Multi-Agent Conflict Resolution with ABA

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Conflict Resolution Example

Jenny:

- I desire a movie that is entertaining.
- Action movies are entertaining.
- I believe *Terminator* is an action movie.
- I believe *Harry Potter* is a fantasy movie.
- $\Rightarrow$ I want to watch *Terminator*.

Amy:

- I desire a movie that is entertaining.
- Fantasy movies are entertaining.
- I believe *Harry Potter* is a fantasy movie.
- I believe *Lord of the Rings* is both an action and fantasy movie.
- $\Rightarrow$ I can watch either *Harry Potter* or *Lord of the Rings*.

Conflict Resolution: Amy tells Jenny that *Lord of the Rings* is also an action movie and could be the choice for both of the two.

Motivation

- Two agents share the same goal.
- Each of the two has its own way to realize the goal; and the two ways are different.
- What is the "process" or "procedure" that finds a commonly agreeable way of realizing the goal?
- How to ensure the "common way" satisfies both agents?

Background – ABA

- Formally, an ABA framework is a tuple $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \mathcal{C} \rangle$ where
  - $\langle \mathcal{L}, \mathcal{R} \rangle$ is a deductive system, with a language $\mathcal{L}$ and a set of inference rules $\mathcal{R}$ of the form $s_0 \leftarrow s_1, ..., s_m (m \geq 0)$,
  - $\mathcal{A} \subseteq \mathcal{L}$ is a (non-empty) set, whose elements are referred to as *assumptions*,
  - $\mathcal{C}$ is a total mapping from $\mathcal{A}$ into $2^{\mathcal{L}}$, where each $c \in \mathcal{C}(\alpha)$ is a *contrary* of α.
- *Arguments* are deductions of claims supported by sets of assumptions.
- *Attacks* are directed at the assumptions in the support of arguments.
- A set of arguments, *Args*, is *conflict-free* if and only if the union of all sets of assumptions that support arguments in *Args* does not attack itself.

ABA - Example

Jenny's beliefs and desires.

Rules:

watchMovie(X) $\leftarrow$ selectMovie(X), entertainingMovie(X)

entertainingMovie(X) $\leftarrow$ actionMovie(X)

actionMovie(*Terminator*)

fantasyMovie(*Harry Potter*)

Assumptions:

selectMovie(X)

$\neg$actionMovie(X)

$\neg$fantasyMovie(X)

Contraries:

$\mathcal{C}$(selectMovie(X)) = {$\neg$ selectMovie(X), selectMovie(Y)| Y $\neq$ X }

$\mathcal{C}$($\neg$ actionMovie(X)) = {actionMovie(X)}

$\mathcal{C}$($\neg$ fantasyMovie(X)) = {fantasyMovie(X)}

ABA - Example (2)

