Maintenance and Limitations Issues of Case-Based Reasoning Technology in a Manufacturing Application

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Abstract

Case-based reasoning (CBR) technology is known for its success in help desk applications and knowledge management. CBR problem solving techniques fit in the manufacturing environment as well. The difference between the two applications is the end user. In a help desk environment, human interaction takes place with the CBR system. In a manufacturing environment the interaction is often with machines or systems. This paper describes the experience of applying CBR technology in a manufacturing application for the Chemical Monitoring and Diagnosis (CM&D) project. Chemical processing is a necessary step in aircraft part manufacturing as it can prolong the life of a machined part. A chemical processing solution, made up of different chemicals, is monitored on a given schedule. If a chemical reading is outside of its normal range, a recovery process takes place so that the chemical solution can continue to support production. Knowledge acquisition captures the experience and knowledge of expert chemical engineers for chemical solution maintenance. CBR technology manages this knowledge in case bases. The CM&D system has identified some limitations and maintenance issues of CBR technology when implemented with other system components. The paper also discusses lessons learned and future research area to provide better CBR technology support for engineering needs.

Background

A chemical processing site has buildings containing chemical tanks which resemble long, narrow swimming pools. Each tank contains a solution made from an average of four chemicals. Some tanks contain up to eight chemicals. Each of the chemicals in the solution needs to be tested at a scheduled time based on the frequency of use of the tank. For example, one chemical is tested weekly, another bi-weekly, and another monthly. The result of the test for each tank is recorded in a log sheet with information such as the test date, the tested chemical name, and the recovery action if the reading falls out of the normal range. More than 1000 chemical tests are performed each week, so there is large potential savings from the CM&D project (Chan and Lammers 1998).

When a lab technician finds a chemical reading out of the accepted range, the person will notify the chemical engineer for the required action. The chemical engineer, based on his/her knowledge, will review the chemical history log and recommend an action. This action can be adding a certain amount of a chemical, drawing some or all of the chemical solution out of the tank, or making up a fresh tank according to a given specification. Adding a chemical affects other chemicals in the solution. The chemical engineer's knowledge and experience are critical to the business process.

A system is needed to provide support for chemical lab technicians to maintain the chemical tanks, to standardize maintenance procedures, to distribute tank maintenance knowledge (Davenport and Prusak 1997) to other chemical processing sites and to provide needed data for the Federal Aviation Administration (FAA). Several database applications have attempted to address the needs of the chemical lab but did not meet the business requirements. CM&D knowledge is not well understood and will change with business process over time. CBR technology (Watson 1997) has demonstrated it can meet these requirements well. The paper discusses how CM&D knowledge was acquired, managed, and maintained in CBR, some limitations of CBR with respect to the manufacturing environment and lessons learned. Research needs are also presented.

Knowledge Acquisition

Knowledge acquisition (Tansley and Hayball 1993) took place at the manufacturing site with the chemical engineers. There are three areas of tank maintenance where knowledge acquisition is required: chemical tanks, rinse tanks, and the make-up of new tanks. Rinse tanks contain water. A machined part going through more than one chemical process requires a rinse in between.

Knowledge acquisition meetings were scheduled at least once a week, if time allowed two consecutive meetings took place. Each meeting was about 2-1/2 hours long. The discussion started from general characteristic of the tank to the specifics of each chemical in the tank solution. These meetings helped the developer understand the business process of the chemical lab so a system can be designed to automate their work process as well as manage the critical knowledge required by the business.

The average time to acquire the information needed for a single tank was two weeks or 3 to 4 meeting sessions. In the first meeting, the first 30 minutes were spent on general information about the tank. It is important to let the user talk freely with little questioning from the CBR developer. The information collected here was often what the expert thinks is important; it is information one needs to consider, even though it may not be needed by the system.

The next 1-1/2 hours were concentrated on the specifics of chemical solution maintenance. It is helpful for the interviewer to act as a CBR tool and see the interviewee as the end user. This helps to establish the requirements in the question and action cycle in the system. Each of the chemicals was discussed in detail. Because the chemical engineers document their data in log books, each entry of a particular chemical was reviewed carefully to determine a standard recommendation. A lot of the data reviewed did not fall into a consistent pattern. In this case the chemist needed to look through the history and recommend an action on a trial basis. Even an experienced chemist sometimes hesitates to suggest a specific recommendation even if promised it would be very easy to change. There was a misconception that what showed on the computer screen was the same as the external environment. A conservative action was always preferred. The chemist interviewed also admitted that it was difficult to write maintenance rules even though the process had been done many times in the past from experience.

The next 10 minutes wrapped up the tank discussion. The remaining 20 minutes was a document review or case based system demo of the information gathered from the previous session. Table 1 and 2 show examples of cases developed in CBR tool from the knowledge gathered from the chemist for a tank. The document review and system demonstration brought out some changes to the maintenance rules and sometimes additional system requirements such as the need for the FAA to audit the chemical history data, and the need to generate required forms for the business process.

