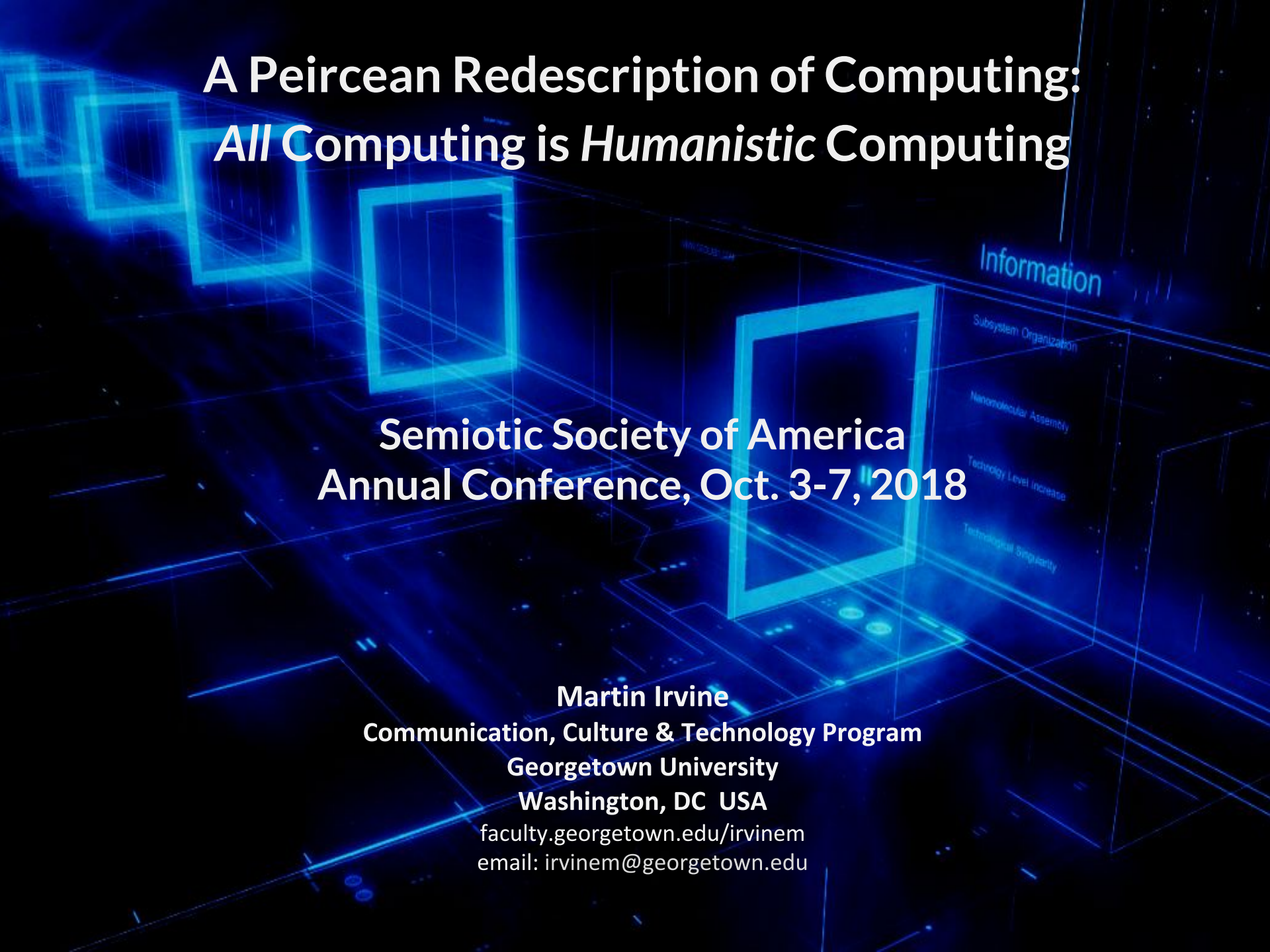
A Peircean Redescription of Computing: *All* Computing is *Humanistic* Computing



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Some background for this presentation:

This talk is a brief interim report from a book in progress on a Peircean semiotic redescription of computing systems, information, and digital media. (A synthesis of 20+ years of research and teaching.)

My argument combines two methods:

(1) a new archival recovery of Peirce's program of "logic as semeiotic," especially from Peirce's unpublished papers from his final period of writing (c.1902-1912) (5 years of research, ongoing); and

(2) expanding and completing Peirce's foundational theory with recent research and theory in cognitive science, linguistics, and theories of computation in computer science.

There are many details and theoretical steps to fill in, but this presentation will provide some key points of what I think are very promising directions for extending Peircean semiotics in our contemporary context.

Expanding on Phil Agre:

> **"[Computing] Technology at present is covert philosophy; the point is to make it openly philosophical."**
>
> **Phil Agre, *Computation and Human Experience* (1997)**

More explicitly:

> **[Computing] Technology at present is covert *semiotics*; the point is to make it openly *semiotic*.**

Key Points in Peirce's Works Relevant to the Foundations of Computing and Digital Information Theory (including unpublished papers)

1 Introductory: Foundations: Morse to Peirce to Shannon: Morse's "System of Signs" and Peirce on Logic Machines, Logic Circuits, and Electrical Sign Actions

2 Elements of Peirce's model of semiosis and sign structures across material states and time:

- **2.1 The Physical Substrate Function (material-perceptible structures of sign properties)**
- **2.2 The type/token distinction and re-tokenization across physical substrates**
- **2.3 Indexical sign functions in semiotic-cognitive artefacts and computing systems**

3 Principle of Homologous Form in the Logical-Semiotic Design of Computing Systems:
Defining and designing physical homologies for two levels of symbols: symbols for representations (meanings, values, "data/information"), and symbols for operations relations, and transitions (logic, metasymbols) implementable in system design.

4 Principle of Delegated/assigned/distributed sign agency: enacting tokenization and re-tokenization (for physical representations) and automating logic processes (over types)

5 Conclusions:
Computation and digital media (classes of types of sign structures) are Artefacts of Human Symbolic Cognition in a continuum with human symbolic capacities.
Consequences of a Semiotic Re-Description of Computation and all things digital.

Prior work and multidisciplinary convergence

Semiotic analyses and models of computation, digital information, and software as symbolic systems have been developed for many years, including studies in information theory, cybernetics, and AI, extending back to the 1950s. Some notable recent contributors (small selection):

Andersen, Peter Bøgh. *A Theory of Computer Semiotics: Semiotic Approaches to Construction and Assessment of Computer Systems*. Cambridge: Cambridge University Press, 1997.

Andersen, Peter Bogh, Berit Holmqvist, and Jens F. Jensen, eds. *The Computer as Medium*. Cambridge: Cambridge University Press, 1993.

Goguen, Joseph A., and D. Fox Harrell. "Information Visualization and Semiotic Morphisms." In *Multidisciplinary Approaches to Visual Representations and Interpretations, Volume 2*, edited by Grant Malcolm, 83–98. Amsterdam; London: Elsevier Science, 2005.

Ketner, K. L. "Peirce and Turing: Comparisons and Conjectures." *Semiotica* 68, no. 1/2 (February 1988): 33–61.

Kockelman, Paul. "Information Is the Enclosure of Meaning: Cybernetics, Semiotics, and Alternative Theories of Information." *Language & Communication* 33, no. 2 (April 2013): 115–27.

Nadin, Mihai. "Semiotic Machine." *The Public Journal of Semiotics* 1, no. 1 (January 1, 2007): 57–75.

Nöth, Winfried. "Semiotic Machines." *Cybernetics & Human Knowing* 9, no. 1 (January 2002): 5–21.

Queiroz, João, and Floyd Merrell. "On Peirce's Pragmatic Notion of Semiosis--A Contribution for the Design of Meaning Machines." *Minds & Machines* 19, no. 1 (February 2009): 129–43.

Rapaport, William J. "Semiotic Systems, Computers, and the Mind: How Cognition Could Be Computing." *International Journal of Signs and Semiotic Systems* 2, no. 1 (January 2012): 32–71.

Skagestad, Peter, "The Mind's Machines: The Turing Machine, the Memex, and the Personal Computer," *Semiotica* 111, no. 3/4 (October 1996): 217–43.

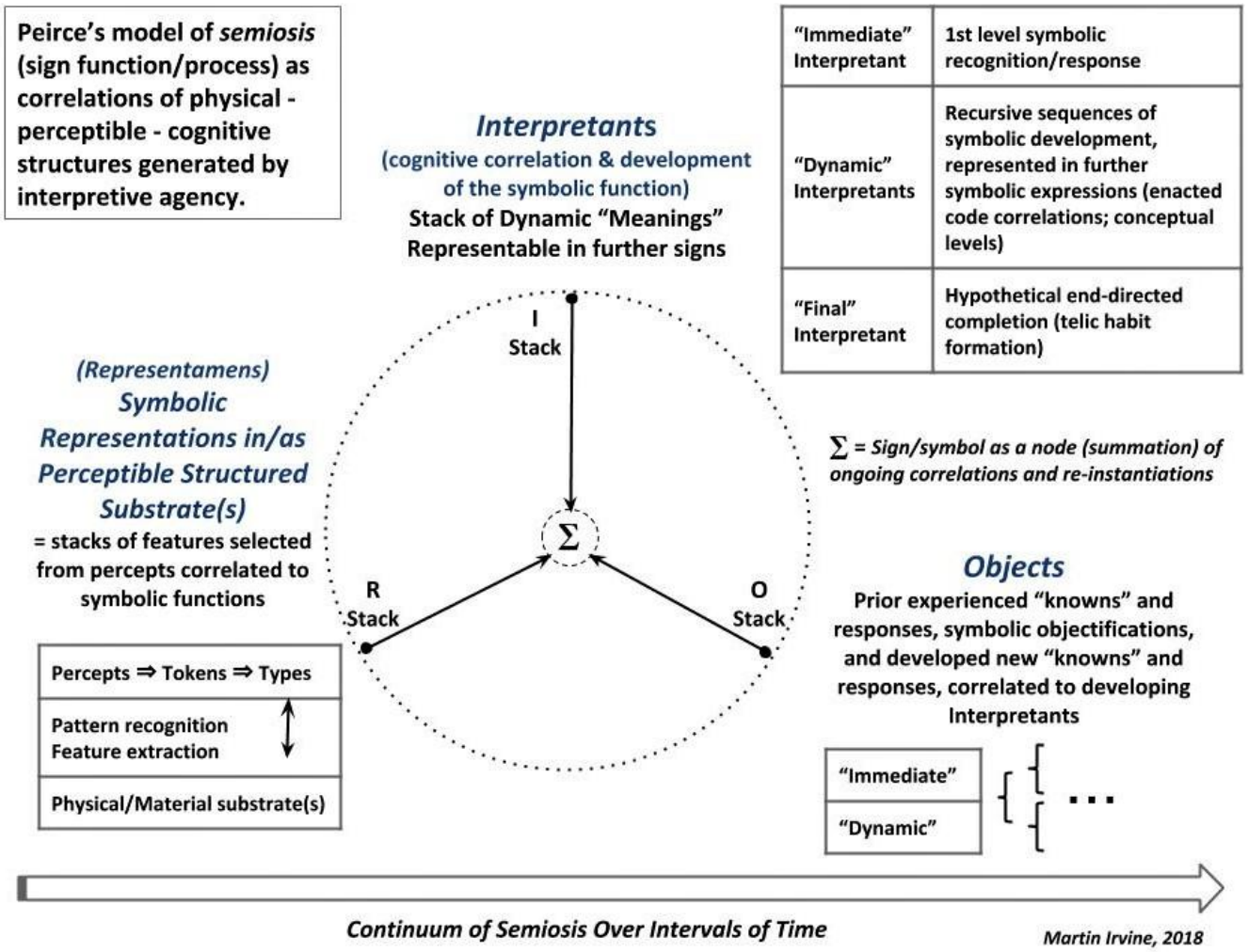
Sowa, John F. *Conceptual Structures: Information Processing in Mind and Machine*. Reading, MA: Addison-Wesley, 1983.

