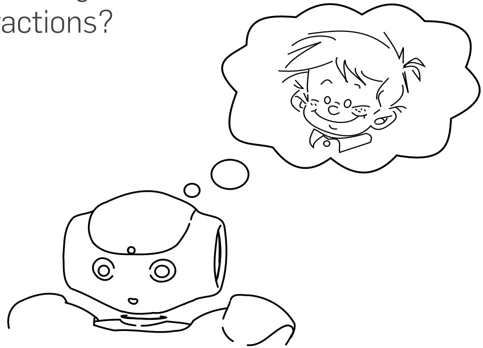
Mutual Modelling in Educational Child-Robot Interaction

Does a second level of modelling enable higher quality interactions?

October 28, 2016

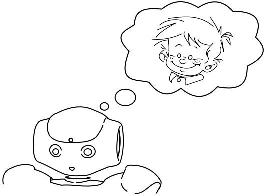


Alexis D. Jacq

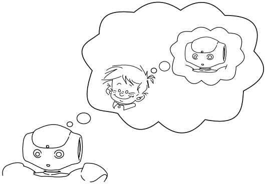
GAIPS INESC-ID **IST**
& CHILI lab **EPFL**

INTRODUCTION

Mutual understanding requires 1st and 2nd order of theory of mind:



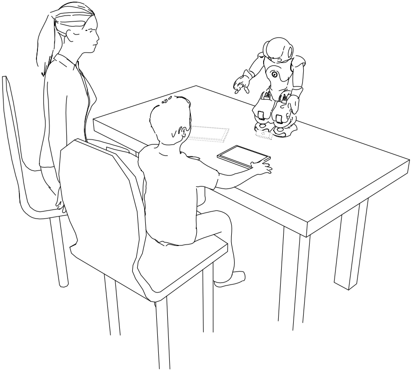
Do I understand you ?



Do you understand me ?

THE COWRITER INTERACTION

Learning by teaching approach:



- a physical robot to induce a "protégé" effect
- the robot is autonomous

Hood, Lemaignan, Dillenbourg, **When Children Teach a Robot to Write: An Autonomous Teachable Humanoid Which Uses Simulated Handwriting**, HRI 2015

OBSERVED ISSUES

The child needs to practice a lot to make progress
Situations of misunderstanding:

- When the child press unexpected button
- when the child is disengaged
- When the child does not perceive the difficulty (or progresses) of the robot
- Incoherent visual behaviour of the robot and the child

How to improve the possibilities of this interaction:

- Long-term interactions ?
- Metric to measure the progresses of the child ?
- Perception of the progresses of the robot ?
- Visual focus of attention of the child ?
- Spatial arrangement between child and robot ?

STUDY 1

- **Hypothesis**: We can do long-term interaction with CoWriter
- **Method**: Back-story, 4 sessions of 1h, 1 session/week
- **Measure**: # of demo by session
- **Result**: not decreasing

Number of demonstrations provided by Vincent over the four sessions.

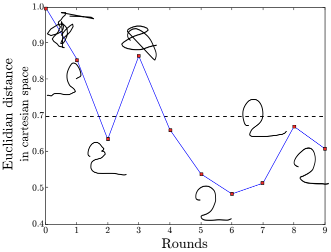
Session	S1	S2	S3	S4	Total
Number of demonstrations	23	34	52	46	155

Jacq, Lemaignan, Garcia, Dillenbourg & Paiva, **Building Successful Long-term Child-Robot Interactions in a Learning Context**, HRI 2016

Lemaignan, Jacq, Hood, Garcia, Paiva, & Dillenbourg, **Learning by Teaching a Robot: The Case of Handwriting**, RAM 2016

STUDY 2

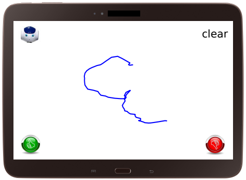
- **Hypothesis**: we can measure improvements
- **Method**: co-designed with therapist, no back-story, 4 sessions of 45min, 1 session/week
- **Measure**: distance between child's demo and ideal templates
- **Result**: we can separate legible and non-legible letters



