Using institutions to model mixed societies of humans and robots

(a few initial steps)

Alessandro Saffiotti

AASS – Center for Applied Autonomous Sensor Systems
Cognitive Robotic Systems Laboratory
University of Örebro, Sweden

asaffio@aass.oru.se
DISCLAIMERS

• Very preliminary work in progress
• Not really my work!

[ Julien Bidot ] [ Federico Pecora ] [ Pedro Lima ]

[ Stevan Tomic ]
Roadmap

1. Institutions
2. A formal model of institutions
3. A simple robot example
4. Finale
What is an Institution?

Roundabout

Trading

Queue
What is IN an Institution?

Roundabout

Trading

Queue

agents

rules

artefacts

agents

rules

artefacts

agents

artefacts

agents
So, what is an Institution?

- An abstract model

\[ I = \langle \text{Roles}, \text{Actions}, \text{Artifacts}, \text{Norms} \rangle \]

\{driver\} \{yield, go, change lane\} \{patch\} \{if ... then ...; do not ...; \}
Why do we need institutions?

- **Regulate direct / indirect collaboration**
  - should we say "regulate joint action"?
  - cf Elisabet’s "pre-aligned representations"

- **Reduce uncertainty / cognitive load**
  - reduce number of possible moves of all actors
  - hence simplify prediction of other actor’s moves...
  - ... and prune search space on my moves
So, can we use them in artificial systems?

- Yes! Tons of work related to Institutions in MAS
  - about ”organizations”, ”norms”, ”coalitions”, ...
  - e.g., MAS normative frameworks (MOISES, TEAMS, ...)
  - But: typically ”disembodied” agents
    
    _no physical world, no physical action and perceptual capabilities_

- Yes! Some recent work on ”Institutional robotics”
  - normative models for muti-robot (swarm) cooperation
  - But: models are not explicit

[ J.N. Pereira, P. Silva, P.U. Lima, A. Martinoli 2014 ]
Our target

- A model of institutions that can be used by robots
  - where the links with the physical world are part of the model
  - and can be reasoned about
Roadmap

1. Institutions
2. A formal model of institutions
3. A simple robot example
4. Finale
A model of Institutions

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

{driver}  {yield, go, change lane}  {patch}  {if ... then ...; do not ...; }

© 2016 A. Saffiotti
**Definition 1.** An Obligation norm is an element \( obl \in OBN \). The set of Obligation norms \( OBN \) is the relation between Roles and Acts:

\[
OBN = \{obn_1, obn_2, \ldots, obn_t\} \subseteq \text{Roles} \times \text{Acts}
\]

**Definition 3.** A planning norm is an element \( pln \in PLN \). A set of planning norms \( PLN \) is a n-ary relation on Acts:

\[
PLN = \{pln_1, pln_2, \ldots, pln_p\} \subseteq \text{Acts}^n
\]

**Definition 4.** An Usability norm is an element \( usn \in USN \). A set of Usability norms \( USN \) is a binary relation of Acts and Arts \( \cup \) Roles:

\[
USN = \{usn_1, usn_2, \ldots, usn_u\} \subseteq \text{Acts} \times (\text{Arts} \cup \text{Roles})
\]
Enter the physical world

$D = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle$
Grounding an Institution

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ G = G_A \cup G_B \cup G_0 \]

\[ D = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Grounding an Institution
Grounding an Institution
**Admissible grounding**

**Definition 11.** Given a particular grounding $G$, for $ag \in A$ and role $\in \text{Role}$, condition for well-formed role-agent grounding is defined as:

$$\text{WellFormed}(\text{role}, \text{ag}) \iff \left( \forall \text{act} \in \text{Acts}.(\text{role}, \text{act}) \in \text{OBN}.(\text{Capable}(\text{ag}, \text{role}, \text{act}) \land \forall \text{art} \in \text{Arts}.(\text{act}, \text{art}) \in \text{USN}.\text{Affords}(\text{art}, \text{act}) \land \forall \text{urol} \in \text{Roles}.(\text{urol}, \text{act}) \in \text{USN}.\text{Affords}(\text{urol}, \text{act})) \right)$$

**Definition 12.** Given particular grounding $G$, and role $\in \text{Role}$, 'cardinality condition' is defined as:

$$\text{Cardinality}(\text{role}) \iff (\min(\text{Card}(\text{role})) \leq |G_A|_{\text{role}} \leq \max(\text{Card}(\text{role})))$$

**Definition 13.** The grounding $G = \langle G_A, G_B, G_O \rangle$, of institution is admissible, if the following condition holds:

$$\forall \text{role} \in \text{Roles}, \forall \text{ag} \in A : (\text{Cardinality}(\text{role}) \land ((\text{role}, \text{ag}) \in G_A \implies (\text{WellFormed}(\text{role}, \text{ag}))))$$
What it means to be part of an Institution?

• If an institution has been grounded in a domain
  – the agents, behaviors and objects involved
    must comply to the norms in the institution

• It constrains the behavior of each agent
  – and simplifies prediction of behavior of other agents

• For the technically curious
  – implemented as constraints in a constraint-based planner
  – more generally, as constraints in a meta-CSP solver...!
Roadmap

1. Institutions
2. A formal model of institutions
3. A simple robot example
4. Finale
A children game

- A runner and a catcher run on a grid marked with letters
- Runner goes to some spot, marked by a letter
- Says a word that starts by that letter, then steps to a new spot
- If catcher gest the runner before that, catcher wins
- If runner visits all spots, runner wins
The game modeled as institution

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]
Grounding the institution

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\( \mathcal{G} \)

\( \mathcal{G}_A \)

\( \mathcal{G}_B \)

\( \mathcal{G}_0 \)

Jim

Dad

Rob1

Rob2
Grounding the institution

\[ \mathcal{I} = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ \mathcal{G} = \mathcal{G}_A \uparrow \mathcal{G}_B \downarrow \mathcal{G}_0 \]

\[ \mathcal{D} = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]

© 2016 A. Saffiotti
Grounding 1: play with dad

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ \mathcal{G} \]

\[ \mathcal{D} = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Grounding 1: play with dad (reverse roles)

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ D = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Playing with the robots

\[ \mathcal{I} = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ \mathcal{G} \]

Rob1: sees QR-tags on the wall

Rob2: reads RFID tags under the floor
Grounding 2: playing with Rob1

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ G \]

\[ G_A \]

\[ G_B \]

\[ G_0 \]

\[ D = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Grounding 2: playing with Rob1

\[ I = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ D = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Grounding 2: playing with Rob2

\[ \mathcal{J} = \langle \text{Roles, Actions, Artifacts, Norms} \rangle \]

\[ \mathcal{G} \]

\[ \mathcal{D} = \langle \text{Agents, Behaviors, Objects, Capabilities, Affordances} \rangle \]
Let’s play!
What’s next?

• **Reasoning with institutions!**
  – how to instantiate, join or leave an institution
  – how to monitor and repair an institution
  – why to use an institution

• **At the computational core of all of these**
  – find and maintain an admissible grounding

• **And some tricky issues**
  – membership to multiple institution
  – nested institutions
What’s next?

• **Reasoning with institutions!**
  – how to instantiate, join or leave an institution
  – how to monitor and repair an institution
  – why to use an institution

• **At the computational core of...**
  – find and maintain an admissible...'

• **And some tricky issues**
  – membership to multiple institutions
  – nested institutions

---

Thank you!

Contact: asaffio@aass.oru.se
Or: stevan.tomic@aass.oru.se

© 2016 A. Saffiotti