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Integration of Case-Based and Ontology-Based Reasoning for the Intelligent Reuse of Project-Related Knowledge

Martin Kowalski[1], Hubert Klüpfel[2], Stephan Zelewski[1], Daniel Bergenrodt[1], and Alexandra Saur[1]

[1] University of Duisburg-Essen, Institute for Production and Industrial Information Management, Universitätsstr. 9, 45141 Essen, Germany
{martin.kowalski,stephan.zelewski,alexandra.saur}@pim.uni-due.de, daniel.bergenrodt@stud.uni-due.de
[2] TraffGo HT GmbH, Bismarckstraße 142, 47057 Duisburg, Germany
kluepfel@traffgo.de

Abstract. The knowledge management techniques case-based and ontology-based reasoning are applied to the domain of complex, especially international logistics or supply chain management projects. The aim is to support the "intelligent", i.e. content-addressed ("semantic") reuse of knowledge about such projects. We present as an example a recommender system for the acquisition and reuse of knowledge about international transport projects based on relevant ontologies integrated in the well-known CBR cycle. The recommender system is implemented using the open source CBR development framework jColibri.

Keywords: Case-based reasoning, knowledge management, knowledge reuse, logistics / supply chain management / transport projects, ontologies.

1 Knowledge Management for Logistics Projects

The management of projects is a well known part of management science. But until now, purely quantitative and "hard" project management techniques like the critical path method (CPM) and the project evaluation and review technique (PERT) have been dominant. This main stream approach can be characterized as:

- numerically data driven,
- primarily operative,
- focused on limited quantitative and isolated objectives, and
- developed only for "hard" performance indicators.

With this main stream approach, only simply structured logistics projects can normally be managed. Complex, especially international logistics projects are often characterised by the following aspects: they cannot be described by simple, primarily numerical data, because numerous non-numerical, i.e. qualitative influence factors, must be considered. Due to the often serious and long-term consequences for the affected logistics service providers, both an operative and a strategic approach is

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necessary. The complexity of a project also manifests itself in that multiple, often conflicting and, first and foremost, qualitative objectives must be taken into account. Due to the qualitative objectives, "soft" performance indicators also need to be considered when evaluating the success of a project.

The following list makes clear the diversity of influence factors and objectives which can play a role in complex international logistics projects and which can often only be represented in non-numerical i.e. qualitative ways.

- means of transport used (e.g. lorries, goods trains, freighters) and traffic carriers (e.g. roads, railway tracks, shipping routes) including their combinations;
- transport links and networks used;
- project-relevant, specialized geographic knowledge of transports links, networks, and junctions;
- regional, national and international transport regulations and usances, which are important for the project;
- indication as to whether the logistics project in question is a one-off or to be repeated: e.g. one-off transport of a large-scale plant or repeated transport of building materials or consumer goods;
- export control regulations and compliance specifications including the prohibitions and limits resulting from them;
- HS-Codes (EU tariffs, foreign tariffs) for customs duties;
- customs formalities and customs preference rules;
- credit rules and document check routines;
- detailed description of the goods to be transported: type of good (e.g. according to the customs catalogue), quantity of the good, size of the good (measurements, weight or volume), packaging of good, possible deployment of a container;
- specifically for goods packaging the following aspects should be considered: packaging material (e.g. wooden boxes, cartons, pallets), packaging aids (e.g. crumpled paper, Styrofoam, nails), package (unit of transport whose packaging material surrounds the product and diverse packaging aids), packing (work involved to pack completely an unpackaged good);
- skills or competences (in the sense of employee qualifications) which were especially important for the execution of the project;
- security precautions to be taken in terms of goods, transport, population, government, environment and data;
- extra legal, ecological and social factors which affect the organization of the logistics project – e.g. configuration of the supply chain or the modes of transport to be used (e.g. climate policy, green logistics, carbon-footprint discussions, corporate ethics and corporate social responsibility);
- critical success criteria or "key performance indicators", which have been identified as especially important for the success or failure of a project;
- quantitative objectives, e.g. project execution duration, violation of due dates, project costs, project revenues, market share;
- qualitative objectives, e.g. customer satisfaction, strengthening the competitiveness, gaining hardly to imitate or to substitute project management competences, increasing the reputation of being cable to manage complex international logistics projects.