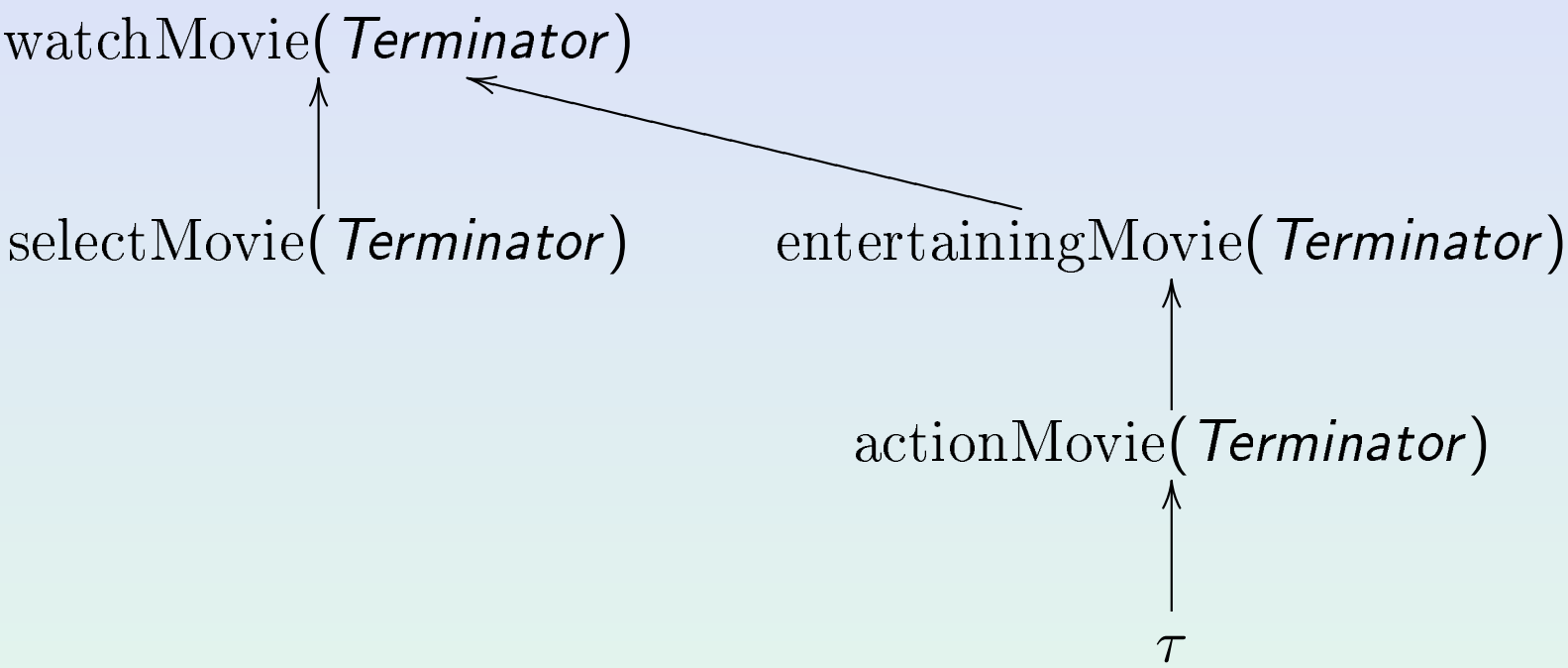

Figure: Jenny's argument for watching *Terminator*

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ABA - Example (3)

Amy's beliefs and desires.

Rules:

watchMovie(X) $\leftarrow$ selectMovie(X), entertainingMovie(X)

entertainingMovie(X) $\leftarrow$ fantasyMovie(X)

actionMovie(*Terminator*)

fantasyMovie(*Harry Potter*)

fantasyMovie(*LoR*)

actionMovie(*LoR*)

Assumptions:

selectMovie(X)

$\neg$actionMovie(X)

$\neg$fantasyMovie(X)

Contraries:

$\mathcal{C}$(selectMovie(X)) = {$\neg$ selectMovie(X), selectMovie(Y)| Y $\neq$ X }

$\mathcal{C}$($\neg$ actionMovie(X)) = {actionMovie(X)}

$\mathcal{C}$($\neg$ fantasyMovie(X)) = {fantasyMovie(X)}

ABA - Example (4)

