From Human-Human Joint Action to Human-Robot Joint Action... and vice-versa !
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Using institutions to model mixed societies of humans and robots

(a few initial steps)

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DISCLAIMERS

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

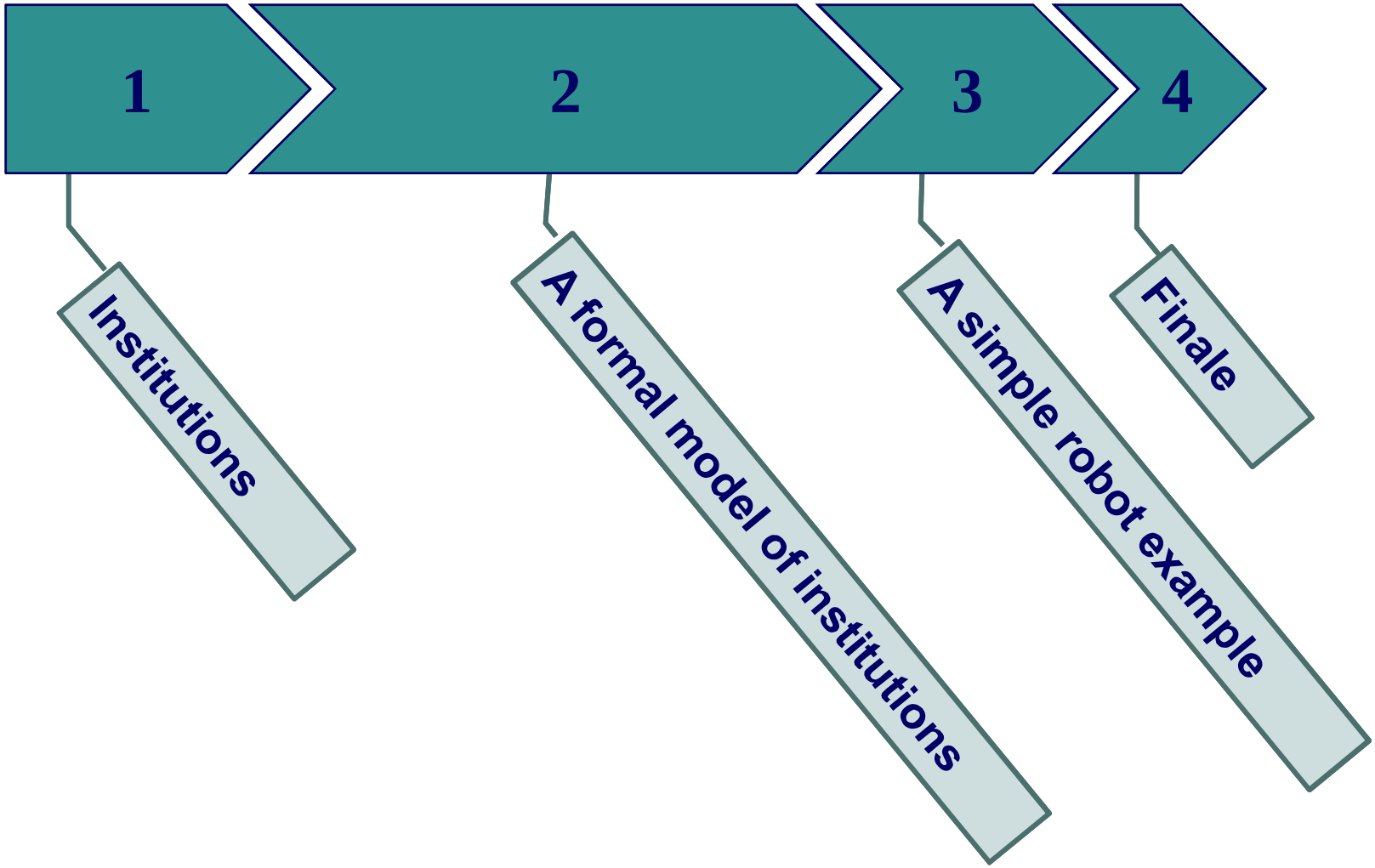
[Julien Bidot]

[Federico Pecora]

[Pedro Lima]

[Stevan Tomic]

Roadmap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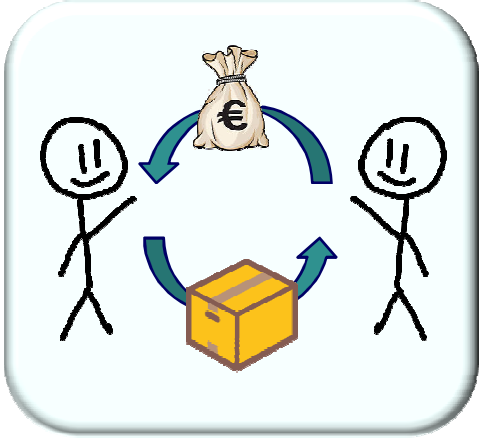
Finale

What is an Institution?

Roundabout

Trading



Queue

What is IN an Institution?

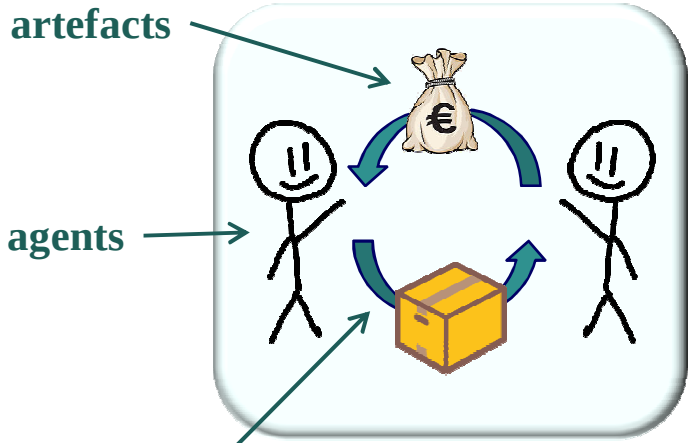
Roundabout

artefacts

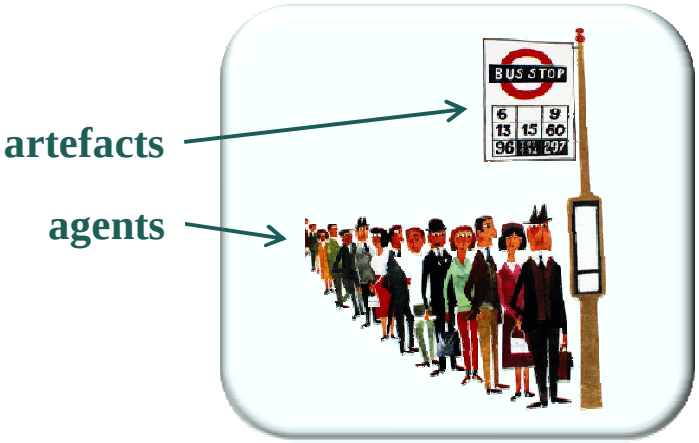
agents

rules

Trading



Queue



So, what is an Institution?

- **An abstract model**

$$\mathcal{I} = \langle \mathit{Roles}, \mathit{Actions}, \mathit{Artifacts}, \mathit{Norms} \rangle$$

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

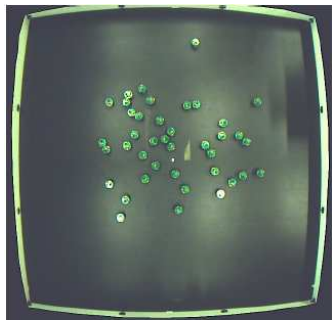
Why do we need institutions?

