Exploring Belief Revision in Cognitive Event Calculi

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Exploring Belief Revision in Cognitive Event Calculi

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Abstract

This poster investigates the implementation of belief revision in Deontic Cognitive Event Calculi (DCEC*), a multi-sorted quantified modal logic that can express first-person beliefs one has about oneself—that is, de se beliefs (denoted by \(\ast\)). The ability for a reasoning agent to hold a set of beliefs that are both consistent and revisable is a necessity for practical human reasoning.

Belief revision has heretofore been explored primarily through logics no more expressive than propositional logic: a logic which can only express relations between truth values of propositions. DCEC* has a substantially greater degree of expressivity than propositional logic. We offer a logical analysis in DCEC* of belief confidence, active belief, and their interaction with belief revision. We provide an approach to account for belief revision in DCEC* and demonstrate the usefulness of an automated reasoner to perform pertinent proofs.

Propositional Logic: Mathematical logic, in which propositions form larger propositions through logical connectives. Propositions can be statements, and the logical connectives include and, or, not, implies, and the like.

First Order Logic: Symbolized reasoning where all sentences have a subject and a predicate that modifies the subject. FOL is based on using objects, rather than propositions.

Creating a Rational Reasoner – Mazes and Lies

Assume an artificially intelligent robot (agent \(\alpha\)) is in a maze. Agent \(\alpha\) knows its goal is to get out of the maze. It explores path \(\phi\) in the maze to the right and finds a dead end. Our agent \(\alpha\) now knows there is a dead end there. This could be shown via first order logic with propositions.

But what if \(\alpha\) encounters a new agent, a liar, agent \(L\). Agent \(L\) tells \(\alpha\) that path \(\phi\) leads to the exit. Clearly, \(\alpha\) should reject this suggestion, which adds new propositions—needing to know and needing to reject contradictions.

L apologizes, and says that path \(\theta\) leads to the exit. \(\alpha\) has two choices: believe \(L\) and find the real exit, or be distrustful of \(L\) and find another dead end (path \(\phi\)). How will agent \(\alpha\) make this decision?

DCEC* provides us with ready made tools to express the decision making process of agent \(\alpha\), in a way that is consistent across problem domains. Our goal is the creation of inference rules in DCEC* to suggest an answer to what agent \(\alpha\) should do.

Belief Confidences, Active Belief, and Belief Revision

We have different strengths in our beliefs. While we might believe both an anecdote and a mathematical theorem, we believe the theorem more strongly than the anecdote. Chisholm (1956, 1957, 1966) suggests connections between rational belief and obligation: for example, a rational agent ought to refrain from believing proposition \(p\) precisely when \(p\) is unreasonable. The translation of Chisholm’s definitions of epistemic terms into the logic of DCEC* suggests introduction rules for belief confidences. The utility of these introduction rules requires further research.

When belief confidence of \(p\) and belief confidence of not-\(p\) have different degrees or times, the agent must choose which belief will drive an action at a specific time. Let’s call this belief the active belief.

DCEC* Candidate Rules

Candidate Rules for Introduction of Belief Confidence from Chisholm (1966):

(1) \(\models (\alpha, t, o, \neg\text{happens}(\text{action}(\alpha, a, \text{accept}(p)), t), t, t)\)

This says that when one ought to refrain from believing \(p\), a rational agent has the lowest belief confidence towards \(p\).

(2) \(\models (\alpha, t, o, \neg\text{happens}(\text{action}(\alpha, a, \text{accept}(\neg p)), t), t)\)

This expresses that when one ought to refrain from believing \(\neg p\), a rational agent has the highest belief confidence towards \(p\).

(3) \(\models (\alpha, t, o, \text{happens}(\text{action}(\alpha, a, \text{accept}(p)), t), t)\)

This rule indicates that when \(\alpha\) is not the case that one ought to refrain from believing \(p\), a rational agent has the lowest positive belief confidence towards \(p\).

(4) \(\models (\alpha, t, o, \text{happens}(\text{action}(\alpha, a, \text{accept}(\neg p)), t), t)\)

This rule shows that when \(\alpha\) is not obligated to refrain from believing \(p\) and is not obligated to refrain from believing \(\neg p\), a rational agent has an indifferential or neutral belief confidence in \(p\) and \(\neg p\).

Candidate Algorithm for Introduction of Active Belief:

(1) If beliefs are consistent at belief level, take all beliefs (with belief confidence greater than indifficence) to be active beliefs.

(2) If beliefs are inconsistent at belief level, take the belief of the highest confidence level and all beliefs consistent with it to be active beliefs.

We are currently developing an introduction procedure for adding new individual beliefs to the active belief set.

Logic Families

Cognitive Event Calculi (CEC) and Deontic CEC (DCEC):

CEC allows us to handle reasoning tasks over beliefs, desires, intentions, and the like. DCEC augmented it with the concepts of obligation and permission. In DCEC*, the * represents de se beliefs: the ability to reason over the beliefs in the first person (“I believe…”).

CEC provides consistent inference rules that work across multiple situations, eliminating the need for creating action-specific predicates. CEC can reason over a wide range of actions default, allowing indirect effect, concurrency, and other traditionally difficult forms of action. It also simplifies reasoning over complex action, compared to standard propositional logic.