Experience-based decision support for project management with Case-Based Reasoning

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Abstract: Projects have to handle a dynamic context with a lot of unexpected events. The more experienced project members are, the more likely it is that they can make the right decisions within critical situations. They can draw on experiences collected within similar situations in the past. By considering knowledge about the customers, divisions and technologies, the transfer of project results to the internal customers can be ensured. In this paper, we introduce an approach where we collect knowledge from project managers and transfer that knowledge into a Case-Based Reasoning system. Thus, experiences describing exceptional situations are stored within a case base. After an experimental evaluation the experiences are structured by three main characteristics: the context of the project, the specific problem and the developed solution. For the latter two characteristics we have chosen an actor-driven approach. In addition, we introduce a framework to integrate the case base into the organizational process.

1. Introduction

The numerous research tasks within the R&T division at DaimlerChrysler are carried out in project organization. Each project has one or a number of internal customers. The aim of project work is to transfer project results to these customers and hereby into the development process which is the next internal *value-adding process*. Project management aims at transferring innovative prototypes, processes, reports and human resources. Project managers in the organization must ensure projects to be carried out on schedule and as efficiently as possible [AP92]. A major challenge in today's industry is to manage projects with ever-increasing *demands* on functionality, quality, cost of development and time to market. Hence, the pressure on research projects is increasing rapidly: Project members have to deal with changes in the internal development division or with the different competitors on the external market.

Meeting these demands requires fast continuous learning of the project teams. Thus, reusing and learning out of past projects should be supported within the R&T division. In this paper, we introduce our approach to structure and store this kind of knowledge supporting reuse of experiences in the domain of project management. This combination of project management and knowledge management produces added value to the project process [Ol00]. Our approach supports project managers in critical situations which endanger the transfer of project results. Therefore, we decided to use the Case-Based Reasoning methodology to store these specific experiences in an organizational memory. The paper is structured as follows: In section 2, principles and benefits of sharing and storing project management experiences are discussed. Section 3 is devoted to the characterization of experiences related to decision making during projects. Retrieval and storage are guided by this context-sensitive schema. We illustrate the system architecture in Section 4. Based on the captured experiences, a vision for future exploitation possibilities of the case base is sketched in Section 5. Related work is described in Section 6. Finally, the paper ends with some conclusions and further work.

2. Value-based decisions in research projects within critical situations

Projects and thus project members have to handle a dynamic and complex context [DL87] with a lot of *unexpected problems and crises* [KW98]. The transfer of project results into the next step of the value-adding process can e.g. be endangered by new time restrictions, new technological trends, changes within the society. Under these circumstances it is crucial to make the *right decisions* and to find solutions jointly with the entire project team.

Everybody involved in that process is continuously learning and can reuse these experiences within new *similar problems* [KNI97]. Employees who have participated in a variety of research efforts and who are familiar with the operating environment optimize their time and system resources when they can draw on past work of their own [GURO98]. Thus, it is more likely that they can ensure transfer of project results in a timely manner. Project success relies heavily on the project managers' ability to interpret problems or opportunities and propose feasible solutions based on prior concrete both *successful and unsuccessful experiences* [DP98, GURO98] with existing systems and environmental constraints [GURO98]. Experience-based continuous learning is essential for improving and innovating products, processes and technologies.

But there are not always experts available to manage a new project - they become a scarce resource [ABHMNST99]. Novices within project work who cannot base their decisions on a variety of past experiences must get the possibility to learn from experts. Especially the reuse of knowledge about unsuccessful experiences during later reasoning provides a warning to both novices and experts and enables them to act predictive [Ko93]. The reasoners are restrained from repeating mistakes [DP98, KNI97] others already made and from inventing solutions from scratch.

The R&T division consists of a lot of employees, customers, technologies, divisions and daily work procedures. Therefore, work-related practical know-how is distributed among people and divisions, stored as work experience, subjective insights, perspectives, beliefs and values all of which are acquired through works performed by people and procedures [Wa99]. However, often there is not enough time to transfer knowledge from experts to novices through direct apprenticeship. The experiences combining knowledge on specifications of the technology, the customer, the different development and production phases, etc., have to be captured. To transfer innovative technologies into practice and to improve quality and productivity continuously within research projects, project management related experience should be stored to make it obtainable at any time. The mentioned problems or issues can be solved by knowledge based decision support. Providing the managers and researchers with structured, consistent, comprehensive and accurate knowledge, would increase efficiency of the R&T division.