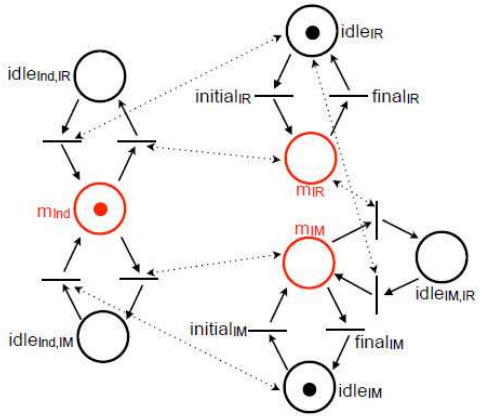
- **Regulate direct / indirect collaboration**
  - should we say ”regulate joint action” ?
  - cf Elisabet’s ”pre-aligned representations”

- **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



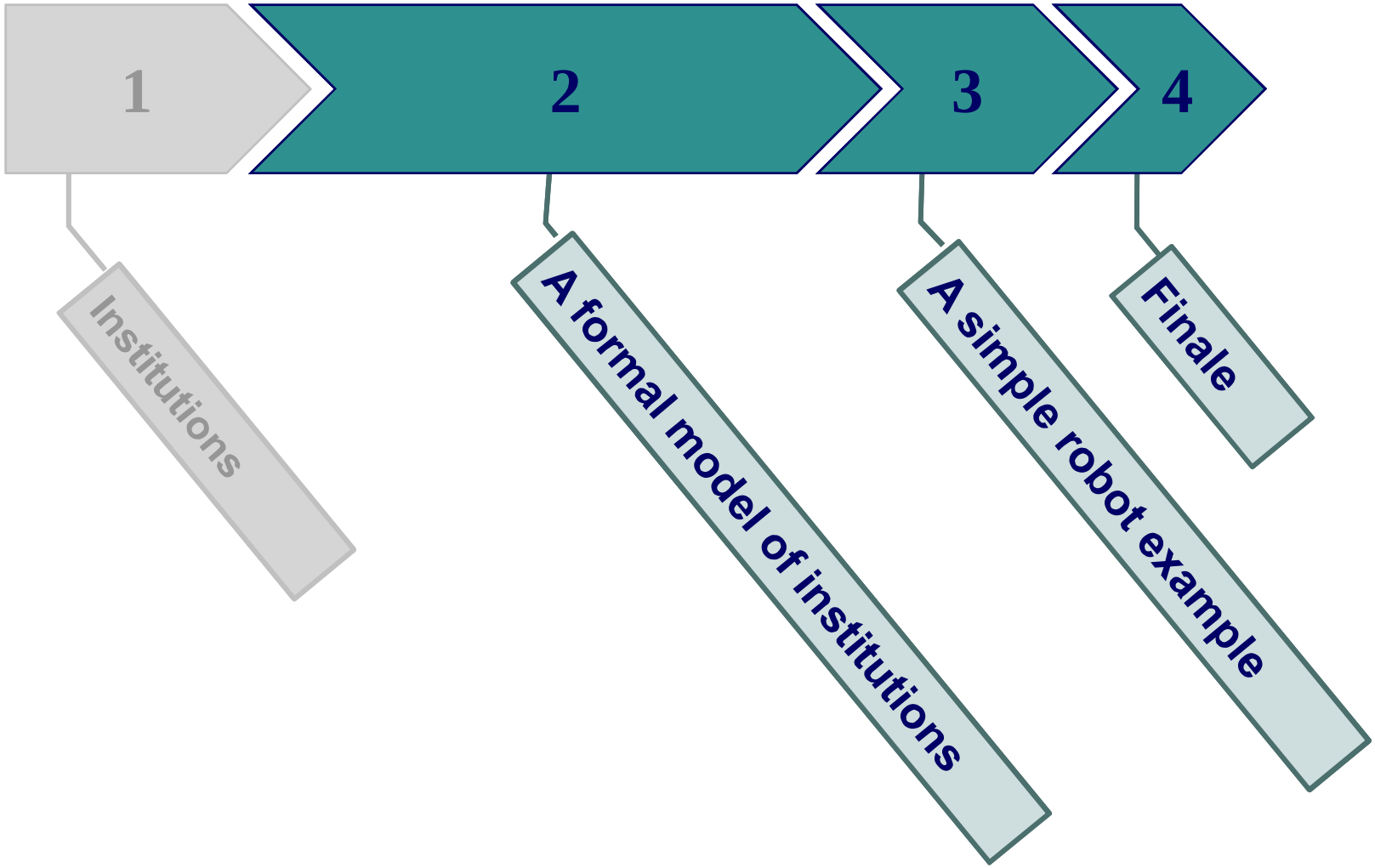


[J.N. Pereira, P. Silva, P.U. Lima, A. Martinoli 2014]

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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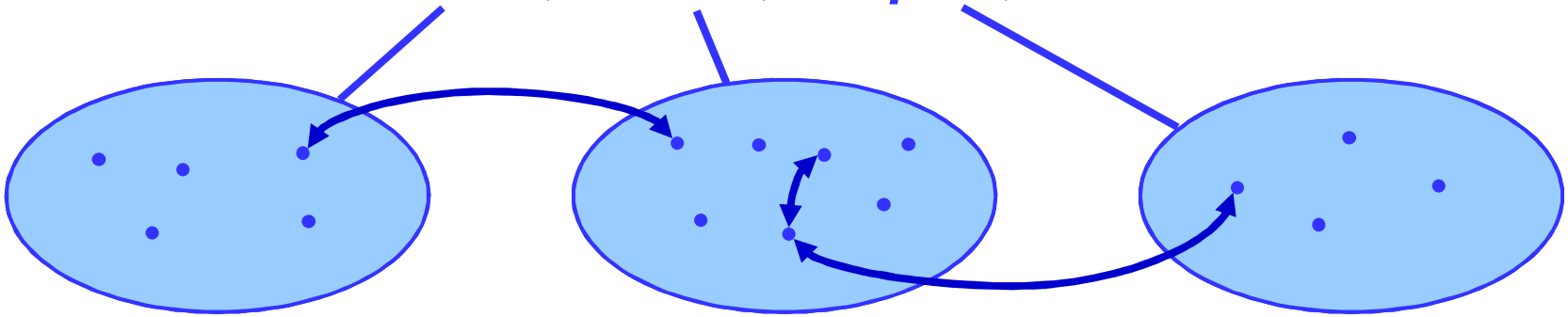
A model of Institutions

$\mathcal{I}$ = ‹ *Roles, Actions, Artifacts, Norms* ›

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

A model of Institutions

$\mathcal{I}$ = ‹ Roles, Actions, Artifacts, Norms ›



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

$$OBN = \{obn_1, obn_2, \ldots, obn_l\} \subseteq Roles \times Acts$$

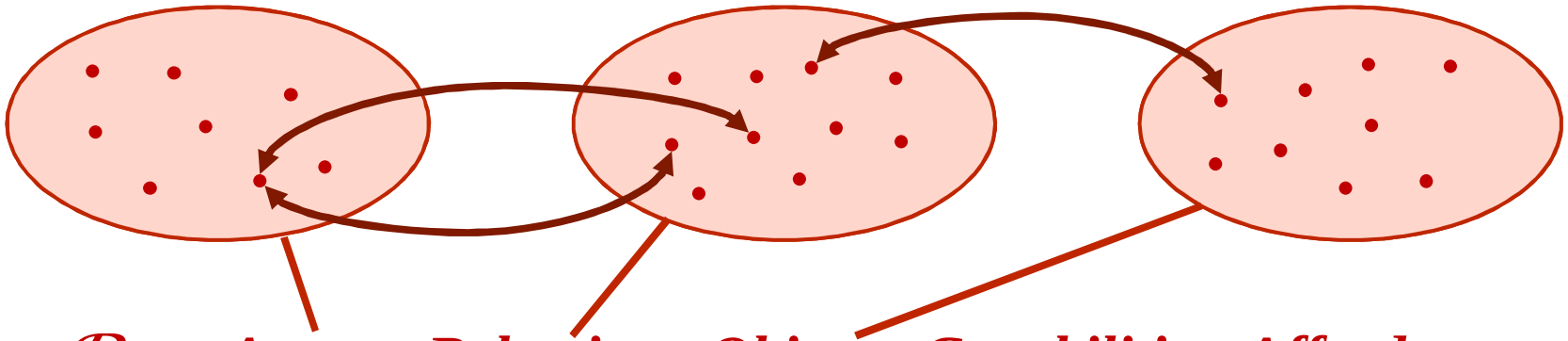
Definition 4. *An* Usability norm *is an element* $usn \in USN$. *A set of* Usability norms *(*USN*) is a binary relation of* $Acts$ *and* $Arts \cup Roles$*:*

