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Interacting Knowledge Bases in the Area of Tension Between Information and Knowledge

a Pattern for Systems of Men and Computer

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ABSTRACT

Managing knowledge is one of the most important issues for many modern enterprises. Even some years after the “knowledge management hype” many organizations are still suffering under a huge flow of information and knowledge. For example most organizations use to write lessons learned reports but don’t have any ideas how to use them.

This contribution offers an approach for solving this problem. Experience shows, that knowledge management by current computer systems are doomed to fail [1], [2]. But due to the exponentially increasing amount of available information computer assistance is required and increasingly essential to be successful. Thus the question emerges, whether (and how it will be possible to support knowledge management by computers.

This contribution shows the scope and leads the way to a model showing how to integrate computer into a social system successfully on the basis of an integrative, emergent knowledge concept and a deducted integration model. Objective of the contribution is the derivation of a design model to integrate a computer based knowledge base into a social system and to derive the requirement profile for a computer agent based knowledge base according to its integration into a social system.

Keywords: knowledge, computer and human system, communication

1. INTRODUCTION

The question, how to manage knowledge efficiently and how to pool the relevant information to have a basis for decision making is a very present one. Since the internet provides (theoretically) access to nearly every information, the question of most operative business shifted from the consideration of existence of information to the consideration of access to information. Basically the challenge of these days is to navigate through this “ocean of information”. This question enjoys great attention [3]. Examples, tragically underlying the challenge are the attacks of September, 11th. Most sources assume that a better combination and selection of information might have prevented the events. Thus the “9/11 commission report” suggests improving the situation by establishing a tighter and more efficient connecting between the information sources:

“The United States has the resources and the people. The government should combine them more effectively, achieving unity of effort. We offer five major recommendations to do that: [...]

- unifying the many participants in the counterterrorism effort and their knowledge in a network-based information-sharing system that transcends traditional governmental boundaries;

[...]” [4].

Basically the scientific essence of the problem is the question how knowledge can be managed efficiently and extracted from information and how a computer can assist in doing that. The information and knowledge about the attacks were available already before September, 11th 2001, but they were covered in an ocean of other information and not combined to each other properly.

Beside the algorithmic aspects (which will not be addressed within this contribution), the fundamental question is what the nature of knowledge looks like and how an artificial knowledge base could be integrated in a human knowledge management system. Since the first step of designing a computer system on the basis of software engineering theory is always to do a proper “requirement elicitation”, the approach of designing a combined human-computer knowledge management will be the consideration of “knowledge” and “knowledge management” [5]. The entire knowledge management domain can be seen as model, which is a combination of four layers.

The first layer (“micro layer”) contains the analysis of knowledge management objects. It deals with theory of cognition as well as epistemology. The essential issue contained in this layer can be summarized in the question about the character of knowledge as well as its relation to information. This layer provides the theoretical understanding for an IT realization of a knowledge construct which is subject to the “meso” level.

The second layer (“meso layer”) comprises all issues related to the question how knowledge becomes a knowledge base. The examinations are made on a more abstract level than the considerations of the first layer. The relation between layer one and two can be compared to Minsky’s [6] levels of agencies or Holland’s Building Blocks [9]. It includes reasoning entities, storage entities, learning proce-

dures and many other aspects. The current “state of the art” in this layer is characterized by content and document management systems as well as search engines [8], because the other layers have been disregarded during software development.

The third layer (“macro layer”) includes the mainly sociological questions about the interaction of knowledge bases. It is enhanced by general communication theory and considerations of the limits of participating entities like the limited capability of humans to express their tacit knowledge. Another aspect of this layer is the emergence of organizational knowledge bases out of agent communities. Foundation is a model of interacting knowledge bases, which lines out the critical factors of a knowledge generation within an organization.

The fourth layer (“meta layer”) deals with the introduction of a working knowledge management system into a special domain. Since the knowledge management is always depending on certain factors of the situation like the culture within an enterprise, the approach has to raise some factors. This layer is influenced by general consulting methods.

