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Survey of Logics used for Knowledge Representation and Reasoning

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ABSTRACT

The current paper is a survey on various types of logic used for knowledge representation and reasoning. Knowledge representation uses symbols to represent knowledge. Any manipulation can be done in automated manner by reasoning systems. The reasoning system uses knowledge base (Knowledge Representation) to do manipulation effectively and automatically. In this paper, the suitability of every logic in typical application is highlighted. Logics such as propositional, temporal, modal, temporal and causal logics are analyzed. Each and every logic is highly suitable for specific applications and may not be suitable for some other application.

Keywords: Artificial Intelligence, Propositional, First-order, Modal, Temporal, Causal, Directed Acyclic Graphs

1. INTRODUCTION

Knowledge Representation in Artificial Intelligence (AI) means representing information in computer and developing algorithms that help in understanding the knowledge. Computer scientists have used the top-down approach for understanding knowledge rather than the bottom-up approach, as the former is easier to represent in a computer.

Logics have lot of applications in knowledge representation and reasoning. Propositional logic is used in theorem provers and program verifiers. Temporal logic has applications in time series data such as stock price in stock exchanges etc. Modal logic is extensively used in linguistics. Causal logic has wide applications in establishing causal relationships between variables in statistics and inference in medical domain.

2. TYPES OF LOGIC

2.1. Propositional Logic

Propositional logic is the study of propositional connectives. The five different operators used in propositional logic are negation(7), conjunction(Ë), disjunction(V), implication(⇒) and equivalence(?). Negation is placed prior to operand as it is a unary operator. Since the other operators are binary, they are included between the operands. In propositional logic, we create formal objects called propositional formulae.

The propositional variables are used as building blocks to represent elementary formulae. The elementary propositions are assembled using connectives. The formulae appear as assembled set of symbols.

One of the latest researches on propositional logic is in belief revision [1-3]. Belief revision is the method used for changing beliefs to consider new pieces of information and is used in databases and in artificial agent in the design of rational agents. The investigation of conviction change inside of dialect sections is roused by two perceptions:

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For example, a rule-based formalization of expert knowledge can be handled easily by users belonging to the same domain. Only when the output is in easy-to-read format, the users can make changes in the rules given.

A lot of beliefs in propositional logic let us use very good algorithms for reasoning. If the agent poses questions several times about the same belief, the belief can be stored in a formula. When the beliefs are modified and the queries form part of the same fragment of the formula, then the formula can be evaluated with ease.

Katsuno and Mendelzon [2] have made the following contributions:

(a) They have changed revision operators so that they are compatible with fragments of logic

(b) Katsuno and Mendelzon have come up with revision operators that characterize their properties. Hence, if an operator is compatible with a fragment, the operator is compatible with all of the fragment's revisions.

(c) The authors find the complexity class of two algorithms namely implication and model checking.

The major work of mathematicians is to examine structures, to suggest properties that might pertain to them and to ask whether these principles are satisfied or not. Predicate logic is the first stage of the formalization of mathematical activity. There are two aspects: first, the formal tools are provided that are enough to name these objects and to express their properties. Second, the satisfaction of these properties is studied in the structures under consideration. The formulae are sequences of symbols that are taken from an alphabet and obey precise syntactic rules. There will not be a unique alphabet but rather an appropriate alphabet called a language, for each type of structure under consideration.

Propositional logic cannot be applied to model checking application since model checking requires the satisfying properties of "there exists" and "for all" clauses for specifying the models.

2.2. First-Order Logic

The paper [3] establishes that intuitionistic First-Order Logic (iFOL) is complete only when it is true in the semantics of evidence, which is increased by a new operator called intersection operator. The proof for completeness can be used to arrive at an algorithm for changing uniform semantics to proofs in intuitionistic First-order logic. The completeness proof establishes semantic validity as useful in theories of logic. It also gives a method for proving that certain formulae cannot be proved through intuition logic.

In the paper [6], Melvin gives a proof for first-order logic statements. The first-order logic of proofs gives semantics that can be represented arithmetically in iFOL. The number of probable worlds are represented semantically by first-order logic of proofs.

In paper [8], the authors develop a theory of the flow of constraints, for three-valued logic in first-order logic. The flow of constraints is used for reasoning and inference in first-order logic. The algorithm which uses the flow of constraints belongs to the P complexity class. A datalog program is proved to be able to represent the flow of constraints. The second contribution of the author is the conversion of a semantic algorithm to an algorithm for flow of constraints.

In [9], an algorithm for developing proofs for first-order logic that can be verified by any proof verifier is developed. Such a proof generator has wide applications since proofs can be produced in remarkably huge number of ways which are incompatible with each other. The algorithm developed by the authors for generating proof certificates is applicable only to first-order logic. However, the algorithm may be used in intuitionistic logic as well as classical first-order logic.

