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PRINCIPLES OF SEMIOTICS AS RELATED TO MEASUREMENT

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ABSTRACT

Semiotics investigates the symbolization, as related to the coding and the decoding of information in a system of signs. The relation of "standing for" is introduced and analyzed here in its elements of conventionality, in particular in reference to the opposition between analogue and digital coding, and its systemic nature is discussed in terms of the classical distinction of syntax, semantics, and pragmatics. Finally, measurement is presented as a peculiar semiotic operation.

KNOWLEDGE LISTING

1. Signs as entities that "stand for" something

2. Coding and decoding

3. Conventionality of signs

4. The opposition analogue / digital in a semiotic perspective

5. The systemic nature of signs

6. Syntax, semantics, and pragmatics

7. Semiotics and communication

8. Applying semiotic principles to measurement systems

1. SIGNS AS ENTITIES THAT "STAND FOR" SOMETHING

{Semiotics} is commonly defined as the *doctrine of signs*, a {sign} being «something which stands to somebody for something in some respect or capacity» according to Charles S. Peirce, one of the seminal thinkers about semiotics itself. The emphasis is here on the relation of "standing for", which in its simplest form can be modeled as follows.

When a purpose is assigned to, or recognized proper of, things, they can be evaluated in their ability to satisfy it. Any given purpose induces a relation of *functional substitutability S* on the set of considered things *T* such that $\forall x, y \in T, S(x,y)$ if and only if *x* is a substitute of *y* with respect to the purpose, i.e., *x* is as able as *y* to satisfy the purpose itself.

Instead of investigating here the general properties of the relation *S* (but at least the observation should be made that in many cases functional substitutability is not a matter of a yes-no alternative, and therefore that *S* could be usually formalized as a fuzzy relation: see also mm_424), let us devote our attention to the specific relation of *identification*. The functional substitution implied in the identification is such that *x* identifies a given *y* if and only if *x* operates as the selector of *y* in a set of candidate things y_1, y_2, … the exhibition of *x* being considered functionally equivalent to the selection of *y* and the non-selection of any other $y_i \neq y$ in the candidate set. In such a relation $S_{id}(x,y)$ let us call *x* and *y* the *identifier* and the *identified entity* respectively: *x* stands for *y*. For example, the sound c-h-a-i-r (a physical thing as a space-time event produced by the utterance of a speaker) could be the identifier chosen to select a chair

instead of any other non-chair object (note that no restrictions have been imposed on the set of the entities which are object of identification: y can be a physical object but also an informational entity).

It is a common observation that different $x_1, x_2, \ldots$ can be adopted as identifiers for the same entity y, $S_{id}(x_1,y)$, $S_{id}(x_2,y)$, … (a chair can be identified by different sounds, possibly pronounced by different persons in different languages in different times, but also by writings, drawings, gestures, …). In this case the $x_1, x_2, \ldots$ are functionally substitutable with each other in their role of identifiers for y, and therefore a derived relation S_{id-y} holds among them. Formally (we will continue to forget the fact that also S_{id-y} could be fuzzy) $S_{id-y}(x_1,x_2)$ if and only if

$$S_{id}(x_1,y) \wedge S_{id}(x_2,y).$$

A fundamental step is taken when the *class* $\hat{x}$ of all the identifiers x for which the relation S_{id-y} holds is abstractly considered as the identifying entity for y, thus recognizing that signs, although instantiated in physical things, are *information entities* (see also mm_111).

2. CODING AND DECODING

Signs generally result from the relation between two elements: identifiers and identified entities. Such a relation is operatively realized and performed in two phases:

