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Information and Cyberspace:

Re-embodying Information Theory

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Introduction

This article is written from the perspective of a second-order cybernetician. It proposes a concept of information that puts Shannon's mathematically abstract definition (Shannon & Weaver, 1949) back into human terms and relates it to current information technology. To appreciate this proposal, the article develops a notion of cyberspace and of the technological artifacts that populate it. Cyberspace is an important expansion of the human world and deserves scholarly attention. The notion of information, here proposed, is of a dual description, relating human action to available technology, broadly conceived. The article concludes with an analysis of the most common metaphors of information and what they individually entail for conceiving information.

Second-order Cybernetics and Embodiment

Second-order cybernetics started with a suggestion by Margaret Mead (1968:2) that cyberneticians enter the cybernetics of their concerns as participants. Subsequently, Heinz von Foerster defined "second-order cybernetics (a)s the cybernetics of cybernetics or the control of control and the communication of communication" (1974). This definition does not specify a meta-level of abstraction. It involves second-order cyberneticians in a recursion that first-order cyberneticians had ignored by developing cybernetics as if they had nothing to do with it: First-order cybernetics is the cybernetics of observed systems; Second-order cybernetics is the cybernetics of participation in systems under construction by their participants. First-order cyberneticians theorized their world from a position outside of it; Second-order cyberneticians see their world as part of it. Accounts for participation start by acknowledging one's cultural history of becoming human, one's living in cultural bodies, that is, bodies that have developed capabilities in coordination with others on which to rely whether by engaging in conversation of abstract issues or in embodied social practices.

By definition, embodied phenomena cannot exist without a body present. Saying "I" is an embodied phenomenon. It needs a body to speak. The "I" does not say all there is to know about its speaker, so its bodily presence constitutes the remainder. "The observer," by contrast, is an abstraction. It has no body. One can attribute anything to it, without expecting any response. Computer programs are disembodied (save for the medium in which they are written) until they enter a computer and determine what the computer does. The computer can break down, the program cannot. First-order cybernetics, by ignoring the materiality from which its theories derived, privileged disembodied accounts, assumed compliance, and blamed the system for its failure to work as designed, for example, by saying "it" broke down or crashed. Hence, another way of distinguishing embodied from disembodied phenomena is to say that the former may disobey its description, the latter cannot.

Gregory Bateson (1972) introduced a distinction that is useful here between *Creatura* and *Pleroma*. Creatura is the world attended to in language and action. It is created by drawing distinctions for the convenience of living. Even physicists who claim to study nature the way it is, cannot help but introducing distinctions that create differences, which they then seek to explain. Natural scientists theorize nature to be explained and make sense. By contrast, Pleroma is the unknown, incomprehensible, always present matter or ground that Bateson described as "the world in which events are caused by forces and impacts and in which there are no 'distinctions'" (1972:450). This is a world that escapes human understanding. The history of science may well be a history of making inroads into Pleroma, creating conceptions of previously unknown phenomena, but Pleroma cannot be exhausted. It is always there.

Thus, while disembodied phenomena may well be completely describable in language, embodied phenomena are not. It is embodiment that gives rise to concepts of noise, perturbations, breakdowns, and equipment failures. What breaks down, however, is not the equipment but it's user's conception of it. Perturbations arise in the absence of appropriate ways to describe the phenomenon of interest, just as unreliability in data making (Krippendorff, 2004:211-256) entails the admission that data do not represent the world as expected by a researcher.

Disembodied Uses of Information Theory

Shannon's *Mathematical Theory of Communication* (Shannon & Weaver, 1949) is a mathematical theory and disembodied as such – save for the book in which it is published. Applied to human communication, it provides two measures of the degree to which the phenomenon of communication disobeys the theory: Noise and equivocation. Noise is a measure of the unexpected variation in a channel of communication, and equivocation as a measure of the equally unexpected simplification. What it cannot recognize are other forms of disobedience, especially from the human senders and receivers supposedly communicating through this channel. For example, authors may resist being theorized as relay stations. Their agency is denied when described in mechanistic terms. Their ideas about those they communicate with have no place in it. And readers may interpret texts in ways not intended by their authors and not imagined by the information theorist. They could be making distinctions other than those that Shannon's theory can relate to senders. Human communicators tend to live in conceptual worlds that the descriptive apparatus of the theory cannot capture. Figure 1 is intended to show these "disobediences." When reading applications of Shannon's measures to human communication, one can hardly avoid noticing the concomitant privileging of its mathematics over obvious human experiences and the increasing reliance on disembodied measures of information. Interestingly, Shannon himself resisted the temptation of calling his theory information theory. He had sensed that there was more to information where humans are involved and, after consulting with John von Neumann, ended up calling his measures entropies. Equating mathematics with objectivity, without permitting those theorized to be heard, is something that second-order cybernetics would discourage on epistemological and ethical grounds.

Figure 1

Kinds of Embodiments

Bateson's (1972) distinction between two worlds, between Creatura, the world that is constructed and knowable, and Pleroma, the world that escapes conceptions but makes itself known by being unpredictably disobedient, can now be crossed with a second and more conventional distinction, the distinction between *inanimate objects* and *living beings*. Inanimate objects can be described in computational or causal terms and realized in mechanisms. They may be modeled by mathematical structures, for example, be built from parts, and set in motion. Living beings, by contrast, cannot be so explained. They are organizationally closed (autopoietic) systems, arise in a history of interaction with their environment, and create the possibilities for their own understanding. They cannot be built to function, although it is not inconceivable to bring mechanisms into being that can develop organizational forms that their designer had not envisioned – but this still is science fiction.

Figure 2 presents the resulting fourfold table. One might not want to confuse these distinctions when conceptualizing information.