The management of such complex, especially international logistics projects, in which influence factors and objectives, like the examples mentioned above, play a key role, is normally referred to in "modern" business literature as supply chain management. Therefore, the terms "complex logistics projects" and "supply chain management projects" will be used interchangeably. Moreover, one must be aware that the qualitative or "soft" influence factors and objectives cannot really be adequately represented by simple performance indicators and corresponding numerical data on business processes, though.

To this end, more complex cognitive structures are required. These are generally denoted as "knowledge". In addition to project management, knowledge management is therefore required for our approach to computer-supported supply chain management. The management of such especially qualitative knowledge, which relates to business (operative and strategic), legal, ecological and social aspects of the design of supply chains, is the so called "good governance" focus of the joint research project OrGoLo which is part of the efficiency cluster "Logistics Ruhr". The acronym OrGoLo stands for "organizational innovations and good governance in logistics networks". The CBR tool presented here is one of the building blocks in the OrGoLo project.

For the reasons mentioned above, the management of complex logistics projects or supply chain (management) projects under consideration here can be regarded as a special logistics or supply-chain-related and project-related variant of knowledge management. The focus of this contribution is, therefore, the knowledge management of complex, especially international logistics projects, which can also be considered synonymously as supply chain management projects.

The knowledge management of projects is dealing in most cases with the acquisition of project-related knowledge, the "intelligent" reuse of the knowledge about previous projects and its adaptation to similar, new projects. The project-related knowledge mostly exists in the form of documents which represent the "lessons learned" of previous projects in natural language with little structure. Because such documents containing know-how, know-what and know-why about both successful and unsuccessful projects exist in large numbers, it is desirable to deal with this knowledge with the help of computer-based systems and make it available for the management of new projects.

Despite the promising preconditions to support the knowledge-intensive business processes of knowledge management with instruments of e-business, the current knowledge management systems are generally restricted to a "naive" or "technical" retrieval of similar documents. The search for a similar document takes place on a purely syntactic level with the help of simple search terms ("string matching"). A content-addressed and therefore "intelligent" search for reusable knowledge does not happen in this way. In the light of knowledge management there is still a lot of knowledge that could be used in new projects but is currently unused. So it is a big challenge for project-related knowledge management to prepare knowledge of experience from finished projects in a computer-accessible way [1].

2 Case-Based Reasoning for "Intelligent" Knowledge Reuse

One of the most interesting business economics approaches of reusing knowledge from already realized projects for new projects is the concept of case-based reasoning or – for short – CBR, which originates from information systems research and artificial intelligence research. [2, 3, 4, 5, 6, 7]. In this paper we will show how project management can be supported by the knowledge management technique of case-based reasoning.

A concrete logistics or supply chain management project is called a "case", and forms the so called case-base or knowledge base (a database containing the case descriptions, case results and case evaluations, see fig. 1 below). The cases also take into account the design, especially the planning, execution and control of logistical process chains and networks (in short: supply chains). Such supply chains contain the transport of goods and information between dispatchers and recipients.

The management of supply chains is usually based on experience and expert knowledge. The experience knowledge can be structured and stored in databases. Expert knowledge does take into account but also goes beyond experience. It integrates a large amount of experience with creative capabilities. The creativity allows for solutions which are new in the sense that they are not directly available from the stored data and cannot directly be derived from first principles. One approach to approximate such expertise in a systematic manner is case-based reasoning.

The reasoning process based on the knowledge stored in the knowledge base of a CBR system is usually divided into four phases of the so called CBR-cycle (see fig. 1): retrieve, reuse, revise, and retain.

