On Criteria For Assessing An Information Theory

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1. INTRODUCTION

There is currently too much emphasis on information technology and too little on matching technology to the requirements of individuals and organisations. As a result, too many information systems are not contributing effectively to the objectives of organisations which have invested large sums of money into the development of these systems.

Computer and communication hardware and software technologies provide an effective means for building Information Systems. Knowledge of these technologies is, however, only one of the tools needed by Information System designers. The proper use of these technologies is of paramount importance, and it critically depends on the Information System designer's understanding of the commodity he is handling – Information.

It is therefore important to devote significant resources to the development of a sound body of knowledge on Information which would provide an authoritative foundation for the work of Information System engineers, that is, those who specify, design, produce and maintain Information Systems; and if you do not think it too pretentious, we could call such a body of knowledge an Information Theory.

Even a casual literature review would reveal a number of contributions to various 'information theories', eg technical, semiotic, etc. They are helpful, but with the exception of Scandinavian work (eg by Langefors), not sufficiently oriented towards Information Systems Design. It is perhaps now worthwhile to revisit the whole problem again.

Any Information Theory would, of course, NOT remove the need for the designers to learn the ART of design of Information Systems. The most that one could possibly hope for is to establish sound foundations. Creativity, intuition, know-how, heuristics, trial-and-error will all still be required; like in the field of electronic or mechanical engineering design.

2. ASSESSMENT CRITERIA

Any knowledge that is to be included into an Information Theory must satisfy certain conditions which would ensure that the theory would attain a scientific status. To define such conditions precisely is difficult because, at present, there seems to be no agreement among epistemologists on the so called Demarkation Criterion ie The criterion which determines what does and what does not represent scientific knowledge.

Both the possibility of an objective proof of correctness, advocated by logical positivists, and falsifiability, suggested by Popper, have been rejected by modern epistemologists without any other generally agreed and applicable alternatives yet emerging from their arguments.

From the engineering point of view, the pragmatic approach to the problem of demarkation appears to be the most satisfactory and will be accepted in this paper. This approach, when applied to our problem, stipulates that only knowledge that is useful for the specification, design, production and maintenance of Information Systems should be considered suitable for inclusion into an Information Theory.

As a way of specifying more detailed criteria for the selection of the knowledge that is suitable for inclusion in such a theory, it may be helpful to formulate a set of questions, based on the above general criterion, that the theory should be capable of answering. Examples of questions formulated for this purpose are given below.

- What are the possible uses of Information?
- What are the potential sources of Information?
- What are effective ways of extracting Information?
- What are effective ways of representing Information?
- What are effective ways of processing Information?
- What are the attributes of Information?
- How to measure Information attributes?
- How to measure value of Information?
- How to enhance value of Information?
- How to protect valuable Information?

Answers to all these questions, and other similar ones, would be of an immediate practical value to system analysts and designers as well as for Information users.

3. TENTATIVE PROPOSALS

In this section, I shall propose a number of outline answers to the above questions. The material is derived from the empirical or, so called, action research carried out at Kingston Polytechnic through a series of Information Systems design projects, rather than from published literature, and therefore no references are made to work of other researchers in the field. These hypotheses are yet to be thoroughly tested and should be considered only as a possible starting point for the formulation of axioms and theorems of a practical Information Theory.

In addition, this section includes comments, explanations and examples which should help the transfer of Information from this paper to its readers, as well as suggestions for further research.

3.1 On Information Uses

The understanding of possible uses of Information helps with defining requirements for Information Systems and with their specification. A considerable research effort is needed in this area to generate knowledge that will help designers to develop systems relevant to requirements and expectations of their clients.

For the purpose of this paper, the uses of Information are considered from two points of view: those of Information users and Information suppliers.

For a user, Information is primarily a means of LEARNING.

Individuals and groups (as well as machines which contain elements of Artificial Intelligence) use Information to modify their knowledge about the Universe by reducing uncertainty about objects or processes which constitute the Universe.

Motivation for acquiring Information may be purely utilitarian, eg to improve professional performance, to design better products, to make more effective management decisions, to plan and control systems, processes or projects correctly, to pass examinations.

Or, motivation may be based on the desire to satisfy curiosity.

Examples of other uses of Information include:

- diversion (eg literature, music, films)
- self reflection (eg judgement).

A supplier may generate Information for the purposes of:

- gaining economic advantages (eg publishing, commercial broadcasting, consultancy, product licensing)
- gaining political advantages (eg campaigning)
- instruction (eg education, training)
- control (eg advertising, propaganda, influencing, process automation)
- self expression (eg painting, writing, composing).