———. *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Pacific Grove: Brooks/Cole; Thomson, 1999.

Tanaka-Ishii, Kumiko. *Semiotics of Programming*. New York: Cambridge University Press, 2010.

Extending Peirce's triadic model of semiosis with recent cognitive science

We have many attempts to diagram Peirce's evolving model of symbolic processes, structures, and actions (at different stages of his career). My (still inadequate) model reveals that Peirce's core theory can be very usefully remodeled in the context of recent theory in cognitive linguistics (e.g., Jackendoff) and theories of extended mind and distributed cognition in semiotic/cognitive artefacts (e.g., Clark, Hutchins). Instead of linear sequences, we should rather consider Peirce's evolving views as attempts to coordinate *parallel processes* (stacks or layers) developing and reconfiguring over time. (No model of triangles with dyadic nodes captures what Peirce was trying to figure out.) There is much evidence in Peirce's writings from c.1902-1912 to support such a model that is usefully completed with recent work in many other fields, especially in the areas where cognitive science and theories of computation intersect.



1) Morse to Peirce, Shannon, and Turing: Signs, Code, and Mathematical-Physical Homologies for Electronic Representations

Samuel Morse, 1837, recalling events in 1832:

[O]n my voyage from Europe [1832], [I recalled] the electrical experiment of Franklin...in which experiment it was ascertained that the electricity traveled through the whole circuit in a time not appreciable, but apparently instantaneous. *It immediately occurred to me that,* ***if the presence of electricity could be made VISIBLE in any desired part of this circuit****, it would not be difficult to construct* ***a SYSTEM OF SIGNS by which intelligence could be instantaneously transmitted.*** The thought, thus conceived, took strong hold of my mind… and **I planned a system of signs, and an apparatus to carry it into effect**.

[Emphases as in original text.]
(From: Samuel Irenæus Prime, *The Life of Samuel F. B. Morse, LL. D.: Inventor of the Electro-Magnetic Recording Telegraph*. New York, 1875.)

[Morse was a proto-semiotician, who began his career as an artist, was a co-founder of the New York Academy of Design, and set up the first Daguerreotype photography studio in the US after meeting Louis Daguerre in Paris -- in the same year that Peirce was born. He also learned chemistry and physics at Yale. While there were rival designs for telegraphy developed in the same era, Morse's system prevailed and became the international standard. Modern telecommunications was "invented" by a humanist, not a technician (in our sense).]

The long tail of Morse…
"The presence (and absence) of electricity in desired (designed) parts of a circuit" is still the foundation of information theoretic signals engineering and digital data design.

Pixel-based screens are literally this (presence of electricity made visible in light spectrum).

“Intelligence”:
19th-century usage for communicable information, intentional meanings; expressible in “a system of signs.”

Peirce uses the term “intelligence” in the same way; one example:

> [T]here is a great advantage in making logic in general, and more especially stechiology [study of *elements*, Peirce’s “speculative grammar”] embrace in its scope all sorts of signs and representations. *Sign* will here be the general name for everything of that sort, whether it be an instrument of music, a mental resolve, a voyage of discovery, or **anything else that plays an essential part in the spread of intelligence**.
>
> MS 602, 1907. Unpublished.

Samuel Morse, A Life in Code

Samuel Morse,
Gallery of the Louvre,
oil on canvas, 1831-1833.
In the genre of
"meta-painting."

No. 117. JUNE 13, 1848.

S. F. B. MORSE.
ELECTROMAGNETIC TELEGRAPH.

The System of Signs.

Example 1st. 1st For Numerals.

Example 2d. For Compound Numerals.
Showing the numerals combined together.

Example 3d. 2d For Letters

The System of Type.

Example 4th. 1st For Numerals.

Fig. 1.

Fig. 2.

Example 5th. 2d For Letters

Example 6th. Type for Circular Portrule.

Fig. 1. Fig. 2. Fig. 3.

Morse Patent drawing, 1848

Samuel Morse with his telegraph receiver, daguerreotype portrait (1847, Matthew Brady, who learned Daguerreotype photography in Morse's studio in New York).

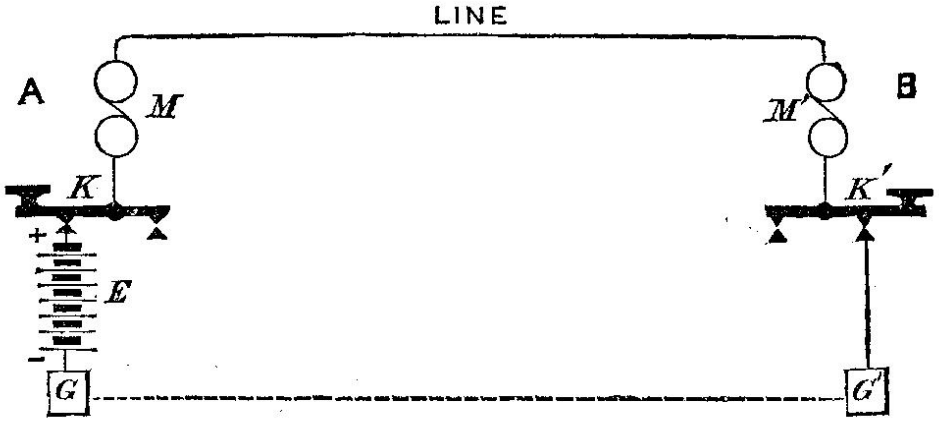


FIG. 9.

Electromagnetic telegraph circuit and early diagram and code chart:

Proto-binary switched circuit code.

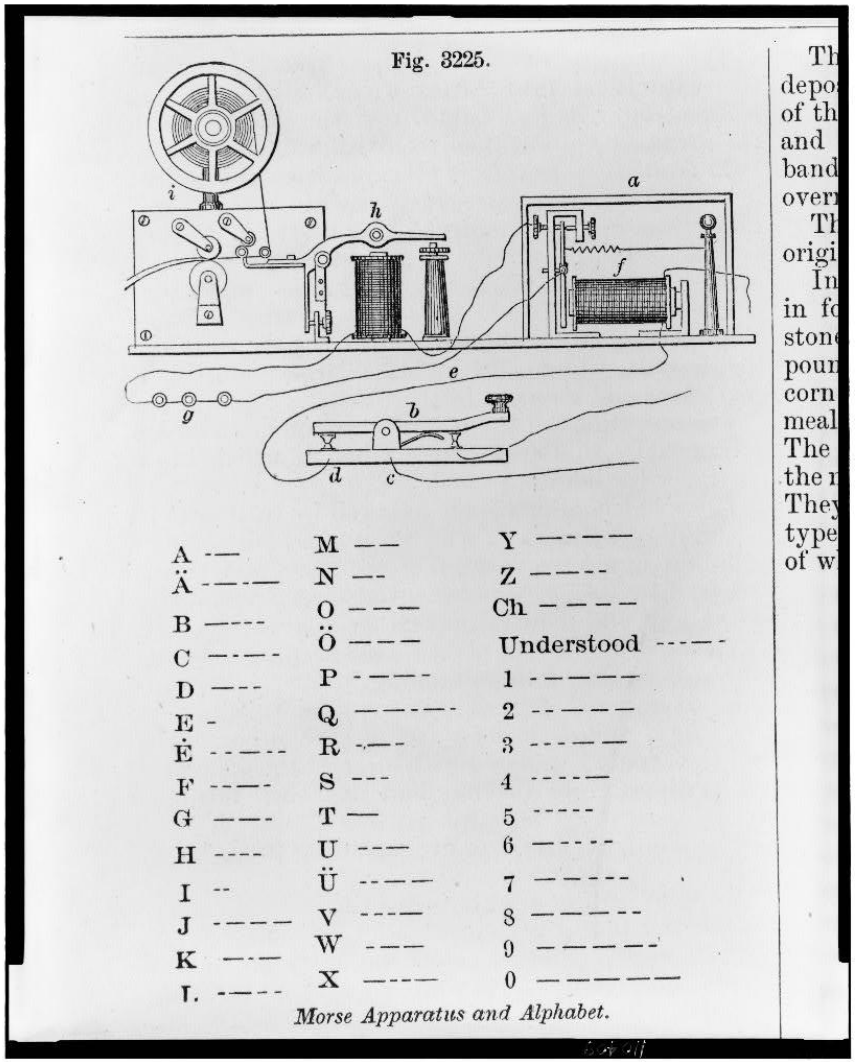


Fig. 3225.

A	·—	M	——	Y	—·——
Ä	·—·—	N	—·	Z	——··
B	—···	O	———	Ch	————
C	—·—·	Ö	———	Understood	···—·
D	—··	P	·——·	1	·————
E	·	Q	——·—	2	··———
É	··—··	R	·—·	3	···——
F	··—·	S	···	4	····—
G	——·	T	—	5	·····
H	····	U	··—	6	—····
I	··	Ü	··——	7	——···
J	·———	V	···—	8	———··
K	—·—	W	·——	9	————·
L	·—··	X	—··—	0	—————

Morse Apparatus and Alphabet.

C. S. Peirce's model of semiosis in "Logic as Semeiotic": semiosic actions

It is necessary to insist upon the point for the reason that **ideas cannot be communicated at all except through their physical effects**. Our photographs, telephones, and wireless telegraphs, as well as the sum total of all the work that steam engines have ever done, are, in sober common sense and literal truth, the outcome of the general ideas that are expressed in the first book of the *Novum Organum*.

[The term] "**sign**" [includes] every picture, diagram, natural cry, pointing finger, wink, knot in one's handkerchief, memory, dream, fancy, concept, indication, token, symptom, letter, numeral, word, sentence, chapter, book, library, and in short whatever, be it in the physical universe, be it in the world of thought, that, whether embodying an idea of any kind (and permit us throughout to use this term to cover purposes and feelings), or being connected with some existing object, or **referring to future events through a general rule, causes something else, its interpreting sign, to be determined to a corresponding relation to the same idea, existing thing, or law**.

MS 774 (1904), EP 2.326

Peirce: Sign actions and interpretants in the path of electrical signals

Every thought, or cognitive representation, is of the nature of a sign. "Representation" and "sign" are synonyms. The whole purpose of a sign is that it shall be interpreted in another sign; and its whole purport lies in the special character which it imparts to that interpretation. When a sign determines an interpretation of itself in another sign, **it produces an effect external to itself, a physical effect**, though the sign producing the effect may itself be not an existent object but merely a type. It produces this effect, not in this or that metaphysical sense, but in an indisputable sense…. Thinking is a kind of action, and reasoning is a kind of deliberate action….

Consequently, the whole purport of any sign lies in the intended character of its external action or influence. **Some signs are interpreted or reproduced by a physical force** or something analogous to such a force, simply by causing an event; as sounds spoken into a telephone effect variations or the rate of alternation of an electric current along the wire, as a first interpretation, and these variations again produce **new sound-vibrations by reinterpretation.**

MS 1476, Drafts of a review of Herbert Nichols' *A Treatise on Cosmology* (1904, pp. 5-6; p.4, second sequence of drafts). Unpublished.

In another earlier draft of this page, Peirce words it this way:

> Some signs are interpreted in actual physical effects or in relations analogous to such effects; as when sound vibrations of speech before a telephone transmitter cause variations in the rate of alternation of an alternating current along the wire, **this series of variations making up a sign that interprets, i.e. translates, the acoustic sign, and in its turn setting up new acoustic vibrations in the receiver, as a reinterpretation**.
>
> (MS 1476, 1904, p. 5, sixth sequence of drafts. Unpublished.)

