UNIVERSITÀ DEGLI STUDI DI PALERMO

dipartimento di ingegneria unipa

CNR ISTC INSTITUTE OF COGNITIVE SCIENCES AND TECHNOLOGIES

ENDOWING ROBOTS WITH SELF-MODELING ABILITIES FOR TRUSTFUL HUMAN-ROBOT INTERACTIONS

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20TH WORKSHOP "FROM OBJECTS TO AGENTS"

OBJECTIVE

How to model and develop teammate robots performing trustful interaction with humans?

- Modeling and representing robot's knowledge
- The robot has decide and act in an autonomous fashion
- The robot has be self-adaptive

KEY IDEAS

- Triggering the decision process by means of attributing mental state to itself and to the others
- Integrating self-modeling and trust
- Employing BDI paradigm and Jason
  - extending BDI reasoning cycle for including self-modeling and justification

HUMAN-ROBOT TEAMING INTERACTION

- Two main situations:
  - Known and unchanging environment
  - Partially known and changing environment

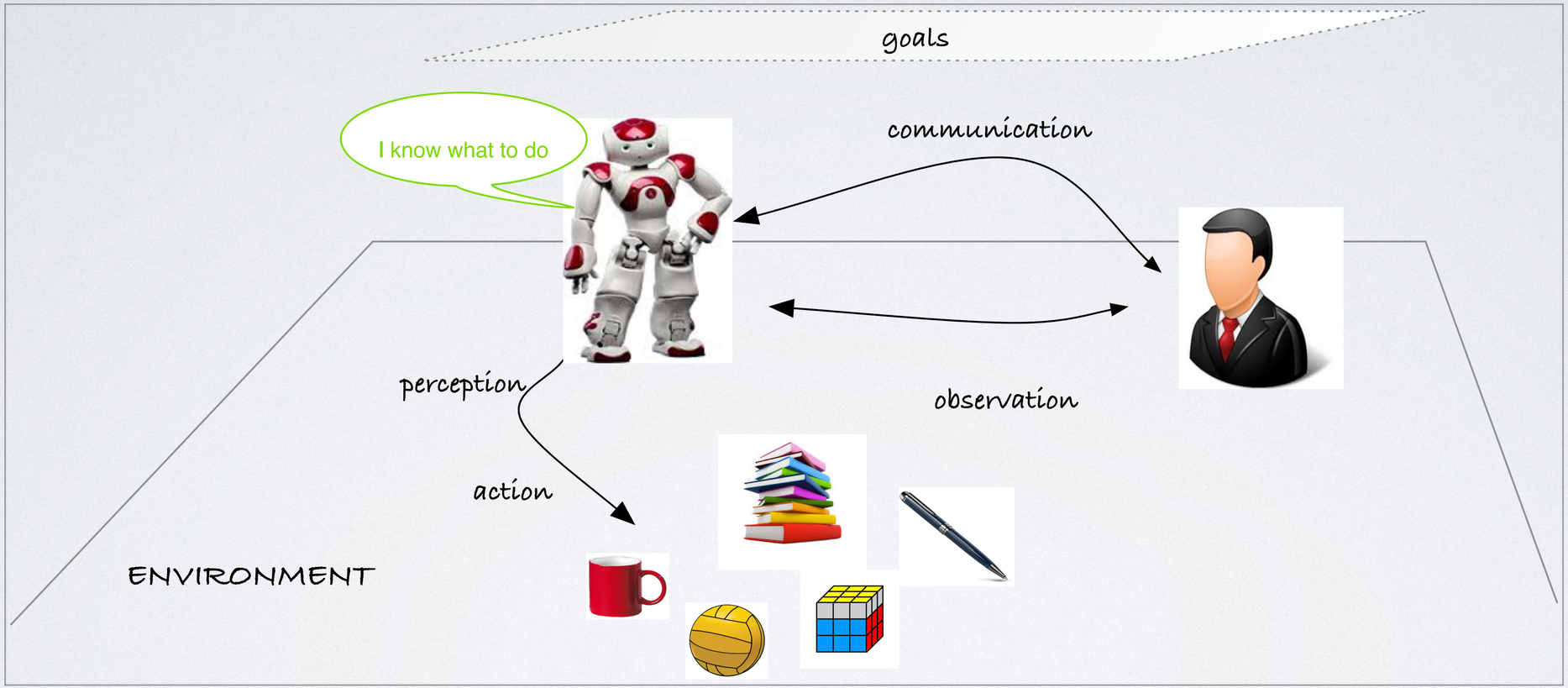
HUMAN-ROBOT TEAMING INTERACTION

- Known and unchanging environment
  - Each teammate knows everything before starting
  - Use knowledge for performing task and plans

