On definitions

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ABSTRACT

Originating from a concern about the use of terms in hydroinformatics, this paper takes up the question of the nature of a definition and its consequences in a technical, and increasingly sociotechnical field like hydroinformatics. It is explained that the way things are defined is not so simple and so obvious as might at first appear, but is in fact an essentially ideological matter, having consequences not only within an individual discipline, but also for the applications of that discipline within a wider context. A mode of definition that satisfies the needs and expectations of hydroinformatics is then advanced.

The notion of a defining self is introduced in order to explain how the influences of the mode of definition attains to a greater influence in social and ecological applications. This influence is exerted through communication, which is necessarily realised through the use of tokens. The four classes of tokens necessary for all processes of communication are introduced, delineated and defined.

The way in which such broad concepts as 'reality' and 'truth' are defined is then seen to influence the definition of a model in the widest sense. Further definitions that are of central concern in hydroinformatics are developed accordingly. The paper concludes with a description of a phenomenon known only by its German name, as *Gerede*, that is at the root of much current confusion of terms in hydroinformatics, as in so many other places, and how its malign influences can be opposed.

Key words | communication, definitions, environmental decision making, Hydroinformatics, judgements, models

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INTRODUCTION

Although most of us may think out of hand that we know what a definition is and how it is used, reference to any philosophical encyclopædia will no doubt persuade us that the way in which we define things is not so simple and straightforward. The question concerning 'right definitions' has puzzled many of the greatest thinkers in every age, while in the last century it emerged clearly as an *ideological* question. The way in which one 'defines a definition' was seen to mark a division in ways of looking at the world as a whole, and especially at the position of mankind within this world (Abelson 1967). This division has caused an understandable confusion in the minds of those who have been exposed to it. This confusion in turn has had the gravest consequences, both for humanity alone, and most clearly so in the first half of the twentieth century, and for humanity and its natural environment inseparably in the second half of that century and into the present century again. Hydroinformatics is intensely concerned with the second of these consequences. Thus a paper on definitions used in hydroinformatics is not the relatively simple, technical matter that it might at first appear to be, but carries deeper issues along with it. As will be explained, this question concerning definitions carries with it also the future of our subject, and is thus of vital importance to all of us in that sense too.

THE ORIGIN AND PURPOSE OF THE DEFINITION

Every department of thought that we call a discipline is, simultaneously, a discipline of language. A discipline of thought is essential to the formation of a discipline of language and a discipline of language is essential to the maintenance of a discipline of thought. Hydroinformatics becomes and remains a discipline just so long as it introduces and maintains a disciplined language.

But what do we mean by a disciplined language? Most languages such as are realised in everyday discourse, are of course not particularly disciplined at all, and indeed they have no need to be so. Most everyday discourse is intelligible enough for most everyday purposes. Following Heidegger (1927/1967), we speak of a *discourse of average intelligibility*. However, as soon as this mode of discourse has to treat a matter that is not so everyday, conforming less to the average experience, then it encounters several difficulties. Thus (*ibid*. 1927/1962, p. 212):

> ''In the language which is spoken when one expresses oneself there lies an average intelligibility; and in accordance with this intelligibility the discourse which is communicated can be understood to a considerable extent, even if the hearer does bring himself into such a kind of Being [or state of awareness] of what the discourse is about as to have a primordial understanding of it. We do not so much understand the entities which are talked about; we are already listening only to what is said-in-the-talk as such. What is said-in-the-talk gets understood, but what the talk is [really] about is understood only approximately and superficially.''

It is then in the nature of this most common kind of discourse that it uses words and expressions in a loose and largely undifferentiated way. Words such as 'sign', 'symbol', 'icon', 'model', 'calibration', 'validation' and so on are frequently used with little regard to their precise meanings. Although, once again, this may be of little real consequence in casual conversation, it can lead to great confusion when matters of some substance, such as are not everyday and average, must none the less be discussed. This confusion in turn leads to apparently endless discussions which seem to have no definite outcomes at all – or may even lead to outcomes that were never intended.

This confusion and the apparently endless and fruitless discussion which accompanies it was well known to the ancients, and in particular to the ancient Greeks and Romans from whom our so-called 'Western' culture is derived, and whose labours have provided the primary languages of modern science and technology. The ancients observed that the confusion was founded upon an undisciplined use of language, and that the root of this undisciplined mode of communicating was the use of imprecise terms. They accordingly set out to *put an end to* such modes of unproductive discourse by making the meanings of words and expressions more precise. These were then ways to 'bring to an end', the Latin *definire*, from which we have the French *définir* (decomposing to *de finir*, such as in *Je lui ai demandé de finir*: *I have asked him to finish*), so that the English verb *to finish* has the same root. By making the basic materials of discourse, and in the first place words, more *definite*, the ancients already forged an instrument, called a *definition*, which would put an end to otherwise uncontrolled and uncontrollable proliferations of discourse, with all their negative consequences.

(Let us briefly observe already here, in passing, that history is replete with examples of the catastrophic consequences of a confusion of definitions. Thus, to take an example that appeared just as these words were being written in the USA on the 60th anniversary of the outbreak of the 1941-45 Asian and Pacific war, Willmott (2001, pp. 39, 47) emphasised: 'The Imperial [Japanese] Navy never understood the difference [in definition] between war and a war, between a war and a campaign, between a campaign and a battle, and instead identified them as one and the same . . . Herein was the setting within which the plan for the Pearl Harbour attack found its proper context . . . The process whereby Japan induced war in December 1941 has all the hallmarks of a national *kamikaze* effort and provokes as much incredulity as the detail of the process and Japan's final decision itself'.)

The word definition is thus itself defined by what it *achieves* in the world of discourse. But how does it achieve this and can it then also be defined by *how* it achieves its purpose?

OBJECTS AND CONTENTS: EXPRESSIONS, MEANINGS AND DEFINITIONS

An object is anything to which a mental process can be directed (Findlay 1963/1995, p. 67). The mental process

directs itself to objects, but it is not itself an object in that it contains other elements which we do not and indeed usually cannot call into our minds during the mental process itself. These other elements are subsumed collectively under the rubric of *content*. Thus (Findlay 1963/1995, p. 30):

> ''The relation between content and object shows a curious reciprocity; objects cannot enter the mind but are made accessible by means of contents; contents, though they are in the mind, are difficult to approach directly, and so are generally grasped by means of objects.''

Accordingly, what are normally called the attributes of objects, such as their colour, for example, are not themselves objects even as they may function as content, but they can none the less be *objectified*. Thus, to continue this last example, the colour 'blue' can be objectified as 'the colour which I can project in my mind when I think of the word ''blue'' ', which is then indisputably an object. An object constructed in this way is commonly called, following the foundational studies of Alexius von Meinong, a *pseudo-object*, and is said to be constructed by a process of *objectification*.

Among all the objects that enter into mental processes there are some which function in a very specific way within their embedding content, in that our awareness of one object causes our minds to pass over to the awareness of another object. Any object which can be given up in place of another object in this way, so that it can take the place of another object in our minds, is called a *token*. The object that is so represented is then said to be *betokened*. In everyday speech, tokens are often referred to simply as 'signs', but this usage is too imprecise to be employed here, signs in the strict sense – to be identified shortly – being but one species of tokens. Despite this, we shall retain the most familiar word, *semiotics*, commonly understood as *the study of signs*, for the study of tokens generally.

Among the most common of tokens are *words*. In their function as tokens, 'words serve a double function: they *express* our inner experiences and they *mean* or refer to the objects of those experiences' (Findlay 1963/1995, p. 61). Findlay explained further (*ibid*):

> ''The tendency to confuse the expressive and the significant function of words goes back to the more fundamental confusion of the content and object of mental states . . . But if content and object are clearly distinguished, and it is realised that no physical object is ever a constituent of any mental state, then it is plain that the sense in which a word is a sign of a mental process in the user of the word, and the sense in which it is a sign of something he is thinking of, are totally different.''

We shall follow a standard practice in the theory of semiotics (e.g. Eco 1976; Klinkenberg 1996) by denoting the fact that an object is functioning as a token for another object by enclosing that betokening object between virgules: / /. We denote the description of the object that comes into our mind, as the *meaning* of the token, by enclosing this description of meaning within guillemets: << >>. We then define the definition of an object x as that function of the mind, $def(x)$, that maps the token that calls x to mind into the signification of x, which is then the *meaning* of the token:

$def(x)$: token for $x \rightarrow$ betokened meaning

This corresponds to the formula of Locke (1690/e.g. 1976, p. 208): 'words, in their primary or immediate signification, stand for nothing but the *ideas* in the mind of him that uses them'. Thus, for example, if we take the word-token /pen/ and, as a one and only meaning of this token, <<a device for writing with ink>>, we have:

$def(pen)$: /pen/ $\rightarrow$ <<a device for writing with ink>>

We may anticipate our later development of this theme already by emphasising that the central element in any definition is the function $def(x)$. We then reflect this central position in our notation by writing the token that initiates the operation of the function by $\square def(x)$ and the meaning that $def(x)$ produces by $def(x)\square$. Thus, for any x:

$$def(x):\square def(x) \longmapsto def(x)\square \qquad (1)$$

where we shall explain the introduction of a barred arrow shortly.

There are four immediate and important consequences of this definition. In the first place we see that definitions are defined only for the case of objects and not for the case of contents (see, already Locke *loc cit*, pp. 205–206 and, more critically, Hume 1748/1999,

e.g. pp. 96–100). A content can only be defined to the extent that it can be 'made objective', or 'objectivised' or 'becomes a pseudo-object' so that it can be represented by a token. As a further example of this property, we now see that a definition must itself also be an object, even though it will most usually be a very different kind of object than that which it defines. We can clearly regard a definition as a form of judgement, and in this case a judgement of the meaning of something that is initially experienced and identified as a token. We experience the definition as 'being the case' or as a 'fact' in relation to the token-like object which addresses it. Then (Findlay 1963/1995, pp. 67, 69):

> ''Meinong proposes to use the word 'objective' for those entities which can be judged or assumed, and which are in some cases facts. He sets them against objects in the narrower sense, which can be given to us by mere ideas (*Vorstellungen*), and which are never the case. We may use the word 'object' to translate Meinong's *Gegenstand* . . . For Meinong's word *Objekt*, which applies only to objects in the narrower sense, i.e. to those which are not objectives, we use the word 'objecta'. Objects therefore divide into the two classes of objectives and objecta.''
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> '' . . . Normally an objective is judged (*geurteilt*) or assumed (*angenommen*); while the objects involved in it are judged about (*beurteilt*) or assumptions are made about them (they are *beannahmt*) . Now it is perfectly possible for an objective to play the part of an objectum in the sense that we no longer judge or assume it, but make judgements *about* it. To do this has the additional advantage of proving, with the greatest possible clearness, that objectives belong wholly and solely to the realm of objects, and are utterly indifferent to the [contingent] workings of our minds.''