How to establish knowledge management in an organization?	meta	layers of knowledge management
How to integrate knowledge bases?	makro	
How does a knowledge base work?	meso	
What is knowledge?	micro	

Figure 1: Layers of knowledge management

The focus of this contribution is set on layer one and three because layer one offers the theoretic foundation and layer three contains the analysis of the knowledge base interactions.

2. KNOWLEDGE

2.1 History and State of the Art

Since the term ‘knowledge’ is used frequently and in a brought variety of situations, the understanding is very different and context sensitive. Because of this huge variety and the intangible character of knowledge, a common definition is hard to find. Many attempts were made by different research disciplines like philosophy or business economy. The proposed concepts very often reflect a certain perspective and contain a certain degree of fuzziness. Thus finding a common definition is very difficult. A good example for a fuzzy definition covering many traditions is Wiig’s knowledge definition: “Knowledge consists of truths and beliefs, perspective and concepts, judgments and expectations, methodologies and know-how. Knowledge is accumulated, organized and integrated and held over long periods to be available to be applied to handle specific situations and problems.” [9,10]. The fuzziness can be demonstrated easily by considering the question whether

operating a mobile phone is knowledge. The definition hardly provides an answer.

In order to find a definition which possesses the lucidity and degree of definability, to be applied to a computer system a stable understanding of knowledge is necessary. Additionally “knowledge tests” like the Gettier experiment [11] need to be passed by the definition.

This contribution provides an indication on what the differences are and how to remove the fuzziness..

From the *organizational or sociological* point of view, knowledge is the basis for any interaction. In this sense it can be understood as a kind of ontology. Thus it becomes a necessary precondition for any organization [12]. Within this interpretation, knowledge is seen as the vicinity and basement of interaction. Interactions are also the starting point of the generation of knowledge [13,14]. Thus a vicinity of knowledge is necessary precondition for any further knowledge.

Philosophy has the longest tradition of considering the term “knowledge” [8,15]. Epistemology is a branch of philosophy, which discovers “knowledge”. The roots of this branch can be tracked back to the Greek philosophers like Aristoteles, Socrates as well as Plato. They developed the basis for some of the present knowledge definitions. Knowledge was considered as a justified, true belief. The idea of knowledge was subject to many revisions over the centuries. Especially in the 17th and 18th century [16,17] and the 20th century [11,18,19] a strong debate about knowledge took place [20]. An important evolution resulting from the debate in the 17th and 18th century is the dialectic process, described by Hegel [16]. Its performance leads to the elicitation of general, true knowledge.

A significant movement of philosophical knowledge research in the 20th century is the constructivism. It considers knowledge as an individual construct, which is assembled by every human individually, framed by categories like time and space [21]. Glasersfeld defines, “[...] that every knowledge, however described, can only exist in human brains and can only be constructed on the basis of his experience” [21]. The consequential application of this theoretic concept is difficult, since it negates an objective truth (which by the way leads to a negation of the theory by itself), but the idea of constructing an image or “modeling” the reality bit by bit helps in understanding the nature of knowledge. The discussion in epistemology over the last century mainly considered the question, whether knowledge can be true at all [22]. Another analogue idea can be found in the cybernetics. Knowledge – in contrast to information – can not be seen as an exact Newtonian element, which can be calculated. Due to its non deterministic and non discrete, complex character and the fact, that any observer might influence it by trying to discover it, the way of thinking about knowledge should be different [19]

Another perspective is the *compiling pragmatic* interpretation [23]. From this perspective, knowledge is the prerequisite to any action. Knowledge is characterized as all cognition and skills, which enable individuals to conduct actions and solve problems. It is also necessary to interpret

information as well as knowledge and it includes sense giving, emotional and normative elements [24]. The already mentioned definition of Wiig [9,10] is an example for a complete pragmatic definition.

