Scenario generation for deliberation with structured arguments

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Argumentation in multi-agent systems

- Argumentation in the reasoning process
- Argumentation in dialogues
    - Persuasion, negotiation, deliberation, ...

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- a_2: The toppings at the pizzeria are very dull, while the bistro has the best steaks in town.

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- ...

Deliberation characteristics

- Mutual deliberation goal
- Unequal roles between agents
- Not all options are known by all agents
- Compatible and conflicting agent goals
- Incomplete information and from different sources

Why use argumentation?

- Argumentation makes dialogues...
  - more efficient
  - more effective

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- But these claims still need validation through
  - Formal analysis
  - Experimentation

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2. Let the agents deliberate
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Deliberation system

- An ASPIC argumentation system $\mathcal{L}$
- A topic language L_t consisting of
  - options L_o
  - goals L_g
  - beliefs L_b
- A mutual deliberation goal $g_d \in L_g$

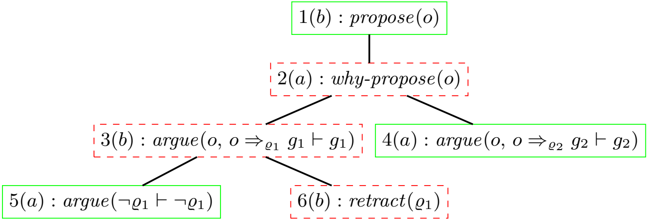
Communication language

Table: The available speech acts in deliberation dialogue

speech act	attacks	surrenders
$propose(o)$	$why\text{-}propose(o)$	
$why\text{-}propose(o)$	$argue(A \vdash p)$ where $o \in A$	
$argue(A \vdash p)$	$argue(B \vdash p')$ where $B \vdash p'$ defeats $A \vdash p$	$concede(p)$
	$why(p')$ where $p' \in A$	$concede(p')$
$why(p)$	$argue(A \vdash p)$	$retract(p)$
$concede(p)$		
$retract(p)$		

Example dialogue

$\mathcal{A} = \{a_1, a_2, a_3\}$ with dialogue goal g_d



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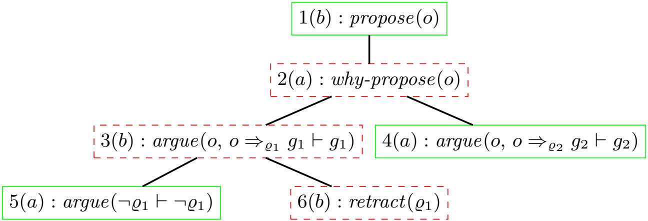

Agents and roles

- A set of roles $\mathcal{R}$
  - A set of options $O_r = \{o_1, \ldots, o_i\}$ such that $|O_r| = n_{O_r}$
  - A set of goals $G_r = \{g_1, \ldots, g_j\}$ such that $|G_r| = n_{G_r}$
- Every agent $a \in \mathcal{A}$
- A knowledge pool K is assigned:
  - a set of pool options $O_K = \bigcup_{r \in \mathcal{R}} O_r$
  - a set of pool goals $G_K = \bigcup_{r \in \mathcal{R}} G_r$

Rule chains

- Idea: reasoning chains from a goal g to an option o

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- Example chain
  $C_{g_d,o_1} = \{o_1 \Rightarrow_{\varrho_1} p_5,\ p_5 \Rightarrow_{\varrho_2} p_2,\ p_2 \Rightarrow_{\varrho_3} g_d\}$

Rule chains

- Idea: reasoning chains from a goal g to an option o
- Example chain
  $C_{g_d,o_1} = \{o_1 \Rightarrow_{\varrho_1} p_5,\ p_5 \Rightarrow_{\varrho_2} p_2,\ p_2 \Rightarrow_{\varrho_3} g_d\}$
- given $l = 3$ and $\{p_5, p_2\} \subseteq S$

Conflict generation

- Every rule chain $C_{g,o}$ has a set of conflicts $\bar{C}_{g,o}$
- containing for every rule $p \Rightarrow_{\varrho} q \in C_{g,o}$:
  - a fact $\neg\varrho$ (an undercutter)
  - a fact $\neg p$ (an underminer)
  - a fact $\neg q$ (a rebuttal)

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  - a fact $\neg q$ (a rebuttal)
- Consider again example chain
  $C_{g_d,o_1} = \{o_1 \Rightarrow_{\varrho 1} p_5,\ p_5 \Rightarrow_{\varrho 2} p_2,\ p_2 \Rightarrow_{\varrho 3} g_d\}$
- Has conflicts $\bar{C}_{g_d,o_1} = \{\neg\varrho 1, \neg o_1, \neg p_5, \neg\varrho 2, \neg p_2, \neg\varrho 3\}$.

