APPLICATION OF NEW TECHNIQUES OF ARTIFICIAL INTELLIGENCE IN LOGISTICS: AN ONTOLOGY-DRIVEN CASE-BASED REASONING APPROACH

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KEYWORDS
case-based reasoning, logistics, ontologies, similarity measurement

ABSTRACT

In most cases, the project management is dealing with the "intelligent" reuse of know-how from previous projects and its adaptation to a similar, new project. 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. In this paper, we present an ontology-driven case-based reasoning system (SCM Project Recommender) that can measure the similarity between knowledge collections, which are written in natural language. The application is implemented by using the open source case-based reasoning development framework jCOLIBRI.

INTRODUCTION

A complete understanding of the structure of business processes in supply chains is essential for success. This holds true 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 qualitative and "soft" factors. These "soft" factors extend 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 structures 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 know-how 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 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"). An "intelligent", i.e. 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]. In this paper, we will show how project management can be supported by the knowledge management technique of case-based reasoning, which is enriched by the use of ontologies.

KNOWLEDGE REPRESENTATION OF LOGISTICS PROJECTS WITH ONTOLOGIES

The few attempts to use case-based reasoning for project management [7, 8, 9] failed 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 are usually heterogeneous with respect to the terminologies used. The use of natural language is necessary for representing qualitative knowledge, but it is an obstacle for the quantitative measuring of similarity between projects. The heterogeneity of terminologies cannot be avoided in complex, especially international logistics projects where a lot of actors (persons, companies, governmental and non-governmental organizations) are involved, which are used to express their thoughts within different person-, 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, on the one hand, the project-related knowledge has to be structured 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.

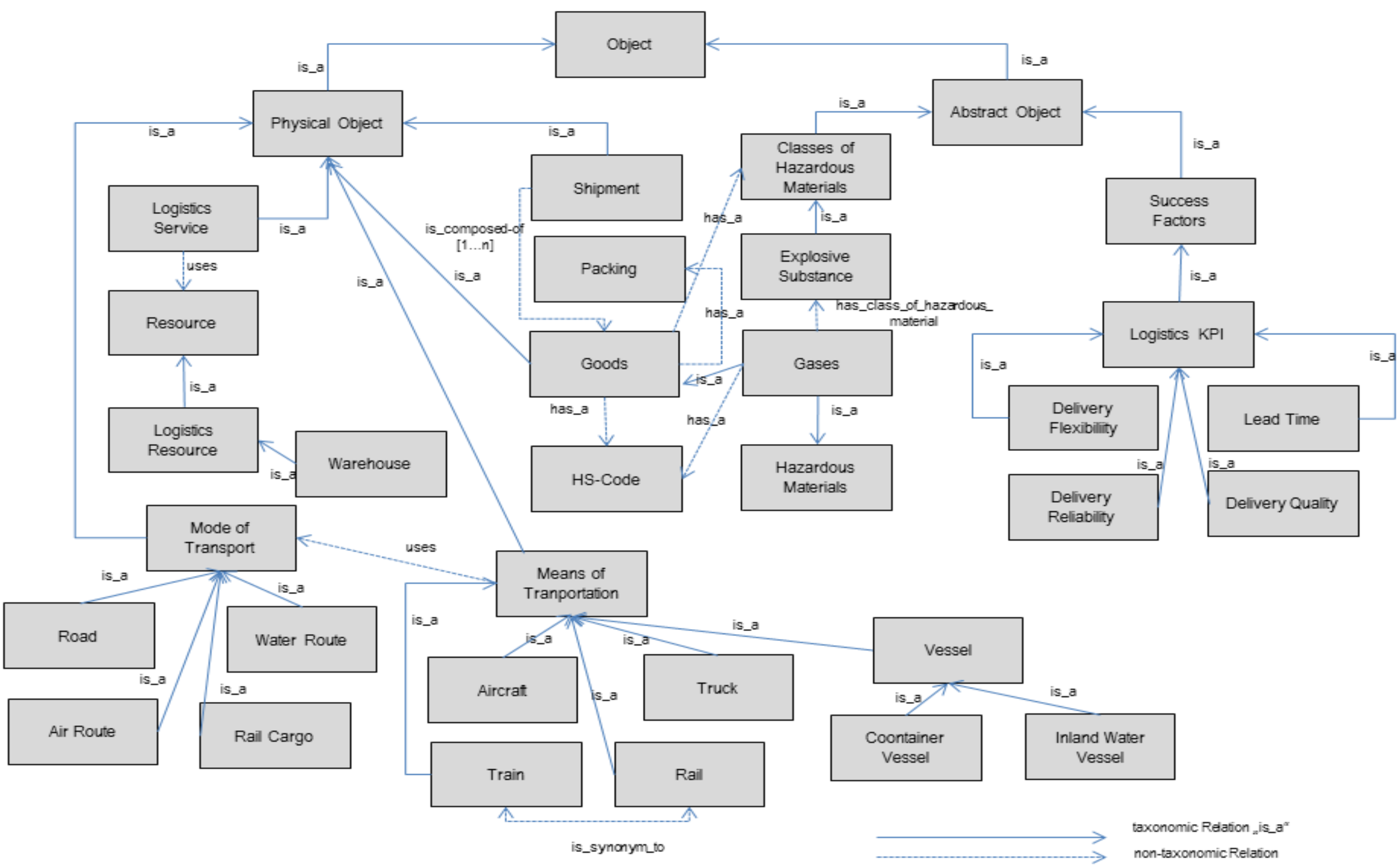
Ontologies offer a way to overcome the defects of operationalization regarding the concept of similarity between qualitative and heterogeneous knowledge about projects, because only with the help of ontologies it seems to be possible to accurately "measure" the semantic distances between natural language 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 logistic 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 sense 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 management science perspective. Therefore, a fundamental goal of the joint research project OrGoLo (Organizational Innovations via Good Governance in Logistics Networks) is to construct a set of ontologies which cater for the above mentioned domain. In fig. 1 below, it is referred to an extract from such an ontology, 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 about 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. 1. Part of an ontology for the domain of logistics projects