3. Managing decision making with Case-Based Reasoning

Storing and reusing experiences for future value-based decision making is realized using the Case-Based Reasoning (CBR) methodology that allows modeling human reasoning and thinking [BBGMW94]. In this section, we present arguments for case-based decision support within research projects as well as our approach to structure and collect the experiences.

3.1. Case-based decision support for research projects

Decision making in research practice requires not only theoretical background but also the art of applying this knowledge to "real-world" problems. The explicit request for reuse of knowledge and experience called for the application of Case-based Reasoning. CBR is a methodology [Wa99] which combines the knowledge based support philosophy with a simulation of human reasoning when past experience is used, e.g. mentally searching for similar situations of the past and reusing the experience gained in these situations [Ko93]. Cases are stored in memory, and the case-based decision support system analyzes them to retrieve similar cases from memory for decision making [BBGMW94].

There were a number of reasons for choosing CBR. The main requirement for the system is the ability to store experiences about *exceptional events or critical situations* (e.g. handling budget cutting) and about the chosen solution at that time. Other approaches (e.g. conventional rule-based systems) were not found suitable as they required strong domain knowledge and representation, whereas decision problems in R&T are difficult to define and structure because each project is different. Therefore, CBR was the choice to fulfill these tasks.

In CBR there is no need to derive new rules for project management to generalize decision making within research projects but to analyze and store experiences from specific problems. Many tasks within projects are high-grade complex so they can never be automated completely [GURO98, SC97].

Furthermore the domain of research projects can never be understood completely, because much depends on unpredictable human behavior [Ko93]. In most problem-solving activities during research projects, the problem solver faces two major issues: first, how to deal with unknown problems and second, how to make decisions in the presence of these unknowns. The main reason why problems are occurring during projects are due to the lack of information [TCW97].

Three factors can introduce *uncertainty and incompleteness* [TCW97]:

(i) The current situation is not known with certainty or completeness (uncertainty in observation).

(ii) The outcomes of actions are not known with certainty (uncertainty in available knowledge and world model).
(iii) The goals are conflicting and trade-offs must be made (uncertainty in goal description and problem domain).

Our approach tries to face these issues combining decision support with Case-based Reasoning. Project managers hereby get the possibility to learn from experiences made in other contexts even if they must handle incompleteness and uncertainty. However, the solutions suggested by the case base have to be seen as suggestions and not as best practices.

3.2. Approach

With the development of a CBR application we want to enable project managers in R&T to make value-adding decisions. They get the chance to find helpful experiences in the case base by an intelligent retrieval which is realized using context-sensitive queries and similarity functions. Retrieval and storage are guided by a defined *schema* that has to ensure the consistency of the organizational memory and thus, aid in effective and efficient learning [ABHMNST99].

At the beginning, it was not clear how artifacts which describe human decisions should be characterized and structured. Finding appropriate characteristics of this application domain is not trivial. It requires a special analysis [Wa99] in the *first place*, which we carried out by studying documents and by interviewing experts in project management. These studies lead us to the decision to chose the *structural* CBR approach. That way we can describe an experience resp. a case with attributes and values that are pre-defined [BBGMW94]. Having defined the case structure, further project analysis interviews, using the case structure, were carried out as a *second step* to collect decision cases. The questionnaire for the interviews was developed on the basis of the pre-structure. The interviews took about 1 1/2 hour each. After collecting the experiences we verified our pre-structure in the *third step* and changed it depending on the new aspects which occurred during the interviews (cf. Fig.1). In the *fourth step* we split the experiences into reusable parts, finally stored in the case base.

Although the collection of experiences seems quite effort-intensive at first, it is important to recognize that only a systematic process guarantees high quality experience. In return, high quality experience encourages its usage, because it is perceived as useful [TAN00]. Providing experiences is not one of the prime objectives of a project [BCR94]. Therefore, it cannot be expected that project teams provide experience on a voluntary basis. But capturing the experience has a positive side effect, the interviewees get the chance to reflect the project - something which is rarely done in daily business [TAN00].

3.3. Structuring experiences

In our CBR system, attributes for the retrieval are organized in object-oriented manner. We use the following main objects to represent the *domain model* describing critical situations within project management: the *context of the project*, the description of the *problem* and the developed *solution* (cf. Fig.1). Below these major characteristics we have defined sub-objects including taxonomies.