Figure 2

The Core of Shannon's Theory

Shannon's mathematical theory is essentially a calculus of diversities (called "entropies" and its measures are labeled H). His second theorem (1949:19) proved that the logarithm function was the only function that preserved the intuition of the additivity of the combinatorial capacities of separate communication channels, for example, that two CDs can store twice as much as one. The choice of the base of 2 for this logarithm is merely convenient. Binary logarithms can be interpreted as the number of distinctions between two sets of things. There is more to this theorem but not needed here. In their non-probabilistic versions, Shannon's entropies count not numbers of occurrences but the logarithm_2 of such numbers.

Shannon's theorems do not predict observable events, as scientific theories are meant to do; for example, a theory of billiard balls bouncing off each other, or a theory of how attitudes change as a function of certain events. In scientific theories, mathematics is subordinate to the observations they claim to explain. In contrast, Shannon's theorems spell out constraints between entropies as measured, what "cannot" be done, leaving room for what "may" be done. If a CD has a certain capacity, one may store less on it but not more. If a communication channel is subject to perturbations or noise, one may be able to restore the distorted transmissions with the help of an additional correction channel of a capacity equal to or larger than the amount of noise encountered (Shannon's tenth theorem). These properties of Shannon's theory are well known. But they do not justify calling any of his entropies measures of information. This will become clear in the following.

Space and Information Society

Space is the product of human activity and is experienced as the ability to move, to act, to create, and to distinguish. So conceived, space does not exist without participation in the world, without recognizing possibilities, acting on them, and in turn being confirmed or not. Space is far from being subjective. It resides in Creatura but not without Pleroma. One may conceive of possibilities to act but in selecting actions to which Pleroma objects, one experiences limits or constraints. For example, in moving through a space, objects encountered along the way make themselves known by literally "objecting" or being in the way of one's path. This seems to be the etymologically most plausible interpretation of the often-carelessly used word "objectivity." Thus, space is an embodied concept. It is the experience of ability, which when acted upon, keeps that experience in touch with Pleroma.

Humans experience numerous spaces, physical spaces in which to move with their body, mental spaces in which to imagine and move conceptually, conversational spaces in which to coordinate conceptions with others and negotiate joint actions, and social spaces in which to move through stages, positions, advance within organizational hierarchies, and make commitments to people.

There is also cyberspace, a much used but sometimes rather nebulous concept, introduced into the literature by the science fiction writer William Gibson (1984) as "A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts… A graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receeding …"

Poetry aside, cyberspace acknowledges the possibility of technologically mediated conversations, entertainment, access to web sites of unknown location, or coordination of actions among very many people that may have never met.

Notwithstanding the recent origin of the word, cyberspace arguably originated when early humans found sticks and stones to be separable from where they were found in their environment, movable to different locations, and shapeable for different uses, as tools, for example, or to build shelters against unwanted intruders. These probably were the first artifacts. The path from that early beginning to contemporary technology took several millennia of development. I contend that *what has changed during this remarkable history is not so much an increase in the amount of information, as suggested by the currently fashionable concept of an information society, but an increase in the ability to make more and finer distinctions and independently address, manipulate, and reassemble what was distinguished more freely than ever before, an increase in the size of cyberspace*. Cyberspace is a truly outstanding phenomenon in need of attention.

Although cyberspace, so conceived, is tied to technology, what matters is less the physicality employed – using electronic signals for communication rather than sound, transmitting text rather than transporting matter, having global organizational forms rather than local ones – but the sheer number of independently manipulable elements available to do something with. The shift from rearranging stones to nanotechnology, the ability to rearrange molecules, build microchips, digitize images and manipulate pixels one-by-one, has dramatically increased the number of combinatorially possible artifacts to build and explore. The human ability to distinguish, construct, play, and communicate with these artifacts constitutes cyberspace.

The Size of Cyberspace

What is the size of cyberspace? In the writing of futurists, it has no limit and putting a number to its size seems preposterous. Given the rapid growth of technology, such a question cannot have no precise answer either. But one can say something of its order of magnitude.

A suitably embodied unit of cyberspace is the smallest individually distinguishable, addressable, and manipulable element. This unit results from what a human actor can do, not what is. Obviously, the size of this unit has changed drastically. Digitalization has taken hold of image processing no more than 20 years ago. The first telephone call was made in 1876. Gutenberg's method of typesetting started in the 15th century. Archaic scripts have been known since a little less than 3000 years.

With the decrease in the size of the smallest rearrangeable units came the exponential increase of their combinatorial possibilities, of the size of cyberspace. Naturally, the size of a cyberspace can be estimated only very roughly. The calculations offered here are intended to err by exaggeration. I will start with the present cyberspace. Observe:

- A bit is a binary digit. It can represent one of two alternative states and amounts to changing a 0 to a 1, a black into a white pixel, or making a left or right turn.
- A byte is a basic unit of computing, an 8-bit sequence that can take any one of $2^8=256$ numbers or ASCII characters.
- A gigabyte computer can store 10^9 bytes, or $10^9 \cdot 8$ bits, which is about 10^{10} bits.
- One billion (10^9) gigabyte computer users on earth could collectively handle up to $10^9 \cdot 10^{10} = 10^{19}$ bits.
- Considering speed, say 1 GHz/sec., and 33 years = one generation of productive human lifespan (1 year = $\pi \cdot 10^7$ sec.), 90% of the time spent for life support (not on a computer), the size of the size of the current cyberspace during this period is about $10^{19} \cdot 10^9 \cdot 33 \cdot \pi \cdot 10^7 \cdot 10\%$ or about:
  10^{36} bits
  10^{36} bits is big, very big: 2 to the power of a 1 followed by 36 zeros.
  About 100 years ago, the smallest individually recombinable units were the letters of the alphabet.
- 27 characters of the alphabet plus punctuation marks amount to 5 bits (32=5bits).
- Suppose at that time there were 10,000 dailies published containing about 10^5 characters each or 10^9 characters per day. Suppose further that as many characters were printed in the form of books. This would amount to $2 \cdot 10^9$ characters printed and read daily.
- Over a period of 33 years, this would amount to $5 \cdot 2 \cdot 10^9 \cdot 33 \cdot \pi \cdot 10^2 = 10^{13}$ bits. Granted about 10 times as much to run the industry and the construction of buildings, 100 years ago, the size of the cyberspace may have been something like:
  10^{14} bits

One thousand years ago, only relatively few people could read and write. The smallest individually distinguishable and independently manipulable unit was the handwritten character. Not that there were other creative activities, like mechanical inventions, but most of these inventions ended up described in books on mechanics and hydraulics, for example. Writing characters was easier than building what they described. The monks who did much of the writing during medieval times mostly copied established texts. Libraries were known for two millennia. But few people could actually use them.

