Applying of an Ontology-driven Case-based Reasoning System in Logistics

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ABSTRACT
The management of logistics projects is a well known part of management science. But until now, purely quantitative and "hard" project management techniques like the critical path method and the project evaluation and review technique have been dominant. With this main stream approach, only simply structured logistics projects can normally be managed. The few attempts to use case-based reasoning (CBR) for project management failed up until now because of the difficulties when identifying those projects which contain useful, especially qualitative knowledge for the current logistics project. In this paper we present an ontology-driven case-based reasoning system (SCM Project Recommender), that can measure similarity between knowledge collections, which are written in natural language. The application is implemented using the open source CBR development framework jCOLIBRI.

General Terms
Automated Reasoning, Knowledge Management, Modeling

Keywords
Case-based Reasoning, jCOLIBRI, Knowledge of Experience, Knowledge Reuse, Logistics, Ontologies, Project Management, Qualitative Knowledge, Supply Chain Management

1. Introduction
A complete understanding of the structure of business processes in supply chains is essential for success. This holds in science as well as in operational practice. Until know, purely quantitative and "hard" success criteria have been dominant. The focus has been on isolated performance indicators. This approach can be characterized as

- data driven,
- primarily operative,
- focused on limited quantitative objectives, and
- developed for "hard" business criteria.

We present a new approach and add extra qualitative and "soft" factors. These extent the approach towards supply chain management. This "strategic" supply chain management can, albeit indirectly, increase competitiveness. The qualitative and "soft" factors cannot really be adequately represented by simple performance indicators and corresponding 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 supply chain management. The basis form established project management tools. Project management can be regarded as a special form of knowledge management. In most cases it is dealing with the "intelligent" reuse of knowhow from previous projects and its adaptation to a similar, new project.

The know-how mostly exists in the form of documents which represent the knowledge of previous projects in natural language with little structure. Because such documents containing know-how about successful projects exist in large numbers, it is desirable to deal with this knowledge with the help of ICT systems and make it available for the planning and management of new projects.

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 the 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 search for reusable knowledge does not happen in this way. In the light of knowledge management there is still a lot 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 finished projects in an accessible way [1].

One of the most interesting business economics approaches of reusing know-how from already realized projects for new projects is case-based reasoning [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.

2. Specific Requirements for CBR in the Logistics Domain
In science as well as in operational practice it is widely known that a holistic understanding of the structure of business processes in supply chains is essential to attain sustainable competitive advantages and to convert these into long term business success. As stated before, qualitative and "soft" factors cannot really be adequately incorporated with simple performance indicators and corresponding "hard" data on business processes, but rather complex, cognitive structures are required which are generally denoted as "knowledge".

Such qualitative knowledge, which relates not only to business (strategic) but also to ecological, legal 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". OrGoLo stands for "Organizational Innovations and Good Governance in Logistics Networks". The CBR tool presented here is one building block of the OrGoLo project.

Logistics projects take into account the management, especially the planning and control of logistical process chains and networks (in short: supply chains). Such supply chains contain the flow of goods, information, and money. The knowledge about such a logistics project is called a "case", and the entirety of this project-related knowledge forms the knowledge base (a database containing the case descriptions, results and evaluations, see fig. 1 below) of the CBR tool. As relevant knowledge domains for the development of the CBR tool, the following aspects should be given special consideration:

- means of transport used (e.g. lorries, goods trains, freighters) and traffic carriers (e.g. roads, railway tracks, shipping routes) including their possible combinations;
- transport links and networks used;
- project-relevant, specialized geographic knowledge of transport links and junctions;
- critical success criteria or "key performance indicators", which have been identified as especially important for the success or failure of a project;
- regional, national and international transport regulations and usances, which were important for the project;
- HS-Codes (EU tariffs, foreign tariffs) for customs duties;
- customs formalities and customs preference rules;
- export control regulations and compliance specifications including the prohibitions and limits resulting from them;
- credit rules and document check routines;
- 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);
- 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 the good, possible deployment of a container;
- 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 consumer goods;
- 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 (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.

3. Using jCOLIBRI as a Framework for Creating CBR Applications

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 ("cases") stored in the knowledge base is usually divided into four phases of a so called CBR cycle (see fig. 1): retrieve, reuse, revise, and retain. The description of a new case is used to retrieve at least one sufficiently similar and – if there exist several sufficiently similar cases – 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.

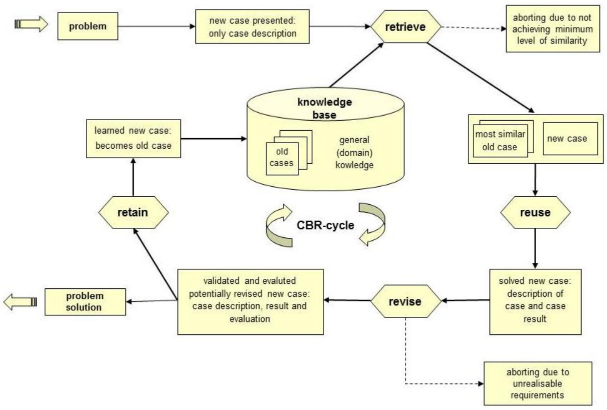

Fig 1: The CBR cycle according to [1] and [4]

The user states his logistics project, the systems suggests a solution (based on the input, the case base and some interpolations), the user refines it (if the suggested solution is helpful), and decides whether the new case (i.e. the result of the previous three phases) should be added to the knowledge base.

In order to implement this CBR cycle in a user-friendly way, we use the framework jColibri, described in detail e.g. in [8, 9, 10].

Part of the retrieval phase is shown in fig. 2. The user provides information on his logistics project – the new case – regarding transport relations, goods, and terms (e.g. customs). The importances of the different input variables can also be specified and influence the search for similar cases in the knowledge base. The "SCM Project Recommender" searches for the most similar cases and presents part of them to the user (i.e. the "solutions"). If the suggested solutions are acceptable, they are then merged with the case description to form a new case which can be revised and added to the knowledge base.

Fig 2: Screenshot for the setting of the parameters of the similarity function implemented in the SCM Project Recommender (in German)

4. Representing Domain-specific Knowledge by Ontologies

The few attempts to use case-based reasoning for project management [11, 12, 13] failed up until now because of the difficulties when identifying those previous projects which contain useful information for the current project. 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 projects which are most similar to the current project. For such similar projects it can be expected that the know-how (i.e. the solution as the case result) can be transferred to the new 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. To some extent, this heterogeneity can be mitigated by broadening the knowledge base. Then, many case descriptions have to be searched when a new project is planned. This task requires the help of computers. Therefore, the knowledge has to be structured on the one hand to be suitable for storage in searchable databases. On the other hand, it must be flexible enough to be as close to the reality as possible.

Ontologies offer a way to overcome the defects of operationalization regarding the concept of similarity between heterogeneous know-how from 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 know-how from 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 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. [1]

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 [6, 14, 15, 16, 17, 18, 19]. Thus the recent combination of case-based reasoning and ontologies has attracted interest [10, 16, 19, 20].

5. Summary

In this article it was shown how possible it is to intelligently reuse knowledge 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 about 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, neither theoretical nor 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 great 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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