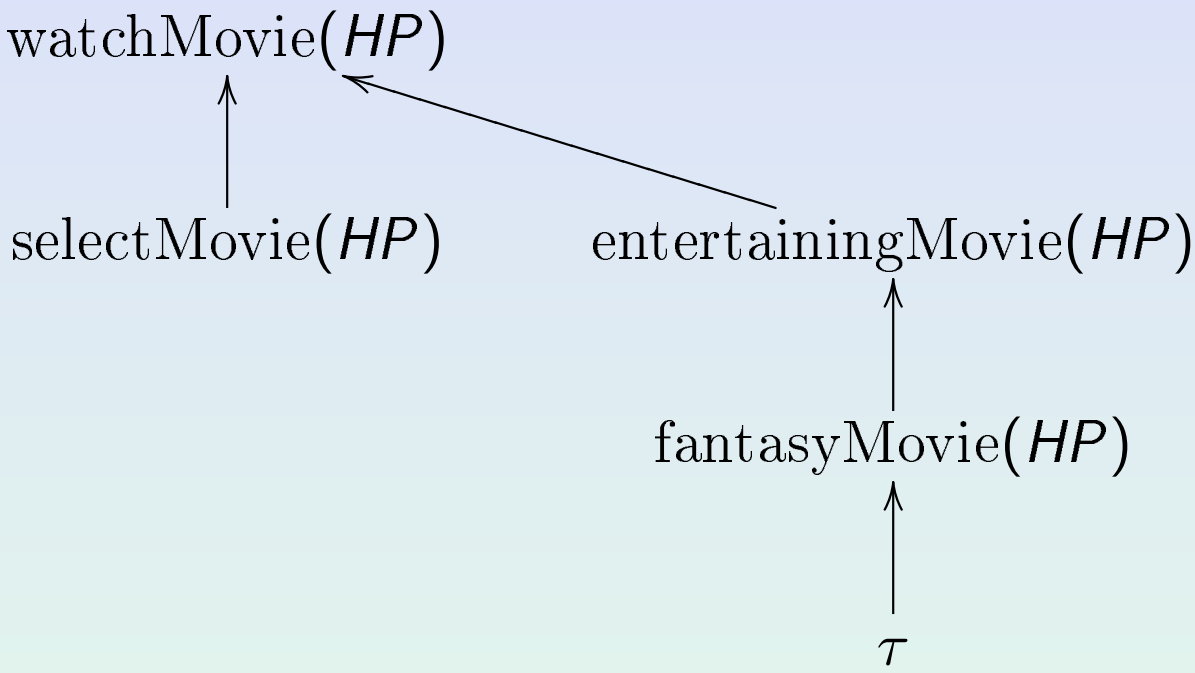

Figure: Amy's argument about watching *Harry Potter*.

Jenny's argument + Amy's argument is not *conflict-free*.

Merge - Example (5)

Agreement is reached by:

- Information exchange of actionMovie(LoR).
- The creation of a new rule that a movie is entertaining if it's both an action movie and a fantasy movie.

watchMovie(LoR) $\leftarrow$ selectMovie(LoR), entertainingMovie(LoR)
entertainingMovie(LoR) $\leftarrow$ actionMovie(LoR), fantasyMovie(LoR)
actionMovie(LoR)
fantasyMovie(LoR)

Merge - Example (6)

