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Information as a Cognitive Construction: A Communication-Theoretic Model and Consequences for Information Systems

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In this paper a model for understanding the concept of information is presented and how the processes of externalization and perception of information by human beings could be understood. This model is different from the standard information theoretic model. It combines the understanding of cognitive information processing as an act of information generation from sense impressions with communication theoretic considerations. This approach can be of value for any system that is regarded as a knowledge system with an in-built ordering structure. As an application some consequences will be drawn for the design of information systems which claims to handle information itself (e.g. multimedia information systems) instead of giving references to bibliographic entities. (Author)

1. Introduction

Speaking about the concept of *information* requires to say a few words about problems in doing so[1]. Speaking about cognitive information processing means to speak about the problems of representing meaning in language and the understanding of the meaning by another person. It happens so that on one day one may think it would have been better to accept *Wittgenstein* when he recommends not to speak about something one cannot speak about (1). But on the other day one feels that ideas have to be discussed. So it should be appropriate to present these reflections on information, cognitive information processing and information systems to a wider audience.

What is the motivation for regarding cognitive information processing as a suitable basis for information theoretic considerations? First of all the multifaceted interpretation of information, especially the focus on a technical interpretation, is well known. Information is measured quantitatively in bits and bytes according to the *Shannon-Weaver* communication model or it is seen as raw material or a commerical commodity. On the other hand, as an information professional who wants to build information systems for knowledge acquisition by human beings, one has to face instead that acquiring knowledge from an external information system means that there must be a form of reception and subsequent cognitive information processing[2]. Therefore it is necessary to get a better understanding of what is meant by storing knowledge in all forms of media (for example in information systems) and what is meant by acquiring knowledge from such information systems.

This point-of-view can perhaps best be illustrated by posing a question: why do we make a difference - or does someone do not make this difference - between the so-called amount of information contained in the numerous trees of a forest with all their individual differences, the amount of information contained in a library of books in our mother tongue or in a foreign language or the amount of information contained in the meanwhile uncountable pages of the World Wide Web? Why do feel some of us even distressed by the amount of information in the Web and not affected in the same sense by the information one could gain from the trees of a forest? Maybe the questions sound silly, but: are we speaking always about the same understanding of *information* and of *contained in*? We will come back to this question in our last chapter.

Next, it has to be characterized what is meant by using the term *information system*. With the invention of new media the claim of these systems towards general or even universal benefit grows although the conceptual context of the systems is unprecise. We will begin with discussing roughly the understanding of information systems.

2. Developments in designing information systems and information retrieval

Historically seen, the first information systems were libraries with subject ordered holdings, for example the shelf presentation of the books and journals or other media. Later on we can distinguish between subject ordered catalogues or databases with bibliographic representations of documents, for example library OPACs without abstracts of the documents contents or online databases with abstracts of the documents contents.

One further step in the development was marked by full-text databases (Online, CD-ROM), for example online hosts like *Lexis/Nexis*; a lot of newspaper databases; electronic encyclopedias or electronic books.

In some sense, the latest development of information systems is characterized by the global networks as the *Internet* and the discussions about the *Information superhighway*. Many problems are discussed within this context. For example we can cite 2 problems out of a list of 10 stated by L. Floridi:

> „stored knowledge on the Internet becomes greater than that which can be accessed"

„accessible knowledge becomes greater than that which can be managed"(2)

The overall development is not only characterized by a trend from referential systems to information containing systems with respective underlying ordering structures but also by globalization of information exchange and - perhaps more important in the long run - by requirements of *intercultural communication* and knowledge access[3]. The community to which an information system is addressed becomes more and more heterogeneous.

To develop a consistent and general theory for all these phenomena of information systems means to give a foundation for

- knowledge *representation*,
- knowledge *ordering*,
- information or knowledge *transfer* between human beings,
- *access* to knowledge in exterior media.

As a common characteristic for all information systems we can state the following **general information problem:**

In order to acquire new knowledge will human beings find the documents or media units they are looking for by the various forms of subject access

To solve this problem a lot of methods and instruments have been invented. For example we can mention *retrieval tools*, mainly intended for processes of searching within a database, for example: combining search terms or categories by Boolean operators; truncation of search terms; the adjacency principle, distance or proximity operators; many linguistic tools (for example stemming or integration of dictionaries); free-text or full-text searching; relevance ranking or relevance feedback.