This text has not yet been discussed. I will treat this MS (and many related unpublished texts) extensively in my book.

Peirce's many discussions of "logic/reasoning machines" and scientific devices must be understood in his larger program of *Logic as Semeiotic*

"Logic as Semeiotic" includes all sign systems and the design principles of instruments, devices, semiotic artefacts, and machine systems:

> Logic should be regarded as coextensive with General Semeiotic, the *a priori* theory of signs…. All these essays, as the title-page says, relate to the Meaning of Signs, generally....
>
> The present volume, however, contains merely an unsystematic reconnaissance of a part of that broader ground. It considers Signs in general, a class which includes pictures, symptoms, words, sentences, books, libraries, **signals**, orders of command, **microscopes**, legislative representatives, musical concertos, performances of these….
>
> MS 634, *Preface (Meaning Preface)*, 1909. Unpublished.

Indexical Functions and Combined Symbol Structures: structures at the foundations of computing theory & system design

An Index can very well represent itself. Thus, every number has a double; and thus the entire collection of even numbers is an Index of the entire collection of numbers, and so this collection of even numbers contains an Index of itself. But it is impossible for an Index to be its own Interpretant.

> MS 478, 1903, EP 2.276 (From the Lowell Lectures *Syllabus*; EP did not publish the whole text, and there are many important draft versions of the section on "Speculative Grammar" with revealing statements on the development of these central ideas.)

The being of a symbol consists in the real fact that something surely will be experienced if certain conditions be satisfied. Namely, it will influence the thought and conduct of its interpreter. Every word is a symbol. Every sentence is a symbol. Every book is a symbol. Every Representamen depending upon conventions is a symbol. Just as a photograph is an index having an icon incorporated into it, that is, excited in the mind by its force, so **a symbol may have an icon or an index incorporated into it, that is, the active law that it is may require its interpretation to involve the calling up of an image**, or a composite photograph of many images of past experiences, as ordinary common nouns and verbs do…

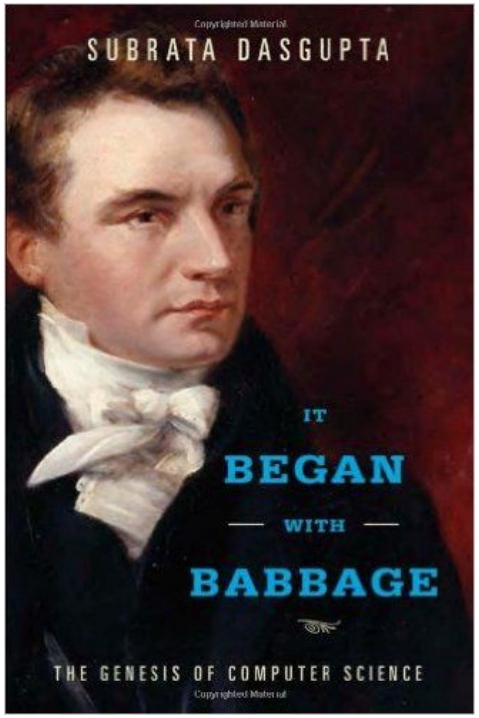
> MS 492, c. 1903, "Logical Tracts, 2, 'On Existential Graphs, Euler's Diagrams, and Logical Algebra'." (Selected pages of this text in CP 4.418-509; many important sections and earlier drafts are unpublished.)

Peirce on the "strata" (layers) of signs and multiple interpretants:

Also foundational for the design of computational processes implemented in physical machines.

Continuing the study of Speculative Grammar, how, **in consequence of every sign determining an Interpretant, which is itself a sign, we have sign overlying sign**. The consequence of this, in its turn, is that a sign may, in its immediate exterior, be of one of the three classes, but **may at once determine a sign of another class**. But this in its turn determines a sign whose character has to be considered. This subject has to be carefully considered, and order brought into **the relations of the strata of signs**, if I may call them so, before what follows can be made clear.

MS 425, *Minute Logic*, 1902 (following the section on "Reasoning Machines"), as CP 2.94 (but incomplete). CP edited a version of this text as CP 2.1-118 from a typescript of the text; many other draft pages in MS unpublished.



C. S. Peirce wrote the obituary for Charles Babbage for the *The Nation*, 9 November 1871. Peirce discusses Babbage's two "engines," and the Scheutz difference engine being used in the Albany Observatory (purchased on the advice of a scientific committee in which his father, Benjamin Peirce, was a member). Peirce cites Babbage many times in his writings.

A symbolic and semiotic view of computing can be found in many contexts in computer science:

"We have come a long way from this association [of computing as calculating with numbers]. We will see that **the domain of computation actually comprises *symbols***—by which I mean things that represent other things (for example, a string of alphabetic characters—a word—that represent some object in the world, or a graphical road sign that represents a warning to motorists).

The act of computation is, then, *symbol processing*: the manipulation and transformation of symbols. Numbers are just one kind of symbol; calculating is just one kind of symbol processing. And so, the focus of automatic computation, Babbage's original dream, is whether or how this human mental activity of symbol processing can be performed by (outsourced to) machines with minimal human intervention. Computer science as the science of automatic computation is also **the science of automatic symbol processing**."

Subrata Dasgupta, *It Began with Babbage: The Genesis of Computer Science* (Oxford: Oxford University Press, 2014)

From: **Michael S. Mahoney, "The Histories of Computing(s)" (2005).**

"**Recall what computers do. They take sequences, or strings, of symbols and transform them into other strings.** The symbols and the strings may have several levels of structure, from bits to bytes to groups of bytes to groups of groups of bytes, and one may think of the transformations as acting on particular levels. But in the end, computation is about rewriting strings of symbols….

Any meaning the symbols may have is acquired and expressed at the interface between a computation and the world in which it is embedded. The symbols and their combinations express representations of the world, which have meaning to us, not to the computer. **It is a matter of representations in and representations out**.

What characterises the representations is that **they are operative**. We can manipulate them, and they in turn can trigger actions in the world. What we can make computers do depends on how we can represent in the symbols of computation portions of the world of interest to us and how we can translate the resulting transformed representation into desired actions."

Though these statements are incomplete as a Peircean semiotic description, they are intuitively correct, and can be completed by merging a Peircean description with all the research going on in related fields. Similarly with the Newell-Simon "physical symbol system" description and model of AI: the theory requires a complete description of the "symbol" in a "physical computing system" context, rather than taking it for granted.

C. S. Peirce: Logic Machines and First Diagram of Boolean Electronic Logic Switches (Gates) (1886)

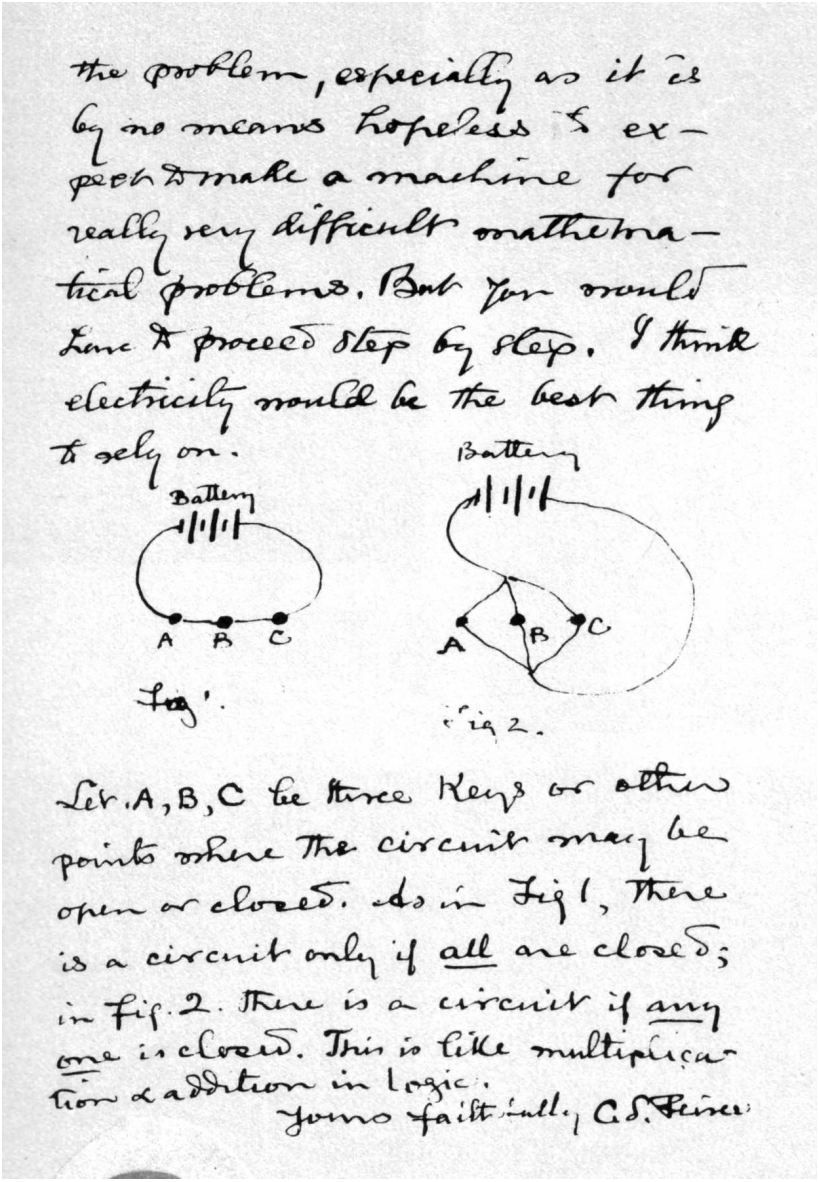
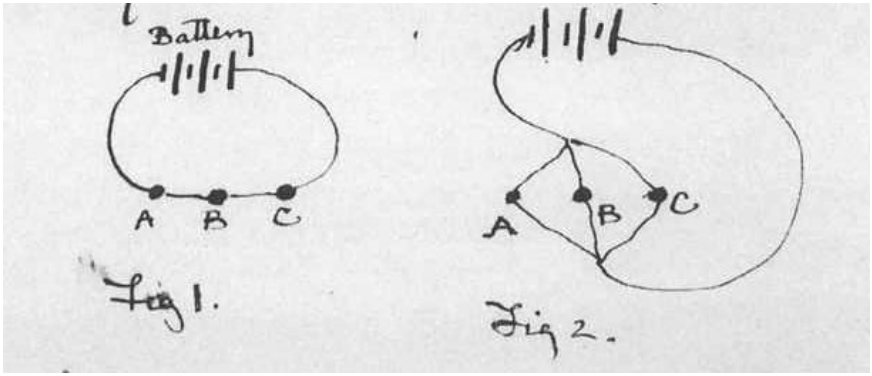

the problem, especially as it is by no means hopeless to expect to make a machine for really very difficult mathematical problems. But you would have to proceed step by step. I think electricity would be the best thing to rely on.

Fig 1. Fig 2.

Let A, B, C be three Keys or other points where the circuit may be open or closed. As in Fig 1, there is a circuit only if all are closed; in Fig. 2. there is a circuit if any one is closed. This is like multiplication & addition in Logic.

Yours faithfully, C. S. Peirce

"I think you ought to return to the problem [of building your reasoning machine], especially as it is by no means hopeless to expect to make a machine for really very difficult mathematical problems. But you would have to proceed step by step. I think electricity would be the best thing to rely on.