ONTOLOGY BASED CASE-BASED REASONING

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 [3, 10, 11, 12, 13, 14, 15]. Thus, the recent combination of case-based reasoning and ontologies has attracted interest [10, 11, 16, 17]. 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-driven and case-based reasoning system for the domain mentioned above and to develop it with computer support.
In order to implement this ontology-driven case-based reasoning system in a user-friendly way, the case-based reasoning development framework jCOLIBRI, described in detail e.g. in [14, 16, 17], is used within the joint research project OrGoLo.

THE RELEVANCE OF PRACTICAL KNOWLEDGE FOR INTERNATIONAL LOGISTICS PROJECTS

The implementation of international logistics projects requires an extensive practical knowledge about the idiosyncrasies with respect to national logistics projects. These idiosyncrasies can appear very differently in individual cases. For instance, the circumstances like different institutions, delivery and payment terms, custom actions, transport and packaging of goods, warehousing operations, national legal systems as well as economic, political, legal and social aspects can differ from country to country. In the case of transnational transports it can come to considerable delays because of, for example, repeated handling of goods and the treatment of goods through the customs. If one knows about this because of experiences acquired in previous logistics projects, one can plan new projects differently and save unnecessary logistics costs. A further example for unnecessary logistics costs can be the ignorance of port maintenance fees. Through the choice of a different port – without port maintenance fees – a transport could become more cost-effective. Through such a system not only the transportation tasks could become more cost-effective, but due to previous experiences the system could also make the project manager aware of possible restrictions and prohibitions in certain countries. These examples show how valuable practical knowledge can be for a company in designing logistics projects.
The “SCM Project Recommender” supports project 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. Furthermore, the “SCM Project Recommender” makes it possible to preserve the practical knowledge of a company and thus makes it available for new employees. This practical knowledge can get lost if the logistics experts drop out of the company due to various reasons. The lack of access to existing practical knowledge can in turn lead to unnecessary logistics costs and possibly to avoidable mistakes.

CASE INPUT AND SIMILARITY CONFIGURATION

The input of the current problem description happens by means of a front-end which can be operated with the help of a web browser on behalf of usability. In fig. 2 the input mask for an exemplary problem is illustrated. This problem encompasses the recommendation of a transportation route whilst taking into account the properties of the transported goods (“Waren”) for a SCM project.

