Handbook of Research on E-Business Standards and Protocols:

Documents, Data and Advanced Web Technologies

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Chapter 8
Ontologies for Guaranteeing the Interoperability in e-Business: A Business Economics Point of View

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ABSTRACT

For e-business, the computer-based processing of value-creation, especially for knowledge-intensive business processes, plays a prominent role with the help of modern information and communication techniques. At least since the further development of the classical Internet for the Semantic Web, the content-based knowledge processing and knowledge transfer have gained more importance. In this chapter it is shown that ontologies represent an auspicious instrument to ensure the interoperability of information and communication systems that have to work together on the work-sharing development of knowledge-intensive business processes. Ontologies become important when agents with heterogeneous knowledge backgrounds co-operate on such business processes. Firstly, the complex and often ill-considered use of the definition of ontology will be discussed critically and its meaning specified. Thereupon it will be shown (with the help of two application areas) how ontologies can be used effectively to support knowledge-intensive business processes in e-business. On the one hand, the chapter is concerned with the management of knowledge of competences, which agents have to have a command of for successful process execution. On the other hand, it is about the management of know-how, which has already been collected from completed projects and should be reused in new projects.

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INTRODUCTION

E-business is characterized by the handling of value-creating business processes with assistance from modern information and communication techniques. For over one decade the internet has played an important role as a technical base-infrastructure for computer-based – metaphorically often referred to as "electronic" – information and communication processes. Over the last few years the semantic web has gained, from a business economics point of view, a growing importance relating to the further development of the "classical" internet, because the focus is on the handling and transmission of content (semantic level) and not on information and engineering technical design of the network infrastructure (syntactic level). This content-based knowledge processing and knowledge dissemination is one of the main concerns of business economics concerning the management of knowledge-intensive business processes, because the primary value creation is carried out by "knowledge workers", which transform their business process relevant knowledge, for example, into "added values" or "problem solutions" for their potential customers.

In modern, work-sharing – often even "globalized" – economic systems the realization of knowledge-intensive business processes is shaped by work-sharing economic activities. To achieve the intended process aims, for example the above mentioned "added values" and "problem solutions", an effective collaboration (interoperability) of the agents involved in the process implementation is necessary. As e-business processes are being discussed in this chapter, it must be remembered that both human beings and information and communication technical systems ("computers", "machines") are considered as agents. For the sake of brevity, the terms ICT systems and their users will be employed in the following.

To guarantee the interoperability between ICT systems on the one hand as well as interoperability between these systems und their users on the other hand, it is necessary to have a common understanding regarding the process relevant knowledge on the level of the content-based knowledge processing and knowledge dissemination, although this common knowledge understanding does mostly not exist in economic reality. Instead of that, work-sharing and knowledge-intensive business processes are generally characterized by wide knowledge heterogeneity on the semantic level. Therefore many reasons come into consideration, for example idiosyncratic concepts for application software ("SAP terminology"), historically grown business vocabularies and professional terminologies from different functional areas. In addition, in companies and even in single business units, different acronyms are used for the same things. There are also specific difficulties on the semantic level when, as a result of cultural differences, certain terms, e. g. "responsibility", are interpreted differently. The dissemination of e-business leads to more companies which belong to different linguistic, economic and cultural traditions working together on joint projects. Such cultural differences are behind the fact that knowledge heterogeneity on the semantic level in the context of e-business is of prime importance. For a further, more in-depth analysis and also a systemisation of the reasons, which could cause the problem of knowledge heterogeneity on the semantic level, the appropriate technical literature should be referred to (see for example Kim & Seo, 1991; Sheth & Kashyap, 1992; Park & Ram, 2004). Above all, Kajan and Stoimenov have provided a detailed focus on the problem of data (knowledge) heterogeneity in the area of e-business (Kajan & Stoimenov, 2005).

The reasons outlined above lead to the conclusion that the knowledge necessary for business processes is often spread throughout multiple, incompatible legacy (software) systems within a company and it is saved in conflicting formats (Park & Ram, 2004, p. 596). In contrast to this, successful efforts have been made to introduce standards for document formats in which most of the process and company relevant knowledge is held (see for example the current overview by Kabak & Dogac, 2010). These standardisation efforts in the area of document formats have not, however, been crowned by a breakthrough success (Kabak & Dogac, 2010, p. 11:30). The same is true of the efforts to improve the interoperability between ICT systems with the introduction of standards for the exchange of information between heterogeneous systems. These efforts suffer from the fact that too many mutually incompatible interoperability standards exist, which hinder each other. The lack of success of these standardisation efforts can be explained, on the one hand, by the fact that the old legacy (software) systems which have been used for years in companies reveal a large level of inertia, which makes the introduction of new systems extremely difficult. On the other hand, many companies, which offer software for the creation, saving and use of business relevant documents, have attempted to distinguish themselves from the competition by emphasising the alleged or actual pre-eminence of proprietary document formats.

Due to the above mentioned difficulties, one can only agree with the following diagnosis of the situation offered by Park and Ram (when their reference to the data and information is replaced by the primary knowledge of interest here): "Data management in a heterogeneous environment has been one of the most challenging problems … In particular, establishing semantic interoperability among heterogeneous and distributed information sources has been a critical issue attracting significant attention from research and practice" (Park & Ram, 2004, p. 596). Kajan and Stoimenov also underline the importance of semantic interoperability with regard to the task of resolving the semantic conflicts arising in e-business when using heterogeneous ICT systems (Kajan & Stoimenov, 2005, p. 62). The importance of the integration of heterogeneous ICT systems in order to achieve semantic interoperability can only be quantified, from a business point of view, with great difficulty. In particular, it is hardly possible to specify concrete costs of ICT systems integration in the context of e-business with a view to enterprise application integration projects or B2B applications. Corresponding quantifying efforts fail as a rule due to the diversity of corresponding integration projects and the difficulty of obtaining valid internal data from the companies affected.

Nonetheless there does exist some indication as to the magnitude of the costs of such integration projects. A study by Forrester Research from 2005 reported that, in the integration projects examined, average (direct) costs of – 2 different numbers were given in the source – 6.3 or 6.4 million US dollars were incurred (Koetzle et al., 2001). The actual costs incurred by businesses would probably be higher still, because the considerable indirect costs for the overstepping of time and budget limitations for such integration projects have not yet been included in the estimate. The extent of these indirect costs could become crucial, because, according to the above mentioned study by Forrester Research, less than 35% of the integration projects examined keep to their cost and time budgets (Koetzle et al., 2001). The same study pointed out that the integration projects examined stretch out for more than 20 months on average when integrating an average of seven different ICT systems (Park & Ram, 2004, p. 596). Therefore it seems plausible that projects for the integration of ICT systems could produce such a high level of costs.

A topical example for the prime importance for business of the integration of ICT systems in order to achieve semantic interoperability can be seen in the recent work at EDEKA PLC, one of Germany's leading supermarket chains. In the large scale integration project „Lunar" [Schütte, 2011; EDEKA, 2011, pp. 3, 4, and 26], approximately 8,000 retailing operations as well as 7 wholesale operations, which presently use a whole host of different software systems for the planning and running of their business processes, will be converted to a single software standard on the basis of the ERP-software family from SAP. The integration project is planned for 2007 – 2012, but it will probably be 2015 before the synergetic advantages from the integration can be fully utilized. For the execution of the project around 100,000 man-days for the expertise of external consultants as well as a budget of 349 million euros (as at June, 2010) have been planned. This budget only includes the direct costs, not the considerable indirect costs which will be incurred by the individual operations, which need to make sure their organisation is fully integrated with the new software architecture. It is not only the costs which in this case top the average costs from the above mentioned study by Forrester Research by a factor of 50 that underline the operational importance of such integration projects. In fact it is the internal company returns on integration that prove to be more remarkable. Synergetic advantages from integration can be measured at 1% of net turnover. As the net retail turnover alone of the EDEKA group was 39.06 billion euros in 2010 [EDEKA, 2011, p. 6], synergies can be calculated – roughly – at a level of 350-400 million euros per year. Internal company expectations for the returns of the integration project are, partly, even higher.