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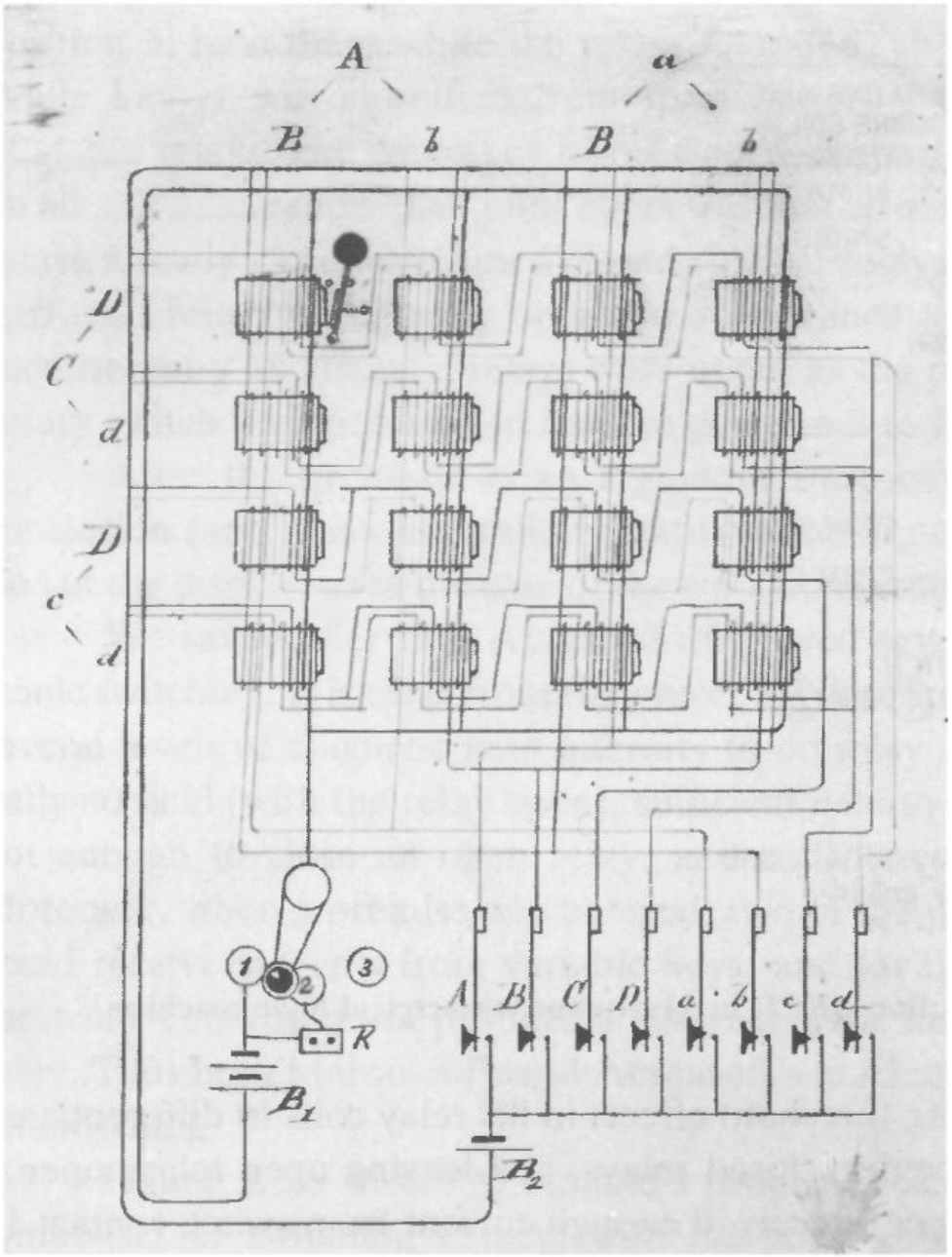
(Peirce, Letter to Allan Marquand, 1886, W 5.421-22)



Peirce's diagram for improving Alan Marquand's electromagnetic switched logic machine, c. 1886.

16 switches for 4-term syllogisms, set by keys to select syllogistic form.

From Alan Marquand Papers,
Firestone Library, Princeton University

Claude Shannon,
Design for Combining Switching Circuits Modeled on Boolean Symbolic Logic

(1) *A Symbolic Analysis of Relay and Switching Circuits* (MIT Thesis, 1936-37)

(2) "A Symbolic Analysis of Relay and Switching Circuits." *American Institute of Electrical Engineers*, 57, no. 12 (December 1938): 713–23

(1) Drawing from MIT Thesis (1936-37), p. 5

hinderance of the circuit formed by connecting the circuits a-b and c-d in parallel. A relay contact or switch will be represented in a circuit by the symbol in Fig. 1, the letter being the corresponding hinderance function. Fig. 2 shows the interpretation of the plus sign and Fig.3 the multiplication sign.

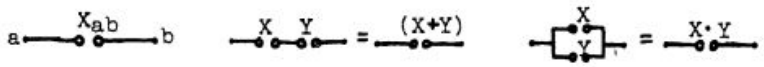


Fig. 1 Fig. 2 Fig. 3

This choice of symbols makes the manipulation of hinderances very similar to ordinary numerical algebra.

Peirce's conception for logic switches was re-discovered by Shannon in the 1930s.

(2) Published version, 1938

THEOREMS

In this section a number of theorems governing the combination of hindrances will be given. Inasmuch as any of the theorems may be proved by a very simple process, the proofs will not be given except for an illustrative example. The method of proof is that of "perfect induction," i.e., the verification of the theorem for all possible cases. Since by postulate 4 each variable is limited to the values 0 and 1, this is a simple matter. Some of the theorems may be proved more elegantly by recourse to previous theorems, but the method of perfect induction is so universal that it is probably to be preferred.

$$X + Y = Y + X \qquad (1a)$$

$$XY = YX \qquad (1b)$$

$$X + (Y + Z) = (X + Y) + Z \qquad (2a)$$

(3*b*), however, is not true in numerical algebra.

We shall now define a new operation to be called negation. The negative of a hindrance X will be written X' and is defined as a variable which is equal to 1 when X equals 0 and equal to 0 when X equals 1. If X is the hindrance of the make contacts of a relay, then X' is the hindrance of the break contacts of the same relay. The definition of the negative of a hindrance gives the following theorems:

$$X + X' = 1 \qquad (6a)$$

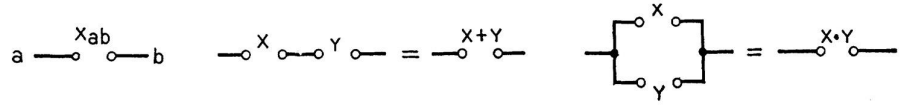


Figure 1 (left). Symbol for hindrance function

Figure 2 (middle). Interpretation of addition

Figure 3 (right). Interpretation of multiplication

Key Texts by Peirce on Logic/Reasoning Machines & Semiotic Foundations

C. S. Peirce, "Logical Machines," *The American Journal of Psychology* 1, no. 1 (1887): 165–70.

Cites:

Babbage's analytical engine

Stanley Jevons's machine

Alan Marquand's "vastly more clear-headed contrivance"

Peirce clearly understood design homologies for logic.

Logical Machines.

In the "Voyage to Laputa" there is a description of a machine for evolving science automatically. "By this contrivance, the most ignorant person, at a reasonable charge, and with little bodily labor, might write books in philosophy, poetry, politics, laws, mathematics, and theology, without the least assistance from genius or study." The intention is to ridicule the Organon of Aristotle and the Organon of Bacon, by showing the absurdity of supposing that any "instrument" can do the work of the mind. Yet the logical machines of Jevons and Marquand are mills into which the premises are fed and which turn out the conclusions by the revolution of a crank. The numerous mathematical engines that have been found practically useful, from Webb's adder up to Babbage's analytical engine (which was designed though never constructed), are also machines that perform reasoning of no simple kind. Precisely how much of the business of thinking a machine could possibly be made to perform, and what part of it must be left for the living mind, is a question not without conceivable practical importance; the study of it can at any rate not fail to throw needed light on the nature of the reasoning process. Though the instruments of Jevons and of Marquand were designed chiefly to illustrate more elementary points, their utility lies mainly, as it seems to me, in the evidence they afford concerning this problem.

The machine of Jevons receives the premises in the form of logical equations, or identities. Only a limited number of different letters can enter into these equations—indeed, any attempt to extend the machine beyond four letters would complicate it intolerably. The machine has a keyboard, with two keys for the affirmative and the negative form of each letter to be used for the first side of the equation, and two others for the second side of the equation, making four times as many keys as letters. There is also a key for the sign of logical addition or aggregation for each side of the equation, a key for the sign of equality, and two full stop keys, the function of which need not here be explained.[1] The keys are touched successively, in the order in which the letters and signs occur in the equation. It is a curious anomaly, by the way, that an equation such as A—B, which in the system of the transitive copula would appear as two propositions, as All A is B and All B is A, must not be entered as a single equation. But although the premises outwardly appear to be put into the machine in equations, the conclusion presents no such appearance, but is given in the form adopted by Mr. Mitchell in his remarkable paper on the algebra of logic. That is to say, the conclusion appears as a description of the universe of possible objects. In fact, all that is exhibited at the end is a list of all the possible products of the four letters. For example, if we enter the two premises All D is C, or D—CD, and All C is B, or C—BC, we get the conclusion in the following shape, where letters in the same vertical column are supposed to be logically multiplied, while the different columns are added or aggregated:

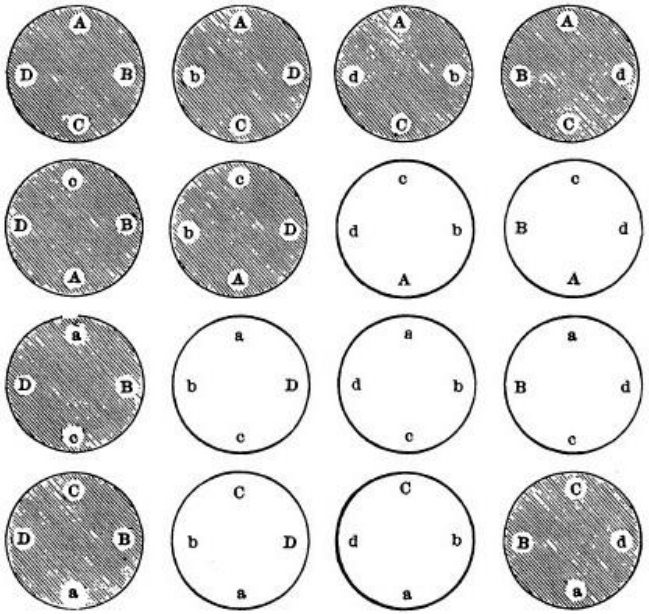
A	A	A		A	a	a	a		a
B	B	B		b	B	B	B		b
C	C	c		c	C	C	c		c
D	d	d		d	D	d	d		d.

[1] Phil. Trans. for 1870.

The capital letters are affirmatives, the small letters negatives. It will be found that every column containing D contains B, so that we have the conclusion that All D is B, but to make this out by the study of the columns exhibited seems to be much more difficult than to draw the syllogistic conclusion without the aid of the machine.