- Reputedly, the largest library of ancient times was the Royal Library of Alexandria. Estimates of the number of books and scrolls it housed vary between 40,000 and 700,000. The documents it kept most likely were small is size, probably not exceeding 10^4 characters in length.
- Although the Library of Alexandria was probably unique, representing half a millennium of writing, to be generous, suppose there were as much as 10 times as many volumes distributed all over the world – think about China that had a long history of writing. (Interestingly, her books were also lost to fire but for different reasons).
- During a 33-year time period, there may have been $33/500 \cdot 10 \cdot (4 \cdot 10^4 \sim 7 \cdot 10^5) \cdot 10^4 \cdot 5$ or between $3 \cdot 10^8$ and $6 \cdot 10^9$ bits published in 10 centers around the world. This would add to:

10^{10} bits.

5000 years ago, when Ancient Egypt wrote pictograms, the number of characters written on monuments, in tombs and on papyrus during a 33-year period were probably small. But there were other notable technological accomplishments: construction.

- The great Cheops pyramid had $2.3\cdot10^6$ stones and took 20 years to build.
- Suppose there were 25 such projects going on at that time worldwide. This brings the size of cyberspace at about 3000 BCE to $33/20\cdot2.3\cdot10^6\cdot25$ or about:

  10^8 bits

12,000 years ago, towards the end of the hunting and gathering period and before the beginning of agriculture, the smallest units that were moved, shaped, and used were small hand tools. The size of the human population is estimated to have been in the 10^6 only a small fraction of which made tools and those who could probably produced not that many during their life time. The size of their cyberspace most likely was less than 10^8 bits.

True, these estimates are rough, very rough. But they merely serve to show the hyper-geometric growth of the number of individually addressable, manipulable, and recombinable units available in the world. Over the last 100 years, cyberspace grew by a factor of $10^{36-14} = 10^{22}$, in the 1900 years before that it grew by a factor of $10^{14-10} = 10^4$, and the 3000 years before CE by a factor of $10^{10-8} = 10^2$.

These numbers should not be confused with any count of the number of particles in the universe. The idea of explaining everything in terms of its particles was introduced by the Greek philosopher, Democritus (470-370 BCE), who saw the physical universe as an arrangement and movement of “atoms,” conceptualized as kernels of pure indistinguishable matter. Democritus did not believe humans had agency, entertained a mechanical conception of individual beings and therefore did not conceive of the possibility that people could create artifacts by assembling his atoms. It speaks for a small cyberspace in Ancient Greece that the making of things, buildings, for example, and crafts, was secondary in importance to understanding how things are. Mechanical notions of human beings have not died. Contemporary quantum physicists are not designers either.

Human Access to Cyberspace

10^{36} bits for the size of the current cyberspace is a computed size. It expresses the possibilities open in contemporary technology to the human population collectively. These possibilities are (mass) produced in fact, measurable indeed, and hence very real. Despite claims that Shannon’s quantities have little to say about everyday life, they currently are everywhere. Whenever one buys a computer, one pays for the size of memory in bytes and speed. When one considers installing a program, one must be weary of how much valuable space it consumes. When one attaches images of Kilobyte size to an email, one needs to be concerned with how long it takes to send. Bits or bytes are measures of alternatives that can translate into human actions, allowing one to move in, participate, and observe the wonders of cyberspace.

Typing is probably still the fastest interface with a computer, faster than clicking a mouse, changing a particular pixel, or dialing a telephone number.

- A very good typist can write about one word/second
- This paper averages 5.5 characters per word. With each character amounting to 5 bits, a word measures about 28 bits.
- 33 years of typing, 10% of the time, amounts to $33\cdot\pi\cdot10^7\cdot10^{-1}\cdot28 = 3\cdot10^9$ bits per individual over a lifetime
- With one billion (10^9) computer users, this amounts to 10^{19} bits for everyone.

10^{19} bits is a miniscule fraction of 10^{36}, which means that nobody can dream of being able to explore all of cyberspace during a lifetime, not even most of it.

As reading is faster than typing and seeing complex visual pattern far easier than creating them from pixels (Reed & Durlach, 1998), entering cyberspace will influence the collectivity of its participants more than they may ever know as measured by what they can do about it. Cyberspace clearly exceeds any one individual's understanding. Individual comprehension must be accomplished by the 10^{13} to 10^{15} synapses of the human brain, most of which are occupied with keeping the human body viable. Experiments have suggested that human comprehension is about two bits per second or 10^{9} bits over a lifetime, which confirms the order of magnitude of the above estimate. Clearly, what individuals face is not even imaginable. This is why theories of cyberspace are unavailable and probably never will be satisfactory. Instead, people rely on conceptual shortcuts, such as the concept of an "information society," which is not particularly detailed, but reflect a sense of the enormity of it.

The numerical sizes of cyberspace assume that the smallest addressable and manipulable units are independent of each other – much like the building of pyramids in Egypt was independent of what happened in China, or to a lesser extent, what a local newspaper in Estonia publishes has little impact on the life of Amazon Indians. In practice, this is no longer quite so. All artifacts in cyberspace connect otherwise independent units and thereby reduce the number of possibilities still available for action. Artifacts create what Bateson (1979) described as "patterns that connect," communication networks being merely one such pattern, and they constrain what else can be done.