The most promising approach to resolving issues of knowledge heterogeneity on the semantic level within work-sharing task fulfillment are ontologies (Zdravković et al., 2010, p. 4). Ontologies mainly come from the field of computer science, in particular from artificial intelligence research, but they have also been discussed in the field of business informatics for quite some time.

From a business economics point of view ontologies have an ambivalent character. On the one hand there is considerable interest in instruments that ensure the interoperability of agents with heterogeneous knowledge backgrounds on work-sharing, knowledge-intensive business processes. On the other hand, the ontologies presented so far with a business economics focus turn out to be totally inadequate, occasionally even catastrophic. This negative finding results mainly from the aspect that ontologies have, to date, mostly been developed by information and computer scientists, who do not have a grasp of the terminological subtleties and the necessary background knowledge of the economic professional language.

Due to the aforementioned reasons, this chapter deals with problems that are to be deplored from the business economics point of view regarding the current state of ontologies. Furthermore, some approaches are pointed out which show how to solve such problems generally. The aim of these considerations is not to oppose the research in informatics, artificial intelligence and business informatics, but rather to provide more understanding of typical business economics mindsets and requirements regarding the practical use of ontologies in e-business.

In the first part of this chapter, the predominant understandings of the term "ontology" will be critically discussed. Most of the authors who tend towards the practical use of ontologies adhere to the frequently quoted definition of ontologies from Gruber. It will be explained that this definition is too superficial and ambivalent from the business economics point of view. As an alternative, a more differentiated and precise understanding of ontologies will be proposed, which is in particular more tailored to the background of work-sharing task fulfillment by agents with heterogeneous knowledge backgrounds.

In the second, more extensive part, two business economics task areas will be examined, in which, on the one hand, knowledge-intensive e-business processes play an important role but where, on the other hand, they suffer from interoperability defects to date. Thus they represent areas for which ontologies could be useful. First, it deals with the management of knowledge of the necessary and available competences of economic agents (management of competence). Second, the management of knowledge of projects will be considered. With the help of these two examples, it should be shown how ontologies ensure a common understanding regarding the process relevant knowledge between agents with heterogeneous knowledge backgrounds in work-sharing, knowledge-intensive business processes and, as a result, to ensure the interoperability in e-business.

BACKGROUND: THE MEANING OF ONTOLOGIES

Ontologies have been attracting attention for about 25 years mainly due to Artificial Intelligence Research and Information Systems Research (see for example Alexander et al., 1986; Farquhar et al., 1997; Fox & Grüninger, 1997; Guarino, 1997; Noy & Hafner, 1997; Benjamins & Fensel, 1998; Cui et al., 1999; Staab & Maedche, 2001; Poli, 2002; Ding et al., 2004; Fensel, 2004; Gómez-Pérez, 2008; Abdoullaev, 2008; Staab & Studer, 2009; Ceravolo & Damiani, 2009; Gavrilova, 2010; Paquette, 2010, pp. 198). But the practical application of ontologies suffers as a consequence of the definition "ontology" remaining vague. Therefore any definition used can lead to misunderstandings. It has sometimes served as a general term for all possible approaches and concepts of information systems research and artificial intelligence research which are related to conceptual structures, for example simple data dictionaries as well as ambitious conceptual data models.

When any attempt whatsoever is made to define more precisely the term "ontology", most of the authors who aim at the practical use of ontologies refer back to the often-cited definition of ontology from Gruber (Gruber, 1993, p. 199; Gruber, 1995, p. 908). However, Gruber did not provide a definitive definition of ontologies, but presented rather two unrelated definitions and expanded these with an auxiliary definition for conceptualizations:

- At first Gruber puts the aspect of definition systems and the language orientation of the modern understanding of ontologies into the foreground: "A specification of a representational vocabulary for a shared domain of discourse... is called an ontology." (Gruber, 1993, p. 199; cursive accentuations from the authors). Here Gruber hints at the pragmatic, epistemological and social component of ontologies: The definitions from the vocabulary of an ontology are used to represent facts from a perceptible real world situation („domain of discourse"), („representational vocabulary"). Additionally, multiple agents are implicitly assumed, because a discourse on a real world situation presupposes communication between multiple agents. Moreover, it is assumed explicitly that multiple agents share a domain of discourse, thus conforming to the real world situation under examination.
- After this Gruber accentuates the aspect of conceptional structuring: "An ontology is an explicit specification of a conceptualization." (Gruber, 1993, p. 199; Gruber, 1995, p. 908; a cursive accentuation of the two originals is omitted; instead of this a deviant cursive accentuation from the authors is used). With regard to content he added illustratively: "A conceptualization is an abstract, simplified view of the world that we wish to represent for some purpose." (Gruber, 1993, p. 199; Gruber, 1995, p. 908.). In the definition of conceptualization, the epistemological und pragmatic components of ontologies are once again hinted at: It contains a view of the world which is structured and presented with the help of conceptualization in such a way that it conforms to some purpose.

As a single component of a definition, there is still a lack of clarity as to what Gruber understands by specification, to which he refers twice ("specification of a representational vocabulary" and "specification of a conceptualization"). Because the problems of this aspect are never expounded, a specification can be interpreted informally as a determination of something. Gruber does also not allow any kind of specification in the second case which relates to a conceptualization, but calls for an explicit specification.

A further aspect of the understanding of ontologies is not expanded upon by Gruber. It concerns the question as to whether the specifications – on the one hand the vocabulary from the definitions of representation and on the other hand from the conceptualization of a real world situation – could be composed in any language or should be restricted to formal languages. In the aforementioned definitions Gruber is non-committal with regard to the natural or formal language of specifications. Sometimes he reveals a tendency to configure ontologies in formal language. He is speaking of "formal axioms" (Gruber, 1993, p. 199) and formulates: "Formally, ontology is the statement of a logical theory" (Gruber, 1995, p. 908). This tendency is seized upon by the authors and radicalized in terms of a special understanding of ontologies. Therefore ontologies are always considered as formal language artifacts. This point of view is often to be found in the specialist literature (for example Studer et al., 1999, p. 4; Tamma & Bench-Capon, 2002, p. 43; Vasconcelos et al., 2000, p. 249).

The aforementioned exegesis for the understanding of ontologies from Gruber could be summarized by the following definition of ontologies: An ontology is the explicit and formal language specification of a conceptualization of phenomena in an extract of reality which is used in common by different agents for the completion of their objectives. It will be shown on closer examination that this definition of ontologies based on Gruber give rise to some problems which will be briefly described, but will not be resolved exhaustively.

EVOLVEMENT OF AN "ENLIGHTENED" UNDERSTANDING OF ONTOLOGIES

Epistemological Basics

The modern understanding of ontologies in terms of the aforementioned alternative definitions does not give any information about the knowledge independent, purely ontological character of the reality and the phenomena of this reality. From the perspective of the philosophical tradition of ontology a pre- or anti-ontological basic attitude could be spoken of, albeit hyperbolically, because the modern understanding of ontology from AI-research and business informatics presupposes – from the point of view of the authors entirely correctly – a combination of ontological and epistemological perspectives. This combination of perspectives is based on the fact that the epistemological "naive" point of view of a real world experience "in itself" – independent of the distortions caused by the cognitive abilities of a subject – is regarded in the modern theory of cognition as being overcome. Instead of this it is assumed that extracts from reality and the connected phenomena are just recognized as results from active cognitive performance, which are achieved by cognitive subjects in the attainment of their aims. Because of this influence of subject dependent cognitive performance, ontologies could never be understood in themselves as phenomena of the real world, but just phenomena of a cognitive subject. Therefore ontologies always have an epistemological component which extends to the conditions of the possibility of real world experiences.