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Role beliefs

- Assign beliefs to a role r depending on the role's options

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- For every option $o \in O_K$ a set of *role-option beliefs* B_r^o is any set such that:
  - if $o \in O_r$ then $B_r^o = C_{g,o}$ for some goal $g \in G_r$
  - if $o \notin O_r$ then $B_r^o \subseteq \bar{C}_{g,o}$ for an arbitrary goal $g \in G_r$ such that $|B_r^o| = n_{B_r^o}$

Option and goal allocation

- An agent $a \in \mathcal{A}$ with role r has:
  - A set of *options* $O_a = O_r$

Option and goal allocation

- An agent $a \in \mathcal{A}$ with role r has:
  - A set of *options* $O_a = O_r$
  - A set of *non-role originating goals* $G_a^{\bar{r}}$ where for every $g \in G_a^{\bar{r}}$ it holds that $g \in G_K \setminus G_r$ and such that $|G_a^{\bar{r}}| = n_{G_a^{\bar{r}}}$
  - The combined set of *goals* $G_a = G_r \cup G_a^{\bar{r}}$

Belief allocation

- An agent $a \in \mathcal{A}$ with some role r is assigned a set of *role-originating beliefs*

$$B_a^r \subseteq \bigcup_{o \in O_K} B_r^o \text{ such that } |B_a^r| = n_{B_a^r}$$

- and a set of *non-role originating beliefs*

$$B_a^{\bar{r}} \subseteq \bigcup_{o \in O_a} C_{g,o} \text{ for an arbitrary goal } g \in G_a$$

- such that $|B_a^r| = n_{B_a^{\bar{r}}}$

Testing scenarios for interestingness

- Scenarios contain expressivity and cover the deliberation problem dynamics

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- Scenarios contain expressivity and cover the deliberation problem dynamics
- Do they cater interesting dialogues?
- Test whether it allows arguments for/against agent's options

Parameters to the scenario generation process

		min	example	max
$n_{\mathcal{A}}$	The number of agents	1	3	6
$n_{\mathcal{R}}$	The number of roles	1	2	6
n_{O_r}	A role r's options set size	2	2	5
n_{G_r}	A role r's goals set size	2	2	5
n_S	The chaining seedset size	10	10	100
l	The length of rule chains	3	3	9
$n_{B^{o}_{\bar{r}}}$	An agent a's negated role-option beliefs set size	0	3	15
$n_{G^{\bar{r}}_{a}}$	An agent a's non-role originating goals set size	0	1	2
$n_{B^{r}_{a}}$	An agent a's role-originating beliefs set size	1	7	15
$n_{B^{\bar{r}}_{a}}$	An agent a's non-role originating beliefs set size	0	2	20

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Option justification

- An agent a's option $o \in O_a$ is a *justified option* if, on the basis of the beliefs $B_a \cup \{o\}$, an argument $A \mathrel{|\!\sim} g$ can be constructed for some goal $g \in G_a$ such that $o \in A$.
- A generated scenario with a set of agents $\mathcal{A}$ has an *option justification percentage*

$$j_{\mathcal{A}} = \frac{|\bigcup_{a \in \mathcal{A}} \{o | o \in O_a \text{ where } o \text{ is a justified option}\}|}{n_{\mathcal{A}} \times n_{O_r}} \times 100$$

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Countered option justification

- An agent a's justified option o, as supported by argument $A \mid\sim g$, is also a *countered justified option* if some agent $a' \in \mathcal{A}$, where $a \neq a'$, can, on the basis of beliefs $B_{a'} \cup \{o\}$, construct a counter-argument $B \mid\sim p$ that defeats $A \mid\sim g$.
- A generated scenario with a set of agents $\mathcal{A}$ has an *option countered justification percentage*