In effect, we can say that only objects can be defined because we extend the world of objects so extensively, following Meinong. We observe, as a second consequence, that we speak of the 'definition of an object' when we might appear to mean, strictly speaking, 'the definition of the token used to represent the object'. Thus, it might appear as though, strictly speaking, we should use $def(\square def(x))$. There is, however, a very fundamental reason for the usage adopted here, which is that in the event that our tokens are words in a technological or, even more, sociotechnical discipline, one and the same word may have several, and even quite disparate, meanings, but each such meaning then corresponds to the particular object which we have in mind when we use the word. Thus, within its linguistic context, the representation of the object x is commonly not a word but a word that is set within a specific denoting context. The denotation in this case clearly follows the object which we have in mind. In real-world dictionaries this is indicated by repeating the word that is defined while following each such repetition immediately with an indication of the specific context that is intended before the corresponding definition is given. As explained later here, this would appear not to be necessary in the case of an ideal scientific language, but even in that case we can motivate it by the simplest of mathematical examples, of mapping the set of positive integers I^+ into itself by functions of the form $f{:}x \longmapsto xn,\ x^n,\ x \in \mathrm{I}^+,\ n \in \mathrm{I}^+$. Then the number 2, for example, maps into the number 4 if $n = 2$, into 8 if $n = 3$, and so on depending upon the function-object that we have in mind during the process. In a similar vein, if we consider the special case that $\square def(x)$ is a word, different words in different languages will commonly refer to one and the same object. Thus, we may speak of 'the definition of a river' rather than 'the definition of the word /river/', on the understanding that 'river' can be replaced by *fleuve*, *Flüsse*, or any number of other words in other languages. This usage marks our present approach as quite resolutely *essentialist*, in that we suppose that definitions convey information which may provide meanings. This contrasts with the *prescriptive* approach as represented by modern formalism, where the definition is *restricted* to the token and does not refer to the object which is in the mind and which it thereby betokens (Abelson 1967). As we shall see later, this difference corresponds to a profound ideological difference in the view of the relation between mankind and its languages.

The third consequence follows from the first when we observe that already within any one 'natural' language (English, French, German, etc.), there will be 'overlaps' between some of the $\square def(x)$s and between some of their $def(x)\square$s, so that these collections will not normally be 'crisp' sets in the classical (Cantorian) sense. It is only necessary that x is an object that can be designated: the collection of x's does not necessarily have to have a structure. However, because the basic notions of classical

set theory will most likely be the most familiar to readers, we shall often simply use the term 'set', when describing the collections of objects with which we are here concerned. We shall denote the set of x's by $\{x\}$, the set of $\Box def(x)$'s by $\{\Box def(x)\}$, the set of $def(x)\Box$'s by $\{def(x)\Box\}$, but we shall continue to describe the function that connects these in the same way for every x by $def(x)$.

With this notation, then, we can define a more general function $def(x)$ that maps a set $\{\Box def(x)\}$ into a set $\{def(x)\Box\}$. This notational movement from the anonymous instance to the more general 'domain→codomain' transformation case mimics that employed in mathematics generally, where, to return to our previous example, the mappings 1→1, 2→4, 3→9, etc., provides the anonymous instance $x \longmapsto x^2$ which maps the set of positive integers, I^+, into itself: $\mathrm{I}^+ \to \mathrm{I}^+$. We observe here that we have already earlier introduced a barred arrow, $\longmapsto$, in the anonymous case, but a straight arrow in the definite, including the 'domain→codomain', case. We then recall from the teaching of elementary mathematics that we can visualise any function f that performs this kind of mapping in terms of the shooting of an arrow from some kind of *source* to some kind of *target*. This metaphor then serves to emphasise that it is the set of arrows that indicates both the set of sources and the set of targets. It is in order to emphasise this dependency in that branch of mathematics that is used to describe mappings of the kind exemplified here by definitions, that is, in *Category Theory*, that some authors use the notation $\Box f$ to represent the source *set* of the mapping realised by the function f, and $f\Box$ to represent the target *set* of the mapping realised by f. Then $\Box f$ and $f\Box$ constitute unary operations on f. Since the $f\Box$ of one function f may act upon the $\Box g$ of another function g to provide a composite function, fg, we introduce further a binary partial operation to accommodate this. Then *Category Theory* is defined by these operations and by the axioms:

fg is defined if and only if $f\Box = \Box g$,

$(\Box f)\Box = \Box f$ and $\Box(f\Box) = f\Box$,

$(\Box f)f = f$ and $f(f\Box) = f$, (2)

$\Box(fg) = \Box(f(\Box g))$ and $(fg)\Box = ((f\Box)g)\Box$,

$f(gh) = (fg)h$.

The ordinary equality sign, as exemplified above, is used only in the symmetric sense, that if either side is defined then so is the other, and they are equal. In the event that the asymmetric sense of equality may arise – so that we can only assert that if the left side is defined then so is the right side and that these are equal – another notation is required, but we shall make no use of this here.

Freyd and Scedrov (1990) then explain that:

> "A theory such as this, built on an ordered list of partial operations, the domain of definition of each given by equations in the previous, and with all other axioms equational, is called an *essentially algebraic theory*."

We should observe further that in many disciplines, including much of the literature on Category Theory, the terms /morphism/, /domain/ and /codomain/ are used instead of /arrow/, /source/ and /target/ when the source and target are sets (see Barr and Wells 1995).

(For our own part we may observe [following E. Rossinger, private communication] that Category Theory, together with the Allegory Theory that we shall do no more than mention here, is not regarded as a part of mathematics by some mathematical purists, and especially by the Bourbakist school. This is primarily because the objects which these theories address are not restricted to mathematical objects, but can equally well be non-mathematical objects, as already exemplified. It is precisely this feature, however, that makes these theories so applicable to studies of the kind that predominate in hydroinformatics, and especially on its sociotechnical side: see also Abbott (2000)).

The fourth consequence of our definition is that it necessarily leads us into the study of self-referencing systems. This was obvious already as soon as we spoke of a 'definition of a definition', which could clearly be extended indefinitely. Now we observe further levels of self referencing in that every list of definitions introduces tokens that have in turn to be defined. Such 'circles' of representations and meanings have been called, since the nineteenth century writings and teachings of Wilhelm Dilthey (e.g. 1976), *hermeneutic circles*.

DICTIONARIES AND ENCYCLOPAEDIAS

According to the differing nature of their self-referencing properties, or hermeneutic circles, we have two names for defining those functions, $def(x)$, which, when taken together with their source sets and their target sets, provide the categories of definitions. Taking their cues from linguistics, the one of these is called a *dictionary*, and the other is called an *encyclopaedia*.

A mapping of the form $def(x)$ is said to provide an *ideal dictionary* if and only if every element of the target set $def(x)\square$ is composed exclusively of sets of elements of the source set $\square def(x)$. Thus, an ideal dictionary is a *closed and completely self-referencing system*. For his part, Foucault (1966//1970/1989) spoke in this case of a 'language that only ever speaks about itself'.

We have already introduced a notational device for distinguishing between the function that takes the domain into the codomain, for which we use a straight arrow and the function that takes a particular input datum to its corresponding output datum, for which we use a barred arrow. This distinction is often required because the domain and the codomain are determined by their relation, as source and target, of the function. Thus in Category Theory a function is not only a rule, but it is a rule that must be taken together with its domain and codomain. This condition corresponds to the need to maintain a very strong form of typing. Thus the function $def(x)$ has to be taken together with the $\{\square def(x)\}$ and the $\{def(x)\square\}$ upon which it operates: very obviously, for example, the category defined by $def(x)$ operating on words in the English language is not the same as the category defined by $def(x)$ operating on words in the French language even as the nature of the act of definition remains the same. If, however, we do keep to the example of any one particular natural language as this functions within the greater part of a society at a particular time, we see that:

1. *Every word, when understood as the representation of a specific object, has one and only one definition*. Of course, the one word may still have several *connotatively* different meanings even when associated with one and the same object, but then each element of the target set is composed of all of these connotative meanings.
2. *Two or more words may nonetheless share the same definition*. Thus, in British politics, 'Conservative' and 'Tory' nowadays have identical definitions, regardless of their different historical origins. In more general terms, two distinct elements in the source set $\{\square def(x)\}$ may map into one and the same element in the target set $\{def(x)\square\}$.
3. *There are some meanings for which we can find no words at all within the language concerned.* This is to say that, in this linguistic example at least, we may have words in other languages that do express these otherwise inexpressible meanings, as will be illustrated later in this paper. We may also, of course, have all manner of life experiences that possess great meaning to us, but for which we can find no words at all.

It follows that the function $def(x)$ as defined in Equation (1) is injective, but, not being surjective, it is not bijective. This situation is schematised in Figure 1.

An *ideal encyclopædia* is one that does not possess this totally self-referencing property at all, so that it effectively already presupposes – and in fact is also presupposed by – the existence of a dictionary. It presupposes much more again, however, for whereas we might characterise the ideal dictionary as a *completely closed system*, as something that is ideally invariant in time, an ideal encyclopædia is an *always incomplete system*, taking as its themes matters of interest occurring in the world outside itself, a world which is forever changing. As we shall intimate later, these two ideal cases correspond to two distinct *models* of description of meaning, the one proceeding through the definition of objects in terms of definitions of other objects and the other proceeding through statements of beliefs about and relations between objects.

Of course, real dictionaries and real encyclopædia differ quite considerably from their ideal counterparts. Most prosaically, both of these real forms are provided with total-ordering functions $\overline{O}(\{\square def(x)\})$, providing sets $\{def(x_i),\ i = 1,2,\ \ldots,\ ii\}$, where, recursively, $\overline{O} = \overline{O}(\{\square def(x)\})$. More basically, in semiotics, the difference between these real forms is commonly expressed in

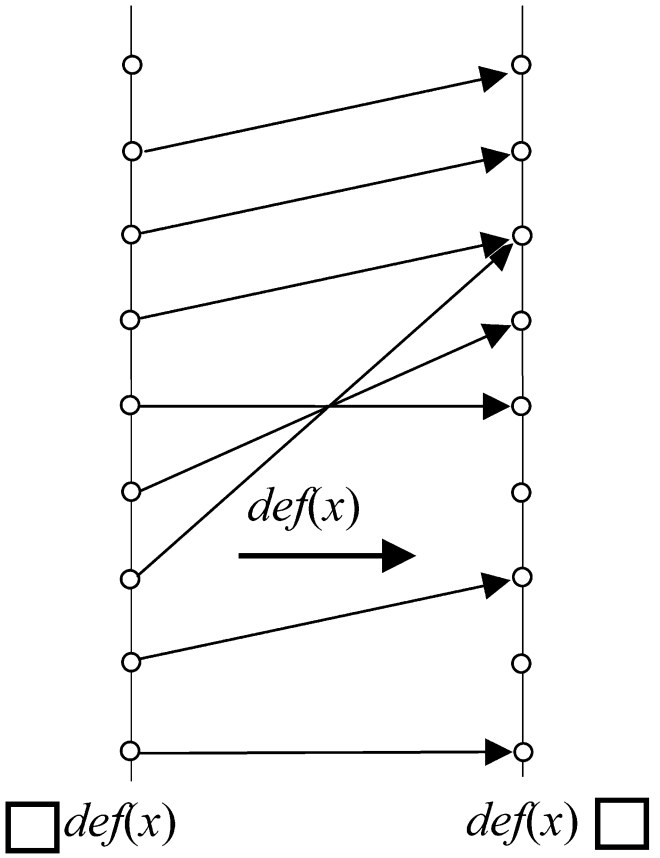

Figure 1 | Mappings from tokens to the meanings associated with these tokens.

terms of differences between *analytic propositions*, these being propositions that are always true simply by virtue of the meanings of their component terms, and *synthetic propositions*, understood as propositions that can only be judged as true or false on the basis of conditions outside of themselves (Klinkenberg 1995, pp. 108–110; much more definitively, see Kant 1787/1924/1971, pp. 58–66//1929, pp. 48–55). Thus, the distinction here goes back to the Meinongian one between words as signs of mental processes and words as referents to events occurring outside the thinking subject, as already introduced above. Whereas the first is of dominant interest within disciplines like linguistics, the second is of a much greater interest in subjects like hydroinformatics which have to do with information of and communications about 'the real world'. In semiotics, as just observed, these two forms of defining systems are said to constitute two different *models* – but then 'model' is a word that still has to be defined here in its full generality. Despite their differences at the level of models, however, we still have to insist that real encyclopædia can only be built upon the foundations provided by real dictionaries, so that definitions are as important in hydroinformatics as they are in any other discipline. We should observe, if only passing, that whereas the dictionary model of meaning can be formalised within Category Theory, the encyclopædia model of meaning, having to do with so many other kinds of relations between objects, cannot generally be so constituted. The encyclopædia model has instead to be constituted in terms of allegories, so that its formal representation falls under the subject matter of *Allegory Theory*.