In the past years numerous proposals were made for *data enhancements*. These enhancements should guarantee better retrieval results measured by recall or help the user to comprehend better the contents of documents. The proposals can be summarized as follows: In *bibliographical databases* we know enhancements by tables of contents; structured indexing data or abstracts. Nowadays methods of automatic indexing are taken heavily into consideration.

In *knowledge-oriented databases* it is popular to integrate multimedia features such as: pictures; sound; animations; videos or interactive elements.

Special attention is nowadays given to the design of user interfaces or generally to the design of human-machine interaction. Numerous investigations yielded as result that users of information systems need support for searching an information system effectively. Therefore these features often are directed primarily to assist the search process by browsing elements. In more detail we can mention the following elements: graphical user interfaces, use of pop-up menus, buttons or icons; integration of online help functions; hyperlinks between the objects of a database; use of navigational tools for the design of individualized search and browsing paths, backtracking or forwarding and the integration of multimedia elements.

3. The conventional paradigms of information science

In an overall consideration one can say that all the above mentioned efforts follow certain information theoretic paradigms. These paradigms are mainly inspired by information technology and can be formulated in the following form:

- Information systems do not only *refer* to information - they *contain* information
- We can recognize an amalgamation of books (or classical forms of text) and information systems in a *multimedia* setting
  and as a consequence for the learning processes and environments
- The forms of *knowledge acquisition* will change (or, as many followers of information technology would prefer to say, they even have to change) by means of
  - *Computer Based Training*
  - *Distance learning*
  - The possibilities of the *Information superhighway*

If one is interested what all these efforts have effected for the efficiency of information systems to their users, it becomes most obvious that the progress made has been not so significant as formerly expected.

This assessment can be supported by own experiences with information systems or by some quotations. We refer to just one rather pessimistic sounding statement by *Wilfred Lancaster et al*:

„What evidence exists that technology has solved the subject access problem? Not much.
The conclusion that emerges most clearly is that, if one wants to know the best things to read on some topic, there is no substitute for consulting an expert, either directly or indirectly (e.g. an expert-compiled bibliography)"(8)

For anyone designing, implementing or running an information system this opinion must be a challenge.

With the advent of the new data networks we can even see the creation of new metaphors. In the past we were afraid that we seemed to be *drown in the flood of information*, but today *we are surfing the Internet*, or *we are lost in hyperspace*.

These metaphors indicate that we are faced with a new understanding of infomation. Information is now described by new attributes as superficial or cursory, it will loose its connection to content. Not the research for senseful or useful information is the goal of using an information system, but moving at a surface becomes the goal. It is regarded as a nice attendant symptom if we find something useful by serendipity.

As a consequence of all these observations it seems very necessary to develop a theory of information. This

theory should be built upon a concept of information that has to be reflected according to the human (cognitive) requirements and it should be a communication oriented theory, therefore able to consider not only the dimensions of knowledge but also the dimensions of actions.

This consequence has been proposed by other authors, too, for example one can cite *Erhard Oeser*:

> *„We need a genuine fundamental theory of information that has to integrate and incorporate both existing technical information theories and biological, neuropsychological information theories."* (9)

Before giving now some ideas or proposals for such a theory, it is necessary to summarize once more the nowadays commonly accepted guiding principles for constructing information systems, the conventional or classical paradigms in a more abstract setting:

Information as it is produced by authors and stored in information systems has some properties: first, it is an entity. Therefore it can be raw material, a commodity and it has a value of its own. Furthermore it can be divided into units and these units can be represented, stored and retrieved as *semantic units* or so-called *informational units*. It must be emphasized that this concept includes the idea that these units are *de-individualized units*.

Furthermore, if the total amount of information increases, it is possible to accumulate it. *Karl Popper* has characterized this process in his idea of *world 3*, as sum of all true propositions about the real world, if the world is regarded as an ordered world (10). Within the information paradigm this idea is even generalized to all forms of knowledge or propositions about anything and not limited to scientific knowledge.