Another idea of explaining knowledge is the approach based on considerations from the *information theoretical* and information technological point of view. Objective of this approach is to find a knowledge definition which is able to be encoded. This approach explains the elements of knowledge by looking at several levels of 'integration' [25,26]. Krcmar/ Rehäuser identify four levels: character, data, information and knowledge.

Obviously the definitions of knowledge (as the definition of „knowledge management“) can be grouped into two categories. A technology oriented perspective as well as a human oriented perspective [8]. The theoretical background of both approaches determines the orientation of the related “knowledge” definitions. The human oriented definitions emphasize the individual, human related character of knowledge. These definitions often include some fuzziness, which goes back to the integration of different ideas and to the claim of the definition to be universal valid. The technology oriented definitions of knowledge are based on the elements and axioms and their combination. Thus the knowledge definition is due to its construction by information often less capacious in terms of its meaning and sense.

The gap between knowledge and information prevalently occurs as a major problem within the attempt to define knowledge. In consequence, it becomes a problem in the scope of knowledge management activities, too [3,23].

Knowledge can also be classified according to several criteria like content or attitude. One common classification of knowledge, which is based on its attitude is the categorization in explicit and tacit knowledge [12,27]. In this classification the tacit knowledge is, „what the knower knows, which is derived from experience and embodies beliefs and values” [14]. Subjective aspects as well as a difficult transferability are also remarkable for this type of knowledge. The elements of tacit knowledge are experience, beliefs and values. Furthermore tacit knowledge can be the starting point for the generation of new knowledge: „the key to knowledge creation lies in the mobilization and conversion of tacit knowledge“ [14]. Explicit knowledge is available to other persons. „Explicit knowledge is represented by some artifact, such as a document or a video, which has typically been created with the goal of communicating with another person” [14]. Thus this kind of knowledge has already been expressed and made available for the external world.

Another classification regarding the contents of knowledge is the distinction between declarative and procedural knowledge [25,28,29,30]. It is especially interesting from the economical and technical point of view. While declarative knowledge covers attributes, conditions, circumstance as well as facts, it answers the question ‘what things are’ [30]. Procedural knowledge covers routines, recipes and

standardized skills as well as cause and effect relations [25,30]

2.2 Emergence and Systems Theory

To give the ability of at least representing knowledge to a computer, it is necessary to have a definition of knowledge which allows decomposing knowledge into information. Also an assembly of information to knowledge has to be possible. It has to be discrete. This is a preliminary step to achieve a “Berechenbarkeit” – Turing computability [31]. Supplementary the capacious character in terms of its meaning and sense has to be maintained to avoid losing the “strength of knowledge” and becoming a heap of information.

Another idea about how knowledge could be composed by information gives the emergence theory [32]. The emergence theory describes how “small” entities form a bigger system with greater capacity (for example in terms of problem solving) than the sum of single entities capacity. Emergent behaviour is called “autopietic” in systems theory. This phenomenon always includes the requirement of exceeding a critical mass. Emergence phenomena are very common in nature and can be found at most levels of abstraction with a broad variety of entities from ant colonies to human brains and cities [32].

Basically the preliminary conditions for such behaviour are different. Johnson [32] emphasizes “self-organizing” activities of the elements, “complexity” and “locality”. “Self-organizing” behaviour means in his senses an ability to interact and thereby find an order without superior management. It also includes “intelligent” “programming” of the participating entities which could be different roles during the life cycle or certain inherent rules of behaviour. An example is an ant colony, where the “self-organizing” behaviour leads to the ability to a dynamic and complex community with high-capacity without central management [33]. The complexity describes a certain quantity of entities, which perform reciprocal action. The quantity of entities is called “ α -complexity”, the degree of reciprocal action “ β -complexity”. Locality means that the interaction of entities takes only place between an entity and its vicinity. This is measured by “ β -complexity”. Surowiecki [34] defines the occurrence of intelligent behaviour by diversity, independence and decentralization. Diversity and independence together mean, that a certain amount of entities is given, which are not related to each other in a strong manner. It means a high complexity (“ α -complexity” and “ β -complexity”) as well as a low correlation of content and rules of each entity. Decentralization is given in case of the absence of a central management.

