Case-Based Problem Solving for Knowledge Management Systems

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Abstract

Case Based Reasoning (CBR) is an intelligent systems methodology that enables information managers to increase efficiency and reduce cost by substantially automating processes (i.e., diagnosis, scheduling, or design). By identifying and ranking the relevance between a new case and previously encountered cases (i.e., stored in the case base), CBR systems can capture and share all of an organization's related knowledge capital for future use, and knowledge recycling can optimize resources spent on research and development. Unfamiliar cases are solved and documented by retrieving and adapting solutions from similar stored cases. Sample applications include a proposed knowledge system designed to enhance the NASA-KSC Shuttle Processing Out-of-Family Disposition process, which addresses any operation or performance outside expected range or one that has not previously been experienced. CBR technology can yield productive results by transforming problem report and interim problem report related documentation into explicit knowledge that can be reused to obtain solutions for new anomalies. Applying CBR technology to the Out-of-Family Disposition process can transform the organization into a *learning organization* that continues to grow in intellectual capital and related applied knowledge. This paper discusses the application of the NaCoDAE Conversational CBR (CCBR) system for this process. NaCoDAE is a software package developed at the Naval Research Laboratory. It uses CCBR technology to store cases, questions, and actions; and has a built-in method that efficiently searches for the most relevant cases.

Introduction to Knowledge Management

Knowledge Management (KM) is an increasingly important new business movement that promotes the creation, sharing, and leveraging of knowledge within an organization to maximize business results. Today's environment renders new skills obsolete in a matter of years or months. These changes point out that future success will depend on "a good deal of formal education and the ability to acquire and to apply theoretical and analytical knowledge" (Becerra-Fernandez, et al., 1998a). Loss of knowledge is a problem that companies must address, even when they are not faced with the threat of downsizing. For example, many information technology-consulting firms currently face a 10% annual turnover, even when revenues are growing by 30% per year (Reimus, 1997). Therefore, assuming constant revenue per professional employee, a growing information technology-consulting firm of 100 would need to add 40 new professionals (10 due to turnover, 30 due to revenue growth) the following year. The percentage of professionals with less than two years tenure in the firm is 30.8%. In other words, at any point in time, 30.8% of the firm's knowledge workers lack sufficient depth in organizational-specific knowledge. Therefore, effective tools for capturing and leveraging knowledge are essential for organizations to maintain their competitive edge.

The real question now becomes, how can a company better elicit and reuse its knowledge? There are various tools and practices to increase an organization's learning ability. It is up to the organization to adopt the methodologies and software tools that best address their demands for storage and reusability of past project experiences. The majority of KM projects currently in place attempt to create some kind of a *knowledge repository* to store explicit knowledge of organizational information. This includes storing decisions as well as their justifications (i.e., the reasons why decisions were made). Explicit knowledge should be carefully organized, and its access should be intuitive. Intranet and GroupWare tools are implemented to gather knowledge as teams create it in project collaborations, and to help them work together in an organized and coordinated fashion. There are many different types of tools aiming to provide solutions to different challenges of KM context environment. It is equally important to identify how an organization improves the knowledge sharing culture among their employees. Knowledge management in general tries to organize and make available important know-how, wherever and whenever it is needed (Becerra-Fernandez et. al., 1998b). This includes processes, procedures, patents, reference works, formulas, "best practices", forecasts, and fixes. Technologically, Intranets, GroupWare, data warehouses, networks, bulletin boards, and video-conferencing are key tools for storing and distributing this intelligence (Maglitta, 1996).

Case-Based Reasoning

Case-based reasoning (CBR) is a methodology where past experiences with corresponding solutions are stored in an electronic database of cases (i.e., a *case base* or *case library*) for quick and effective retrieval (Aamodt & Plaza, 1994). CBR has performed well on some KM tasks; Davenport and Prusak (1998) note that "Case-based reasoning programs have been shown to bring about marked improvements in customer service." It does this by mimicking the way humans use their experience to solve problems. CBR emulates human problem solving by retrieving relevant *cases* (<problem,solution> experiences) from the case base. Relevant cases are those whose problems are similar to the current problem; their solutions typically require adaptation.