For *complex* problems within R&T it is essential to store experiences together with the specific context [TAN00] which contains attributes like the project duration, the technology and information about the customer (cf. Fig.1). Without the information about the context it would be impossible to find a suitable solution. For the representation of the problem and the solution we have chosen an *actor-driven approach* to reproduce the social complexity of a case [DL87]. The attributes describe the different "players" with their specific situations including their *goals*, *resources*, *opportunities* and their *intents* concerning the project [CT99, CTABTF95]. In our approach, we have figured two main players: on one side the player endangering the project process, the so called "causer" of the problem and on the other side, the "project team". This concentration on the different players supports the reasoner to focus the reasoning on the important parts of the problem [Ko93] by pointing out that human behavior has to be considered when making value-based decisions.

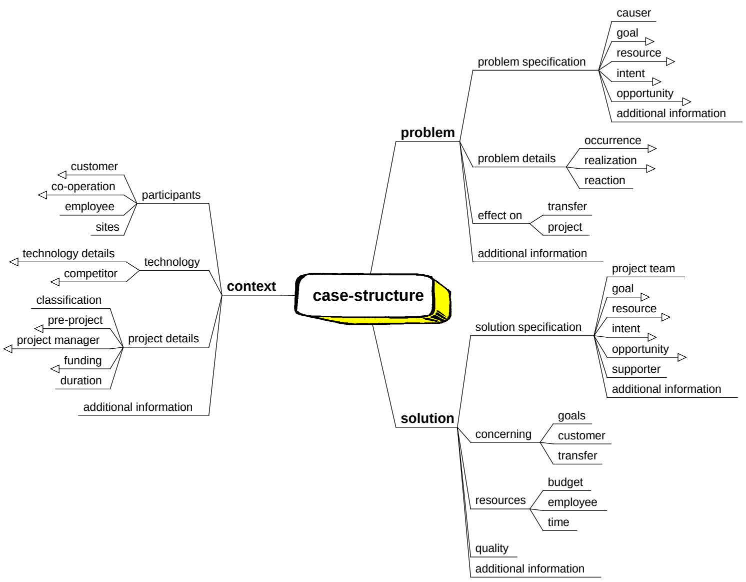

Fig.1 description scheme of attributes

If, for example, a project with the topic of telematics is starting it would be helpful to see what critical situations occurred in other projects with a similar context (e.g. similar technological tasks, the same customers). Hence, project risks for the new project can be defined based on stored cases.

Furthermore, our retrieval allows problem-specific search which enables project managers to find useful experiences they previously were not aware of and also did not expect to find [ABHMNST99]. It is of importance to know which other players (e.g. suppliers, divisions, etc.) have to be considered and what kind of goals and intents they have, endangering the project goal. To find a suitable solution for possible problems it is also vital to know what kind of intents the players could aim.

In our schema we store the knowledge anonymously. This simplifies knowledge collection because the employees are more open and thus more motivated to exchange their experiences.

4. System implementation

In the following, we will give an overview of how we have implemented the described structure into a running system enabling the user to find experiences from past projects. The system's architecture is divided into two parts (cf. Fig.2): the *orenge box* and the *Apache Tomcat Server*.

