A Semiotic Model of Interacting Systems

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Abstract

A fundamental notion in taking a systems view of the world is that systems interact. This paper considers the question of how systems interact and what the general features of system-system interaction are. A semiotic model of system-system interaction is developed which focuses on the essential aspects of interaction and leads to the formation of a typology of systems. The functional architecture presented by the model highlights the type of knowledge and functions required in order to achieve certain levels of communication. This reveals three broad categories of system - the syntactic system, the information processing system and the intentional system - with various levels of sophistication in each depending on the system's ability to manipulate, transfer and store signs.

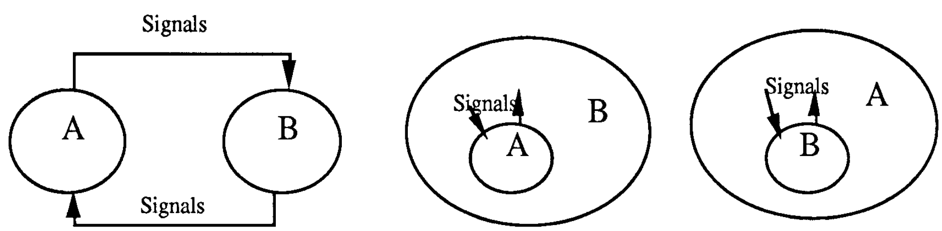
1 Introduction

In human computer interactions misunderstandings are common. The human may assume that the computer understands more than it does. The cryptic messages displayed by computers assume a certain knowledge on the part of the user. Almost always, the expectations which the computer holds of the user are hidden deep in the software design. Similar problems have been commented upon in human interactions with everyday objects such as doors and telephones [1], video cassette recorders [2] and highly complex systems such as aircraft and power plants [3].

A fruitful understanding of these and related problems may be obtained by treating the human as a complex system and abstracting issues concerned with any system system interaction. Casting this model in semiotic terms, i.e. looking at interaction from the perspective of the signs which are necessary for various types of interaction, permits a typology of interacting systems to be produced. This reveals three broad categories of system - the syntactic system, the information processing system and the intentional system - with various levels of sophistication in each depending on the system's ability to manipulate, transfer and store signs.

It is generally viewed that a system interacts with its environment (e.g. [4]) and t is generally viewed that a system interacts with its environment (e.g. [4]) and indeed a system is often defined as being the areas which a system can affect (e.g. [5]). However, every system is itself an environment for other systems and hence interacts with its subsystems. Moreover, systems interact with other systems 'on the same level'. The general case of interacting systems is illustrated in Figure 1(a), with the possible variants shown as Figure 1 (b) and (c).

Figure 1 also illustrates that interaction occurs through the exchange of *signals.* A signal is the elementary particle (viewed at some level of abstraction) of interaction. In this paper the nature of interaction is considered by looking at two forms of interaction - communication and action. Considering communication allows us to develop a functional architecture of interacting systems. This architecture can be used to distinguish clearly between communication and action and to place systems with various capabilities into a typology. It also highlights the other processes and types of knowledge which have to be present for communication to occur.



(a) General model of system-system interaction

(b) System B as environment of system A

(c) System A as environment of system B

Figure 1 Views of system-system interaction. (a) is the general case

2 Communication and action

Systems interact. A seed interacts with the earth and so obtains necessary nutrients for its growth. A hammer interacts with a nail and drives the nail into a piece of wood. I interact with a chair and obtain support and comfort. Such examples of system-system interaction may be considered *actions.* An action is a *physical* interaction. It involves a transfer of energy between the interacting systems.

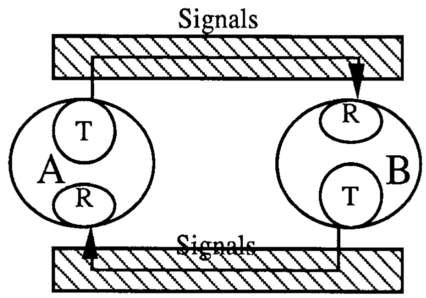
On the other hand, when I have a conversation with another person, our interaction is typically non-physical. We do not touch each other, yet we are clearly interacting. In such cases we would describe the interaction as *communication.* I may consider my interaction with this computer as communication. I communicate with my dog. Although in everyday language, communication and action are treated as different types of interaction, there are clear similarities. A conversation between two people involves physical characteristics. The sound of the voice is conveyed to the recipient through sound resonance on the ear drum. Communication involves action. Physical interactions may also communicate. If I press a button marked 'withdraw cash' on an automatic telling machine, I am communicating a desire to withdraw some money from my account.

Communication and action are intrinsically linked. Gaines [6] argues that actions and communication are simply linguistic distinctions,with actions being directed to the world of physical systems and communication to the world of mental systems such as humans. However, he also recognizes a world of human-machine systems which include both physical and mental aspects and it is in this world that understanding communication is most difficult and important.

2.1. What is communicated?

All interaction involves the exchange of signals and yet communication and action are different. What are the essential characteristics of communication?

Within semiotics or information theory, models of interaction typically emphasize the transmission of signals from a source to a destination. Eco [7] defines a communicative process as 'the passage of a signal, from a source, through a transmitter, along a channel to a destination' (p.8). A similar model is presented by Laszlo [8] following von Bertanffly. Cherry [9] summarizes the work of Shannon and Weaver ([10]) in a similar fashion. We can enhance the model of Figure 1(a) by showing the transmitter and receiver (called *receptor*, here) of signals and thus develop a model of interacting systems necessary for any interaction. This is shown in Figure 2.



(a) General model of
system-system interaction

 communication channel T = Transmitter R = Receptor

Figure 2 Enhanced view of system-system interaction.

Lyons [24] adopts a deliberately narrow view of communication and sees it as 'the intentional transmission of information by means of some established signaling convention' (p. 32). A number of views of communication are presented by [11]. George Miller [12] employs a similar definition, but without the 'intentional'. McCroskey [13] focuses on meaning - communication is the process of stimulating meaning in the mind of another. Cherry [9] sees communication as a social process, involving the sharing of elements of behaviour and Berlo [14] as quoted in [11] defines communication as 'a process involving the transfer of matter-energy that carries symbolic information'.

Most of these authors have as their primary interests natural language as the means for communication and this influences their definitions. For the purpose of the discussion here - to examine communication between systems in general - we need steer a fine course between the linguistic view and the semiotic view of communication.

In the first instance, we need to deal with unintentional communication. If I see some smoke and take this as a sign of fire, or if I see certain types of grasses in a meadow and become aware that there is a swamp there, there can be no intention on the part of the fire or the swamp to communicate its existence to me. Natural systems communicate, but unintentionally.