For the subject- and function-dependent framework within which the concrete experiences of real world situations and their phenomena happen, the term "conceptualization" has emerged from both the current discussions on ontologies and the established modeling theory. The definition of conceptualization means an abstract and simplified point of view of phenomena of a real world situation, which is interesting for subjects in the attainment of their aims (Gruber, 1993, p. 199; Gruber, 1995, p. 908; Studer et al., 1999, p. 4). The aims of the subjects involved determine which aspects of the perceived or imagined phenomena are relevant for the subjects. Conceptualization, therefore, always means the functional- and subject-dependent commendation of relevant aspects of reality.

The conclusion of a conceptualization process involves concepts. A concept is regarded here as a generic, that is not as a single case specific unit of thought. This corresponds to the extensive analysis of the definition of concepts by Bunge (Bunge, 1998, pp. 51 [p. 51: "unit of thought"], pp. 64, and pp. 99). A concept should summarize similar experiences of a real world situation to one unit. Thereby real world perceptions and ideas which are possible for a subject as experiences of reality are structured by their thinking. This pre-structuring of possible real world experiences through concepts can turn out differently because of the aims and the cognitive influences of a subject. Therefore conceptualizations always accompany the knowledge of formative ("epistemological") pre-structuring of possible real world experiences.

Concepts represent the "basal" elements of ontologies. Regarding each concept, three dimensions must be distinguished:

- The identifier of a concept is the name of the concept under which a concept is addressed ("articulated") as a content of knowledge.
- The content of a concept (concept-content, concept-intension) is the entirety of all attributes which describe a concept as a unit of thought.
- The range of a concept (concept-range, concept-extension, reference) is the entirety of all similar experience objects from a real world situation which are summarized to a unit of thought.

Linguistic Fundamentals

According to the "linguistic turn" of the modern epistemology, thinking and language are inseparable: No thinking is possible outside language; each language is shaped by characteristic patterns of thinking. Because of the impossibility of "speechless thinking", a linguistic spoken unit corresponds to a unit of thought with every concept. With language units which correspond to concepts of thoughts, we are referring to definitions. So it is also possible from the perspective of language orientation of the modern understanding of ontologies to consider definitions as the "basal" elements of ontologies. From this perspective, the conceptual pre-structuring of possible real world experiences could also be considered as a definitional pre-structuring of possible real world experiences. According to the aforementioned three dimensions of concepts as units of thought, three dimensions of definitions could be distinguished: The identifier of a definition is the name of the definition to which a definition can be addressed ("articulated"). The content of a definition (content-definition, content-intension) is the entirety of all attributes which define a definition in terms of content (constitutive or substantial attributes). The range of a definition (definition-range, definition-extension, reference) is the entirety of all similar experiences of a real world situation which fall under this definition.

In the following no distinction will be made between concepts and definitions as "basal" elements of an ontology. Instead of that both expressions will be used in parallel. When thought content is meant, concepts from the epistemological point of view will be spoken of. In contrast to this, definitions are preferred if ontologies are mentioned from the linguistic-analytical point of view. Furthermore in the context of ontologies there exists a third expression: instead of concepts or definitions classes are often referred to. Classes are summaries of similar objects – so called "instances" – to a unit of design or implementation. This wording arises from the environment of the object-oriented design-approach of automated information processing systems. This will be preferred when ontologies are being discussed which are implemented or should be implemented in "object-oriented" computer-based knowledge management systems. According to these object-oriented designs of ontologies, the single experiences, entities or individuals which are summarized into a concept as a unit of thought or fall under a definition are from now on called instances.

The totality of all representational definitions (or concepts) with which the sum of possible real world experiences in an ontology is structured, will be discussed in papers about ontologies under different notations: as vocabulary, thesaurus, terminology, data dictionary, data repository or as a set of representational terms. Mostly the vocabulary, which provides the representational definitions to describe real phenomena, is the central element of an ontology. In rare cases ontologies are equated with a representational vocabulary, which means a "reduced", purely terminological understanding of ontologies is at hand.

Explicitness and Formalization

The main interest which information systems research and artificial intelligence research have in ontologies is based on, from the point of view of the authors, the characteristic requirement, that the conceptualization of possible real world experiences should not only be composed linguistically somehow, possibly composed implicitly in our every day speech. Instead of this, ontologies as understood here are based on the double postulate that the conceptualization of possible real world experiences should be specified explicitly as well as in formal language.

The explicitness postulate represents a big challenge for the construction of ontologies. In the field of engineering and economic sciences it is usual to introduce only the "basic" definitions explicitly. Because of the common shared, natural language pre-understanding of all normal definitions, a whole reconstruction of used notional concepts is generally not expected, let alone achieved. It could not be assumed – at least currently – that the artifacts of information system research and artificial intelligence research, like knowledge-based systems and multi-agent-systems, have such a conceptual pre-understanding. In complete contrast, first attempts to explicate the numerous presuppositions of natural language pre-understandings to make them accessible, for example, for the knowledge-based systems have proved to be very difficult.

The formalization postulate is another complicated aspect. It takes into account that knowledge-based systems need formal language representations of the relevant knowledge contents for their internal operations. This is the same for the interoperability of "intelligent" software systems, when they communicate with each other in e-business for the work-sharing completion of knowledge-intensive business processes in the semantic web.

There are doubts concerning the formalization postulate as to whether it will ever be possible to specify completely accurately the "basic sense" or "semantics" of natural language conceptualized real world experiences with the help of explicit formal language explanations. For the sake of brevity, it is not possible to consider these doubts here, but reference can be made to the frequently discussed "Chinese room" thought experiment by Searle (Searle, 1980, pp. 417).

The conceptualization of real world situations through ontologies distinguishes itself from another aspect which, from the economic point of view, is of practical relevance for economic problems. It applies to the social components of ontologies. This results from the fact that some agents use the same conceptualization of real world experiences as soon as they have agreed on a common ontology ("shared ontology paradigm").

The sharing of a commonly used ontology plays an important role in e-business and the semantic web with work-sharing, knowledge-intensive business processes. Because the agents – both people as well as software systems – could only communicate and coordinate their activities for the work-sharing completion of a common task ("distributed problem solving") without frictions when no linguistic barriers of understanding restrict the possibility of a common real world experience. A mutually employed ontology represents a necessary but not sufficient instrument to preclude such linguistic barriers of understanding between the interacting agents.

An Expanded and Specified Definition of Ontology

To summarize the aforementioned arguments on the modern understanding of ontologies, a second, content-enlarged and specified work definition of ontologies can be identified: An ontology is an explicit and formal language specification of these linguistic means of expression which are considered necessary for the construction of representational models of a common conceptualization of real phenomena used by several agents. Thereby the conceptualization extends to these real phenomena which are regarded by the agents as observable or imaginable in the subject- and goal-dependent restricted real world situation and which are used or needed for the communication between the agents.