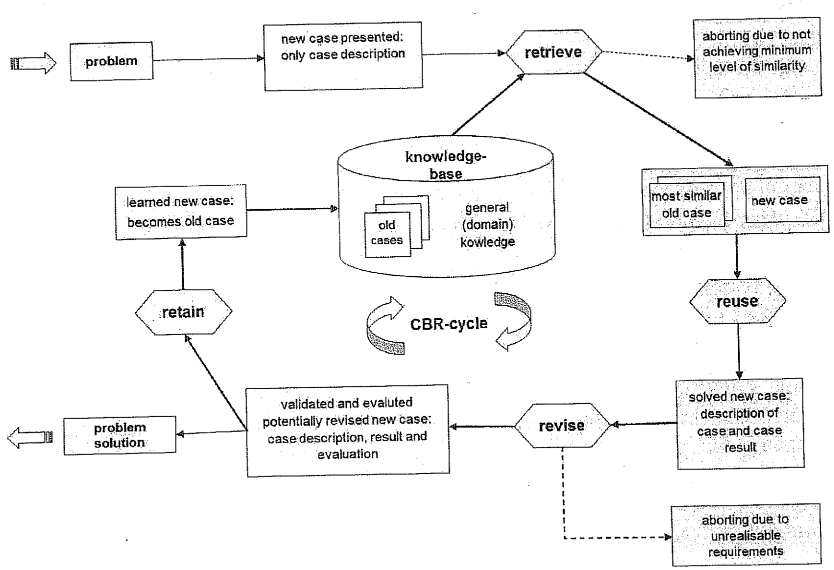

Fig. 1. The CBR cycle according to [2] and [1]

The description of a new case is used to retrieve at least one sufficiently similar and – if several sufficiently similar cases exist – at least one most similar case in the knowledge base. Having found such a sufficiently and most similar case in the knowledge base, the result of this case is reused by adopting it to the new case. The adopted result for the new case is potentially revised according to validation and evaluation criteria. The description, result and evaluation of the new case are combined in order to form a "learned new case" which is stored in the case base in order to retain the new acquired knowledge.

The case-based reasoning process sketched above turns out to be very interesting from a business perspective, because it provides a computer-based reconstruction of how people, both in private as well as in business, solve everyday problems. They orientate themselves to the successful solutions which were created by themselves or a third party for similar problems and which were carried over into the collective memory of a person or a company. Therefore, case-based reasoning has, from the perspective of business decision makers, the advantage of a higher cognitive adequacy

The situation can be compared to the problem of diagnosing an illness from the symptoms and prescribing a therapy. If one knows about similar cases in the past (i.e. similar symptoms), the diagnosis and therefore the therapy can be transferred to the case under consideration. The task is therefore to find those previous problems which are most similar to the current problem. For such similar problems it can be expected that the knowledge concerning the previous problems, i.e. their solutions as the case results, can be transferred and adopted to the new problem.

Considerable difficulties do, however, exist in the concrete application of the general concept of case-based reasoning in business practice. This is why it has been used for very simple, purely numerically characterized logistics problems so far, e.g. to solve travelling salesman problems. The application problems extend to three main areas. Firstly, it is extremely difficult to judge the similarity of projects (cases) especially if qualitative influence factors and objectives belong to the realistic case description. The difficulties arise because, on the one hand, similarity is a genuinely quantitative term and is in need of a metric measure of similarity, whereas, on the other hand, qualitative influence factors and objectives make such a quantification impossible prima facie. Secondly, there is much leeway in the application of case-based reasoning in terms of defining threshold values for "sufficiently" similar cases and – if several sufficiently similar cases exist – how many of these cases should be used in the construction of a solution for the new case. Thirdly, there are no generally applicable algorithms for adopting the results of old cases to gain a solution for the new case.

