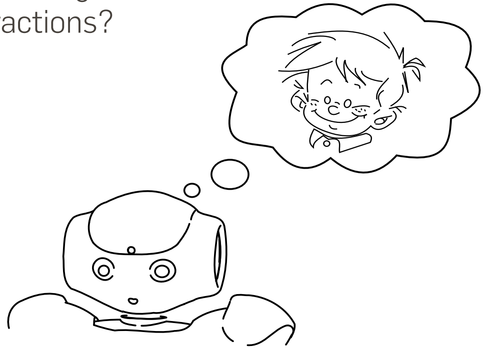
Mutual Modelling in Educational Child-Robot Interaction

Does a second level of modelling enable higher quality interactions?

September 19, 2016

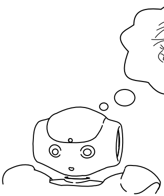


Alexis D. Jacq

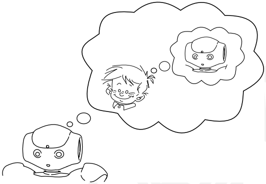
GAIPS INESC-ID **IST**
& CHILI lab **EPFL**

INTRODUCTION

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



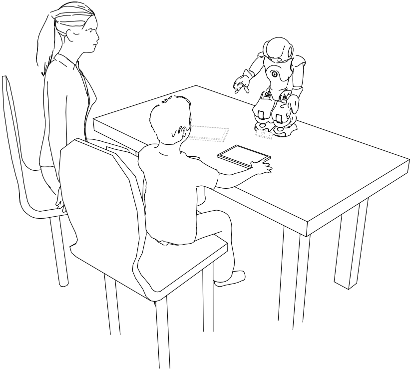
Do I understand you ?



Do you understand me ?

THE COWRITER INTERACTION

Learning by teaching approach:



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

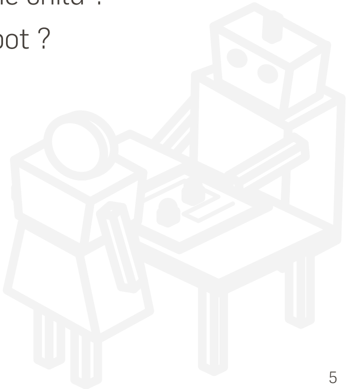
OBSERVED ISSUES

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 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 ?



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

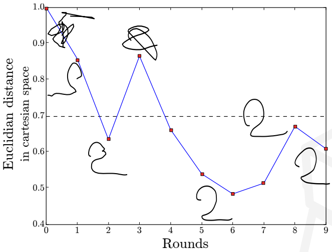
Number of demonstrations provided by Vincent over the four sessions.

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

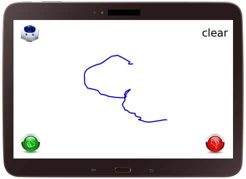
- **Hypothesis**: we can measure improvements
- **Method**: co-designed with therapist, no back-story, 4 sessions of 45min, 1 session/week
- **Measure**: distance between child's demo and ideal templates
- **Result**: we can separate legible and non-legible letters



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



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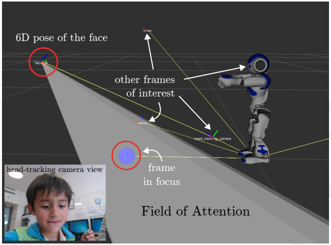
FOCUS OF ATTENTION

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

to summarize:

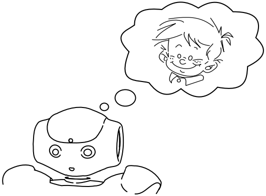
- (S1) Long-term interactions
- (S2) Metric to measure the progresses of the child
- (S3) Information about the perception of the progresses of the robot
- (S4) Estimation of the visual focus of attention in real time

PROJECT FOR INCOMING YEARS

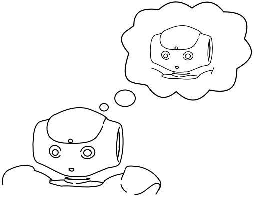
My goal is to develop a cognitive architecture that

- 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

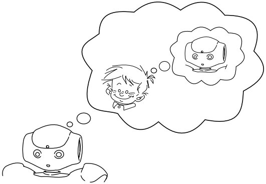
MUTUAL MODELLING



M_R [C] (1st level)

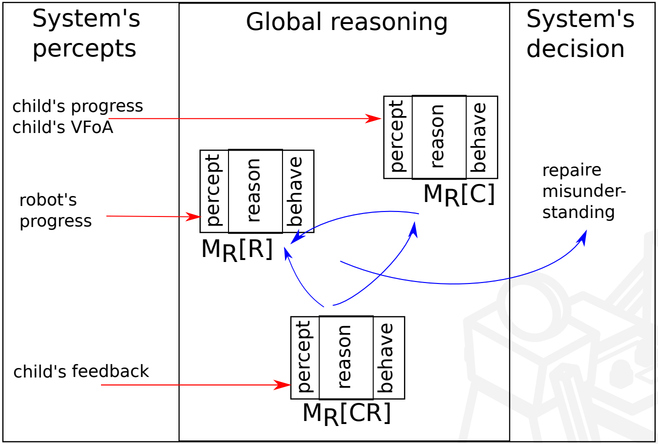


M_R [R] (1st level)