3.2 On Information Sources

To design ways of effective capture of required Information, one must understand its availability – its sources.

My view is that Information is imbedded in all objects and processes in the Universe, natural or man-made. It is present there and available to be extracted if and when required. Cherry blossom indicates that Spring has arrived, broken down machine-tools signal the need for repair, despatch of a product from a factory triggers preparation of an invoice.

Certain artifacts and artificial situations, real as well as abstract, are created specifically for the purpose of acting as sources or carriers of Information. For this role, one generates static or dynamic patterns such as:

- symbols (eg text, diagrams, music notation)
- signals (eg voltage levels, positional indicators)
- images (eg drawing, photographs, paintings)
- three-dimensional objects (eg sculptures, scale models), or
- states of physical objects (eg magnetic states of computer storage devices).

These artifacts, whose main purpose for their existence is to serve as sources or carriers of Information, are regarded as components of Information Systems.

3.3 On Information Content

The capability of retrieving Information from its carrier is associated with INTELLIGENCE, human or artificial. The intelligence is a property of MIND, which again can be human or artificial.

Different minds will capture different Information from the same source depending on the state of knowledge resident in those minds and on prevailing conditions during Information extraction.

Information has a meaning relative to a context within which it is extracted. Information content is thus context-dependent.

For example, if someone addresses you in Japanese, the amount of Information you will be able to extract from this communication will depend on your knowledge of Japanese language, customs, conventions, gestures and facial expressions as well as on the situation in which the conversation takes place (eg a romantic encounter, a visit to a museum, a business meeting).

This dependence of the Information content on context is rather self-evident, and yet too often overlooked in the Information System literature. The lack of understanding of this aspect of the problem may well be a reason why technologists are so unsuccessful in providing relevant Information to 'naive' users. They seem to ignore the fact that the capability of extracting Information from the Information carrier is related to knowledge resident in the mind that does the extraction.

3.4 On Information Representation

In general, the purpose and mode of Information processing will determine the most suitable representation of the Information.

For example, natural language whilst convenient for informal conversation may be too ambiguous and slow for a rapid exchange of ideas between two specialists cooperating on a task; they normally prefer the use of jargon, codes, free hand sketches etc.

A considerable research effort is currently directed into formalisms for Information representations.

3.5 On Information Processing

Information resides in static or dynamic patterns of energy and matter. These patterns can be transformed, stored, and transmitted over distances with a view to providing opportunities for minds to capture embedded Information.

Let us consider an example. Information on all transactions (that is, on movements of material, goods and money and on performance of services) in a manufacturing company is captured and stored. This is done by observing patterns of business activities, as they occur, and recording them into computer memory by creating suitable patterns of memory states. Although all Information that is required for controlling company operation may be thus available, it will not be in a suitable form for the presentation to decision makers and will therefore be 'processed' until desired parameters are shown explicitly. The 'processing' is done by operating on patterns of digital signals carrying Information with a view to refining their Information content.

To summarise then, Information is NOT processed directly. Rather, various operations are applied to patterns which carry Information, that is, to data, signals, symbols, images etc.

The expression 'Information Processing' although correct only in a remote sense, is valid as a way of conveying the purpose of processing. In contrast, expressions such as 'data processing' or 'image processing' describe what actually occurs.

The proposition that Information resides in patterns of energy and matter implies that any extraction, storage, processing, transfer, or retrieval of Information must be supported by some expenditure of energy.

3.6 On Information Attributes

The usefulness of Information to a particular user depends on its:

- relevance
- accuracy
- up-to-dateness
- timeliness
- location of delivery
- medium of presentation
- format of presentation
- control of delivery, and
- cost.

The measurement of Information attributes is not at present properly understood.

3.7 On Measuring Information Value

In business situations, Information is considered as a resource because it improves performance of decision makers and other Information users, and therefore adds economic value to business processes.

Similarly, Information adds value to processes in political, administrative, social, educational and leisure/entertainment systems. In such systems though, the economic added value component is much less important than the non-monetary, qualitative valuation.

Very little is at present known about measuring or enhancing value of Information.

3.8 On Protecting Valuable Information

The importance of Information as a means of gaining economic or political advantages and of controlling individuals or large sections of the population is such that effective ways of protecting it from the unauthorised or inappropriate use are urgently needed.