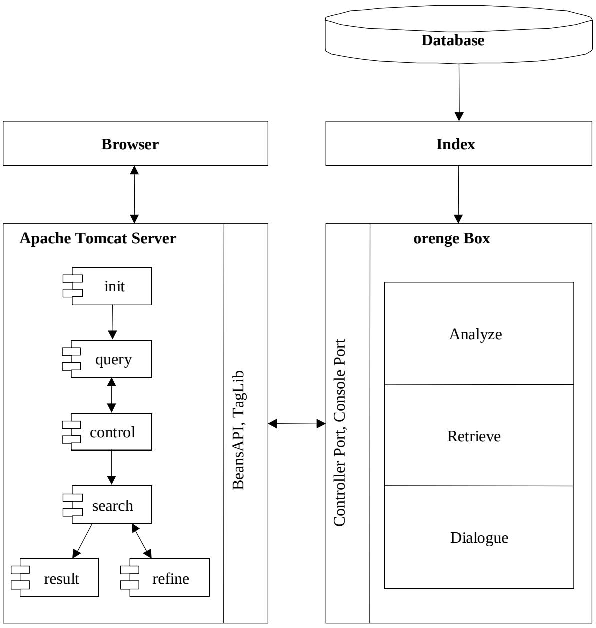

Fig.2 system architecture

The first part is managed by the *orenge box* which is part of empolis orenge base system (open retrieval engine). This system provides components for structural (cf. 3.3) and conversational Case-Based Reasoning. The cases collected within the interviews are stored in a *Database* and then transformed into an *Index*. This Index is used by the orenge box components *Analyze*, *Retrieve* and *Dialogue*. The *Analyze* component administrates the used language (German) and is necessary to configure and start the orenge box. The *Retrieve* component retrieves the appropriate cases for a given query. The *Dialogue* component constructs questions which refine a given query, if for example, there are too many cases retrieved. These questions are based on the attribute schema we described above. The query and the result of the retrieval is analyzed and questions are then generated regarding the chosen algorithm (entropy [R99]) to improve the result. The Console Port can be used to start and stop the orenge box with a remote command, whereas the orenge box communicates with the second part of the system via the Controller Port.

The second part of the system is managed by an *Apache Tomcat Server*. This server provides an implementation for the Java Servlet and JavaServer Pages (JSP) technologies. This project uses only the JSP ability of Tomcat and communicates over the programming interface (orenge BeansAPI and TagLib) with the orenge box.