$$USN = \{usn_1, usn_2 \ldots, usn_u\} \subseteq Acts \times (Arts \cup Roles)$$

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

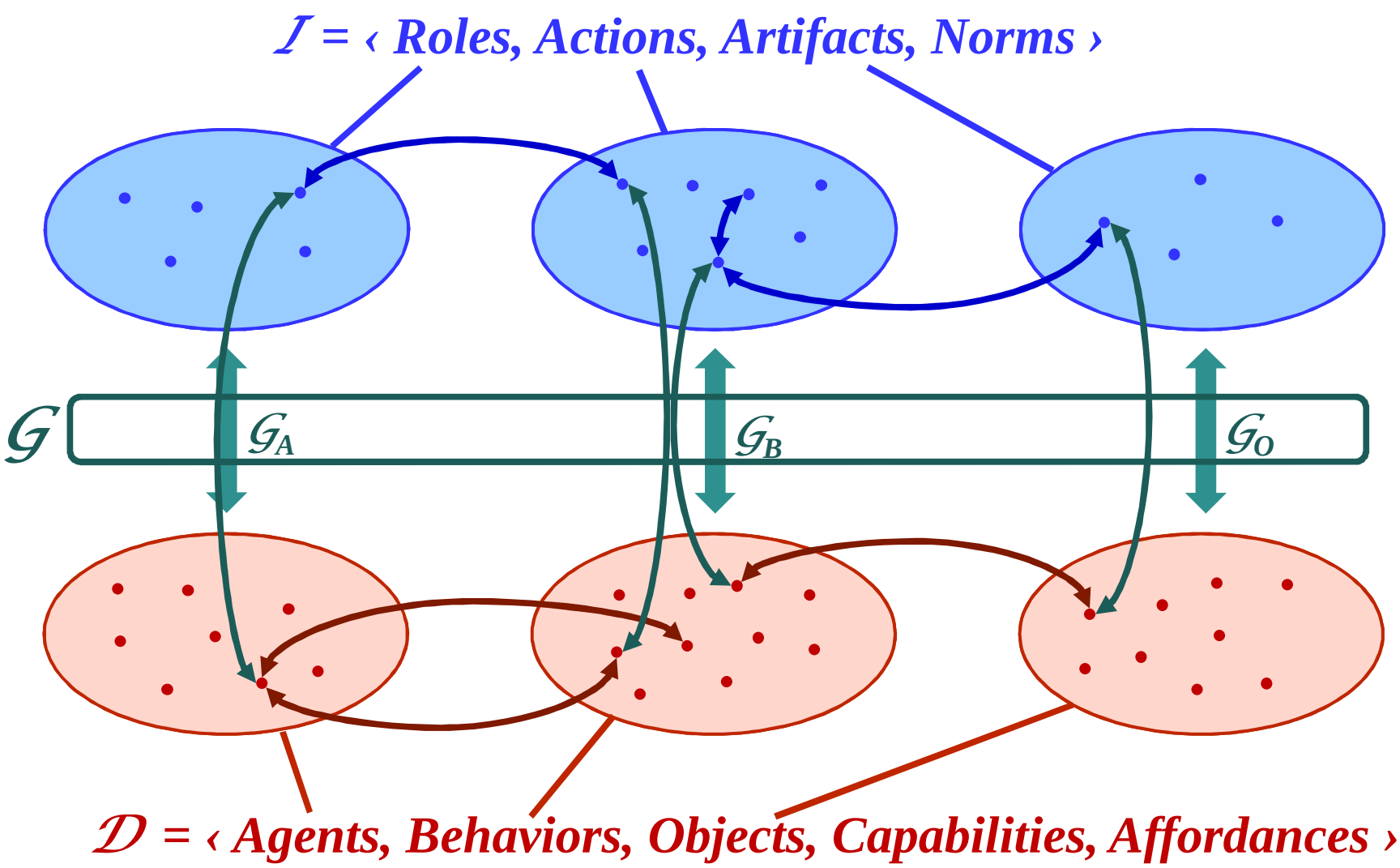
$$PLN = \{pln_1, pln_2 \ldots, pln_p\} \subseteq Acts^n$$

Enter the physical world



$\mathcal{D}$ = ‹ Agents, Behaviors, Objects, Capabilities, Affordances ›

Grounding an Institution



Grounding an Institution

Grounding an Institution

Admissible grounding

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

$$\begin{aligned}&\mathbf{WellFormed(role, ag)} \iff \\ &(\forall act \in Acts.(role, act) \in OBN.(\mathbf{Capable(ag, role, act)} \wedge \\ &\forall art \in Arts.(act, art) \in USN.\mathbf{Affords(art, act)} \wedge \\ &\forall urol \in Roles.(urol, act) \in USN.\mathbf{Affords(urol, act)}))\end{aligned}$$

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

$$\begin{aligned}&\mathbf{Cardinality(role)} \iff \\ &(min(Card(role)) \leq |[\mathcal{G}_A]_{role}| \leq max(Card(role)))\end{aligned}$$

Definition 13. *The grounding $\mathcal{G} = \langle \mathcal{G}_A, \mathcal{G}_B, \mathcal{G}_O \rangle$, of institution is admissible, if the following condition holds:*

$$\begin{aligned}&\forall role \in Roles, \forall ag \in A : (Cardinality(role) \wedge \\ &((role, ag) \in \mathcal{G}_A \implies (WellFormed(role, ag)))\end{aligned}$$

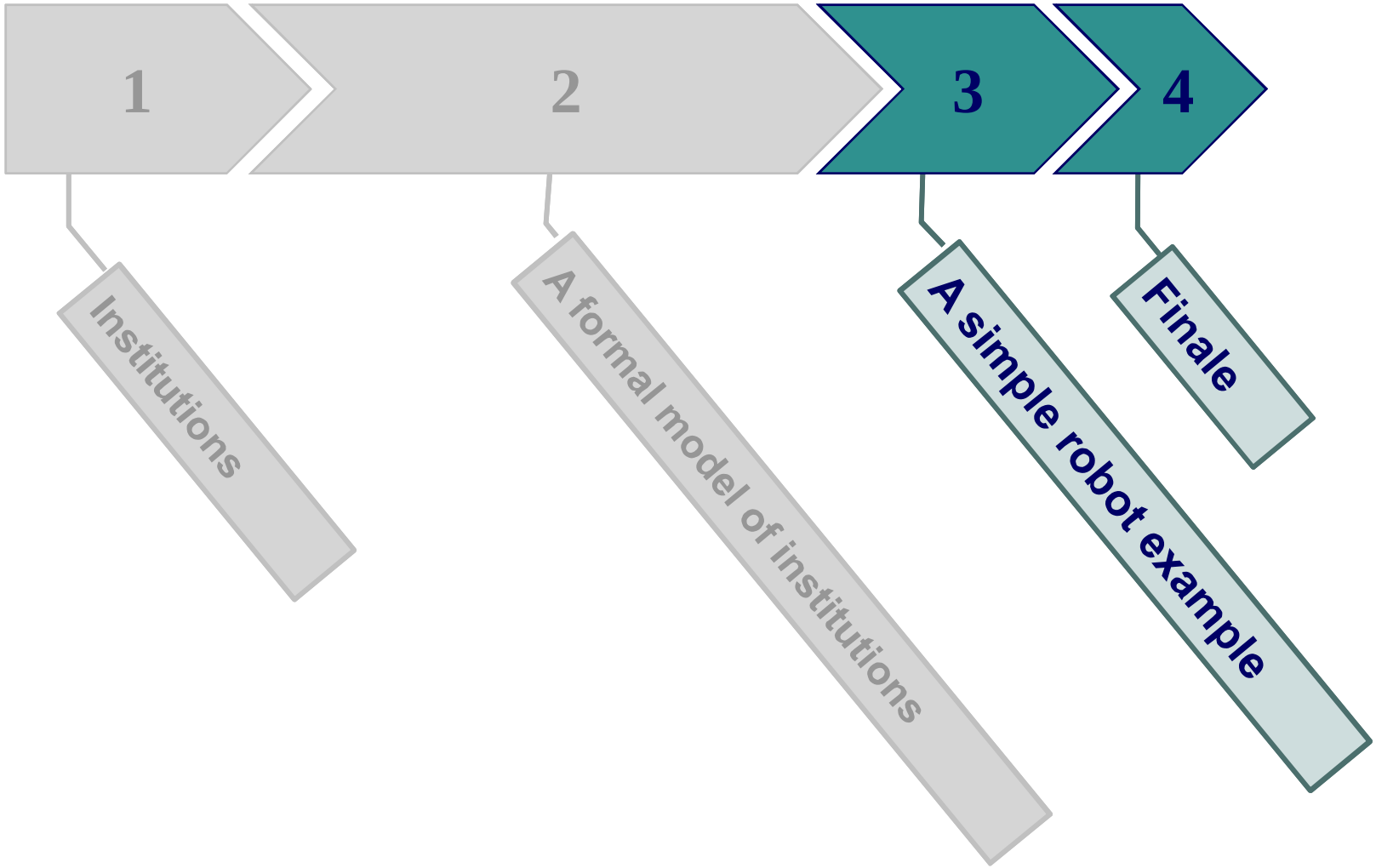
What it means to be part of an Institution?