CBR is also an expert systems approach that is a popular alternative to rule-base architectures. Although it may be difficult for experts to explain their decision rules, they are often able and willing to tell war stories about their experiences, which facilitates the development of a case base and its indexing scheme.

CBR systems input a problem description from the user, compute its similarity with the problems in the case library, and retrieve solutions from the cases whose problems are most similar. Cases that capture problem-solving experiences or lessons learned are organized in a structured case base and indexed so that they can be easily retrieved and adapted to solve new problems. A system of this kind can prevent recurrences of mistakes and repetition of work.

There are several advantages to using CBR. In domains that lack a strong domain theory, model based reasoning is not practical. When the relationship between the case attributes and the solution or outcome is not understood well enough to represent it in rules, or when the ratio of cases that are "exceptions to the rule" is high, rule based systems become impractical. CBR is especially useful in such situations because it models the exceptions and the novel cases (Morris, 1995). Often a solution can be derived from the combination of more than one case. These solutions are modified and combined to provide a solution of a newly entered case. It is here where methods for adaptation are used, providing the user with steps to combine and derive a solution from the collection of retrieved solutions.

NRL: Extending the Case-Based Reasoning Concept

The Navy Center for Applied Research in Artificial Intelligence (NCARAI) has been involved in both basic and applied research in artificial intelligence since its inception in 1982. NCARAI, part of the Information Technology Division within the Naval Research Laboratory, is engaged in research and in development efforts designed to address the application of artificial intelligence technology and techniques to critical Navy and national problems. NCARAI's NaCoDAE[1] (Navy Conversational Decision Aids Environment) tool was designed to minimize the loss of organizational knowledge, efficiently use lessons learned databases, and foster the creation of CBR applications for solving Navy and other DoD problems (Breslow & Aha, 1998). Several NCARAI projects have focused on designing, implementing, and evaluating practical extensions of NaCoDAE. This software, intended to aid Navy and other DoD personnel in decision aid tasks, is based on *conversational* CBR (CCBR) technology, as explained below. NaCoDAE has the advantage that it is free and publicly available, and because it was developed in Java it can be adapted to execute on the WWW, freeing the distribution of knowledge from geographical constraints. Originally based on Inference Corporation's CBR products, which were used to implement NASA-GSFC's RECALL application (see Section 4), NaCoDAE has been extended to simplify case authoring tasks (Aha & Breslow, 1997) and to address distributed crisis response planning tasks (Aha et al., 1998b).

CCBR tools have been specifically designed to solve interactive KM tasks, and our focus will be on using NaCoDAE. Each case in NaCoDAE has three components:

1. The *description* summarizes, in natural language text, the experience/lesson.
2. The *state* contains a set of <question, answer> pairs that are used to guide a user to the closest matching lesson. These pairs characterize the lesson's context. A case's description and state together define the *problem* it addresses.
3. The *solution* provides a recommendation for others confronted with a similar situation.

The outcome of applying a case's solution to a case's problem is assumed to be acceptable (i.e., all cases capture *positive* experiences), although negative experiences can also be accommodated.

CCBR problem-solving behavior can be exemplified by considering a *lessons-learned* application. When users encounter new problems, they enter the characteristics of the new situation as a *query*. Initially, a user enters a textual description of their problem. NaCoDAE responds by computing the similarity of this description with the stored descriptions of each case. It then displays the most similar case solutions to the user, along with questions from their respective states. These questions provide a focus of attention; the user can answer any of them to refine their query. In response, NaCoDAE re-computes similarities (i.e., by comparing the case's states with the query's <question, answer> pairs), which updates the case and question displays. Thus, solutions (lessons) to problems that closely match the query are displayed, which allows users to retrieve relevant related lessons. If some of the displayed lessons have a high similarity to the query, then they may provide insight on how to solve the query, and can be selected by the user to reapply in some new way. Users can create new cases by revising

[1] www.aic.nrl.navy.mil/~aha/cbr/nacodae.html

retrieved solutions so that they are applicable to the new situation. These new cases, which reflect what has been learned through experience, can be submitted for addition to the case base. In this way, the system can learn as its users learn.

