Lessons Learned During HVAC Installation

Ian Watson

AI-CBR

Dept. of Computer Science

University of Auckland

Auckland

New Zealand

ian@ai-cbr.org

www.cs.auckland.ac.nz/~ian/

Abstract

This paper describes the implementation of a knowledge management tool to capture and reuse the lessons learned from the installation of HVAC equipment. It has been developed as an adjunct to an existing system that uses case-based reasoning to reuse previous HVAC installation specifications and designs. The system described lets engineers recall details of installation and commissioning and operational problems with HVAC systems. The paper discusses how lessons learned support the reuse and revision processes of the traditional CBR cycle.

1 Introduction

Several papers have been presented recently describing the author's work in collaborating on the development of a case-based reasoning (CBR) system, called Cool Air, that supports the installation of HVAC (heating ventilation and air conditioning) equipment [Watson & Gardingen 1999a & b]. This system has been successfully fielded and made a significant return on its investment. It was designed with to meet several goals:

- to reduce the installation specification and quotation time from five days or more to two days,
- to reduce the margin of error built in to pricing and thereby produce more competitive quotations, and
- to reduce the burden on head office engineers in checking every detail of every specification.

The fielded system met these goals and generated an impressive return on its investment. However, although it was capturing and reusing HVAC designs and specifications it was not adequately or consistently enabling the lessons learned during design and installation to be applied. This was because the system did not proactively offer relevant lessons learned (LL) to engineers. Instead, like most LL repositories it relied on engineers actively searching for and retrieving the LL knowledge.

This paper describes simple enhancements to the Cool Air system to support the proactive delivery of LL knowledge to engineers when that knowledge is relevant thus enhancing its knowledge management (KM) role. The status of the enhancements described are currently that of a research demonstrator.

2. System architecture

Cool Air is a distributed client server system operating on the Internet. On the engineers (client) side a Java applet is used to gather the customer's requirements and send them as structured XML to the server. On the server side another Java applet (a *servlet*) uses this information to query the database (approx. 14,000 records) to retrieve a set of similar records. This process takes the original query and relaxes terms in it to ensure that a useful number of records are retrieved from the database. This is similar to the *query relaxation technique* used by Kitano & Shimazu [1996] in the SQUAD system at NEC, although as is discussed in [Watson 2000] we have improved its efficiency using an introspective learning heuristic. The Java servlet then converts the set of records into XML and sends them to the client side applet that uses a simple k-nearest neighbour algorithm to rank the set of cases.
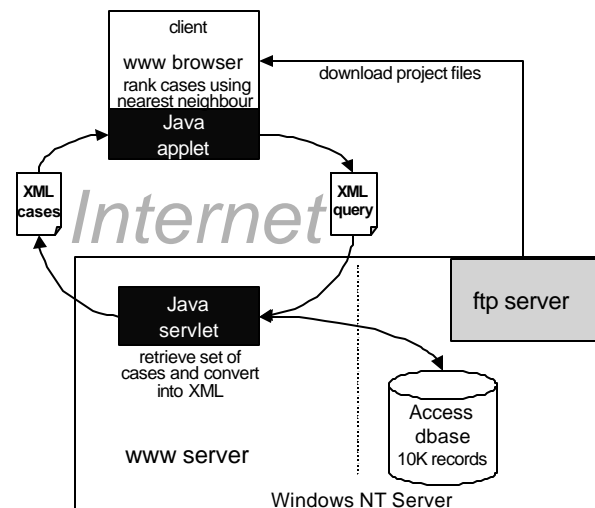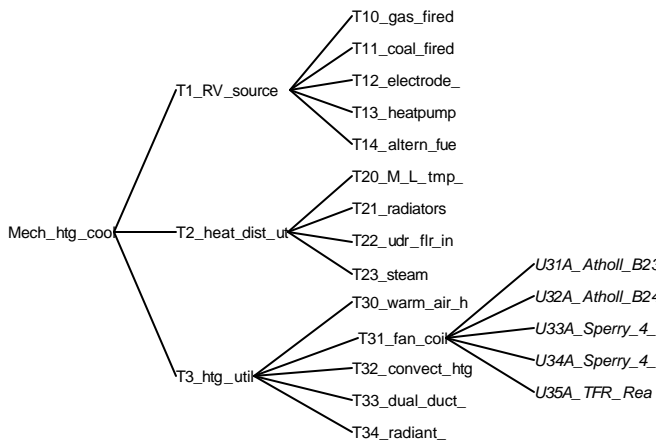

