A Survey of Non-Monotonic Reasoning

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Classical logic is purely deductive by nature. This has a certain monotonicity as consequence: If a proposition is deducible from a set of premises, this statement is still deducible if we enlarge this set of premises. So new information can never invalidate old information. On the other hand, common-sense reasoning must be inductive in some way: Since we seldom know all the relevant information, we have to make assumptions which seem plausible at that moment, yet which may turn out to be wrong in the light of new information. Therefore, common-sense reasoning is "non-monotonic". However, traditional logic is insufficient to handle such a reasoning pattern. If you increase your set of premises with new information, this set may become inconsistent, so the reasoning based on classical logic alone will simply reduce to triviality, and consequently anything will be deducible.

Non-monotonic reasoning originated in the field of artificial intelligence, and has become a rapidly growing area in the last decade. This paper discusses two of the most prominent formalizations of common-sense reasoning. No prior knowledge of formal logic is required.

1 Introduction

In our daily life, every one of us is faced with situations where we must draw conclusions from some given data. For instance, when someone tells me that Bruce Wayne either lives in Gotham City or in Metropolis, and I learn that he does not live in Metropolis, then I will conclude that he indeed lives in Gotham City. Or when there is no doubt that all inventors are wacky and I hear that Gyro Gearloose is an inventor, then I must be prepared to infer that he is wacky. However, when it is known
that if one eats sugar then this will cause tooth decay, and my girlfriend argues that since she never eats sugar, so she will never have tooth decay, I seriously doubt this argumentation. In simple examples like these, we all have a feeling when an argument is sound or when it is erroneous. But when we have a large number of initial statements and we try to deduce some other fact from these, then it is not immediately clear if this results in a sound argumentation (just listen how politicians sometimes argue). Here is where formal logic comes in. Its task is the investigation of correct arguments on the basis of truth-conditions. Logic, then, formalizes that part of our common language that is concerned with statements and the drawing of conclusions from other statements.

Now, in classical logic, a statement is assumed to be either true or false, but not both. Further, we say that a statement \( A \) follows logically from a set \( S \) of premises if \( A \) is a true statement whenever all elements of \( S \) are simultaneously true statements (in other words, the "conditions" that make all elements of \( S \) simultaneously true, also make \( A \) true). From this definition the following property is immediate: If \( S \subseteq S' \) and \( A \) follows logically from \( S \), then \( A \) follows logically from \( S' \). We say therefore that classical logic is monotonic: Once a statement follows from a set of premises \( S \), we may enlarge \( S \) arbitrarily, \( A \) will still logically follow from this enlarged set.

Monotonicity is perfectly reasonable as far as classical logic is concerned, since here the premises serve as a complete description of the setting we are arguing about. However, this is in grave opposition to our everyday life, where we seldom have a complete picture of all those constraints relevant for our daily activities. We always have some gaps in our knowledge, yet this obstacle does not hamper us in order to carry on. We are constantly forced to make assumptions which may turn out to be wrong in the light of new, more accurate information. In other words, new information may invalidate old information (or assumptions), so common-sense reasoning does not obey the principle of monotonicity, it is non-monotonic.

On the other hand, the fact that our knowledge is incomplete does not mean that we jump to conclusions at random. Rather, based on our past experience and our partial knowledge, we employ a mechanism (indeed, the notorious "common sense") to help us deduce statements which seem plausible at that moment.

Let us consider an example. Say, there is a new recording of Beethoven's ninth and I just simply must have it. Suppose I know the following:

The store "Cash'n Carry" usually sells the latest record releases.

Given no further information, there are good chances that this store sells my desired new Beethoven record. Of course, I can always imagine scenarios where "Cash'n Carry" does not sell this record. But I will never be able to obtain that record if I only sit in my room and study all possible reasons why "Cash'n Carry" won't sell it. So the only rational behaviour for me is to assume

"Cash'n Carry" sells the new recording of Beethoven's ninth;