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Integrations with case-based reasoning

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Abstract

This commentary succinctly summarizes work in integrating case-based reasoning (CBR) with other reasoning modalities. Including CBR in mixed mode approaches promotes synergies and benefits beyond those achievable using CBR or other individual reasoning approaches alone. Numerous examples of hybrid systems, with pointers to significant references, are provided.

1 Introduction

Case-based reasoning (CBR) has been successfully integrated with other reasoning modalities in multimodal reasoning (MMR) systems. The approaches most frequently integrated with CBR are rule-based reasoning (RBR), model-based reasoning (MBR), constraint satisfaction problem (CSP) solving, information retrieval (IR) and planning approaches. Tasks that seem especially amenable to MMR include interpretation, argumentation, design, synthesis and planning. Among the benefits attributed to using CBR in MMR systems are: more accurate modeling of domain knowledge; compensation for the lack of complete domain models; simplification of the knowledge acquisition process; improved solution quality; improved explanatory power; improved run-time efficiency; leveraging of past problem-solving experiences; and compensation for the shortcomings of one approach through use of the strengths of another (Aha & Daniels, 1998; Rissland & Skalak, 1991). Early forums for discussing and disseminating work on MMR were the *1998 AAAI Workshop on Case-Based Reasoning Integrations* (Aha & Daniels, 1998) and the *1998 AAAI Spring Symposium on Multimodal Reasoning* (Freuder, 1998). A comprehensive overview and survey of CBR integrations is available in Marling *et al.* (2002). In this commentary, we briefly summarize the state of the art in CBR integrations and provide pointers to the literature for the interested reader.

2 CBR integrations

2.1 Integration with rule-based reasoning

The first reasoning modality to be successfully integrated with CBR was rule-based reasoning. The earliest CBR/RBR systems were built for statutory legal domains, where statutes naturally correspond to rules and legal precedents naturally correspond to cases. CABARET used a rule-based agenda mechanism to integrate past cases with legal regulations in the domain of United States tax law (Rissland & Skalak, 1991). CABARET pioneered a domain-independent architecture in which there are independent CBR and RBR co-reasoners, each of which monitors and

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communicates its own processing and results, and an agenda-based controller that proposes and prioritizes tasks for the two co-reasoners. Another early legal system, GREBE, integrated CBR and RBR to determine and justify legal conclusions for cases in the area of Texas employment law (Branting, 1991). IKBALS operated in the domains of Australian worker disability law and lending by financial institutions (Zeleznikow *et al.*, 1994). This system also integrated information retrieval techniques to give users access to legal treatises.

CBR/RBR hybrids have since proliferated, in diverse domains and applications, ranging from planning nutritional menus (Marling *et al.*, 1999) to harmonizing melodies (Sabater *et al.*, 1998). ANAPRON integrated CBR and RBR for speech synthesis in pronouncing American surnames (Golding & Rosenbloom, 1991). This system used CBR to increase the accuracy of a primarily RBR system by handling exceptions to pronunciation rules. SaxEx integrated background musical knowledge into a primarily CBR system for generating expressive musical performances (López de Mántaras & Arcos, 2002). In SaxEx, cases are musical scores with their associated expressive parameters, and rules are used to retrieve and adapt cases.

2.2 Integration with model-based reasoning

Model-based reasoning was first combined with CBR in CASEY, a medical application that employed actual patient cases and a physiological model of the human heart to diagnose heart failures (Koton, 1988). CASEY was noted for achieving superior system efficiency compared to what was possible using the physiological model alone. Protos, another early system, used a multi-relational model of the knowledge used to diagnose auditory diseases to improve case retrieval. Two case features could be determined to be similar if a sufficiently strong relational path connecting the two features was found in the domain model (Porter *et al.*, 1990). A more recent CBR/MBR hybrid, CARMA, provides advice to ranchers to assist in the management of grasshopper infestations (Hastings *et al.*, 2002). It combines numeric models developed by entomologists with historic cases of infestations. This system has been used by Wyoming ranchers since 1996. FABEL integrates CBR, MBR and RBR to assist architects and civil engineers with architectural design (Gebhardt *et al.*, 1997). It contains several independent problem solvers, some case-based, some model-based and some rule-based. Another system to incorporate CBR, MBR and RBR is T-IDDM, which provides decision support for managing patients with Type I diabetes (Montani *et al.*, 2003). FormTool is a commercially fielded CBR/MBR hybrid that generates formulas for coloring industrial plastics at General Electric (Cheetham & Graf, 1997). CREEK is a framework for building knowledge-based systems that seamlessly integrate CBR with MBR (Aamodt, 1994, 2004). In CREEK, cases are embedded within a general domain model in order to capture and exploit both general domain knowledge and specific cases.