- for a given entity y to be identified, an identifier is obtained by means of an operation of {*coding*}: an information entity $\hat{x}$ is at first associated with y, and then an identifier x is selected such that $x \in \hat{x}$; for example:

the word
"chair"

the sound c-h-a-i-r
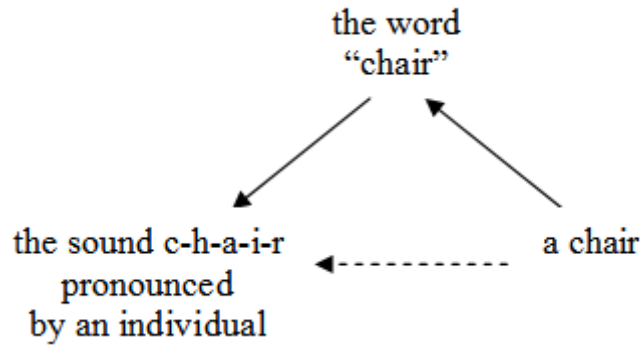pronounced
by an individual

a chair

Figure 1 – An exemplification of the structure of a coding operation

- for a given identifier x, the identified entity is obtained by means of an operation of {*decoding*}: an information entity $\hat{x}$ is at first identified, by means of a pattern recognition, as the class to which x belongs, and then an entity y is selected as associated with $\hat{x}$; for example:

the word
"chair"

the sound c-h-a-i-r
pronounced
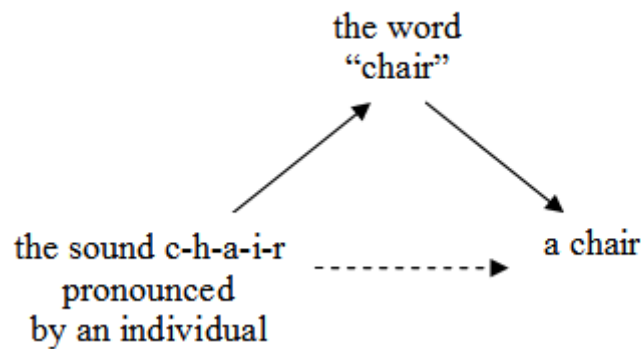by an individual

a chair

Figure 2 – An exemplification of the structure of a decoding operation

(see also mm_137).

The previous two diagrams are instances of a more general "semiotic triangle", in which the "standing for" relation is represented as follows:
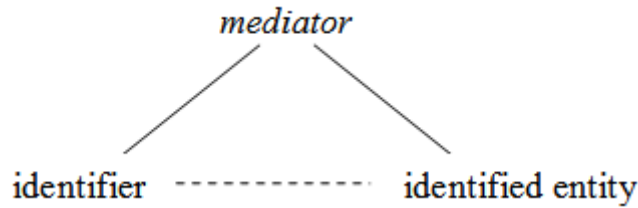
Figure 3 – The "semiotic triangle"

where the dotted line expresses that the relation is indirect and a "mediator" is usually required to connect identifiers and identified entities.

In the history of Semiotics diagrams of this kind have been widely adopted to present and generalize the relation that we have introduced as between identifiers and identified entities. For example, F. de Saussure defined it in terms of "signifiers" and "signifieds" (and called "signification" the relation itself), while L. Hjelmslev used the terms "expression" and "content" respectively.

These diversities witness the different interpretations and emphasis put on the elements of the relation. For example, the mediator has been thought of as either the *sense* of the identifier (chairs are identified by means of the term "chair" because of the meaning associated with such a term, i.e., the set of features which are shared by everything to which the term applies, the so-called *intension* of the term), or the *set of the entities* the entities to what the identifier stands for (the so-called *extension* of the term), or the *subject* with the competence to maintain the relation, or the *social context* of the individuals who agreed to associate the identifier with the identified entity.

In the case the entity to be identified belongs to the physical world (let us mention again that it could be a purely informational entity, as in the case one is talking about words or numbers) a common, although surely not necessary, situation is such that the relation between the physical thing chosen as identifier and the identified entity is mediated by *two* informational entities, for example:
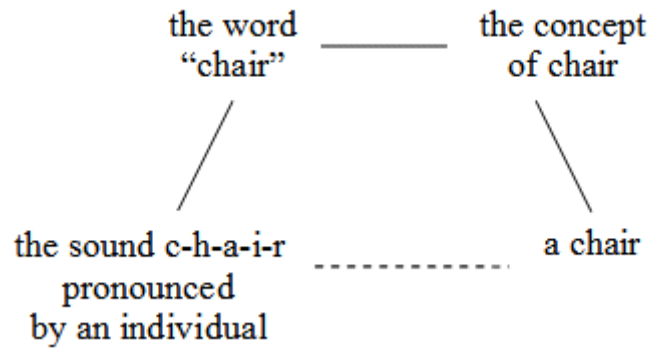
```
     the word  _____  the concept
      "chair"               of chair
            /                      \
           /                        \
          /                          \
  the sound c-h-a-i-r  - - - - - - - - -  a chair
      pronounced
     by an individual
```