THE DEFINING SUBJECT: THE SELF AND ITS SELFHOOD

We have defined definitions in terms of 'functions of the mind', but we have now increasingly to enquire into whose mind this is. In a world in which nature is being subjected to so much destruction and desolation, and where an ever greater number of humans are being reduced to destitution, this question comes to be posed ever more urgently. As hydroinformatics as a whole, regardless of its different approaches, attempts to reduce and even reverse this tendency to increasing desolation and destitution through its application of advanced information and communication technologies to the worlds of the waters, so it must inevitably pose this question. Hydroinformaticians are themselves proxies for their fellow humans and for the creations of nature, and in this position they must relate their own selves and their own selfhood to the selves and selfhoods of others through that substance, water, that is common to all life on Earth. Whether it is through the ways of a data mining for knowledge discovery that is directed to 'listening to nature' so as to 'understand what nature is trying to tell us', or whether it is through its ecological associations, in which hydroinformaticians participate in alleviating and restoring the lives of their fellow creatures, or whether it is in the direct

sociotechnical direction, in which hydroinformaticians strive to provide the means for their fellow humans (directly) and other creatures (indirectly) to participate in the decisions that so influence their lives, questions concerning the 'self' and 'selfhood' are constantly and increasingly posed. We may conceive that these 'other selves' create objects in their minds and associate these objects through their own content, and these processes cannot be indifferent to us. How are we then to *define* 'self' and 'selfhood' in this general context? There are obviously very many approaches to this question, and correspondingly a considerable literature has been devoted to it. Since the self cannot 'it-self' be an object, it can only be objectified for the purpose of expressing its meaning by the application of metaphor and allegory, and many such devices can be found in the literature for this purpose (e.g. Hermans 1996). However, most current approaches to expressing the meaning of 'self' and 'selfhood' follow one or the other of two encyclopædic models, the one corresponding to a *computer metaphor* and the other to a *narrative metaphor*. The first, being associated with agents, agenthood and agent communication languages, will probably be the most familiar to hydroinformaticians. The second, which is however closer to our present theme, is more associated with the humanities and is often traced back to the work of Henry James (1890/1902) on the psychology of the self. In particular, James' characterisation of the 'self-as-knower' with both a 'sense of personal identity' and a 'sense of sameness' remains apposite to our present theme despite its logical-empiricist origins (see also the collection of essays in James 1957). In a very different vein, however, it also relates back to the now classical definition originally given by Hegel (albeit with two obvious Biblical allusions) in the *Phänomenologie des Geistes* (1807//1952). This is in turn best known, nowadays, as the starting point for one of Kierkegaard's three great explorations of an already rapidly advancing nihilism as this was experienced at the level of the individuated self. Kierkegaard's (1849/1920–31//1989) formula becomes, in one of the better translations into English:

> ''The self is a relation that relates itself to itself, or is the relation relating itself to itself in the relation; the self is not the relation but is the relation relating itself to itself.''

Thus, in the notation of Category Theory, the definition of the self, s, as denoted by $def(s)$, is:

$$def(s) = s{:}s \rightarrow s, \tag{3}$$

so that $\Box s = s$ and $s\Box = s$. In popular terms, then, the self might be described as 'the ultimate *self*-referencing system' in that, so to say, 'it defines itself'. Formulae similar to that of Kierkegaard have taken a prominent place in the works of several later authors (e.g. Sartre 1943//1958). Among these authors, however, it is probably Sartre who has most popularised the concept of (or, more strictly, 'the thought of') the *other* as something that is defined by the *self* in the image of this self, and which in this process simultaneously defines another, and higher, state of the self. This self then relates the other to itself in the same manner as its own self, and thereby it is said to attain to a higher state of *selfhood*. To the extent that a self creates objects within the same value system as itself, so it transcends its view of its world in terms of objects, as items of *primary reflection*, and instead attains, if only by degrees, to states of *secondary reflection*, often popularly called 'self-realisation'. We then call the resulting self a *subject*, being one who views the others as subjects too. This then applies not only to fellow humans, but to all other creatures. Thus, when Gabriel Marcel said (see Troisfontaines 1968, part 3, p. 8) that 'to be a subject is not a fact or a point of departure, but a conquest and a purpose of life', he was regarding the subject in just his way.

Thus, when the other is experienced in this way, it is said also to have attained to *selfhood* in the mind of the self, and this is then, entirely symmetrically, the necessary condition for the individual experiencing the other, his-*self* or her-*self* also to attain to *selfhood*. It is only within this relation that any kind of authentic interaction can take place at all between the self and the other.

The self is of course not a single whole, but is divided within itself. Sartre gave the example of the person who says 'I am ashamed of myself' to illustrate this, although this 'I-me' distinction is also found in James (e.g. 1890/1902) and is there more psychological than existential. The inner division goes very much deeper, as identified and analysed by Kierkegaard, both within the inner and the outer worlds of the self, but we only need some notion of

these concepts to proceed further.* These notions are already fundamental to the entire 'ecological' and 'green' movements, as these function at both their individual and social levels, and so they are fundamental to hydroinformatics. They also motivate aid programmes of all types and descriptions. For more current and mainly psychologistic views on self and selfhood, reference may be made to the extensive bibliography of Hermans (1996).

THE DEFINABILITY OF REALITY AND TRUTH, OF SPACE AND TIME

If we keep to the computer metaphor of self and selfhood, we can similarly describe each part of the division within the self as an *agent* which may attain to *agenthood* as it interacts with other agents within the self and the other while recognising these other agents as 'equal partners'.

Continuing with the metaphor of computing, this development of the agents to agenthood is associated with the development of *competencies* on the part of these agents. In studies of agent-orientated systems, the notions of agent and agency are thus inseparable from those of competence (Shoham 1997). In our present essentialist view, then, each self has an *inner world*, which it normally experiences as something inseparable from its Being and is contained entirely within itself, and an *outer world* which it normally experiences as being entirely outside itself. The outer world includes the others with whom the self may conduct a discourse in their status as subjects, and other, and usually less animate, objects with which the self does not normally conduct a discourse. Then, roughly following Augustine (398//e.g. 1961), *reality is the name that the self gives to the interface between its inner and its outer worlds and a truth is the self's intimation of the oneness of these two worlds*. Thus, reality is only defined through the name of a something that may very well not be 'objectivised', or 'made objective', or indeed may conceivable not even 'exist' at all. Entirely consentaneously, truth is defined in terms of an intimation that can only be 'objectivised' or 'made objective' by well-chosen and illustrative descriptions of the special feelings of pleasure and satisfaction that it evokes within the self, which can again only be described and characterised in terms of its associated objects through the devices of a finely-tuned *rhetoric*. We refer to Augustine (398//e.g. 1961, and specifically sections IV.15; X.23; XI.3–7 and XII.25–32; see also Chisholm 1966 and 1982, and Findlay 1961) for the paradigmatic explanation of the processes of objectivisation in these cases. It is remarkable that the experience of truth so beautifully delineated by Augustine is reaffirmed even in the logical-positivistic writings of Henry James (e.g. 1976). The relation of this essentialist and experiential definition of truth to the experience of 'mathematical truth' is very well described in popular form by Huntley (1970).

Reverting now to the observation of the inner division of the self, as is commonly identified with various agencies, and thus agents, we see that there may be any number of realities and truths even within any one self and certainly over a considerable number and range of perceptions of the others. In everyday discussion we speak, using visual metaphors, of a multitude of 'points of view' or 'perspectives', and then essentially upon objects. *An object that is seen from a particular point of view or within a certain perspective is then called a phenomenon*. The study of the ways in which the inner world of the individual self influences its view of its outer world, and how this in turn influences its own inner world again, is the subject of *phenomenology*. We can of course only speak about *a* truth: *the* truth, the Platonic *noumenon*, remains forever closed to us.

We experience reality as extending over space and proceeding in time, while we usually experience truth as coming to presence in space and time. Now so long as we are treating of reality and truth in a purely modern-scientific manner, so that space is totally orderable, perfectly measurable, additive within a dimension and multiplicative over dimensions, and time is also totally orderable, perfectly measurable and additive, we feel no need to enquire further into the definitions of space and time. However, as soon as hydroinformatics moves out

*If we may be permitted to proceed to a deeper level for a moment, we may observe, following Jung (1944//1953) that the self, being self-referencing to the point of defining itself, can only objectify itself in terms of mutually contradictory statements. Thus, from the *Iśa Upaniṣad*, verse 4, in the more poetic and accessible, but less academic, translation of Purohit and Yeats: 'The Self is one. Unmoving, it moves faster than the mind. The senses lag, but Self runs ahead. Unmoving, it outruns pursuit. Out of Self comes the breath that is the life of all things.'

into its sociotechnical dimensions, these idealities of modern science become inadequate and we are obliged to consider our definitions of space and time much more carefully and generally (see the collections of essays in Law 1986 and Law 1991). We then recall from Kant (*ibid*, p. 42//p. 71) that 'Space is . . . the subjective condition of sensibility under which alone outer intuition is possible for us'. This space is then not even a component of content, let alone an object, but something much less and much more: the necessary condition for the operations of content in its dealings with our outer world. How then is this to be objectified for the purpose of defining space? The solution of this problem was long sought, and was largely found, through the introduction of processes of *measurement*: space became definable just to the extent that it could be measured. We may recall that, already for Descartes, 'I call a *dimension* the mode and the manner according to which any object at all is regarded as measurable.' Entirely consentaneously, *geometry*, as the first pure science, began with this means of definition through its ideal objectification of space. However, the *arithmetic* theories of measure – and even such a deviant theory as that of Whitehead (e.g. 1920) – demonstrate that 'an exact measurement' would necessitate an infinite thermodynamic entropy production, i.e. it would consume an infinite quantity of negentropy or 'free energy' (Kolmogorov and Fomin 1961; Brillouin 1956). An 'exact definition' of space is thus unrealisable. Apart from this, however, the hydroinformatician has, it seems, little to learn about the definition of space.