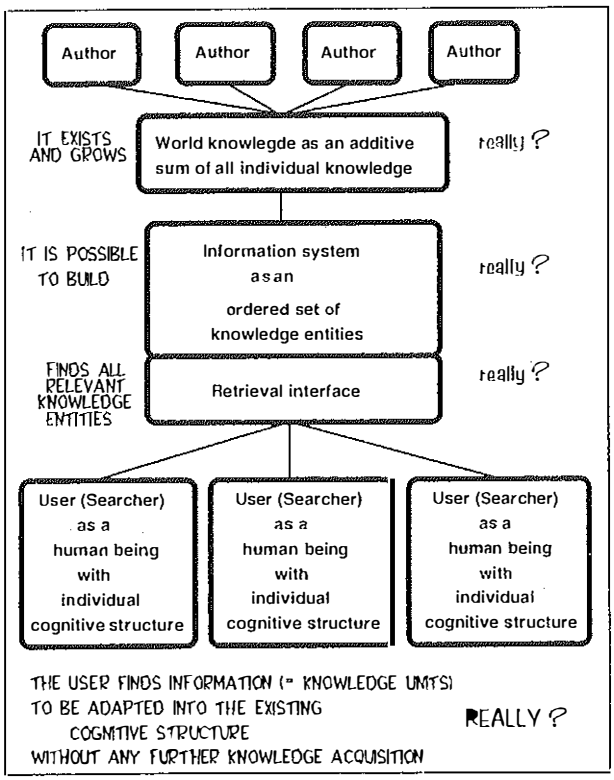
The exchange of information between persons or between a person and an information system is described by a sender-receiver model. In a pronounced form - the so-called *conduit metaphor* - this means (11): the information (as a sum of its units) remains unchanged during the transmission, it arrives at the receiver in the same form as it was submitted by the sender, we can pick it up and take it away[4].

Applying these ideas to information retrieval systems, one can state:

> *Information retrieval - and therefore the above mentioned information problem - is an act of problem solving.*

Asking a question must be answered by retrieving and submitting informational units. These units will then answer the question. This can only be true if one believes that it is possible to design information systems containing informational units as a one-to-one representation of the knowledge about the world.

One can summarize this in another way by looking at the following illustration:



This model raises some questions: the conduit-metaphor can explain how mere facts or data can be transferred and acquired as factual knowledge if the respective general concepts are already present but it cannot explain the acquisition of structural knowledge. Furtheron there are problems explaining paradigm shifts for certain concepts, for example, how should one handle the understanding of *matter* before and after the invention of relativity theory?[5]

If we now remember that the receiver of information is a human being and that any sense perception depends on an act of cognitive information processing it is necessary to develop the ideas of conceptualizing information via communication acts by considering constructive and cognitive arguments.

4. Information processing: a constructive and cognitive viewpoint

We will first present some propositions and afterwards give some arguments. The propositions are:

- There is no information without cognitive structures; knowledge is the knowledge of human beings.
- Information cannot be accumulated *outside* a cognitive structure.
- Externalization of information into information systems - respectively the reception of information out of information systems by human beings - is not a process of self-evidence, instead it must be explained by an information theoretical model. Externalization and reception of information from any media must be explained by models of cognitive information processing and knowledge acquisition.

What arguments can be given that support these propositions?

First of all, human information processing must be seen in the context of communication acts. Human beings grow up and live in a natural and in a socio-cultural environment. They get unflinching sense impressions from their surrounding, these impressions give rise for cognitive information processing[6] The visions of the world which surround the human being are constructed as his or her cognitive effort. The real world - it does not need to be discussed if it exists - cannot be recognized objectively, it must be modelled within the cognitive structure of any human being separately. Most impressions are not the impression of only one individuum, they are shared by many people. As social beings with ability to act and to speak, these individuums want to share the individual impressions with other human beings by communicating about them. Learning, knowledge acquisition and building up cognitive structures must be seen as a steady process with testing former acquired structures by new impressions and communication[7].

This model can be seen as the basis for any information transfer between human beings, whether the communication is a verbal or non-verbal one.

Within such a model a central question - to be answered necessarily - is the existence of criteria for the success of information transfer between human beings. Only if this question can be answered satisfactorily, one can hope to answer the question for any process of information transfer from media to human beings.