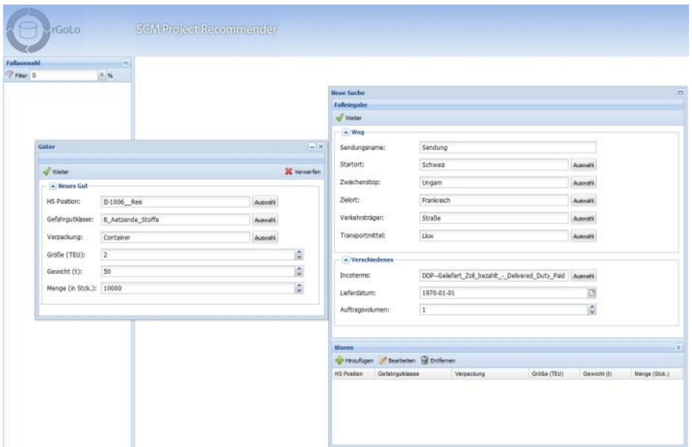


Fig. 2: Input mask for adding a new case (in German)

Grouped beneath „Weg“ all fields are situated that deal with the transport like starting place, intermediate goal, transport carrier and means of transport. Next to the input elements is the button which, in the case of instance fields, opens up a selection of ontologies.
Beneath “Waren” an input field for the shipment name and a button “Ware hinzufügen” is found. By clicking on this button an input dialogue for goods opens up.
The basic development work for the ontology-driven case-based reasoning 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 that is expressed in terms of natural language.
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 case-based reasoning 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. 1 above. In such an ontology graph the nodes represent linguistic means of expression (concepts or classes) and the 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 knowledge of aspects of similar 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, 10].

For example, a part of the retrieval phase of the ontology-driven case-based reasoning system implemented in jCOLIBRI is shown in fig. 3.

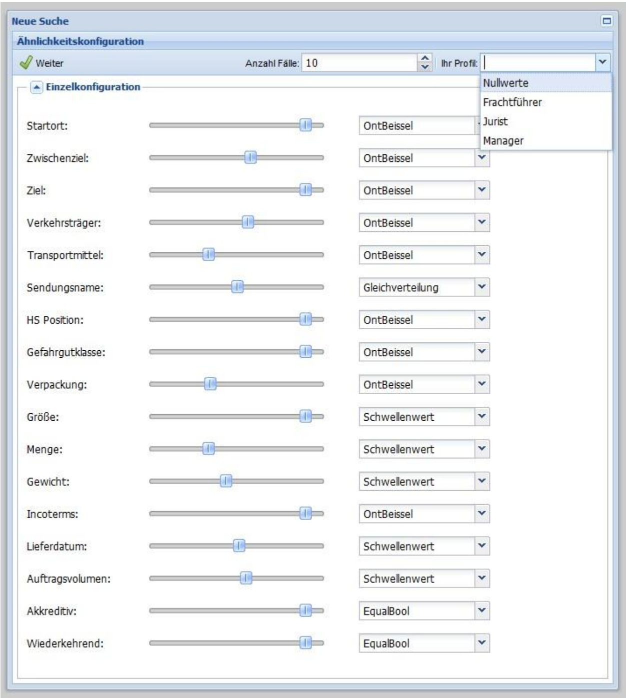


Fig. 3: Input mask for the setting of the similarity functions (in German)

The user provides information on his new project ("case") regarding transport relation, goods, and other terms (e.g. customs). The weights of the different influencing factors can also be specified. These weighted influencing factors determine the search for similar cases in the knowledge base. Furthermore, the user has the possibility to specify the number of cases to be displayed. The "SCM Project Recommender" searches for the most similar projects and presents them to the user.

A found case contains the problem-related depiction of experiences which have been acquired during the implementation of the case. It is represented through the description, the outcome and the evaluation of the case. The description of the case contains the characteristics that are necessary for the problem-related description of the situation. The outcome of the case describes the inferences of the depicted case. The evaluation of the case completes the case through an assessment of the outcome of the case (see fig. 4).

Additionally, a minimum degree of similarity can be predefined that has to be achieved by the most similar case. Moreover, the user is able to see in statistics how similar the individual components of the case are to the entered case describing the new project. If the suggested solutions are acceptable, they are then adapted to the new project description to form a new case which can be revised and – if successfully revised – be retained within the knowledge base.

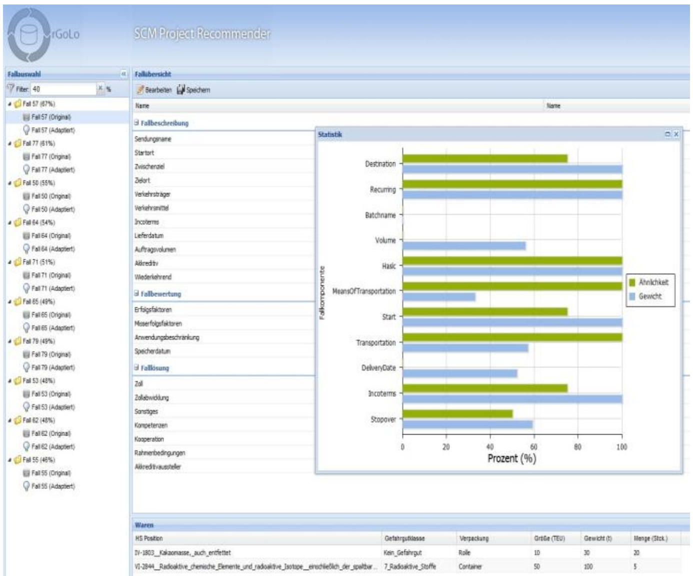


Fig. 4: An overview of the new-found, most similar case (in German)

THE SCM PROJECT RECOMMENDER ARCHITECTURE

In this section, we present an overview on the main features of the "SCM Project Recommender" architecture.