HUMAN-ROBOT TEAMING INTERACTION

- Partially known and changing environment
  - Each teammate interacts mainly for:
    - Enhancing knowledge on the environment and on himself
    - Acquiring knowledge on what to do
  - Each teammate is:
    - aware of his own limitation and capabilities
    - establish a level of confidence in the other

HUMAN-ROBOT TEAMING INTERACTION

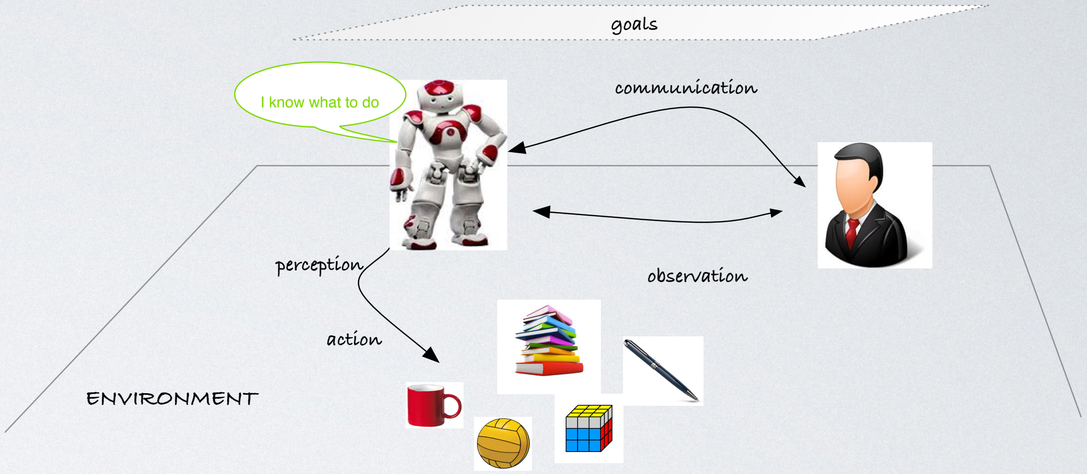


HUMAN-ROBOT TEAMING INTERACTION

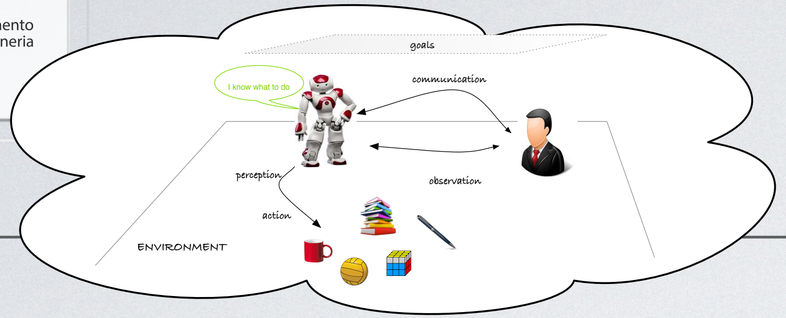
- Complex systems
  - where requirements are identified at runtime
    - changing environment conditions
    - presence of interacting users
  - global behavior emerges at runtime
- Need for exhibiting adaptation

A NEW PERSPECTIVE

- Changing perspective
- Robot is part of the environment



  - it senses itself as part of the environment along with all the other objects/agents



goals

I know what to do

communication

perception

observation

action

ENVIRONMENT

CHALLENGES

- Environment is not known a-priori
  - plans, tasks and all that is necessary for acting and deciding cannot be established at design time
- Equipping the robot with the ability **(at runtime)** to select the best action to perform
  - Knowledge acquisition
  - Decision-making process
- Several ingredients trigger the decision process:
  - goals, capabilities, mental states, emotions, **trust**…in general: awareness

SELF-MODELING AND TRUST

- The role of self-modeling and trust -> triggering the decision process
- The robot si able to create a model of the self
  - It is able to select an action on the base of what it knows about itself
  - it is able to decide which action to adopt