Figure 1. System Architecture

Figure 2. A Portion of a Symbol Hierarchy for Mechanical Heating & Cooling Systems

Once a matching case is retrieved the engineer obtains the installation specification files from the company FTP server. These files include CAD drawings, technical specifications, bills of quantities, contracts and notes (or *trouble tickets*) made by previous engineers describing problems with installation, commissioning and operation of the HVAC system. This requires that the engineer actively downloads, via FTP the appropriate trouble tickets and reads them. The engineer is not presented with the file name and location of trouble tickets from other similar installations, which may be relevant. Consequently the lessons learned from previous installations are not being transmitted

There are few publications referring to KM specifically in the construction industry, for example Cser et al., [1997] but there is a growing body of work about the application of CBR to KM. In particular a AAAI workshop on *Exploring Synergies of Knowledge Management and Case-Based Reasoning* [Aha et al., 1999] and a workshop at ICCBR'99 on *Practical Case-Based Reasoning Strategies for Building and Maintaining Corporate Memories* [Gresse von Wangenheim & Tautz, 1999]. This growing interest is not surprising since the recognition of similar problems and their solutions are central to both CBR

and KM. Moreover the use of the Internet as a vehicle for supporting distributed KM is becoming more common [Caldwell et al., 1999].

Figure 3 shows parts of three example trouble tickets; one describing the need to reduce noise when installing a system in a residential nursing home, another describing the true installed diameter of some ducting and the third describing a problem with a thermostat when located to far from a controller. Trouble tickets are indexed by *Code* (this refers to the job type), *Location*, *Client* (including a reference for client type) and a list of the equipment and contractors used (not shown in Figure 3). In each trouble ticket the problem and its solution are recorded. The trouble tickets are indexed in Cool Air's database by these key features, along with a file reference to the trouble ticket itself.

3 Lessons learned

The LL system offers a proactive two stage reminding. In the first stage when the set of similar installation records (typically between 10 & 20) is sent to the client all associated trouble tickets of these installations are also sent to the client. Since these installations are similar it is reasonable to assume that any problems encountered with these installations may be relevant. Engineers can peruse these and use the information gained to improve the resulting design. In CBR terms the trouble tickets are being used to inform the case reuse and case revision or adaptation processes.

Once a specification for the job is finalised the details for this new project are used to re-search the knowledge repository to obtain trouble tickets that might be relevant to the proposed job type, location, client type, equipment and contractors. This is relevant because the final *adapted* project specification may include significant variations from the cases upon which it was based and consequently it is valid to check its proposals for potential installation, commissioning or in-use problems.

Retrieval of trouble tickets uses CBR and the same abstraction hierarchies used by the query relaxation algorithm of the Cool Air system. An example hierarchy for mechanical heating and cooling equipment is shown in Figure 2. Using this hierarchy it is easy to

Figure 3. Three Sample Trouble Tickets

see that U31A Athol and U32A Athol are both types of fan coil, are similar and hence may share similar problems.

Searching is not performed on the body of the trouble ticket itself. Like many CBR systems Cool Air is featured based and it does nor perform textual case-based reasoning [Ashley 1999]. Neither are trouble tickets retrieved using an iterative conversational CBR process [Aha & Breslow 1997] However, the possibility of using either textual CBR, conversational CBR or both is being looked at as a possibility for future research.

