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Fielded applications of case-based reasoning

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Abstract

This commentary describes notable commercial applications of case-based reasoning, including systems that have been in continuous profitable use for over a decade. It is divided into sections on engineering applications, help-desk applications and on-line case-based reasoning.

1 Engineering applications of case-based reasoning

The purpose of this review is not to list all commercially fielded case-based reasoning (CBR) systems, (even as far back as 1997 over 130 major companies worldwide were fielding CBR applications (Watson, 1997)), but rather to highlight some particular milestones in the commercial application of CBR. Many techniques or methods derived from AI research seem to spend decades in the laboratory producing research prototypes before ever being fielded for commercial or societal benefit. This was not the case for CBR. Even while CBR was still in its infancy, applications of CBR were being successfully fielded. In 1987, as DARPA started its funding of the US CBR community, work started at the Lockheed Missiles & Space Company in California on a system that was to become one of the first and most influential CBR systems.

Lockheed's CLAVIER (Hinkle & Toomey, 1994) is an interesting system for several reasons. Firstly, it replaced a manual system that was inherently case-based (this is a common property of many successfully fielded CBR systems). Secondly, it supported all aspects of the CBR cycle (retrieval, reuse, revision and retention). Finally, CBR was turned to only as a last resort; Lockheed had tried to use mathematical modelling and expert systems methods but had failed. CLAVIER, which advises engineers on layouts of composite parts in large autoclave curing ovens, is notable for the simplicity of the system as its case representation only records the approximated geometric shape of the parts, their relative positions in the autoclave and the settings of the autoclave. Much seemingly vital information, such as composite makeup and resin chemistry, is totally ignored. Finally, CLAVIER was successful because "it has been in continuous daily use…since September 1990…saving thousands of dollars each month" (Hinkle & Toomey, 1994). CLAVIER was important to the CBR community because its well-documented success gave confidence to others to try this new problem solving method.

Another fielded engineering application of CBR was created by Snecma Services, a subsidiary of the engine manufacturer Snecma. Jointly with General Electric aircraft engines, Snecma has developed the CFM56-3 engine that equips all Boeing 737s. To reduce maintenance costs, an innovative project called Cassiopee (Heider, 1996) was led by the CBR company Acknosoft (now called Kaidara International). Troubleshooting represents about 50% of airplane downtime, and the main goal was to halve the time required for diagnosis, which means an overall reduction of 25% in downtime. It uses a combination of CBR and fault trees, either trees derived from the Boeing maintenance manual or decision trees generated from the stored cases. CBR is then used to retrieve similar cases so that solutions to problems can be found faster than they would be by going through the diagnostic steps of the manual. The system is linked to the illustrated spare parts catalogue and to relevant electronics technical documentation. It enables airlines to share troubleshooting experience worldwide. As a manufacturer, Snecma can validate the technical content of the reported cases and regularly update the case base by means of CD-ROM. Cassiopee is one of several systems, including Homer (Göker & Roth-Berger, 1999) and

SIMANTIC (Lenz *et al*., 1998), that informed the development of the INRECA methodology for engineering CBR applications (Bergmann *et al.*, 2003).

A third successfully fielded application of CBR had a goal of diagnosing locomotive faults (Varma & Roddy, 1999). Each locomotive has many sensors. When a sensor or group of sensors reaches or exceeds a set value a fault message is generated. ICARUS (Intelligent Case-based Analysis for Railroad Uptime Support) has a case base where each case was a locomotive repair action and the set of faults for that locomotive in the time preceding the repair action. New sets of fault messages were compared with the historical cases to determine probable causes for the faults and repair actions to correct the cause of the faults. ICARUS was fielded in 1997 and has been in constant use since that time.

2 Help-desks and customer support

Applications such as CLAVIER, Cassiopee, and ICARUS firmly established CBR as applicable to engineering and technical domains. However, it was an application of CBR within customer services that proved to be one of the most commercially profitable areas for CBR. During the 1990s we all became increasingly familiar with the use of customer call centres and calling the "800 number" for tech support. Compaq computers (now a division of HP) aimed to "elate every customer by being accessible, responsive, enthusiastic, courteous, helpful and caring" (Acorn & Walden, 1992) while at the same time cutting margins. Prior to March 1991 Compaq dealt only with dealerships and their staff, while after this date their engineers became "customer facing" 24x7. To satisfy the demand for tech support Compaq implemented a help-desk application called SMART (Acorn & Walden, 1992). Handling call logging and routing at the heart of SMART was a CBR system for technical diagnosis that enabled technically untrained customer service representatives to resolve over 95% of customer calls (the remainder were escalated to engineers). The CBR system developed by Inference Corporation (Inference was purchased by eGain) was a conversational case retrieval system. Such systems became the technology of choice for customer service centres of companies like Thompson Consumer Electronics (Thomas *et al*., 1997) and General Electric (Cheetham, 2003a).

Help-desk applications of CBR evolved into self-service applications with the wide uptake of the web in the mid 1990s. Broderbund Software (the makers of games like MYST) along with Inference implemented a web server version of their helpdesk software (Watson, 1997). For the first time, over Christmas 1995, customers could access a tech support web site and directly query a case base to resolve their problems. Such applications are now commonplace but it is interesting to note that this innovation did not come out of an academic research lab but rather out of a direct commercial need (i.e., to reduce the number of customer support staff required over the busy and expensive Christmas holiday period).