The situation regarding time, however, is of a much greater concern to the hydroinformatician, as well as to many others (see, for example, Wittgenstein 1958, p. 26). For Kant (*ibid*, p. 46 // p. 74, 75) 'Time is a necessary representation that underlies all intuitions. . . . Time is . . . given *a priori*. In it alone is actuality of appearance possible at all. Appearances may, one and all, vanish: but time (as the condition of their possibility) cannot itself be removed.' Thus the device of objectifying time by introducing measures of it directly, in imitation of space, is not possible: a further step in abstraction is required. This step, which appears to have dated back at least to ancient Babylon and Pharaonic Egypt, was to employ space as a source of metaphors for time. These metaphors were sought, and largely found, in the ever-changing positions of the sun, the moon, the planets and the stars relative to an observer on Earth, whereby measurements of distances on Earth could be used to provide measurements of time, as exemplified by the sundial and the astronomical observatories of ancient times. By these means time could be objectified and thereby defined. This metaphor so impressed the ancient Greeks (who were very sensitive to such conceptual movements!) that they could not ascribe it to any human agency, but only to the work of a god, whom they then identified with *Cronos*, he being himself the fruit of the union between the goddess of the earth (*Gœa*) and the god of the heavens (*Uranus*). This attribution was then expressed through the orthographic contiguity of the words in ancient Greek for *Cronos* (Κρόνος) and for time (χρόνος). Time which is measured and thus defined in this way is accordingly called *chronological time*. We employ the word *clock* generally for any device, artefactual or natural, that realises this correspondence between time and its measurable representations in space. This time is clearly something quite other than time as it is experienced in our everyday affairs, which instead provides a wide variety of *experiential*, or *subjective*, times. Thus, although the hydroinformatician working in a purely modern-scientific domain need be concerned only with chronological time, when working in the sociotechnical domain, which includes the ecological domain, and in the domain of the natural environment generally, he or she must take account of the times of human and other creatures' experiences, which are for much the greater part experiential, or subjective, times. Thus the hydroinformatician working with natural organisms and their habitats should for the most part only use chronological time for reference when reporting results and relating these to human activities, working otherwise with the experiential times of the organisms and their habitats. For example, the blossoming of certain plants may occur in April in one year and in February in another year when measured in our chronological time, depending on the sequences of weather conditions which these plants experience. However, in these plants' own experiential time, what we call /April/ and /February/ are experienced and interpreted as one and the same thing, namely <<blossoming time>>. Only when the sequence

of experiences is strongly influenced by the movement of the heavenly bodies, as occurs for example in tidal processes, or, more weakly and over a longer span, with the intensities of solar radiation, do experiential and chronological times come into some kind of correspondence (see, especially, Cloudsley-Thompson 1978, and Palmer 1978, and, more generally again, the whole work edited by Fraser et al. 1978).

THE FOURFOLD MEANS OF COMMUNICATION, STARTING WITH SIGNS AND SYMBOLS

Communication is a process that the self conceives as proceeding backwards and forwards between its own inner world and the inner worlds of the other(s). This proceeds essentially through processes of *betokening*, in which either an object is given up in place of another object by the self to the other and is accepted as such by the other, or the other gives up an object in place of another object to the self and is accepted as such by the self. It is usual to distinguish four classes of betokening processes, and thereby four classes of tokens. We shall first distinguish the two of these which are of the most immediate relevance to our present theme. These are, from the point of view of the self:

1. Signs (in the strict sense)

A sign (in the strict sense) is a token that, when given up to the other *is replaced* by that which it evokes (and in this case *signifies*) in the mind of the other. Thus, to use a familiar metaphor, the sign is that object which introduces the entirely other object which it evokes (and in this case signifies) onto the stage of consciousness, and then, having done its job, steps back into the wings of the stage, leaving the stage entirely to the signified object. Its category thus has as the simplest form of sign function:

Sign function: betokening object→betokened object (4)

2. Symbols

A symbol is a token that, when given up to the other, *replaces* that which it evokes (and in this case *symbolises*) in the mind of the other. In this case then, to continue with the previous metaphor, the symbol is that which, after introducing that which it evokes (and in this case symbolises) onto the stage of consciousness of the other, sends this, now symbolised object into the wings and takes over the role of this object itself. Thus, the symbol function proceeds in the opposite sense to the sign function. Its category takes the form:

Symbol function: betokened object→betokening object (5)

In Category Theory, the category obtained by reversing the direction of the arrows in a given category, as exemplified by Equations (4) and (5), but then so that what was the target set in the one becomes the source set in the other, and *vice versa*, is said to be the *dual* of that given category. Thus, the *sign function* and the *symbolisation function* are seen to provide dual categories when the domain and the codomain of the one become, respectively, the codomain and domain of the other.

It may be useful to give two simple examples that will be familiar to most hydroinformaticians. The simplest of all partial differential equations is that which describes a continuous rectilinear translation or advection of any measure f with a velocity u along a direction x in time t. We represent this process by:

$$\frac{\partial f}{\partial t} + u\frac{\partial f}{\partial x} = 0 \tag{6}$$

We can read this as a sign, in which case we are led to think about the physical process of advection occurring in space and time that is so signified. We can, however, equally well regard it as symbolising the process of advection, so that we can operate with this equation without ever thinking about what it 'means', the equation having now taken over the stage from all our thoughts of worldly processes. Thus, to make of this a second example, if $f = u$, as the momentum per unit mass that is being advected under these conditions, we could write Equation (6) in a conservation form as:

$$\frac{\partial u}{\partial t} + \frac{\partial (u^2/2)}{\partial x} = 0 \tag{7}$$

and then differentiate Equation (7) to obtain the original form of Equation (6):

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = 0 \tag{8}$$

In this operation of differentiation that produces Equation (8) we do not care at all what *f, t*, *x* and *u* signify–they could signify anything at all for all that we care during this process–for we are only concerned with them as symbols that are adaptable to mathematical manipulation. They have completely taken over the stage in our attention. A more detailed discussion of the historical background and the social consequences of this symbolisation process in technology is provided by Abbott (1999). There it is seen to have provided a paradigm, called the *symbolic paradigm* in science and technology, that has extended over a period in history that is called the *symbolic era*. Hydroinformatics is nowadays marked by a more general reaction to the ideology of that era. This reaction is identified at the technical level with *sub-symbolic processes*, as exemplified by artificial neural networks, many evolutionary algorithms, classification systems as exemplified by applications of support vector machines and the many other developments of this kind that so occupy the pages of the *Journal of Hydroinformatics*. Similarly, the engineer, and to a considerable extent the scientist too, nowadays work in socially-orientated applications for the most part with signs through the user interfaces of tools that encapsulate all the operations of symbolic processes, so that we may now speak of a *post-symbolic era* (Abbott et al. 2001).

Now it is commonly observed in Category Theory that the dual of a given category may describe a process that is very far removed conceptually from the process described by the given category. The category of signs and the category of symbols with interchanging domains and codomains are no exceptions in this respect. They obviously provide very different means to communicate, corresponding to very different intentions on the parts of the communicating agents, both from the side of the self and from the side of the other. The directed-graphical representation of the category of the communicating sign is then usually perceived as a tetradic structure as shown in Figure 2.

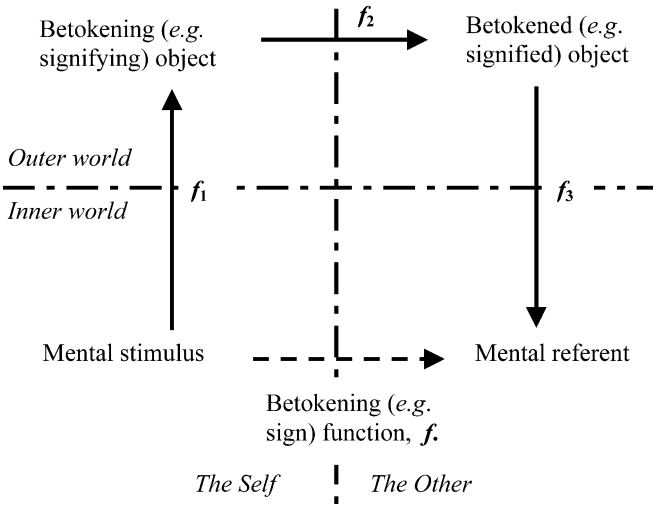

Figure 2 | The tetradic structure of a betokening function, such as a sign function (adapted from Klinkenberg 1996 p. 93).

We see that the arrow *f* in Figure 2 corresponds to the composition *f* of the mappings f_1, f_2 and f_3, so that $f = f_1 f_2 f_3$, i.e. $f(\square f) = f_3\,(f_2(f_1(\square f_1)))$ and $\square f = \square f_1$.

Communication through the use of symbols in the mathematical sense nowadays proceeds for the most part in two directions, the one being between our own selves and the machine-other and the second being between the productions of this machine-other – which we may interpret as communications from the machine-other – and our own *understanding* of how this device is actually functioning. The first is concerned with the representation of processes in symbolic forms suited to our own understanding and means of mental manipulation, as just exemplified above, and the translation of these into statements like numerical schemes, that are better adapted to the ways of working of our machines, as 'the others', and the programming of these latter forms into a working code. The most common aids to symbolic manipulation, or 'methods', are then those of elementary algebra and calculus, Taylor series and Fourier series, occasionally augmented by Fourier Transforms. The second direction of symbol-enabled communication is concerned with the self's own understanding of how its machine-other is functioning *in reality* on the basis of the productions of this machine. We then use much of the same methods,

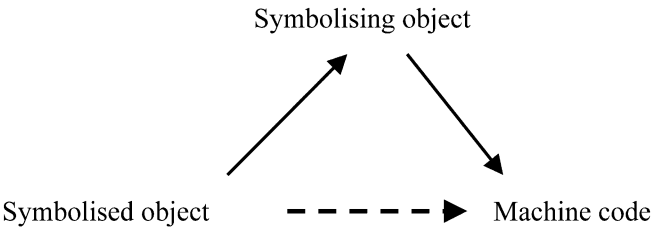

Figure 3 | The encapsulation of knowledge in information.

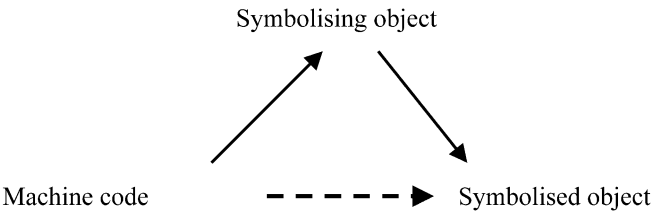

Figure 4 | The interpretation of information as knowledge.

albeit in other ways. This process has been described further by Abbott (1993; see also Abbott and Basco 1989).

We can provide categories for these two complementary processes by adapting the triadic structure used by some semioticians to represent the action of the token generally to represent the action of the symbol. In the first of the above cases this provides the category shown in Figure 3, while in the second case it provides the category that can be seen in Figure 4.

In the first case, 'that which is significant', or 'has meaning' for the designer of the knowledge encapsulating device, is transformed into a machine-compatible code, which we may conceive, at least in metaphorical terms, as 'having meaning', and therefore 'being significant' to the machine. In the second case, certain outputs of the machine, and usually outputs from carefully chosen 'test rigs', are analysed by the designer in order to understand 'what the machine is really doing' under the instructions of his or her code (see Abbott and Minns 1998, pp. 463–517). These two processes are again seen to produce categories that can be construed as dual. Once yet again, in this respect, we observe that they are markedly different processes and it is correspondingly often observed that a person with a high level of competence in the one may display a lesser competence in the other.