The most simple test is to examine the success of an initiated action. For example, if one is asked for a fork and gets a knife, something in the communication failed. Usually this will give the necessity for a correction of the previous action. We all pass through numerous situations like this or similar ones while we are growing up and later on during our whole life.

All human experiences are stored in the cognitive memory. Any new situation, all sense impressions are compared first with this memory. The impressions may fit to some structure already acquired, they may be more or less similar or they may be entirely unknown and new. In the last case a new conceptualization is necessary and leads to the generation of new knowledge. This leads to the conclusion that the memory is of ultimate importance for any cognitive information processing and can be seen as a further organ of sense, perhaps the most important one[8].

In our life we have to conceptualize many different actions and we are communicating with many different people. We have to identify them as known or unknown, we have to group or classify them as similar or dissimilar. All this is done by means of abstract processes. As a result we acquire abstract knowledge and can communicate in verbal form about this when we have acquired the respective verbal designations. In this way, we do not only conceptualize actions but also objects and their respective denotations.

The processes described have to be seen as processes enduring the whole life, they are part of the ontogenetic development of any human being and they are supported by phylogenetic processes. So we can say that the forming of the cognitive structure is a never ending process.

Now one can ask the question, what makes a communication about abstract concepts successful? We only can test the successful use of previously acquired abstract concepts in a communication situation with another person who also knows about this special abstract concept and can use it correctly. This test certainly is a more difficult or problematic one as the formerly discussed test of actions. One has to assume that the partner of the communication process uses this concept in a correct way. In general this means, the successful communication of abstract concepts depends on a vice-versa-modelling of the cognitive structure of both partners in the communication act. Although this test cannot be described in a more precise way, one can see it as a generalization of testing the success of an action.

With a terminus technicus the requirements for this test are described as *Coupling of cognitive structures.* Neurophysiologists tell us that the process of perception, the comparison and recognition of the known or unknown is supported by one important attribute of the human brain that they call *plasticity.* We do not compare and decide along the categories of true or false, primarily we are looking for similarities.

After regarding the direct communication act, we will now discuss externalization of cognitive information in media and the reception of information from media. For this discussion it is useful to distinguish different forms of knowledge, for example

- *procedural* knowledge (or knowing how to do)
- *data* or *fact* oriented knowledge (or knowing what)
- *structure* oriented knowledge (or knowing why or about)

The last form of knowledge can be differentiated further into

- *verbal* knowledge, understood as knowledge that is represented for communication in verbal form, and
- *systematic* knowledge, understood as knowledge about relations between concepts. For systematic knowledge it does not matter, if this knowledge is represented in a verbal form or not.

This distinction makes clear that *knowledge* in our context must always be understood as the result - precisely, the ordered or structured result - of cognitive information processing.

Although the above mentioned distinction seems necessary it must be emphasized that the forms of knowledge are not always - perhaps never - to be separated from another. There exist many examples that acquiring proce-

dural knowledge may need in part a form of verbalization or that acquiring a verbal concept of an action may need the respective procedural knowledge and so on.

If one wants to construct information systems for knowledge acquisition by human beings one has to explain how all forms of knowledge can be stored in externalized form and how an information transfer is imaginable from these media into a cognitive structure. The previous discussion about forms of knowledge should indicate that for each form of knowledge a distict form of storage is necessary. This problem sounds serious enough, even more serious is it to handle the overlap between the different forms of knowledge in one information system for different people with different cognitive structures.

5. Domains of reference for storing and acquiring knowledge

In this chapter, we will propose the consideration of so-called *domains of reference* for storing data that should be the basis for a cognitive reception process. These domains should be seen as a substitute for cognitive structural knowledge which cannot be externalized. The domains resemble scripts as they were invented by artificial intelligence or other propositions of context setting for knowledge. In the context regarded here, these domains should be understood in a very broad setting. They include not only knowledge in form of propositional statements (as it is known for scientific knowledge) but also context in an everyday sense of different cultural environments[9]. It is necessary that all forms of knowledge be disambiguized by context settings, therefore these settings are described by several domains of reference which later on become important for externalization and reception of information from media sources. In a rough structure one can mention at first the

Domain of inter-individual validity

This domain has the most far-reaching claim for validity, sometimes it is called objective. Only logic and its laws can be seen as the tool to fulfill this claim. On the other hand this tool cannot represent all forms of knowledge, simply because conventional logic is lacking the dimensions of space and time.

