


Mental Events and Mental Objects

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- For a single-agent domains, knowledge about one's own knowledge and reasoning processes is useful for controlling inference.
- In a multiagent domains, it becomes important for an agent to reason about the mental states of the other agents.
- Example Bob and Alice scenario 
- It requires a model of the mental objects in someone's head(knowledge base) and the processes that manipulate these mental objects.

A formal theory of beliefs

- Relationships between agents and mental objects: believes, knows, wants, intends ... are called **propositional attitudes**
- Lois knows that Superman can fly:
 - $\text{Knows}(\text{Lois}, \text{CanFly}(\text{Superman}))$
- If Superman is Clark, then we must conclude that Lois knows that Clark can fly:
 - $(\text{Superman} = \text{Clark}) \wedge \text{Knows}(\text{Lois}, \text{CanFly}(\text{Superman})) \models \text{Knows}(\text{Lois}, \text{CanFly}(\text{Clark}))$
- “Can Clark fly?” – No. Need descriptions
- If an agent knows that $2 + 2 = 4$ and $4 < 5$, then we want an agent to know that $2 + 2 < 5$. This property is called **referential transparency**

A formal theory of beliefs

- For propositional attitudes like *believes* and *knows*, we would like to have **referential opacity**

Modal logic address this problem

- Modal logic includes special modal operators that take sentences (rather than terms) as arguments.
- Example: “A knows *P*” is represented with the notation $K_A P$,
 - where **K** is the modal operator for knowledge,
 - agent A (written as the subscript) and a sentence

Opacity: blur, condition of lacking transparency

Possible Worlds And Accessibility Relations

- In modal logic, consider both the possibility that Superman's secret identity is Clark and that it isn't.
 - **Clark=Superman and Clark!=Superman**
- Build a model, that consists of a collection of **possible worlds** rather than just one true world and the worlds are connected in a graph by **accessibility relations**
- “Bond knows that someone is a spy” is ambiguous.

$\exists x K_{\text{Bond}} \text{Spy}(x)$

which in modal logic means that there is an x that, in all accessible worlds, Bond knows to be a spy.

- Bond just knows that there is at least one spy:

$K_{\text{Bond}} \exists x \text{Spy}(x)$

The modal logic interpretation is that in each accessible world there is an x that is a spy, but it need not be the same x in each world.

Knowledge and belief

- Knowledge in terms of AI is something which is always true
- Belief on the other hand deals more with probability
- After extensive study, it is commonly said that knowledge is justified true belief
- Example:
 - Eating food necessary for living, so we eat.
 - Gambling to gain money. Probability. Believe we will win
- **Knows(a, p)** – agent a knows that proposition p is true
- Lois knows whether Clark can fly if she either knows that Clark can fly or knows that he cannot
 - **Knowswhether(a, p) \Leftrightarrow knows(a, p) \vee knows(a, \neg p)**

Knowledge, time and action

- Belief is also something which can change over time. For example:
- Lois believes Superman flies today
T(Believes(Lois, flies(Superman)),Today)
- The same will not be true in 100 years when he died of old age