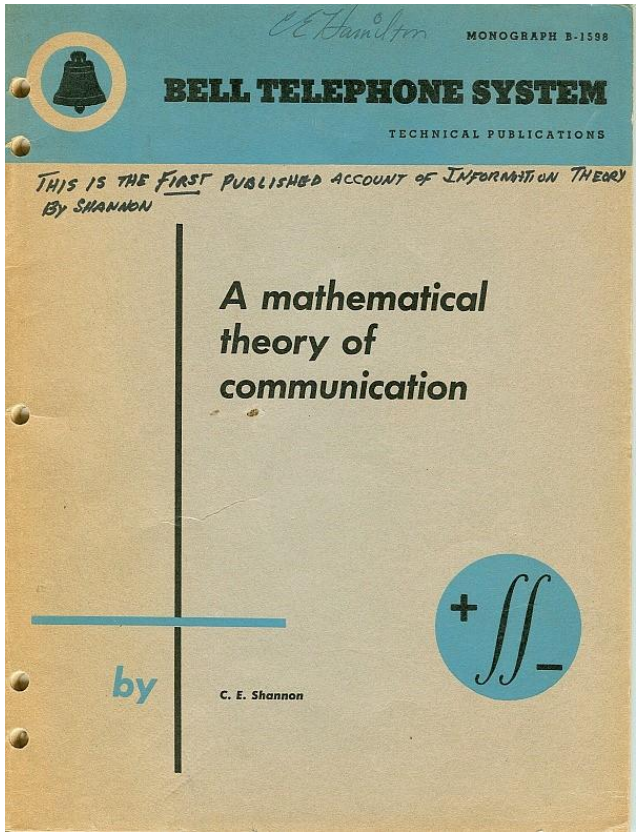
Mr. Marquand's machine is a vastly more clear-headed contrivance than that of Jevons. The nature of the problem has been grasped in a more masterly manner, and the directest possible means are chosen for the solution of it. In the machines actually constructed only four letters have been used, though there would have been no inconvenience in embracing six. Instead of using the cumbrous equations of Jevons, Mr. Marquand uses Professor Mitchell's method throughout.[1] There are virtually no keys ex-

[1] It would be equally true to say that the machine is based upon Mrs. Franklin's system. The face of the machine always shows every possible combination; putting down the keys and pulling the cord only alters the appearance of some of them. For example, the following figure represents, diagrammatically, the face of such a machine with certain combinations modified:



This face may be interpreted in several different ways. First, as showing in the shaded portions—

Next step:
From Peirce to Shannon and Information Theory as Covert Semiotics



From: *A Mathematical Theory of Communication*, 1948

"The fundamental problem of communication is that of **reproducing at one point either exactly or approximately a message selected at another point**. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages."

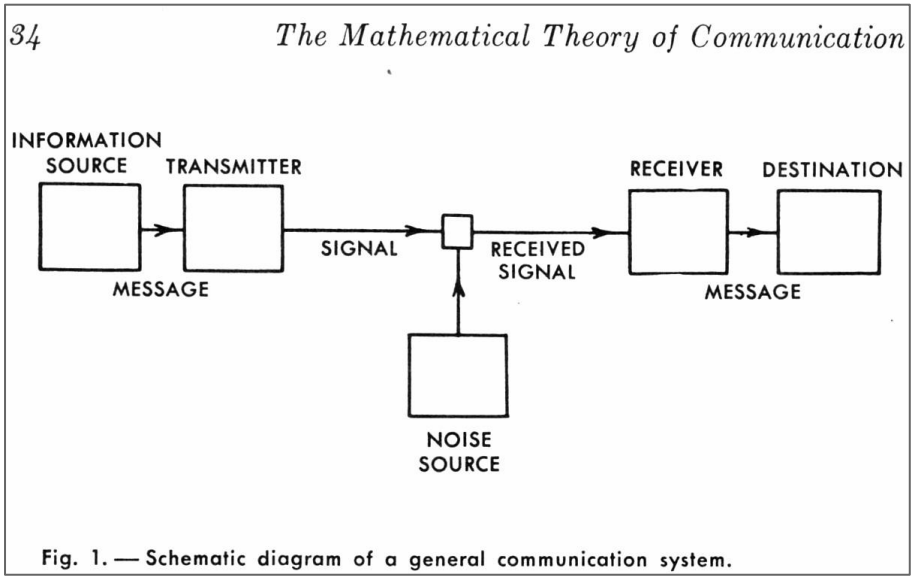


Fig. 1. — Schematic diagram of a general communication system.

"Information Theory" as Digital (Binary) Data Design in the Shannon model is an *engineering solution to a semiotic problem*:

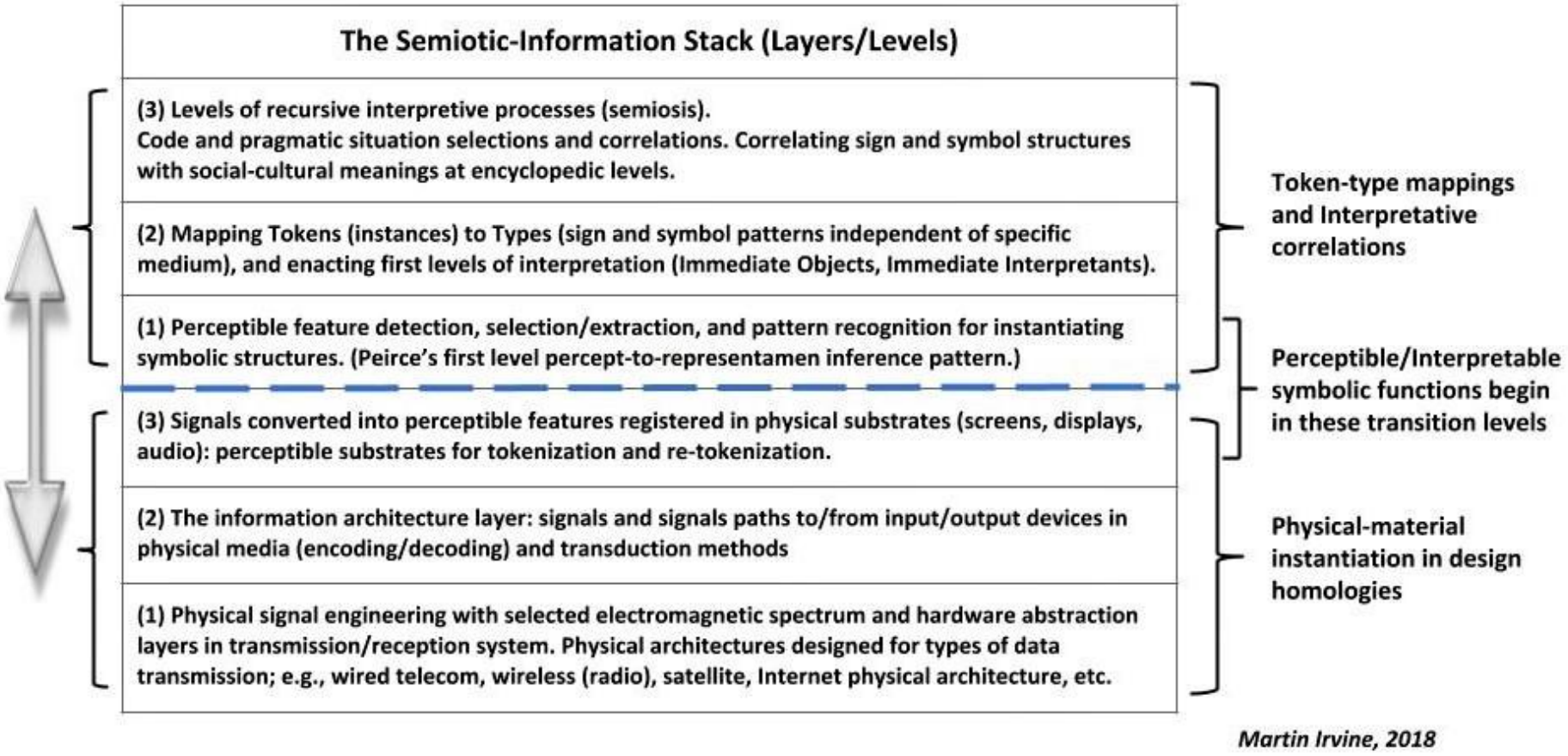
The semiotic design problem solved in information theory is:

How to use selected slices in the energy continuum of the electromagnetic spectrum as a *substrate* for designing *structure-preserving structures* for reliable *tokenization* and *re-tokenization* of the distinguishable, interpretable *patterns* of the symbolic systems encoded.

Modeling representations in binary bit sequences enabled the convergence of telecommunications and computing: any sign system could be digitized and distinguished in data types (sound waves, text characters, mathematical symbols, and matrix of light values for images).

Shannon and Bell Labs-MIT standardization on the bit (binary digit) is a perfect mapping (design homology) of mathematical structure and values ({1,0}, base-2 number system) and logical values (true/false, yes/no, 1/0) to electronic structures (open/closed circuits, on/off, presence/absence of current, +/- voltage charge).

Extending Morse, the symbolic values (types) of sequences of {1,0} mapped to electronic states are reciprocally convertible to token representations of whatever sign system is encoded.

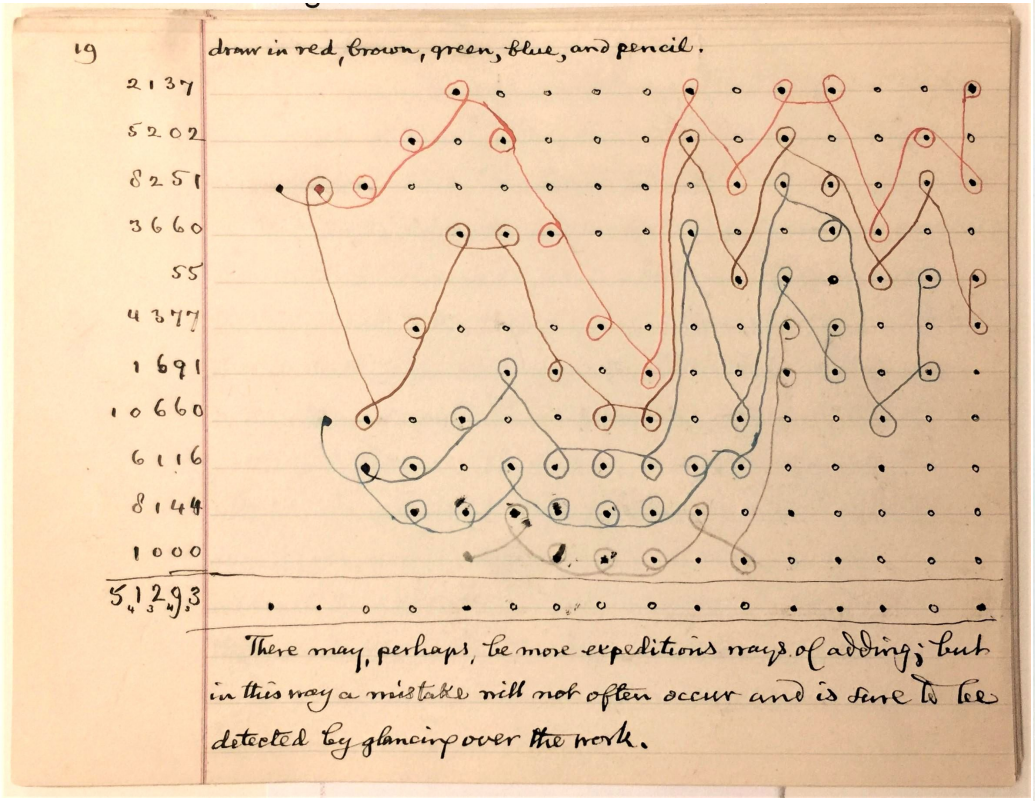


The information-theoretic models are designs for creating *semiotic subsystems* in *structure-preserving structures* of electronic units as substrates for tokenizing and re-tokenizing perceptible-interpretable sign/symbol structures.

The engineering solution for reliable electronic *tokenization substrates* is an *intra-system* design; it is not about semantics or completed semiotic structures because meanings and intentions are *everywhere presupposed*: all sending/receiving of any signal or message is by semiotic motivation and agency. Else, what's the point of defining an "information theory" for electronics *at all*?