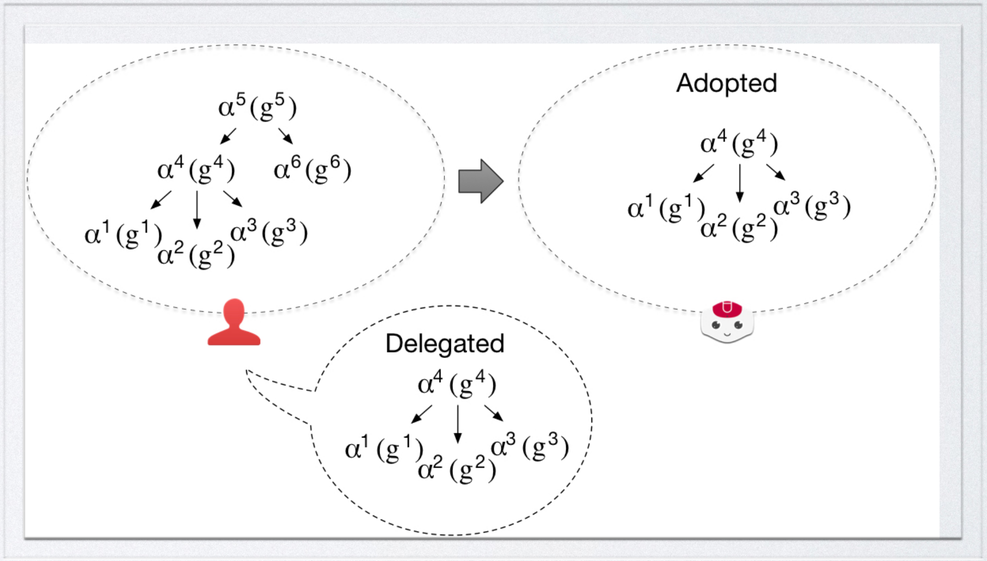
IMPLEMENTING SELF-MODELING ABILITIES

- Exploiting BDI practical reasoning and the trust model
- We extend the deliberation process

THE TRUST MODEL

- *The trust of a trustor agent in a trustee agent for a specific context to perform acts to realize the outcome result.*

$$TRUST(\mathbf{X}\ \mathbf{Y}\ \mathbf{C}\ \tau\ g_X)$$



THE BDI REASONING CYCLE

Robot has:
to commit or delegate actions and
reason on its own action

```
1.  B ← B0;          /* B0 are initial beliefs */
2.  I ← I0;          /* I0 are initial intentions */
3.  while true do
4.    get next percept ρ via sensors;
5.    B ← brf(B, ρ);
6.    D ← options(B, I);
7.    I ← filter(B, D, I);
8.    π ← plan(B, I, Ac); /* Ac is the set of actions */
9.    while not (empty(π) or succeeded(I, B) or impossible(I, B)) do
10.     α ← first element of π;
11.     execute(α);
12.     π ← tail of π;
13.     observe environment to get next percept ρ;
14.     B ← brf(B, ρ);
15.     if reconsider(I, B) then
16.       D ← options(B, I);
17.       I ← filter(B, D, I);
18.     end-if
19.     if not sound(π, I, B) then
20.       π ← plan(B, I, Ac)
21.     end-if
22.   end-while
23. end-while
```