Secondly, the 'stuff' of which communication is often referred to as 'information'. Information is a confusing term used by different authors to mean different things. Most notable is the distinction which must be drawn between syntactic information which is the subject of information theory [10] and semantic information which is the type of information referred to in this paper unless otherwise stated. In both cases, information can be viewed as 'surprise value'. Information is to do with things which were unknown, or which could not be known before the information was derived. Semantic information is 'an increment of knowledge' [20]. With this definition, communication frequently does not convey information. For example, if a recipient is told something which s/he already knew.

Related to information is the notion of meaning. Is it meaning which is communicated? If I perceive someone waving two flags in a particular manner, I might realize that s/he is using semaphore. However, since I do not understand the signals, I cannot obtain any meaning from them. The same is true if someone communicates with me in a language which I do not understand. Communication does not have to convey meaning.

The essential part of communication alluded to in the above quotations and made explicit by Eco [7] is that communication depends on a signalling convention. Every act of communication '...presupposes a signification system' ([7], p.9). Lyons [24] also includes the necessity of an established signalling convention in his definition. Meaning and information may be *derivable* from a communication of signals given a signification system. However, it is the existence of the system of signification - a system which relates signals to meaning - which is essential for communication.

2.2. Understanding communication

In system-system interaction, it seems useful to distinguish between communication which is concerned with concepts, ideas, emotions and desires and action which is concerned with physical, causal relations between objects. We also have the notions of a sending and a receiving system.

The exchange of signals is communication if *either the sender or the receiver* is able to derive by some mechanism some signification from the signals so transmitted or received. By signification is meant that the signals are linked to some network of representations which signify, or stand for, other things. Whenever, we describe something as communication, it is important to consider the standpoint from which the observation is made. This needs to reveal the level of abstraction of the analysis and the perceptions of the systems concerned in the interaction.

Four categories of interaction may then be discerned.

(i) A pebble dropping into a pond is the interaction of two systems which does not qualify as communication. This is because neither system is capable of associating the signals produced with anything else. There is no meaning to this event for either system. Both sender and receiver attach no signification to the interaction.

(ii) A person who observes ripples on a pond and hence arrives at the conclusion that a pebble has recently dropped into the pond is involved in a communicative interaction. Communication has occurred because the person has interpreted the signals and has derived some signification from the interaction. The receiver attaches signification to the signals received, but the sender (i.e. the pond as viewed as a system) had no intention of communicating anything.

The system of signification may be embedded in a non-human system. Say a system, S, has been developed which monitors the surface of the water by means of a float which will trigger some display mechanism if it is disturbed. If S is attached to a light bulb which lights when the surface is not placid then the interaction is communication (rather than simple action) if a system takes it that the lighting of the bulb *means* (or *signifies)* that a pebble has fallen into the pond

iii) If I shout at my computer, demanding that it should function more quickly, say, I am communicating with the computer (even though it does not know that I am communicating with it). In this case the sender attaches signification to the interaction, but the receiver does not, since (in this case) the receiver is unable to receive the signals.

(iv) If I command a dog to 'sit', I am communicating with the dog *and* it communicates with me (whether it sits or not). Both sender and receiver are aware of the signification (though presumably to a different extent).

Communication is the exchange of signals plus a signification system which associates the signals with some structure which may be said (by some system, from some declared perspective) to stand for something else. The lighting of the light bulb stands for some disturbance on the water. The shout at the computer stands for some feeling of anger, the word 'sit' stands for some the desired position of the dog.

2.3 The effectiveness of communication

The relationship between the sender, the receiver and the signification attached to the signals exchanged suggests that there is a continuum to the effectiveness of communication. At the top level - 'perfect' communication - all the signification attached to the signals intended by the sender is derived by the receiver. Perfect communication would seem unlikely in human-human communication, but is not unusual in simple machine-machine communication. Less than perfect communication involves various degrees of effectiveness in communication which are a function of the amount of signification intended by the sender and derived by the receiver. The receiver may derive more or less than the sender intended. This may be a good or bad thing for the sender and/or receiver. Failed communication is when no signification is derived from the signals, although some was intended

Another issue with communication is concerned with whether the meanings derived from any communication are true. In machine-system communication, there is always the possibility of faulty communication, when a fault in the mechanisms conveys some signals which no longer correlate with the assumed system of signification. In this paper, we do not discuss such matters, being concerned purely with how communication occurs. However, the model developed in the next section does highlight where communication problems may arise.

3 A model of communication

The model of communication presented so far has identified the existence of a system of signification which enables communication to be distinguished from action. Communication involves a system of signification. In this section we develop a more detailed model of what this means and where notions of meaning and information fit into the model of communication.

Looking inside the receiving system we can identify three major processes and the signals which are passed from one to another. The overview of the model of communication - the high-level functional architecture of an interacting system - is shown in Figure 3. This diagram may be described as follows.

Signals are units of transmission (at some level of abstraction) which travel through a communication channel. The receptor process (process 1) receives the signals and transforms the raw signals into a structured set of signals called a *message*, making use of existing knowledge. Process 2 (Derive semantic contents) transforms the message (again making use of existing knowledge) into a representation of the *semantic contents* of the message. It may be necessary for the message to be re-formed and the signals can be passed back to process 1 for this to occur. Process 3 derives *information* from the semantic contents of the message and updates the store of knowledge (if this is possible) or transmits the information directly to the transmission processes (section 3.7). If information cannot be derived from the semantics of the message, process 3 may pass the message back to process 2 where the semantics can be re-formulated.

In the following sections, the details of each of these parts of the functional architecture are examined in more detail. All parts of the system are necessary for effective communication. By examining them in more detail we can see the role of each part of the architecture.

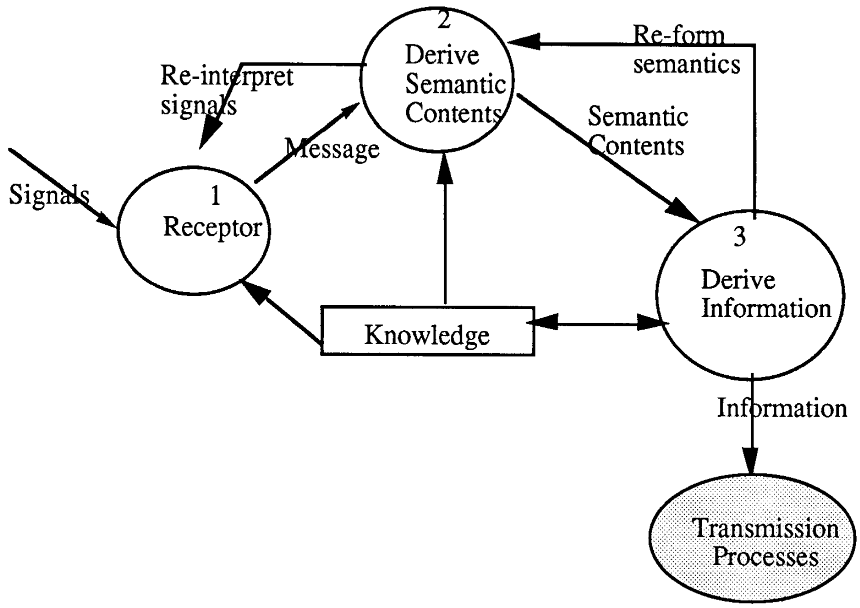


Figure 3. Main processes involved in receiving a communication

3.1. Signals and channel

Signals are units of transmission. They travel along a channel between the source and the destination system. Humans have five senses which define the signals which we can receive. We have built machines which can send and receive many other signals such as infra-red or ultra-violet light, ultra-high frequency sounds and so on.