- **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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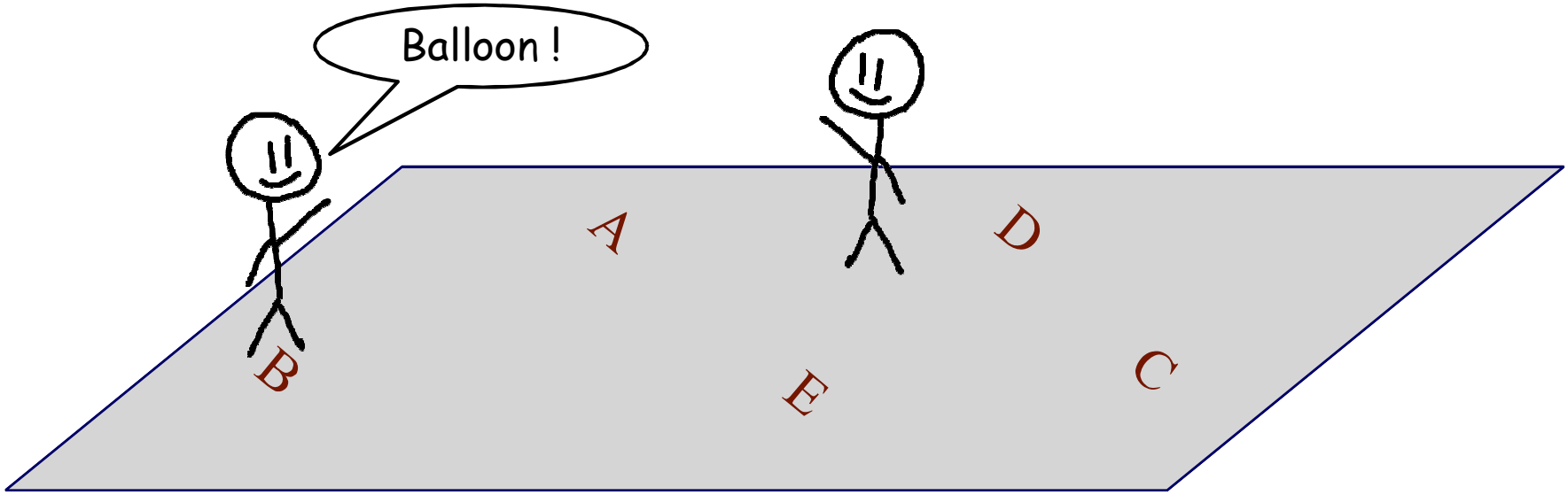
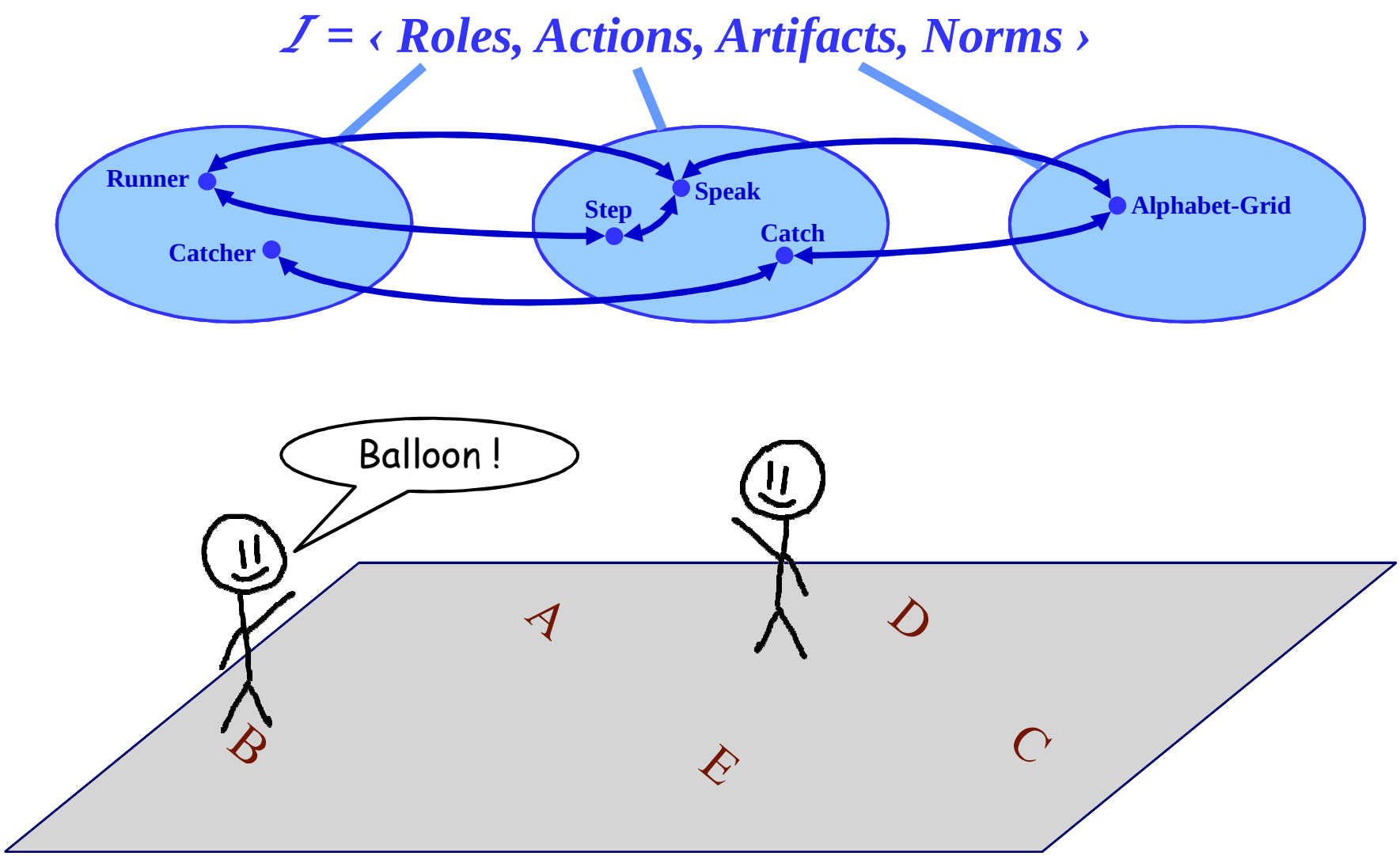
A children game

