Semantics, Communication, and Probability

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Logic, Linguistics, and Intelligent Interaction In logic the distinctions between language, interpretation and communication are quite clear, in natural language understanding less so. But maybe natural language semantics has something to learn from new directions in logic. A first lesson was taught by Richard Montague long ago, but there are some new things to learn now.

Logic, narrowly conceived, is the design and use of formal languages for thought, the study of their strengths and limitations (the trade-off between expressive power and complexity), and the use of these tools in clarifying what goes on in the mind of a mathematician, or in the memory of a computer carrying out a program. Montague's lesson for NL understanding was that NL can be studied with the methods from logic.

Broadly conceived, logic is the study of intelligent interaction, rational adjustment on the basis of evidence, transformation of our conceptualisations of the world on the basis of received information. See [1] for an overview, and for a logic textbook emphasizing this broader perspective.

Intelligent interaction is also a central topic in natural language understanding, for intelligent interaction is what natural langauge is for. A desire to explain why human beings are so good at communication using language is one of the reasons for being interested in linguistics.

Formal Models of Communication In dynamic epistemic logic (see [3] or [2]), a state of affairs is a multi-agent Kripke model, and acts of communication are operations on states of affairs. The Kripke model represents what the agents know (or believe). If an agent a is uncertain about the truth of p, this is represented by an inability of a to distinguish p-worlds from non p-worlds. The act of communication represents how this knowledge (or this belief) gets changed by information exchange.

A paradigm example is public announcement. A public announcement of a true fact p has the following effect on a Kripke model. All non p-worlds get removed from the model, and the accessibility relations representing the knowledge or belief of the agents get restricted to the new class of worlds. The result is that p becomes common knowledge among all agents. But many other kinds of communication can be modelled: messages to specific individuals, messages to all agents that happen to pay attention, and so on.

Knowledge, Belief, and Probability In epistemic/doxastic logic (the logic of knowledge and belief), there is also a new trend, where knowledge and belief are linked to probability theory. Theories of subjective probability [6] agree well with Kripke model representations of knowledge and belief.

To turn a Kripke model into a probabilistic model, all one has to do is to add, for each agent, a probability distribution over the set of all worlds to the model [5]. Knowledge of a cannow be linked to certainty: assigning probability 1 to a statement. Belief can be linked to assigning probability $> \frac{1}{2}$ to a statement.

This way, it is possible to explain certain properties of belief that are hard to cope with without bringing in probabilities. If an agent believes p (say: 'Bonfire is not a winner') and also believes q (say: 'Salinero is not a winner'), it does not follow that the agent also believes $p \wedge q$. So belief is not closed under conjunction, and hence the belief operator is not a normal modal operator (in the technical sense: $\Box$ is normal if from $\Box\phi$ and $\Box(\phi \to \psi)$ it follows that $\Box\psi$).

Connection with Natural Language Semantics Probabilistic semantics for natural language would link language (content words) to the world in a loose way (looser than the traditional truth-functional way), in the perspective of an agent (here is where subjective probabilities of the 'knowing subject' come in).

Example: vague or uncertain attribution. 'Bonfire is black'. In a probabilistic Kripke model M, in a world w, for an agent a, this gets a probability $P_{a,w}$. If the probability is 1, this means that a knows that Bonfire is black, and it follows that it is true that Bonfire is black. In a case where the statement is judged as less than certain by a, we can say that a believes that Bonfire is black. Now it does not follow that it is true that Bonfire is black.

Program Work out a probabilistic multi-agent semantics for natural language along these lines. See [4] for a first sketch. Connect up with work on distributional semantics.

References

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