Human Access to Cyberspace

I will now identify five artifacts that populate contemporary cyberspace. Each creates characteristic patterns that connect otherwise independently addressable elements in cyberspace. Each has occupies spaces in somewhat different ways.

Data, texts, images, computer programs, and contexts for these. These seemingly unlike artifacts have in common that pattern are simultaneous. A digitized image consists of a certain number of pixels that are independently alterable in principle, given suitable software, but when saved, all neighborhood relations among its pixels are preserved or fixed – regardless of what the image represents. A meaningful image occupies as much space as a meaningless one. The same can be said about texts and sets of data. Without the ability or intent to alter an image, it exhausts:

$$\begin{aligned} H_i(\text{Data}) &= \text{number of binary digits needed to store the } i^{th} \text{ set of data} \\ &= \log_2(\text{Number of possible data with the same number of units as the } i^{th} \text{ text}) \end{aligned}$$

and thereafter functions as one aggregate unit. Collections of data or images and sequences of texts are simply additive:

$$H(\text{All data}) = \Sigma_i\, H_i(\text{Date}) \text{ bits}$$

Computational advantage may be taken from the knowledge of the grammars that render certain combinations of characters illegitimate and non-occurring; of repetitions that make, say, parts of an image redundant; of inefficient computer programs that could be shortened. But without that knowledge and especially when adherence to rules is not strict, for example, when spelling errors and ungrammatical constructions may occur, any one set of data – text, image, computer program, and context – occupies the same space as any one of the set of possible data of the same size.

Copies, duplicates, reproductions. Each copy consumes the same space as its original and the total is a function of the number of duplicates entered into cyberspace. If the original consumes $H_i(\text{Image})$ bits, **N** copies consume:

$$H(\text{All copies of one}) = \mathbf{N} \cdot H(\text{Original}) \text{ bits}$$

Copies probably are most common in cyberspace: computer programs bought of the shelves are mass-produced, and so are books, video recordings, downloadable music, and operating systems. In a way, copying is the most unintelligent use of cyberspace. It creates conformity, but also preserves what has proven valuable to many. Mass communication is a gigantic copying machine, but lucky for the remaining cyberspace size, the patterns it reproduces tend not to be short lived.

Connections, communication networks, hypertexts, references, and citations. These pertain to pattern over time, geographical distances, and different texts, in any case, across several variables or nodes. Hardwiring a network of devices exhausts the space one would have available when each device would work independent of each other. Quantitatively:

$$H(\text{Connections}) = T(A{:}B{:} \ldots Z) = H(A) + H(B) + \ldots + H(Z) - H(AB\ldots Z) \text{ bits}$$

Where A, B, …, Z are the nodes of the network, H(A) is the entropy in node A, independent of any other, and H(AB…Z) is the entropy of the connected nodes (Ashby, 1969). When a telephone connection is established, two telephones are coupled during that connection and what is said on one end is heard on the other. That telephone connection occupies T(A:B) bits while it is ongoing. Entering time or any one-way connection, such as references to literature, say, from A at time t to B at time $t+\Delta$ adds two already mentioned quantities to the above (Garner, 1962; Krippendorff, 1986; McGill, 1954; Shannon & Weaver, 1949), see Figure 1:

$$H(\text{A transmission}) = T(A_t{:}B_{t+\Delta}) = H(A_t) + H(B_{t+\Delta}) - H(A_t, B_{t+\Delta})$$

$$H(\text{Equivocation}) = H_{Bt+\Delta}(A_t) = H(A_t, B_{t+\Delta}) - H(B_{t+\Delta})$$

$$H(\text{Noise}) = H_{At}(B_{t+\Delta}) = H(A_t, B_{t+\Delta}) - H(A_t)$$

One-to-many communication, which relies on a network that reproduces the same arrangement of characters or pixels as many times as there are readers of mass produced books or listeners of the same entertainment, exhausts $(m+1)\cdot H(\text{Messages})$, where m is the number of readers of the same message. Half a century ago, when the mass media could attract national audiences, this was the quickest way to reduce the then available cyberspace. Totalitarian regimes maintained themselves by flooding their cyberspaces with identical messages, leaving their citizens only insignificant choices. With the expansion of cyberspace to interactive media, the telephone network, the World Wide Web, mass media can no longer exhaust the expanding cyberspace, ushering in a different form of citizenship.

Algorithms are mathematical functions embodied in a computer. Computation is a deterministic process that runs through a sequence of steps as specified by a computer program. Computations are applied to data, images, or character strings, produce transformations of them (results), requiring additional spaces for both, and take time. There are no obvious relationships between the size that algorithms occupy and the size of the data to which they apply – except that since the advent of personal computing, computer programs have become larger, more powerful, and require ever increasing memory spaces to be run.

For this discussion, algorithms are of three kinds.

(1) **Computer algorithms** that serve the computational tasks within individual workstations, analytical engines, SPSS statistical package, housekeeping aids, and virus protection software.

(2) **Network algorithms** that search the Internet for web sites, following hypertext links, route telephone connections.

(3) Human-computer and human-network **Interfaces** (interactions) that mediate between users and the algorithms accessible in individual workstations, screens, keyboards, mice, voice recognition devices.

Interfaces enable users to select among algorithms in cyberspace, sometimes with the click of a mouse, or by entering a string of characters. The ability to select among programs that perform complex functions, as opposed to change characters or pixels probably is the most remarkable feature of cyberspace. It amounts to the ability of users to *delegate* routine and repetitive work to artifacts in cyberspace and accomplish a great deal with relatively few decisions. Ashby (1956b) called such artifacts “intelligence amplifiers,” mechanisms that are capable of running through alternatives that exceed human abilities in speed or number. To serve as intelligence amplifiers, these algorithms must respond to users’ actions.

Interfaces that enable selections among network algorithms provide users with the frequently described feeling of traveling through cyberspace, roaming through texts along hypertext connections, moving from one web site to another along links. The selection of algorithm provides a sense of being in charge even if it means getting lost in cyberspace by new adventures.