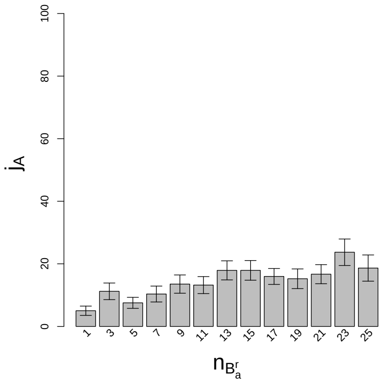
$$\bar{j}_{\mathcal{A}} = \frac{|\bigcup_{a \in \mathcal{A}} \{o | o \in O_a \text{ where } o \text{ is a countered justified option}\}|}{|\bigcup_{a \in \mathcal{A}} \{o | o \in O_a \text{ where } o \text{ is a justified option}\}|} \times 100$$

Experimental setup

- Generate and play scenarios repeatedly
- 1000 runs with random parameter settings
- Apply metrics...

Option justification

Average option justification percentage (with standard errors of the mean) with $n_{B_a^r} \in \{1, \ldots, 25\}$



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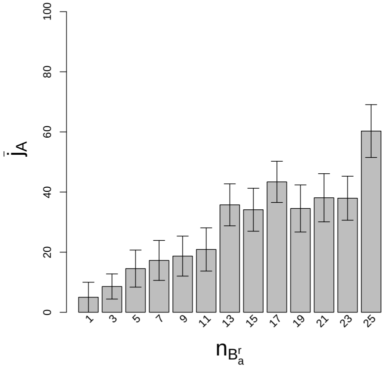

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Most influential parameters?

- Multiple linear regression analysis

Table: Input parameters and their influence on $j_{\mathcal{A}}$ and $\bar{j}_{\mathcal{A}}$

	option justification $j_{\mathcal{A}}$				countered option justification $\bar{j}_{\mathcal{A}}$			
	β	t	P	*ideal*	β	t	P	*ideal*
I	-0.49	-18.95	< 0.001	3	0.15	-3.56	< 0.001	5
$n_{B_a^{\bar{r}}}$	0.25	9.73	< 0.001	8	0.03	0.78	*NS*	10
$n_{B_a^r}$	0.24	9.57	< 0.001	21	0.37	8.48	< 0.001	23
n_{O_r}	-0.19	-7.51	< 0.001	3	-0.16	-4.01	< 0.001	2
$n_{B_{\bar{r}}^o}$	-0.15	-5.74	< 0.001	5	0.194	4.59	< 0.001	13
$n_{\mathcal{R}}$	-0.07	-2.67	< 0.01	3	0.117	2.86	< 0.01	5
n_S	-0.06	-2.37	< 0.05	20	-0.15	-3.55	< 0.001	40
$n_{\mathcal{A}}$	0.02	0.61	*NS*	6	0.39	9.66	< 0.001	6
n_{G_r}	0.01	-2.67	*NS*	3	-0.10	-2.52	< 0.05	6
$n_{G_a^{\bar{r}}}$	0.01	0.22	*NS*	2	0.14	0.37	*NS*	2

Experimental results

- Out of the 10 input parameters 7 have a statistically significant influence on $j_{\mathcal{A}}$
- Out of the 10 input parameters 8 have a statistically significant influence on $\bar{j}_{\mathcal{A}}$
- When $j_{\mathcal{A}}$ is important: vary l
- When $\bar{j}_{\mathcal{A}}$ is important: vary $n_{\mathcal{A}}$
- $n_{B_a^r}$ has a big influence on both

Most interesting dialogues

- Maximize $j_{\mathcal{A}}$ and $\bar{j}_{\mathcal{A}}$
- Lineair model predicts: get the maximal outcome

Most interesting dialogues

- Maximize $j_{\mathcal{A}}$ and $\bar{j}_{\mathcal{A}}$
- Lineair model predicts: get the maximal outcome
- Produces $j_{\mathcal{A}} = 53\%$ and $\bar{j}_{\mathcal{A}} = 99\%$

Research results

- A methodology for experimental research with argumentation in MAS
- Identify the most interesting parameter settings
- Identify which parameters to vary

Future work

- Larger project to show use of argumentation in MAS
- Strategies...
- More expresive logics and frameworks...