Signals are simply the primitive elements of a communication channel. Individual sounds are signals as are phonemes, electrical pulses, gestures, animal 'grunts and snarls', marks on paper and so on. Individually signals do not signify anything. However, they have the potential to signify a great many things depending on how they are combined and the signification system to which they are attached.

Signals exist in time and space. and have characteristics associated with these dimensions [9] such as the duration of a sound or the location of a mark on a page in relation to other marks. Signals may be considered binary signals in that either they exist or they do not exist.

For example, the letter S is to be transmitted through the auditory channel as three tonal blips, thus; blip, blip, blip. A comma indicates a short period of silence - the absence of a 'blip'. It should be clear that

blip, blip, blip

is different from

blip,blip,,,,,,,,,,,blip,,,,

and it is likely that any system will interpret the first in a different way from the second. The transmission of signals therefore requires some structure to be observed and if this structure is not as anticipated, the signals my be taken to signify something other than what was intended. This problem is nicely illustrated by a child's handwriting in which the gaps between the letters are often larger than the gaps between words. Interpreting the signals is extremely difficult because the usual conventions for parsing the signals has been lost.

The channel of communication provides the medium through which or by which the signals are conveyed from sender to recipient. There may be multiple channels of communication and there may be parallel channels. Each channel associated with a type of signal. Certain signals are more appropriately transmitted through certain channels than others. For example,. a complex drawing is not easily transmitted by verbal or tonal signals through the audio channel.

Problems arise if the channel is 'noisy', i.e. if it allows other random signals to interfere with the transmission of the intended signals. Noise is a characteristic of all communication. (Syntactic) information theory [10] is primarily concerned with the channel of communication and the amount of noise which enters into the signals. An important design decision is the need for redundancy in the signals transmitted to ensure that they are received without error.

3.2. Signs and symbols

When signals are received and interpreted they may become signs i.e. they may signify something else. If a signal simply provides a stimulus, it is not a sign since it does not signify (for the recipient). A signal acting as a stimulus is what we have called an action.

In order to signify something, a signal must be placed into a context of a system of signification which links the purely syntactic expression of the signal(s) to a semantic system. Meaning may be derived from this relationship. It is this relationship - between the signal(s) and the things signified which is a sign. Eco ([7], [15]) emphasizes that it is the relationship which is the sign by saying that a sign is always a sign-function. Also following Eco, we may use the term *sign-vehicle* for the syntactic part of the sign (i.e. for the signals once they are associated with a semantic system) and *sign contents*, or meaning for the semantic part of the sign. Symbol is used by a number of authors (e.g. [3]) to indicate the thing which the receiving system 'understands' - i.e. the sign contents. A symbol is the conceptual side of a sign. C. S. Peirce (in many senses one of the founders of semiotics) uses the term 'interpretant' for this ([7], [9]).

Semiotics is littered with other terms which are not particularly useful for our purposes. The classic Peircean trichotomy identifies three types of sign - symbols, icons and indexes (or indices). Symbols are a class of sign which are connected to the thing which they refer to by virtue of some convention, or arbitrary relationship. Icons have a similar structure to the thing which they signify. They have a natural resemblance. Indexes are signs which are really affected by the object. The glowing of a fire is an index of the heat of the fire. There is also considerable discussion about whether a sign refers to a class of objects (a legisign) or whether it refers to specific tokens or instances of objects (sinsign).

Several of these distinctions assume that there is a person who is interpreting the signals. Moreover, different interpreters will consider icons to be indexes, and indexes to be symbols. Such a classification does not help in general system-system interaction and in this paper we have no need to exploit such classifications. Similarly, we have no need to dwell on a discussion of the syntactics, semantics and pragmatics of signs. Syntax is concerned with the sign's expression, semantics with the sign's content (by content we mean semantic content) and pragmatics with how understandable the sign is and how useful it is by various different individuals or cultures.

Following and interpreting Eco [7] who bases his model on Hjelmslev [16], we may define the

- signifier (or sign-vehicle) which is the signals when placed in a relationship with a system of signification
- signified (or sign content) which is the (conceptual) entity associated with a signifier when put in relationship with a system of signification
- sign (or sign-function) which is the relationship between the signifier and the signified

Both the sign-vehicle and the sign content have a substance representing what each is and various different forms, or representations. The term 'symbol' is reserved for the substance of the sign content.

For example, consider Morse code. I may choose to relate the letter 'S' to a sequence of three signals, say of short duration. However, I can *express* these signals in a number of different ways, or though a number of different media - e.g. as three dots on a piece of paper, as three electronic sounds 'blip, blip, blip' as three flashes of light, and so on. The *form* of expression and the *substance* of expression constitute how the sign is expressed.

In a similar way I can alter the content of the sign - the semantic component. In this system the content of the sign is the (concept of the) letter 'S'. The *substance* of the content is (the symbol) 'S'. This may be represented in various *forms* e.g. displayed (in varying 'fonts' such as 'S', 'S' or '**S**'), spoken or represented in the mind of the receiver as some mental concept. The form of the content describes the way that the substance, or concept is represented. This is illustrated in Figure 4.

A sign for the letter S

Expression (Signifier, or Sign-Vehicle) (Syntax)		Content (or Signified)	
Substance (the signals)	**Form or medium**	**Substance (or symbol)**	**Form or representation**
blip, blip, blip	sound		displayed as an
		(the concept of)	'S', 'S' or '**S**'
flash, flash, flash	light	the letter	spoken
• • •	marks on paper	S	mental representation

Figure 4 Expression and Content of Signs

The content form is another sign expression. If the signification is to remain in the receivers head, expression is unnecessary and it is more useful to introduce the notion of *representation* of the content. We can, therefore, posit that the content is represented in the mind of the receiver, without getting involved in a discussion of exactly how this representation is physically accomplished. If the sign content is to be further transmitted, then the content form becomes the expression of another sign. This 'infinite semiosis' is an important part of a semiotic definition. Signs are only expressible as other signs.