Of course, these processes are those followed by the 'tool builder': the user of the tool, the 'tool user', proceeds along a different path again when translating the output of the tool into actionable knowledge (Abbott 1993).

It might at first appear as though the choice of which token should serve as a sign or as a symbol is quite arbitrary: it may appear as though anything at all may serve as a sign or as a symbol for almost anything at all to someone or the other. However, the classes of symbols must in fact differ from the classes of signs in ways that will facilitate their specific way of functioning as just described above. This can perhaps best be seen by first considering how symbols can most easily present themselves when 'taking over the stage' from that which they symbolise. This presentation must be such as to enhance their acceptability and thus their legitimacy as symbols rather than signs, for it is clear that whoever or whatever introduces itself onto the stage and then proceeds to take possession of the stage, as a symbol has to do, must exhibit some trait or traits of similarity to that which it symbolises. There must then be traits that are recognised by the audience of users, who are therefore more inclined to accept the legitimacy of the symbol, *qua* symbol. Referring back to the use of symbols in mathematics, and thence in science and technology, it is instructive to follow the origins of their selections. Taking first the example of the velocity, this was originally symbolised in its entirety, subsuming both its magnitude and its direction, by the first letter in /velocity/, or, more historically correctly, */velocité/* as v. The advantages of using orthogonal coordinate systems in mechanics led, before the introduction of tensor and vector notations, to the need to use three different letters, which gave rise to the use of u, v and w as the velocities along the x, y and z coordinate directions, the letters u, v and w then also being neatly sandwiched between x and the symbol long accepted for time, t. The symbol x in turn had much longer historical precedents as <<the unknown>>, being an entity which itself of course had to remain unknown only until it could be determined. But such digressions into the archaeology of scholastic thought must necessarily be truncated at this juncture. It is only necessary to understand that if science and technology had not been formulated primarily in French at the

time when this usage came into practice, but instead had been formulated in another language, such as German, the notation would have been different. It is in this sense that the choice of symbols, as of signs also, is essentially arbitrary.

Similarly, but in less specialised contexts, /black/ for <<mourning>>, or /a weighing scale/ for <<justice>> all constitute symbols in that they take one or the other aspect of that which they symbolise, and use this to replace the symbolised object. It is by these means that these symbols attain to recognition as symbols, and thus their legitimacy as symbols, by those whose acceptance they require (see Klinkenberg 1996, pp. 189 and 193). Thus, the symbols are tokens possessing some socially accepted identifying element. In the theory of semiotics this process is described in terms of a *partitioning* of the symbolised object and a selection of one of the parts so as to provide a *correspondence* with one of the parts provided by a partitioning of the object that the symbol has to replace in the minds of its audience. The semiotician then speaks of a 'corresponding partition' (*découpage correspondant*) that applies in the case of the symbols. Which parts are chosen in this process still remains arbitrary, however, and there is no intrinsic motivation to adopt any one particular correspondence over another.

In the case of the sign, no such device is necessary, since the sign, as a signifying object that has now done its job, hands over the stage to the signified object, which is legitimate in its own right. Thus, the sign, having fulfilled its purpose, is legitimised by what it has already done, while the signified object is legitimised simply by virtue of its presence in consciousness. For example, if u signifies a fluid velocity, this fluid velocity itself stands in no need of any legitimising feature. The semiotician in this case speaks of a 'non-corresponding partition' (*découpage non correspondant*). Otherwise, however, signs can in principle be chosen just as arbitrarily as symbols.

CONTINUING TO INDICATORS

An indicator is a token that is chosen by virtue of its resemblance to a particular attribute of the object which it betokens, so that it is determined by a process of correspondence with an element in the partition of the betokened object. By virtue of the legitimacy thus attained, the indicator can take over the stage from the object which it indicates, so that it functions in this sense in the manner of a symbol. However, unlike the symbol, the choice of the particular element that constitutes an indicator is now highly motivated, or even determined, by this resemblance. Thus, an indicator resembles a symbol in the sense that it is defined by a corresponding partition of the betokened object and can thereby replace the betokened object in our thoughts, but it differs from a symbol in that it is defined in a quite highly motivated, rather than in a relatively arbitrary, way. The examples of /smoke/ for <<fire>> and /green/ for <<environmental protection>> are examples of indicators. More pertinent to our present interests is the example of the indication of a velocity vector in a graphical user interface. This may be indicated by an arrow or a blob with a line element, but there are scarcely any other alternatives that are sufficiently motivated to provide the required indication.

As established in the definitive work on the origins of logical thought by Husserl (1900/1901//1970) and as subsequently developed by Husserl and several other phenomenologists, indicators are described and analysed at a much great depths than can possibly be followed here, but then taking on more of the nature as well as the name of indicative signs. Although 'indicators' and 'indicative signs' are not, strictly speaking, synonymous, and despite the corresponding risk of confusion on the semiotics side of our subject, it will be more advantageous in the present context to use the term '*indicative signs*' instead of 'indicators' (see, for example, Husserl 1938/1948//1973, pp. 235 *et seq*). Signs in the strict sense, which are not 'indicators' or 'indicative signs' but have an expressive power, are then called *expressive signs*.

AND CONCLUDING WITH ICONS

Icons resemble signs in that they point towards and thereby introduce a something else, which they therefore signify; correspondingly they are generated through non-corresponding partitions. However, unlike signs in general, which are tokens that can be chosen in a relatively

arbitrary way, icons are tokens the choice of which is more or less strongly motivated by the nature of their respective signified objects.

Klinkenberg (*loc cit*, p. 193) gives the examples of a photocopy, the reflection in a mirror and an architectural plan, among others. Icons have a special significance in hydroinformatics when they are used to symbolise selfhood. A video clip of a flock of birds alighting upon an open stretch of clear blue water (preferably accentuated by framing this event within glittering ice-flows or lush vegetation!) provides an example of an icon that directs our minds towards the 'primal purity of nature in all its naturalness', whereby the birds in particular became imbued with an own selfhood, and thereby enter into another and higher value system in our estimation. The video clip is strongly motivated, but it does not constitute a 'mere' indicator – the frame of ice-flows or vegetation serves that purpose – but it points towards a something that is much deeper and more profound. In terms of its semiosis, the partition at the level expressed by <<the visual image of the alighting birds>> proceeds independently of any partition of the intrinsic value of the life-world of these creatures in the fullness of their selfhood. This example illustrates what are generally called the *technologies of persuasion*, such as are necessary adjuncts to the activities of the hydroinformatician working in the social sphere (see Thorkilsen and Dynesen 2001).

THE GENERAL TYPOLOGY OF TOKENS

We have concentrated here on a division of tokens according to their different functions, but we have also tried to sketch the way to a more architectonic typology in terms of the differences in motivations and correspondences of partitions of these tokens relative to those objects which they betoken. Concentrating more on this latter aspect (Klinkenberg *loc cit*, p. 189) provides Table 1.

When we discussed the dictionary and the necessary incompleteness of dictionaries within the confines of linguistics, we observed that there were some meanings which could be expressed by tokens – that in this case were words – and others that could not. The question

Table 1 | The criteria used in the theory of semiotics for typifying tokens (from Klinkenberg 1996, p. 189)

	Motivated	Arbitrary
Corresponding partitions	Indices or indicative signs	Symbols
Non-corresponding partitions	Icons	Signs in the strict sense

naturally arises, and has been discussed in one way or the other for centuries, as to whether a more general process of semiosis would allow for every meaning to be represented. Would it ever be possible to construct even so much as a model of an ideal dictionary that would provide bijective mappings between the representation of objects and the represented meanings of these representations? Already in hydroinformatics practice we observe the use of images, that are nowadays usually coloured and are becoming increasingly dynamic, to induce meanings into the minds of those who should be persuaded of certain ways of proceeding rather than other ways of proceeding in the worlds of the waters. More recently, this process has started to move further again, to providing means for the others to express themselves on matters of water and the environment, with a similarly extended arsenal of semiotic devices at their command (e.g. Jonoski 2002). We shall return to this issue in a moment when we consider the use of words from different languages in a single text, and again when we speak further of the technologies of persuasion.

We may distinguish two major streams of thought that have developed concerning the matter of the completeness of the set of betokening-to-betokened functions over the last century. The one, already identified here by the name of logical positivism, as associated with authors ranging from Mach to Carnap, proposed a project whereby every meaning within a specific – and most commonly mathematical – language should be expressible, with the implicit corollary that every question that was posed within this language should be decidable through the construction of a suitable algorithm, called a *decision procedure* (see for example Carnap 1934//1937, and, by

way of retrospection, 1954). From this point of view, language is a completely human construction, and thereby totally subject to the workings of human reason. The other, opposing, stream of thought, as reinitiated in the nineteenth century by Kierkegaard, Schopenhauer and Nietzsche, and represented in more recent times in 'the West' by the phenomenologists and existentialists on the more philosophical side and several socially-engaged churchmen on the theological side, castigated this project and opposed it at every turn (see for example John Paul II 1999). From their perspective, mankind is just as much a product of language as language is a product of mankind. As Wittgenstein expressed this matter, not only is the ritual of the myth a form of language, but every language of a society implicitly contains all the myths of the society as residues of its primal truths, learnt over eons of time, that are more or less automatically passed on to those who learn and further employ the language: 'Our language is an embodiment of ancient myths . . . A whole mythology is deposited in our language' (see Rhees 1982).

We may then define a *natural language* of a social group as the sum of the means necessary to express the myths of the group, understood as the repositories of the most profound truths of the group. The spontaneity of the emergence of the so-called 'Green', 'Ecological' and 'Environmental' movements, such as may be directed to the welfare of all manner of creatures as well as to our fellow human beings, cannot be understood in any other way than this. *The language of hydroinformatics as it proceeds further into its sociotechnical dimensions (which again include its ecological and general-environmental dimensions) thus itself becomes increasingly a natural language*. It follows that although it must make use of scientific languages as means for accessing its scientific 'assets', as exemplified here by the use of fragments of Category Theory and Object Theory, it cannot remain constrained to scientific language as it goes about its work in the real world.

(We must further observe in passing that the word *natural* has a very distinctive meaning, and not least in mathematical contexts. It refers in the first place as an adjective to any token that cannot be defined in terms of more primitive tokens. Thus, within the mathematical context, the expression '*natural numbers*' refers to numbers that do not permit of definition in terms of any other numbers (Manin 1977, e.g. p. 17; see also Abbott 1991, pp. 109, 110). In the same vein, the expression '*natural transformation*' in Category Theory refers again, but now more generally, to a token, and in this case a symbol, that is a primitive to all betokening, and in this case symbolisation, processes within the theory (Granger 1994, pp. 155–182; see also Abbott 2000)).

The consequences for hydroinformatics of the adoption of the present position are momentous in the extreme, leading for example to a complete reversal of the so far established paradigm of decision-making in society by placing a new emphasis on the use of narrative discourse as the most immediate expression of natural language (see, for example, the questionings of Durning 1999, de Jong 1999, and Hoppe 1999, on the side of Policy Analysis; and the consequences drawn by Abbott and Jonoski 2001, and Jonoski, 2002, on the side of Hydroinformatics. See further Weingart 1999 and White 1994).