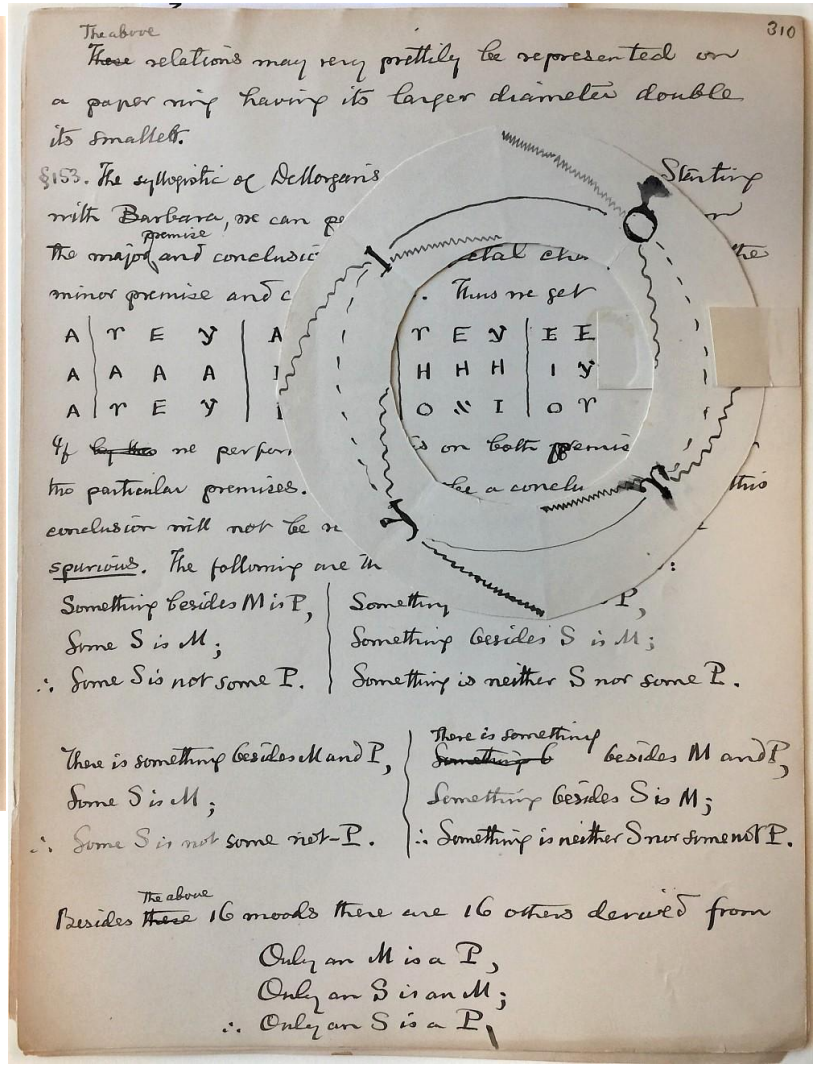
Meaning isn't *in* the communications system; it *is* the system.

Peirce and devices for automating reasoning:
Devices for Binary (Base-2) Computations and Logic Machines



MS 1, *On the Simplest Possible Branch of Mathematics"* (1904): p. 19. Methods for computing in binary (base 2) arithmetic.

Peirce's manuscripts and notebooks contain hundreds of pages of diagrams and devices for computation, and for representing necessary reasoning processes in designed artefacts ("constructions," devices, and aids for "diagrammatic reasoning").



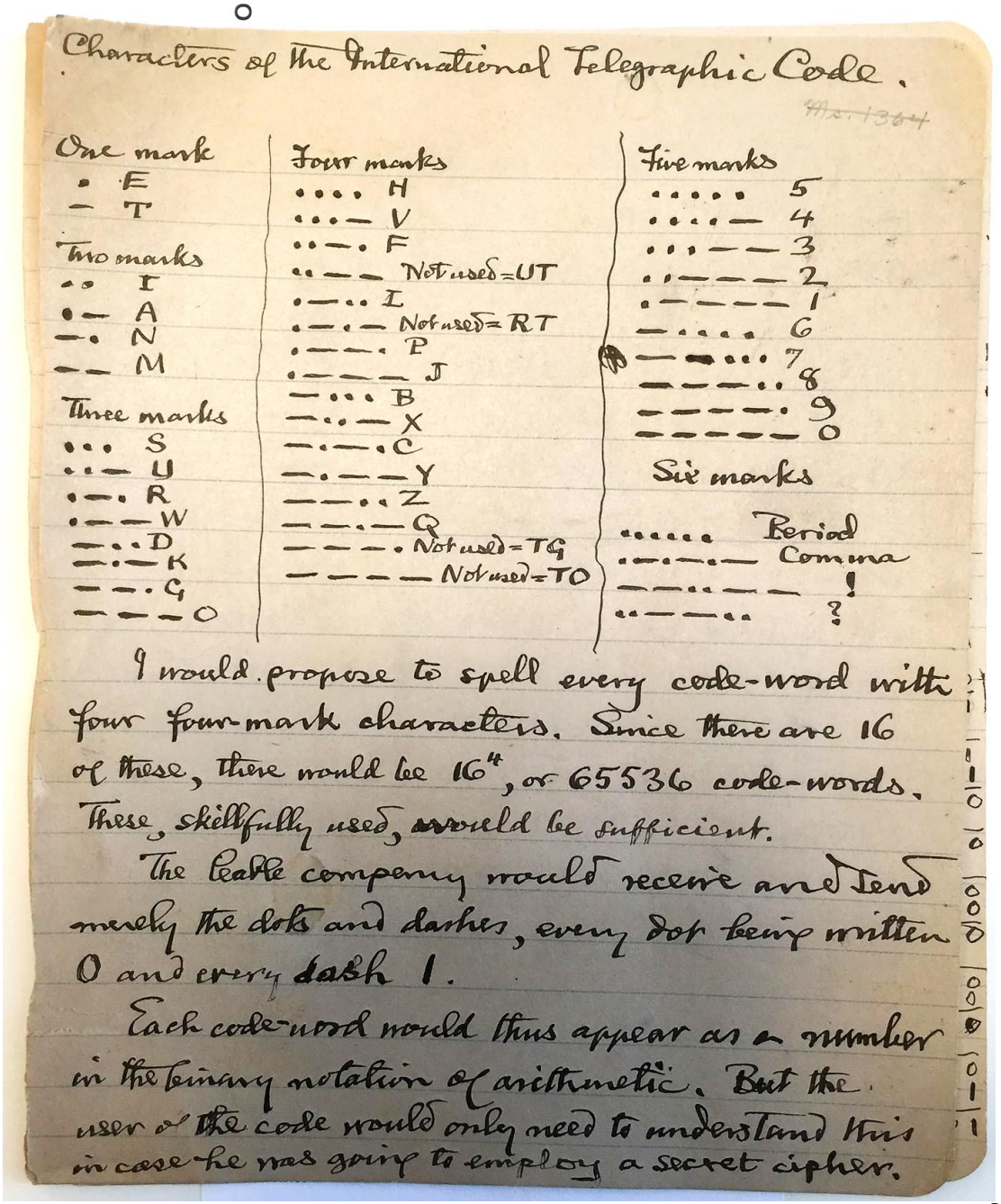
MS 415, *De Morgan's Propositional Scheme* (1890). Paper "logic machine" (marked slide wheel) for demonstrating valid syllogisms.

Peirce, MS 1361, c.1902

On telegraphic code and a cypher in binary for Morse Code

In 1898, Peirce wrote to Henry Cabot Lodge just after the Spanish-American War broke out, offering his method for encrypting Morse code (which may be the technique described in here in MS 1361):

"My ingenuity ought to be rendered serviceable. I cannot make it so without backing. I could make a machine which would write a **cipher dispatch**, as secure as a combination lock, and as readily as an ordinary typewriter, and **a companion machine would translate it as fast as a stock ticker**, -- every dispatch in a different cipher which the machine itself would discover. This would be valuable to merchants in war times." (MS L 254)


Characters of the International Telegraphic Code.

One mark
. E
— T

Two marks
.. I
.— A
—. N
—— M

Three marks
... S
..— U
.—. R
.—— W
—.. D
—.— K
——. G
——— O

Four marks
.... H
...— V
..—. F
..—— Not used=UT
.—.. L
.—.— Not used=RT
.——. P
.——— J
—... B
—..— X
—.—. C
—.—— Y
——.. Z
——.— Q
———. Not used=TG
———— Not used=TO

Five marks
..... 5
....— 4
...—— 3
..——— 2
.———— 1
—.... 6
——... 7
———.. 8
————. 9
————— 0

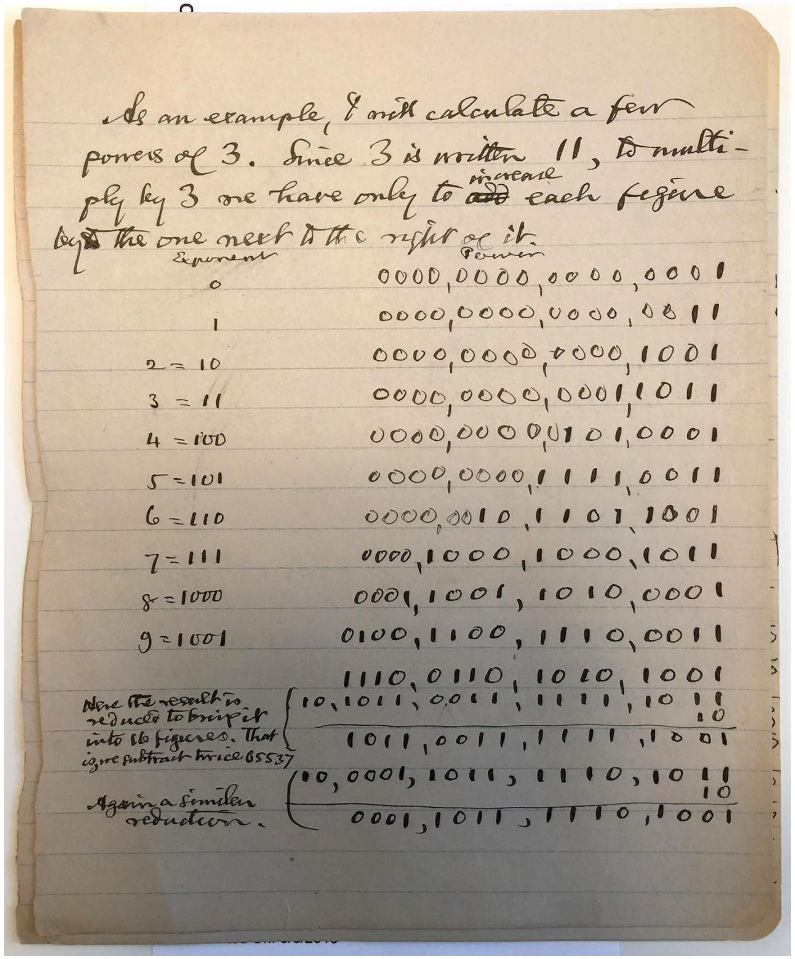
Six marks
..... Period
.—.—.— Comma
——..—— !
..——.. ?

