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Eighth Workshop on the Validation and Verification of Knowledge-Based Systems

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■ The Workshop on the Validation and Verification of Knowledge-Based Systems gathers researchers from government, industry, and academia to present the most recent information about this important development aspect of knowledge-based systems (KBSs). The 1995 workshop focused on nontraditional KBSs that are developed using more than just the simple rule-based paradigm. This new focus showed how researchers are adjusting to the shift in KBS technology from stand-alone rule-based expert systems to embedded systems that use object-oriented technology, uncertainty, and nonmonotonic reasoning.

The Eighth Workshop on the Verification and Validation of Knowledge-Based Systems was held in conjunction with the Fourteenth International Joint Conference on Artificial Intelligence (IJCAI-95) in Montréal, Québec, Canada. As knowledge-based systems (KBSs) have changed in their application and development techniques, the question of how to establish confidence in a KBS continues to remain important. The theme of this year's workshop was the changes in the development, use, and characteristics of KBSs. The papers can be partitioned loosely into the verification of three categories of KBSs: (1) hybrid, (2) embedded and integrated, and (3) traditional.

Today, KBSs are often built using multiple programming paradigms, such as object oriented and neural network, which can be combined with the rule-based programming paradigm for more robust systems. These systems can be nonmonotonic or provide for uncertainty in conclusions. Researchers at the workshop are concerned with verifying the first category of KBSs, *hybrid KBSs*. This research encompasses work in changing the development cycle of the KBS to make the product and process easier to verify and validate.

In "Specification Refinement of Object-Oriented KBSs," A. Vermesan (Foundation for Research in Economics and Business Administration, Norway) looks at KBSs that perform reasoning in a framework of structured objects. Her approach is to verify that as details are added to the specification of a KBS, these additions are consistent with the initial abstract specification. Thus, Vermesan's approach is to verify a hybrid KBS as part of the formal development process. The paper describes a model of object-oriented KBSs using algebraic specifications that focus on design. P. Chander, R. Shinghal, and T. Radhakrishnan (Concordia University, Canada) also approach verification and validation as an integral part of the KBS life cycle in "Goal-Supported Knowledge Base Restructuring for Verification of Rule Bases." In this paper, Chander and his colleagues incorporate the knowledge-acquisition process into the verification and validation process by specifying the expert information as a goal-to-goal progression of the system. Looking at a more traditional rule base system, they portray the progression in a graph. Using the goal specifications, they can easily extract paths from the graph to perform a variety of evaluations on the system progression.

Although traditional rule-based systems have been studied heavily in terms of verification and validation, hybrid KBSs made up of multiple programming paradigms are a topic of research that has only recently been investigated. In "Critical Examination of Subsumption Anomalies in Hybrid Systems," R. Mukherjee and R. Gamble (both of University of Tulsa) research the previous verification work performed on hybrid systems and extend this work to better detect KBS anomalies. Their paper deals with hybrid systems that integrate the object-oriented and rule-based paradigms. Mukherjee and Gamble improve on the verification of hybrid KBSs by thoroughly detecting the problems that arise with inheritance in such KBSs. The problems arise when rules perform actions given information about a class as well as information about a subclass of the class.

Other types of hybrid KBS that require research are those that allow for uncertainty in the knowledge. In "Rule Base Coverage Measures Applied to Testing Rule Bases with Uncertainty," V. Barr (Polytechnic University) develops a system for testing the dynamic computation of rule bases with certainty factors. The system is combined with a traditional verification and validation system to cover multiple aspects of KBS testing. The system uses a directed acyclic graph similar to that of the group from Concordia University to structure the rule base and proposes ways to guide the testing by determining appropriate test data. The certainty factor combination method used by the rule base being tested is placed in the coverage algorithms used to traverse the graph. T. Terano and K. Kobayashi (both of University of Tsukabu, Japan) also examine rule bases with uncertainty in "Changing the Traces: Refining a Rule Base by Genetic Algorithms." They use genetic algorithms to improve the performance of a propositional KBS by detecting and correcting errors caused by inadequate certainty factors. Terano and Kobayashi's system automatically refines a rule base from a small amount of test data. This refinement is performed by maintaining traces of rule executions and applying genetic operations to improve the rule traces and the certainty factors associated with the rules.

The final type of hybrid system that was considered at the workshop is the nonmonotonic KBS, which incorporates default logic into the rule-based reasoning. N. Zlatareva (Central Connecticut State University) investigates logical inconsistencies, structural incompleteness, redundancies, and intractabilities in "Verification of Non-Monotonic Knowledge Bases." The study is based on the premise that a belief-revision facility, such as a truth maintenance system, joined with a KBS might not succeed in recovering the possible knowledge base problems investigated and that new semantic errors can be introduced through nonmonotonic reasoning. Zlatareva extends her previous research in contradiction-tolerant truth maintenance systems for distributed verification of nonmonotonic KBSs. Also presenting research on nonmonotonic KBSs was G. Antoniou (University of Newcastle, Australia). In "Integrity and Rule Checking in Non-Monotonic Knowledge Bases," Antoniou focuses on extending established verification and validation techniques for rule-based systems to perform integrity checks and rule checks on rule-based KBSs that incorporate default logic. His techniques check rule pairs against default instances that are incorporated into the reasoning mechanism. An important aspect of the work is the modification of the underlying monotonic inference relation to capture the fact that rules can only forward chain.