The knowledge in Table 1 was implemented in this way. If case 24 succeeded, the case called for an action of adding 55 gals HNO3 and 15 gals of HF. The CM&D application would generate an Add form which contained tank information and chemical add information. The chemist would review the information; he/she could override the recommendation. If the add amount was approved, the Add form information would be stored into the database and a physical form would be sent to the shop. After the shop completed the chemical add, the shop technician would fill in the actual adds on the Add form with the completion data and remark. The database and the case base would be updated. If case 25, shown in Table 2, succeeded the system would generate a Disposal form. Business process was similar for both forms.

Case 24	
Question:	*Answer:*
Please enter the ID of the chemical tank.	Aub-M8
What test do you like to perform?	HNO3
What is the reading of HNO3?	58 to 68
What is the reading of Etch Rate?	2 to 3
Action:	
1) Add 55 gals HNO3 and 15 gals of HF.	

Table 1: A sample case showing “Add” maintenance action

Case 25	
Question:	*Answer:*
Please enter the ID of the chemical tank.	Aub-M8
What test do you like to perform?	HNO3
What is the reading of HNO3?	69 to 85
What is the reading of Ti?	Normal
What is the reading of Etch Rate?	4.8 to 5
Action:	
1) Check temperature. 2) Check HNO3 concentration, consider adding HF. • If the chemical level is high, check the chemical analysis log and either: • Dump a portion of the tank contents • Dump all of the tank contents	

Table 2: A sample case showing "Disposal" maintenance action

After the interview, the collected information was documented for system development. It was important to know what information was needed for CBR development and what was not. Again, it was helpful to think as a CBR tool. If the information needed were not there or conflicting maintenance rules were found, continued discussion with the chemist was necessary. The CM&D project faced some very difficult maintenance rule definitions when a chemical had dependencies on 3 or 4 other chemicals and one could affect the other. Some tank discussions took up to 4 meetings to complete.

Once the chemist knew the kind of information required, the meetings went faster. The goal of each meeting was to complete at least 2 tanks. Knowledge acquisition for CM&D project took 2 months in 15 meetings and covered 14 chemical tanks, 11 rinse tanks, and the make-ups of the chemical tanks.

Knowledge Maintenance

In the CM&D application, chemical tank maintenance knowledge is developed and stored in case bases. All other chemical tank data is stored in database. Case bases have to work with other components in the CM&D application. While knowledge processing technologies deal with unstructured data but technologies managing data requires structured, a parse routine has to translate the natural language representation from case base to a kind of machine language so it can be processed by the rest of the system. Those two knowledge sources must be kept synchronized and equivalent. Synchronization extends into the development cycle, especially during test. Changes to the human knowledge base are first tested in the case base system with user interaction. The case base is passed to the application for another cycle of testing. Additional time is needed to be allocated in the schedule for this.

The maintenance approach on the CM&D project is to eliminate the natural language case base input/output and maintain only the machine language case base input/output. To support this approach, tools were created to maintain and create case bases for the project. Table 3 shows an example of a machine language case. Such tools

Case 7	
Question:	*Answer:*
_HQ#HNO3_TQ#	69 to 85
_HQ#Ti_TQ#	<3.4
_HQ#Etch Rate_TQ#	2.51 to 2.8
Action:	
_HACT#_HCOND#Add_TCOND#_HRA#_HAND#_HPA#_HLST#15_SLE#gals_SLE#HF_SLE#_TLST#_TPA#_TAND#_TRA#_TACT#	

Table 3: An example of a machine language case

are typically out-of-scope of the existing CBR technique. The CM&D approach is possible because the chemical processing domain knowledge is broad but not extremely complex. Further research is needed to determine if the CM&D approach can be applied to other knowledge domains where a similar architecture is needed.

Since CBR component is only one component of a complete application, the CBR case base must also be synchronized with respect to the database in the application. For example, if a chemist's knowledge about a tank changes, then those changes impact the data in the database may also affect the case bases.

The project's approach is to handle all knowledge maintenance in a single tool which will coordinate and synchronize change. Currently, there are few CBR techniques and tools for integrating with non-CBR knowledge sources. This is an area which needs further research.

CBR Limitations

Usually, CBR tools require human interaction. A user describes the problem to the CBR system, the system provides a list of questions related to the problem for the user to answer. After the user gives the answers to the questions, another list of question is presented for the user to answer. This iteration goes on several times until the user's response triggers an action.

In the CM&D application, CBR is not a stand-alone system, but a component of a larger application. To perform its function, it must communicate with other components, not directly with a human user. This architecture has a major impact on the application of the CBR technique and management of knowledge. The compilation of input/output from/to a machine-readable form is needed. CBR technology is limited here because there are few techniques and tools to perform this step.

Lessons Learned

Unlike a help desk system which is usually a stand-alone application with a human end user, an engineering application often requires integration with other systems to support a business process. While CBR tools provide a superior user interface feature for the human end user, they are limited when integrating with other systems. Additional work such as formal language input and output needs to be defined.

The CM&D system applied CBR technology in the manufacturing environment demonstrated the basic functionality and advantages of CBR. The development of CM&D system helped to automated the business process in the chemical lab. The maintenance rules for chemical tanks were standardized for the first time. CBR technology helped manage and distribute the chemist's knowledge by making it available to other organizations in the company that need the information. The project has explored CBR technology in the chemical monitoring area. Although there were some limitations discovered, continuing research and improvement of CBR tools will bring the technology to more engineering applications.

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