3.3. The receptor

The receptor is the mechanism which receives the signals and produces a coherent structured set of signals. Hence it is most important that the receptor is tuned to the form of the sign's expression. The sensitivity of the system to the signals is a feature of the receptor. Also, the receptor has to actively process and organize the signals which it receives.

In the Morse code example, the letter S is to be transmitted through the expression as three tonal blips, the receptor has to

(i) be able to 'recognize' a blip

(ii) recognize not a blip

(iii) remember that there has been some previous blips.

The receptor has to be sensitive enough, yet robust enough to deal with difficulties and noise.

In terms of the model presented here, the receptor is passive with respect to the signals which it can receive. Issues concerned with how a system focuses attention, or with the active seeking of signals in the world may be attributed to some some higher level function of the system which organizes and direct s the receptors available, perhaps tuning them or making them more or less sensitive.

Figure 5 illustrates, conceptually, the operation of the receptor function. This type of diagram has already been used in this paper (Figure 3). We may call such diagrams 'sign-flow diagrams' following the notion of data flow diagrams, ([17], [18]). Sign-flow diagrams describe the type of signs which are communicated between the functions (or systems) illustrated by the circles. Boxes show the knowledge stores which are logically necessary for the function to do its work. Since they are sign-flow diagrams, we need to provide the reader with some notion of the meaning of the sign-vehicles which are the actual labels used on the diagram. Hence the description of the labels used are part of the diagrams. A particularly useful feature of the sign-flow (or data flow) diagrams is that of hierarchy. The processes numbered 1.1, 1.2, etc. are a true, finer grained description of the process 1 in Figure 3 and all sign-vehicles shown flowing into or out of a process are shown at each appropriate level.

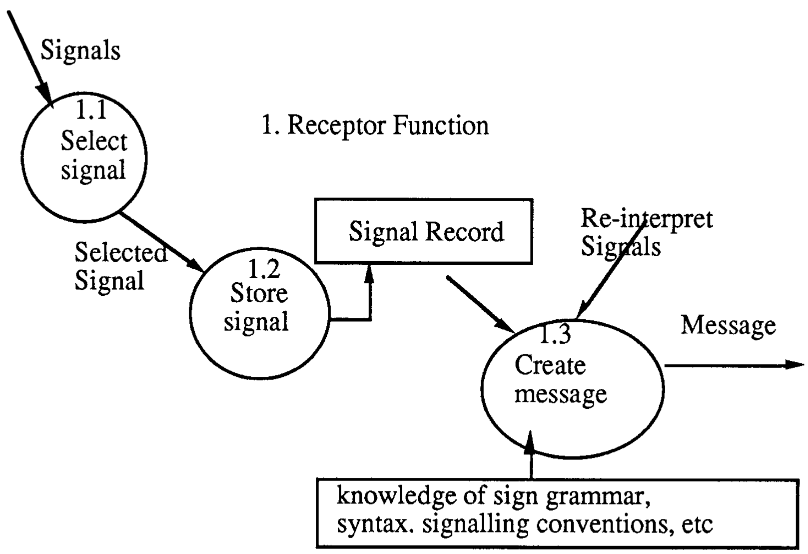
Figure 5 may be interpreted as follows

1.1 Through this process, the receptor has to sense the signals. It will be tuned to the type and intensity of the signal and its position in time and space. It has to separate the signals from the noisy world.

1.2. Selected signals are then stored in some (short-term) memory called the signal record.

1.3. The create message process forms the signals into a message which is a coherent, structured set of signals. This process provides enough structure for the next stage of the interaction (see Figure 3 and Figure 6). In order to structure the signals, the receptor needs access to the grammar of the signalling system. The message is passed to the next process. The 'Create message' process may be required to re-interpret the signals (i.e. to restructure them) if the derive semantic contents process cannot interpret the message.

For example, process 1.1 selects the 'blips' from the world by means of being attuned to a suitable sound frequency. Each 'blip" (each individual signal) is stored (process 1.2) until the message can be created (process 1.3). In the case of Morse code this process divides up the individual 'blips' according to the length of the gaps between the blips. Once three blips have been arranged into a message, the message is sent to process 2 of Figure 3 so that the semantic contents can be derived.



Signals - the elementary particles of communication

Selected signal - the signals which the system is capable of receiving

Message - a structured set of signals

Re-interpret Signals - the Message returned along with contents indicating why it could not be interpreted (see section 3.4)

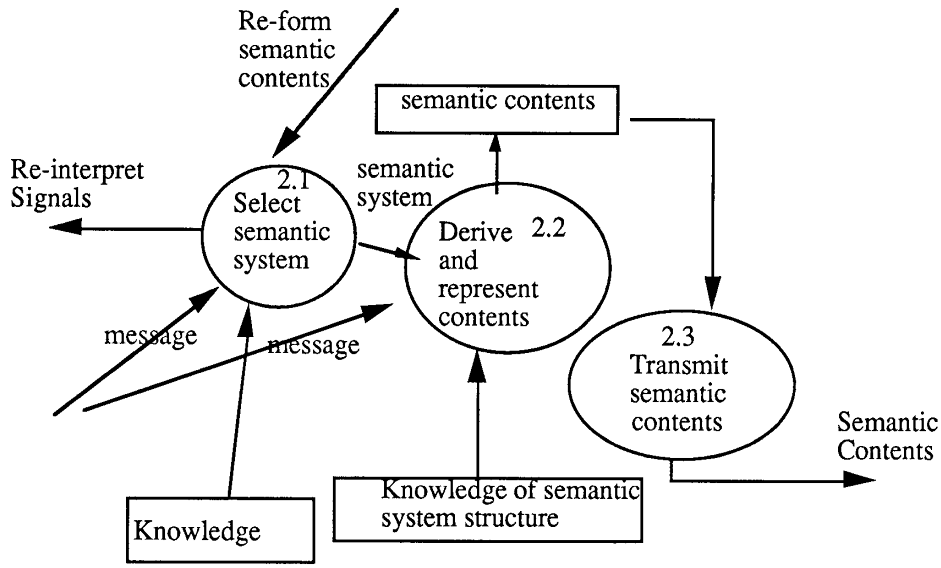
Figure 5 The functioning of a receptor

3.4. Deriving Semantics

Meaning does not simply reside in the message. It has to be derived in relation to previous knowledge and experience. Once the system knows what is being referred to (signified) it has obtained the semantic contents of the message.

The processes involved in this are illustrated in Figure 6. The message is received by process 2.1 which is responsible for selecting a suitable semantic system (the system of signification). This structure is passed to process 2.2 along with the message so that the semantic contents can be derived. If the semantic contents subsequently has to be re-formed and. the semantic contents is passed back by process 3 (see Figure 3), a new semantic system may be required. The message is then 'decoded' (process 2.2) by referring the message to the semantic system in order to determine the semantic contents. This is represented in some form in the system and stored in a memory called 'semantic contents'. Process 2.3 subsequently transmits a suitable contents to the derive information process.