This definition of ontologies is the basis of this chapter. This differs from popular understandings of ontology in many respects:

1. The linguistic orientation of the modern understanding of ontology is especially emphasized. In particular – in contrast to Gruber – an ontology is defined as a specification of linguistic means of expression and no longer as a specification of a conceptualization. From this point of view, an ontology specifies – explicitly and in formal language – the entirety of all linguistic means of expression which are generally available in the application context of the ontology for the representation of knowledge. This doesn't mean a renunciation of Gruber's understanding of ontology, but "just" a different accentuation in favour of the linguistic dimension of ontologies.
2. The entirety of the linguistic means of expression of an ontology defines "per constructionem" the entirety of all representational models which could be constructed with the help of the linguistic means of expression that are specified in an ontology.
3. The use of formal language is a constitutive attribute of ontologies. This does not correspond to all other conceptions which are to be found in the corresponding specialist literature. Instead of that several authors also accept natural language ontologies (for example Poli, 2002, p. 642).
4. Regarding the conceptualization of a real world situation, phenomena are spoken of which are distinguished as observable or imaginable. The first consideration is that real world situations could extend to observations of reality (cognitions) as well as to contents of thoughts about reality (imaginations). Second, the formulation "observable or imaginable" expresses that it depends on the epistemological pre-decisions of the common users of an ontology which real phenomena they consider as observable and imaginable for a real world situation. Depending on these pre-decisions, different conceptualizations of each real world situation could result. This underlines the epistemological component of ontologies.
5. Furthermore, regarding the conceptualization of real world situations, a restriction on these phenomena which are used and are necessary for the communications between agents occurs. So it is ensured that for the

coordination of agents which work together on the work-sharing fulfillment of a common task, the entirety of all possible real world experiences is not relevant. In fact, only those parts of their real world experiences which the agents have in common in order to communicate with one another – with regard to the intended task-fulfillment – are of interest. All other possible experiences which are irrelevant for the communication between agents represent private experiences of the agents. These "private" real world experiences could be relevant for the actions of the agents concerned, but do not play an important role for the coordination of agent activities for the completion of work-sharing tasks. So ontologies, which are used mutually for work-sharing tasks, just have to extend only to these aspects of possible real world experiences of the agents which are of interest for the communication between agents regarding the coordination of their activities.

6. Finally, the formulation "used or needed" means that these phenomena from the conceptualized real world situation which are of interest for the communication between agents regarding the coordination of their activities, could be understood from two different points of view. On the one hand, only such phenomena which are used by the agents in their communication for working together on work-sharing tasks could be considered. On the other hand, phenomena could be included which are factually not used by the agents for their communication, but which should counterfactually communicated by the agents in their work-sharing task-fulfillment in order to achieve the planned task because they are needed for the coordination of the task fulfilling activities of the agents.

Characteristic Components of an Ontology

The extended and specified definition of ontologies explained beforehand does not even nearly exhaust the wealth of ontologies in terms of their content. Despite the various aspects which have already been described, it is not enough to reduce ontologies to mere collections of concepts or definitions. Rather, ontologies contain in general at least three other characteristic components:

- attributes, describing the properties of those entities belonging to a concept.
- relations, specified by relationships between concepts, and
- constraints, which restrict the use of concepts in representations of real world situations to the semantically correct use of concepts.

Regarding the concept attributes, one should distinguish between constitutive (essential, substantial) and accidental attributes. A concept is defined by its very nature as the entirety of its properties. Each defined concept property is the expression of a constitutive concept attribute. The constitutive concept attributes are in an ontology generally not considered as stand-alone concepts, but – if at all – are added in a natural or formal language definition text to the name of the concept. In contrast to this, the accidental concept attributes are in an ontology generally considered as independent concepts. This happens with a large number of concepts which are connected with each considered concept via binary relations.

For example the concept "enterprise" could be defined as an economic institution which provides services for a third party's needs. The definition "an economic institution which provides services for a third party's needs" is added in an ontology as a natural language definition text to the concept name "enterprise". The formulations "economic institution" and "provides services for a third party's needs" deal with two concept properties which have the quality of expressions of constituent concept attributes. Accidental attributes of the concept "enterprise" apply in contrast, for example, to the size and the legal form of an enterprise. They are assigned to the concept "enterprise" via binary relations, for example as concept "enterprise size" with the help of the relation "has enterprise size" or as the concept "legal form" with the help of the relation "has legal form". The instances of the concept "enterprise" differ in several combinations of expressions from the accidental concept attributes, like "small" vs. "big enterprise" or "private limited company" vs. "stock company", respectively.

The relations which specify the relationships between concepts of an ontology could be distinguished into terms of taxonomical on the one hand and non-taxonomical relations on the other hand.

Taxonomical relations serve to form from the unstructured amount of all concepts of an ontology a system of concepts as a so called "core" of an ontology. The concepts are systemized with the help of a taxonomic relation generically, i.e. independent of specific real world situations. The most common is the so called "is a"-relation, which is a sub-concept relation. With the help of this, super- and sub-ordinate relationships between the concepts of an ontology are introduced: If two concepts k1 and k2 achieve the "is a"-relation, i.e. if the relation „k1 is a k2" is correct, then the concept k1 is a sub-concept of the concept k2; vice-versa, the concept k2 is a super-concept of the concept k1. Taxonomical relationships, which are the elements of a taxonomical relation, always extend themselves between concepts – and not between their instances. Thus taxonomical relations have the quality of meta-linguistic relations.

In contrast to this, non-taxonomical relations have a domain-specific character. They refer content-wise to each conceptualized real world situation, the so called "domain" of an ontology. For example the non-taxonomical relation "has competence in" can sensibly be used between the concepts "agent" (natural or artificial) and "kind of competence" in an ontology for the conceptualization of the real world situation of "business economics competence management", while it makes no sense to use it for another real world situation, like the accounting policy. Non-taxonomical relationships, which are elements of a non-taxonomical relation, always extend between instances of a concept-specific set of instances. Thus non-taxonomical relations have the quality of object-linguistic relations.

Often the construction of an ontology ends with the formal language specification of their concept set, their taxonomical relation(s) and their non-taxonomical relations. This would disregard the "semantic dimension" of ontologies. This represents, from the point of view of the authors, one of the most interesting – but also most complicated – aspects of the research of ontologies in the field of knowledge level engineering. The semantics of an ontology comprise all constructs which should restrict the use of the concepts of an ontology in representational models of a real world situation to the semantically correct use of concepts. Therefore these constructs were mentioned above as "constraints".

The semantic constructs are one of the most "exciting" fields of modern ontology research. The main challenge is to prepare the meaning of concepts in such a way that they can be considered correctly and completely by computer-based knowledge management systems. Therefore it is necessary to specify the main semantic constructs of an ontology in formal language. That is why ontologies use in essence formal language.

The semantic constructs are first and foremost inference and integrity rules. Also axioms are referred to (Noy & Hafner, 1998, p. 618; Tham et al., 1994, pp. 4), whose completion should ensure correct use of concepts. The inference and integrity rules build the "semantic heart" of an ontology.

Inference rules determine how implicitly enclosed knowledge can be made available from knowledge that exists explicitly in the knowledge base of a knowledge-based system. Such rules of inference have generally been known for many years. In the field of formal logic, like the predicate logic, they are researched intensively as one of the most important components of "formal semantics". To this belong established rules of inference, like the "modus ponens" or the "modus tollens", but also lesser-known rules of inference, like the combination of resolution and unification rules. Especially the latter combination of rules has been proved as very effective for fitting automatic information processing systems – so called theorem provers – with logical conclusion abilities.

The aforementioned examples do not belong to the rules of inference from the semantic dimension of ontologies. Instead of this, rules of inference of formal logic are assumed as "meta-linguistic" rules of inference in knowledge-based systems as known and are often implemented in a separate system component – the "inference machine". So the rules of inference of formal logic will not be discussed in this chapter. The rules of inference from the semantic dimension of ontologies have an object-linguistic character. Object-linguistic rules of inference are similar to the meta-linguistic rules of inference of formal logic regarding the ability to explicate implicit knowledge. In contrast to formal-logical rules of inference they refer not only to the external form – for example the predicate-logical form – of the explicit knowledge, but they also evaluate knowledge about the content – the intensional meaning – of these concepts and relations, which are referred to explicitly in the formulation of the rule. So the object-linguistic rules of inference from ontologies are also called rules of content-sensitive derivation of knowledge.

Rules of integrity build the second group of semantic constructs beside the rules of inference which definitively shape the semantic dimension of ontologies. Rules of integrity specify which connections of concepts – beyond their syntactically correct connection – are semantically allowed. This could be demonstrated in natural language, when instead of abstract concepts natural language definitions are used: For example the sentence "at night it is cheaper than in America" is syntactically correct, but not semantically, because it makes no sense. Rules of integrity are a universal tool with whose help the semantically correct use of concepts, their attributes and the relations between concepts in an ontology can be exacted. It restricts the use of the above mentioned constructs to the semantically correct usage of these constructs.