It should be observed, corresponding to this on the side of definitions, that one of the classics of logical-positivistic thought, the *Principia Mathematica* of Whitehead and Russell (1910/1925), defined a definition in a quite different way to that employed here. Thus (*ibid*, vol. 1, p. 11) 'A definition is a declaration that a certain newly-introduced symbol or combination of symbols is to mean the same as a certain combination of symbols of which the meaning is already known'. The approach that is followed in that case is thus again purely prescriptive, and indeed it continues in the same vein over all aspects of definition (*ibid*, vol. 1, pp. 11–26).

The programme of logical positivism, extending even to the requirement of 'exact definitions' and 'infallible proofs' in mathematics, has been rejected by many, if not most, practising mathematicians. An unparalleled exposition of this dispute in its mathematical context is provided by Lakatos (1976/1979).

MODELS

We may now define a model in the very general but simple terms that our subject requires as follows:

A model M of an object x, denoted by M(x), is that which provides a set of indicative signs $(i_1, i_2, \ldots, i_j, \ldots, i_{jj})$ *all of which have x as their referent and which can be operated upon by a function of the mind, mod(x), to provide an expressive sign e, =e(x), that expresses a truth about the object x*. Thus, more formally:

M = M(x) if and only if M(x) provides $(i_1, i_2, \ldots, i_j, \ldots, i_{jj})$ *such that:*

$$mod(x): (i_1, i_2, \ldots, i_j, \ldots, i_{jj}) \rightarrow e \quad (9)$$

where what is expressed by e, =e(x), is true of x.

Put another way again, only when $M(x)$ provides a set of indicative signs that constitute the domain $\square mod(x)$ of some $mod(x)$ can it constitute a model for x. It is easily seen that this definition applies to all conventional applications of /model/, such as /an artist's model/, a /model-year of a particular motor car/, a /physical model/, a /numerical model/, or even, when properly formulated, a /data model/. It also, however, casts such less obvious objects as /geographies/, /histories/, /legends/, /sagas/, /myths/ and many others as models when the mappings also impose particular kinds of spatial differentiations (such as by the use of different colourings in the cartographic tokens used in geographies), or total or partial ordering in experiential and chronological times in the other named examples, upon the indicative signs (Abbott 1992). To return to our more mundane earlier examples, a collection of velocity vectors on a monitor screen may express in the mind of the viewer the existence of isolated circulations, or trains of eddies, or local tidal races or other features of a flow in a physical prototype. If the expression $e = e(x)$ truly expresses such a meaning, so that $mod(x)$ can provide a 'reading of a meaning' into the set of indicative signs (such that the presence of this meaning in the inner world of the modeller coincides with the outer-world experience of the modeller, whereby this modeller has an intimation of the oneness of these two experiences) then the device that provides the set of indicative signs constitutes a model. The structure induced by the function $mod(x)$ is shown in Figure 5.

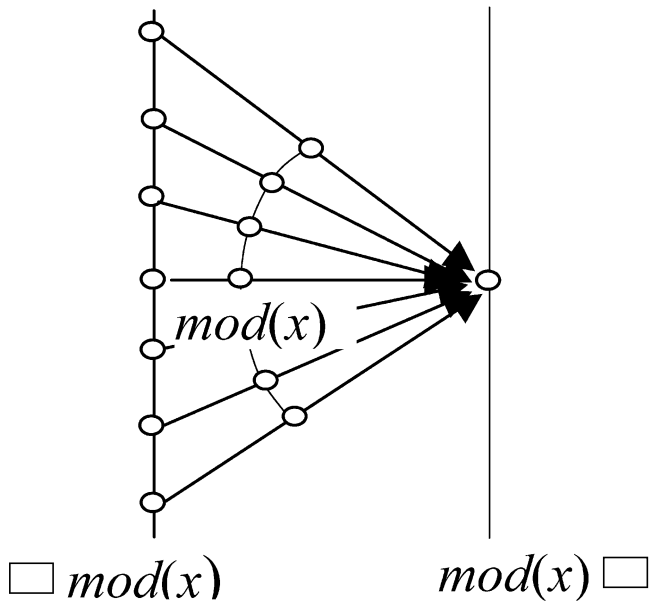

Figure 5 | The category generated *mod(x)*.

In the event that a device provides a set of indicative signs appertaining to an object x for which no function $mod(x)$ exists, then this set is said to constitute *data* for x. The construction and operation of devices for evolving functions $mod(x)$ from data for x is already an important part of hydroinformatics, called *data mining for knowledge discovery* (see Babovic and Keizer 2000).

It is seen that, since the codomain contains one and only one element for any one $mod(x)$, the system composed of the function $mod(x)$ with the indicative signs as domain and the expression sign as codomain must again constitute a category. We may of course only refer to *a* model of x, because, in principle, there may be any number of individual models of x corresponding to different choices of the types of domain and codomain presented to $mod(x)$ in the category. This is to say that in reality we never actually apply $mod(x)$ to an object in the Meinongian sense of an *objectum*, but only to a phenomenon associated with the object, which can then only be an object in the sense of an *objective*. Thus, for example, when we speak about /a model of the Rhine/ we really always mean something like <<a model of the time-varying water levels and discharges along the Rhine>> or <<a model of the distribution of phosphates along the

Rhine>> or something else of this, essentially phenomenological, kind. It follows that we should really understand by the /*x*/ employed above the phenomenological *objective* and not the *objectum* which is the physical locus of the phenomenon. Since, however, the entire phenomenology is in each case implicit in the source set that is proffered to the function $mod(x)$, we could then, at a stretch, define /a model for *x*/ simply as $<<\square mod(x)>>$ when $<<mod(x)\square>>$ exists and is true. This notation corresponds to the intuition that functions like *def* and *mod* are archetypal, being conterminous with content generally, so that the contexts within which they are applied can only be denoted by the types of their source sets, or domains, and their target sets, or codomains.

We observe that this definition of a model may appear to differ from the popular one. Most persons would suppose that a model already exists if it simply provides a set of indicative signs, but all existing dictionary usages insist that, however and whatever indicative signs are provided, that which provides them does not constitute a model unless these indicative signs can be associated in the mind to provide meaning. Thus:

'*no capacity to induce meaning: no model*'

Accordingly, to continue our earlier example, it is only if the observer of a field of velocity vectors is able to distinguish such relevant features as circulations, eddies, vortex streets and tidal races that a model exists. Further to this again, all existing usages insist that the meaning provided by the expressive sign must in this physical case be true relative to the observed state of the outside world. Thus, we have further:

'*no capacity to induce truth: no model*'

In the practice of *numerical modelling*, it is unusual for the truth of the expressive statement to impress itself on the mind of the modeller on the basis of the indicative signs that are first produced by the machine. Usually the code is run repeatedly under different sets of assumptions in such a way that, on average, the expressive sign increases its veracity during the sequence of runs. Each model-object is then a consequence of a preceding model-object and in turn provides a precedent for a succeeding model-object again. Following Meinong, we then speak of a sequence of *implected* objects (see, more definitively, Abbott 2000). A more common term nowadays is that of 'nested objects', but these are really quite different entities: 'nested' has the connotation of the one object being *contained* within the successor-object, while 'implected' has the connotation of the one object being *woven into the very fibre* of the successor-object. When an intimation of truth is attained – by whatever means – that is adequate for supporting the intentions of the modeller, this implection process is ended, at which point the sequence of implected objects is said to be *closed*.

The process of implection carried out on the objects employed to provide the indicative signs whereby the modeller arrives at his or her truth is the process that is called *calibration*. The model that is provided by the closure of this process of implection is said to be *validated*. If, for example, the sequential inundation of a land area is observed in a model to take 6 hours and it is known from experience that it should take 60 hours, then again no model exists – even though in that case the model might still signify that we should be looking askance at the infiltration rates into the soil and indeed of the entire modelling of the subsurface flows. In this case the model has not been calibrated and thus cannot have been validated either (see further Cunge 2002).

It follows further that a device, such as an artificial neural network, that has been trained to transform, for example, rainfall recordings into runoff records with a good agreement with observations, does not as it stands constitute a model, since no meaning can be adduced from it for the observed behaviour. Of course, such a device may be very valuable in practice and its predictions may be accurate, and so true, but it is not a model in terms of the centuries-long established definition. At another extreme, we observe that the curve of a graph can sometimes be construed as a model when it provides an expressive sign. (In this case the set of indicative signs is in principle infinite, but we do not need to modify our definition so as to satisfy this, purely conceptual, possibility).

We observe further that models of different classes may have to be connected together through compositions of their mapping functions in order to provide expressive signs and thus to function as models at all. Thus, for example, a numerical-hydraulic 'model' may provide a

water depth of one meter at a certain place, but the true significance of this – what it really expresses to the human-other, or what it really *means* – only emerges when this place is identified within a geographical context. It is essentially because of this feature that so much effort has been expended on providing seamless interfaces between numerical-hydraulic models and geographical information systems (GISs). The numerical hydraulic model is in this case still a model, but then only because it provides an expressive sign through the agency of the artefactual GIS-other.

KNOWLEDGE

Hydroinformatics is nowadays very taken up with knowledge, seeing in the provision and exchange of knowledge means to improve the state of the world through improvements in the employment of its waters (Abbott 2001; Abbott and Jonoski 2001). The case of the model, and with this the modelling process encapsulated in the function $mod(x)$ in Equation (9) above, illustrates a process of a taking up of objects into consciousness within a medium of content, and the application of transformations, or mappings, upon these objects together with the products of these transformations or mappings. Such processes must then necessarily alter the inner world of the self in which they occur, and then, further, they may alter the outer world of that self by the actions of the self upon the others that follow from this self's own inner world modifications. The impressions again of these outer world changes upon the inner world of the self complete a cycle of development that, ideally at least, should repeat itself in the general development of selfhood. Of course, this ideal process remains always incomplete in practice.

The changes that occur in the inner world of the self through this implection process and which change the way in which the self behaves relative to its outer world are naturally associated with the notion that the self changes its 'inner state' by acquiring something. This something that causes these observable changes is, as a first approximation, that which we call 'knowledge'. Since the 'acquisition of knowledge' is essential to the self in its striving towards selfhood, 'knowledge' is then necessarily existential, that is, it is inseparable from the Being of the self.

Theology, of course, expands upon this again, by extending the notion of knowledge to comprehend the direct intimation of reality and truth outside of the direct conscious experiences of the self. This is still necessarily realised by an outside agency, and in this perspective by virtue of *grace*, such as is inseparable from a state of the inner world of the self which is called *faith*. The relations are then expressed in the formula of Anselm, of *Credo ut intelligam*, or 'Faith precedes knowledge'. Several existential and phenomenological philosophers have extended this formula outside of its theological origins and into the sphere of the secular. We may then broaden the definition of knowledge so as to comprehend all such positions as follows (Barth 1938–1950/1961, III, 3, p. 188):

> ''By the knowledge of an object by men we understand confirmation of their acquaintance with its reality in respect of its existence and its nature. . . . Their acquaintance with it, instead of being a contingent and outward determination of their own existence, now becomes a necessary and inward determination. Knowing, they are affected by the object known. They no longer exist without it but with it . . . Whatever else and however else they may think of it, they must begin by thinking of the truth of its reality. . . . Its truth has come home to them, has become their own. And in the process they themselves have become the truth's. This event, this confirmation, in contrast to mere cognizance, we call knowledge. Cognizance becomes knowledge when man becomes a responsible witness to its content.''