For example, the process 2.1 receives the message 'blip, blip, blip'. The semantic system of Morse code is selected and hence the message can be connected to the concept of a letter 'S' (process 2.2). This is stored. If a single 'S' is transmitted to the deriving information process it is unlikely that information can be successfully obtained. Process 2.3 therefore waits until an informative message is received - say the 'S' is stored until an 'O' and another 'S' is received. The semantic contents 'SOS' is transmitted (process 2.3) to the derive information process.



message - a structured set of signals

Re-interpret Signals - the Message returned along with contents indicating why it could not be interpreted

semantic system - description of the semantic system selected

semantic contents - the content of the sign. The result of applying the semantic system structure to the message.

Re-form semantic contents - semantic contents along with contents indicating why it could not be interpreted (see section 3.5)

Figure 6 Deriving the semantic contents

3.5. Information and Knowledge

Although the sign has been related to the concept (or interpretant) that is, in some sense the meaning of the message has been understood, the system has yet to deal with that meaning. For example, if I successfully derive the semantics of a message such as

'...the tragic universe of Joseph Conrad...'

I have concepts of Joseph Conrad, the author, and all I know about him and his writings. I also have the concepts of a universe and tragedy. These concepts link to other concepts with relationships to other concepts and so on. Although I 'understand' the message, do I have the ability to successfully interpret the semantics and to what extent can I integrate the semantics which I am able to interpret with my existing knowledge?

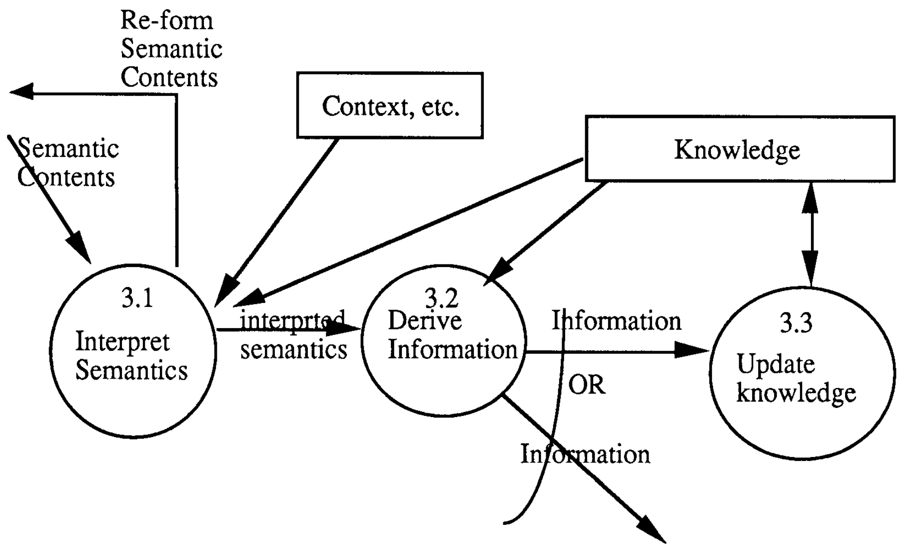
In processing the signals '...the tragic universe of Joseph Conrad...', a system has to derive the semantics and interpret them within the context of the current interaction and previous knowledge. Someone trained in literature will be able to interpret the same semantic contents far more fully than I, because of their richer mental concepts and associations. To some of you reading this, virtually no meaning will be obtained from the above phrase even though you have successfully derived the semantics of the message.

The ability to derive (semantic) information from the semantic contents of the message depends on

- the ability of the system to interpret the semantic contents of the message
- the ability to integrate the semantics of the message so interpreted with existing knowledge.

In the Morse code example, I must be capable of interpreting the semantics of 'SOS' in terms of it being a distress call. I may have correctly derived the semantics from the code, but I may not have the required previous knowledge to be able to interpret it as a distress call. If I can interpret the semantics as a distress call, what information can I derive from this? It may be that I knew that the other system was issuing a distress call already. In such cases the message provides no information - there is no 'surprise value'. It may be that I didn't know this and so I am able to update my knowledge accordingly. It may be that such information will directly trigger some other function of the system.

The process of deriving information from the semantic contents of a message is illustrated by a sign-flow diagram in Figure 7. Process 3.1 interprets the semantics in relation to the system's current state of knowledge and the context of the interaction. The interpreted semantics are passed to process 3.2. If it is not possible to interpret the semantics, the semantic contents along with some indication of the problem is passed back to process 2 (Figure 3). Information is derived though process 3.2 in relation to existing knowledge. Some systems will have the ability to update the content and/or structure of their knowledge store in the light of this information (process 3.3). Other systems will not have this capability and the information will flow directly to the transmission processes.



semantic contents - the content of the sign. The result of applying the semantic system structure to the message.

Re-form semantic contents - semantic contents along with contents indicating why it could not be interpreted

interpreted semantics - the result of associating the semantic contents with current context and stored knowledge

Information - new knowledge. The result of associating the interpreted semantics with existing stored knowledge.

Figure 7 Deriving information

3.6. Summary

The three stage model of deriving meaning from signals has been suggested before ([19], [22], [23]) and is reminiscent of a number of philosophical accounts. In 'Beyond Belief', Daniel Dennett [21] explores the issues in trying to determine what (and if) beliefs are. His concept of a notional world seems related to the concepts which have been used in this paper - of signs, systems of signification and derivation of information. However, Dennett does not explicitly consider a semiotic perspective in his philosophy.

Although in this paper, we cannot hope to pursue the philosophical ramifications of the model presented here, it is interesting to look at the comparison of Dennett's model and the model presented here. Deriving from the work of Kaplan and from Perry, Dennett [21] produces a four stage model of belief derivation.

- physical features + design considerations = syntactic features

- syntactic features + linguistic conventions = character
- character + context = content
- content + circumstances = extension

This seems to echo the features of our semiotic model that

- signals + syntactic system = message
- message + semantic system (system of signification) = semantic contents
- semantic contents + context (and other knowledge) = interpreted semantics
- interpreted semantics + knowledge = information (actually obtained)

3.7. Transmission

Receiving signals and deriving semantics and information from them is only half the story of interaction. The other half is the transmission of signals. To a large extent this can be seen as the reverse of the receiving processes. Firstly, however, we need to consider what triggers the process of transmission of signals. We can identify three triggering mechanisms and hence identify three types of system; the syntactic system, the information processing system, the intentional system.

1. The syntactic system

A system interacting with another system simply emits signals in response to the receipt of signals; for example, the pebble falling into the pond. There is no sense of semantics in such systems. There is a direct casual link between the receiver and the transmitter. Transmission is unintentional and without meaning (for the system itself).