Although a CCBR case base could be developed incrementally over time as users uncover new lessons and solve new problems, most case bases are not developed incrementally. Instead, cases are typically *authored* in a systematic software engineering process designed to ensure good problem-solving coverage and minimize conflicts. This process reduces concerns that end-users might create new cases that significantly deteriorate overall system performance.

Several challenges exist with producing CCBR case libraries that guarantee good retrieval performance. First, it is easy to construct a case library but often difficult to engineer one that performs well. NaCoDAE's research focuses on simplifying the case-authoring task to ensure high retrieval precision and efficiency (Aha & Breslow, 1997; Aha et al., 1998a). Second, system validation remains an important issue; the extent to which the case base covers the domain must be assessed (Smyth & McKenna, 1998). Third, care must be taken to ensure that the system knows its limitations. This can be partially addressed by using learning techniques to tune the system's similarity function. Still, if the case base does not have a sufficiently similar case, the recalled solution may be inappropriate. To prevent recalling inappropriate cases, the system should warn the user that no similar cases have been found in the case base. Morris (1995) suggests that "the case database should be designed to include both examples where the proposed solutions succeeded and where they failed." However, it is not always necessary to include both types of examples, provided that the set of "positive" cases suffices for the intended appropriation. For example, Inference Corporation, a commercial CCBR tool vendor uses only positive cases in its help-desk applications.

NaCoDAE was integrated with the fast query-retrieval system Parka-DB, which was developed at the University of Maryland (Hendler et al., 1996). This integration enhanced NaCoDAE's dialogue capabilities. In particular, it could previously not derive inferences from a partially constructed query. In this integration, NaCoDAE passes its query to Parka-DB as a set of relational assertions that constitutes a knowledge base. Given a model of the case library, which must be constructed by the case author, Parka-DB can then find questions that have only been *implicitly* answered by the query's current contents. It returns all such answers to NaCoDAE, which are then immediately incorporated into the query. In this way, users can retrieve solutions by answering fewer questions, on average, which improves retrieval efficiency (Aha et al., 1998a).

NaCoDAE's development team created a Cooperative Research and Development Agreement with Inference Corporation on the topic of evaluating potential extensions of their CBR products. Topics being pursued include investigations on integrating conversational CBR approaches with model-based approaches, featured selection, and on other tasks related to CCBR. We describe an application of NaCoDAE in Section 5.

NASA Goddard Space Flight Center: Managing Lessons Learned using Case-Based Reasoning

NASA has over the years enjoyed the advantage of having a very stable workforce. Unfortunately, recent pressures to downsize are causing the organization to suffer depletion in its knowledge base. This phenomena, coupled with the need to minimize repetition of work has generated a need for the creation of NASA's Lessons Learned Information System (LLIS). Its purpose is to collect and make available the lessons learned from the aeronautics and space activities derived from almost forty years of experience. Those who may benefit from the experiences of others will use these lessons. Both government and industry have long recognized the need to document and apply the knowledge gained from past experience to current and future projects, in order to avoid repeating of past failures and mishaps. Through this system, NASA seeks to facilitate the early incorporation of safety, reliability, maintainability, and quality into the design of flight and ground support hardware, software, facilities, and procedures.

NASA-GSFC needed a way to automate the access to the lessons learned repository so that it could be used more efficiently. The organization needed a way to stop recurrence of problems, encourage implementation of best practices, and reduce operation costs by minimizing the number of meetings and increase communication and collaboration between teams. GFSC decided to implement their LLIS system in a prototype to capture and reuse the lessons learned using CBR, implemented in the RECALL (Reusable Experience with Case-Based Reasoning for Automating Lessons Learned) system.[2] Systems and software engineering lessons learned on projects were primarily captured, although other relevant lessons could also be incorporated. CBR provided an alternative approach to more traditional information access mechanisms, such as database query schemes and keyword searching. Furthermore, it gave the organization a way to minimize recurrence of problems, and as a result costs were reduced. An operational prototype of RECALL can be found at http://hope.gsfc.nasa.gov/RECALL.