The second domain is the

Domain of de-individualized validity

The laws or rules of this domain are not as strong as the previous ones, they are results of our growing up in a sociocultural environment. By continuous practice we regard many rules as obligatory. By thourough inspection - perhaps when travelling to another country - we can state in most cases we would declare a rule as self-evident if it is only one of many possibilities.

The next special domain is a whole group of various domains characterized by

Subject specific de-individualized validity

This domain describes the result of every education and training with accompaning specialization of the individual being. Well-known examples of these domains are our scientific disciplines and communities with specific conceptualizations and language representations. Members of such a community find it easy to communicate with other members of the community but difficult to discuss with non-members about domain specific subjects. When discussing subjects outside the specific domain any member of the domain has to adjust him/herself to the new domain. We all know of examples that this may be difficult.

Then we have the

Domain of validity as a result of communication acts

We all are affected by this domain every day of our life and it is difficult to describe the influence of this heterogeneous domain in our living and thinking. At least one can say that there are influences and that this domain has connections and interactions to all other domains. Examples are any forms of social gatherings or groups (for example the family, the neighbourhood, working environment, sportsclubs and so on) with their own habits. By regarding this domain, one can perhaps see best, that in everyday life we are not perceiving our world - we are constructing our world by cognitive processes.

Finally, a further domain must be mentioned, the

Domain of individual experience and episodic validity

It is evident that the validity of such a domain cannot be generalized in a form that it gains validity for many persons. But it is also evident that any personal decision - and forms of knowledge acquisition from media as well - highly depend on this domain.

It has to be stated that we are far from operationalizing the concept of domains of reference for designing specific information systems. But we think it is an approach for understanding the overall possibilities and limits and that it is necessary to take them into account by constructing information systems especially if they claim to contain knowledge in an ordered structure.

As a conclusion the task of externalizing cognitive information can be characterized as the sum of

- Externalizing data or facts
- Externalizing some structure in form of
  - verbal knowledge and
  - systematic knowledge
- Externalizing cultural and social frames in the sense of the discussed domains of reference

Now once more we have to ask for a test for the successful reception of externalized information by a human being. From the point of view of human communication it is evident that it is not possible to communicate with an information system. Therefore none of our tests for a successful communication - and this means a successful transfer of information - can be used. How can one introduce conditions for the successful reception of *externalized* information by a human being? Without being able to answer this question completely, it can be derived from the previous given arguments that the externalization of knowledge forms and knowledge structures must be in correspondence to the respective forms and structures of a person. Furthermore externalization needs some form of storage of one or more domains of reference and that any person who wants to create cognitive information by reception of externalized information must already have acquired the respective domains within its cognitive structure. Once more we stress the need to distinguish between the domains that can be seen as interpersonalized or depersonalized and the domains of individual validity.

We can come to a conclusion: whenever we speak of information as externalized or stored raw material for reception by a human being, this can only be justified if and only if the human being owns an appropriate referential systems for interpreting the externalized data.

Sometimes the argument of *subjectivism* or *solipsism* is objected against the presented position of cognitive information processing. Without going into details it can be said that cognitive information processing has a function for the survival of human beings as an *autopoietic system* individually or as a whole. This includes for every living person - and for human mankind in total - to communicate with other persons about shared impressions. If one is interested in successful communication - and this is an evolutionary necessity - it is not possible to develop a standpoint of subjectivism or solipsism[10].

It is easy to see that certain data can be the origin for information generation for one person and completely senseless for another. It is a matter of question whether we can speak of externalized information if only one person is able (owns the referential structure for interpretation) to generate information from stored data or whether more than one (how many?) persons must be able to do so. In an intercultural context it becomes debatable whether there exists any externalized data that is equally a source for the same kind of cognitive information by any two different people.

After discussing this theoretical framework we will now draw some first consequences for designing information systems. Not all are entirely new but within the presented framework they can be supported by new arguments.