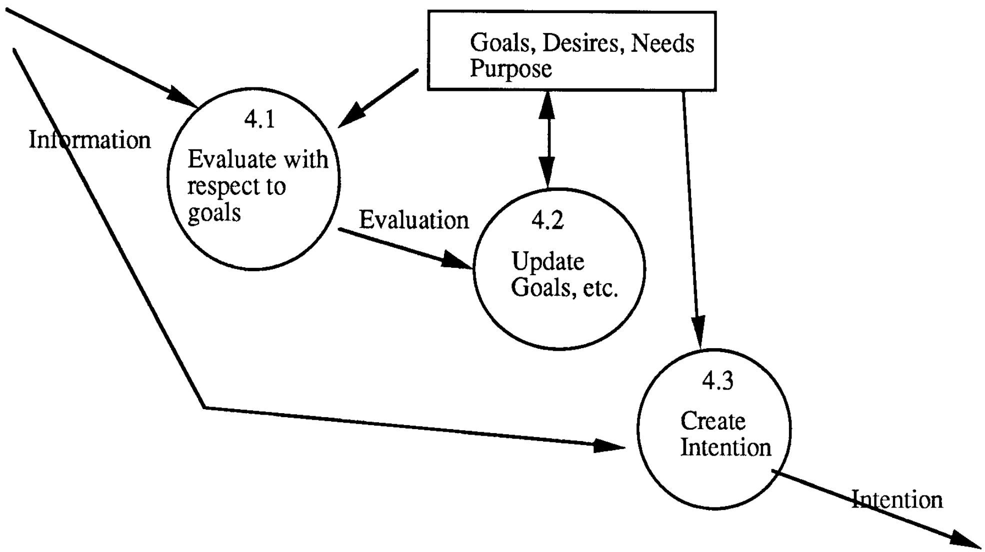
2. The information processing system (IPS)

The information processing system reacts directly to information derived from the receipt of signals. Instead of storing the information for later use, the information processing system has a link between deriving the information and transmitting another message. It is a semantic system, complex enough for the signals to signify some other thing, for processing to be based on the manipulation of symbols and the translation of these into signals for transmission.

3. The intentional system

Intentional systems transmit signals with the purpose of communicating some signification to another system. They do so in order to further their goals which must, therefore, be represented within the system. Intentional systems have the ability to store knowledge rather than reacting to information flows. Whether the production of an intention is always triggered by information derived from the receipt of signals or whether the trigger mechanism arises internally in the system is a moot point which this paper does not attempt to address. Both are consistent with the sign-flow diagram in Figure 8.

The remaining parts of the transmission process involve the creation of the semantic content of the required message (Figure 9) and translating it into appropriate signals and transmitting the signals (Figure 10). There are many considerations involved here to do with selecting an appropriate medium, how the pragmatics of the signs are considered and so on. These can be left out of the current discussions since they do not affect the functional architecture. Figure 9, dealing with the create T-message process concerns all things semantic and pragmatic. The transmitter process deals with only syntactic aspects.

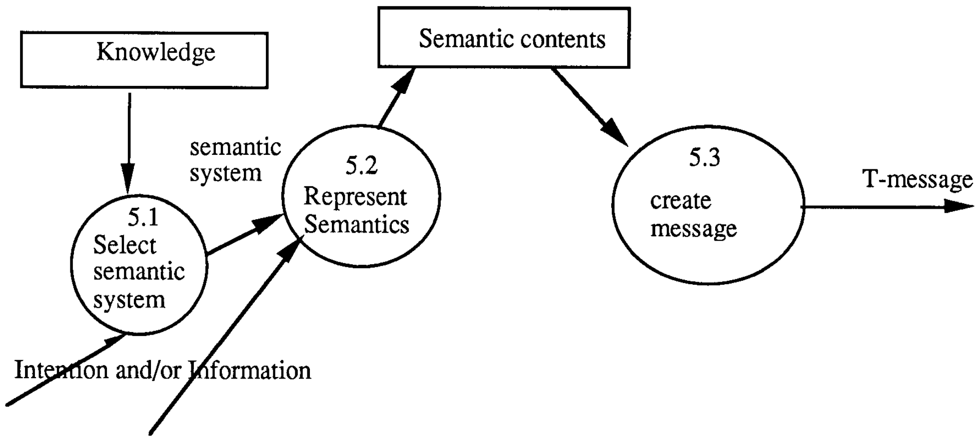


Information - new knowledge. The result of associating the interpreted semantics with existing stored knowledge.

Evaluation - a measure of how well current goals are being achieved

Intention - the intention to transmit a message

Figure 8 Create Intention



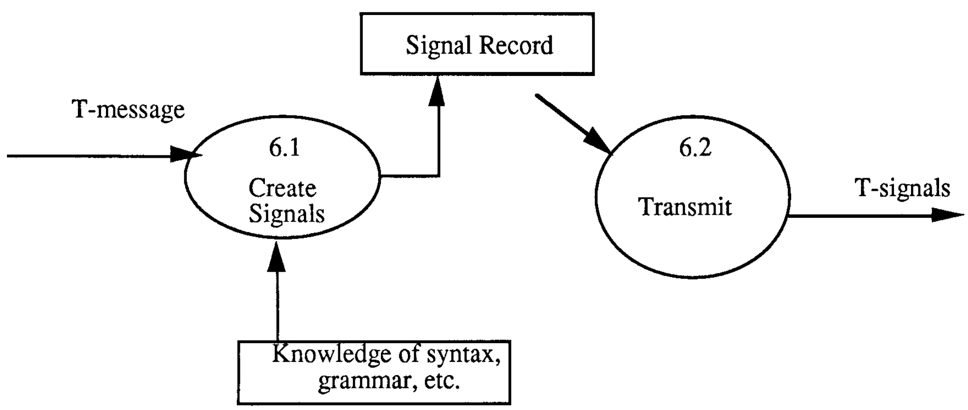
Information - new knowledge. The result of associating the interpreted semantics with existing stored knowledge.

Intention - the intention to transmit a message

T-message - a structured set of signals (called T-message to distinguish it from message)

semantic system - description of the semantic system selected

Figure 9 Create T-message



T-message - a structured set of signals (called T-message to distinguish it from message)

T-signals - the elementary particles of communication (called T-signals to distinguish them from Signals)

Figure 10 Transmission

4 Communicative systems

We can now put the various processes together and represent the receipt and transmission of signals for the three types of system. This is shown in Figure 11. The dotted lines illustrate the two alternative paths from receipt to transmission for the syntactic system (linking the receptor and the transmitter) and for the information processing system (linking processes 3 and 5).

