelyn Fox Keller's little book on the same topic.

[8] According to Wikipedia the cost of a "whole genome" sequence is down to about $1,500 as of 2015 – though this is not literally the entire genome. https://en.wikipedia.org/wiki/Whole_genome_sequencing

[9] Citations as needed…

writable medium in which a lot of numbers could be stored. The medium came first, and everything in the First Draft was a thinking through of the possibilities opened up by this new medium for architectures of automatic control. The modern computer is what happened when Eckert's memory met von Neumann's need for a computer that could model the explosions of hydrogen bombs.

Sense 3: Digital Conditional Control

I can see no plausible grounds to deny the applicability of the words "digital" and "computer" to a machine, like the Harvard Mark 1, which worked essentially like a mathematical player piano by reading one instruction at a time from a single tape and carrying out the encoded operation. exploiting the speed of an electronic machine like ENIAC meant finding a way to automate not just the processing of a particular sequence or loop but of intertwined sequences and nested loops. That meant coming up with a way of automating decision making: for example by doing one thing next if a certain variable is above zero, otherwise do a different thing.

The capability for conditional branching is often seen as the foundation of modern (i.e. digital) computing. In the terminology of computer science, a machine able to do that (and a few other things equally simple) is often called "Turing complete." I am usually reluctant to let theory drive historical categories, but in this case I do have to admit that there was something remarkably powerful about this little capability that underpins the power and flexibility of modern digital technology.

[Need to think this through more!]

Digital Platforms

From an abstract viewpoint, one frequently taken within computer science, the only thing a computer can do is to transform a digital input sequence into a digital output sequence.[10] The operations specified by the program, executed in the correct order and provided with sufficient temporary storage, determine the mapping of inputs to outputs. Theoretical computer scientists took from the work of Alan Turing an idea that all digital computers meeting a rather low bar are fundamentally interchangeable as anyone could, with sufficient time and storage, be programmed to mimic the functions of any other. In that, abstract, world hardware and software are largely interchangeable as any missing hardware capability more elaborate than addition and conditional branching, from a multiplication operation to a graphics coprocessor, could in theory be replaced with code.

This leads us to the concept of a "platform," central to the burgeoning field of "platform studies" and to much economic and technical analysis of digital phenomena. When we interact with modern digital systems we are dealing with specific applications. These programs, themselves hugely complicated machines, sit on top of many different layers of hardware and software: libraries, APIs, operating

[10] This temporality is also at the heart of "formal methods" in computer science. What programmers can see is the static text of a program, but what they care about is its behavior when executed – i.e. its dynamic behavior. One cannot fully understand the behavior of code without testing it (something captured most starkly in the famous proof that a program cannot determine whether a program will ever halt). However, there are many useful things that static analysis can reveal about the behavior of code over time.

systems, network stacks, virtual machines, and microcode. The platform of a particular application consists of the resources it needs to operate, but those platforms sit atop other platforms in the manner of the famous conception of the world balancing on a stack of turtles. The layering of technologies shields each level of the stack from the specifics of the other levels – for example the application programmer does not need to write different code depending on whether her program is working over a cellular or wired data connection. This modularity is facilitated only by the distinctive digital capabilities discussed above: the interchangeability of different digital representations and the automation of digital control in which data and instructions can be treated interchangeably.[11]

Digital Practices and Cultures

The concepts of "digital practices" and "digital cultures" have recently become popular in academic settings, particular to describe artistic training, ethnographic studies, and media theory. The validity of such categories rests on the assumption that there are parallels in the changes that occur in different communities when practices and cultures are remade around digital technologies. Digital practices have spread lab by lab, community by community, and application by application. The fundamental technology of digital computers and networks takes many different shapes and supports many different kinds of practice. One cannot pretend, for example, that the changes in practice and culture that occurred with the adoption of digital simulation techniques at Los Alamos around 1948 are exactly the same that occurred with the adoption of digital exercise logging technology over the last decade.

The stacking of platforms accounts for the difficulties we face in trying to analyze computer applications using the same tools that historians of technology and science studies scholars have applied to other technologies. For example, Donald Mackenzie famously supported his call to "open the black box" of technology by tying specific details inside nuclear missile guidance systems to strategic shifts in American nuclear doctrines. Such arguments are harder to mount across the stack of technologies found in modern computer systems. When studying social interaction on Facebook the specific of the firm's algorithms are unmistakably relevant, but there is only a lose coupling between underlying network technologies, web protocols, or processor instruction sets and the kinds of behavior that occur in the online communities that these technologies make possible. Any attempt to mimic Mackenzie's work by explaining the functioning of Twitter with reference to details of the Intel instruction set would be less than convincing.[12]

Yet we should not therefore assume that the digitality of "the digital" is found only in the lower levels of these stacks of platforms, with the processors and memory chips, and that understanding what is happening down there is only indirectly useful in understanding the kinds of affordances that shape user behaviors and experiences. In fact the very existence of an automated stack of platforms is a hallmark of the combination of digital media and automated digital control that has defined modern computing since the 1940s. Thinking this through offers a historical route to understand what is truly digital about these phenomena.

(!)

Digital control automates sequences of operations. Like other forms of automation, this has profound effects on the organization of the work being automated, the task as experienced by humans working

[11] This paragraph is a little shaky.

[12] Looking at the algorithm studies literature should help make this more pointed – the argument to develop is that algorithms matter, but can't be considered in isolation from the materiality and technologies than embody them.

with the machine, and the skills they need. The earliest computer programs were specific to particular machines, as each computer was unique. So code typically functioned only within the organization in which it was produced. By the 1950s, however, IBM and other companies were selling standard computer models. This meant that code could be packaged and distributed digitally from one site to another. I have argued elsewhere that the concept of a “package” predated discussion of “software” and originated within the SHARE IBM user group specifically to describe the bundling of code with the documentation, standard configurations, and reproducible packages needed to facilitate its journey from one site of operations to another.[13]

The question is whether there are any fundamental characteristics of digital technologies that create meaningful parallels between all these local transformations, or at least common analytical tools with which to understand the range of digital practices and cultures that develop though them. Our challenge is to develop insights of the kind I have gestured to here, about the characteristics of digital representations and the capabilities of digital control, sufficiently to provide a basis for understanding what is truly “digital” about different digital practices and cultures and what is merely contingent and local.

Conclusions

[Keep old conclusions for previous paper – have some new ones].

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