Autonomous systems are temporarily closed to organization. Systems of this kind probably are the most useful but also the most dangerous artifacts in cyberspace as they largely exceed comprehension by innocent users whose life is affected by them. These systems are temporarily closed to organization in the sense that once their operation is established, they do what they are designed to do, with users having varying degrees of influence over how the system works. The word “agents” have been applied to them, but it is not always clear who is in command, the system, its designer, or its human user. Now, four kinds will be distinguished:

(1) **Control systems** essentially are homeostats (Ashby, 1956a), designed to keep certain variables in relation to each other. Examples are automatic pilots, industrial production robots, inventory control systems, ignition controls in automobiles, and scheduling systems, for instance, of assembly lines. Control systems sense and act without human involvement – except for installing and terminating them. The operation of complex control systems is easier initiated than stopped, however, because many people and technical variables tend to rely on them for balance, and switching them off can create havoc that those involved resist. One may not notice control systems until they break down, like the network of controls for the power grid in the United States. In 2003, it broke down in a chain reaction and caused the biggest blackout in the history of the United States, with researchers scrambling for years to understand what went wrong.

(2) **Advising systems** do not act on their own. They can become closed, however, when coupled to the actions of their users, their advisees. The 1987 stock market crash was caused in part by several individually sensible algorithms for suggesting when to buy and when to sell stocks. Without fully understanding the dynamics of the stock market or the algorithms they relied on, traders blindly followed the systems’ advice. Since these systems did not interact and their advice allowed traders no time for thinking about global effects, they brought the stock market to a cliff where it crashed. The deployment of the minuteman missiles in the United States antimissile defense system is a largely automated system, but it requires human decisions somewhere in the chain before a counterattack can be launched. In the area of consumer monitoring, advising systems have become increasingly sophisticated and intrusive to consumers. There are seemingly innocent systems that issue coupons, and flash advertisements depending on what they bought. Others develop consumer profiles of the users of credit cards to advise marketing departments. There is also so-called spywhere, computer programs that invade a personal computer and report back to their owner what the user does, types, or looks at. These are particularly insidious system as they offer advise about people who are unaware of being observed while in cyberspace.

(3) **Community support systems** are open networks that become autonomous only on account of their users’ decisions to include or exclude members, topics, languages, and interaction styles. Their technology provides enough possibilities for participants to identify themselves as they wish and contribute to their proceedings, including codetermining the closure properties of the community. Multiuser discussion groups (MUDs), Usenet News Groups, and various lists for discussing scientific issues, new age psychology, and artistic matter have sprung up on the Internet and maintain themselves

as relatively stable virtual communities that control their own boundary and internal organization. Usenet users often spent much of their time participating in one or more groups and for many this is what cyberspace is all about.

(4) **Self-replicating (destructive) algorithms** are impenetrable from their outside, closed. They attach themselves to networks, emails, and web sites unnoticeably, and become destructive when entering a computer: Computer viruses, worms, snakes, and Trojan Horses operate slightly differently. Common to all of them is their invisibility to computer users, except through the destruction they cause. Because of their impenetrability, the only option left for protection software is to quarantine them when detected. The space occupied by such algorithms is miniscule, but the destruction they cause can be devastating to many cyberspace users.

The Naturalizing History of Technology

Technology is an ecology of artifacts in use. The artifacts that populate cyberspace are of dual description as well. On the one hand, they are embodied in matter and cannot interact within cyberspace without being so embodied. On the other hand, they were all once created by someone who understood how to make them work, and are now handled by users who may not know how they work but what they can do for them. In time, the designers of artifacts are forgotten while technology moves on, becomes naturalized, transparent, taken-for-granted, and the ground for subsequent developments. In this regard, artifacts behave like the words in any language. All words started as someone's words before they gained common currency.

The consequence of naturalizing the artifacts in cyberspace is that their users no longer think of them as means to ends. They become part of their users' culture, a cyber-culture. When someone makes a telephone call, he or she no longer thinks of speaking into a telephone receiver that sets all kinds of things in motion but speaks to another individual. When one browses the Internet, one no longer thinks of sitting in front of a computer screen, pondering the location and makeup of the browser; one becomes immersed in what one comes to see as a consequence of what one does. When naturalized, the furniture of cyberspace becomes invisible, unproblematic, and reliable, and what matters is what it connects one to. When artifacts turn problematic, break down, or do something unexpected, people become aware of them and seek to understand why their conceptions do not fit how the phenomenon is embodiment. Computer viruses, mistakes, and unexpected happenings demonstrate the vulnerability of (a naturalized conception of) cyberspace.

A Human-centered Definition of Information

Gregory Bateson defined "information – the elementary unit of information – (as) a *difference which makes a difference*." (1972: 453, italics in the original). This can serve as my point of departure. He recognized, correctly, that in understanding messages, their physicality is irrelevant, only differences, and among these, only those that matter. Some differences are measurable but not noticeable. Others may be noticeable but are unimportant or irrelevant. One takes into account only the differences that are important in a particular situation and in acting on them, one creates other differences elsewhere.

For Bateson, differences are fundamental. He describes how differences travel though sensory-motor coordinations and through chains of human communication. If a message could not be otherwise, it cannot inform. For something to inform, that something must be perceived as exhibiting differences, as having more than one version. Bateson did not restrict his notion of information to humans. It led him to differentiate between how a stone responds to being kicked and how a dog responds to being kicked. Responding to physical forces (signals) as opposed to differences distinguishes dead matter, including technology, from living beings, including humans.

It would therefore be mistaken to apply Shannon's theory to mechanically distinguishable units, signals, or features of messages; interpret the entropies resulting from this application, his measures of variety, as measures of information; and live in the illusion of their objectivity. They then describe mechanical artifacts. In estimating the size of cyberspace, I applied Shannon's measures to units that are individually distinguishable, addressable, and manipulable, at least by someone. In this application, they count human abilities, not objects. However, they still leave a gap between what ordinary users of cyberspace can do – including information and communication theorists, who are humans after all – and what that army of technological wizards can create who have collaborated for centuries in enlarging the spaces of their own expertise and cyberspace in general.