Current KBSs have changed in their underlying use and characteristics. For example, knowledge reuse and combination have become important when building KBSs. In addition, KBSs can be embedded in other software systems in which they must react to changing situations that can be critical. Because of this thrust, researchers are investigating ways to combine different KBSs or portions of a KBS that have been developed by different experts such that they are verifiable. W. Gambetta (University of New South Wales, Australia) addressed the second category of KBS, *embedded and integrated KBSs*, in "Obtaining a Compromise View: Verification and Validation Problems in Integrating Knowledge Bases." The focus of this research is on the understanding that different KBSs can use different ontologies to describe their concepts, such as with the viewpoints of different experts. The verification goal is to develop a model that covers the maximal-compromise viewpoint. Gambetta attempts to verify the consistency of the expert knowledge and the difference in terminology between experts by developing an ontology tree for each viewpoint and connecting them to form one tree. Once a single-ontology tree is constructed, more traditional verification and validation using dependency graphs can take place.

Additional research in developing formal methodologies for integrating KBSs with conventional software was presented by P. Kiss (Sentar), R. Lewis (Quality Research), and R. Plant (University of Miami) in "Quick Planner for Verification and Validation of Distributed Hybrid Systems." This team assessed the existing methodologies and models for developing KBSs and constructed an overall framework for integrating conventional and KBS software into a single distributed system. Within this framework, they have begun to build a verification and validation methodology for the integrated system called the QUICK PLANNER.

Verification is much easier to perform on small KBSs. In this regard, M. Mehrotra (Pragati Synergetic Research) looks at ways to manipulate very large KBSs into smaller components for verification and validation. In the final paper in this category, "Requirements and Capabilities of the Multi-Viewpoint Clustering Analysis Methodology," Mehrotra discussed the development of a tool that discovers multiple, significant structures within large homogeneous KBSs. The premise is that no one single viewpoint is sufficient to comprehend a complex KBS. The clustering tool groups rules that share common properties and identifies the concepts that underlie these groups using a two-phase approach: (1) cluster generation and (2) cluster analysis. One important use of the tool is in embedded KBSs such that, when given the proper input, clustering can detail which rules are implicitly connected through side effects in external routines.

Although KBSs have undergone many changes over the years, the rule-based programming paradigm is still prevalent. Thus, researchers continue to more deeply investigate issues in the third category of KBSs: *traditional rule-based systems*. As more techniques are developed, the KBS verification and validation communities look forward to their scalability and extension to more complex KBSs.

In "Inference Engine Greediness and Subsumption of Conditions in Rule-Based Systems," D. O'Leary (University of Southern California) investigates the need for additional verification testing on a KBS when a greedy inference strategy is used. Traditional verification and validation of KBSs does not consider different inference strategies. O'Leary focuses on subsumption anomalies, detailing how they are affected with respect to greediness and how the anomalies that are detected can be corrected. Often, researchers find that anomalies previously found in the verification of a KBS are applicable in a setting where a structure similar to a KBS is used. In "Applying Rule Base Anomalies to KADS Inference Structures," F. van Harmelen and M. Aben (both of University of Amsterdam, The Netherlands) determine that many of the same anomalies found in a developed KBS can be found in the KADS inference structures. These inference structures comprise inference steps and knowledge roles. Each knowledge role represents some domain knowledge, and each inference step represents the relation between input knowledge roles and output knowledge roles. van Harmelen and Aben represent an inference step as an analog of a rule, reformulating the inference step to detect known KBS verification and validation anomalies.

The final two papers in this category are theoretical in nature. In "A Tool for Testing Confluence of Production Rules," J. Schmolze (Tufts University) and W. Synder (Boston University) use rewrite rule systems to investigate their connection to KBSs. In particular, they have developed a tool that automatically tests a KBS for confluence. *Confluence* is a property of rewrite rule systems that, when combined with termination, guarantees that unique results are obtained by the system independent of the order in which the rules execute. The primary reason for this investigation is that these KBSs are easier to verify because many verification techniques apply to a KBS that is both confluent and terminating. L. Laita (Univ. Politécnica Madrid, Spain) and E. Roanes-Lozano (Univ. Complutense Madrid, Spain) construct a Boolean algebra that is associated with a propositional KBS in "Verification of Knowledge-Based Systems: An Algebraic Interpretation." The algebra allows for the effects of adding rules, facts, and constraints to the KBS so that consistency is maintained. Their algebraic approach allows them to verify a KBS using REDUCE.

There were two panel sessions at the workshop. The first panel session presented information on access to KBS verification and validation resources. O'Leary led the panel that included details about a discussion list, VaVTalk, that researchers can join by sending e-mail to vavtalk@cenparmi.concordia.ca. Collections of papers in this area can be found in O'Leary (1994), Preece and Suen (1993), Gupta (1991), and Culbert (1990).

The second panel session closed the workshop with a discussion of the future of the verification and validation of KBSs. Practically, mature tools are needed that can be commercialized. However, it was agreed that formal methods of specification and modeling are also needed to verify complex KBSs used in critical domains. Additional research is needed in this area and its integration into the KBS life cycle.

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