We observe that as soon as we regard our fellow creatures as subjects we commonly project our own experiences of knowledge acquisition and employment on to these creatures also. We then suppose that such functions as $def(x)$ and $mod(x)$ are not confined to humans alone, but are shared with many other, and possibly all, our fellow creatures, albeit using very different semiotics to those that we employ and which have been introduced here.

INFORMATION IN RELATION TO EDUCATION AND TRAINING

Information in the present sense can only have the form of tokens that are presented to the self into which knowledge

is to be induced. Information can then only be transformed into knowledge to the extent that the vehicles for mapping betokening objects into betokened objects – and specifically the sign functions, symbol functions, indicator functions and icon functions – are already present as knowledge within the self. Thus, the acquisition of knowledge through the provision of information presupposes the presence of another knowledge again that will implement this acquisition. In hydroinformatics, as in several other disciplines besides, we refer to such an enabling knowledge as constituting a *knowledge frame* (Abbott 1993). It is this knowledge frame which contains the various functions that provide meaning to the tokens that are presented to the self within any such *learning* context or situation, and all transformations from information in the form of tokens to the corresponding knowledge must occur within the one or the other such frame. We also often say that the new knowledge *comes to presence* within its corresponding knowledge frame. This process is clearly also recursive: all new knowledge that comes to presence may provide, and indeed will commonly provide, enhancements of existing knowledge frames, and even new knowledge frames again. When regarded as objects, the knowledge frames are again always incomplete objects, but, to the extent that knowledge is accumulated, the previous such incomplete objects become implected in the succeeding, so to say, 'less incomplete', object.

These objects also always remain incomplete in the real world, but each successive object absorbs and subsumes its predecessor as more and more knowledge is assimilated. When the acquisition of knowledge in this way is associated in its turn with an agent of the self, its manifestation is the development of an increased outer world competence. We observe, still following Meinong's terminology, that the process of implection may stop when a certain desired or acceptable level of competence is attained, in which case the set of implected objects is once yet again said to be *closed*. When this process is confined to one or only a few agents, we speak of *training*. In the case that this development extends over more, and even many, agents, so that the set of implected objects remains *open*, we speak instead of *education*. Thus, in its primitive sense, /*training*/ applies to a development of one aspect or agency of the self towards selfhood, which can be completed in time, while /*education*/ is associated with a movement of the self as such towards its selfhood, a condition which is never completed in time. In either event, *information is that which has the capacity to augment the knowledge of the self and thus induce the development of the self towards its selfhood*. For the genesis of these now well-rehearsed formulations in the era of Enlightenment, see Hume (1739/2000, e.g., pp. 286–290).

The requirement of Enlightenment and indeed of the entire modern movement of which Enlightenment was one part, that everything in the world should be ordered, numbered and computed, or even more, as Spinoza expressed the matter most succinctly, that 'the whole world should be reduced to a tautology', has led to the discipline of *information theory*, as celebrated in the works of such as Szilard, Shannon and Brillouin. Although the definitions of /*information*/ given by these authors obviously has its own relevance, they are, on the one hand, so well known and, on the other hand, so specialised, that we shall not discuss them here. (See, at its broadest range, Brillouin 1956).

Clearly, information in its functioning is itself a function of content, so that its definition necessitates objectification, which in this case is easily available in the sense that the Latin *informare* derives from the infinitives *to shape*, *to form* an idea of, or *to de-scribe* (Andrews *et al*. 1879). As it is assimilated into knowledge, information is that which shapes objects, forming them within the matrix of content so as to provide circum-scribing descriptions as elements of thought. Thus, the processes just introduced correspond to those which we commonly identify with *communication* between the self and the other and *vice versa*. Communication presuppose the existence of channels and tokens that are shared between the self and the other and, being so shared, they are held in common by both: 'speaking together' always implies the presence of a common language. (See, further to this, Heidegger 1939/1971).

The process that proceeds in the opposite direction to that of 'information→knowledge' is that whereby knowledge becomes represented in tokens, whereby 'knowledge→information'. The knowledge concerned in

this latter case is then said to be *encapsulated* in the respective tokens, as already introduced above.

Corresponding to the division of the self and the formation of its various agents with their different agencies or *faculties*, knowledge has long been divided into different parts, commonly called *disciplines*. Each one presupposes a particular configuration of the inner world of the self, so that each constitutes 'a world in itself', so to say. The collection of all such actual and real worlds is then said to constitute a *universe*. Thus, an institution directed to the development of selfhood was originally intended to accommodate all these worlds, as *faculties*, so as to constitute a *university*.

UNDERSTANDING AS A PRODUCT OF PREDICATIVE JUDGEMENT

Clearly, understanding is something else, and mostly something more than knowledge, just as to understand someone is something else and usually something more than simply knowing them.

In the case of understanding, which we conceive as situated, so to say, 'on the other side of knowledge' from that of information, the mode of objectification is apparent simply from the meaning of the decomposition of the words used to represent it. For example, we may have metaphoric objectifications in terms of standing – *for-staa* in Danish, *under-stand* in English, *ver-stehen* in German – and in terms of taking or taking hold of something – *com[me]-prendre* in French and *be-grijpen* in Dutch. In its relation to knowledge, understanding clearly occurs when knowledge becomes the subject of predication. Thus, from the time of the Englightenment, with Hume (1739–40/1999, e.g. p. 15), understanding was conceived as the faculty of factual reasoning or reasoning from experience, where reason was in turn understood as the faculty of immediate intuition and demonstration. In the more general terms employed here, we may regard understanding as *that process occurring within the self which changes the knowledge of the self in the direction of advancing its selfhood without the acquisition of further information from outside the self*. Of course, information by its very nature can initiate, and promote this process, and this function of information is of the greatest relevance to hydroinformaticians when they wish to induce understanding, but the process of understanding is different in kind to the processes of communication, of 'information→knowledge'. *Understanding arises only when knowledge works upon itself in the direction of advancing the self in the direction of its fulfilment in selfhood*.

JUDGEMENTS

It is only through the faculty of understanding that anything like a token can have 'meaning', so that /meaning/ in the sense of a definition presupposes the presence of this faculty. Since the times and works of Husserl (as exemplified here by 1938/1948//1973) it has been usual to identify the transformation 'knowledge→understanding' with the process of making judgements, which are then necessarily predicative judgements. Husserl, as usual, is unsurpassed in his description of the process involved in terms of objects and their objectification (*op. cit*. p.62):

> ''O*bjectification* is thus always an *active achievement of the ego*, an active believing cognizance of that of which we are aware, this something being *one* and continuously the *same* through the continuous extension of consciousness in its duration. It is that which is identified in distinct acts which form a synthesis; in this synthesis we are aware of it as the same, as that which can always be recognized, or also as that which is freely repeatable in recollections or freely producible in perceptions (when we go there and take one more look). It is precisely this identity, as the correlate of an identification to be carried out in an open, boundless, and free repetition, which constitutes the *pregnant concept of an object*. Just as every other praxis has its practical goal, the that-about-which of the act, so the existing object is, as existing, the goal of the doxical, the act of cognition, the act which explicates the existent in its modes of being, which are here called determinations. To be sure, it is really only on the higher level that the *confirmation* [*Feststellung*] of the existent, of its how and what, which constitutes the objectifying function of the judgment, becomes a confirmation to which we can return again and again and, as such, a permanent possession of knowledge. This is the level of the act of predicative judgment, the sedimentation of which is found in the declarative statement. As the sedimentation of a store of knowledge, this confirmation is freely available,

> preservable, and communicable. Only the act of predicative judgment creates this store of knowledge and the objects of knowledge in the pregnant sense of the term, and not the act of judgment typical of merely receptive contemplation, although the latter already creates knowledge which persists as habitual. *Every act of predicative judgment is a step in which a permanent store of knowledge is produced*. It is in itself a complete step in determination . . . and the primal cell of thematic determination.''

A judgement is thus made on the basis of the information available at the moment of judgement, and often the judgemental act is deferred so as to access as much information as possible in the time available. We often therefore speak of making a judgement on the basis of the available *facts*. These facts are, consentaneously, those which the self considers desirable, or even necessary, in the making of its judgement. The self then makes its judgements based upon its own beliefs about itself and the facts that it has available that it considers (or 'judges to be') relevant, and it does this by taking an *attitude* towards these facts. It is only on the basis of this attitude towards the facts that it proceeds to a judgement. We may then formalise each such process most simply as a string of inferences, as follows:

$$(beliefs,\ facts) \rightarrow attitudes \rightarrow judgements \rightarrow decisions \rightarrow actions \quad (10)$$

where both the action and the facts are observables and, of course, the <<action>> may subsume also a total inaction.

We now see that, whereas Equation (10) represents the simplest judgement process about things, including 'the other', as facts, the self's judgement about the underlying beliefs of the other, as an *understanding* of the other, corresponds to the same structure but with the arrows reversed:

$$(beliefs,\ facts) \leftarrow attitudes \leftarrow judgements \leftarrow decisions \leftarrow actions \quad (11)$$

where now, however, both the action and the facts are observables. The set of all mappings of the form of Equation (11) covering all judgement-related agencies of the other are then said to correspond to the determination of a *profile* of the other (Abbott 2000). We observe that Equation (11) with interchangeability between domains and codomains would appear to behave as the dual of Equation (10). A judgemental process is then said to be *transparent* to the self if the inference strings in both Equation (10) and Equation (11) are simultaneously available and can be called to presence at will within the mind of the self.

(We cannot resist observing, in passing, that the duality of Equation (10) and Equation (11) corresponds to Kierkegaard's celebrated aphorism that 'we live our life forward, but we understand it backwards').

JUDGEMENT ENGINES, FACT ENGINES AND ADVICE-SERVING SYSTEMS

A judgement engine is a device that takes the profile of the other and the sociotechnical facts relevant to the situation of the other as input and which provides a judgement upon the best course of action of the other as output. A fact engine is any device that feeds the judgement engine with the facts that this judgement engine requires. Generally, a judgement engine is served by several fact engines of different kinds, such as, on its scientific-technical side, data networks, numerical models, sub-symbolic models, GISs, GPSs, cartographic coordinate transformation systems and devices for interpreting the products of remote sensing devices, such as those of satellites, aerial photography and weather radars.

A system composed of one or more judgement engine(s) that can accommodate a range of profiles of the others involved in a project, and which is fed by facts that are relevant to the project, constitutes an *advice-serving system* if its actions are in the form of items of advice directed towards these others involved in the project. We observe that the judgement engines of advice-serving systems must normally incorporate encapsulated knowledge (Abbott and Jonoski 2001; Jonoski 2002).

SCIENCE, TECHNOLOGY AND SOCIETY: SCIENTIFIC, TECHNOLOGICAL AND SOCIETAL DISCOURSES

Among the worlds into which the self may divide itself there are three which are of primary importance to

hydroinformatics. These are the worlds of *science, technology* and *society*. Each has its own way of communicating, and so its own way of using tokens, corresponding to a scientific discourse, a technological discourse and a social discourse, which last may itself cover a range of overlapping discourses, such as *rhetorical discourse*, *narrative discourse* and the *Gerede* which we shall introduce shortly. There is a tendency from the side of semioticians to identify the divisions themselves with differences in the respective discourses and we cannot be indifferent to this tendency here, but must again try to accommodate it.