MAPPING TRUST TO BDI

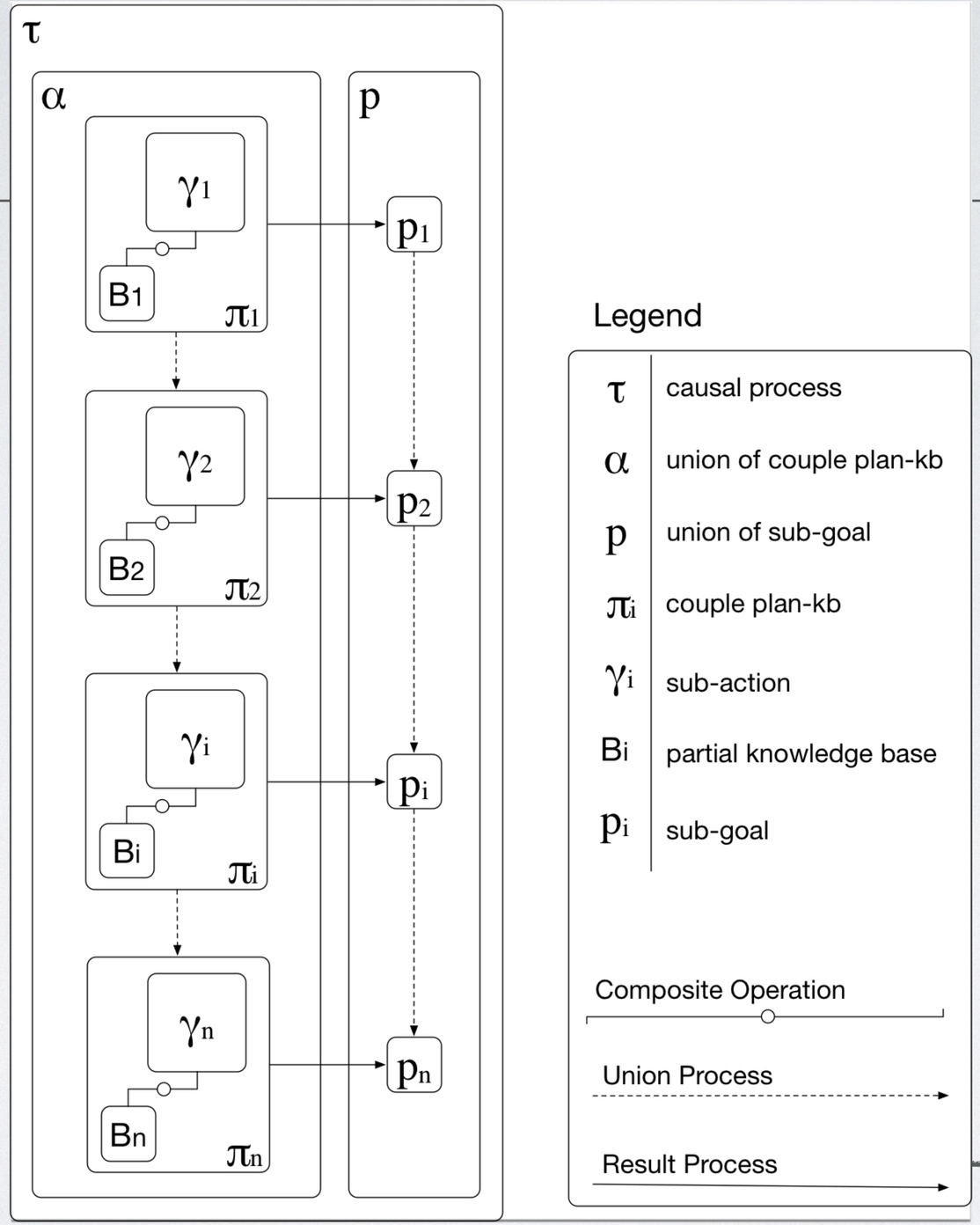
- Making beliefs explicit
- Breaking down actions and results —> plans and sub-results

$$TRUST(X\ Y\ C\ \tau\ g_X)$$

$$\text{where} \quad \tau = (\alpha, p) \quad \text{and} \quad g_X \equiv p;$$

$$\tau = (\alpha, p) \quad \text{where} \quad \alpha = \bigcup_{i=1}^{n} \pi_i \quad \text{and} \quad p = \bigcup_{i=1}^{n} p_i$$

$$\pi_i = \gamma_i \circ B_i \Rightarrow \alpha = \bigcup_{i=1}^{n} (\gamma_i \circ B_i)$$


τ
α
p
γ1
B1
π1
p1
γ2
B2
π2
p2
γi
Bi
πi
pi
γn
Bn
πn
pn
Legend
τ causal process
α union of couple plan-kb
p union of sub-goal
πi couple plan-kb
γi sub-action
Bi partial knowledge base
pi sub-goal
Composite Operation
Union Process
Result Process

