Towards a Theory of Information

Information: Mystical Fluid or a Subject for Scientific Enquiry?

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1. INTRODUCTION

To be honest, I was amazed that such a symposium as this was assembled. I said to our host, in accepting his invitation, that there exists a perfectly adequate though immature theory of information, which can enable us to understand business information systems and the place of information technology within them. As far as I could see, we had no need to go 'towards' a point at which we had already arrived, all we needed to do was to get on with an exciting but clearly defined task of improving our theory. However, I am glad that I have taken part in this symposium because it has destroyed my complacency.

I had imagined that discussion would have been launched from a platform of common understanding far greater than has been displayed. But the ideas which seem to me most basic and essential for a scientific study of information were not even shared by all the members of this symposium. Presumably, then the lack of consensus among the readership of The Computer Journal is even more severe.

Let me assure you that I am not advancing an eccentric theory of my own. The theory of information to which I refer is semiotics (the theory of signs) with a two thousand year history. It can serve us as a framework for selected ideas from many established disciplines (ranging from anthropology through philosophy to engineering) and it shows how to make them relevant to solving problems in the use of information. My aims in this essay are to direct attention to the wealth of available knowledge, to recommend the semiotic framework for organising it and to convey my own enthusiasm for this rewarding subject.

I shall treat the topic in the following way. Firstly, I shall point out the inadequacy of the fashionable view of information in the EDP community which regards it as a kind of mystical fluid. Secondly, I shall introduce the idea of a *sign* as a suitable primitive on which to base a science of information. Thirdly I shall show how signs can be classified and their properties can be studied. Fourthly, I shall indicate that 'information' has many *different* meanings, each one being a precisely defined property of signs. Fifthly, I shall claim that Semiotics stands (or will do so one day) to the social sciences as physics now stands to the natural sciences. Finally, I shall indicate valuable sources of ideas and the problems of exploiting them in our field. The length of this essay permits only a sketch to be drawn so I beg that my superficiality will be excused.

2. MYSTICAL FLUID?

The engineering and mathematical aspects of computing and telecommunications need only a limited view of information. Mostly that need is supplied by Shannon's information theory or, more precisely his probability theory of signal transmission and coding. Gordon Scarrott has attacked this narrow theory on its own ground and has shown it wanting in the field of meaningful communication. Shannon himself was well aware of its limitations. Human affairs, to which the application of computers and telecommunications are applied, call for a far richer understanding of information.

The problem about gaining a richer understanding of information is the temptation to forsake science for a land of mysticism. Notions that are even less well understood than information are invoked for its explanation. This is quite clear if you collect together a bunch of definitions from the literature on which we raise our experts in EDP, MIS, DSS, Systems Analysis and so on.

Examples of the blatant chemical engineer's view of information are the following.

'...data are first condensed into information and from this information meaning is distilled' (Keay: 1969).

'The distillation of data through its being processed in the creation of information.' (H.D. Clifton: 1978).

'Data is the ore, the raw material from which information is developed' (H. Dorn: 1981).

This analogy has some everyday usefulness but it serves no scientific purpose. More careful attempts at definition begin correctly to place people in the picture by using notions such as 'knowledge', 'meaning', 'uncertainty', 'ideas' and so on. For example.

'(Information) is data that have been processed and are meaningful to a user.' (Ahitiv Niv. & Seev Neumann: 1983).

'The word 'information' is best used to denote a combination of fact plus a meaning an observer attributes to it'. (P. Checkland: 1981).

'Information is all material pieces of knowledge which may be used rationally in making a choice among alternatives by a decision maker who has the responsbility and authority to make that choice.' (M. McCosh & M. Scott-Morton: 1978).

Even sustained attempts to devise a theoretical foundation for information systems fall into the same trap. Langefors and his followers employ definitions such as the following:

Datum – one term of a message
Data – symbols for representing a part of a message
Information – (1) any knowledge or message useful for decision or action (2) a compound idea or the meaning derived from data

Elementary concept (eg (person, weight, time)) – a kind
of information that specifies only one kind of property for the class of objects
is the smallest kind of information
is a kind of occurence of information
Elementary message [eg (SMITH 11 STONE, DEC 84)]
is a piece of knowledge
is conveyed by data

(Summarised from Langefors and Samuelson: 1976 pp 49–55 & p. 94)

These definitions ultimately appeal to mentalistic notions such as 'meaning' 'knowledge', 'idea', 'concept'. At one point '*the reader is urged to verify that the e*(limentary) *concept* ... is, in a natural sense, the "*smallest* kind of information" that can be defined'. (ibid p. 50). The urging is not accompanied by any advice on how this verification should be attempted; introspection is presumably the technique of investigation at which the authors are hinting. Information, one is forced to conclude, is not a good primitive concept for a science.