Holland [7] sees aggregation, non-linearity, flows and diversity as underlying properties and tags, internal models and block building as basic mechanisms.

As all definitions describe slightly different ideas, the criteria coincide partially. While Surowiecki is more focused on intelligence of human crowds, Johnson describes the emergence more generally.

What does this concept of emergent behaviour represented by “self-organization”, “complexity”, “locality”, “diversity”, “independence” and “decentralization” mean in terms of a emergent knowledge definition? Is it possible to answer the question what knowledge is based on by applying the emergence theory?

2.3 Working Definition of Knowledge

The problem whether and how knowledge can be assembled out of information and was already mentioned above. Obviously simply bringing information together doesn't make knowledge out of them. Among others, two key-criteria of knowledge, already mentioned above, are the problem solving ability and the “sense giving character”.

How can these characteristics emerge from information? The answer lies in the application of the emergence criteria on information to form a model, which creates emergent behaviour between information.

To give the possibility to information to perform self-organizing activities, it is necessary to enable the information to become active and to affect other information. This can be realised by connections between the information which provide an impact as well as a kind of sense. The performance of the management of these connections between information is subject to the carrier of the knowledge. In the human case this management is associated with the term “intelligence”.

Diversity is achieved by a critical mass in relation with independence (differences). Diversity is a precondition for information becoming knowledge, which is comprehensible, if knowledge is considered as a tool for problem solving. Problem solving also requires a diversity of information.

Independence of information is applied as statistical independence in the sense of correlation, which is necessary to ensure by bringing together complimentary information. A huge heap of similar information does not help any further. Decentralisation means, that information need to be linked within a network, which is not limited by constraints such as a hierarchy.

Complexity as well as locality also results in a network-like understanding of knowledge. *Compiling these criteria against the background of the previously mentioned knowledge definitions, a network based definition with sense-making links arises.* For the knowledge creation based on information, a critical mass of information has to be reached. This critical mass is reached, if the network is able to solve a problem within the context of use. This context of use (e.g. a problem) also allegorates the sense of the knowledge [35]. In case of a computer based knowledge management, the context of use is contributed by the user or by a specific program (CAD, workflow, etc.) which captures a context of use. The sense giving connections of information enable the information to become a “knowledge-ready” content, the context of use exceeds this sense inherent content to a holistic justification.

If the critical mass is reached, the network is called “knowledge atom” [9,10] because it is the smallest form of knowledge. According to the previously mentioned categorization it is interpretable as describing a process or declaration (see figure 1).

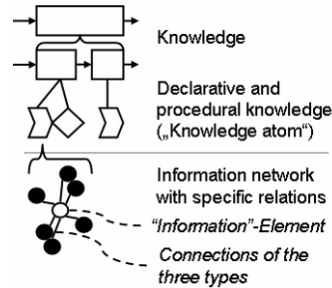


Figure 2: knowledge model

knowledge show [5,36,37,38,39]. The concept was also proven within some test cases.

A very important connection of information is the implication connection (first type), describing all interactions, which influence another information. This needs to be specified more detailed in the certain context, for the business environment a logical and process impact make sense. A logical relation (second type) could be understood as a rule. This could mean that another knowledge element causes this element to be true or to be of another certain value.

The third kind of relations is abstraction and concretion relation (depending on the direction). They describe general aspects of an element or a more concrete and specific element.

Every kind of relation can be considered without watching the other dimensions. In this case, it is just a normal network showing the connections of e.g. the processes or how a system is composed.