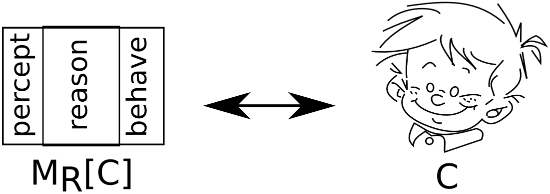
M_R [C,R] (2nd level)

USING MODELS



MISUNDERSTANDING (BY THE ROBOT)

When the robot misunderstands the human:

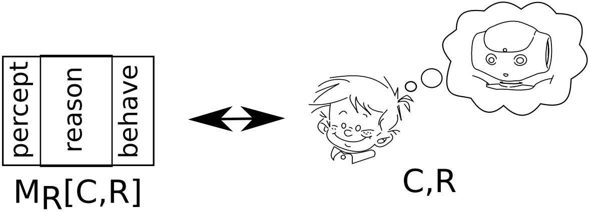


Prediction error:

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

MISUNDERSTANDING (BY THE ROBOT)

When the robot misunderstands how the human perceives it:

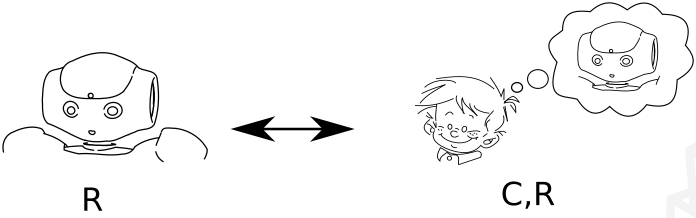


Prediction error:

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

MISUNDERSTANDING (BY THE CHILD)

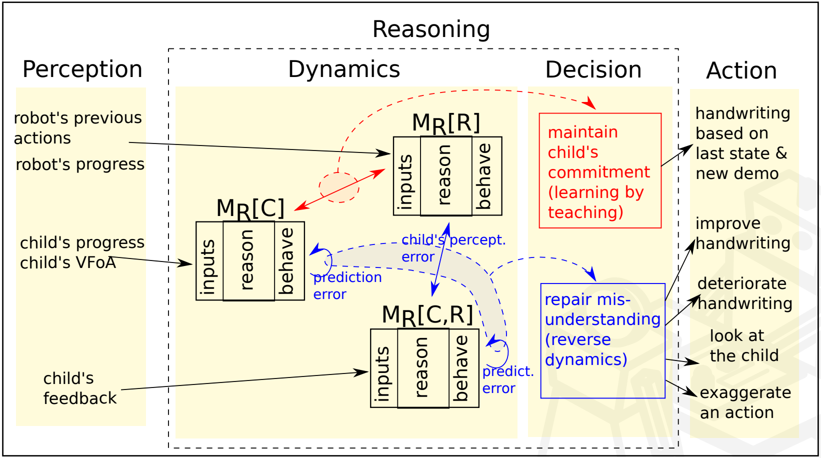
When the human misunderstands the robot:



Child's perception error:

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

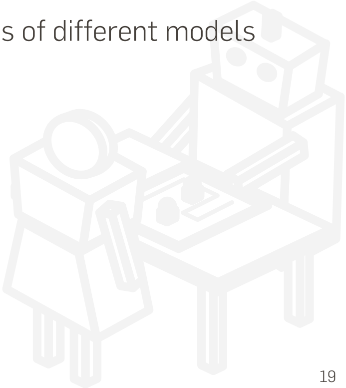
COGNITIVE ARCHITECTURE



PARAMETRIZATION

How to train the robot:

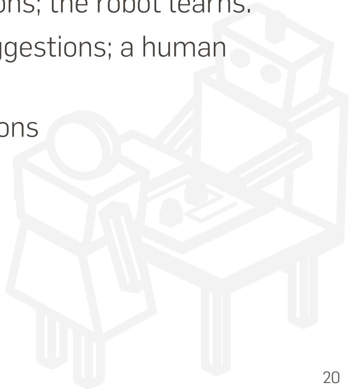
- learning the dynamic between variables of different models
- learning how to make decisions



PARAMETRIZATION

Decision making

1. **Wizard-of-Oz**: A human makes decisions; the robot learns.
2. **Mixed-initiative**: The robot makes suggestions; a human agrees or disagrees
3. **Autonomous**: The robot makes decisions

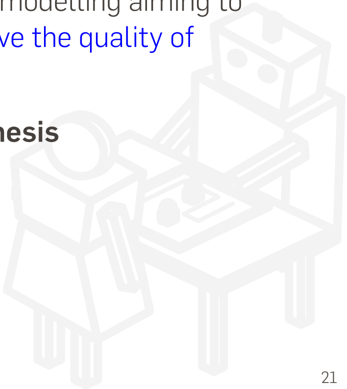


VERIFICATION

Hypothesis:

- Decisions made with a second level of modelling aiming to maintain mutual understanding, improve the quality of human-robot interactions.