Figure 4 – The structure of the semiotic relations

so that each arrow in the diagram :

```
  a symbol  ———————→  a concept
        ↗      ⟍    ⟋    ↘
         \      ⤬      \
          \    ⟋  ⟍     ↘
  an identifier  - - - - - - →  an identified
     object                        object
```
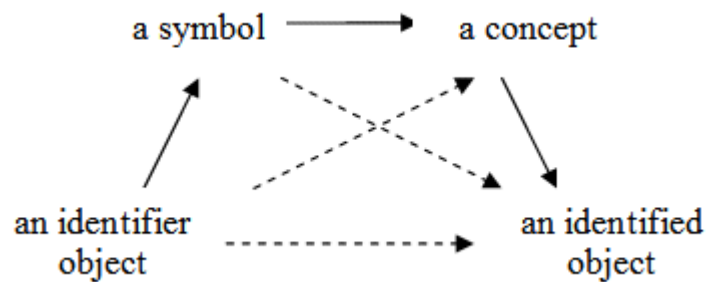
Figure 5 – The "standing for" relations

represents a partial realization of the "standing for" relation.

Semiotics has been particularly working on the *informational component* of the "standing for" relation, therefore often minimizing, or even neglecting, the analysis of the relation between the symbols and the physical things adopted as support for them. From now on we will accept this general standpoint, and follow the terminology proposed by C. Ogden and I. Richards who describe the "standing for" relation in terms of {*symbols*} that stand for {*referents*} (see also mm_59).

3. CONVENTIONALITY OF SIGNS

The "standing for" relation is a complex one: the same symbol could stand for different referents, and different symbols could stand for the same referent (e.g., in the case of the linguistic phenomena of *polysemy* and *synonymy* respectively). This suggests that such a relation is not inherent to the entities involved in it: an entity becomes a symbol only as the result of a choice.

The issue of the (degree of) arbitrariness of signs has been thoroughly inquired by many philosophers, who noticed its fundamental implications in terms of autonomy of symbols in relation to referents and therefore, generally speaking, of language in relation to reality. For example, in Plato's Cratylus the problem of "right names" for things is discussed, and it is concluded that «whatever name you give to a thing is its right name; and if you give up that name and change it for another, the later name is no less correct than the earlier, just as we change the name of our servants; for I think no name belongs to a particular thing by nature».

Following Peirce, signs are usually distinguished in three broad categories, characterized by their increasing degree in conventionality:

- {*indexes*}, such as "natural signs" (smoke standing for a yet unseen fire) and "signals" (a phone ringing standing for a waiting call), for which the symbol is causally connected to the referent, so that every subject informed on the connection is able to infer the existence of the relation;

- {*icons*}, such as images or onomatopoeic words, for which the relation symbol-referent is based on some mutual resemblance or imitation of the related entities; in this case the relation can be intensively learned (e.g., the higher the sound the angrier the speaker) and is easily, while often implicitly, shared among cultural communities;

- {*symbols*} (in specific sense), such as those constituting many elements of textual languages, for which the relation symbol-referent is purely conventional (obtained sometimes by an explicit ruling convention, sometimes by usage), so that it must be learned according to an extensive strategy, i.e., by explicitly listing the symbol-referent pairs.