We must reject the verbal habit that treats information as a mystic fluid, and we must improve upon definitions which appeal to notions that are themselves as difficult or even more difficult to define.

3. SIGNS

A science should employ only the simplest of primitive concepts, preferably ones that can be demonstrated without any need for formal definitions. Theories based on introspection will not do. Our definitions ideally should be ostensive ones. If we cannot convince our sceptic by words we should be prepared to take him by the hand and show him what we mean. At least this criterion of ostensive definition should apply to a minimum number of primitive concepts upon which we can build our theories; given them, we shall be able to justify the elaborate verbal and mathematical superstructures.

Physics does well in its use of simple, ostensible, primitive concepts. The ideas of *physical body* and a *physical event* can be demonstrated easily enough although they are both very general notions encompassing all the directly observable subject matter of the discipline.

Semiotics has an equally straightforward starting point, the notion of a sign (subsuming the signal or transitory, event-like signs). A verbal definition of a sign is unnecessary because the notion should be defined ostensively. What can be provided is a gloss on the idea, or a commentary which might accompany the demonstration. You may first assure the sceptic that he is going to be introduced to physical things – objects, events or properties of objects and events – for there is nothing etherial about any sign. You can show him a book, a clock face, the TV, a free sachet of a sample of shampoo, the red glow of a heating element, an etching, a child's footprint on the kitchen floor; afterwards take him into the street and show him goods in a shop window, traffic signals, flashing lights on cars, people talking, and a lowering mass of dark cloud in the sky. As you point out these physical things you can show him how you can use them to tell you about the other things to which they relate. The fresh footprint enables you to search for your small son in the house without wasting time looking in the garden. The etching of a market square in another town enables you to demonstrate exactly where you used to live as though you were standing in the market square itself... Gradually, to the most stubborn sceptic the idea should become clear that people can use one physical thing to refer to another or indeed to refer to very complex physical situations that would be tedious and difficult to explain or demonstrate. To be regarded as a sign, the physical things had to be able to play a role in human (possibly animal) behaviour, enabling appropriate action to be performed at some distance of time or space.

4. CLASSES OF SIGNS AND THEIR PROPERTIES

In the course of the demonstration you will have introduced the sceptic to certain major categories of signs

INDEX ICON SYMBOL

These are, left to right, progressively more dependent upon social conventions and less immediately understandable biologically as it were. The index is linked to what it refers to by a causal process which may be discerned by repeated observation: the darkness of the clouds indicating rain or the redness of the heating element indicating the temperature. Animals use indexes. Icons are like models. They present to the senses something like the effects produced by the object it refers to: the TV and the etching being good examples. Symbols are the most characteristically man-made signs and they depend upon social conventions to form and sustain them.

In addition to these classes of signs, index, icon and symbol, introduced by C.S. Peirce about a century ago, I think it is useful to distinguish two extreme cases.

SAMPLE WHOLE

They account for the information which George Rzevsky described in his contribution: the information conveyed by a micro-chip about itself. Samples have long been used in business for giving information about products. The whole of anything is always the best form of information about itself and this extreme class of self-referring signs should not be overlooked in designing systems: consider for example how large a store must be before you decide to keep an inventory instead of inspecting the stock itself. Business examples of indexes are by-product information; examples of icons are graphs of networks and mathematical models; but, of course, the computer mostly processes symbols. Computers are very limited in the information they can process; on the other hand business systems employ the full range of signs and an appropriate theory of information must encompass them all.

Obviously space does not permit the numerous other ways of classifying signs by be explained here. The semiological classifications differ from the Land and Kennedy-McGregor style of typology of information which is a useful pragmatic check-list intended for a particular stage of systems analysis. Semiotics aims to be very general and applicable not only to business information systems but equally well to problems of animal communications, mass media, design of primary school teaching materials and theatre criticism and so on.

Pragmatic classifications of 'information' cannot be transferred between problem situations although they can usually be explained in the more fundamental terms of classes of signs. Semiotics is already rich enough to make the multiplying of pragmatic typologies unnecessary if not counter-productive.

Once we can use reliable operational tests by classing signs unequivocally, we can begin to explore the properties associated with different classes. Physics makes distinctions between solids, liquids and gasses and then looks for properties appropriate to materials in each class. Distinctions such as 'base-metals' and 'precious-metals' belong to pre-scientific alchemical thinking. Physics explores properties of materials by doing very different kinds of things to them such as seeing the effects of shining light on or through (optics) striking them (acoustics), subjecting them to heat or electric currents (theories of heat or electricity). In just the same way, semiotics finds different properties of signs by doing very different things to them.