In the interests of brevity, only the first of the three difficulties mentioned above will be examined in more detail here to judge cases on their similarity when qualitative influence factors and objectives belong to the case description.

3 Representing Knowledge about Logistics Projects by Ontologies

The few attempts to use case-based reasoning for project management [8, 9, 10] failed up until now because of the difficulties when identifying those previous projects which contain useful, especially qualitative knowledge for the current project. It is difficult to measure similarity between knowledge collections (documents), though. They are written in natural language and usually heterogeneous with respect to the terminologies used. The use of natural language is necessary for representing qualitative knowledge but is an obstacle for the quantitative measuring of similarity between projects. The heterogeneity of terminologies cannot be avoided in complex, especially international logistics projects with a lot of involved actors (persons, companies, governmental and non-governmental organizations) which are used to express their thoughts within different company or organization specific and national languages.

To some extent, the idiosyncrasy of particular projects can be mitigated by broadening the case base (knowledge base) of a case-based project management system. Then, many case (i.e. project) descriptions have to be searched when a new project is planned. This task requires the help of computers. Therefore, the project-related knowledge has to be structured on the one hand to be suitable for storage in searchable databases or – more precisely – in case or knowledge bases. On the other hand, the representation of project-related knowledge must be flexible enough to be as close to the reality of project management as possible.

Ontologies offer a way to overcome the defects of operationalization regarding the concept of similarity between qualitative and heterogeneous knowledge about projects, because with the help of ontologies it is possible to "measure" the *semantic* distances between natural language terms which are used for the representation of especially qualitative knowledge about different projects.

In more general terms: 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 actors. Thereby the conceptualization extends to these real phenomena which are regarded by the actors 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 actors [1].

The development of ontologies for business relevant domains has not yet progressed far. Up until now, ontologies have unfortunately been presented as being developed, as a rule, by computer scientists and engineers who possess little feel for the subtle differences in business terminology.

Especially for the domain of complex, international logistics projects (and –synonymous – supply chain management projects) there are as of yet no ontologies which were acceptable from a business perspective. Therefore a fundamental goal of the joint research project OrGoLo is to construct a set of ontologies which cater for the above mentioned domain. In fig.2 below, an extract from such an ontology is referred to, which is represented in the form of a graph with nodes and directed edges (ontology graph). The nodes represent some of the linguistic means of expression which are necessary for the articulation of knowledge of projects from the aforementioned domain. The directed edges represent some of the taxonomic ("is a") and non-taxonomic relations, which are typical for the content dependencies between these linguistic means of expression.