The „SCM Project Recommender" constitutes a stand-alone application and is based on the requirements of the joint research project OrGoLo. When developing the „SCM Project Recommender" it has been drawn on field-tested open-source components as far as possible so that, on the one hand, the code basis, which is to be mainained, stays manageable and, on the other hand, interested developers find familiar surroundings.

The back-end consists of a Java-based servlet which runs within a servlet container (here: Apache Tomcat). The heart of this servlet consists of a modified version of the jCOLIBRI CBR-Framework which accesses the case base (here: MySQL) by use of the „Hibernate"-library and the ontology by use of „OntoBridge". The ontology as well as the databases can be located on a local or a remote server. The ontology can be edited through the ontology editor Protégé developed by the Stanford University. The access to the OWL file can take place via SFTP (under Linux) or through SMB (under Windows). It is planned to provide basic editing tools on the web interface at a later point in time.

The communication with the Web-based front-end and with possible third party applications happens through the open source Google Web Toolkit (GWT) so that the back-end is also executable in "Cloud" (i.e. Amazon Web Services or Google App Engine) after some simple adjustments. Besides, because of the application of GWT the development of Client-"Apps" is possible. With the help of these Client-"Apps" an application of the SCM Project Recommender on mobile platforms is also conceivable. The Web-based front-end based on JavaScript and HTML5 is generated automaticly

out of the Java source code by means of the GXT-UI toolkit. Thereby, the demands on possible external developers are narrowed down to the knowledge of the programming language Java.
The following fig. 5 shows the system architecture in a schematic way as it is implemented currently in the joint research project OrGoLo.

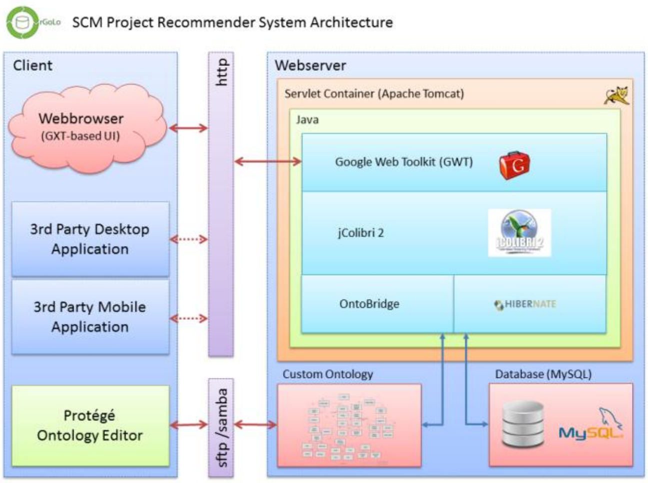


Fig. 5: System architecture of the SCM Project Recommender

SUMMARY AND OUTLOOK

In this paper it was shown how it is possible to reuse knowledge intelligently in the context of complex, especially international logistics projects through the integration of case-based and ontology-driven reasoning. By means of this integration of the two knowledge management techniques, which were developed independently of each other by information systems research and artificial intelligence research, it was possible to define an operational, computer-supported and calculable benchmark for the similarity between projects (cases) when the knowledge about these projects is primarily represented in a natural language, i.e. qualitative form. A prototypical ontology-driven case-based reasoning tool called “SCM Project Recommender” was developed to demonstrate the feasibility of this integration approach. This tool was implemented using the case-based reasoning 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 assessing cases regarding their similarity when case descriptions are available in 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 whole case-based reasoning system. Furthermore, it is necessary to develop novel algorithms to adapt the results of old cases to gain a solution for a new case. This development task presents a particularly great challenge because, with regard to such adapting algorithms, only very rudimentary approaches exist, which are limited to very narrowly defined areas of application and cannot be transferred to other areas.

ACKNOWLEDGEMENTS

This contribution presents results from the joint research project OrGoLo (Organizational Innovations via Good Governance in Logistics Networks). This project is supported by the German Ministry for Education and Research (BMBF) under the sign “01IC10L20A”. The authors are grateful for the support.