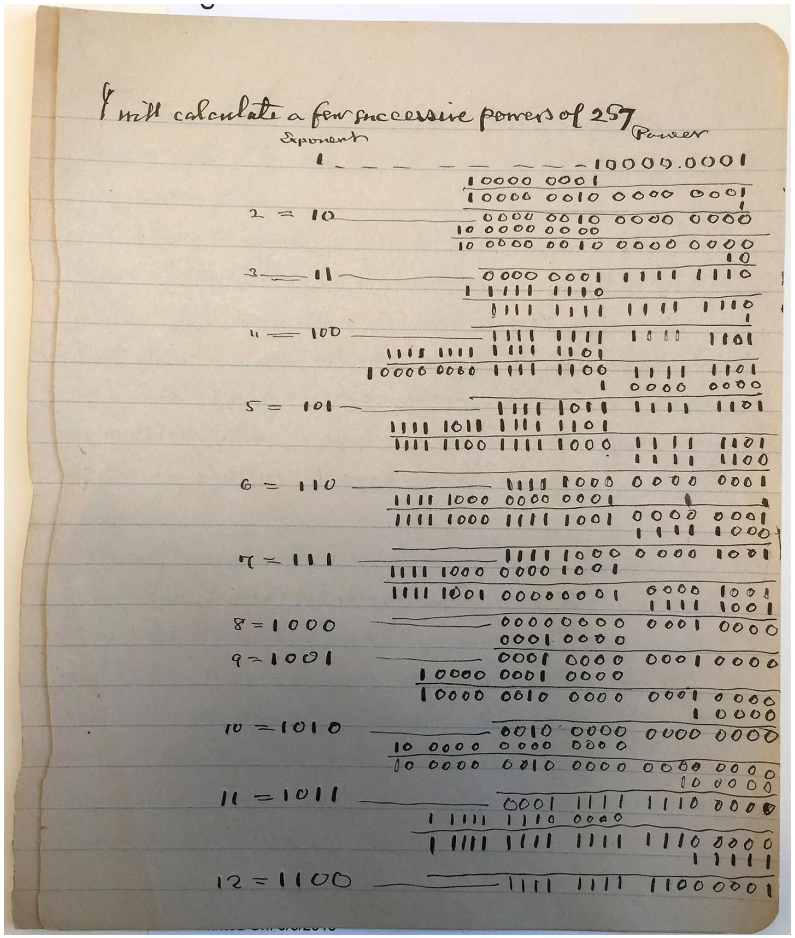
I would propose to spell every code-word with four four-mark characters. Since there are 16 of these, there would be 16^4, or 65536 code-words. These, skillfully used, would be sufficient.

The Cable company would receive and send merely the dots and dashes, every dot being written 0 and every dash 1.

Each code-word would thus appear as a number in the binary notation of arithmetic. But the user of the code would only need to understand this in case he was going to employ a secret cipher.

Peirce outlines an encryption scheme for telegraph code in binary form, and method for using prime numbers as "keys" -- 32 years before similar use in WWII

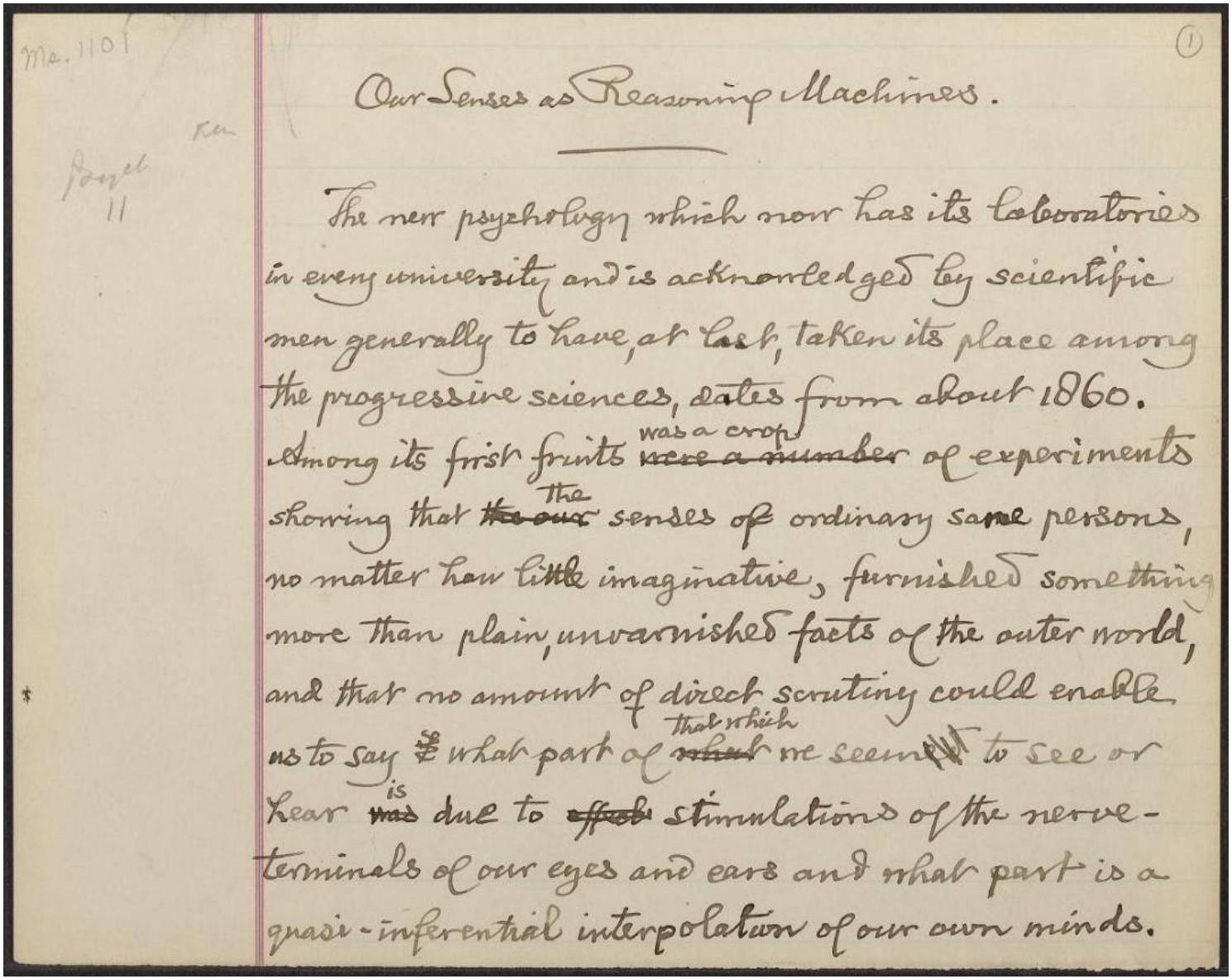




Peirce understood the technique for encoding/decoding alphanumeric characters in **binary strings**, a method underlying all digital text representations from the first computers with teletype keyboards, to standardization on ASCII, and now in Unicode, the international standards for byte-code representations for all written languages (no contemporary text software would work without it). Again, these are formal-physical homologies for tokening and re-tokening written signs as instances in physical substrates.

Some notable pages from Peirce's unpublished papers

MS 1101, 1900



Ms. 1101

Pagel
11

(1)

Our Senses as Reasoning Machines.

The new psychology which now has its laboratories in every university and is acknowledged by scientific men generally to have, at last, taken its place among the progressive sciences, ~~dates~~ from about 1860. Among its first fruits ~~were a number~~ was a crop of experiments showing that ~~the our~~ the senses of ordinary sane persons, no matter how little imaginative, furnished something more than plain, unvarnished facts of the outer world, and that no amount of direct scrutiny could enable us to say ~~in~~ what part of ~~what~~ that which we seem to see or hear ~~was~~ is due to ~~effect~~ stimulations of the nerve-terminals of our eyes and ears and what part is a quasi-inferential interpolation of our own minds.

Peirce,
MS 425, 1902

we know or care, be a hundred ways of thinking in passing from such a premiss to such a conclusion. But the question is whether, granting that there be such a thing as truth, which can be ascertained at all, such a way of adding conclusion to premiss, as that under examination, would lead to the ascertainment of the truth by the speediest path, or not. The whole logical inquiry relates to the truth; now the very idea of truth is that it is quite independent of what you or I may think it to be. How we think, therefore, is utterly irrelevant to logical inquiry.

Reasoning by Machinery.

I must be excused for dwelling on this point, for no other in all logic, although it is a science of subtleties, is so hard to see. The confusion is embedded in language, leaving no words available to epigrammatize the error. Now it is not of fools exclusively, but of the greater part of the thinking world that words are the money. A celebrated treatise is entitled "Logic, or Computation."

Peirce: Quasi-Minds and Sign Mediation

[A] Sign may be defined as a Medium for the communication of a Form. It is not logically necessary that any thing possessing consciousness, that is, feeling or the peculiar common quality of all our feeling should be concerned. But it is necessary that there should be two, if not three, quasi-minds, meaning things capable of varied determinations as to forms of the kind communicated.

As a medium the Sign is essentially in a triadic relation, to its Object which determines it, and to its Interpretant which it determines….

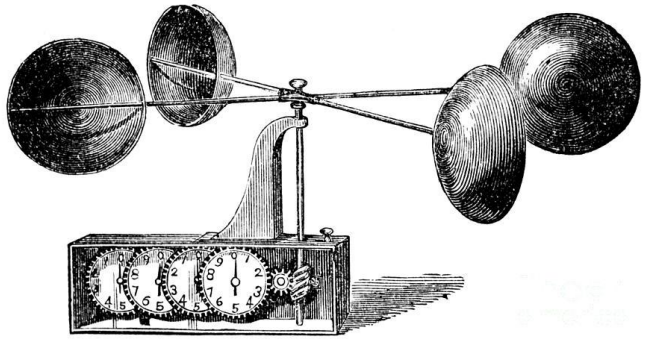
That which is communicated from the Object through the Sign to the Interpretant is a Form; that is to say, it is nothing like an existent, but is a power, is the fact that something would happen under certain conditions.
(MS 793, 1906, pp.1-3)

Indices and Indexical Functions Technically Mediated & Instantiated

THE ROBINSON ANEMOMETER.

It is true, however, and highly important in the development of exact logic, that the different kinds of symbols are connected in certain ways. An index points to its object in certain respects, and it must refer to some icon of those respects. **A Robinson's anemometer is a purely physical representamen, or index, of the wind.** It may be arranged to record upon a chronograph the instant at which every ten miles of air has passed by it. **The chronograph record is thus made the interpretant of the anemometer, in a purely physical way**. Now, the intervals between the records on the chronograph-fillet constitute an icon of the behaviour of the wind. A little reflection will enable the reader to convince himself inductively that an icon is thus connected with every index. In like manner, a symbol cannot existentially denote anything, without appealing to an index to represent the individual denoted.

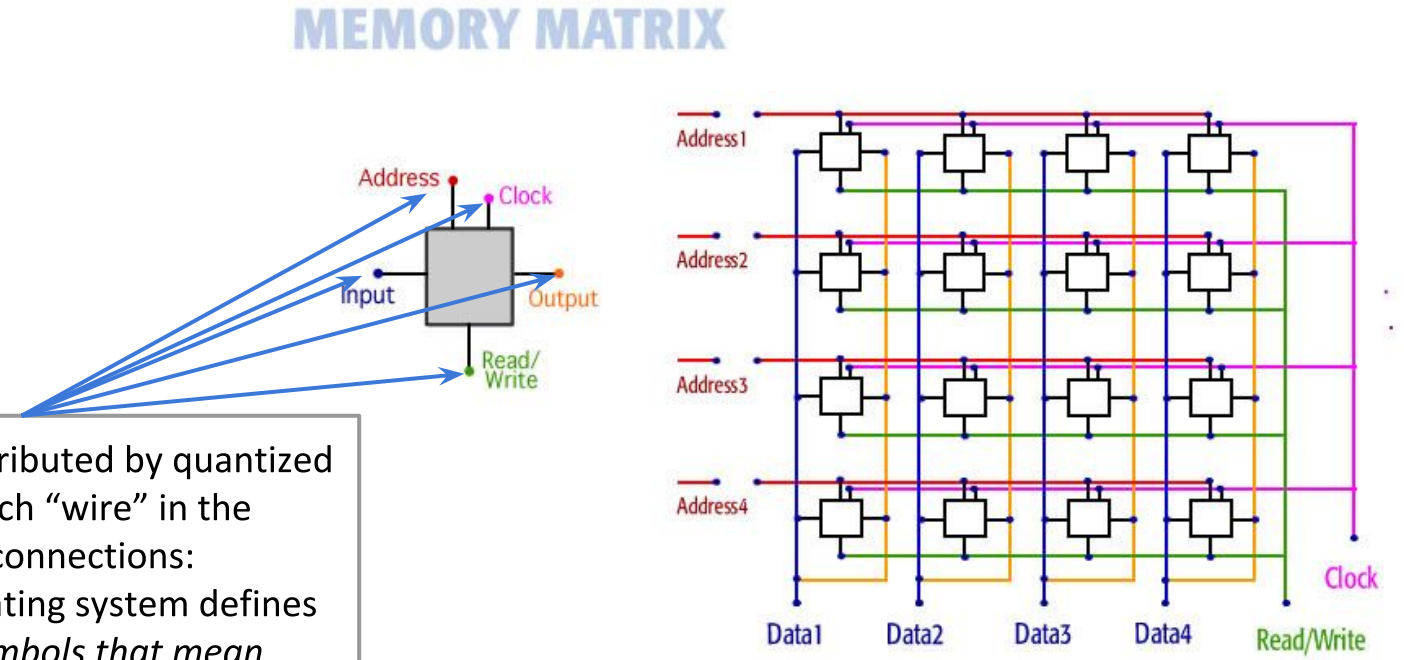
(MS 1147, 1901, draft, numbered pp. 10-11. Unpublished)



Computation: Distributing Indices in Memory Matrices for Digital Tokenization

A basic memory matrix diagram, scalable to *n*-implementations of units.

