Relevant Reasoning: Its Key Role in Discovery and Prediction

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Abstract:
This essay presents an informal and elementary introduction to relevant reasoning and relevant logic, and shows that relevant reasoning based on strong relevant logics will play an indispensable role in various computational intelligent systems where discovery or prediction is intrinsically important task.

1 Introduction

Reasoning is the process of drawing new conclusions from given premises, which are already known facts or previously assumed hypotheses to provide some evidence for the conclusions. It is the process of going from what we do know or assume (the premises) to what we previously did not know (the new conclusions), and therefore, it is a way to acquire new knowledge as well as a way to expand our known knowledge. In general, a reasoning consists of a number of arguments (inferences) in a certain order, i. e., a reasoning is an ordered process.

Note that in our philosophical definition of reasoning as above, though the premises of reasoning are intended to provide some evidence for the conclusions of reasoning, they need not actually do so. Therefore, based on our philosophical definition of reasoning, we need some criteria to distinguish good (correct, valid) from bad (incorrect, invalid) reasoning. It is logic that deals with the correctness or validity of reasoning in a general theory (academic discipline). Logic is primarily about reasoning (inferring); in particular, it is the study of what constitutes correct reasoning, i. e., the study of the methods and principles used to distinguish good (correct, valid) from bad (incorrect, invalid) reasoning.

On the other hand, there may be many different kinds of evidential relations between premises and conclusions of various reasoning, and therefore, different evidential relations may lead to different correctness and validity criteria for reasoning. Any science is established based on some fundamental principles and assumptions such that removing one of them or replacing one of them by a new one will have a great influence on the contents of the science and even lead to creating a completely new branch of the science. Logic is not an exception even if it is considered to be "the science of sciences" and "a science prior to all others". Different philosophical motivations on fundamental principles and assumptions lead to different logical validity criteria and different logic systems.

It is indubitable that the ability of reasoning is one of the most fundamental characteristics of human intelligence, and therefore, it should be an indispensable facility provided by any computational intelligent system. Although reasoning and its automation was the most actively investigated subject in both Computer Science and Artificial Intelligence disciplines, there are still many open problems concerning the fundamental characteristics of reasoning and many important issues concerning the efficient implementation of reasoning on computers. For an application-oriented engineering discipline such as software engineering, knowledge engineering, or information security engineering, it is very important to know and understand the fundamental principles and assumptions of a logic system when we use it in an application system with reasoning facility.

Discovery is the process to find out or bring to light of that which was previously unknown. Prediction is the action to make some future event known in advance, especially on the basis of special knowledge, and therefore, it is a notion must relate to a point of time to be considered as the reference time. For any discovery and prediction, both the discovered and/or predicted thing and its truth must be unknown before the completion of discovery and/or prediction process. Because reasoning is the only way to draw new, previously unknown conclusion from given premises, there is no discovery and/or prediction process that does not invoke reasoning.

This essay presents an informal and elementary introduction to relevant reasoning and relevant logic, and shows that relevant reasoning based on strong relevant logics will play an indispensable role in various computational intelligent systems where discovery and/or prediction are intrinsically important tasks.

2 Viewpoint

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2.1 Conditional as the Heart of Logic

In logic, a sentence in the form of 'if...then...' is usually called a conditional proposition or simply conditional which states that there exists a relation of sufficient condition between the 'if' part and the 'then' part of the sentence. In general, a conditional must concern two parts which are connected by the connective 'if...then...' (also called conditional relation) and called the antecedent and the consequent of that conditional, respectively. The truth of a conditional depends not only on the truth of its antecedent and consequent but also, and more essentially, on a necessarily relevant and conditional relation between them[1,7,8]. The notion of conditional plays the most essential role in reasoning because any reasoning form must invoke it, and therefore, it is historically always the most important subject studied in logic and is regarded as the heart of logic[1].

When we study and use logic, the notion of conditional may appear in both the object logic (i.e., the logic we are studying) and the meta-logic (i.e., the logic we are using to study the object logic). In the object logic, there usually is a connective in its formal language to represent the notion of conditional, and the notion of conditional, usually represented by a meta-linguistic symbol, is also used for representing a logical consequence relation in its proof theory or model theory. On the other hand, in the meta-logic, the notion of conditional, usually in the form of natural language, is used for defining various meta-notions and describing various meta-theorems about the object logic.