- 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

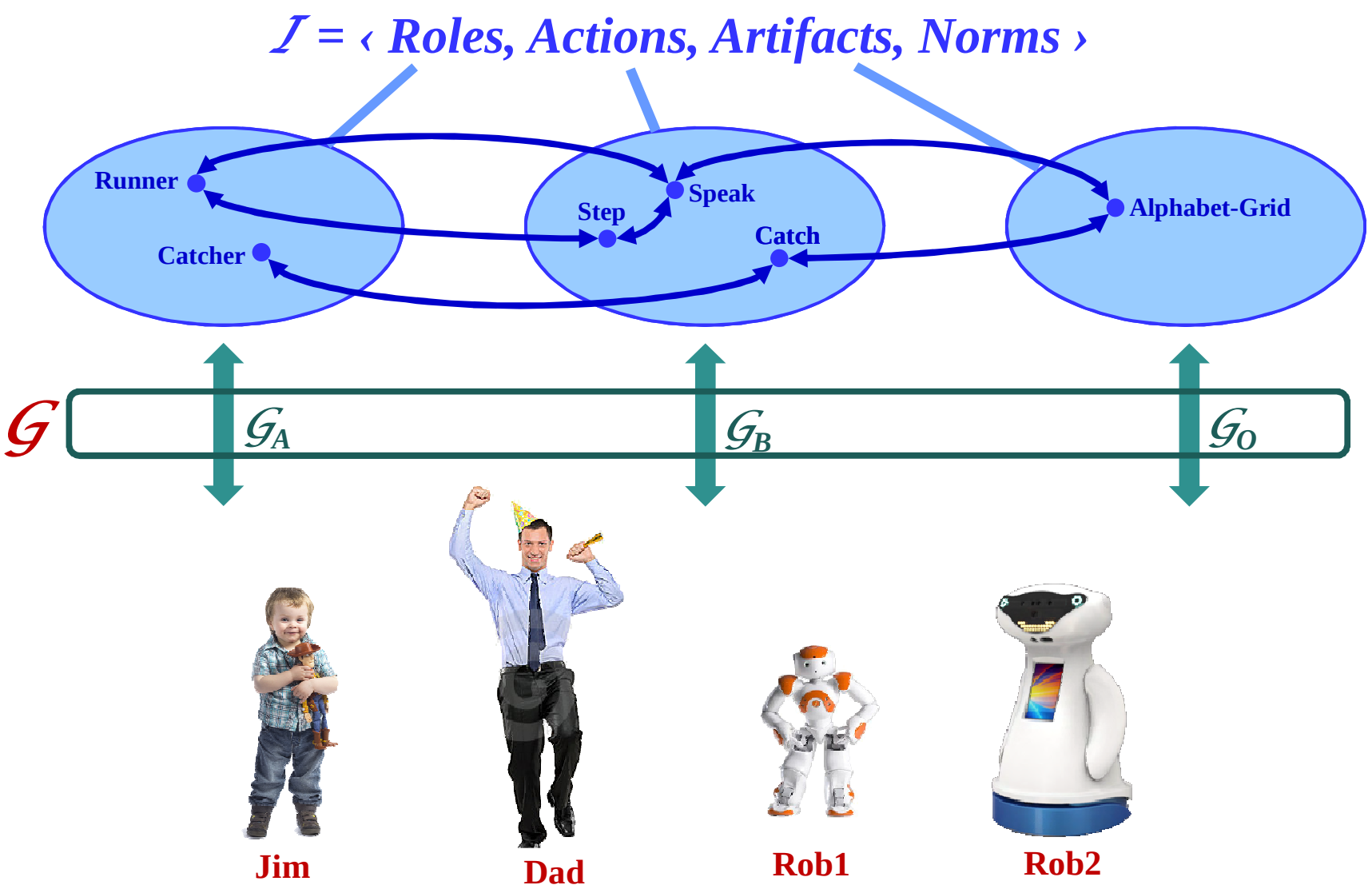
[Ali Abdul Khaliq]