Demonstrations of "2" provided by the child

STUDY 3

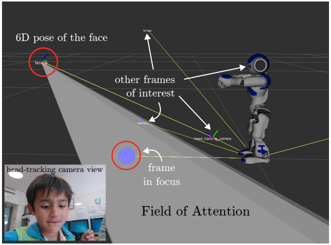
- **Hypothesis**: children perceive the progress of the robot
- **Method**: adding two buttons for evaluation
- **Measure**: correlation between children evaluations and robot progress
- **Result**: 5 of 8 children gave an evaluation correlated with robot's progress



Jacq, Lemaignan, Garcia, Dillenbourg & Paiva, **Building Successful Long-term Child-Robot Interactions in a Learning Context**, HRI 2016
Lemaignan, Jacq, Hood, Garcia, Paiva, & Dillenbourg, **Learning by Teaching a Robot: The Case of Handwriting**, RAM 2016

FOCUS OF ATTENTION

1. Head-pose estimation: Dlib's 68 facial features + 3D mesh of human face, RGB camera
2. Visual focus of attention: cone of 40°based on nose direction
3. Object in focus = object in the cone



STUDY 4

- **Hypothesis**: the estimation of the focus of attention is robust enough to be used for **with-me-ness** estimation (with-me-ness = frequency the child has in focus objects he is expected to look at).
- **Method**: 6 subjects filmed during activity
- **Measure**: correlation between human annotation and estimation of the system
- **Result**: r=0.46, good estimator of humans perception

Lemaignan, Garcia, Jacq, Dillenbourg **From Real-time Attention Assessment to “With-me-ness” in Human-Robot Interaction**, HRI 2016

STUDY 5

- **Hypothesis**: Child-Robot Spatial arrangement influences the interaction.
- **Method**: 12 subjects, within subject study (face-to-face vs side-by-side)
- **Measure**: child's feedback + with-me-ness
- **Result**: feedback more positive in side-by-side condition.

Johal, Jacq, Dillenbourg, Paiva **Child-Robot Spatial Arrangement in a Learning by Teaching Activity**, ROMAN 2016

to summarize:

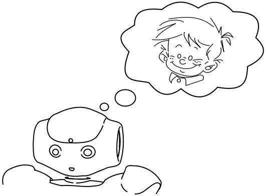
- (S1) Long-term interactions
- (S2) Metric to measure the progresses of the child
- (S3) Information about the perception of the progresses of the robot
- (S4) Estimation of the visual focus of attention in real time
- (S5) Child-Robot Spatial arrangement influences the indulgence of the child.

PROJECT OF MY PHD

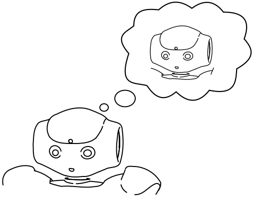
My goal is to develop a cognitive architecture that

- takes as input progress of the child, focus of attention, perception of robot's progress...
- builds models of agents (robot, child, robot perceived by child)
- detects and repairs misunderstanding

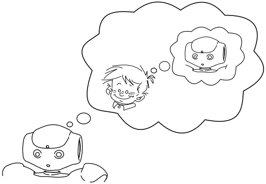
MUTUAL MODELLING



M_R [C] (1st level)

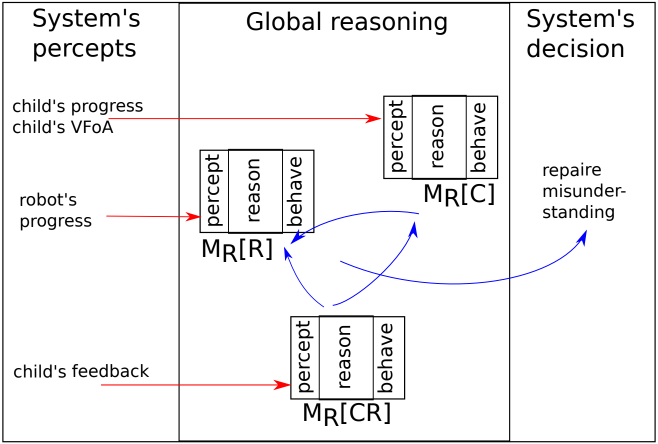


M_R [R] (1st level)



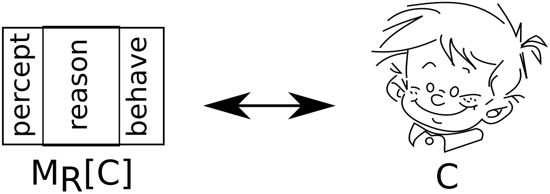
M_R [C,R] (2nd level)