From the viewpoint of object logic, there are two classes of conditionals. One class is empirical conditionals and the other class is logical conditionals. For a logic, a conditional is called an empirical conditional of the logic if its truth-value, in the sense of that logic, depends on the contents of its antecedent and consequent and therefore cannot be determined only by its abstract form (i.e., from the viewpoint of that logic, the relevant relation between the antecedent and the consequent of that conditional is regarded to be empirical); a conditional is called a logical conditional of the logic if its truth-value, in the sense of that logic, depends only on its abstract form but not on the contents of its antecedent and consequent, and therefore, it is considered to be universally true or false (i.e., from the viewpoint of that logic, the relevant relation between the antecedent and the consequent of that conditional is regarded to be logical). A logical conditional that is considered to be universally true, in the sense of that logic, is also called an entailment of that logic. Indeed, the most intrinsic difference between various different logic systems is to regard what class of conditionals as entailments, as Diaz pointed out: "The problem in modern logic can best be put as follows: can we give an explanation of those conditionals that represent an entailment relation?"[5]

2.2 Traditional Relevant Logics

Classical mathematical logic was established in order to provide formal languages for describing the structures with which mathematicians work, and the methods of proof available to them; its principal aim is a precise and adequate understanding of the notion of mathematical proof. Classical mathematical logic was established based on a number of fundamental assumptions. Among them, the most characteristic one is the classical account of validity (i. e., a reasoning/argument is valid if and only if it is impossible for all its premises to be true while its conclusion is false) that is the logical validity criterion of classical mathematical logic by which one can decide whether the conclusion of a reasoning/argument really does follow from its premises or not in the framework of classical mathematical logic. However, since the relevance between the premises and conclusion of a reasoning/argument is not accounted for by the classical validity criterion, a reasoning based on classical mathematical logic is not necessarily relevant, i. e., even if a reasoning based on classical mathematical logic is classically valid, the conclusion of that reasoning may be not relevant to its premises at all[1,7,8]. On the other hand, in classical mathematical logic the notion of conditional, which is intrinsically intensional but not truth-functional, is represented by the notion of material implication, which is intrinsically an extensional truth-function. This leads to the problem of "implicational paradoxes", i. e., if one regards the material implication as the notion of conditional and regards every logical theorem (in the form of conditional) of classical mathematical logic as a valid reasoning form or entailment, then a great number of logical theorems of classical mathematical logic present some paradoxical properties and therefore they have been referred to in the literature as "implicational paradoxes"[1,7,8]. Note that the above facts are also true to various classical conservative extensions or non-classical alternatives of classical mathematical logic (e. g., all modal logic systems of strict implication) where the classical account of validity is adopted as the logical validity criterion and the notion of conditional is directly or indirectly represented by the material implication.

Traditional relevant logics ware constructed during the 1950s-80s in order to find a mathematically satisfactory way of grasping the elusive notion of relevance of antecedent to consequent in conditionals, and to obtain a notion of implication which is free from the so-called "paradoxes" of material and strict implication[1,2,5-8]. From the beginning of the 1950s, the pioneers Moh, Church, and Ackermann proposed some relevant logic systems to show their accounts of what a "relevant" logic should be. The first one of relevant logics is Ackermann's logic system Π'. Ackermann introduced a new primitive connective, called "rigorous implication," which is more natural and stronger than the material implication, and constructed the calculus Π' of rigorous implication[1], which provably avoids those implicational paradoxes. Anderson and Belnap modified and reconstructed Ackermann's system into an equivalent logic system, called "system E of entailment". Belnap proposed an implicational relation, called "relevant implication," which is stronger than the material implication but weaker than the rigorous implication, and constructed a calculus called "system R of relevant implication". E has something like the modality structure of a classical modal logic S4, and therefore, E differs primarily from R in that E is a system of strict and relevant implication but R is a system of only relevant implication. Another important relevant logic system is "system T of ticket entailment" or "system T of entailment shorn of modality" which is motivated by Anderson and Belnap[1,2]. A major characteristic of the relevant logics is that they have a primitive intensional connective (relevant implication or entailment) to represent the notion of conditional and their logical theorems include no implicational paradoxes[1,2,5-8]. The underlying principle of the relevant logics is the relevance principle, i. e., for any entailment provable in E, R, or T, its antecedent and consequent must share a propositional variable. Variable-sharing is a formal notion designed to reflect the idea that there should be a meaning-connection between the antecedent and consequent of an entailment. It is this relevance principle that excludes those implicational paradoxes from logical theorems of relevant logics. Also, since the notion of entailment (or relevant implication) is represented in the relevant logics by a primitive intensional connective but not an extensional truth-function, a reasoning based on the relevant logics is ampliative but not circular or tautological. Moreover, because the relevant logics reject the principle of Explosion (i. e., everything follows from a contradiction), they can certainly underlie paraconsistent reasoning.

2.3 Relevant Reasoning Based on Strong Relevant Logics

However, although the traditional relevant logics have rejected those implicational paradoxes, there still exist some logical theorems in the logics, which are not natural in the sense of conditional. If we regard the relevant implication as the notion of conditional and regards every logical theorem (in the form of conditional) of relevant logics as a valid reasoning form or entailment, then a great number of logical theorems of relevant logics present some paradoxical properties like that of classical mathematical logic. The present author named these logical theorems "conjunction-implicational paradoxes" and "disjunction-implicational paradoxes" because the antecedent of a conjunction-implicational paradox represented by a conditional includes unnecessary and needless conjuncts or the consequent of a disjunction-implicational paradox represented by a conditional includes unnecessary and needless disjuncts[3,4]. Therefore, in the framework of any traditional relevant logics, even if a reasoning/argument is relevantly valid, neither the truth of its conclusion in the sense of conditional nor the relevance between its premises and conclusion can be guaranteed necessarily[3,4]. This situation is the same as that in classical mathematical logic.