MANAGEMENT OF COMPETENCES

TASKS AND CHALLENGES

Competence management is concerned with the special form of knowledge that plays an important role in business economics practices. It pertains to competences in the sense of action-enabling knowledge.

The task of competence management is firstly to identify relevant competences that are necessary for the implementation of knowledge-intensive business processes. The competences of agents within a company are also of interest. Under some circumstances the competences of agents belonging to suppliers or cooperation partners must be considered, e.g. with regard to supply chains or virtual corporations. Secondly, agents should be assigned to business processes for which they are best suited (competence matching). Having assigned agents, if competence gaps are still at hand measures must be taken to close them. In the short term, these gaps can be filled by third parties, whereas in the long term, in-company competences can be developed, assisted by appropriate measures of human resources development.

While the competence-matching tasks can be undertaken relatively successfully using business economics instruments, the identification of necessary process-side and agent-side competences has been difficult for years. The main reason is that the definition of knowledge is very vague

Sample 1.

```
   person_X, process_Y, subject_Z:
   process_Y:training [has_universe of discourse ->> subject_Z;
                       has_training_level -> professional;
                       has_member ->> person_X]
→  person_X:staff     [has_competence_in ->> subject_Z].
   project_A, project_B, person_C, subject_D:
   (project_A:project [needs_competence_in ->> subject_D;
                       was_evaluated -> successful]  AND
   project_B:project  [needs_competence_in ->> subject_D;
                       was_evaluated -> succsessful]  AND
   (NOT equal(project_A,project_B))  AND
   person_C:staff     [has_contributed_in ->> project_A]  AND
   person_C:staff     [has_contributed_in ->> project_B])
→  person_C:staff     [has_competence_in ->> subject_D].
```

and used with various semantic nuances. Also, no clear and uniform system of different types of competences exists. The existing multiplicity of so-called competence catalogues (e.g. Canada Revenue Agency, 2008; Paquette, 2010, pp. 96, and pp. 125) and the latest attempts at national and European level to establish a consistent framework of qualifications for both academic and vocational education and advanced training based on "standardized" competence profiles like the European Qualifications Framework (European Commission, 2008; Young, 2008) is more an expression of "Babylonian confusion of ideas" as an operable concept for the identification of competences.

Ontologies as Enabler for a Precise Understanding of Competences

Due to the aforementioned defect of operable definitions, ontologies of competences represent a highly interesting approach to support the mainly computer-based management of competences regarding the identification of existing and necessary competences for knowledge-intensive business processes. The first such ontologies of competences are still being built (Liao et al., 1999; Jie et al., 2000; Harzallah et al., 2002; Lau & Sure, 2002; Sure et al., 2004; Dittmann & Zelewski, 2004; Paquette, 2010, pp. 215). Most of these ontologies of competences are limited to specify the definitions of competences and to systemize their definitional interdependencies. They only exhaust the terminological and taxonomical instruments of ontologies. In this chapter it should be shown how the special instrument of rules of inference could additionally be used to enrich the semantics of ontologies of competences.

Two examples show in the demonstration (Sample 1) how object-linguistic rules of inference could be specified for the content-sensitive derivation of knowledge in the domain of the business economics management of competences. They are composed in a notation which is similar to the predicate-logical knowledge representation and is typical for ontologies ("->" represents a monovalent, "->>" represents a set-valued non-taxonomical relation).

The two rules of inference enable to derive knowledge of competences of staff of an enterprise, which is not explicitly saved in this way in the knowledge base of a knowledge-based system, but is included implicitly in some knowledge components.

The first rule of inference ( ) expresses the plausibility assumption that an employee who has participated in a training course on a special area has a competence in this area, in so far as the requirements of such training have reached a professional level. The second rule of inference ( ) expresses the plausibility assumption that an employee has a specific competence, when he has worked on at least two different projects, for which this competence was needed for the successful completion of the projects and that the projects have already been evaluated successfully.

Both aforementioned – extremely simplified – examples clarify not only the character of object-linguistic rules of inference, but also the two characteristic attributes of ontology-based management of knowledge of competences.

At first it must be remembered that also in ontologies, knowledge about competences is represented in formal language. Otherwise, no computer-based processing of this knowledge would be possible, like for example automatic conclusions, which means the computer-based derivation of implicit knowledge. But "formal language" does not mean "quantitative" or "numerical". Instead of this, it allows predicate-logical expressions of ontologies, for example, to work with constructs which appear to be natural language. For example variables like "person_X", "project_A" and "subject_Z", concepts like "staff" or "training" as well as relations like "has_competence_in" and "was_evaluated" are understood directly by the human users of a computer-based competence management system. This contributes to the acceptance of computer-based competence management systems in everyday business life. But from the point of view of a computer constructs like "person_X" are just "strings", which means this is just a "meaningless", purely syntactically defined string. A normal computer could not deal correctly with the competence-related information contained in the two aforementioned rules of inference. It does not possess the content understanding of the natural language meanings of the constructs, which for a human reader of the constructs are "self-evident".

At this point the semantic dimension of ontologies comes into play: Because of the interaction of the semantic constructs of an ontology, it should be guaranteed that a computer, which could only work internally with operations defined in formal language, can also work with the natural language constructs regarding their natural language meanings. This correct use of knowledge represented in formal language will be achieved in that, with the help of semantic constructs like rules of inference and integrity, the use of the formal language constructs ("strings") are limited to such possibilities of use which seem meaningful for the human viewer from the perspective of a natural language construct. So the major challenge for the design of ontologies consists of the task of completing their concepts and relations with additional rules of inference and integrity – or other semantic constructs – in such a way that the use of concepts is restricted to the semantically correct use of concepts.

The semantic dimension of ontologies is the main force which allows for computer-internal operations with knowledge representations in formal language on the one hand, and, on the other hand, also comprises knowledge about the meanings of concepts (and relations) into the computer-based knowledge processing. This means the boundaries of conventional, purely syntactically based information processing are pushed in the direction of "life-world problem solving competences". In this expansion of the computer-based knowledge processing capability to a content understanding of the knowledge represented in formal language, knowledge level engineering of artificial intelligence research has led to the enrichment of business economics knowledge management.

Furthermore, ontologies give the possibility of clearing the naive idea that computer-based knowledge management systems just work with "quantitative" or "numerical" knowledge. Instead of this, the two aforementioned examples of object-linguistic rules of inference illustrated that ontologies do not have problems working with constructs which are formulated in natural language. In this way it is possible to make computationally accessible the multifaceted qualitative knowledge of an enterprise, which plays an important role in the field of knowledge management from the business economics point of view. So the general prejudice is broken that computer-based knowledge management systems are limited to "just formal" representations of real world situations. The semantic dimension of ontologies also enables specification of conceptualizations of possible real world experiences which are – fully or partly – composed in natural language. At this point, purely formal language terms of ordinary computer programs come up against a vocabulary which consists of natural language definitions. The correct use of these natural language definitions is defined within an ontology with the help of additional semantic constructs.

Practical Problems with the use of Ontologies of Competences

A first problem of ontologies of competences extends to the epistemological quality of competence-related rules of inference. They are distinguished clearly from the rules of inference of formal logic. The rules of inference of formal logic are characterized by their property of truth preservation. The rules of inference of an ontology do not, in general, have this desirable epistemological property of truth preservation. The conclusions which could be made with the help of rules of inference of an ontology generally provide no secure knowledge. So it is the character of these rules of inference that they just allow for plausible, intuitive or pragmatically proved conclusions, but do not have the stringency of truth preservation of formal logic.

For example, the first rule of inference ( ) represents the assumption of plausibility, that an employee who participates in any training on a special field has the competences in this field if the level of the training was professional. There are several reasons why this "plausible" conclusion could lead to errors. So it could be possible that an employee has participated in such training but did not learn anything there. The employee might have failed an exam designed to test his learned professional competence. Maybe the employee has gained a participation certificate (in the field of commercial advanced training this should be expected), but he has not increased his level of knowledge, because he was hindered by "social interaction" with other participants from gaining such functional competences. The reasons for the failure of the aforementioned plausibility conclusions could be many and varied.

