Distributed Synthesis of First Order Specifications for Agents with Partial Information

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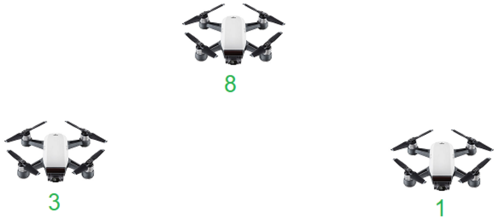
Distributed setting

- Infinite set $\mathcal{A}$ of agents with unique id ; Finite set of actions Σ



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- Broadcast communication

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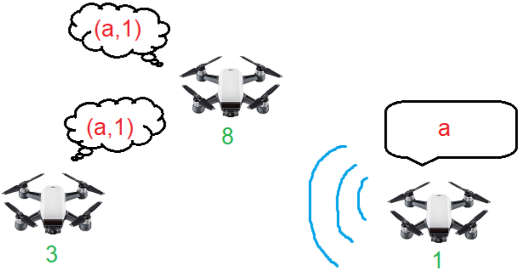

Execution trace: (a,1)

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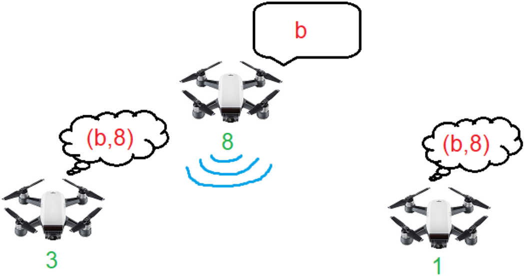

Execution trace: (a,1) (b,8)

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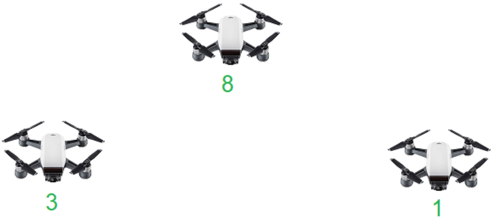

Execution trace: (a,1) (b,8) ... $\in (\Sigma \times \mathcal{A})^\omega$

Distributed setting

- Infinite set $\mathcal{A}$ of agents with unique id ; Finite set of actions Σ
- Broadcast communication
- Uncontrollable actions

Execution trace: (a,1) (b,8) ... $\in (\Sigma \times \mathcal{A})^\omega$

First order logic

Example of specification: redundant acknowledgement

Whenever a request is made to an agent, it is later granted by the same agent and a different one.

$$\forall x.\mathrm{request}(x) \Rightarrow \exists y_1, y_2.$$
$$\left(y_1 \sim x \wedge y_2 \not\sim x \wedge \bigwedge_{i \in \{1,2\}} (y_i > x \wedge \mathrm{grant}(y_i)) \right)$$

Strategy synthesis

Local strategy

$(\sigma_{\text{ag}})_{\text{ag} \in \mathcal{A}} : (\Sigma \times \mathcal{A})^* \to \Sigma_{\text{cont}}$

or

Centralized strategy

$\sigma : (\Sigma \times \mathcal{A})^* \to \Sigma_{\text{cont}} \times \mathcal{A}$

Strategy synthesis

Local strategy

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$\Updownarrow$ Equivalent $\nwarrow$ too much info

Centralized strategy

$\sigma : (\Sigma \times \mathcal{A})^* \rightarrow \Sigma_{\mathrm{cont}} \times \mathcal{A}$

Partial information (PI) setting

Execution trace: (a,1)

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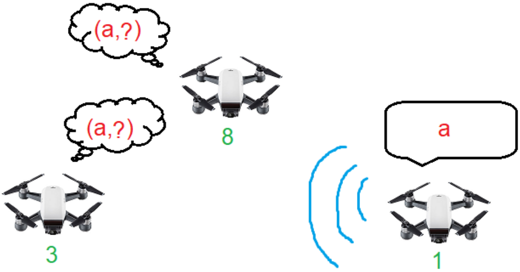
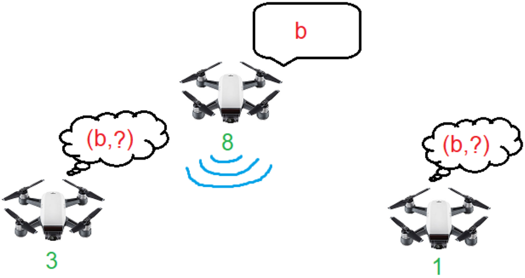