In [10], Pavel Klinov establishes a relation between description logic with probability to probability based first-order logic. The authors clarify certain doubts on description logic with probabilities. This is done by converting description logic with probability to First-order probabilistic logic. It is proved that the conversion is semantically correct. Lastly, the authors describe the results of the semantic properties of description logic of probability on modeling based on probabilities.

In [11], the authors deal with verification of computer programs through theorems in first-order logic. It is well known that arriving at theorems in first-order logic is extremely difficult. It is also not easily possible to check for completeness or soundness of the theorems of first-order logic. The authors make use of testing on models to find mistakes in the theorems. The authors have provided a theorem that assists in arriving at program models automatically and test cases. A sample application is the program verification system called Autocert that tests the programs employed in flights in aerospace technology. The authors have arrived at counterexamples for the theorems employed in Autocert.

First order logic cannot be applied to time-series data application since the truth statements in first order logic cannot be varied with respect to time.

2.3. Temporal Logic

Yuchu Qine et al [12] discuss about Annotated Probabilistic Temporal (ATP) logic. The logic of time and probability are expressed through probability distribution over threads. The authors define ATP program's syntax . ATPs are used for defining practical applications in the real world. A list of practical applications of ATP is given below

Big financial firms spend a lot of money in predicting what would be the fluctuations in the stock prices in future.

There is a web portal which lists all the major terrorists and their organizations. Several agencies are registered with the portal that belong to the US government. The web portal has several rules that have been obtained about the terror groups' activities.

Firms that provide electricity need to reason about which cables must be set right. This can be done by finding out which of the electrical cables are likely to fail.

Temporal logic cannot be utilized as a part of fuzzy logic applications since fuzzy logic requires the determination of probabilities or degrees of faith in explanations.

2.4. Modal Logic

The addition of syntactic property to a axiomization in modal logic make the property become semantically true in all circumstances. In the current research [13] a method is proposed to make the statement true in only local circumstances but not in all states. Also all the agents need not know that the statement is true. This result is attained by the addition of relational atoms to the language that represent quantification over all formulae. The authors show that this can be achieved for a large modal logic class and a number of syntactic properties.

Modal logic cannot be applied to fuzzy logic applications since modal logic does not have methods of specifying probabilites which occur in fuzzy logic.

2.5. Causal Logic

Causality [14] means law-like necessity, though probabilities indicate exceptionality, uncertainty and absence of consistency. Still, there are two convincing purposes behind beginning with, and focusing on probabilistic investigation of causality; one is genuinely direct, the other more inconspicuous. We say, for instance, "neglectful driving results in accidents" or "you will fall on account of your apathy". One knows that the precursors just have a tendency to make the outcomes more probable, not completely certain. Any hypothesis of causality that deals with such expressions should in this manner be cast in a dialect that recognizes different shades of probability - to be specific, the dialect of probabilities. We take note of the fact that probability hypothesis can be applied in the utilization of causal demonstrations, including financial aspects, the study of disease transmission, humanism, and brain science. In these areas, examiners are concerned not simply with the vicinity or deficiency of causal associations, but with the relative qualities of those associations and with methods for gathering those associations from perceptions. Likelihood hypothesis gives both the standards and the method for adapting to and drawing conclusions from such perceptions. Probability hypothesis permits us to concentrate on the primary issues of causality without needing to adapt to mysteries of this kind.

A causal structure of an arrangement of variables A corresponds to a non-cyclic graph where each node identifies with a segment of A and each association gives a causal relationship among the variables. A causal structure serves as an outline for confining a “causal model” - a definite determination of how every variable is influenced by its parents in the acyclic graph.

If a directed path exists between A and B in all minimum structures that correspond with the information, A is said to causally influence B. Here we liken a causal structure with a scientific hypothesis, since both contain an arrangement of free parameters that can be changed in accordance to fit the information.

Causal reasoning has applications in medicine in the determination of the efficacy of new medicines. Medicines can be tested in two groups of patients with one group taking the medicine and the other a placebo. One can determine if the medicine indeed cured the illness. Causal reasoning may also be used in law where a judge has to determine based on the available evidence, whether the person who is convicted is indeed the cause of the crime. It is applicable to statistics where we need to determine if one variable is the cause of the other variable or both the variables are just correlated without a causal relationship.

Causal logic cannot be applied to quantum logic domains since quantum logic requires variables to be in superposition state which is not possible in causal logic.

3. CONCLUSION

The uses of various types of logic in knowledge representation and reasoning , has been discussed with specific applications. Propositional logic is used in theorem provers and program verifiers. First order predicate logic is applied in model checking and finite model finding. Temporal logic has applications in time series data such as stock price in stock exchanges etc. Modal logic is extensively used in linguistics. Causal logic has wide applications in establishing causal relationships between variables in statistics and inference in medical domain.

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