BIBLIOGRAPHY

[1]. Zelewski, S., Bruns, A., Kowalski, M.: Ontologies for Guaranteeing the Interoperability in e-Business: A Business Economics Point of View. In: Kajan, E.; Dorloff, F.-J.; Bedini, I. (eds.): Handbook of Research on E-Business Standards and Protocols: Documents, Data and Advanced Web Technologies, IGI Global, Hershey 2012, pp. 154-184.
[2]. Aamodt, A., Plaza, E.: Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches. In: AI Communications (AICOM), Vol. 7 (1994) 1, pp. 39-59.
[3]. Xiong, N., Funk, P.: Building similarity metrics reflecting utility in case-based reasoning. In: Journal of Intelligent & Fuzzy Systems, Vol. 17 (2006) 4, pp. 407-416.
[4]. Kolodner, J.: Case-based reasoning. Morgan Kaufmann Publishers, Mateo, CA 1993.
[5]. Watson, I.: Applying case-based reasoning. Techniques for enterprise systems. Morgan Kaufman Publishers, San Francisco, CA 1997.
[6]. Avramenko, Y., Kraslawski, A.: Case based design – Applications in process engineering. Springer, Berlin 2008.
[7]. Dogan, S., Arditi, D., Asce, M., Günaydin, M.: Determining attribute weights in a CBR model for early cost prediction of structural systems. In: Journal of Constructions Engineering and Management, Vol. 132 (2006) 10, pp. 1092-1098.
[8]. Chou, J.: Web-based CBR system applied to early cost budgeting for pavement maintenance project. In: Expert Systems with Applications, Vol. 36 (2009) 2, pp. 2947-2960.
[9]. Li, Y., Xie, M., Goh, T.: A study of project selection and feature weighting for analogy based software cost estimation. In: Journal of Systems and Software, Vol. 82 (2009) 2, pp. 241-252.
[10]. Beißel, S.: Ontology-based Case-based Reasoning – Development and Evaluation of Semantic Similarity Metrics for the Reuse of Project Knowledge in Natural Language (in German). Doctoral dissertation, University of Duisburg-Essen. Gabler, Wiesbaden 2011.
[11]. Assali, A.A. Lenne, D., Debray, B.: Case Retrieval in Ontology-Based CBR Systems. In: Mertsching, B., Hund, M., Aziz, Z. (eds.): KI 2009, Advances in Artificial Intelligence, Vol. 5803. Springer, Berlin, Heidelberg 2009, pp. 564-571.
[12]. Assali, A.A., Lenne, D., Debray, B.: Heterogeneity in Ontological CBR System. In: Montani, S., Jain, L.C. (eds.): Successful Case-Based Reasoning Application, SCI 305. Springer, Berlin, Heidelberg 2010, pp. 97-116.
[13]. Maedche, A., Staab, S.: Measuring Similarity between Ontologies. In: Gomez-Pérez, A., Benjamins, V.R. (eds.): Knowledge Engineering and Knowledge Management. Lecture in Notes in Computer Science, Vol. 2473. Springer, Berlin, Heidelberg 2002, pp. 251-263.

[14]. DeMiguel, J., Plaza, L., Díaz-Agudo, B.: ColibriCook: A CBR system for ontology-based recipe retrieval and adaption. In: Schaaf, M. (ed.): ECCBR 2008: The 9th European Conference on Case-Based Reasoning – Workshop Proceedings. Tharax, Hildesheim 2008, pp. 199-208.
[15]. Wu, Y., Cao, C., Wang, S., Wang, D.: A Laplacian Eigenmaps based semantic similarity measure between words. In: Zhongzhi, S., Vadera, S., Aamodt, A., Leake, D. (eds.): Intelligent Processing V, Proceedings of the 6th IFIP TC 12 International Conference. Springer, Berlin 2010, pp. 291-296.
[16]. Recio-García, J.A., Díaz-Agudo, B., González-Calero, P., Sánchez-Ruiz-Granados, A.: Ontology based CBR with jCOLIBRI. In: Ellis, R., Allen, T., Tuson, A. (eds.): Applications and Innovations in Intelligent Systems XIV. Springer, London 2006, pp. 149-162.
[17]. Díaz-Agudo, B., González-Calero, P., Recio-García, J.A., Sánchez-Ruiz-Granados, A.: Building CBR systems with jCOLIBRI. In: Science of Computer Programming, Vol. 69 (2007), pp. 68-75.