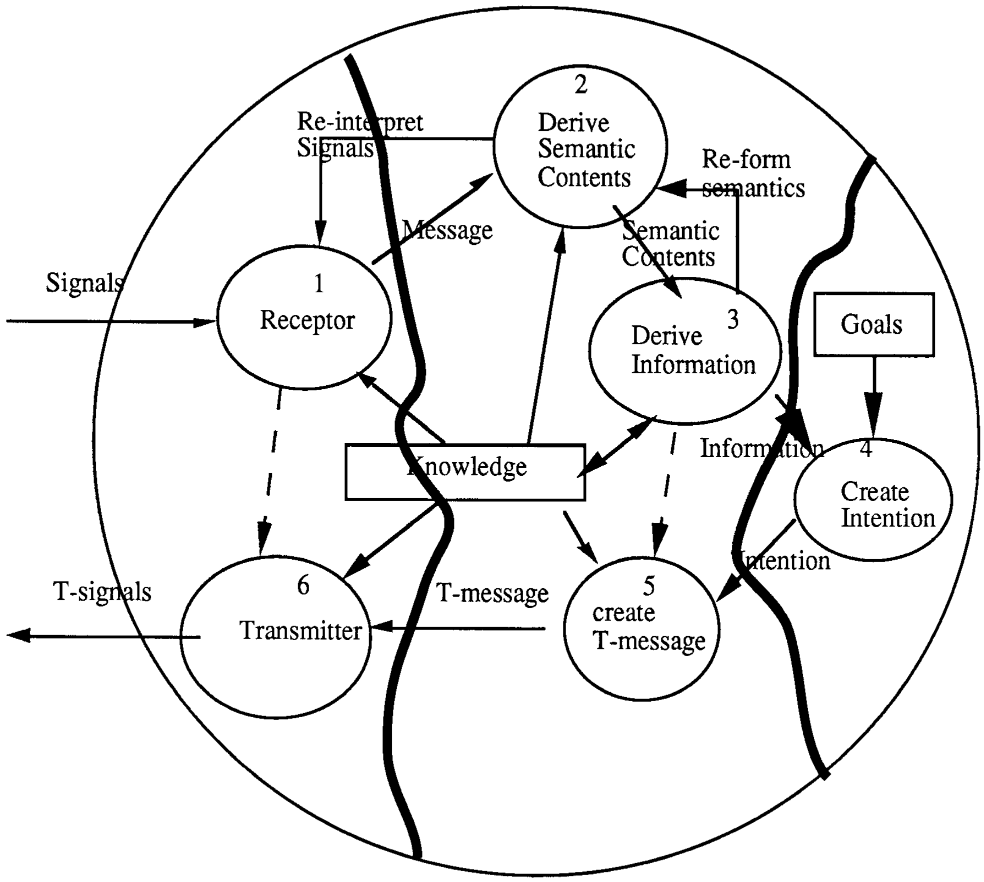


Figure 11 General model of communicative systems

4.1. The Broadway example

In this example, the functional architecture developed in Section 3 is applied to a recent experience which I had in Sydney, Australia. If the supposed semantic structures and misunderstandings appear trivial, then perhaps the reader has more knowledge than I did at the time. The example concerns the transmission and receipt of a message concerned with how I could get a bus from the train station to the University of Sydney. It illustrates the various processes and knowledge structures which were necessary for the interpretation of the signals.

1. Form Intention (process 4)

Ask the attendant how to get a bus to the university

2 Create T-message (process 5)

Where can I get a bus to the University?

(Including decisions on using the spoken medium and expressing it through the audio channel, etc.)

3. Transmit (process 6)

utter the phrase 'Where can I get a bus to the University?'

4. Receive and store signals (processes 1.1 and 1.2)

Phonemes preceded and succeeded by longer gaps

5. Create message (process 1.3)

'Broadway'

6. Derive semantic contents (process 2)

The semantic structure may be conceptualized as shown in Figure 12. This illustrates the current state of my knowledge. The sign-vehicle 'Broadway' is associated with only two concepts (which are themselves complex concepts); 'Musical shows' and 'New York'. This structure is transmitted (through process 2.3) to step 7.

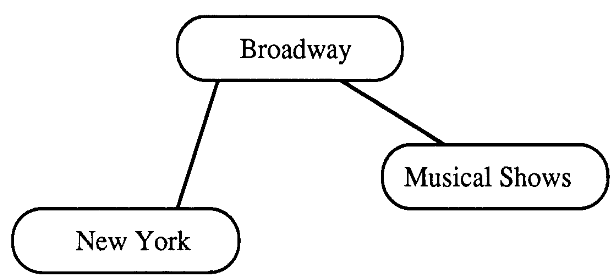


Figure 12 Conceptual view of semantic contents of message 'Broadway'

7. Derive Information (process 3)

Interpreting the semantics (process 3.1) is difficult. The context informs me that the received message is unlikely to be a joke about Musicals and the New York connection seems tenuous to say the least. Re-forming the semantics (process 2) provides no further enlightenment since there are no other semantic systems which can be associated with 'Broadway'.

8. Re-interpret signals (process 1.3)

Since the semantics cannot be used to derive useful information, the signals are re-interpreted.

Did he say The Broad Way? The broad way? 'broad way?'

Try the message 'broad way' (i.e. recognize that the signals may have had a gap between 'broad' and 'way')

9. Derive semantic contents (process 2)

A conceptual view of the semantic contents associated with this wider interpretation of the signals is shown in Figure 13. From this structure a number of semantic contents can be obtained which are transmitted to the derive information process.

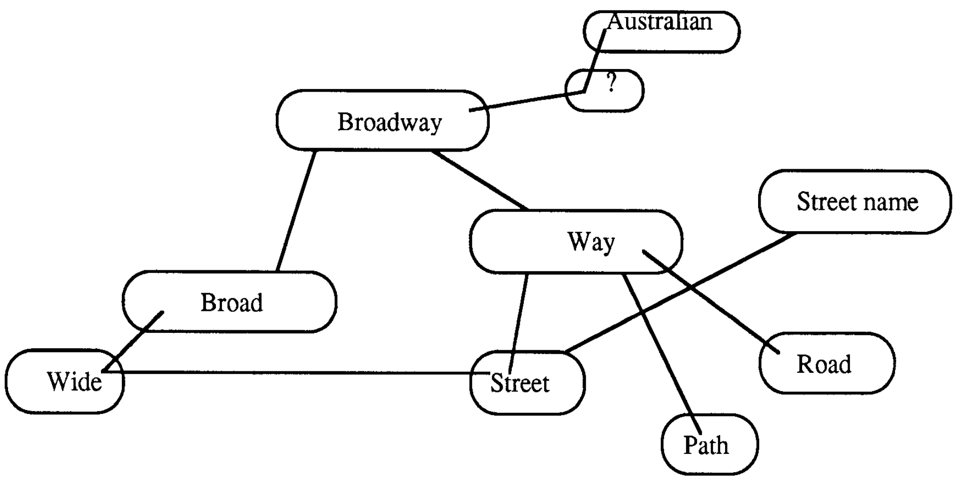


Figure 13 Conceptual representation of semantic structure associated with 'broad way' message

10.Derive information (process 3)

A number of interpretations of the semantics (process 3.1) are available.