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```

$$A_c \leftarrow action(B_{\alpha_i}, Cap)$$

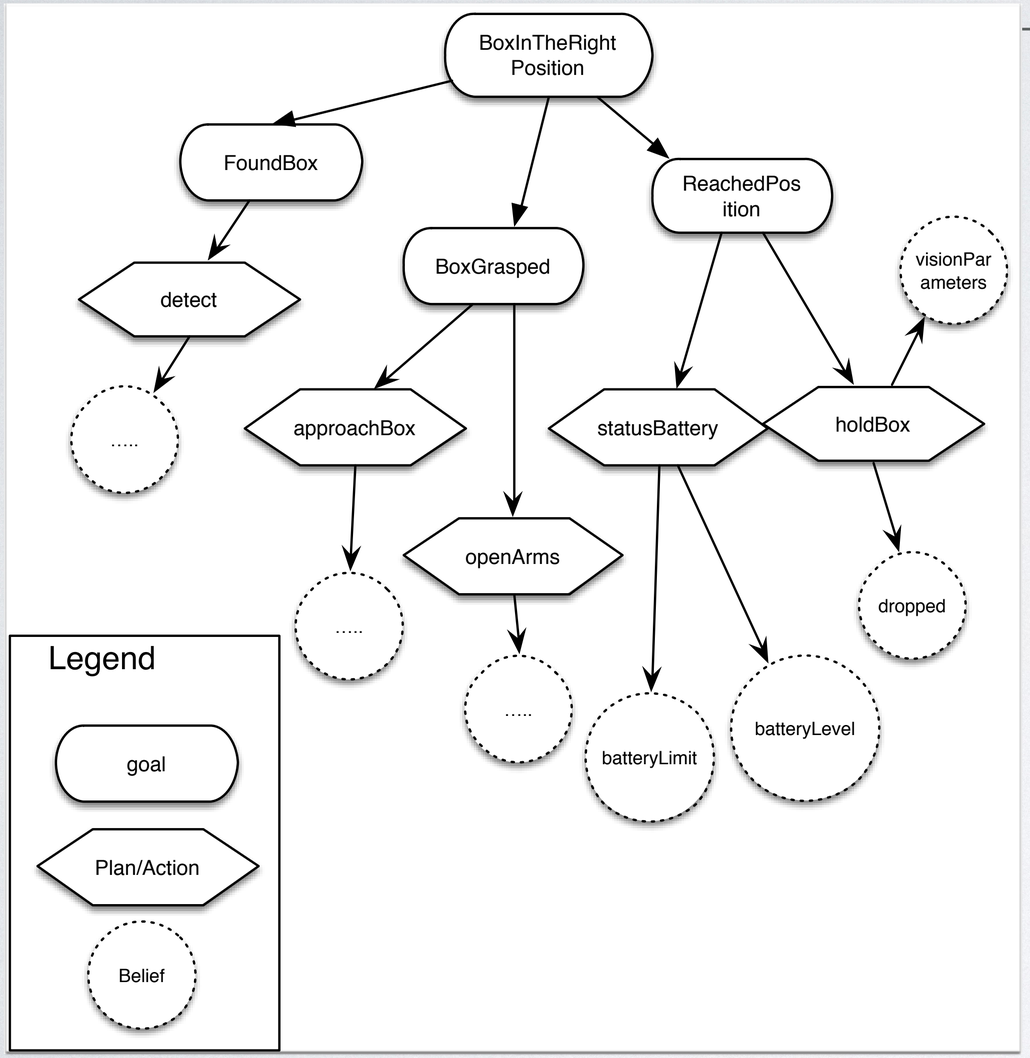
$$evaluate(\alpha_i);$$
$$J \leftarrow justify(\alpha_i, B_{\alpha_i});$$

Self-Modeling
Trustful interaction

THE ROBOT IN ACTION

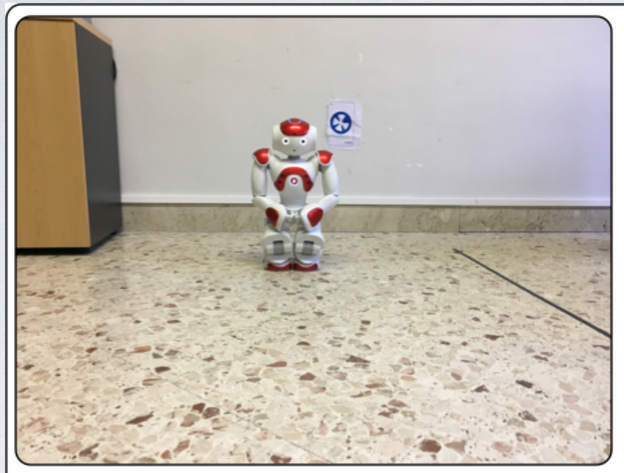
- Jason Agent
- CArtAgO artifact
- CArtAgO @Operation
- a reference model of the environment
  - all the internal elements of the agent/robot as part of the environment