Take the frames of a movie for an obvious example. While film editors can cut and paste the individual frames of a film, movie viewers are unable to see these frames and respond to continua of figures and grounds instead, and among these only those that matter to them. Bateson's observation would not support separating objective differences from subjective distinctions, but makes clear that cyberspace is an aggregated capability. Its size in bits expresses not what is the case, but what is humanly possible, regardless of intent, access, or perception. It concerns not ontology but collective ontogenesis.

I want to reformulate Bateson's idea into a definition of information that is applicable to being in cyberspace. By reference to Figure 2, any definition is an artifact in language, of course, a social artifact, one that can be argued with, but also be enacted and thereby be embodied elsewhere.

I propose two modifications to Bateson's definition of information, both are epistemologically motivated. First, consider that a difference is an attribute of comparing two things. The word difference gives the impression of denoting something that exists without an observer. Yet, from a second-order cybernetic perspective, differences result from drawing distinctions that someone is capable, willing, or set to make and act upon. Distinctions acknowledge activity, agency, and participation in the phenomenon of interest. Differences do not. Whereas measuring instruments may respond to differences, human actors have the choice of drawing some distinctions and not others.

Second, Bateson's "*difference*$_{(i)}$, which makes a *difference*$_{(ii)}$" needs to be entangled. His *difference*$_{(i)}$ is the difference that is noticed and present, the textuality of what is available. It the difference created by drawing distinctions within sensory experiences. His *difference*$_{(ii)}$ pertains to another empirical domain, one that matters, is important or significant. I am therefore proposing:

> *Information arises when distinctions drawn within a present domain* (a text, for example) *lead to distinctions that matter in another domain, unlike the present one* (the context of a text).

The expression "lead to" signifies logic. To the extent one is aware of the distinctions involved and capable of justifying to others why one kind inform those that matter, one uses the logic of abduction. *Abduction* is an inference that is, just as the word suggests, not logically conclusive, and neither deductive nor inductive. It proceeds from something in one domain to something in a logically different domain, and is based on *the best hypothesis of how the two are connected* (Eco, 1994; Josephson & Josephson, 1994; Krippendorff, 2004:36-38; Peirce, 1931).

Thus, information is never there to begin with, it must be abducted from something present, something that has textuality, multiple facets woven together, which have to be distinguished and disentangled or read as needed. The reference to a "best hypothesis" implies that there are other hypotheses, less appropriate ones, but hypotheses nevertheless. A hypothesis is always open to question. It may be wrong. Hypotheses also reside in language. Figure 3 depicts what has been discussed so far. Here are four examples to illustrate how information arises.

Figure 3

- For an obvious example, the number of rings in the cut of a tree trunk provides information about the age of that tree, based on the hypothesis that a tree grows one ring each year. This hypothesis is well established, so well that it is taken to be a fact. But without that hypothesis or fact, the number of rings would be meaningless and could not provide information about a tree's age.
- For a more probabilistic example, consider noticeable differences in people's pronunciation. One may notice an accent and leave it there. But knowing something about the correlation between certain phonetic habits and the region where these habits are at home enables a listener to identify relevant features of the accent in lieu of their correlation and infer a speaker's geographical or cultural origin. An accent becomes informative to the extent it distinguishes among places of origin that matter.
- Thirdly, consider the absence of responses to letters written to a friend. They mean nothing as such, unless that writer entertains one or more hypotheses, starting with the most reasonable one for why no response was received: (a) the letters may have gotten stuck in the mailbox and were never sent, (b) the friend could have moved to a different address and didn't get mail, (c) the friend could have been prevented from responding (died, is in a hospital, or on a safari), (d) the letter could have been chewed up by the friends dog, (e) the friend no longer cares, has ceased to be a friend, etc. Naturally, one eliminates hypotheses that seem unlikely, knowing how the post system works or the habits of the friend. What the absence of a response informs the letter writer about the friend depends on the hypothesis chosen as the best one. And it may later turn out to be mistaken. The uncertainty of the hypothesis translates into the uncertainty of the inference.
- Finally, *The New York Times* financial section lists pages of numbers and alphabetical characters in very small type size, occasionally interrupted by readable headlines, suggesting that these are the values of stocks, bonds, precious metals, and foreign currencies. Most readers of this section attend to only a few of these, to numbers pertaining to their investments. With the help of a hypothesis of how the stock market works, small noticeable changes can come to live and compel readers into action, into buying or selling. For the majority of people the financial pages are uninformative numbers. And indeed, without a hypothesis of how they relate to something that matters, they cannot inform actions.

Two Ways Abduction can be Embodied

Hypotheses and justifications of abductions *occur* in language, in communication. One may have learned about the relationship between the age and number of tree rings in school and might be talking to someone before adopting a hypothesis of why that friend is not responding. One might get advice from a broker on how to interpret stock market fluctuations. These verbalizations and the metaphors to be discussed shortly are linguistic constructions, **artifacts in language**, and they occupy the upper right quadrant in Figure 2.

Many everyday abductions are not contemplated or discussed, however. Print, television, and radio, the most common sources of information, provide sensory experiences to begin with, but are attended to only for what they tell about what one wants to know besides them, about their contexts, about events in distant but important parts of the world. The ability to read, write, and actually also to see, is acquired and mastered to the point of being mindlessly executed abductions. In literate societies, the human body is virtually shaped by its handling of text. Literacy is a reliable **bodily practice**. While reading, one senses the texture of characters and may distinguish words, sentences, paragraphs, etc., but one has no idea of how to go from there to what matters. Readers are not aware of any hypothesis. They do not apply rules of grammar, for example. They simply read, looking through texts to something that interests them. One becomes aware of abductions only when one encounters disruptions, an unfamiliar word that prompts consulting a dictionary, an unusual expression that lead to pondering just what the author could have had in mind, or an image that seems to have been tampered with, encouraging speculations of why. Being literate means practicing what outsiders may describe as abductions in unproblematic coordination with other readers of the genre (speakers of a language and participants in a culture). Theories of reading exist of course, in academia, for example, but none is conclusive of how readers link texts to their contexts. Readers read with their body. In Figure 2, bodily practices are seen as Pleroma and occupy its lower right quadrant.