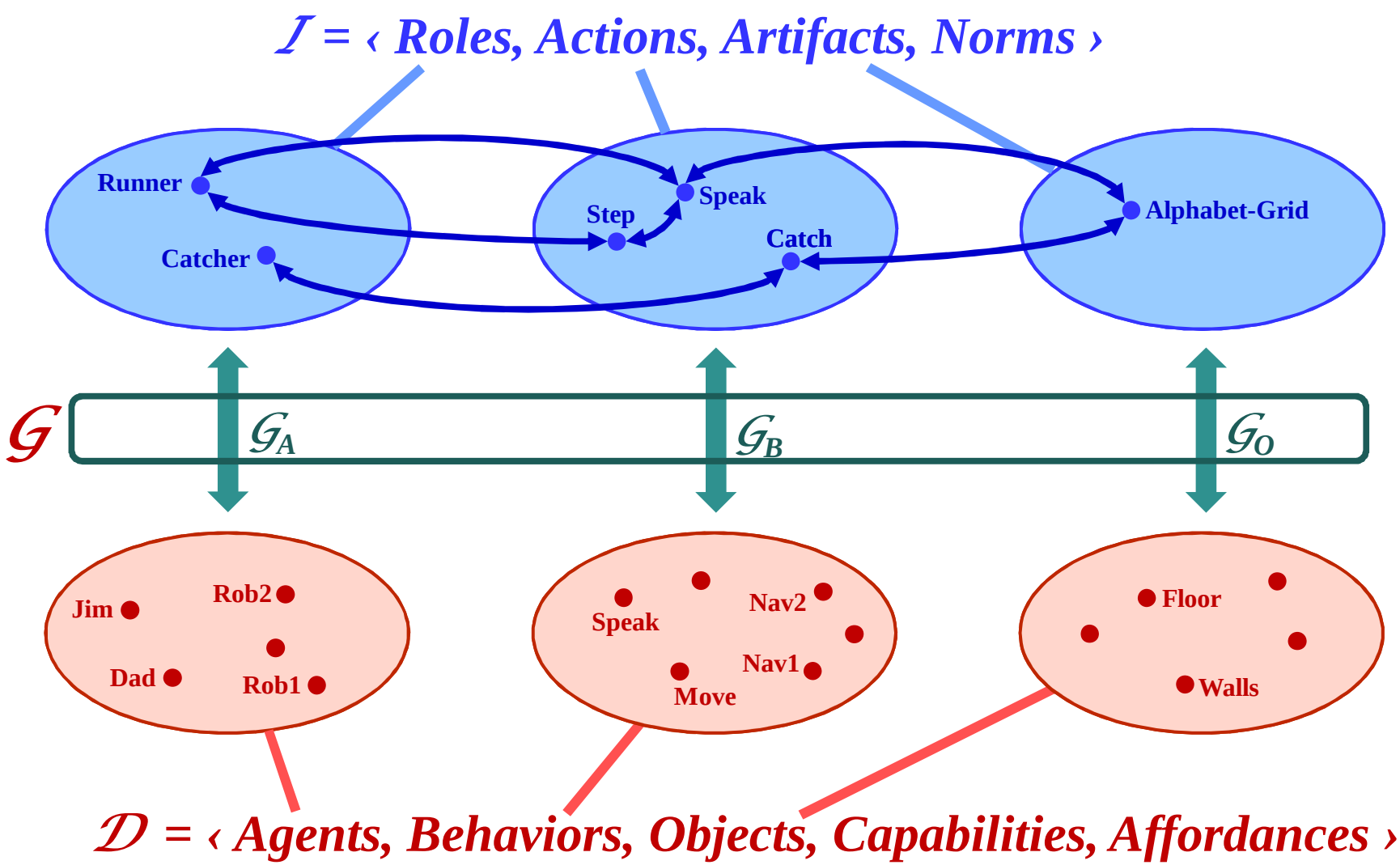
The game modeled as institution



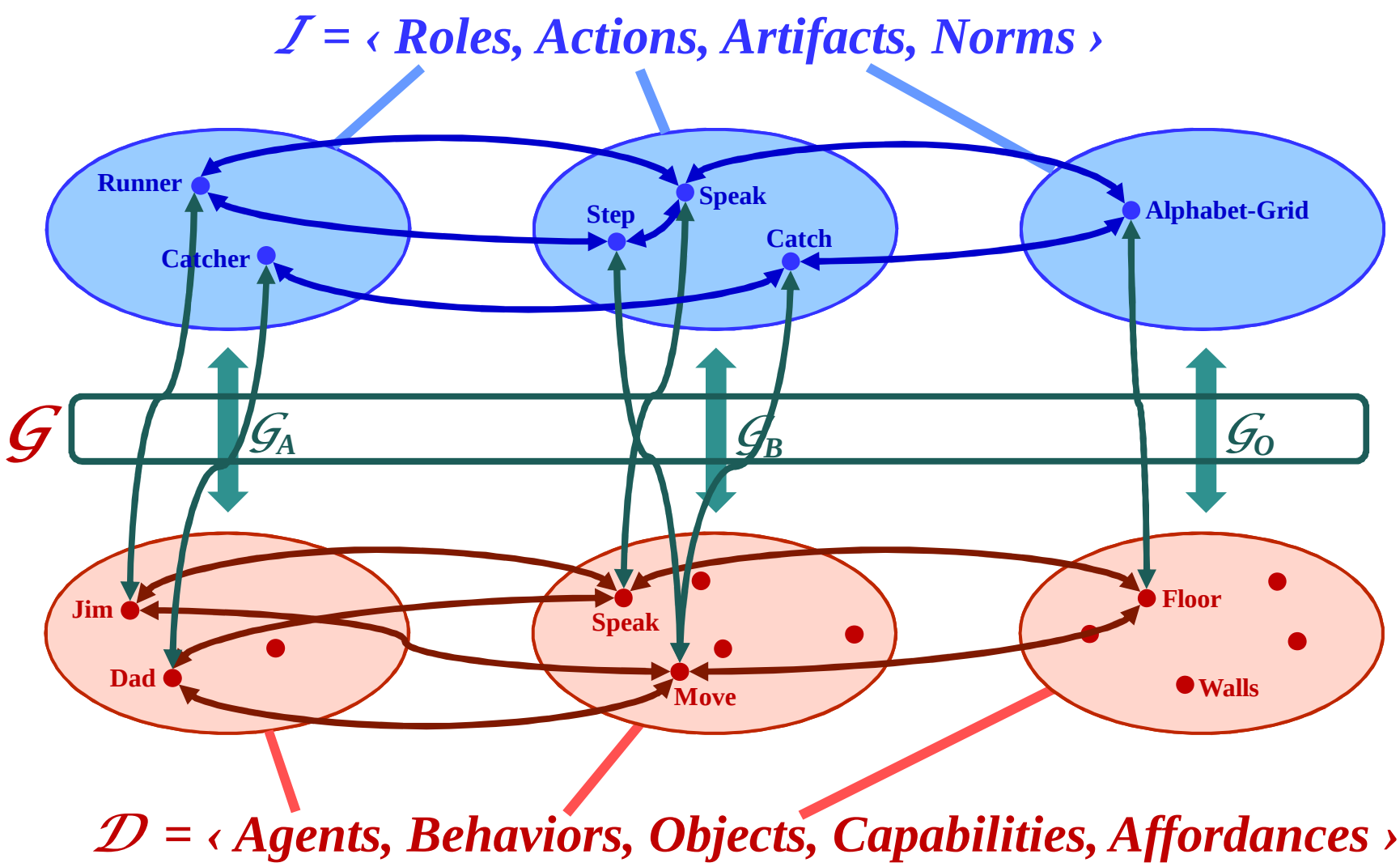
Grounding the institution



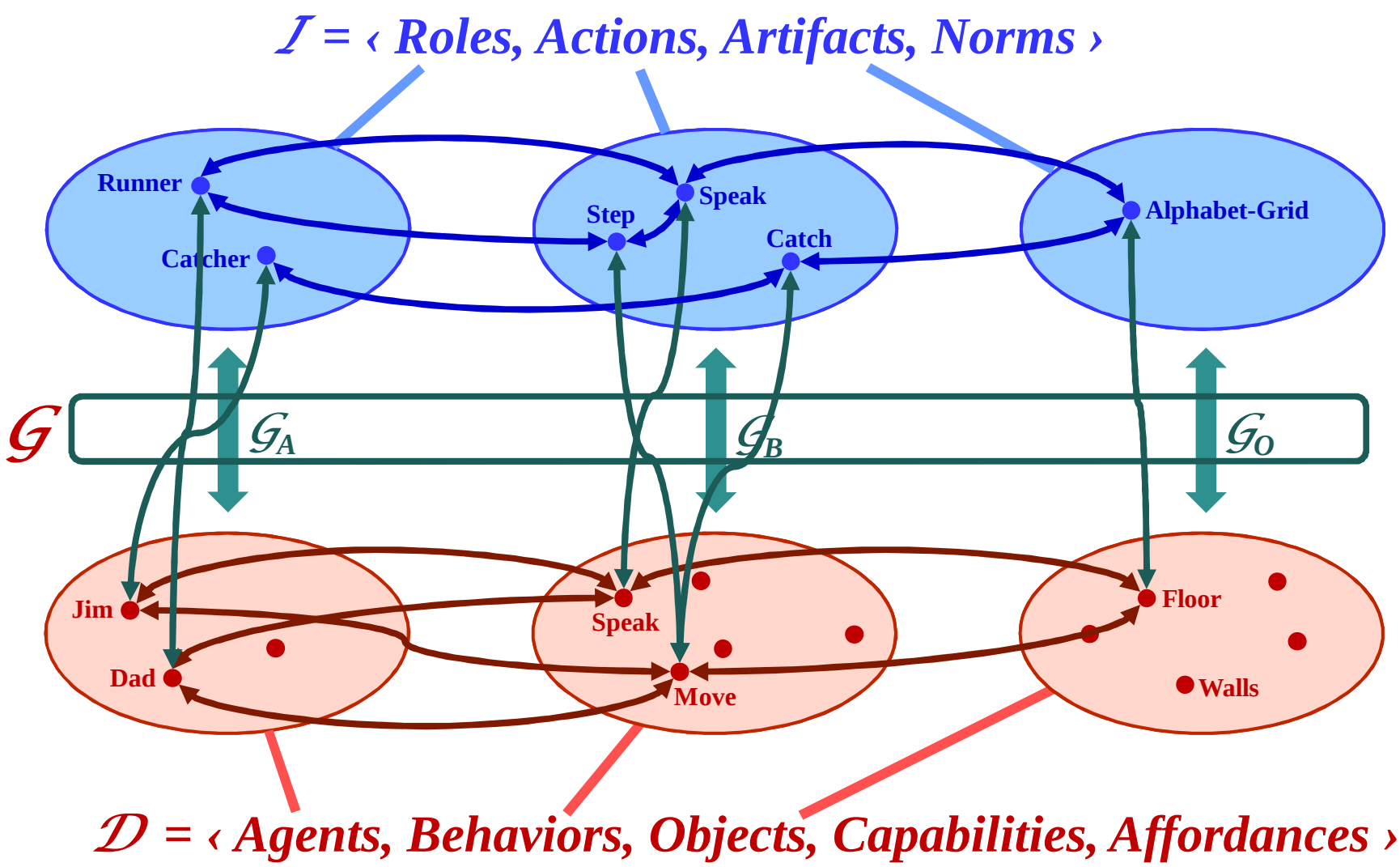
Grounding the institution



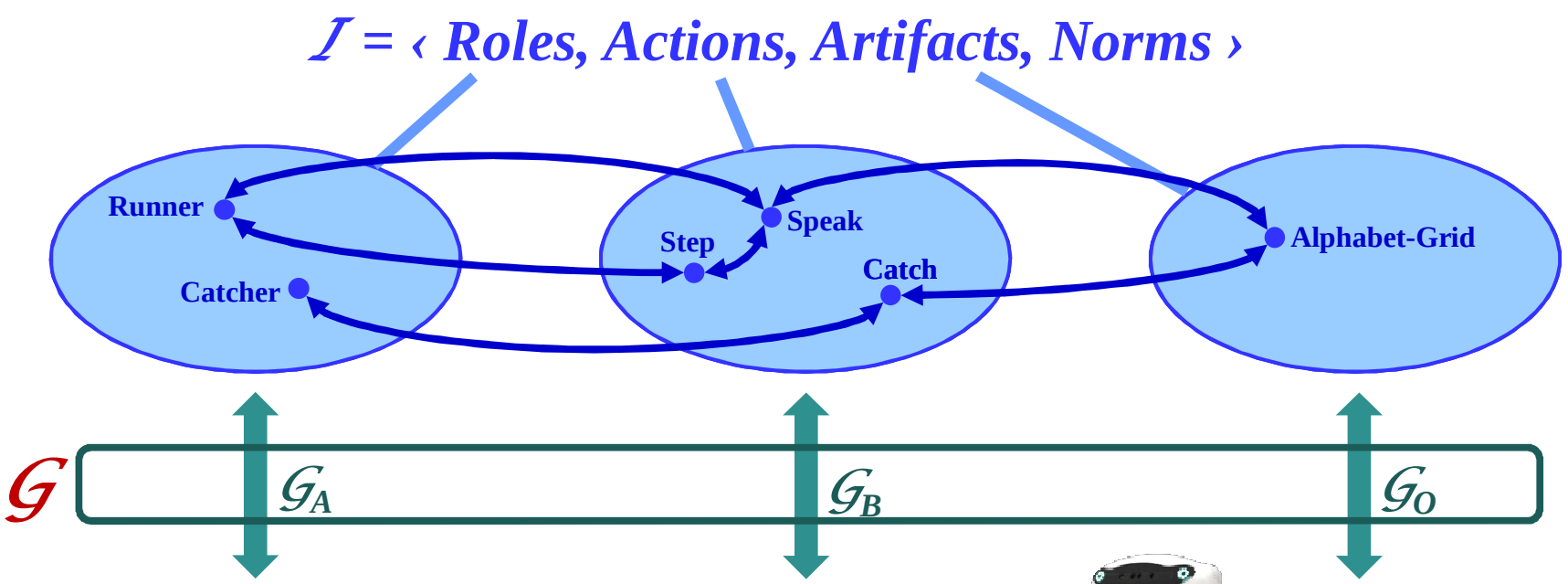
Grounding 1: play with dad

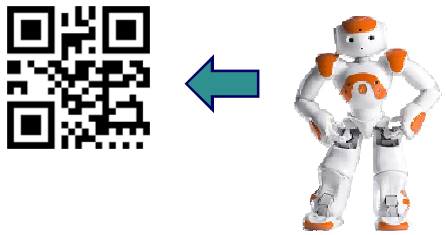


Grounding 1: play with dad (reverse roles)