5. AMOUNTS OF INFORMATION

One kind of operation we can perform on signs is to compare them in ways that reveal what we naively think of as the different amounts of information they contain. But there are many ways of carrying out these comparisons and they yield different results. A sophisticated approach to information quantities takes account of the operations performed.

'Information' applied to signs is like the term 'size' applied to physical bodies. Depending upon the tools and methods you use to do the measuring, you produce such different size measurements as 'length', 'volume', 'mass', and so on. No one would claim that these are the same. Similarly, 'information' has numerous quite different meanings depending upon how you do your measuring.

Let me explain these interpretations of 'information' in a little more detail. For a fuller explanation and references see Stamper (1971). Everyday in a computer department you will hear people ask, 'how much information?' when we mean, 'how many characters/bytes/words?'. Such a measure only applies to signs which are constructed from tokens selected from a well-defined set, an alphabet for example. A second and almost equally familiar information measure is Shannon's entropy measure of bit-per-second or bits-per-signal which depends on the relative frequencies of signals coming from a source. It is only meaningful when you talk about a source which displays statistical regularity. A third measure requires one to define a logic into which your information (ie signs) has to be translated. The amount of logical information depends upon how many standard logical formulas are *implied by the signs* you are measuring. A fourth measure involves a person who *adjusts his betting odds* in the light of the sign you are measuring. In this case your 'apparatus' involves a specific person and a specific problem or betting proposition. *These four different measures of information differ from one another as much as do length, mass, volume and area as measure of size.*

6. PHYSICS AND SEMIOTICS COMPARED

Classifying and characterising different examples of signs is one of the tasks of semiotics, the theory of signs. Also, as physics is concerned with investigating the properties of physical bodies and events, so is semiotics concerned with investigating the proprieties of signs. In doing so, semiotics leads to the study of 'information' and 'meaning' which are exposed as vague generic notions, just as vague in their ways as the physical concepts of 'size' and what used to be called the 'vital force' of a body and is now explicated variously as momentum, linear and angular or energy, kinetic or potential. Physics and semiotics parallel one another as shown in Figure 1 although, in its present stage of development, semiotics is almost like the physics of the middle ages, if we are to judge from the definitions cited above.

The ideas in the Figure are to be found widely in the literatures of several disciplines. The lack of material specifically written for a readership of information system specialists may account for its lack of currency in our community. I have attempted elsewhere to present some

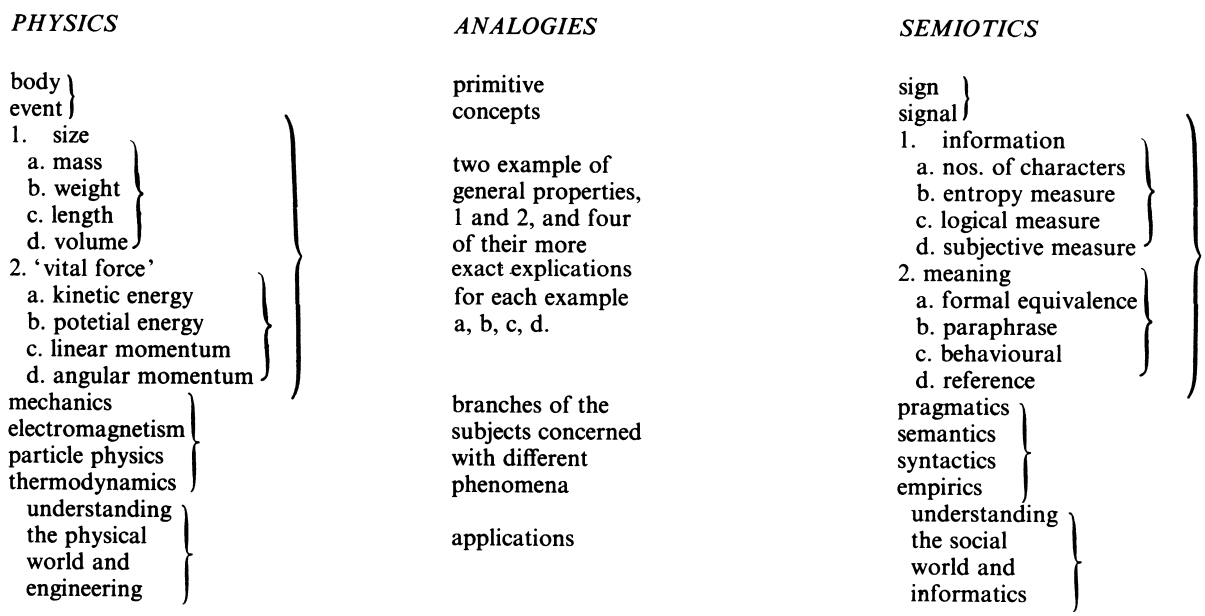

Figure 1. Physics and Semiotics in parallel

of these ideas carefully selected for their relevance to informatics, (Stamper 1973).