THE ROBOT IN ACTION



1 +!ReachedPosition: true $\leftarrow$ goAhead; holdBox. $[\tau]$;
2 +!goAhead: batteryLimit(X) & batteryLevel(Y) & $Y < X \leftarrow$ say("My battery is exhaust. Please let me charge."). $[\gamma_1^+]$;
3 +!goAhead: batteryLimit(X) & batteryLevel(Y) & $Y \geq X \leftarrow$ execActions. $[\gamma_1^-]$;
4 B_1: batteryLimit, batteryLevel ;
5 +!holdBox: dropped(X) & visionParameters(Y) & $X == false \leftarrow$ execAct(Y). $[\gamma_2^+]$;
6 +!holdBox: dropped(X) & visionParameters(Y) & $X == true \leftarrow$ say("The box is dropped."). $[\gamma_2^-]$;
7 B_2: dropped, visionParameters ;

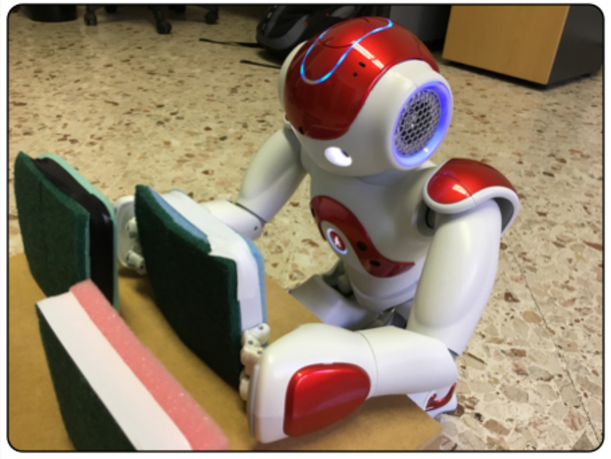
THE ROBOT IN ACTION



Initial Position

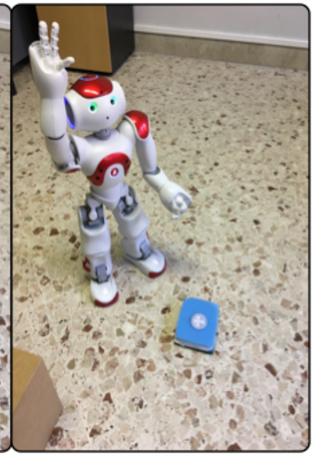
Boxes Assets

Detecting Phase

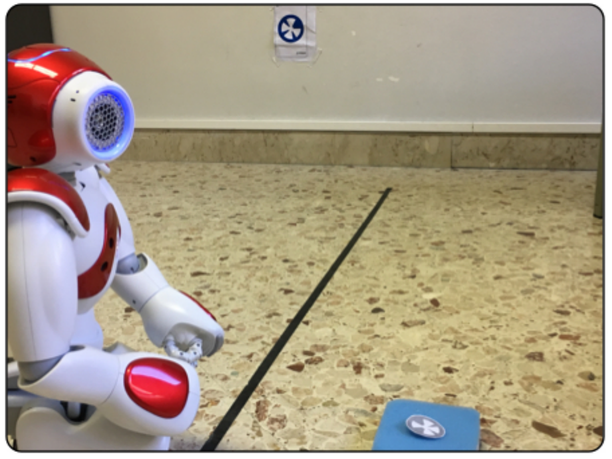


Taking Box

Box Dropped



Justification Phase



Box In The Right Position

CONCLUSIONS AND REMARKS

- Equipping the robot with self-modeling abilities
- Integrating Trust model with BDI deliberation process
- Exploiting JASON and CArtAgO
  - natively support BDI theory and have a well-established counterpart for actions, plans, knowledge implementation

CONCLUSIONS AND REMARKS

- Trust as a first element for triggering the decision process
- The integration in the BDI cycle —> two main elements of interaction
  - self-modeling
  - trust level in the interaction
- In the future:
  - implementing the other levels of adoption/delegation by Falcone&Castelfranchi
  - adding organization (MOISE)
  - adding other elements for triggering the decision process —> theory of mind

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Thanks for your attention!

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