Playing with the robots

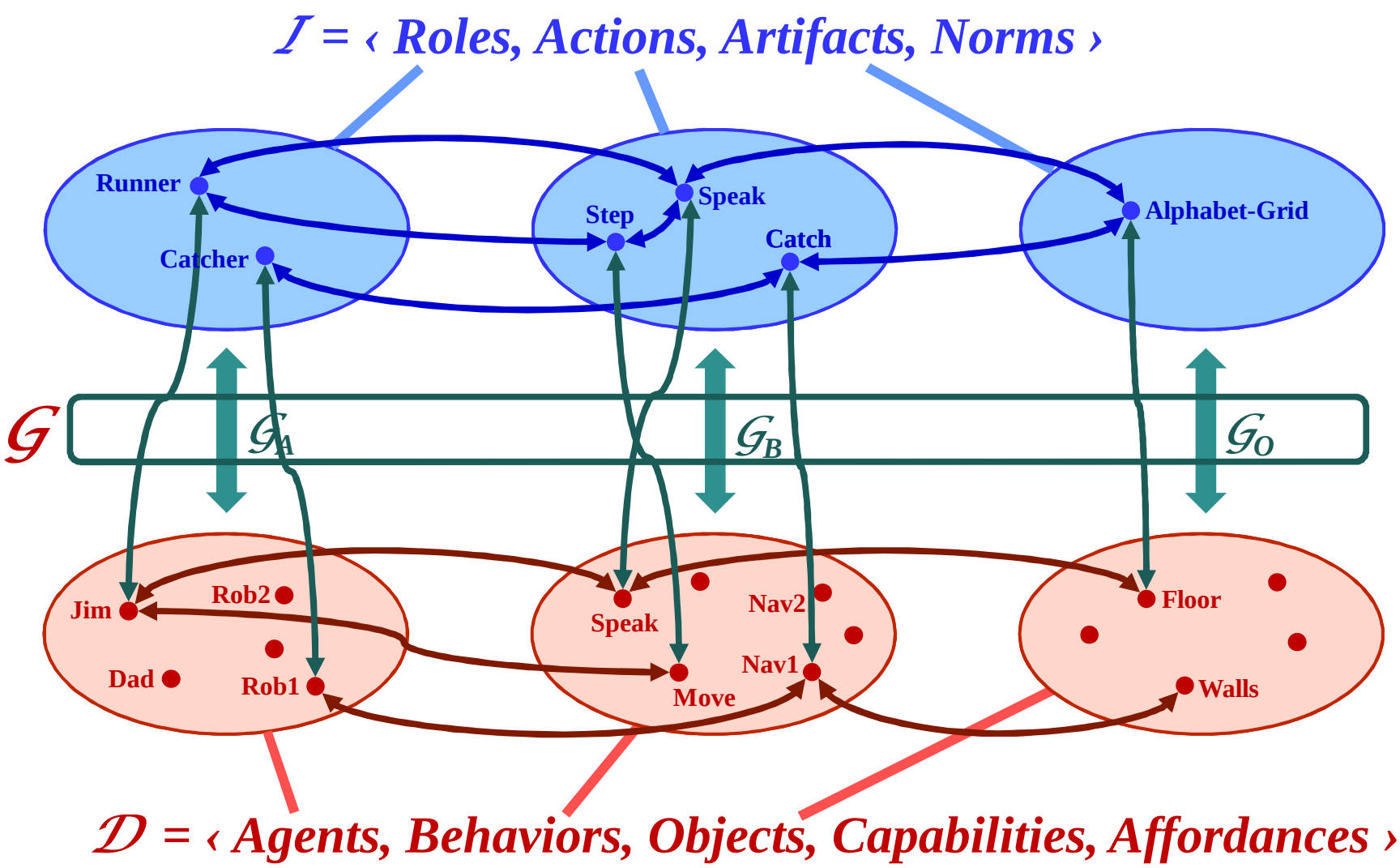




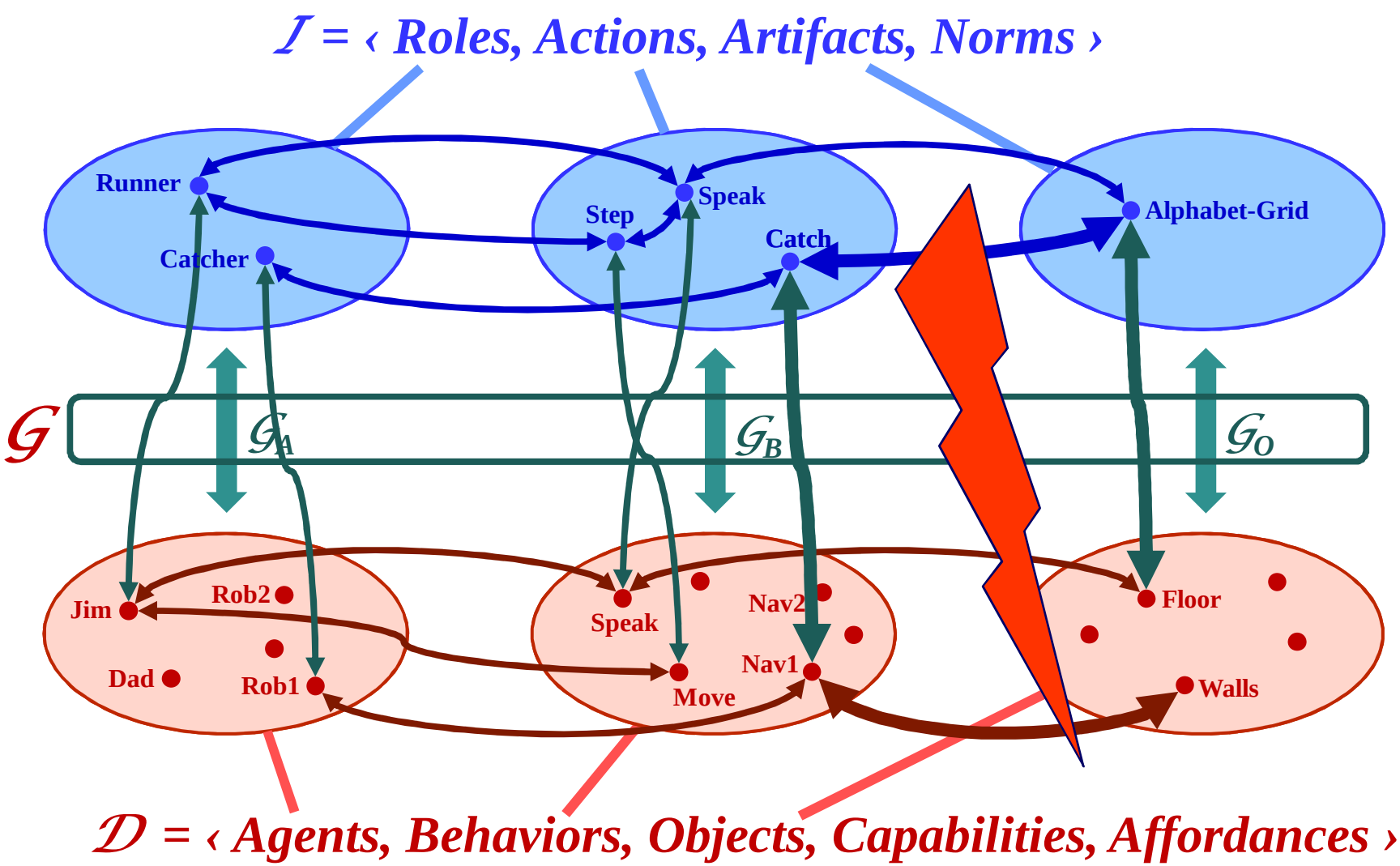
Rob1 : sees QR-tags on the wall

Rob2 : reads RFID tags under the floor

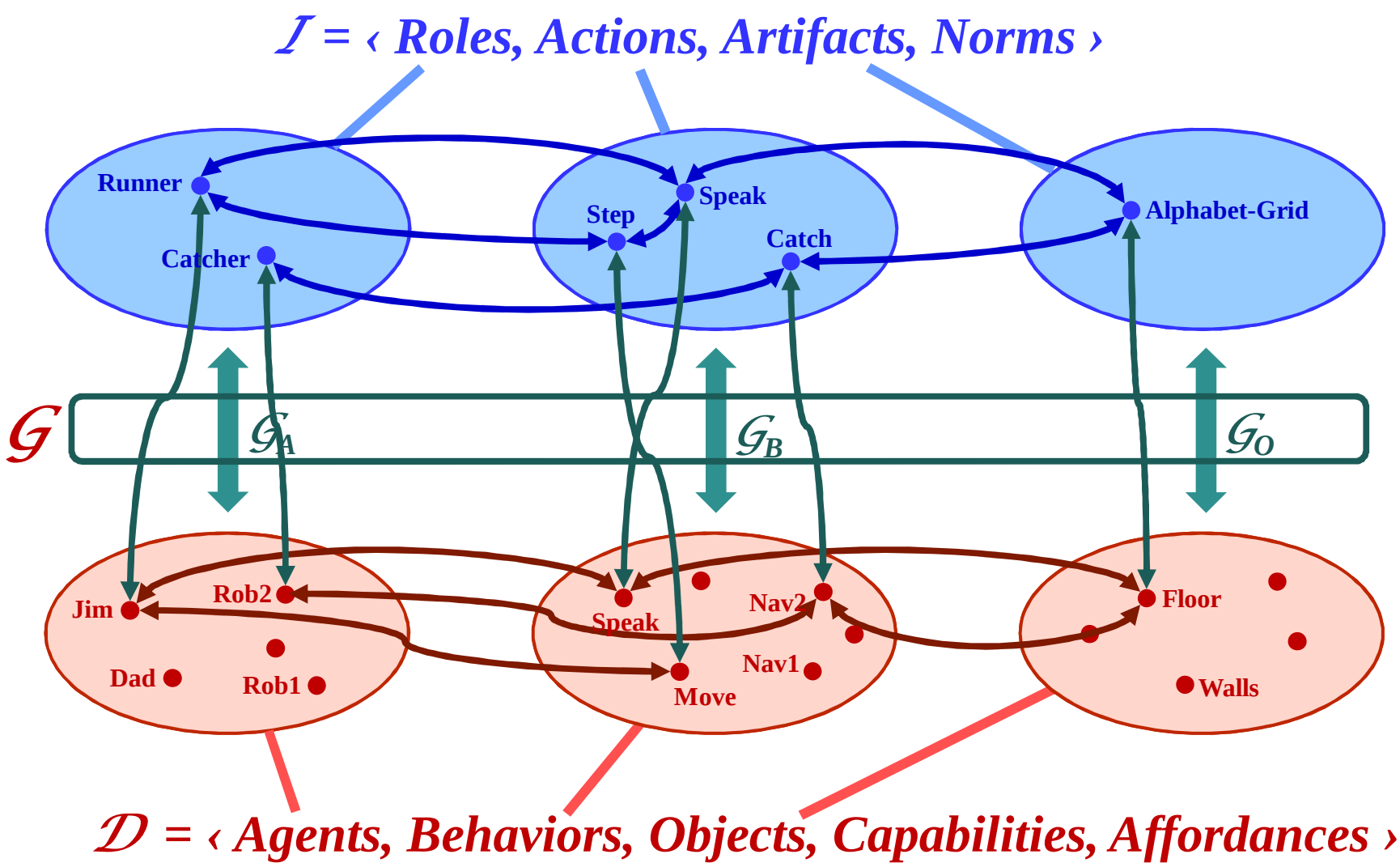
Grounding 2: playing with Rob1



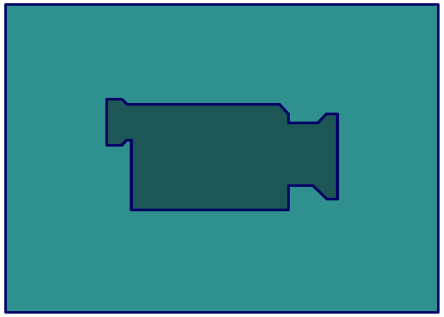
~~Grounding 2: playing with Rob1~~