Also the assumption of the second rule of inference ( ), that an employee has a specific competence, if he has worked on at least two different projects in which this competence was necessary for a successful project execution and which were evaluated successfully, could be brought into doubt with many counter-examples. So the necessary competence can be brought in by other team members rather than by the employee under consideration. Also there can be doubt as to why working on at least two different projects should be pivotal for gaining a competence by "learning by doing". A causal stringency between gaining a competence and the numbers of projects on which someone has worked cannot be derived from any kind of competence or behavioural theory. Also in this second case it would not be difficult to find further reasons for the failure of the aforementioned plausibility conclusions.

From the aforementioned arguments, an insuperable epistemological "trade-off" between the security of knowledge on the one hand and the depth of conclusions on the other hand arises: Either one asks for the strict truth preservation which is guaranteed from the rules of inference of formal logic. Then safe knowledge from the use of these rules of inference can be generated. But the epistemological price which has to be paid means that a plenty of plausible, only in some cases false conclusions must be dispensed with which could have been drawn from existing knowledge (for example about competences, projects or trainings). Or one should demand as large a pool of potential conclusions as possible which could be extracted from an existing knowledge base. In this case the rules of inference of formal logic as well as the content-sensitive rules of inference of an ontology are used. But also in this case an epistemological price has to be paid, because the use of rules of inference of an ontology goes hand in hand with the forgoing of truth preservation, so uncertain knowledge will be produced. No escape exists from the aforementioned trade-off, at least not until today.

With decisions regarding the design of economic knowledge management systems, a position has to be taken on the aforementioned trade-off. Which position is advisable could not generally be determined from the business economics point of view. But the authors have the opinion that it is desirable for the practical use of ontologies with their rules of inference to allow such conclusions to be applied with "middle" stringency, which are typical for the "lifeworld" experience context of business economics practice. In business economics practice truth preserving conclusions are not always important. Rather, "risky" conclusions are of greater practical relevance. They cannot produce certain knowledge, but have the power of plausible conclusions. So ontologies with their rules of inference have more importance for the practice of knowledge management than most outsiders acknowledge who have been discouraged from the purely formal language appliance of ontology research.

A second problem of ontologies of competences is concerned with the limitation of at most binary formulas, which can be understood both as relations and as equivalent predicates. This binary limitation holds for all internationally standardized ontology languages, as for example RDF/RDFS (Staab et al., 2000), OWL (Antoniou & van Harmelen, 2004) and F-Logic (Kifer et al., 1995; Angele & Lausen, 2004), as well as for software tools designed for the construction and maintenance of ontologies, like for example Protégé (Noy et al., 2000) and OntoEdit/OntoBroker/OntoSuite (Decker et al., 1999; Sure et al., 2002). This binary limitation of formulas infringes upon the business economics requirement to express knowledge about competences in natural ways with the help of at least three- or four- or even five-part formulas.

A central role for ontologies of competences is played by the meta-knowledge that an agent has a competence (as action-enabling object-knowledge) of a specific kind with a specific value or that a competence of a specific kind with a specific value is needed for a knowledge-intensive business process. This meta-knowledge needs the following three-part formulas ("competence relations"):

- has_competence(person_A, type_of_competence_Y, value_of_competence_Z)
- needs_competence(process_B, type_of_competence_Y, value_of_competence_Z)

As simple as these three-part formulas seem to be, it is still difficult to implement them computationally with the help of current ontology languages and software tools. Because of the limitation to at most two-part (i.e. binary) formulas, special tricks are needed which can only be mentioned here in passing. For a more detailed definition and discussion of these tricks see Zelewski & Alan (2005, pp. 493).

The main idea of solving this problem of expressing "intrinsically" three-part competence relations with the help of binary formulas in an ontology consists of an artificial reification. This consists in general of transforming the class of all elements which have a three-part competence relation into a similarly large number of instances of a newly-built, artificial class of competence statements. With the help of these competence statements, several binary auxiliary-relations should be coupled in such a way that the original content of an element of a three-part competence relation is reproduced in a way, which conserves its meaning, but in a more elaborate way.

For clarification, the following example is illustrated. It concerns the meta-knowledge that a person “Alex_Klippert” has with regard to the competence kind “Java_Programming” the competence value “expert”. In this natural way the meta-knowledge is represented as an element of the aforementioned three-part competence relation “has_competence” as follows:

- has_competence(Alex_Klippert, Java_Programming, expert)

Because formulas for such three-part competence relations in existing languages of ontologies and software tools are not provided, the following artificial auxiliary construction must be used:

- on the level of concepts for the class „statement of competence“:
  statement_of_competence [contains_kind_of_competence => kind_of_competence;
  concerns_agent => agent;
  contains_value_of_competence => value_of_competence]
- on the level of instances, i.e. for concrete statements of competence (soc):
  soc_4711:statement_of_competence [contains_kind_of_competence -> Java_Programming;
  concerns_agent -> Alex_Klippert;
  contains_value_of_competence -> expert]

In this way it is possible with the help of some instances from the class “statement of competence” to represent the meta-linguistic knowledge as to which agents have which kind of competence and which value of competence. So the problem will be solved in a formal language way to represent competence-related knowledge in an ontology of competences. But from the business economics point of view it is still unsatisfactory to express a simple fact – the meta-knowledge of a person’s competence – in such a complex and indirect way as illustrated above.

This problem is heightened because of the fact that with the three-part competence relation “has_competence” until now a very simple variant of competence-related knowledge has been regarded. But the business economics competence management is aware of at least two other determinants of the pragmatically rich in content representation of knowledge about competences.

First, it must be considered that competences do not have a static character, but could change over time „dynamically“. On the one hand, competences will be “unlearned” if they are not used and renewed in practice. On the other hand, competences could be strengthened with use in different practical cases and in combination with other knowledge areas. Because of these two reasons, statements about competences of agents are not timeless, but must be limited to a plausible timeframe. The concrete specification of this timeframe is very difficult. There have simply not been enough studies regarding the invalidation of competences because of a long-term non-use of these competences.

Second, rules of inference with regard to competences, like the above mentioned examples and showed, can demand plausibility for themselves. So it should be possible for an ontology-based competence management system to give a degree of plausibility for the knowledge about competences which was derived with the help of rules of inference. It measures the “stringency” of these rules of inference which are used for the explication of implicit knowledge about competences of agents.

When both aforementioned determinants of a pragmatic representation of knowledge about competences are considered, one must cross over on the concept level to five-part competence relations. Because this is just possible for at most binary formulas in ontologies, it is necessary to use artificial auxiliary constructions with in total five binary auxiliary relations:

- statement_of_competence [contains_kind_of_competence => kind_of_competence; concerns_agent => agent; contains_value_of_competence => value_of_competence; true_for_the_period => time_interval; has_the_degree_of_plausibility => real_value]

Rules of integrity could be added to limit elements of the class of competence statements to such elements which are plausible or definitionally necessary. Also part of this is the rule of integrity that a concrete competence statement is just valid for a special period which ends in a maximum of ten years after the last event of the acquisition of competence or the training of competence regarding the concrete kind of competence. This rule of integrity is based on an assumption of plausibility that a competence "fades" if more than ten years have gone by after the competence was acquired or was refreshed with the help of training. Another rule of integrity can, for example, ensure that the degree of plausibility of a concrete statement of competence has just real-valued numbers from the definitional interval [0;1].

MANAGEMENT OF PROJECTS

Reuse of Project Knowledge as a Challenge

Project management is a special form of knowledge management. In most cases it is dealing with the "intelligent" reuse of know-how from finished projects and their adaptation to a similar, new project. The know-how mostly exists in the form of documents which represent the knowledge of old projects in most instances in natural language and only partly numerically. Because such documents with know-how about old projects in companies exist in large numbers, it is obvious to deal with this project knowledge with the help of ICT systems and to disseminate this knowledge between the partners which want to carry out a new project together.