4. THE OPPOSITION ANALOGUE / DIGITAL IN A SEMIOTIC PERSPECTIVE

The latter two categories, icons and symbols, can be meaningfully expressed in terms of the *opposition between analogue and digital*, as traced back to the concept of *structure* modeled and formalized in Measurement Theory (see also mm_59). The opposition A/D concerns the strategy adopted for *coding and decoding the meta-information* that complements the information that symbols convey on referents. Indeed, together with the information enabling the selection of referents, in many cases some structural information must be maintained in coding and recognized in decoding. For example, if the referent is a grade in {A,…,E} the observation of a physical support coding the symbol "B" should bring both the information "is B" (and "is not A, and not C, …") and the (ordinal) meta-information "is less than A but more than C, …". Therefore:

- *analogue* is the strategy by which the meta-information is coded in the support configuration, so that both coding and decoding correspond to the application of a homomorphic (i.e., structure preserving) mapping;
- *digital* is the strategy by which the meta-information is maintained in the coding rule, so that the physical support is only required to be able to assume at

least two distinguishable configurations (those usually symbolized as "0" and "1"), as specified in Shannon's Theory of Information.

This characterization accounts for the nature of *opposition* of the strategies of analogue and digital coding:

- the definition of the code rule can be intensive in analogue cases, whereas must be extensive in digital cases: while analogue codes can be analytically defined, the lack of structure forces digital codes to be defined by explicitly and completely listing the occurrences symbol-referent;

- the set of information entities to code can be non completely pre-identified in analogue cases, whereas must be pre-identified in digital cases: for example, to increase the cardinality of the set of the possible symbols to code on a physical support an analogue code can be adopted as is, whereas a digital code must be redefined.

On the other hand;

- analogue coding can be adopted only if some meta-information is available, whereas digital coding is always available for finite sets of symbols;

- supports adopted in coding must be able to maintain the meta-information in physically distinguishable configurations in analogue cases, whereas can be very simple since only two distinguishable configurations are in principle required in digital cases.

It should be noted that mixed (partly analogue, partly digital) coding rule are common, as in the case of the usual numerical notation, in which the single digits are digitally coded while the positional rule is analogue.

5. THE SYSTEMIC NATURE OF SIGNS

The "standing for" relations are seldom defined as single and independent coding rules. Rather, their conventionality is considerably restricted by the effects derived by their *systematic definition* (as an example, consider the possibility of reconstructing the meaning of a linguistic term, i.e., "decoding" it, by means of its etymological analysis).

Natural languages, such as English or Italian, are far more complex than artificial languages, such as the formalism of mathematical logic or computer programming languages, also because they include a huge amount of exceptions, i.e., irregularities, in their coding and decoding rules. Nevertheless, the fact that some systematic effects progressively emerge from historical usage instead of explicit decision, as indeed in the case of natural languages, does not reduce their relevance but only the uniformity of the system of rules.

This systemic component was called *language* (*langue*, in French) by Saussure, who contrasted it with *speech* (*parole*, in French), regarded as the individual act of selection and actualization of symbols that stand for intended referents by means of some coding rules of the language. Any specific film would be therefore the "speech" of the "language" of cinema, an example highlighting that *langue* / *parole* is actually the dichotomy code / instance or schema / usage, as Hjelmslev termed it. «Each of these two terms achieves its full definition only in the dialectical process which unites one to the other: there is no language without speech, and no speech outside language: it is in this exchange that the real linguistic praxis is situated» (Barthes).

Dialectical is also the process by which the decoding of composite structures of symbols, e.g., sentences, is performed: paradigmatically, whenever coding rules are *context-sensitive* (a typical characteristic of natural languages), not only the meaning

of a sentence is derived from the meaning of its constituting parts, but also the meaning of such parts could depend on their role in the sentence, so that it can be determined only after some hypothesis of the meaning of the whole sentence itself. This generally makes the recognition of the "standing for" relations a complex, recursive process, and again this explains why the constructs of artificial languages are defined as context-free whenever recognized as adequate (as an example of the role of context in rule evaluation, consider two possible definitions of the disjunction operator OR: if $v(x)$ is the truth value of the sentence x, in classical logic such an operator is context-free, since

$$v(x \vee y) = f(v(x), v(y)) = \max(v(x), v(y))$$

; on the other hand, in the case of probabilistic logic

$$v(x \vee y) = v(x) + v(y) - v(x \wedge y)$$

and therefore the operator is context-sensitive, because

$$v(x \vee y) \neq f(v(x), v(y))$$

, with the term

$$v(x \wedge y)$$

playing the role of context).