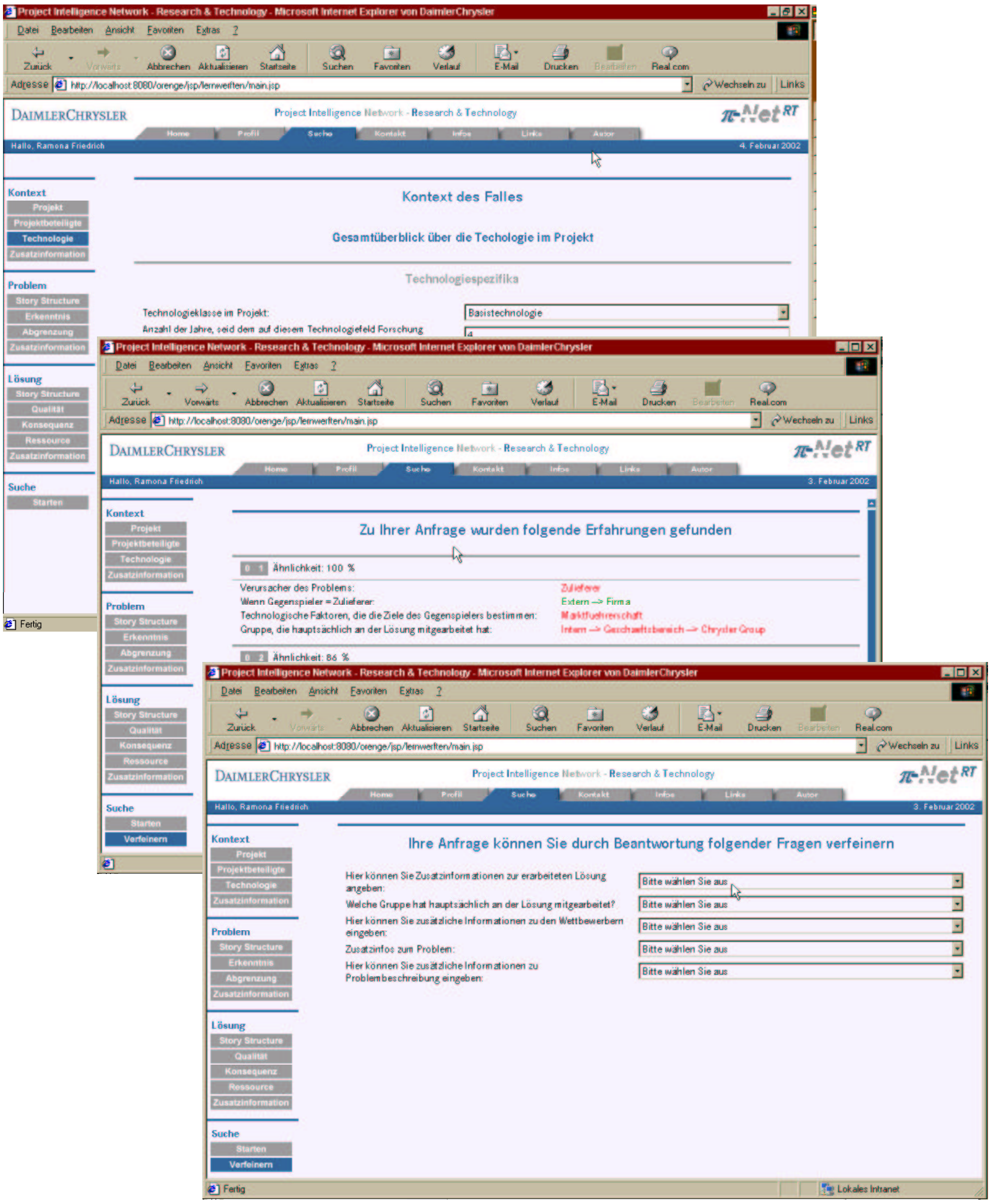

Fig.3 Screen shots of the system

The components implemented within Tomcat are *init*, *query*, *control*, *search*, *result* and *refine*. The *init* component initializes all the information needed by orenge like paths, configuration, number of retrieval results, used language and the query requested by the user. Since there are around 100 questions related to the specific attributes, the *query* component displays only a part as a form of attributes within a Browser like Netscape or Internet Explorer inside an HTML-Page (cf. Fig.3). After the user or the project manager filled the form the *control* component is initiated. The control component sends the actual query to the orenge box and it is possible to route the control component via a navigation bar back to the query component and display other questions or to start the *search* component (cf. the bottom layer of Fig.2). The search component (cf. Middle layer of Fig.2) shows an excerpt of the results which are part of the retrieved cases and offers the user the ability to look at each single result in more detail or to refine a result. If the user wants to refine a result, the *result* component is activated (cf. top layer of Fig.2) and, with the help of the Dialogue component of orenge, questions are generated and displayed.

After explaining how the system's architecture is implemented, we are illustrating an extraction out of the developed system (cf. Fig.3).

5. Using the case base

In the previous section we showed how the process of reusing and continuous learning is supported by a Case-Based Reasoning system. An actual deployment of a case base requires the system to be embedded into an organizational infrastructure that provides funding and strategies to consolidate reuse and learning. In the following we explain how we are planning to integrate the case base into daily work within R&T.

5.1. Stand-alone solution

At the beginning, we thought about integrating the case base into the organizational infrastructure as a *"stand-alone solution"* where employees could get the possibility to use the stored experiences during the project process. No matter what kind of time restrictions and what kind of problems project managers would have, they could be supported during the process by using the web-based system. The problem is that users resp. project managers would be left alone with the system. On one hand, experts willing to store their knowledge do not get any help to structure their experiences. And on the other hand, users who are seeking for a solution must interpret the retrieved cases on their own without getting any support and without having any chance to discuss their actual problem. That is, why we decided to chose another approach.

5.2. Using the case base within a project management community

We are planning to integrate the case base into a *"project management community"*. Researches resp. project managers thereby will get the chance to identify and import experiences out of various projects (cf. Fig.4). They could communicate and analyze their problems of daily practice no matter what kind of problems they are involved in.

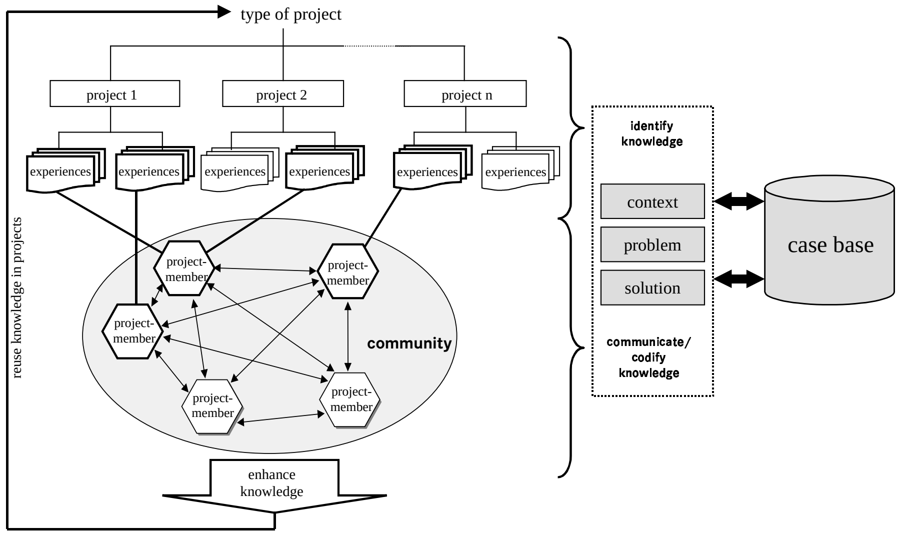

Fig.4 integration of the case base in a community

The integration has the following advantages for both, the success of the community and the development of the case base:

- the case structure can be used as a guideline for discussions in the community
- the moderation of the community meetings also has to consider the main characteristics of the domain model
- this structure is being tested on the end user side and can be revised if necessary
- the performance of the system, the user feedback and the usage of the system are issues which can be considered during the integration
- experience from past projects stored in the case base can be studied and debated collaboratively (in computer supported meetings)
- the users need not to be knowledge engineers
- current and urgent problems can be discussed within the community and similar problems and their solutions stored in the case base can additionally be used
- the worked out solutions have the right structure for the case base and new experiences can then be saved in the case base simultaneously
- the cases stored can help identifying experts for the community.

With this approach it will be easier to motivate the employees to communicate project experiences because they are more open when meeting others with similar problems in a face-to-face conference. Thus, community meetings encourage human intervention and discourse. There is more support and still active communication than with the "stand-alone solution". We think that this is the answer to achieve value-based decisions within critical situations in projects by learning from the experiences collected and exchanged in communities.

6. Related Work

There are various topics in CBR which have influenced our work. The INRECA Methodology [Be01] describes how knowledge containers can be used to store information. There are four knowledge containers*: Vocabulary, Similarity Measure, Adaptation* and *Case Base*. The vocabulary container holds all knowledge about definitions, names and structure of the CBR system. The similarity container includes the measures which establish the retrieve process by using an index function. The adaptation knowledge container covers knowledge used to transform the retrieved solutions regarding the actual problem. In comparison to the other knowledge containers the case base contains dynamic knowledge and is taken directly from the given data sources. Furthermore, the cases are represented in an object-oriented form. Each case is described as an object with an attribute-value pair representation. Each object is an instance of a class which is again a part of a class hierarchy.

Frank Maurer [Ma01] constructs the connection between CBR and Knowledge Management. It describes business processes and states that existing process centered systems should be improved by attaching knowledge to activities. In addition, it addresses the problems of business process representation, of how strong a system meets the restriction in the described business process and of how a traditional system can be used as a base system.

KM-PEB [AMNSK00] is an experience base for knowledge management tools. It implements a framework of seven components (*goals, acquisition, processing, preservation, distribution, utilization* and *valuation*). The goals give the information about which ability should be built on a specific level of abstraction. The acquisition describes how a systematic collection of knowledge can be realized. The processing component is responsible for the generation of new knowledge. The preservation addresses the persistent storage issue of knowledge. The distribution component deals with the question of how knowledge should be shared among different users. The utilization copes with the challenge of persuading the user to apply the stored knowledge to new problems. The valuation inspects if the stored knowledge still corresponds to the real world. Moreover, the experiences are available on the world wide web by any web server implementation similar to our application.

In this paper we focus on all these issues and add the actor-driven approach to structure and reuse experiences in our application domain of project management within R&T.

7. Conclusion and further work

The always increasing requirements in the dynamic and complex environment of research projects call for prompt and right decisions within critical situations. We showed why it is insufficient to follow rules to transfer project results into the next value-adding process.

In this paper we presented our approach for decision support within research projects by using Case-Based Reasoning which allows the storage and reuse of experiences about specific situations. These experiences were collected from domain experts for modeling, structuring and filling our case base. We also illustrated the different components of the system's architecture including the orenge box and the Apache Tomcat Server. The retrieval mechanism thereby contains a context-sensitive search and is based on a schema that guides the characterizations of experience items. This means that the users do not need to be knowledge engineers. They get the possibility to find useful experience they previously were not aware of. Additionally, we described how our case base can be embedded in the organizational infrastructure by creating a project management community enabling project managers to communicate and analyze retrieved cases.

Further tasks are to improve the community concept and the case base. We expect to contribute to the ever-increasing demands for more productive and innovative research work. Our future work will also include the integration of the case base into the organizational process as suggested above. Applying our system for other domains within the value-adding chain at DaimlerChrysler (other than R&T) is a future endeavor.

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