2.3 Integration with constraint satisfaction problem solving

Constraint satisfaction problems (CSPs) are solved by finding values for variables that meet given criteria for acceptable combinations of values. The first CBR/CSP hybrids were CADSYN, which used design constraints for case adaptation to generate structural designs for buildings (Maher & Zhang, 1991), and JULIA, which used a constraint propagator to identify and resolve constraint violations in planning meals for groups of diners (Hinrichs, 1992). CHARADE combines CBR and CSP for handling emergencies in fighting forest fires (Avesani *et al.*, 1993). Here, CBR is used to quickly assess emergency situations and CSP is used to determine how to best exploit available resources to handle the emergency. COMPOSER solves assembly sequence and configuration design problems (Purvis & Pu, 1996). In COMPOSER, cases are represented as CSPs and standard CSP techniques are used to adapt cases. ADIOP diagnoses interoperability problems in asynchronous transfer mode (ATM) networks (Sqalli & Freuder, 1998). This system models a diagnostic problem as a CSP, and uses CBR to compensate for incompleteness in the CSP model.

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CADRE combines CBR and CSP to assist with the design of architectural floor plans (Faltings, 1996; Hua & Faltings, 1993). In CADRE, cases represent buildings, and constraints aid in dimensional and topological adaptation of cases. IDIOM composes apartment layout designs, relying on interaction with designers for design interpretation as well as on CBR and CSP (Smith *et al*., 1995).

2.4 Integration with information retrieval

CBR has been integrated with information retrieval to enable the retrieval of useful text documents in large, unstructured document collections. SPIRE lets users retrieve documents from a large legal corpus, without having to specify formal queries (Rissland & Daniels, 1996). It uses a case-based analysis to drive an IR engine to generate a standard query through relevance feedback using the most important cases of legal documents and passages. The Stamping Advisor assists feasibility engineers in evaluating designs for stamped metal automotive parts at Ford (Leake *et al*., 1999). Past part designs, along with their associated design problems and solutions, are the cases in this system. IR is used in the Stamping Advisor to assist in retrieving company guidelines relevant to the design at hand. CARE-PARTNER integrates CBR, RBR and IR to assist clinicians with the long-term follow-up care of cancer patients who have undergone bone marrow transplants (Bichindaritz *et al*., 1998). Here, cases contain patient specific problems and solutions, rules encode standard practice guidelines, and IR provides clinicians with relevant documents from the medical literature to support evidence-based clinical practice.

2.5 Integration with planning

To solve planning problems, CBR has been integrated with both STRIPS-style planning and hierarchical planning. PRODIGY/ANALOGY was the first system to combine CBR with STRIPS-style planning (Veloso, 1994). PRODIGY/ANALOGY is a domain-independent generative planner that uses cases to guide search, improving efficiency over traditional first-principles planning. It implemented the concept of *derivational analogy*, which allows problem-solving processes, rather than specific problem solutions, to be reused. The Joint Maritime Crisis Action Planning (JMCAP) system integrates CBR with hierarchical planning for military operations (desJardins *et al*., 1998). JMCAP integrated past maritime crisis action planning experience with an existing hierarchical task network in order to more closely model human planning processes. The Hierarchical Interactive Case-Based Architecture for Planning (HICAP) system is another military system that integrates CBR with hierarchical planning (Muñoz-Avila *et al*., 1999). This domain-independent system was tested on planning non-combatant evacuation operations, which remove non-military personnel from dangerous situations. HICAP combines experiences from past military operations with general military planning guidelines and standard operational procedures.

3 Conclusions

Integrations of CBR with other reasoning modalities continue to proliferate, providing both practical benefit and insight into multi-modal reasoning processes. Hybridization is fast becoming the standard, rather than the exception for CBR systems, owing to user expectations as well as to technical advantages. As institutions and individuals come to depend on electronic medical records, online legal corpuses, e-commerce product databases and other electronic resources, interoperability and synergistic reasoning combinations become increasingly important and necessary.

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