6. SYNTAX, SEMANTICS, AND PRAGMATICS

A fundamental classification to isolate the different contributions to the complexity of the "standing for" relation was proposed by Charles W. Morris, who suggested three basic sub-disciplines as the constituting components of Semiotics: {syntactics} (also, and more commonly, called syntax), {semantics}, and {pragmatics}. Despite their large reciprocal autonomy, such disciplines can be presented in terms of progressive extension of scope:

- *syntactical* is the information dealt with as *data*, taking into account the collection of available signs and its structure; a basic issue of syntax is *parsing*, i.e., the check that a sentence is well formed according to a given set of syntactical rules;

- *semantic* is the information dealt with as data provided *with meaning*, taking into account (also) the entities to what the signs stand for; a basic issue of semantics is *truth evaluation*, i.e., the check of the correspondence between the content of a sentence and the actual state of the reality (it should be noted that the evaluation of the truth of a sentence does not always require the interpretation, i.e., the "semantization", of the sentence itself; for example, tautologies in propositional logic (e.g., $A \vee \neg A$) are true for any interpretation of *A*; this establishes a distinction between *linguistic* and *empirical truth*);

- *pragmatic* is the information dealt with as data provided with meaning *and value*, taking into account (also) the relation of signs to interpreters and therefore issues related to behaviors, subjective interests, utilities, …; a basic issue of pragmatics is *relevance assessment*, i.e., the check that a sentence is actually useful for its deemed receivers.

The distinction among these disciplines and their goals can be exemplified by means of that particular system of signs that is mathematics:

- the formula " $2)\sqrt{+} \leq x$ " is not well-formed, so that a fortiori neither its meaning and truth nor its utility for a given subject can be evaluated;

- the formula "2+3=4" is well-formed, its meaning can be evaluated and is actually false in the usual interpretation of its constituting signs;

- the formula "1=1" is well-formed and is true, but plausibly useless for most subjects.

Given the centrality of the "standing for" relation, semantics can be considered the core component of Semiotics. Nevertheless, the threshold between syntax and semantics is not always well defined, and often actually a matter of "point of view". For example, in the case of Morse coding the physical support is an electric current, whose patterns are interpreted as sequences of "dots" and "dashes", whose patterns are in their turn interpreted as sequences of alphanumeric characters; the sequence "dot-dash" is then a semantic entity with respect to an electric signal but it is a syntactical entity with respect to its deemed interpretation, i.e., the character "a".

7. SEMIOTICS AND COMMUNICATION

An important area of application of Semiotics is *communication*, i.e., the transfer of messages conveying some sort of information from a sender to a receiver through a channel (see also mm_133, mm_135). The standard model for a basic communication system has been defined by Shannon: the message generated by the sender is coded into a pattern of signs, here called a signal, that is transmitted by the channel and finally decoded again into a message for making it accessible to the receiver.

sender ——message——→ coder ===signal===⟹ decoder ——message——→ receiver
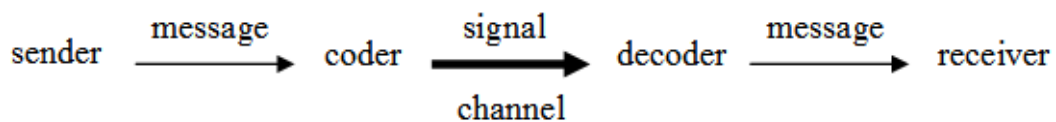channel

Figure 6 – The structure of a communication system

As formalized by Shannon, the communication problem – how to maximize the probability that the received message is the same as the one generated by the sender even in presence of a noisy channel – specifically relates to syntax. The general semiotic nature of the problem has been shown by Roman Jakobson, who suggested that each of the six components of a communication system:
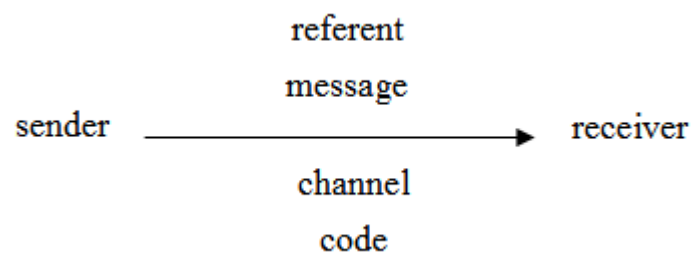