6. Consequences for the design of information systems

At first it seems useful to give a new interpretation of an information system:

An information system contains no information but every information system (even full text databases) has a built-in model of knowledge which depends on time based, social and cultural dependent conceptualizations and certain domains of reference so that the stored data of an information system may be used for acquisition of knowledge under the following assumptions:

- the user (the individual cognitive structure) has already acquired the domains of reference used for externalization
- the user is able to understand or to interpret the concepts used in the information system

This abstract characterization can be detailed in some points: Information systems have a time-dependent function and benefit for a group of users with a specific subject oriented interest and socio-cultural background. Therefore, it is not possible to build a time-independent universal information system or to accumulate all knowledge in one informationsystem. For representing knowledge, information systems must integrate those domains of reference necessary for the user groups they are addressed to. Every form of knowledge (as differentiated before) needs its own form of externalization in an information system.

From this, some propositions about special features of information systems can be derived:

- *Searching features* are appropriate for precise concepts with individual or proper names (without semantic ambiguity) but less useful for forms of fuzzyness or ambiguous conceptualizations.
- *Browsing features* are undispensible, but they must offer more than mere alphabetical lists of words.
- Even better are *navigational aids* which represent forms of semantic context or structure. There should consist tools that help users for *conceptualizing* their search interests within specific domains of reference and tools for *disambiguating* the conceptualization and representation in any documentary language. For an electronic library catalogue this can mean not only to integrate a structured vocabulary but also some kind of electronic dictionary or encyclopedia.
- Furthermore, it is useful to add *systematic* trees and *associative* links.

In the eyes of information professionals some of the consequences may be seen as self-evident, others as too abstract as to realize them within a special information system. It is the advantage of the presented model that some of the pretended self-evident - but not always realized - features are being substantiated by this model. The more abstract consequences need further investigations and it is not a matter of discussion that they have to be detailed further before one can realize them in future information systems. But if one accepts the proposed model of cognitive information construction the guiding principles for the realization of information systems will have changed. It

should be emphasized here that it also gives some hints for limits of information systems that may be of their own value.

7. Some consequences for information ethics

Concludingly some consequences for information ethics will be presented that can be derived from our considerations. We will explain this by shortly mentioning only 3 important consequences. The first one is that the conceptualization of information as cognitive construction takes human beings into the focus of consideration and not technical means, processes or products. Secondly, information cannot be seen mainly as raw material or commercial commodity; the value of information has to be assessed only by the human beings themselves, and thirdly, any individuum is responsible for its own cognitive information processing.

Now, we can come back to our question at the beginning of the paper. We have to face that for our survival within a community - be it a professional, private, political or any other community - that the generation of information from exterior sources is not regarded of equal sense or value. Nowadays we consider it usually more important to generate information from books of a library or from the Internet than getting impressions by regarding trees of a forest or listen to story tellers. Even more, the society, the mass media and our respective individual environments around us generate a kind of pressure for an assessment as to which one of the many exterior sources is of more importance than another one.

This leads to the conclusion that in the societies of our times the usefulness or even the value of information generation from exterior sources is not only a matter of pure epistemology but also - or even stronger - a question of the social surrounding. Perhaps this question and ideas for handling it will be largely vitalized by the many forms of intercultural dialogues we are now having to face and which are strongly promoted by the existing global networks.

Notes

1 The present paper is the written version of a talk given at the International Conference on Conceptual Knowledge Processing, held in Darmstadt, Feb.28-Mar.1, 1996

2 At the moment we will not precise the difference between *information* and *knowledge*. Roughly speaking, we consider knowledge as the structured or ordered result of cognitive information processing. This difference will become more clear in the later course of discussion.

3 The importance of this problem is demonstrated by an increasing number of papers, cf. for example (3-7).

4 For a more detailed discussion see (13)

5 This example has been discussed by T. Kuhn in (14)

6 As a general reference for this point of view one see (15)

7 This argumentation relies on the theories of H. Maturana or E. von Glasersfeld. In their writings more background could be found which in summary is known as *radical constructivism.*

8 This point of view is stressed by G. Roth (14)

9 The word culture is used here in a very broad sense, it includes the meaning, that a scientific community or an organization can have ist own culture.

10 For this point we reference more to the writings of H. Maturana and E. von Glasersfeld (note 7)

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