USING MODELS



MISUNDERSTANDING (BY THE ROBOT)

When the robot misunderstands the human:

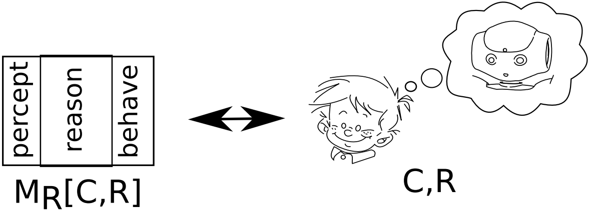


Prediction error:

$$\Delta\left(P_R^{t+1}[\mathrm{C}]\,;M_R^{t+1}[\mathrm{C}]\right)$$

MISUNDERSTANDING (BY THE ROBOT)

When the robot misunderstands how the human perceives it:

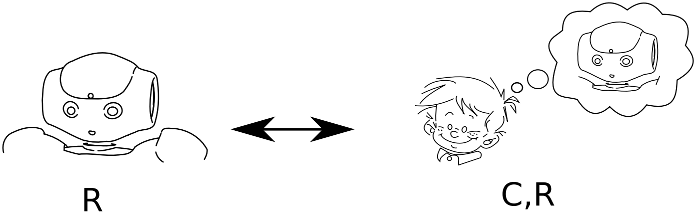


Prediction error:

$$\Delta\left(P_R^{t+1}\,[\mathrm{C,R}]\,;M_R^{t+1}\,[\mathrm{C,R}]\right)$$

MISUNDERSTANDING (BY THE CHILD)

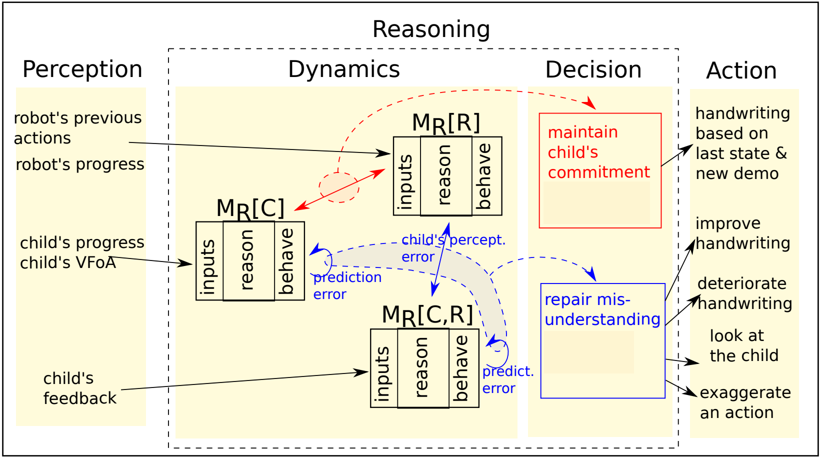
When the human misunderstands the robot:



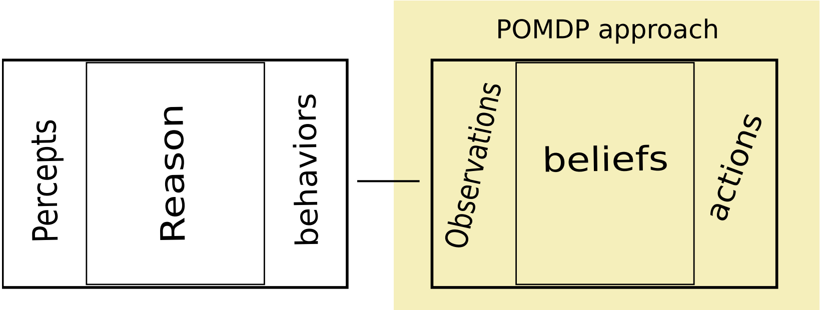
Child's perception error:

$$\Delta\left(M_R^t\,[\mathrm{R}]\,;\,M_R^t\,[\mathrm{C{,}R}]\right)$$

COGNITIVE ARCHITECTURE



MODEL OF AGENTS

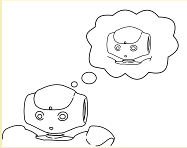


assumptions:

- an observation is a set of events
- each event is associated with a deterministic reward
- each event has a value of truth/intensity, between 0 and 1
- the belief state is the set of all values of truth of events

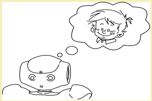
REASONING AND DECISION MAKING

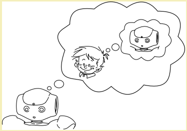
Reinforcement learning



- Receive observation O^t and reward R^t
- Update belief state B^t
- Chose action A^t

Inverse Reinforcement Learning





- Receive observation O^t and action A^{t-1}
- Update belief state B^t and reward R^t
- predict action A^t

Reinforcement learning in the space of observations (MDP)

MISUNDERSTANDING DISTANCES

Belief error between models M_1 and M_2:

$$\Delta_B(M_1\,,\ M_2) = \sum_{event\ \ e} \left(B^t_{M_1}[e] - B^t_{M_2}[e]\right)^2$$

Reward error between models M_1 and M_2:

$$\Delta_R(M_1\,,\ M_2) = \sum_{event\ \ e} \left(R^t_{M_1}[e] - R^t_{M_2}[e]\right)^2$$

REAPARING MISUNDERSTANDINGS

(ex: the robot have a good writing, but the robot receives a negative feedback)

Prediction error

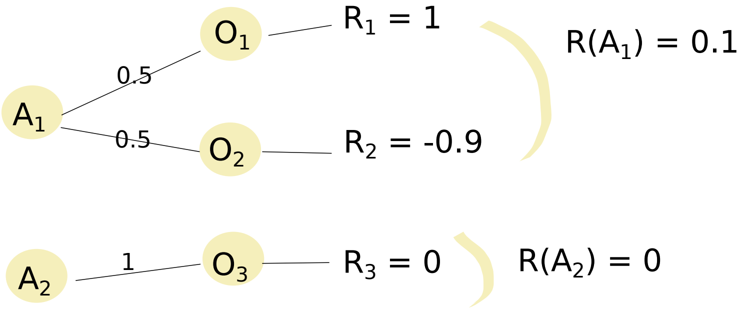
- Error of reward: the goal of the child is not understood
- Error of belief: the child did not well observed the robot (child perception error)

Child's perception error

- Error of reward: the robot must adopt a more understandable behavior (next frame)
- Error of belief: the robot must communicate/show its state (verbally or exagerating action)

UNDERSTANDABLE BEHAVIOR

How to make IRL easyer for other agents ?



CONCLUSION

I have:

- a rich educational interaction where we can extract relevant information about child's mind

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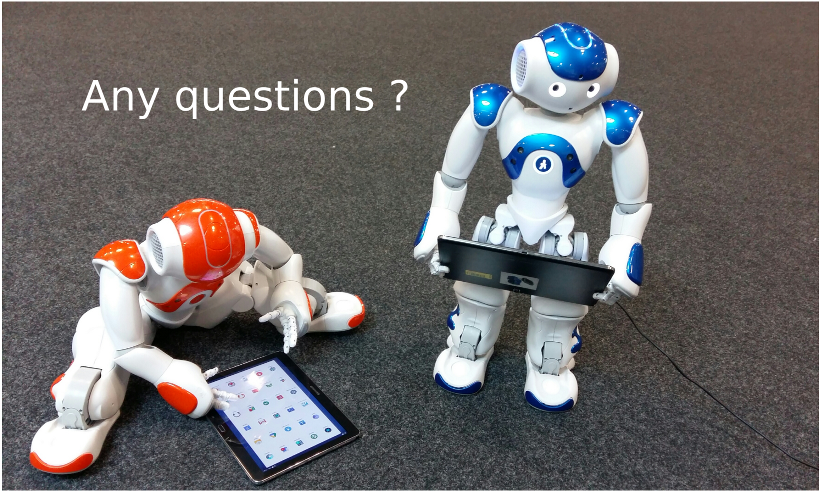
I am working on an architecture:

- that uses this information in order to detect and repair misunderstandings

I believe:

- such an architecture could be easily generalised to other human-robot interaction

THANK YOU !



QUALITY OF INTERACTION

- With-me-ness
- ♯ of demonstrations over longer term (» 4 session)
- Duration of “free” session
- Human judge (video annotation)
- Progress of the child