The given definitions of knowledge allow a deduction of an idea, what the critical mass could look like. They answer the question, how many information are required to make knowledge out of information? One already mentioned approach to explain the nature of knowledge, which helps to answer this question, is the subdivision of knowledge into declarative and procedural knowledge. By using this subdivision it is possible to describe a certain domain or circumstance entirely. The description of this domain can be thought as a blueprint, covering all declarations (the explanation of all entities properties and characters) and all procedures (changes of declarations and interactions). Depending on the domain knowledge can be covering very complex areas or very simple circumstances. The smallest part of knowledge - a ‘knowledge atom’ [9,10] - can be thought as a single “knowledge” element with a vicinity of all required ideas to understand the included information (and be finally able to apply it).

The limitations of such a knowledge definition as well as representation become apparent, too. Due to the individual character of knowledge a knowledge representation can not be complete. If the attempt is undertaken to make knowl-

Necessary elements, which are not found very often in the given definitions, are the connections and relations between the elements - the vicinity of each element. The different connections can be of various types as theoretic ideas about modelling

edge explicit (what is basically the same as finding the corresponding representation of knowledge based on information) a single information has to be taken as starting point. This information can lead the attention to its vicinity, which can be investigated for further connections. This is a recursive process, which need to be aborted after several cycles due to the giant complexity of a knowledge network. Thus only a limited knowledge domain can be presented entirely [40,41]. This explication process is in line with given approaches based on other knowledge definitions [13,42]. Knowledge is, according to this definition, in certain boundaries and under certain constraints manageable by an IT-system.

3. MANAGING KNOWLEDGE

3.1 Knowledge Bases

The basis of considering knowledge management is the understanding of knowledge (as defined) and about the knowledge managing entities. They determine the communication and interaction, which is the real core of knowledge management as well as the basis to any social system [3,43].

The entities are characterized as “knowledge bases”. Knowledge bases are considered as autopoietic systems in terms of knowledge handling. The working definition covers organizations (autopoietic system of autopoietic systems) as well humans (autopoietic system of non autopoietic systems). These knowledge bases exchange their knowledge by interaction and especially by communication. Based on this understanding knowledge management can be seen as a network of knowledge bases (vertices) and interactions as well as communication (edges) [42]. Thus the knowledge management system (interacting knowledge bases) can be formalized as graph.

Every knowledge base can also be seen as agent [42]. An agent is “anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators” [44]. Every agent has an own behaviour, which sometimes can be very simple (e.g. a neuron) or very complex (e. g. a company). There is a huge variety of different descriptions of agents. Russell/ Norvig use a PEAS (Performance, Environment, Actuators and Sensors [44]. To have a complete view on agents, a PAGE+R (Perceptions, Actions, Goals and Environment + Rules) description is used in this contribution. Goals as well as rules (which specify the way of behaving) express the agent’s performance and allow a more differentiated view. Russell/ Norvig distinguishes between five types of agents: “simple reflex agents”, “model based agents”, “model based, goal based agents”, “model based, utility based agents” and “learning agents” [44]. The different types describe the different complexity and flexibility in the agent’s behaviour. Learning agents are able to change their behaviour and their underlying activity model. An autopoietic agent can be seen as the sixth type because it would not only be able to learn, but to change the way of

learning, too. This kind of agents is not yet available, but is under development. Such an agent would be able to change its source code on it’s own. The concept is pretty close to self-debugging software, which is also under development [45]. Such a learning Process would be isomorphic to the double loop learning introduced by Argyris/ Schön [46].

Holland [7] adds two types of abstraction level of agents. He distinguishes between single agents, and meta agents, which consist of several single agents. Their “behaviour depends on the interactions of the component agents in the network. The aggregate agents may again be aggregated to add new hierarchical levels” [7]

In the further considerations of this contribution knowledge bases will be considered as meta-agents composed of type five and especially type six agents.