Two Limits of Abduction

Recall that the logarithm of the number of the smallest individually addressable elements of an available text indicates the largest number of distinctions that could be drawn in it. Mapping a large number of possible distinctions into the smaller set of distinctions actually drawn amounts to equivocation, which is guided by the best hypothesis chosen. This part is unproblematic. In the absence of any evidence about what is to be inferred, there is no logical justification for what the best hypothesis is on which abduction is justified. From a God's eye perspective, that hypothesis should have some basis in the patterns that connect a given text to the context that matters. When such connections do not exist in fact, a hypothesis would not be warranted or arbitrary, and the information that is abducted on its account may turn out to be invalid, misleading, or correct to a degree not better than chance. Stated positively:

The chosen hypothesis must be born out – at least in its consequences – *by patterns in cyberspace that connect the apparent textuality to a domain that matters.*

There is an analogue to Shannon's 9th theorem on the capacity of communication channels (Shannon & Weaver, 1949:28) and Ashby's (1956a: 206-213) Law of Requisite Variety:

To be informed about what matters, the number of distinctions drawn
must equal or exceed the number of distinctions that matter.

Metaphors of Information

Justifications of abductions, the best hypothesis chosen, occur in language. Much of language is metaphorical, not referential or logical. Metaphors of information seemingly bypass the need for justifications and entail an own logic that deserves attention and contrast to the proposed definition of information. Metaphors explain something in terms of something else, in terms of a domain of experiences that is more familiar than the domain presently faced (Lakoff & Johnson, 1980). The property of metaphors that is important here is that they introduce entailments that guide their users in often-unnoticed ways.

Metaphors are not welcome in the established representational view of language and in much of science writing, which envisions language as a system (Volosinov, 1986) regardless of its use (Saussure, 1959/1966). Yet, metaphors permeate talk and emerge particularly when something seems too complex or difficult to grasp. Cyberspace is a prime candidate and metaphors of it abound. Metaphors provide what one may call convenient conceptual shortcuts that are purchased, however, by blindly adopting their entailments. To make that point, the following examines seven common metaphors of information.

- One of the most pervasive metaphors of information is to regard **information as an entity** that behaves much as objects do. This is evident when speaking of giving information to someone, putting information on the web, or of retrieving information from a textual database. In fact, information retrieval operates on character strings, not on information by any conception. The metaphor entails that the entity in question somehow exists regardless of whether humans recognize it or not. It also attributes objectivity to information. As an entity, something either is information or it is not.
- An extension of the above is the metaphor of **information as a valuable resource, as** something **that can be paid for, exchanged, traded,** and **owned**. Copyright laws have built the idea of ownership of information into its injunctions, and it is remarkable how much money is at stake in settling copyright infringement cases and how much effort governments expend on enforcing regulations that essentially

preserve the entailment of this metaphor. Speaking of conversations as information exchange, as a place where people trade information tit for tat, reduces conversations to rational but also impoverished encounters.

- The metaphor of **information as an agent** is evident when claiming that information spurned a technological development or compelled someone's action. It entails a transfer of human agency to information. It nourishes the conception that information does the work that people normally do, rendering humans subservient to what their environment tells them, as programmable or reactive components of systems. A whole discipline, memetics (Dawkins, 1989), is built on this metaphor. Assigning agency to information is allied with the rational consensus that began during the enlightenment, celebrating knowledge for its own sake, as being independent of human understanding, and picturing humans as imperfect, flawed, subjective, and biased.
- Perhaps another version of the metaphor of information as an agent is the metaphor, often used by lawyers, that **documents speak for themselves**. Although documents cannot make a sound and require careful reading to be understood, this metaphorical construction encourages single correct readings. Since multiple readings of documents are typical in real life and especially in adversary court proceedings, this metaphor legitimizes textual authorities, such as judges, who are given the power to determine what a document "says."
- A metaphor that acknowledges human psychology is the metaphor of **information as uncertainty reduction**, already used by Shannon. The model case is asking and answering questions. Asking a question reveals an uncertainty that a proper answer eliminates. While asking and answering questions is a common conversational move, overextending this metaphor depicts individuals as plagued by Cartesian uncertainties and in continuous search for correct and accurate representations. The metaphor has generated much psychological research (see Berger & Godykunst, 1991). What generates this uncertainty remains largely unreflected and social phenomena have no place in its entailments.
- Probably the most pervasive metaphor in communication is the container metaphor (Reddy, 1979; Krippendorff, 1993). It builds on the metaphor of information as an entity, but goes beyond it by considering **information as contained in messages**, words, and images. It renders messages as the vehicles for information to be shipped from one place to another. The sender packs information into a message that the receiver is then expected to unpack or remove. Folk physics suggests the law of substance invariancy: The receiver can remove from a container only what its sender has put into it (one can't put wine in a container and pour out milk). Living in this metaphor has many remarkable entailments. So, communication becomes the extent to which participants enter and remove the same contents from the messages that mediate between senders and receivers, and do so correctly. Should differences among receivers become evident, the metaphor privileges the authors, their intentions, as determinants of the information that *their* messages contain. It is truly amazing to see how thoroughly the container metaphor has saturated conceptions of language and communication. It underlies the distinction between content and form, basic to most studies of literature. It fuelled the early conception of content analysis in communication research (Berelson, 1952; now hopefully out dated, see Krippendorff, 2004). It delegitimizes readers' interpretations, and makes writers or speakers responsible for what listeners hear.
- The metaphor of **information as transmission** resembles that of the container metaphor. It replaces the substance constancy of the container metaphor by the presumption of a common, shared, and invertible code. Senders encode the information in their head into a medium, a writing system, for example, or electrical impulses, that allow it to be transmitted through a channel to its destination, at which point it is decoded into the mind of a receiver. For transmission to be perfect, decoding and encoding must be

> inverse operations, and if both parties operate with the same code, they would have to end up with the same information in their head. But since the sender comes first, the job of the receiver is to figure out what the sender meant, all of which is presumed encoded in the message. Although many of Shannon theorems concern coding, his calculus does not require the presumption of code sharing.