Execution trace: (a,1)

- Agent 1 p.o.v.: a
- Agent 3 p.o.v.: a
- Agent 8 p.o.v.: a

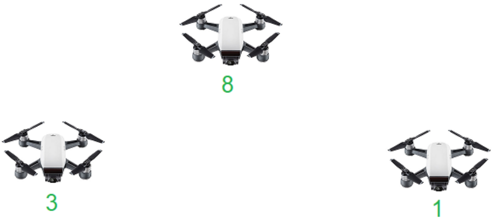
Partial information (PI) setting



Execution trace: (a,1) (b,8)

- Agent 1 p.o.v.: a b
- Agent 3 p.o.v.: a b
- Agent 8 p.o.v.: a b

Partial information (PI) setting



Execution trace: (a,1) (b,8) ... $\in (\Sigma \times \mathcal{A})^\omega$

- Agent 1 p.o.v.: $\underline{a}$ b ... $\in (\underline{\Sigma} \cup \Sigma)^\omega$
- Agent 3 p.o.v.: a b ...
- Agent 8 p.o.v.: a $\underline{b}$ ...

PI synthesis

PI strategy

$(\sigma_{\mathrm{ag}})_{\mathrm{ag}\in\mathcal{A}} : (\underline{\Sigma} \cup \Sigma)^* \to \Sigma_{\mathrm{cont}}$

PI synthesis

PI strategy

$(\sigma_{ag})_{ag \in \mathcal{A}} : (\underline{\Sigma} \cup \Sigma)^* \to \Sigma_{cont}$

Fact

PI strategies are strictly weaker than full info. strategies

PI synthesis

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Fact

PI strategies are strictly weaker than full info. strategies

FO without order $\simeq$ counting specifications

Counting PI strategy

$(\sigma_{\mathrm{ag}})_{\mathrm{ag} \in \mathcal{A}} : ((\underline{\Sigma} \cup \Sigma) \to \mathbb{N}) \to \Sigma_{\mathrm{cont}}$

PI synthesis

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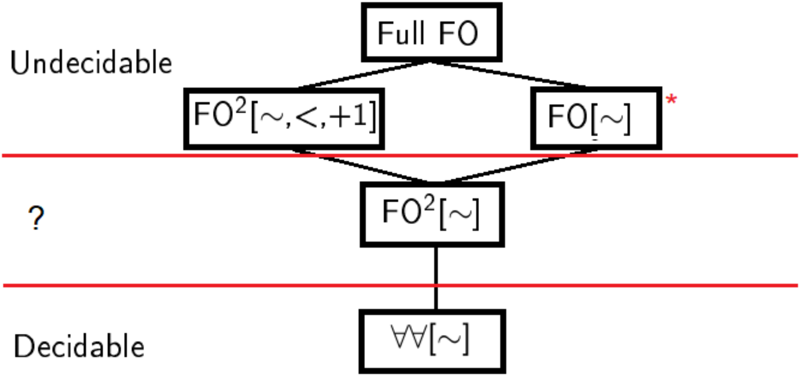
Fact

Counting PI strategies are strictly weaker than general PI strategies

(Un)decidability of PI synthesis



*: even for counting strategies

What next? (WIP)

Future works

- close gap of decidability; other logics?

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Thank you for listening, any question?

Formal FO definition

FO

action "happens later" (F) "same agent"

$$p := a(x) \mid x < y \mid y = x + 1 \mid x \sim y$$

$$\varphi := p \mid \neg\varphi \mid \varphi \vee \varphi \mid \exists x.\varphi$$

"next position" (X)

Fact

PI strategies are strictly weaker than full info. strategies

Example

- Environment does two consecutive *a* on agents ag_1 and ag_2 (possibly equal),
- then System replies on some agent ag_3 (different from both ag_1 and ag_2) either eq if $\mathrm{ag}_1 = \mathrm{ag}_2$, noteq otherwise.

Intuition

ag_3 cannot distinguish between the two cases

Fact

Counting PI strategies are strictly weaker than general PI strategies

Example

- System does an *a* on some agent ag_1,
- then Environment does a *b* on ag_2 (can be equal to ag_1),
- then System does a c_1 and a c_2 (in any order) on ag_1 again,
- then System does a eq on ag_3 if $\mathrm{ag}_1 = \mathrm{ag}_2$, noteq otherwise.

Intuition

ag_1 does c_1 then c_2 if $\mathrm{ag}_1 = \mathrm{ag}_2$, the other order otherwise