The understanding of an agent underlines the presence of communication as a necessary condition for knowledge transfer and management. The reason can be deduced from an example (*pars pro toto*), where a human is considered as an agent. In this case his or her knowledge can be seen as represented by rules. As the “rules” of an agent can not be studied directly by an external observer the agents activities and communication (its interactions) have to be interpreted to conclude which rules “control” the behaviour. Thus without interaction (especially communication) knowledge can not be made explicit. Among other conditions the quantity of interaction is correlated with the probability of making knowledge explicit. Beside the quantity of interaction the reciprocal understanding of the knowledge transfer partners is important. The sociology considers a common system as precondition for every communication. Every system is characterized by a common binary code (sociological view [43]) or common ontology (view of computer science [47,48]). The interaction of different systems can only be performed if an intersection of ontology or an understanding of the other binary code is granted.

Communication is seen based on the model of Gitt [49,50] and Luhmann [43]. Gitt divides the communication into five levels.

The first level – the statistics – deal with the transfer of character and the related quantitative aspects. It considers communication in the sense of Shannon/ Weaver [51], who analysed the transfer of pure data. *Level one* correlates with layers one and two of the ISO-OSI model [52]. As the “reflex agent’s” behaviour is limited to reactions on pre-defined situation or perceptions, it is able to take part in a communication on the statistical level and sometimes – depending on the complexity of the amount of rules – also in a communication on the syntax layer (layer two).

Level two of Gitt’s communication model comprises the syntax of communication. Syntax contains all rules how elements of a language, a character set or any other symbols can be combined. This level describes, “how it technically works”. Thus layers three and four of the ISO-OSI model are comparable. As the agents which contain a model are able to handle a communication, which is syntax-based, they are able to understand code (see figure 3).

Level three includes the understanding of the content (semantics) of each communication. It requires the connection of several information to produce a statement. This kind of communication is difficult to computer systems, as they are limited in the understanding of ontology. Because only a learning entity is able to adapt to a meaning [21,53]. Thus the learning agent is the only computer based agent, which is able to take part in such a communication. In consequence the missing three layers of the ISO-OSI model are included in this communication level.

Level four of Gitt's communication model comprises the reference to activities. He calls level four the "pragmatic" level. The pure information and content of the communication is exceeded by an action-related intention. Basically the question "what has to be done" is answered by a level four communication. A computer is not yet able to find a solution without pre-defined boundaries and tools.

Level five contains the apobetic aspect of a communication. The content of this communication level can be summarized in the question "why do I send this information". The fifth level is actually the most important since it provides a reason as well as justification for the communication [51]. It helps to negotiate and achieve the goal of sender and receiver. Especially a computer system, which is able to take part in a level five communication is not yet available, whether it is thinkable is still an unanswered question. If it was possible to develop such a system, it would need to be autopoietic (in the words of systems theory), it would need to be able to perform double loop learning (organization theory) or (in the words of Gitt's communication model) it would need to be able to take part in an apobetic communication. In the words of computer science it is necessary to develop a concept for a learning Turing machine for which an isomorphism to a normal Turing machine can be found.

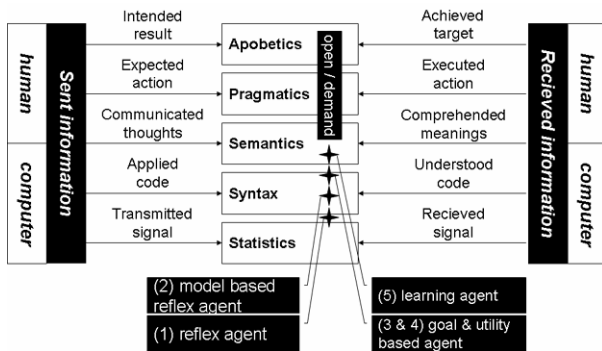


Figure 3: communication model (cp. [50], p.6)

If all presented models and ideas are combined, a general "macro layer" model of a knowledge management system emerges. The question whether an IT knowledge base can be integrated in such a system appears as a question of ontology and thus semantic communication. The question of a realization of such a system is a "meso layer" issue of implementing the theoretical "micro level" knowledge concept. Analyses of the interactions, taking place within such an organizational knowledge base are subject to the mathematical model of knowledge management.