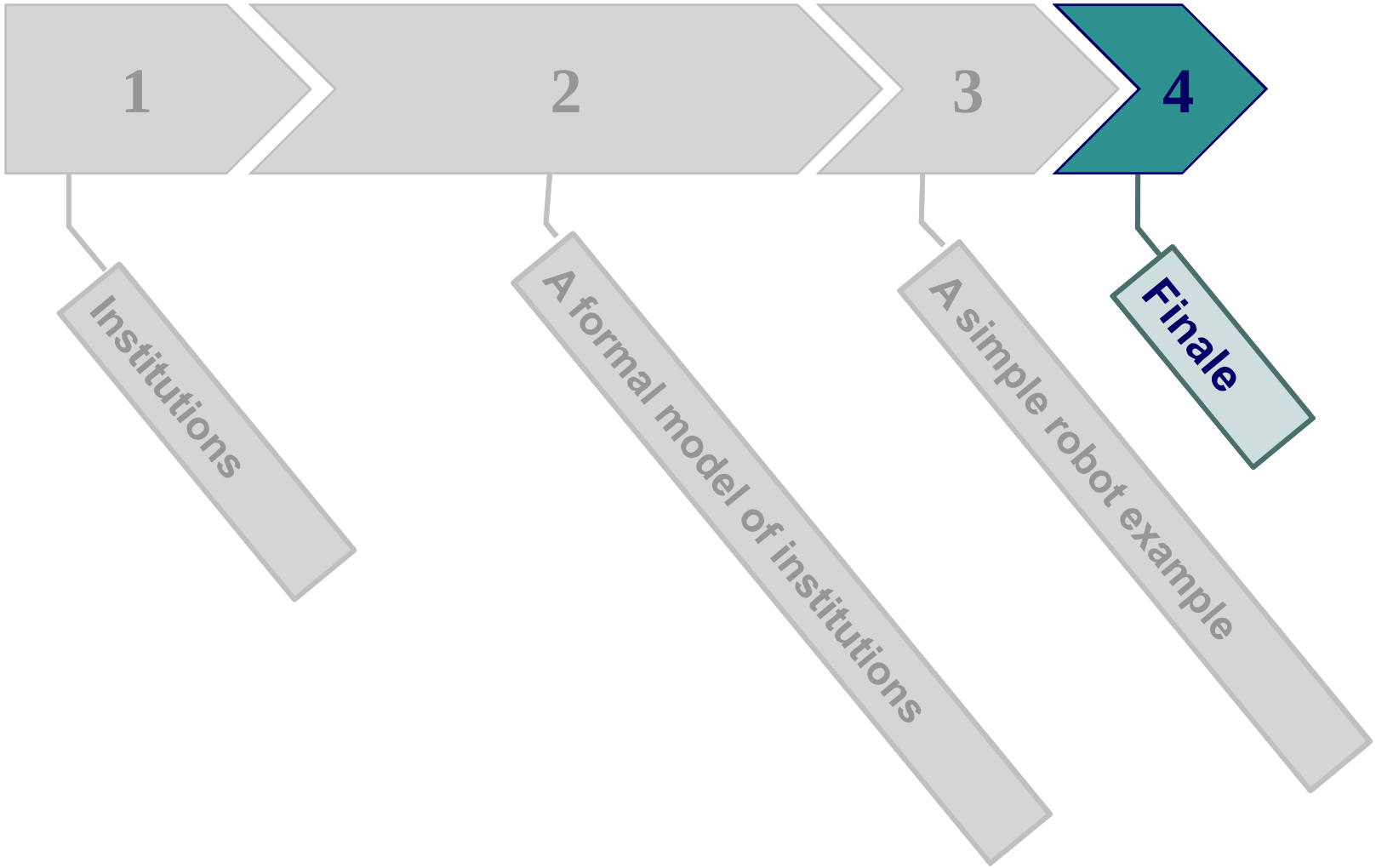
Grounding 2: playing with Rob2



Let’s play!



Roadmap



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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

Swindon, UK

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Thank you!

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