Figure 7 – The components of a communication system

is associated with a specific *function*, more or less present and emphasized in each communication act. Indeed, if the prominence is usually given to the referent (i.e., the "content" of the message, correspondingly to the so-called *referential*, or *cognitive*, *function*), in many messages the role of the other functions must be also taken into account to fully understand the communication act itself. According to Jakobson, a communication can differently stress:

- the position of the sender (*emotive function*) on the communication subject (e.g., in terms of rage or irony);

- the orientation towards the receiver (*conative function*), as typically in the case of imperative sentences, whose aim is indeed to convey commands to receivers;

- the role of the channel (*phatic function*), whenever a support to the management of the communication itself is required, for example to check

whether the channel is still operative between the sender and the receiver (e.g., "are you still there?");

- the formal structure of the message itself (*poetic function*), for example when homophonies, rhymes, … are adopted;

- the requirements on the code (*metalinguistic function*), typically whenever the sender and the receiver want to check whether they are using the same coding rules (e.g., "what do you mean?").

The semantic component is critical in the communications with a prevailing referential function, and the problem of the truth evaluation of their contents can be generally posed. The other functions are instead oriented to the pragmatics of the communication: messages such as "fantastic!", or "excuse me", or "repeat please", or … are conveyed to obtain some communicational aim more than to state a meaning.

8. APPLYING SEMIOTIC PRINCIPLES TO MEASUREMENT SYSTEMS

As an operation aimed at expressing in symbols the information empirically obtained on a system about a quantity, measurement can be meaningfully analyzed in its semiotic character. In comparison with other forms of judgment, there are two general grounds of peculiarity for measurement:

- the mediator between the referent (i.e., the measurand) and the symbol (i.e., the measurement result) is an empirical entity, external to both the measured thing and the measurer subject: the measurement system;

- the symbols adopted as identifiers for the measurands are chosen in a formal language, whose composition and structure are explicitly known.

While for a general semiotic system only the syntactical component can be usually formalized (the attempt was done by logics and philosophers of science such as Y.

Bar-Hillel, R. Carnap, and J. Hintikka to quantify the semantic information conveyed by propositions as their "quantity of content": with such a broad connotation, the problem remained largely unsolved and was substantially left aside), these characteristics of measurement allow to consider it in some more specific terms:

- from the *syntactical* point of view: measurement can be thought of as an operation of selection of a symbol from a set, the actual granularity of such a set (as usually formalized in terms of either number of significant digits or expanded uncertainty) depending on the resolution of the sensing device; the usual Shannon's concept of quantity of information can be adopted in this case, such that the quantity of information conveyed by a measurement result increases as its uncertainty decreases;

- from the *semantic* point of view: measurands are always evaluated relatively to a reference, that is explicitly reported in measurement results in terms of a measurement scale (and specifically measurement unit whenever applicable) and that expresses the actual meaning for the (usually) numerical symbols by which the measurand is quantified; each measurement scale is characterized by a type, the most common scale types (nominal, ordinal, interval, ratio, absolute) being linearly ordered according to the algebraic structure they imply on the symbol set; the degree of semantic information conveyed by a measurement result depends thus on the degree of richness in algebraic structure of its scale type (formally, the semantic information increases as the class of admissible transformations for the scale type becomes more specific);

- from the *pragmatic* point of view: because of the existence of functional relations connecting them (the typical case of physical laws), measurands are embedded in a network of pragmatic information allowing to obtain new

measurement results by computation, i.e., by derived measurement; while a completely disconnected measurand can be defined in a totally arbitrary way, and therefore its evaluation is pragmatically useless, the more the measurand is connected (e.g., the greater is the number of functional relations in which it is present), the higher is the degree of pragmatic information conveyed by its values.

Even this summary presentation shows how the semiotic perspective can be useful to understand some fundamental characteristics of measurement (uncertainty, scale types, and derived measurement) in general conceptual framework.

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