A further innovation was the use of CBR for corporate knowledge management. SQUAD (Kitano & Shimazu, 1996) at the NEC corporation provided support for software quality control to employees rather than external customers. A corporate-wide case base was developed using database technology serving 150,000 employees.

3 Case-based reasoning on-line

The use of the Internet as a medium for distributing CBR applications was highlighted by an application for estimating the cost of residential air conditioning systems in Western Australia (Watson & Gardingen, 1999). This system distributed the retrieval process between client and server side applets in a two-stage retrieval process that used an SQL retrieval technique (derived from SQUAD) and a k-nearest neighbour algorithm. The paper, which won a Distinguished Paper Award at IJCAI'99, also detailed the development costs and return on investment of the project. However, probably the most well documented fielded CBR system is the plastic colour matching system at GE. A series of papers from (Cheetham & Graf, 1997), which won a Best Paper Award at ICCBR'97, to (Cheetham, 2004) described the creation, costs, benefits, and evolution of an industrial CBR application for selecting a recipe of pigments that match a customer's requested colour. This tool, called FormTool, has been in use at multiple GE Plastics

sites around the world since 1994 and saved GE millions of dollars in productivity improvements and pigment costs each year. The technology developed in FormTool has been used to create an on-line self-service colour selection tool for customers called ColorXpress Select and a plastic grade selection tool that helps select which of GE's 2000 types of plastic best match a customers physical requirements for the plastic (Cheetham, 2003b).

4 Conclusion

CBR has become a standard solution in to many commercial problems in a wide range of engineering applications. Early applications included help-desks and customer support. Recent applications include product recommendation in e-commerce. The other commentaries in this issue (e.g., medical, legal, knowledge management) describe ways that CBR can be applied.

References

Acorn, T.L., & Walden, S.H., 1992. SMART: Support management cultivated reasoning technology for Compaq customer service. In, *Innovative Applications of Artificial Intelligence 4, Proceedings of AAAI-92*, edited by S. Scott & P. Klahr. Cambridge, MA: AAAI Press/MIT Press.

Bergmann, R., Althoff, K.-D., Breen, S., Göker, M., Manago, M., Traphöner, R. & Wess, S., 2003. Developing Industrial Case-Based Reasoning Applications: The Inreca Methodology. *Lecture Notes in Computer Science*, Vol. 1612. Springer-Verlag, Berlin.

Cheetham, W., & Graf, J., 1997. "Case-Based Reasoning in Colour Matching" *Lecture Notes in Computer Science*, Vol. 1266. pp.1-12. Springer-Verlag, Berlin.

Cheetham, W., 2003a. "Lessons Learned using CBR for Customer Support" *The 16th International FLAIRS Conference*, St. Augustine, pp.114-118. Florida, May 12-14.

Cheetham, W., 2003b, "Global Grade Selector: A Recommender System for Supporting the Sale of Plastic Resin" *Lecture Notes in Computer Science*, Vol. 2689. pp.96-106. Springer-Verlag, Berlin.

Cheetham, W., 2004. "Tenth Anniversary of Plastics Colour Matching" *The Sixteenth Conference on Innovative Applications of Artificial Intelligence*, pp.770-776. San Jose, California.

Göker, M. & Roth-Berghofer, T. 1999. "The Development and Utilization of the Case-Based Help-Desk Support System HOMER", *Engineering Applications of Artificial Intelligence*, Volume 12, Issue 6, pp. 665-680, Elsevier Science.

Heider, R., 1996. Troubleshooting CFM 56-3 Engines for the Boeing 737 Using CBR & Data-Mining. In, *Advances in Case-Based Reasoning*, Smith, I. & Faltings, B. (Eds.), pp.513-18. Lecture Notes in AI 1168, Springer.

Hinkle, D., & Toomey, C., 1995. "Applying Case-Based Reasoning to Manufacturing" *AI Magazine* 16(1): 65-73

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.). AAAI Press / MIT Press, Cambridge, MA.

Lenz, M., Hübner, A. & Kunze, M. 1998. Textual CBR. In: Case-Based Reasoning Technology From Foundations to Applications. Lenz, M., Bartsch-Spörl, B. & Burkhard, H.-D., & Wess, S. (eds.). *Lecture Notes in Computer Science*, Vol. 1400, Chapter 5, Springer-Verlag, Berlin.

Thomas, H., Foil, R.,& Dacus, J., 1997. "New Technology Bliss and Pain in a Large Customer Service Center" *Lecture Notes in Computer Science, Vol. 1266*. Springer-Verlag, Berlin Heidelberg New York. pp. 166-177.

Varma, A., & Roddy, N., 1999. "ICARUS: A Case-Based System for Locomotive Diagnostics" *Engineering Applications of Artificial Intelligence*. vol. 12, no. 6, pp.681-690. Elsevier Science.

Watson, I., 1997. *Applying Case-Based Reasoning: Techniques for Enterprise Systems*. Morgan Kaufmann Inc., San Francisco, CA.

Watson, I., & Gardingen, D., 1999. "A Distributed Case-Based Reasoning Application for Engineering Sales Support" *in the Proceedings of the 16th International Joint Conference on Artificial Intelligence (IJCAI-99)*, Vol. 1: pp.600-605. Morgan Kaufmann Inc., San Francisco, CA.