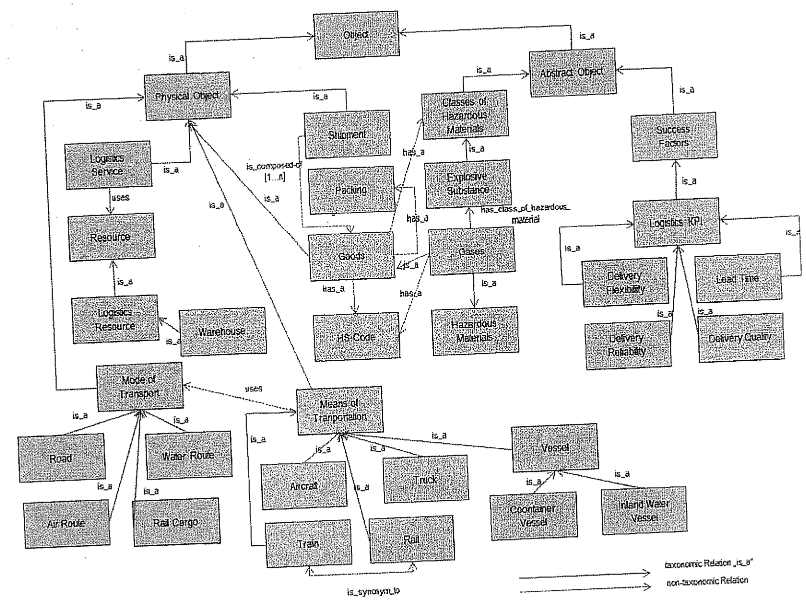

Fig. 2. Part of an ontology for the domain of complex logistics projects

One big challenge for the joint research project OrGoLo is to develop ontologies for the domain of complex, especially international logistics projects and – synonymous – supply chain management projects which can do justice to both the linguistic usage in practice in companies and other organisations as well as the stricter requirements of business terminology. Moreover, it is necessary in these ontologies to include different descriptions for the same data in different languages as well as different standards, e.g. HS-Code. Finally, it is desirable to expand the ontologies to inference and integrity rules ("heavy weight ontologies") which allow for the comprehension of such knowledge over and above purely terminological knowledge, which allows for the production of new knowledge (inferences) and the protection of the consistency of existing knowledge (integrity).

4 Integrating of Case-Based and Ontology-Based Reasoning

It is a special "craft" of ontologies to compare *qualitative*, which means non-numerical attributes of projects and display them on a *quantitative* similarity scale for case-based reasoning. First approaches at solving this highly difficult problem already exist [3, 11, 12, 13, 14, 15, 16]. Thus recent combinations of case-based reasoning and ontologies have attracted interest [11, 12, 17, 18]. However, these first approaches remain limited to simply structured domains with principally quantitative knowledge.

For the domain of complex, especially international logistics projects and – synonymous – supply chain management projects with considerable qualitative knowledge relevance there has been, in contrast, no corresponding research presented. Therefore, one central goal of the joint research project OrGoLo is to design an ontology-based and case-based reasoning system for the domain mentioned above and to develop it with computer support.

In order to implement this ontology-based CBR system in a user-friendly way, the CBR development framework jColibri, described in detail e.g. in [17, 19, 20], is used within the joint research project OrGoLo. The jColibri framework comes with a detailed example called "Travel Recommender". This example application is used as a blueprint for the "SCM Project Recommender" that supports projects managers with respect to the management of supply chain projects in the context of complex, especially international logistics projects. The major aim of the "SCM Project Recommender" is to assist e.g. dispatchers, when managing supply chains by providing access to expert knowledge from previous projects.

The basic development work for the ontology-based CBR system extends, on the one hand, to implementing domain specific ontologies within the jColibri development framework and, on the other hand, to developing a benchmark for the similarity of projects which refers primarily to qualitative project-related knowledge which is expressed in terms of natural language. The domain-specific ontologies were mentioned in chapter 3.

A benchmark for the similarity of projects on the basis of primarily qualitative project knowledge was developed in the joint research project OrGoLo and can also be found in the CBR development framework jColibri. This similarity benchmark is conceptually based on the measurement of the path lengths in a tree or network like graph, with whose help the domain-specific ontology is represented. See the exemplary ontology graph in fig. 2 above. On such an ontology graph the nodes represent linguistic means of expression (concepts or classes) and directed edges represent semantic dependencies (relations) between these linguistic means of expression. The knowledge of a supply chain management project can be classified on such an ontology graph. On this basis, similarities between projects are defined in which the length of paths between nodes, which represent content-wise similar knowledge of aspects of projects, is measured. In this way, it is possible to evaluate the mainly qualitative project-related knowledge, which is available in documents on previous projects, e.g. as lessons learned, with the help of quantitative similarity benchmarks. With regard to the details of this demanding transformation of primarily qualitative project-related knowledge into quantitative similarity measurements, please see the detailed commentary in [1, 11].

For example, a part of the retrieval phase of the ontology-based CBR system implemented in jColibri is shown in fig. 3. The user provides information on his new project ("case") regarding transport relation, goods, and other terms (e.g. customs). The weights of the different influence factors can also be specified. These weighted influence factors determine the search for similar cases in the knowledge base. The "SCM Project Recommender" searches for the most similar projects and presents part of them – i.e. the "problem solutions" (case results) – to the user. If the suggested solutions are acceptable, they are then adopted to the new project description to form a new case which can be revised and – if successfully revised – be retained within the knowledge base.