Despite the promising preconditions to support the knowledge-intensive business processes of project management with instruments of e-business, the current project management systems are generally restricted to a trivial retrieval of similar documents. The search for a similar document just happens on a purely syntactic level with the help of simple search words in the form of character strings ("string matching"). A content-addressed search for reusable knowledge does not happen in this way. In the face of previously mentioned reasons for knowledge heterogeneity there is still a whole host of know-how that could be used in new projects but is currently unused. So it is a big challenge for project management to prepare computer-based knowledge of experience from already realized projects in a way that could be reused for new projects.

Case-Based Reasoning and Ontologies

One of the most interesting business economics approaches of reusing know-how from already realized projects for new projects is case-based reasoning (Riesbeck & Schank, 1989; Kolodner, 1993; Aamodt & Plaza, 1994; Watson, 1997; Xiong & Funk, 2006; Avramenko & Kraslawski, 2008). In this chapter it will be shown how project management can be supported by the knowledge management technique of case-based reasoning. The few attempts to use case-based reasoning for project management (Dogan et al., 2006; Chou, 2009; Li et al., 2009) failed up until now because of the extreme difficulties of identifying these old projects which were most similar to the new project. For such similar projects it can be expected that the know-how from these projects is easy to transfer to the new project. This approach could not be transformed so far because of the difficulty of the "measuring" of the similarity between knowledge collections (documents) mostly represented in natural language and because of the heterogeneous know-how from projects. This task could, if at all, just be fulfilled with the help of computers because of the huge quantity of know-how to be processed.

So ontologies offer a perspective to overcome the defects of operationalization regarding the concept of similarity between heterogeneous know-how from projects, because ontologies "measure" the semantic distance between natural language terms which are used for the representation of know-how from different projects. It is a special "craft" to compare qualitative, which means non-numerical attributes of projects and display them on a quantitative similarity scale. First approaches at solving this difficult problem already exist (Elleuch et al., 2008, pp. 27; Wu et al., 2010, pp. 293; Beißel, 2011, pp. 156). Thus the recent combination of case-based reasoning and ontologies has attracted interest (DeMiguel et al., 2008; Assali et al., 2009; Assali et al., 2010; Roth-Berghofer et al., 2010; Beißel, 2011).

A Realistic Example

The following will show a realistic example of how to use an ontology concerning knowledge about projects for the implementation of information and communication techniques to identify a most similar old project and to reuse the know-how of this old project for the management of a new project. The example, slightly modified, has been taken from a research project carried out by a doctoral candidate at the Institute for Production und Industrial Information Management in Essen (Beißel, 2011, pp. 170, especially pp. 188). In this research project, a software prototype for ontology-based case-based reasoning was developed, which allows the reuse of knowledge of complex implementation projects in the field of information and communication techniques. It is based on the standard software packages Protégé (for ontologies) and myCBR (for case-based reasoning) which were connected in an innovative way. Also considered was an innovative algorithm for calculating the similarity between qualitative attributes.

This example considers the new project to make for a customer a patch management with Windows Server Update Services (WSUS) to close security gaps of a computer system with the system software Windows XP by implementing small software packages ("patches") and to eliminate other small defects. This new project represents the new case "WSUS". The case data base comprises of much information about the ten already realized implementation projects as old cases. It deals with cases of real world business practices. With the help of the software prototype for ontology-based case-based reasoning, an old case was identified in the case data base which was very similar to the new case. For this old case "online-banking" a web application had to be implemented on a server which was run in a customer enterprise under the system software Suse Linux. In Table 1, the main project attributes of both cases are presented.

The whole comparison of both cases cannot be considered here for the sake of brevity (see for details Beißel, 2011, pp. 192). Instead of this, it will merely be taken as an example of how the partial similarity of two projects regarding the project attributes with qualitative values can be determined with the help of a domain specific ontology. It deals with the project attribute "application software" which determines that in the new case the application software Windows Server Update Services (WSUS) has to be in-

Table 1. Project attributes of the new und the very similar old case

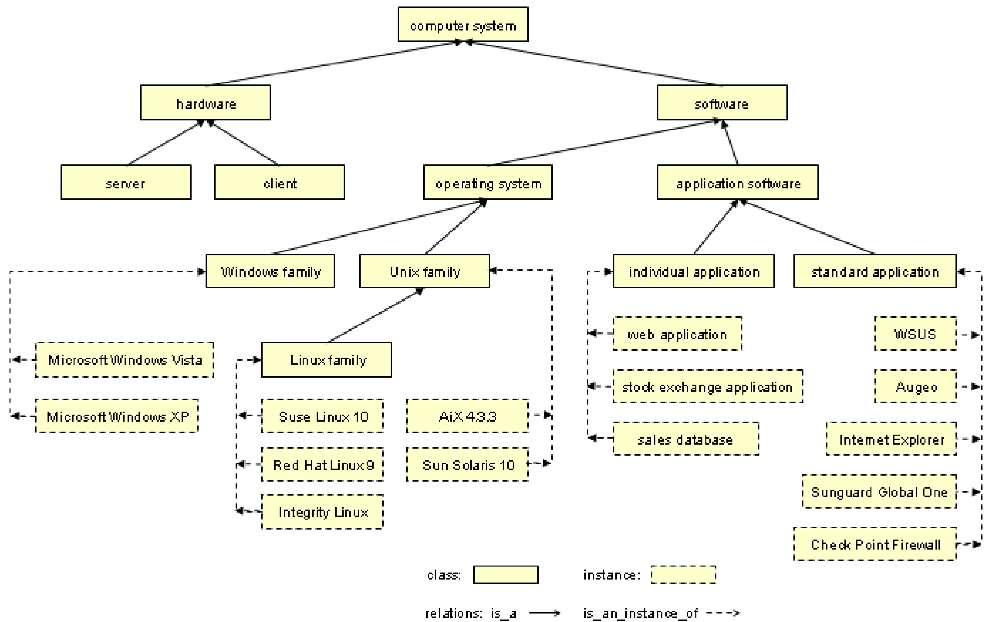
classes / subclasses	attributes und relations as slots of the (sub-) classes	data of the new case "WISU"	data of the old case "online-banking"
project	project_type	installation	installation
	US-$	420,000	290,000
	personel_days	300	250
	considers_hardware	unknown	Server 8
	considers_operating_system	Microsoft Windows XP	Suse Linux 10
	considers_application_software	**WSUS**	**web application**
hardware / server	model	unknown	Dell Power Edge
	type	unknown	Rack
operating system	name_of_operating_system	Microsoft Windows XP	Suse Linux 10
	family_of_operating_system	Windows	Unix
application software / standard application	application_name	Windows Server Update Services	
	field_of_application	network	
	number_of_similar_implementations	9	
Application Software / individual application	application_name		web application 4711
	field_of_application		internet
	customer_department		trade
	customer_name		anonymous

stalled, but in the old case a web application had to be installed for application software.

In both instances "WSUS" and "web application", it will be first determined that they belong to two different classes "standard application" and "individual application" in the underlying ontology. But these two classes at least agree regarding both attributes "application name" and "field of application". Both instances can be compared, to begin with, regarding these common attributes. With the help of further discussions, which cannot be expanded upon here, both instances get a very low similarity of 0.1 concerning the values "WSUS" and "web application" of the attribute "application name". In contrast to this, the similarity between the values "internet" and "network" of the attribute "field of application" has a bigger value of 0.6. Because both attributes "application name" and "field of application" are judged to be of similar importance regarding their relevance for the actual purpose (e.g. estimation of project costs), the average weighted similarity of both instances regarding the project attribute "application software" and regarding the common attributes gets the value 0.35.