In general, from the viewpoint to regard reasoning as the process of drawing new conclusions from given premises, as a general logical criterion for the validity of reasoning defined by a logic system, the logic must be able to underlie relevant reasoning as well as truth-preserving reasoning in the sense of conditional, i. e., for any reasoning based on the logic to be valid, if its premises are true in the sense of conditional, then its conclusion must be relevant to the premises and must be true in the sense of conditional[3,4].

In order to establish a satisfactory logic calculus of conditional to underlie relevant reasoning, the present author has proposed some strong relevant (relevance) logics, named Rc, Ec, and Tc[3,4]. The strong relevant logics require that for a valid reasoning/argument represented by a conditional, its antecedent includes no unnecessary and needless conjuncts and its consequent includes no unnecessary and needless disjuncts. As a modification of traditional relevant logics R, E, and T, strong relevant logics Rc, Ec, and Tc rejects all conjunction-implicational paradoxes and disjunction-implicational paradoxes in R, E, and T, respectively. What underlies the strong relevant logics is the strong relevance principle: If C is a logical theorem of a strong relevant logic, then every propositional variable in C occurs at least once as an antecedent part and at least once as a consequent part[1,3,4].

Since the strong relevant logics are free of not only implicational paradoxes but also conjunction-implicational and disjunction-implicational paradoxes, in the framework of strong relevant logics, if a reasoning/argument is valid, then both the relevance between its premises and its conclusion and the truth of its conclusion in the sense of conditional can be guaranteed in a certain sense of strong relevance. This is an intrinsically important characteristic of strong relevant logics that all the other logic systems do not have. At present, we did not find other new "paradoxes" in strong relevant logics. Therefore, we can say that at present the best logic systems to underlie relevant reasoning satisfactorily are strong relevant logics.

Because for any discovery or prediction, one has no explicitly defined goal (note that it is a proving but not a reasoning if one had such a goal) before the discovery or prediction process, and both the discovered or predicted thing and its truth must be unknown before the completion of discovery or prediction process, it is rational to require that the reasoning performed in discovery or prediction is relevant. This requirement is, in particular, philosophically important for scientific discovery or prediction, because to evaluate the things discovered or predicted by reasoning, scientists must ask the most general criterion that is independent of the empirical contents the scientists are doing and gives the guarantee for soundness of discovered or predicted thing. What is the most general criterion? Where we can find the most general criterion? It is logic, as "the science of sciences" and "a science prior to all others", that can provide such criterion, and it is strong relevant logic that can underlie relevant reasoning satisfactorily such that scientists can use it to evaluate the things discovered or predicted by reasoning in a non-circular/non-tautological fashion.

3 Conclusion and Perspective

The strong relevance in the sense of conditional is indispensable to any valid reasoning for discovery and prediction. You should invoke relevant reasoning, if you really want to discover some new things or predict some future events by reasoning. sIndeed you certainly did relevant reasoning when you discovered some new things or predicted some future events. Relevant reasoning based on strong relevant logics will play an indispensable role in various computational intelligent systems where discovery or prediction are intrinsically important tasks.

Today, relevant logic has become an important branch of philosophical logic. It is the only family of logics to deal with the relevant account of validity in reasoning. As a knowledge representation and reasoning tool, relevant logic has many useful properties that the classical mathematical logic and its various classical *conservative extensions* or *non-classical alternatives* do not have. Relevant reasoning based on strong relevant logic can play many important roles in Knowledge Science as well as Computer Science, and in facts, many challenging problems cannot be solved if one do not invoke somehow relevant reasoning.

4 References

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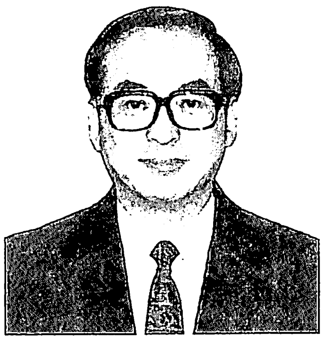

Jingde Cheng is a professor of computer science at Graduate School of Science and Engineering, Saitama University in Japan. He received the Bachelor of Engineering degree in computer science and the Best Graduate Award from Tsinghua University in China in 1982, and the Master of Engineering degree and the Doctor of Engineering degree, both in computer science from Kyushu University in Japan, in 1986 and 1989 respectively. Before he joined Saitama University in 1999, he was a research associate (1989 – 1991), an associate professor (1991 – 1996), and a professor (1996 – 1999, as the first foreign professor in Japanese national universities) at Kyushu University. He is a senior member of ACM, and a member of IEEE-CS, IEEE-SMC, IEEE, and IPSJ. Jingde Cheng's current research interests include relevant and ampliative reasoning, relevant logic and its applications, epistemic programming paradigm for scientific discovery, autonomous evolution of knowledge-based systems, anticipatory reasoning-reacting systems, persistent computing, and information security engineering environment. He received the Best Paper Awards from several international conferences.