Of course, semiotics can draw upon the wealth of discoveries in many branches of study. To understand how organisations are welded together through the use of information we need to look closely at the ways in which all sign-processes arise in the complex patterns of human culture. Formal information systems employing computers can be seen in the fuller context as highly specialist, rather fragile embellishments upon the vast natural structures of information systems that are our societies.

The rules of our complex systems of cultural norms, including linguistic norms, are mostly *implicit* in the behaviour of people in social groupings. *Formal* systems based on *explicit* rules are the ones in which computers can be employed. They are only a small part of the overall information system of a business which is otherwise largely informal and dependent upon people. Only rarely do we have recourse to formal and explicit definitions of these rules. This is often the case where the forces of social cohesion are not powerful enough to sustain them *informally*, as, for example, in organisations. Formal systems butress those information systems which must link activities widely spread through time and space (eg legal systems) where the constant rehearsal of the relevant norm in a social group is not available as a device to keep an informal system intact. One other reason for introducing formality is to supplement the ordinary discourse of a working community with the technical vocabulary to handle large and intricate populations of objects and processes them with a precision beyond the powers of natural language. Finally we should not fail to notice the role of formalisation to impose artificial norms which run counter to the natural norms for the social group, exemplified by oppressive legislation or those, too familiar, ill-constructed bureaucratic systems.

7. THE MAIN BRANCHES OF SEMIOTICS

We traditionally classify the problems of semiotics into three (I prefer four) main areas: pragmatics, semantics, syntactics and empirics (I add). They can be illustrated in terms of their relevance to the use of computers. *Pragmatics* deals with the use of signs by people. How do they use them? What is significant to people? How sensitive are people to different kinds of signs – spoken, written, non-verbal? Given a computer display or a data collection document, what parts of it seem more important? What misunderstandings take place and why? How does one programmer set about understanding the work of another when bugs arise? What features make for good and bad design for system documentation? These are all important practical questions.

Semantics deals with the purported relationships between signs and what they signify (reality?). These are questions about meanings. Does the user of data from a computer system attach the same meaning to them as the supplier of the data? How do you specify meanings? Dictionaries? Semantic nets? How can one systematically discover what a user means? You cannot get far in this area without confronting the ancient and basic questions about the nature of reality.

Syntactics deals with the forms and structures of signs, especially with language. Rules of syntax, rules for mechanically transforming signs and rules governing their equivalence all belong to syntactics. It is a self-contained activity. The central issues of programming belong to syntactics: computability, program correctness, consistency of data, equivalence of meaning (notice a quite different meaning of 'meaning'). Syntactics is a relatively safe haven from philosophical issues.

Empirics deals with a narrow class of problems in which signs are used repeatedly. Attention focusses upon the probabilities of different sign types being generated, their risks of being transmittd erroneously, their re-coding so that transmission can be more reliable and efficient. In short, these are the issues facing a designer of equipment used for handling signs. Empirics grew out of the work of telecommunication engineers.

8. SOURCES AND USERS OF IDEAS

Surely the theory of signs is broad enough and rich enough already to be taken seriously. It encompasses all aspects, the mechanical, the abstract, the philosophical and the human.

Most people can confine their attention to some limited field of semiotics. If you are concerned with programming then you can limit yourself to syntactics. If your concern is system configuration, you can get by mostly with empirics. If you work on the human aspects of systems then pragmatics will suffice. However, if you are a systems analyst who must understand an informal, business system and specify an efficient formal system to do some useful job in that business, then you have to understand semantics as well as all the other fields. Semiotics is the most appropriate foundation for systems analysis.

Ideas used in semiotics come from every point of the compass. That is what is so exciting and fascinating about the subject. Anthropology, social psychology and psycho-linguistics are rich in ideas for pragmatics. Semantics mostly relies upon linguistics and philosophy. Syntactics uses mathematics, logic, and programming whilst empirics uses statistics, probability theory, engineering and experimental psychology. Despite this diversity, these ideas cohere because they are gathered together for a clear purpose.

9. WORK TO BE DONE

So let us stop talking about 'going towards a theory of information' and recognise that we are in the midst of it. Let us get on with the work.

The work of developing this theory is plentiful. It is exciting and it is useful.

At present, it consists largely of raiding many existing disciplines to gather useful material for our kind of work. I take it that our kind of work in the BCS is anything concerned with putting information technology to work for some business or social purpose. Too great an emphasis has been placed, far too long upon merely putting IT to work. That certainly sells hardware and software and keeps most of us gainfully employed. But to use information effectively for business and social purposes opens up a range of problems calling for the broadest vision of information. I hope I have persuaded a few more people to join the raiding parties looking for relevant ideas.

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