In Peirce's terms, sign-to-binary state correspondences require ***indices*** to physical substrate locations that represent homologies of values (1, 0) for **structure-preserving re-tokenization**.

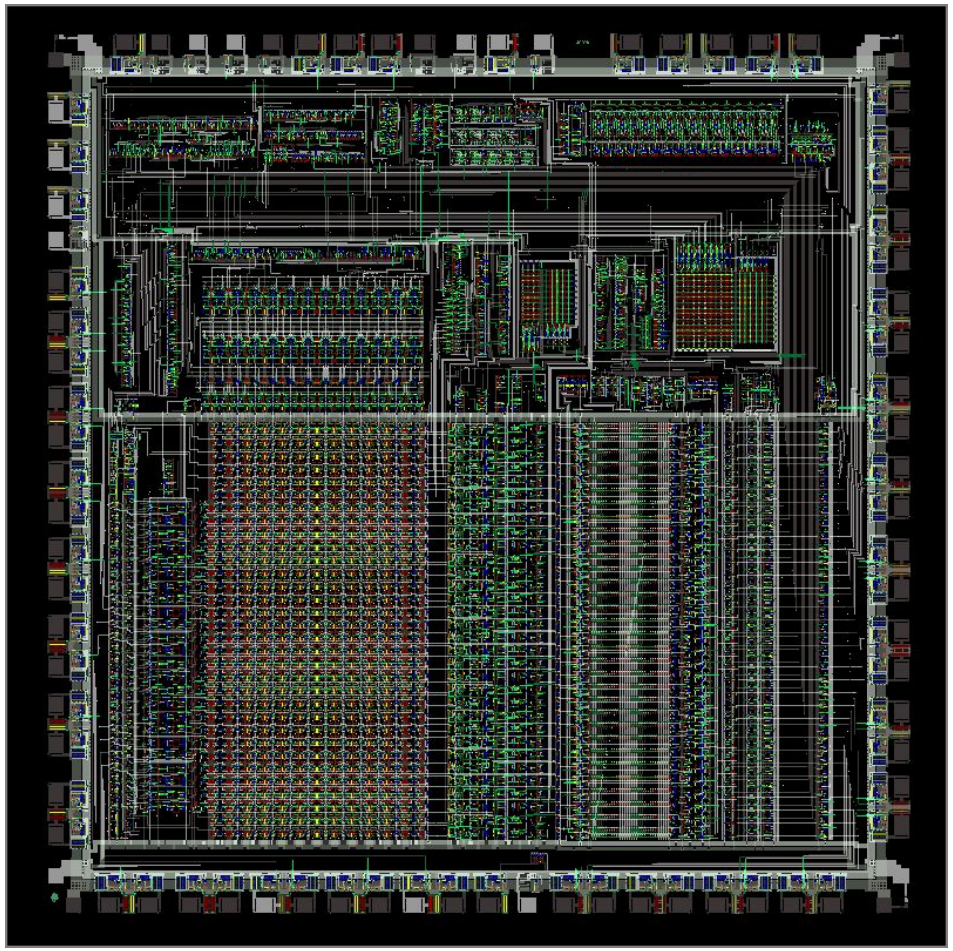


Binary code is distributed by quantized signals to/from each "wire" in the input and output connections:
a program + operating system defines and distributes *symbols that mean things* (units of representable symbol structures) and *symbols that do things* (perform actions and operations).

Visualizing unobservable sign action and representations:

the designed homologies for symbolized abstractions, digital token instances, and the logic of operations, relations and transformations over symbolic structures.

Programming Code (abstract symbols) is enacted *physically* by *design homologies* for computing logic flow and state transitions.



Peirce: Homology of Form and Possibility of "Interactive" Programming, c. 1911. Design of a "logic machine" is itself a semiotic act.

From MS S 51:7-8 (1910-11), unpublished.

[begins broken off, introduction to question of reasoning machines:]
facts represented. Even this is not enough. It would be necessary to feed into the machine the fact of the degree of reasonableness of certain ideas, -- that is to say, the fact that they, in a certain measure, accord with what has been before ascertained about the ways of truth. It is far, far beyond what we could as yet explicitly represent. But **there is nothing inconceivable in it**. When all this was **at last fed into the machine**, it is not to be supposed that the handle could be turned and the conclusion from these premisses be ground out. *The* conclusion! There is no such thing. From the simplest premiss, the conclusions are innumerable. Look at all the propositions of geometry that are yearly added to the stock of conclusions from a few axioms and postulates! No, it will be necessary that **the machine should receive a certain direction** which should confine its results to a certain class of consequences and to a certain order of complexity within that class. Otherwise there would be a multitude of conclusions that no one infinite series could compass. **It is, however, quite conceivable that that, too, should be done**, and that **the conclusion should be worked out by machinery**, and should **be there to be interpreted by human thought** if desired, having up to that time not entered into any human mind. That would be a proposition, -- a *pensandum*, a *cogitandum*, not yet *pensatum* or *cogitatum*; and such pensandum would be what is meant by a *proposition*….

Note: These pages from MS S 51 have been haunting me ever since I discovered them two years ago. Has anyone come across other (probably fragmentary) page sequences in other MSS from this era (1910-11)?

I will treat this text in my book, but let's parse out a few implications here.

Peirce continually returned to the question of whether or how a logic/reasoning machine would be possible beyond numerical calculations and simple syllogistic logic. Here he imagines the possibility of an automated process more closely approximating human reasoning by introducing choice, branching or conditional logic, and sorts or orders of abstraction. The clincher is imagining the possibility of a non-deterministic interactive process -- a human agent providing directions to a machine process while it was *in process*, and the machine working out a process in its architecture that delivers results to human interpretation.

As many know, Peirce was an expert Latin scholar, and he frequently uses Latin terms with the force of their grammatical and semantic significance for concepts with no lexical equivalents in English. In this paragraph, the Latin terms are revealing: (future passive participles) a *pensandum* = to be weighed, evaluated, considered; a *cogitandum* = to be thought or pondered, distinguished from, but in relation to, (past participles) *pensatum* or *cogitatum*, something having been considered, or valued, and something having been thought, something already in mind. Peirce uses the Latin distinctions in a processual, interpretive context: past participles have the sense of objects already formed, future passive participles (gerundives) as that which needs to be formed, a prompting to form the objects of thought by inferences from given sign information. (As Peirce frequently stated, the meaning of a sign is always a *potential future*.) In computation, functions are designs for projecting futures (patterns for input/output relations symbolically represented). Algorithms are designs for enacting symbolic futures.

Computing systems and digital media (in design and implementation) are part of the semiotic *artefactual continuum*

That mysterious thing called Reason which, without the exercise of any force…, **only acts through signs, spoken or written or "scribed" or imagined**. That which has made all our wonderful **engines, wireless telegraphs, telephones, phonographs**, and a thousand other wonders possible, has been the differential calculus, by which scientific men are instructed how to make the experiments that will be important. What is this "differential calculus"? **It is a system of *signs*** invented by the great philosopher Leibniz....

Reason is in itself, -- whether it is anything all by itself, -- we cannot say. It is mysterious. It is what makes man's life noble. It is what gives a man self-control. **It acts through words or other signs.**

From MS 514 (Misc. pages) (c.1911), unpublished.

Note on the use of sources referenced:

I'm not using the sample of texts from Peirce's unpublished papers presented here simply to indicate where Peirce may have been "first," or a predecessor, or may have anticipated the descriptions and models of modern computing and information design (as formidable and interesting as these facts are for intellectual history!).

Rather, we can read the cumulative evidence of Peirce's integrative philosophy -- across the physical sciences, mathematics, logic, technical design, and history of philosophy -- as a well-supported foundation for extending his "logic as semeiotic" to our own cross-disciplinary concerns, and understanding the tacit and unconsciously employed semiotic design principles of computing and information systems.

Computing systems and information technology are now deeply connected to our daily cognitive life and all symbolic behavior, but, so far, methods for exposing the *semiotic artefactuality* of our "semiotic machines" are not widely known. Peirce's integrative semiotic philosophy, extended in a Peircean way, opens up new intersecting paths of knowledge, research, and theory in computer science, the cognitive sciences, and related fields in logic and philosophy (philosophy of mind, language, computing, and information). There is much progress in this work already underway, and there is a wide-open opportunity for anyone working in semiotics to unblock paths of inquiry and develop a contemporary integrative view by extending the path that Peirce opened up.

What are the consequences of a Peircean semiotic redescription of computing systems and digital design?

Computation and digital media structures are *artefacts of human symbolic cognition*.

Digital electronic computing systems are based on semiotic design principles, *homologous designs* of "logic as semiotic" implemented in physical electronic and material substrates for (1) instantiating token structures of symbolic types, (2) enacting logical patterns of recursive interpretation (automatable semiosis), and (3) returning interpretable representations for further *artefactual intelligence*.

Everything designed in/for computing systems is in the service of one or more human sign/symbol system, and the very design of computing and digital information is based on implementing formal symbolic homologies in computational and data substrates.

With the design homologies for combining *symbols-as-data* and *symbols-as-operations-over-data*, computation and digital media processes are designed as structures of symbols that *mean* things inter-specified with symbols that *do* things in the most sophisticated way we've yet invented.

As a designed artefact of the human symbolic faculty -- implemented by means of "logic as semeiotic" -- *all* computing is *humanistic* computing!

Consequences of recovering the semiotic foundations of computing for our current system of disciplines, knowledge domains, and education

Returning to the introductory thesis:

Computing technology at present is covert *semiotics*;
the point is to make it *openly semiotic*.

And in every age, it can only be the philosophy of that age, such as it may be, which can animate the special sciences to any work that shall really carry forward the human mind to some new and valuable truth. Because **the valuable truth is not the detached one, but the one that goes toward enlarging the system of what is already known**.

C. S. Peirce, "First Rule of Logic," MSS 442, 825 (1898)

I think this is the "valuable truth" that has been hiding in plain: a Peircean view reveals that both the *physical designs* and the *sign and symbol systems* served in computing systems (large or small) are part of an *artefactual continuum* of the human symbolic faculty.

What if this "valuable truth...that enlarges the system of what is already known" were taught in introductions to computing and digital media from elementary school on? What if this were the starting point for everyone's participation in "technology"?

Comments and suggestions welcome!

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