All of these metaphors of information shortcut the hypotheses that enable abducting information about what matters. They are incommensurate, however, with the human-centered definition of information developed above. They not only fail to reveal their hypothetical nature, they attribute information to textual qualities rather than to what humans are able to do with them. Literary scholars have no doubt about the difference between form and content. Engineers have no doubt that information is in the signal, waiting to be properly decoded. The fact that such metaphors are widely used – not just everyday conversations but also scientific discourse – suggests that their entailments have not yet significantly impaired their users actions. It also attests to the pervasiveness of first-order science that protects users from getting into such troubles. From a second-order cybernetic perspective, metaphors are not wrong. They merely limit their users' conceptual abilities and unwittingly direct their attention along the path of the metaphors' entailments.

My proposal of a human-centered alternative provides a conceptual yardstick that reveals the wholesale surrender of human agency in the established theories of information and communication.

Summary

This paper, once a presentation, proposes a shift in conceptualizing information from a disembodied to an embodied concept. It prepared the ground for this proposal by developing a conception of cyberspace, as having a size and being populated by technological artifacts, full of possibilities but no meanings in and of itself. Artifacts are human constructions, technological artifacts in matter, social artifacts in language, both are used and constitute Creatura, the world of one has a chance of knowing. The paper also argued that this created world is inextricably tied to unconceptualized matter and bodily practices, Pleroma, without which language cannot be spoken and actions are not real. It then proposed a definition of information that relied on hypotheses about the naturalized patterns of artifacts in cyberspace to abduct information about what matters. Finally, it looked into common metaphors of information to show how disembodied concepts of information result from blindly following the entailments of common metaphors of information.

Of particular interest is the hyperexponential growth of cyberspace, which this paper recognizes. The spaces occupied by the technological artifacts it houses often go far beyond the capacity of individual understanding and purposeful human collective actions. This new social artifact, cyberspace, contains technologies that we may no longer be able to grasp, theoretically and practically, but have to hypothesize in order to live with them. The notion of information here proposed constitutes one step in that direction.

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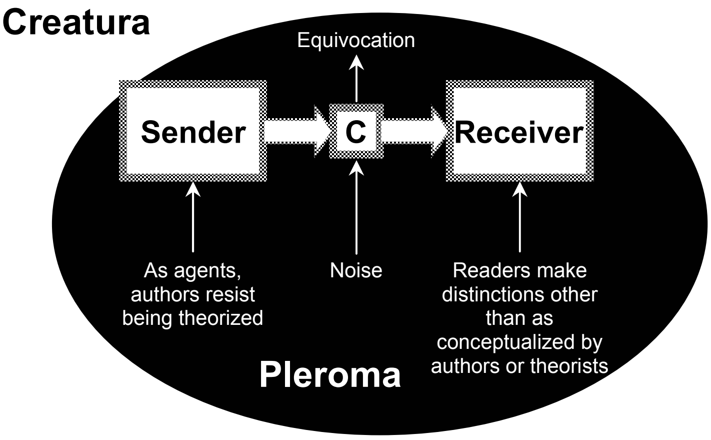
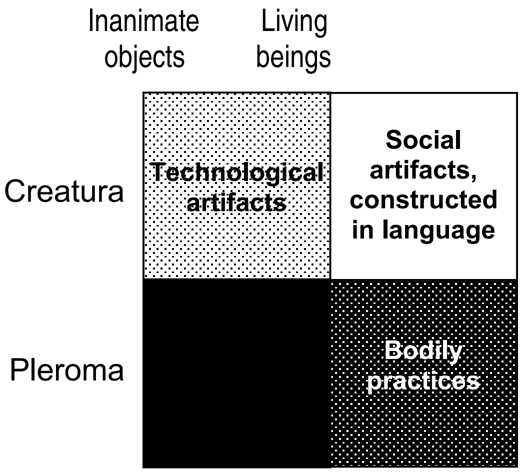
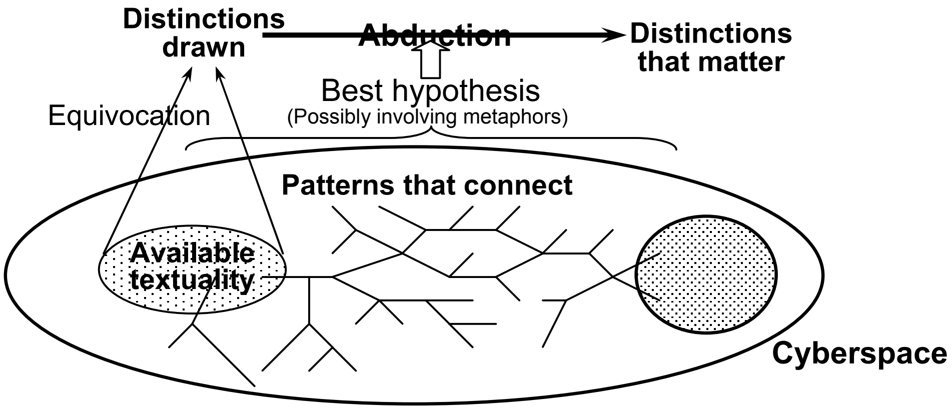


Shannon ‘s Theory Embodied in Human Communicative Practices
Figure 1



Kinds of Embodiments
Figure 2



Abduction of Information and Its Relation to Patterns in Cyberspace
Figure 3