(a) Broadway = street name (e.g. he would tell me about a street wouldn't he)

(b) Broadway = a broad way, = a wide street/path

(c) Broadway = 'A broad way' and a broad way is a particular Australian concept (cultural unit, [7]). (We are in Australia and they may have different meanings for expressions).

The knowledge store is tentatively updated with a variety of these options and information is derived. Using the context there's a wide street somewhere

11 Form Intention (process 4)

'Go and see is there's a wide street'

12. Receive signals (process 1)

Perceive sign on wall with the letters 'Broadway' inscribed on it. Hence create message (process 1.3) 'sign which says "Broadway"'

13.Derive semantic contents (process 2)

The conceptual view of the appropriate semantic structure of signs on walls may be a proposition along the lines of

If there's a sign on a wall Then that's the name of the street

Hence Broadway = street name

14. Derive information (process 3)

Broadway is the name of a street in Sydney. Hence update the knowledge structure giving the conceptual representation of Figure 14.

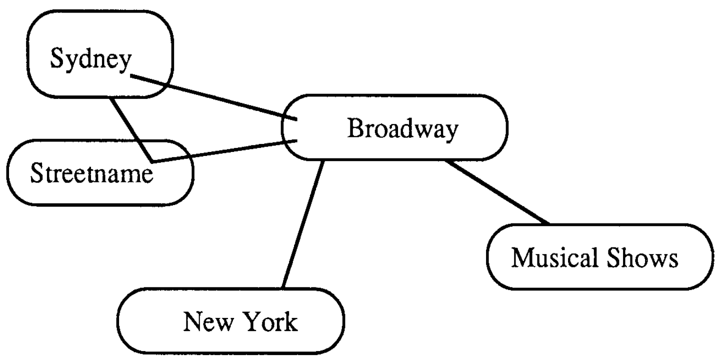


Figure 14 Portion of the assumed conceptual structure of knowledge after inferring that Broadway is a street name in Sydney

5 A Typology of interacting systems

In section 4, a general model of interacting systems was presented and in section 3.7, three main types of system were identified with respect to the mechanisms which trigger the production of signals. We can now look at the types of system in more detail

5.1 Syntactic systems

These simple stimulus-response systems are characterized by the receipt and transmission of a single signal. A direct link exists between processes 1.1 and 6.2. This type of interaction is what we have called an action.

More complex syntactic systems have the ability to store signals and create messages. Such systems, therefore, have access to some form of syntactic knowledge which allows the Create message process (1.3) and Create T-message (process 6.1) to function. The length of the signal record is another variable feature of syntactic systems. A short record will only permit certain parsing of the signals.

Syntactic systems embody a physical model of the system with which they can interact. This is a function of

- the signals receivable and transmittable
- the length of the signal record
- the complexity of the syntactic knowledge store
- the complexity of the create message and create T-message processes

All systems have a syntactic component which defines with which other system they can interact.

5.2 Information processing systems (IPS)

Information processing systems are semantic systems capable of communication rather than just simple action. Each of the components of such systems as identified by the architectural features of processes 2, 3 and 5 and the complexity of these processes, has an impact on the level of sophistication of these communicative systems.

The simple IPSs have a single system of signification which allows them to derive semantic contents from the message received from process 1.

More sophisticated systems have access to a variety of semantic systems and can select alternatives. This gives the system more flexibility to interact with a variety of systems and to re-interpret signals if required.

The ability of the system to store semantic contents (the length and capabilities of this store to represent semantics) is another feature which effects the complexity of such systems.

The complexity of the system's representation of the context defines its ability to interpret semantics. This is effectively a model of the interaction and can contain, the signals, messages, semantic systems, semantic contents, interpreted semantics, information derived and system goals for all receipts and transmissions. The ability of the system to reason with this knowledge and to undo previous decisions is a measure of its sophistication.

The complexity of the knowledge base, the richness of the connections, the content and the form of the representations measures the system's ability to derive information.

Some systems, which we could term 'learning systems' have the ability to update their knowledge base. Some of these will update only the contents, but others may update the structure as well. The various levels of self-knowledge associated with this capability defines the complexity of the learning system.

IPSs embody a conceptual model of the systems with which they can interact in addition to the physical model contained in the syntactic component. In order to communicate with another system, an IPS requires a shared semantic system. Indeed the IPS's semantic system is effectively a model of the other system's concepts and the degree of similarity between these system is vital to the effectiveness of any communication.

In order to represent contents, the IPS must have a model of itself which can be stored and reasoned about. Similarly learning system have various levels of self-knowledge which allow them to change their content and structure.

5.3 Intentional Systems

Many systems have an implicit purpose which will drive the production of signals and this can be considered a rudimentary intentional store. Intentional systems as described here have access to this knowledge and can use this to reason about the information which has been derived and how this affects the systems goals.

Other intentional systems have the ability to update their goals and this distinguishes another class of system. The way in which goals are represented affects the ability of the system to relate current information to system goals.

6 Conclusion

This paper has developed semiotic model of interacting systems. The model highlights the necessary processes, stores of knowledge and types of signs which are necessary for communication to occur. The complexity of each component defines the level of sophistication of the communication system. Within this view of systems, we have identified three main types of system. The syntactic system does not have access to a system of signification and cannot therefore communicate. It can interact with other systems as defined by its ability to send and receive signals and it may be able to store and parse signals with respect to a system of grammar or syntax. Syntactic systems do not have the power to represent anything, though another system may use them to represent other things.

Information processing systems have access to one or more systems of signification and therefore are able to derive meaning from signals. The semantic systems which they do have are critical to the effectives of any communication and it maybe that many human-machine misunderstandings can be alleviated if the human were aware of the system of signification embodied by the system. In effect, the system of signification is a conceptual model of the systems with which it can interact. Some information processing systems are learning systems and have access to their own knowledge and can learn by updating this with new information. IPSs react to the derivation of information by transmitting signals.

Intentional system have access to their desires, goals and intentions. Information is not simply a trigger to produce signals. Information is used in association with the system's goals or purpose to trigger the production of messages.

The model presented in this paper is at a certain level of abstraction which was chosen in order to emphasize the main components of the functional architecture. However, each of the circles in Figure 11 is a system (as indeed is each of the circles in Figures 5 through 10) and the lines between the circles represent the lines of interaction which are required for the system to function. The model presented here can, therefore, be recursively applied to the processes identified as crucial to communication. This will reveal another level of analysis which is not appropriate to develop in this paper.

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