A fine balance must be found between the protection from misuse and freedom to properly use Information.

On one hand, one must allow individuals and organisations to protect their valuable Information, whilst on the other hand, there is a need to prevent exclusive ownership of vital Information which would create Information monopolies capable of preventing the execise of an appropriate and reasonable control, learning for self-improvement, pursuing leisure activities and trading in Information and thus generating wealth through an Information-based economy.

To achieve effective protection of valuable Information, one needs legislations. To devise fair legislations, one needs considerable knowledge on how to measure and utilise Information value.

Acknowledgement

This is a somewhat extended version of an invited contribution to a Seminar TOWARDS A THEORY OF INFORMATION organised by The Computer Journal and held at Middlesex Polytechnic on 26th September 1984.

Information, the life blood of organisation

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1. INTRODUCTION

Much 'theory' is already taught and discussed under the general heading 'Computer Science'. However, such theory is mainly tactical, concerned with proposing and optimising techniques for tackling quite specific problems in the effective use of a preconceived automaton that was originally shaped by instant invention and primitive technology. We now have powerful and flexible micro-electronic technology, but we are still using it to make automata directly descended from the pioneer von Neumann machine. Hence there is a need for a more fundamental strategic theoretical model of information to guide the design of future automata so that they meet human information processing needs easily and naturally. Thus a 'theory' of information worthy of the name must have two essential attributes:

(i) It must be based on observation of the use and nature of information;
(ii) It must offer useful guidance to those concerned with the design and use of information systems.

Although 'Computer Science' as presently interpreted sometimes meets requirement (ii) it would be difficult to claim that it has sound foundations according to requirement (i). It follows that there is a clear need for a broader understanding of 'information' to meet both criteria (i) and (ii).

2. ORGANISED SYSTEMS

To illuminate the nature and role of 'information' it is first necessary to define the term 'organised system' (OS) as an interdependent set of components whose activities compliment one another either by design or following Darwinian natural selection. Every living organism is an OS in this sense but an inanimate physical assembly, such as the solar system cannot be regarded as an OS since its actions, although well ordered are in no sense deliberate so that there is no self repairing mechanism.
Within such an understanding of the concept 'OS' there are two distinct classes:

(i) Natural OS. For example every living organism, animal or vegetable, is a natural OS and so is an organised group of living creatures such as a nest of social insects or a cooperating group of people.
(ii) Artificial OS. Any artefact or organisation designed by people to serve human needs. For example a machine or meaningful text.

In human organised society there is a third class that is a synthesis of a natural and artificial OS. For example every commercial firm is a natural OS of people supported by artificial OS's used for purposes such as storage/retrieval of current information, whose effective operation plays a vital role in the survival of the natural people system.

The ultimate function of 'information' is to control the actions of the components of an OS, for survival of a natural OS, or to optimise fitness for purpose in the case of an artificial OS.

Thus 'information' bonds the components of an organised system by causing them to work together, hence information can usefully be regarded as the lifeblood of organisation.

For such reasons the intrinsic properties of information can be defined, described or discussed only in the context of the OS concept and indeed the structures and behaviour of information are derived from the natural structures and behaviour of natural organised systems.

3. INFORMATION AND ACTION

The proposition that the ultimate function of information is to control action has some important consequences for the essential distinction between an information device and an action device.

An action device such as an electric motor, a power transistor or a muscle is connected to a physical load whose magnitude determines the power level for which the action device must be designed. The function of a transistor used as an information device is indistinguishable from the function of a transistor used as an action device – indeed any action device can also be used as an information device. However, the great majority of information devices are not connected to any physical load, but are required only to drive other information devices. We can therefore operate them at as low a power level as we please and since energy is the ultimate scarce resource in nature this means that we make an action device as large as we need and an information device as small as we can – a policy that applies equally to natural action and information devices. The recent spectacular refinement of information technology, still in progress, has been achieved primarily by making ever smaller electronic devices.

4. FUNCTIONS OF INFORMATION

Although the ultimate function of information in every context is to control action, in organised human society information plays such a fundamental role that we have evolved other uses for our information handling skills. The uses of information can be classified under four main headings:

(1) To accumulate experience and the abstract of experience that is 'knowledge'. Since experience can be represented by symbols, eg in natural language and then recorded in documents it is possible to accumulate knowledge in libraries over a much longer period than the lifetime of an individual. This facility offers very great survival value to mankind by discouraging, but perhaps not preventing the repetition of known errors.
(2) To explore the consequences of possible actions