This value of similarity is just temporary, because, for the determination of similarity, the knowledge was not yet considered that both instances "WSUS" and "web application" do not belong to the same class. But only instances of the same class can be directly compared because of their homogeneity. For instances which belong to different classes, an ontology-based correction of values of similarity must be executed. This correction measures the extent of similarity between classes that belong to different "semantic positions" in the underlying ontology. This ontology-based correction of values of similarity represents a very difficult task on the one hand. On the other hand, there is a special appeal and

Figure 1. Extract from an ontology for implementation projects in the field of ICT



"added value" to the combination of case-based reasoning and ontologies.

Figure 1 represents a short extract from the domain specific ontology which was developed in the aforementioned research project to determine the similarity of complex implementation projects in the field of information and communication techniques (ICT).

The similarity between two classes which are found in the underlying ontology in different "semantic positions" is determined by the ratio of two numbers of attributes. The first number of attributes is the number of all attributes which the two classes have in common. In the example considered here, for the classes "standard application" and "individual application" the two attributes are "application name" and "field of application". Because each of them belongs to the two classes "standard application" and "individual application", the number of common attributes of both classes is 2 • 2 = 4. The second number of attributes is the number of all attributes of which the two classes have available altogether. These are, according to the aforementioned Table 1, seven attributes altogether.

Furthermore it will be considered for the ontology-based correction of the values of similarity how far two instances, which belong to different classes, are at most away from the first super-class to which both the different classes belong in the hierarchy of classes of the underlying ontology. This is, according to the aforementioned Figure 1, the class "application software". From this the two instances "WSUS" and "web application" are two steps away in the ontology, so the maximal distance of these instances from the super-class is 2. But it must be considered that the similarity between instances from different classes is smaller the greater the distance of instances in the based ontology is. So the measure of similarity in an ontology is the reciprocal value of the maximal number of steps between an instance and the first common super-class. This results in the additional value of correction of ½ = 0.5.

On the whole there is the following result: The partial similarity of projects between the new and the old case regarding the relational project attribute “application software” consists of two components. It concerns, on the one hand, the weighted average similarity of both instances “WSUS” and “web application” regarding their two common attributes with the value 0.35. On the other hand, the ontology-based correction of this value of similarity has to be regarded. The correction factor concerns the similarity between the two classes, to which both instances belong and which belong in the underlying ontology to different “semantic positions”. The correction factor is here (4/7) • 0,5 ≈ 1,143. So for the partial project similarity between the new and the old case regarding the relational project attribute “application software” the value is 0,35 • 0,143 ≈ 0,050.

In the same way, the partial project similarities regarding all other project attributes have to be calculated. The complex ontology-based correction of the value of similarity can be dispensed with, if two instances, which specify both projects of the new and the old case regarding a relevant project attribute, belong to the same class in the underlying ontology, and thus to the same “semantic position”. The sum of the values of similarity of all partial project similarities results in the value of similarity for both cases of the implementation of information and communication techniques.

In the aforementioned way, it is possible to determine the similarity of projects which are characterized by some non-numerical, i.e. qualitative and generally natural language project attributes. So an essentially larger amount of experience-based knowledge about already realized projects can be used for the management of new projects, as was normal on the basis of purely quantitative measures of similarity in case-based reasoning without recourse to ontologies. Therefore, e.g. the estimation of project costs for the preparation of participation in project advertisements can be executed with the help of computers in e-business from a larger knowledge base and it can be more reliable than it was with quantitative, especially statistical forecast techniques.

FUTURE RESEARCH DIRECTIONS

Further works of research are necessary in some fields to support more effectively the work-sharing execution of knowledge-intensive business processes in e-business than has up until now been the case. For the computer-based execution of such business processes, from the business economics point of view, the following desiderata should be fulfilled.

Software tools for ontologies are mostly limited to edit ontologies terminologically and taxonomically. Much work is done on the graphic visualization of the taxonomical connection of all classes and instances. The possibilities of specifying rules of inference and integrity for ontologies have not yet been fully developed, if attempted at all. The only substantial exception are software tools for ontologies which are based on the very expressive, both predicate-logical and object-oriented formal language F-logic. Because F-logic does not correspond to the “mainstream” of standardization efforts in the semantic web in favour of RDF/RDFS and OWL, it has to be feared that the cognitive potential of rules of inference and integrity will not be fully utilized through ontologies in e-business in the near future. To avoid this, more value must be placed on the capability of semantic web standards such as RDF/RDFS and OWL to implement rules of inference and integrity without any limits on their predicate-logical power of expression.

Ontologies are a very good instrument to structure and explicate formal language domain knowledge of knowledge-intensive business processes in e-business. But at this time ontologies have been developed by computer scientists and information scientists, who have little understanding of the subtle differences of business economics definitions. As a result, established ontologies suffer from manifold content-wise deficiencies. Consequently, from the business economics perspective, there is a growing need for ontologies which represent the domain knowledge of knowledge-intensive business processes in a business-friendly manner.

The combination of case-based reasoning with ontologies seems to be promising for the management of complex projects in e-business. But current software tools for the implementation of case-based reasoning and ontologies, like for example myCBR and Protégé, do not have the desired functions to integrate these two instruments successfully. For example, it is possible to integrate into the software tool Protégé values of similarity in the nodes of a taxonomic hierarchy of classes and to continue processing the similarity knowledge with the help of the software tool myCBR. But these node-specific values of similarity are just scalar values. This is just enough to capture the similarity between two directly following nodes of classes or instances. For more than two directly following nodes of classes or instances as well as indirect following nodes of classes or instances, complex, matrix-like information structures are needed, which could not be considered in the nodes of software tools like Protégé as values of similarity. So software tools for the implementation of case-based reasoning and ontologies have to be developed further regarding their functionality for the consideration of this type of complex information structures.

CONCLUSION

In the future e-business will play a more important role regarding the computer-based execution of knowledge-intensive business processes as is currently the case. This expectation is based on the growth of the work-sharing cooperation of some agents both from different areas of expertise as well as from different companies. This trend proves the importance of "secondary" forms of project organization within a company that has been growing for many years, on the one hand. On the other hand, cooperation between companies has been playing an ever more important role in the economy for years, e.g. developments like supply chain management and virtual corporations. Regarding the importance of the semantic web and of social networks not just for private but also for commercial interactions, the ability of companies to support knowledge-intensive business processes with the help of modern information and communication techniques also increases in importance. Ontologies allocate, therefore, a central infrastructure in business economics knowledge management, because with their help it is possible to prepare business process relevant knowledge in a computer-based way. Ontologies are one of the most successful approaches to guarantee the interoperability between information and communication systems at a high knowledge intensity of the considered business processes as well at high knowledge heterogeneity. So ontologies and their computer-based implementations have a high "strategic" value regarding the conceptualization and execution of knowledge-intensive business processes in e-business.

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KEY TERMS AND DEFINITIONS

Agent: In the context of e-business an agent is either a human being or an information and communication technical system (ICT systems).

Case-Based Reasoning: Case-based reasoning is dealing with the "intelligent" reuse of knowledge from already solved old problems ("cases") and its adaptation to similar, but new und yet unsolved problems.

Competence: Competence is a special form of knowledge in the sense of action-enabling knowledge.

Conceptualization: A conceptualization is an abstract and simplified point of view of phenomena of a real world situation, which is interesting for subjects in the attainment of their aims.

Inference Rule: A rule of inference determines how implicitly enclosed knowledge can be made available from knowledge that exists explicitly in the knowledge base of a knowledge-based system.

Integrity Rule: A rule of integrity specifies which connections of rule-specific concepts – beyond their syntactically correct connection – are semantically allowed.

Ontology: An ontology is an explicit and formal language specification of those linguistic means of expression which are considered necessary for the construction of representational models of a common conceptualization of real phenomena used by several agents. Thereby the conceptualization extends to these real phenomena which are regarded by the agents as observable or imaginable in the subject- and goal-dependent restricted real world situation and which are used or needed for the communication between the agents.