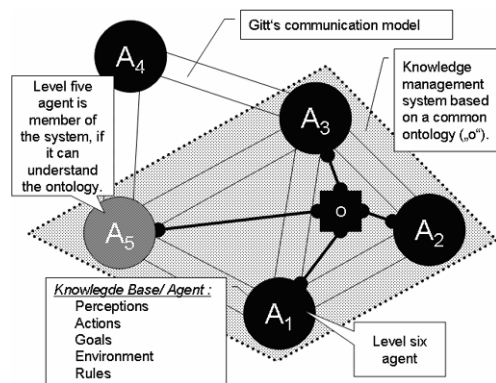


Figure 4: interaction graph

3.2 Mathematical Model of Knowledge Management

The knowledge management model includes several terms a parameter. They reflect the individual situation of an organization. The model can be used quantitatively, but the primary purpose is to reflect the qualitative interdependencies.

As already shown on the basis of the given knowledge definition and their constructivist background, knowledge can only be transferred by communication. This is the starting point for the model. The used variables are explained below:

$W_{KB}(t) = W_{KB}(t)$ is the knowledge asset at the point in time "t" of the considered autopoietic knowledge base [43]. The unit is "knowledge atoms". They have to be defined according to the organization. It could for instance be atomic process steps in a company.

$W_A = W_A$ is the new knowledge flowing into the organization. It could for example be embodied in ideas, external experts (consultants) or new experiences based on experiments. It can be both explicit and tacit knowledge. Tacit knowledge enters the organization for instance embodied in new employees. Mathematically W_A is a vector specifying the skills in several subjects. They need to be similar to the categories of the specified knowledge objectives.

$W_S \in [0, W_{KB}] = W_S$ specifies the knowledge, which leaves the organization. It is embodied in employees, who retire or are dismissed. Lost explicit knowledge could be deleted files or unreadable blueprints. Obviously the value $W_S(t)$ is always smaller or equal to $W_{KB}(t)$.

$W_O = W_O$ specifies the knowledge objectives of an organization. The objectives are represented by a vector. Each value of the vector is assigned to a subject, which represents certain knowledge. By multiplying new knowledge and knowledge objectives the objectives "filter the profile" and cause that only "desired" knowledge is counted by W_{KB} .

$c \in [0,1] = "c"$ reflects the complementary character. It describes how "beneficial" "new" knowledge is to

an organization. Is the “new” knowledge already known, it is not complementary at all ($c=0$). If it matches exactly the current demand, it is absolutely complementary and results in an increasing knowledge base value ($W_{KB}(t)$).

$o \in [0,1]$ = The “compatibility of ontology value” (“o”) gives an indication, whether the “new” knowledge can be understood by the organization. If the understanding of the meaning of words for example is different, a knowledge transfer becomes problematic. In the worst case it is impossible due a “torn-off” communication.

$a_1, a_2, a_3(t)$ = the “knowledge growth parameter” help to adjust the model to special situations. They cover soft skills, trust and further determinants of communication success as well as creativity and intellectual capability of the participants.

The model is developed based on Holland’s ideas of the assessment of a dynamic system [7]. It seems obvious, that the knowledge asset is depending on the previous situation ($t-1$). This fact results in a recursive function. It is also apparent, that the knowledge asset is subject to addition and subtraction of knowledge.

$$[1] \quad W_{KB}(t+1) = W_{KB}(t) + W_A - W_S$$

As knowledge addition and subtraction is not a function of time, but an occasional value, they do not have time as parameter.

The knowledge asset is especially important to an organization if it matches the knowledge objectives. The way of “filtering” knowledge can be adapted to the organizations strategy, if the emphasizes are not only on the core competence. This can be done by using “non zero” values in every category (element) of the vector.