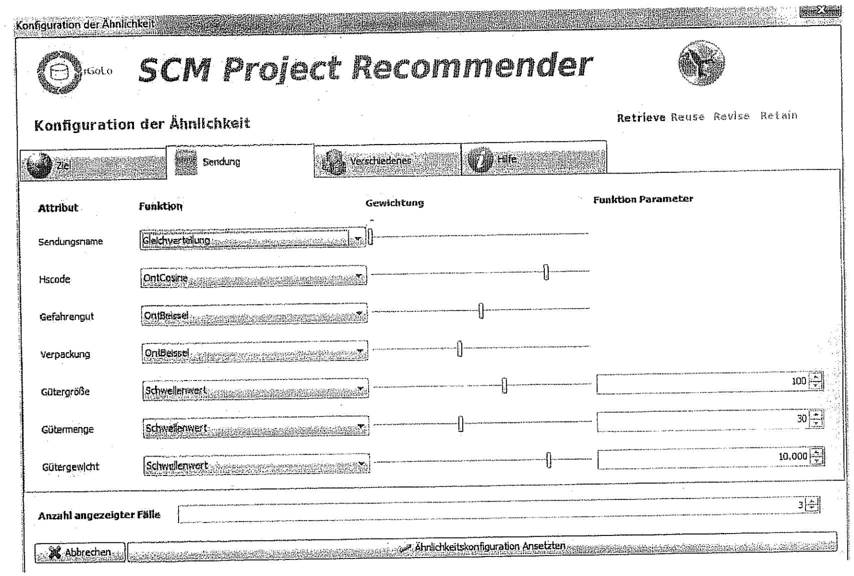

Fig. 3. Screenshot for the setting of the parameters of the similarity function implemented in the SCM Project Recommender (in German)

5 Summary and Outlook

In this paper it was shown how possible it is to intelligently reuse knowledge of supply chain management projects in the context of complex, especially international logistics projects through the integration of case-based and ontology-based reasoning. By means of this integration between two knowledge management techniques, which were developed independently of each other on the part of information systems research and artificial intelligence research, it was possible to define an operational, computer-supported calculable benchmark for the similarity between projects (cases) when the knowledge of these projects is primarily represented in natural language, i.e. qualitative form. A prototype CBR tool called "SCM Project Recommender" was developed to demonstrate the feasibility of this integration approach. This tool was implemented using the CBR development framework jColibri.

However, only the first of the three challenges which need to be mastered to be able to use the general concept of case-based reasoning in practice was examined here. It deals with the solution to the problem of judging cases regarding their similarity when case descriptions are available with qualitative knowledge. In contrast, more research is required to define "expedient" values for "sufficiently" similar cases and – if several sufficiently similar cases exist – to ascertain the number of cases which should be used in the construction of a solution for a new case. On the one hand, the effectiveness and the efficiency of case-based reasoning systems are influenced by the definition of the values and the number of cases. On the other hand, no theoretical or empirically secure knowledge exists on how such definitions affect the effectiveness and efficiency of the system. Furthermore, it is necessary to develop novel algorithms to adopt the results of old cases to gain a solution for a new case. This development task represents a particularly big challenge because with regard to such adopting algorithms only very rudimentary approaches exist, which are limited to very narrowly defined areas of application and cannot be transferred to other areas.

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Editors
Prof. Dr.-Ing. Uwe Clausen
Fraunhofer Institute for Material Flow
and Logistics IML
Dortmund
Germany

Prof. Dr. Michael ten Hompel
Fraunhofer Institute for Material Flow
and Logistics IML
Dortmund
Germany

Prof. Dr. Matthias Klumpp
FOM Institute for Logistics and
Service Management
Essen
Germany

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