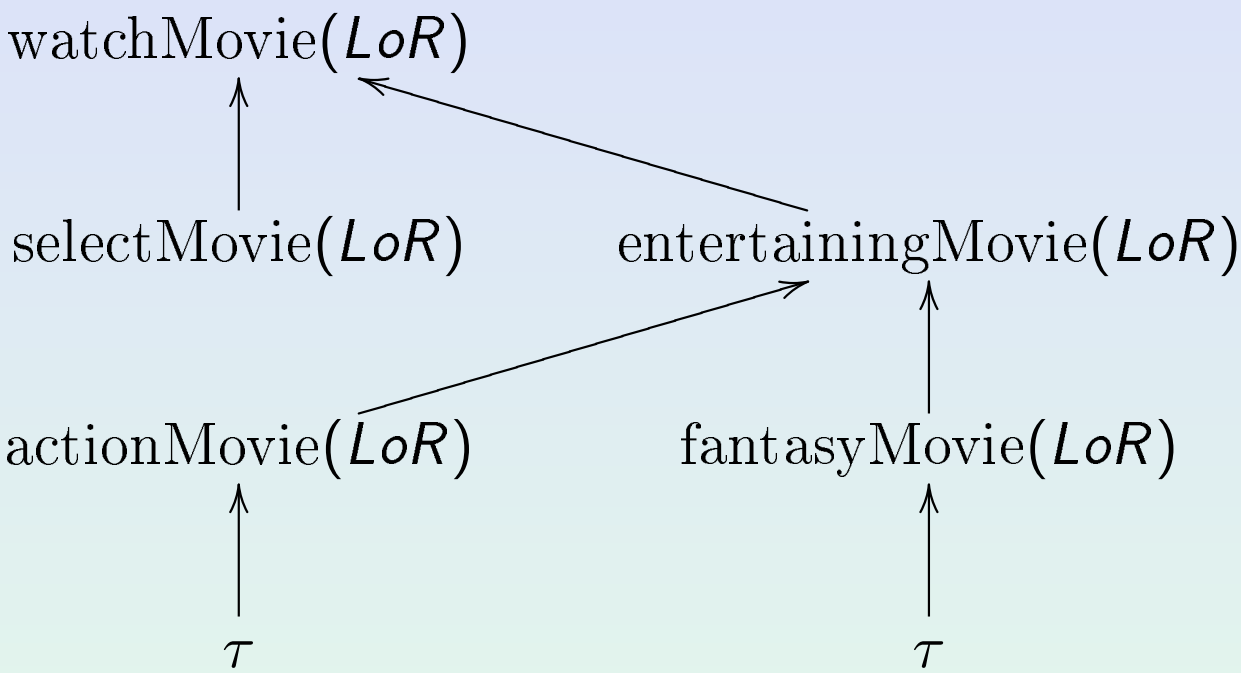

Figure: Argument for watching *Lord of the Rings* in the merged belief base.

Merge

Conceptually, conflict resolution in our setting is:

- Two agents share the same high level *goal*, $\mathcal{G}$.
- Each agent i has its own mean, δ_i, to realize $\mathcal{G}$.
- Conflict arises as the two means, δ_1 and δ_2, of deriving $\mathcal{G}$ are different.
- Resolving conflict between two agents means detecting a commonly acceptable mean, δ, that realizes $\mathcal{G}$.
- To construct a joint ABA framework such that the joint ABA framework supports a conflict-free realization $\mathcal{G}\delta$ of $\mathcal{G}$.
- The joint ABA framework is constructed by "merging" the two ABA frameworks from the two agents.

Definition Conflict & Conflict Resolution

$Agent_1$: $AF_1 = \langle \mathcal{L}, \mathcal{R}_1, \mathcal{A}_1, \mathcal{C}_1 \rangle$. $Agent_2$: $AF_2 = \langle \mathcal{L}, \mathcal{R}_2, \mathcal{A}_2, \mathcal{C}_2 \rangle$.

- **Conflict.**
  A pair of realizations of goals $(\mathcal{G}\delta_1, \mathcal{G}\delta_2)$ such that $\mathcal{G}\delta_i \in \mathcal{L}$, $\mathcal{G}\delta_i$ belongs to a conflict-free extension of AF_i, for $i = 1,2$, and $\mathcal{G}\delta_1 \neq \mathcal{G}\delta_2$.
- **Conflict Resolution.**
  $\mathcal{G}\delta$ belongs to conflict-free extensions of both AF_1' and AF_2', where
  - $AF_1' = \langle \mathcal{L}, \mathcal{R}_1 \cup \mathcal{BR}_2, \mathcal{A}, \mathcal{C} \rangle$ and $AF_2' = \langle \mathcal{L}, \mathcal{R}_2 \cup \mathcal{BR}_1, \mathcal{A}, \mathcal{C} \rangle$
  - $\mathcal{A} = \mathcal{A}_1 \cup \mathcal{A}_2$
  - $\mathcal{C}$ is defined as $\mathcal{C}(\alpha) = \mathcal{C}_1(\alpha) \cup \mathcal{C}_2(\alpha)$ (for any $\alpha \in \mathcal{A}$).

With enough knowledge, if an agent believes a realization satisfies its needs, then this realization is acceptable; if two agents think the same realization is acceptable, then it is a conflict resolution.

Theorem

When there exists a conflict $(\mathcal{G}\delta_1, \mathcal{G}\delta_2)$ between $Agent_1$ and $Agent_2$ with respect to some goal $\mathcal{G}$, if

- $\mathcal{G}\delta$ belongs to a conflict-free extension of $AF = AF_1 \oplus AF_2$ with respect to an argument $S \vdash \mathcal{G}\delta$, and
- there exist arguments $S_1 \vdash \mathcal{G}\delta$, $S_2 \vdash \mathcal{G}\delta$ in AF_1' and AF_2', respectively, such that $S_i \subseteq S (i = 1, 2)$

then $\mathcal{G}\delta$ is a conflict resolution for $(\mathcal{G}\delta_1, \mathcal{G}\delta_2)$.

Future Work

- Conflict-resolution via Dialogue.
- Resolving conflicts for multiple agents cross multiple goals.

Questions?