Granted, that three different types of competence and knowledge are added to the organization by integrating a new employee. His skills are “extrusion” (“ c_1 ”), “injection moulding” (“ c_2 ”), and “personal management” (“ c_3 ”). The knowledge is rated on a scale from 0 (no knowledge) to 5 (expert). In this example, we assume the profile ($c_1=4$, $c_2=4$, $c_3=5$). The knowledge objectives are expressed as numeric values between 0 and 1 showing the importance of the corresponding knowledge category.

$$[2] \quad W_A(t) \cdot W_O = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} \cdot \begin{pmatrix} o_1 \\ o_2 \\ o_3 \end{pmatrix} = \begin{pmatrix} 4 \\ 4 \\ 5 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ 1 \\ 0,5 \end{pmatrix} = 10,5$$

After calculating the efficient knowledge increase, some further aspects concerning the knowledge assets of the knowledge base have to be investigated. If an interaction between the elements (also knowledge bases; for example employees within an organization) takes place, further knowledge develops with a certain probability. This knowledge creation is depending on some parameters.

Beside other parameters, the efficiency of knowledge growth is depending on the magnitude of “knowledge flow”. If the knowledge flow “into” and “out of” an organizational knowledge base becomes very big (all knowledge flows out and the same amount of new knowledge comes

in) the knowledge development potential based on interaction is very limited. Formula [3] summarizes the ideas.

$$[3] \quad W_{KB}(t+1) = (W_{KB}(t) + W_A - W_S - \frac{W_A \cdot W_S}{W_{KB}(t)}) \cdot a_1 \cdot f_{int}$$

After assigning the parameters and converting the formula, the meaning becomes observable (see formula [4]). The old knowledge asset value ($W_{KB}(t)$) becomes scaled by a factor depending on the added and subtracted knowledge.

$$[4] \quad W_{KB}(t+1) = W_{KB}(t) \cdot \left(1 + \frac{W_A(t) \cdot W_O}{W_{KB}(t)}\right) \cdot f_{int}(\tau \cdot i, c, o) \cdot a_1 \cdot \left(1 - \frac{W_S(t)}{W_{KB}(t)}\right)$$

The knowledge creation function on the basis of Itoyama’s and Kamizono’s [54] association function is based on a logarithmic function. Itoyama and Kamizono figured out, that the quantitative aspects of finding associations and combining information takes place in the same manner as a logarithmic function develops. Thus knowledge creation evolves in the same order, because the time and quantity ($\tau \cdot i$) of interactions is comparable to the association time period of Itoyama and Kamizono. The activities of finding associations and developing knowledge by using creative techniques such as brainstorming are also comparable. Due to the character of knowledge definition and the deducted requirement for interaction to reveal and create knowledge the interaction function is a mathematical model of knowledge creation. The interaction, basis to the knowledge creation, is also depending on some parameters like compatibility of ontology, the complementary character and some soft skills.

$$[5] \quad f_{int}(\tau \cdot i, c, o) = c \cdot o \cdot (a_3(t) \cdot \log^{a_2 \cdot \tau \cdot i + 1} + 1)$$

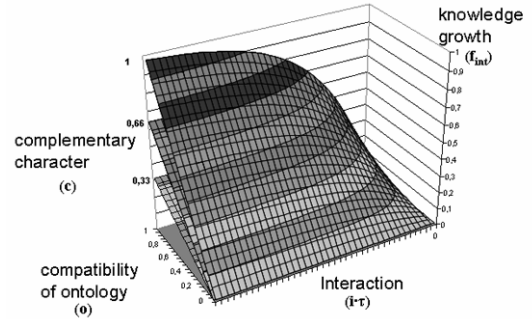


Figure 5: the interaction function

4. CONCLUSIONS

The shown idea about knowledge has many impacts on the overall consideration of knowledge management as the first layer is the basement of the entire knowledge management model. A constructive approach to knowledge management provides many possibility in assessing knowledge as well as knowledge management. Especially because of the accurate numeric character of this model, further research is required to determine the bandwidth of valid values of the parameter.

Particularly the attempts of using computer technology to support knowledge management underline the demand for such a model and drive the efforts to clear the fog of intangibility of knowledge.

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