During the installation and commissioning of the HVAC system engineers will be encouraged to create trouble tickets using simple web-based forms. Once the project reference number is known all the relevant indexed features can be automatically added to the trouble ticket. Leaving the engineer free to concentrate on the body of the trouble ticket. Through the forms interface they will be encouraged to consider both the trouble encountered and the eventual solutions.
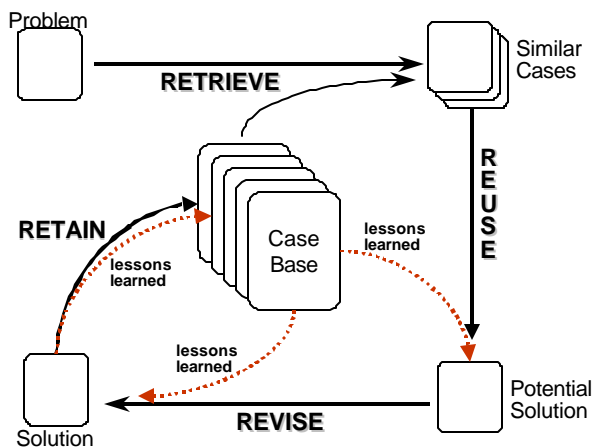

Figure 4 Lessons Learned & the CBR Cycle

4 Conclusions

The first stage of the LL enhancements to the Cool Air system have undergone limited testing in the field and received qualified support. The second stage has not been field tested yet although it has performed satisfactorily in the laboratory. However, I do not underestimate the significant management problems associated with the successful operation of an LL system. Primarily these centre not upon the technology itself, which performs satisfactorily, but upon the management of the process [Davenport, 1997]. Put simply, not all engineers take the time to record problems and their solutions regarding this activity as a non-value adding task or at worst a threat to their experience and value to the company. These issues, as many commentators have noticed, are as important to KM as the technology itself.

However, CBR has proven itself useful in the retrieval of LL knowledge and moreover, in an interesting synergy, the LL

knowledge is useful in guiding both the reuse and the revision or adaptation processes of CBR. This is illustrated in Figure 4, which shows how LL knowledge first informs the selection of a past case upon which to base the subsequent solution and then secondly can be used to anticipate problems with that that solution.

References

Aha, D., Becerra-Fernandez, I., Maurer, F. & Munoz-Avila, H. (1999). Exploring Synergies of Knowledge Management and Case-Based Reasoning. AAAI Workshop Technical Report WS-99-19. AAAI Press

Aha, D. & Breslow, L.A. (1997). Refining conversational case libraries. In, Proc. 2nd. Int. Conf. On Case-Based Reasoning, pp. 267-78. Springer-Verlag.

Ashley, K. (1999). Progress in Text-Based Case-Based Reasoning. Invited talk at the 3rd. Int. Conf. On Case-Based Reasoning. Online (March 2000): www.lrdc.pitt.edu/Ashley/TalkOverheads.htm

Gresse von Wangenheim, C. & Tautz, F. (1999). Practical Case-Based Reasoning Strategies for Building and Maintaining Corporate Memories. Online (March 2000): www.eps.ufsc.br/~gresse/call_ws2.html

Caldwell, N.M.H., Rodgers, P.A. and Huxor, A.P. (1999). Web-Based Knowledge Management for Distributed Design, IEEE Intelligent Systems, September, 1999.

Cser, J., Beheshti, R. and van der Veer, P. (1997). Towards the development of an integrated building management system, Proceedings of the Portland International Conference on Management & Technology Innovation in Technology Management - The key to Global Leadership, PICMET.

Davenport, T. (1997). Information Ecology: Mastering the Information and Knowledge Environment: Why Technology is not enough for Success in the Information Age, Oxford University Press, 1997

Kitano, H., & Shimazu, H. (1996). The Experience Sharing Architecture: A Case Study in Corporate-Wide Case-Based Software Quality Control. In, Case-Based Reasoning: Experiences, Lessons, & Future Directions. Leake, D.B. (Ed.) pp.235-268. AAAI Press/The MIT Press Menlo Park, Calif., US.

Watson, I. (2000). A Case-Based Reasoning Application for Engineering Sales Support using Introspective Reasoning. In Proc. IAAI 2000. Austin Texas. AAAI Press. Forthcoming.

Watson & Gardingen, D. (1999). A web-based CBR system for heating ventilation and air conditioning systems sales support. Knowledge Based Systems Journal, Vol. 12 Nos. 5-6, pp.207-214.

Watson, I. & Gardingen, D. (1999). A Distributed Case-Based Reasoning Application for Engineering Sales Support. IJCAI'99 31st. July - 6th August 1999, Vol. 1: pp. 600-605. Morgan Kaufmann Publishers Inc.