Science can be defined rather conventionally as that activity of the Self that is directed to the accumulation of knowledge within all possible worlds, whether real or unreal, so long as this knowledge is intimated as true. The study of unreal worlds that none-the-less possess 'inner truths' has long and increasingly constituted a part of mathematics, essentially the part commonly called 'pure' – but it has also penetrated deeply into certain parts of the physical sciences over the last century (see Baudrillard 1973; Lyotard 1979, e.g. p. 13//1984, p. 73).

There is then a science of the outer world, with disciplines ranging from anthropology to astronomy and from biology to business, and so on through the alphabet, and there is a science of the inner world, ranging over disciplines like the many branches of 'pure' mathematics, a great variety of logics, various systems of law, the manifold 'systems' of psychology and many, many other. There is then also a long established division between the scientific studies of society, called the *social sciences*, and of scientific studies of nature, called the *natural sciences*. It has further been usual, since the teachings and writings of Brentano (as developed between 1862/1960 and 1889–1915/1930) to divide the natural sciences into worlds dealing with animate nature, which is characterised by the presence of *intention* in its objects, making of them *intentional objects*, and a world dealing with inanimate objects, which are supposed to have no such intentions. Accordingly, the studies of living beings proceeds through analyses of their intentions, commonly leading to the identification of structures of intentionality, while the studies of the inanimate world do not (nowadays) follow this course at all. The manner in which the natural sciences have passed through a geometric era and a symbolic era over the last millenium and the way in which they are now being taken into a post-symbolic era is described in Abbott (1999).

Technology is that activity of the mind that is directed to creation in all the different worlds within which it applies itself. There is then again a division, but now between a technology of the outer world, as appears to be all too familiar, and a technology of the inner world, as represented by such disciplines as psychiatry and – of primary importance to hydroinformaticians – by what have already been illustrated as the technologies of persuasion. We may then again recall the already so much quoted definition of Heidegger (1963//1977, pp. 12, 13; see also Abbott 1991, p, 6):

> ''Technology is therefore no mere means. Technology is a way of revealing. If we give head to this, then another whole realm of the essence of technology will open itself up to us. It is the realm of revealing, *i.e.* of truth.
>
> This prospect strikes us as strange. Indeed, it should do so, should do so as persistently as possible and with so much urgency that we will finally take seriously the simple question of what the name 'technology' means. The word stems from the Greek. *Technikon* means that which belongs to *technē*. We must observe two things with respect to the meaning of this word. One is that *technē* is the name not only for the activities and skills of the craftsman, but also for the arts of the mind and the fine arts. *Technē* belongs to bringing-forth, to *poiēsis*; it is something poietic [creative, formative, productive, active].
>
> The other point that we should observe with regard to *technē* is even more important. From earliest times until Plato the word *technē* is linked with the word *epistēmē*. Both words are names for knowing in the widest sense. They mean to be entirely at home in something, to understand and be expert in it. Such knowing provides an opening up . . .
>
> Technology is a mode of revealing. Technology comes to presence in the realm where revealing and unconcealment take place, where *alētheia*, truth, happens.''

Away and beyond these worlds there are others again, which are those of the study of the human condition, and especially of this condition as it is experienced within its various social settings. These are the worlds of *the humanities*. Among the traditional studies in this latter field are those already mentioned as *rhetoric*. The relations between–and primarily the contrasts between–rhetorical and scientific discourse is well covered by Klinkenberg (1996, pp. 365–376).

As it moves increasingly into paradigms of communication within society, hydroinformatics takes on more and

more the form and substance of a *sociotechnology*. *Sociotechnologies are worlds where social and technological aspects have become so woven together to provide the very fabric of these worlds that they have become inseparable in thought*. A useful metaphor for the sociotechnical is that of a beam that spans between two columns, which are those of the social and the technical. This beam is then a quite other kind of structure than are the columns upon which it is supported. As explained in Abbott (1996; 1999), it is this sociotechnical dimension of hydroinformatics that makes of it a *postmodern technology*, with all the consequences – and literature! – that follow from that position.

GEREDE

Gerede is a German word that has within its various accepted meanings one that is not provided by any English word. It can only be expressed in English at all in such more or less derogatory terms as *gossip, chatter and idle talk*, and indeed it is often translated into English in this way. However, *Gerede* has also a more technical, non-derogatory sense, which is also much more profound, and indeed even possessing certain quite sinister connotations. Its now classical characterisation is that of Heidegger (1927, pp. 167–180//1962, pp. 211–224).

Gerede is a form of discourse in which the persons participating suffer a degradation of selfhood so that the quality of the discourse is degraded correspondingly. *Gerede* is that process which causes a group of persons, all of completely reasonable intelligence, to arrive at decisions which many of these persons individually would consider inappropriate when thinking independently. *Gerede* is that process which causes a group of persons of unimpeachable character to decide upon a project that must appear as in some sense dishonest to several of them when they later come to think about it individually. *Gerede*, however, has in itself nothing whatsoever to do with stupidity or dishonesty, but belongs to a category all of its own. Neither can it be neatly bracketed as some kind of collective trance or hallucination induced by the discoursing, for it has none of the usual attributes of states of trance or hallucination. Neither again does it involve any kind of conspiracy: the nominal 'leading figures' in any such movement are just as surely taken down with the movement when it founders as are any of its other participants. The nominal 'leaders' of such movements may certainly know how to lead them, but, as Carl Jung so succinctly expressed their predicament (1944//1953) 'One cannot possess this kind of knowledge without being oneself possessed by it'. If one tried to characterise it in simple terms at all, one could only say that it arises when the pleasure of sociability, and especially of social conformity, overcomes the pleasure of truth in those participating in the discourse, but that is surely too superficial also. This form of discourse is of course by no means restricted to the spoken word, but extends, and indeed persists for the most part, in written form.

Gerede has always been prevalent in processes of collective decision making, but perhaps never more so than at the present time. *Gerede* may take hold of a group of persons that may range from a few individuals to whole groups of nations, leading to the destruction of much that previous generations had accomplished.

The current movements directed to studies of 'ozone layer depletion' and of global warming through the emission of 'greenhouse-promoting gasses' (already a 100 million dollar a year enterprise!) provide several excellent examples of *Gerede*. The quite devastating critique of so-called 'development aid' by Easterly (2001) illustrates the malign influences of *Gerede* again, but at much larger scales of expenditure again (of around a trillion dollars). Of more immediate interest here, however, is the form of *Gerede* which does so much damage to disciplines. Thus, for example (Klemes 1986):

> ''Hydrology, having no solid foundation of its own and moving clumsily along on an assortment of crutches borrowed from different disciplines, has always been an easy victim of this practice. Every mathematical tool has left behind a legacy of misconceptions invariably heralded as scientific breakthroughs. The Fourier analysis, as was pointed out by Yevjevich (in 1968), had seduced the older generation of hydrologists into decomposing hydrologic records into innumerable harmonics in the vain hope that their reconstruction would facilitate prediction of future hydrologic fluctuations (fortunately few computers were available at the time so that the Fourier fever did not become an epidemic); various statistical methods developed for evaluation of differences in repeatable

> experiments have been misused to create an illusion of a scientific analysis of unrepeatable hydrologic events; linear algebra has served to transform the idea of a unit hydrograph from a crude but useful approximation of a soundly based concept into a pretentious masquerade of spurious rigor now exercised in the modelling of flood events; time series analysis has been used to remake inadequate 20-year stream flow records into 'adequate' 1000-year records, or even more adequate 10,000-year records, and the theory of pattern recognition is now being courted in the vain hope that it will lend scientific legitimacy to the unscientific concept of mindless fitting that dominates contemporary hydrologic modelling. In all these cases, mathematics has been used to redefine a hydrologic problem rather than to solve it.''

To this list we can now add the current frequent misuses of sub-symbolic devices in which all manner of 'strong relations' are established between data sets which in physical reality cannot possibly be much related at all. Corresponding as it does to a reduction of selfhood and thus of agenthood, *Gerede* is most commonly identified subsequent to the failures that it produces as *incompetence*.

Among the means developed to combat *Gerede*, probably the best known and the most publicised is that of *deconstruction*. Deconstruction is the process of subverting *Gerede* with its own instruments but used in other, and indeed opposite, ways. Thus (Derrida 1991, p. 41):

> ''The movements of deconstruction do not destroy structures from the outside. They are not possible and effective, nor can they take accurate aim, except by inhabiting those structures. Inhabiting them *in a certain way*, because one always inhabits, and all the more when one does not suspect it. Operating necessarily from the inside, borrowing all the strategic and economic resources of subversion from the old structure, borrowing them structurally, that is to say without being able to isolate their elements and atoms, the enterprise of deconstruction always in a certain way [also] falls prey to its own work.''

The so-called 'velvet revolutions' that occurred in 1989–1991 in Central and Eastern Europe have become the classical examples of deconstruction. It is important to understand here, however, that this approach provides what is in effect *another language* (*ibid.*, p. 241; see also Derrida 1967//1990):

> ''But is there a proper place, is there a proper story for this thing [deconstruction]? I think it consists only of transference, and of a thinking through of transference, in all the senses that this word acquires in more than one language, and first of all that of the transference between languages. If I had to risk a single definition of deconstruction, one as brief, elliptical, and economical as a password, I would say simply and without overstatement: *plus d'une langue*–no more of one language.''

In the language of postmodernism, *Gerede* is nowadays seen to take a hold upon large numbers of people, so as to form *Grand Narratives*. One of the aims of postmodernism is then to subvert these narratives, such as by deconstructing them.

In its destructive power, *Gerede* has always been closely associated with that which is called in English *nothingness*. This is Kierkegaard's *Intethed*, the *das Nichtige* of Barth and the later Heidegger, and the *le néant* of Sartre and other French existentialists. Nothingness is the abnegation of the self and of selfhood; it is hostile to Being, of the self and of the other, and thus to creation as a whole. For the theologians, nothingness is that which is inimical to God, and thus to His Creation. And then since, in the words of Heidegger, 'Language is the house of Being', it is in the first place hostile to and destructive of language.

Among the many traits of nothingness identified and analysed by Barth, a central one is its need to impress with all manner of pseudo-achievements using the most exaggerated and bombastic language. As Kierkegaard expressed this trait, nothingness is always 'going beyond' anything that has come before: it is always proclaiming new 'achievements', it is always seeking for new and ever more exciting 'headlines'. In his usual delightfully ironic manner, Kierkegaard observed how extraordinary were the claimed achievements of his own time in the direction of an enhanced 'spirituality': 'After all, Jesus only transformed water into wine, but these geniuses have gone so much further: they have succeeded in transforming wine into water!'

We must refer to the classical exposition of Barth (1938–50//1961, pp. 289–531 of the third volume of the third part of that monumental work) concerning the nature, ambitions and fatal weaknesses of nothingness. That which nothingness fears most and which it does everything that it can to evade is *truth*. And since the foundation of truth in language resides in its definitions, these are among our most powerful weapons against these forces of destruction.

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