[2] http://llis.gsfc.nasa.gov

NASA-KSC: Solving Problems Using Conversational Case-Based-Reasoning in the Out-of-Family Disposition Process

When the domain theory is weak, it is difficult to justify or explain a position based on first principles. Drawing the analogy to similar solutions helps assess unfamiliar cases. In the Out-of-Family Disposition process, unfamiliar cases are referenced to be solved and documented. Thus this process lends itself to the adoption of a system capable of capturing all knowledge for future use. The Out-of- Family Disposition process was created to provide information on any operation or performance outside expected range or which has not been previously experienced. Among all the anomaly dispositions the following are considered to be Out-of-Family:

1. Material Review Board (MRB) anomalies
2. (OMRSD) waivers/exceptions
3. Unexplained anomalies

Thus, adopting technologies that can maximize the benefits obtained from the Out-of-Family disposition knowledge base can be used throughout the entire organization.

CBR technology can enhance the Out-of-Family Disposition process by documenting unfamiliar troubles in a way that make the solutions to these cases available to the rest of the organization. As more unfamiliar cases get documented within the CBR system, the organization's knowledge capital asset will increase, and the solutions for all cases will be made available to the rest of the organization. Therefore, a CBR application for this task can potentially transform NASA into a "learning organization" that continues to grow in intellectual capital and related applicable knowledge that can benefit the entire organization.

The Out-of-Family Disposition process is also confronted with organizational difficulties in the areas of information management, knowledge dissipation, knowledge retrieval, and applications of its knowledge capital. For these reasons, this process is an ideal initial target for the application of CCBR technology. A CCBR prototype would support:

1. knowledge capture, since CCBR would be used to process all information,
2. the gathering of relevant documentation and data and converting it into reusable knowledge,
3. ease of access, so organizational knowledge can be made applicable to new projects, and
4. a centralized repository of related documentation, for example within the lessons learned repository,

Organizations with significant intellectual capital (e.g., NASA) must elicit and capture knowledge for later use to effectively utilize organizational resources. By reusing previously acquired knowledge the organization can save time and capital. To catalog organizational knowledge for reuse, appropriate tools must be developed. CCBR technology can improve the decision-making by identifying scenarios previously encountered and by adapting the previous experiences to the current problem scenario, in order to provide a solution. CCBR systems can combine cases if their problems are similar to the current query.

Conclusion

Organizations with significant intellectual capital, such as NASA and the Navy, require eliciting and capturing knowledge for later reuse in order to effectively utilize organizational resources. By reusing previously acquired knowledge, an organization can achieve savings in time and capital. In order to catalog organizational knowledge for reuse, appropriate tools must be developed. NCARAI's NaCoDAE tool is designed to minimize the loss of organizational knowledge, efficiently use lessons learned databases, foster the creation of CBR applications, and to apply them to KM problems, particularly in decision aid tasks. NaCoDAE is based on *conversational* CBR (CCBR) technology. CCBR tools enhance decision making by identifying similar scenarios previously encountered and by adapting the previous experiences to the current problem scenario, in order to provide a new solution. A CCBR system can combine cases if they have similar patterns to that of the current case. In addition, this technology can serve as a learning tool that makes use of all documented experience from past projects and applies it to a present project application. The implementation of CCBR technology has the potential of transforming the decision making process into a continuous learning system. CCBR does this by incorporating, interpreting and storing present projects in the case base as they're solved, to reuse at a later date or when a similar case scenario is encountered.

CCBR technology is ideal for the implementing a lessons- learned repository; it can apply the stored information to future cases. CCBR can generate a new solution that best fits the current conditions, making use of previous lessons learned. In general, a CCBR system's performance will increase with its case library size, and thus its ability to provide more accurate solutions. The more information contained within the case base, the richer the combination of patterns and the wider the range of choices from which CCBR can combine and generate a solution.

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