This can be developed in two sub-hypothesis



VERIFICATION

Sub-hypothesis 1:

- The second level of modelling enable different decisions from a robot that does not have this second level.

Experimental approach:

- Human judge and/or Objective comparison. Short experiments, Large number of subjects. Control: 1st level MM

VERIFICATION

Sub-hypothesis 2:

- The quality of human-robot interactions is greater with the robot that has the second level of modelling.

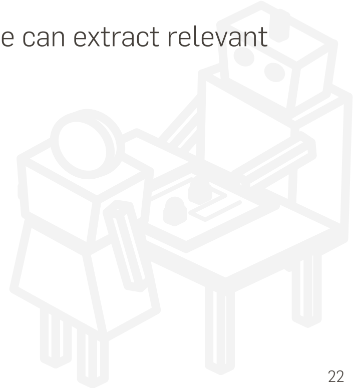
Experimental approach:

- Long-term experiments in real educational/therapeutic context. Small number of subjects. Control: no MM, 1st level MM

CONCLUSION

I have:

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



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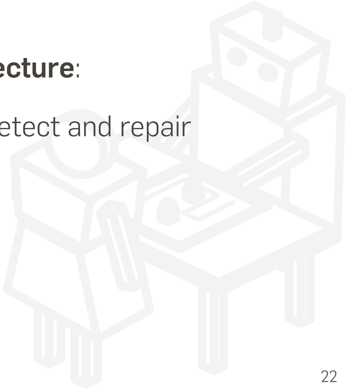
I want to develop and evaluate an architecture:

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



CONCLUSION

I have:

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

I want to develop and evaluate an architecture:

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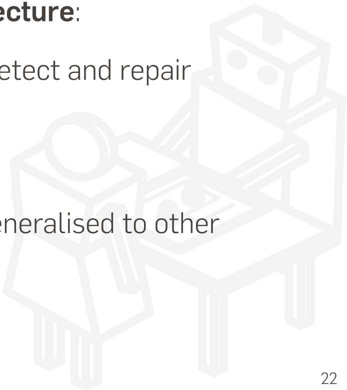
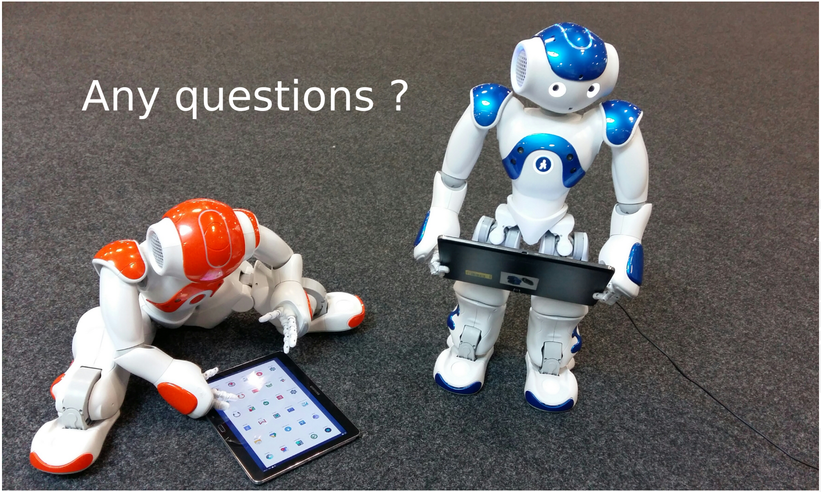
I believe:

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



THANK YOU !



DECISION MAKING

M_R^t [C]	provides robot with positive feedback
M_R^{t+1} [R]	current level of handwriting = 0.1
M_R^{t+1} [C,R]	current level of handwriting = 0.7
$\Delta = 0.6 \geq \Theta$	high error, must be repaired
Reverse dynamic	what leads to small level of handwriting in M_R^t [C,R] ?
M_R^{t+1} [C,R]	current level of handwriting = 0.1
P_R^t [C]	child give negative feedback
P_R^{t-1} [R]	robot writes letters with very poor style
P_R^{t-1} [C]	child is looking at the tablet
P_R^{t-2} [R]	robot is looking at the tablet
P_R^{t-2} [C]	child is looking at the robot
P_R^{t-3} [R]	robot is looking at the child
Decision 1	robot looks at the child
M_R^{t+2} [C]	child is looking at the robot
Decision 2	robot looks at the tablet
P_R^{t+3} [C]	child is looking at the tablet
Decision 3	robot writes letters with very poor style

ENCODING DYNAMIC OF AN AGENT

- a node encodes the value (truth or intensity) of a variable between 0 and 1
- when the change of the value of one node is followed by the change of value of another one, we create/reinforce a link between these nodes. ($\sim$Hebbian learning)

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