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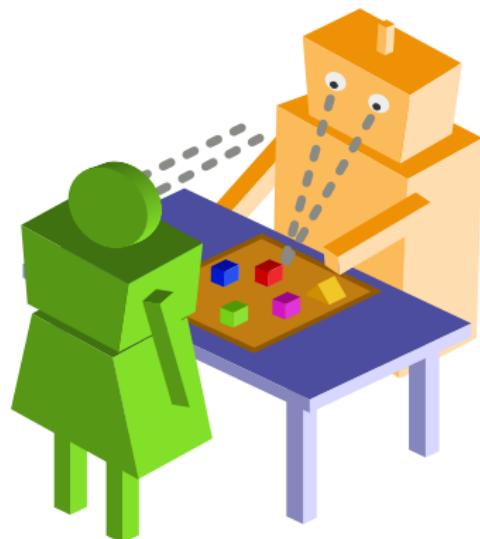
Co-designed head to toe

Towards end-to-end participatory design

University of Plymouth | 02 Mar 2022

Séverin Lemaignan

PAL Robotics Senior Scientist AI & Social Interactions



situation assessment

symbolic grounding

symbolic reasoning

SYMBOLIC SOCIAL COGNITION FOR ROBOTS

ontologies

perspective taking

cognitive architectures

social situation assessment

joint action

ROS4HRI

natural language processing

REAL-WORLD SOCIAL AUTONOMY

learning of social policies



DATA-DRIVEN HRI

large datasets

theory of mind

group dynamics

human-in-the-loop ML

robotics for
learning

CHILD-ROBOT INTERACTION

experimental robotics

HUMAN FACTORS

engagement

responsible AI

anthropomorphism

social robotics

participatory design

persuasion

SOCIAL ROBOTICS

Creating interactive robots that are **embedded and understand their (human) social context; generate and adopt appropriate social behaviours; have a positive impact on human society.**

⇒ designing and implementing the **assistant and companion robots** for tomorrow.

⇒ direct impact on ageing society, education, customer service; **major socio-economic challenge**



SOCIAL ROBOTICS

Major scientific challenges:

- Model open-ended, underspecified situations; rich semantics; complex social dynamics;



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Major scientific challenges:

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- Understand and sustain long-term autonomous social interactions;
- Real-world algorithmic robustness;
- Complex ethical landscape;
- ⇒ cross-disciplinary & holistic approach required
- ⇒ involve all the stakeholders; participatory approach



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- a real robot

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- a real interaction (...with a **human!**)

LET SET OURSELVES A CHALLENGE

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- a **continuous** interaction

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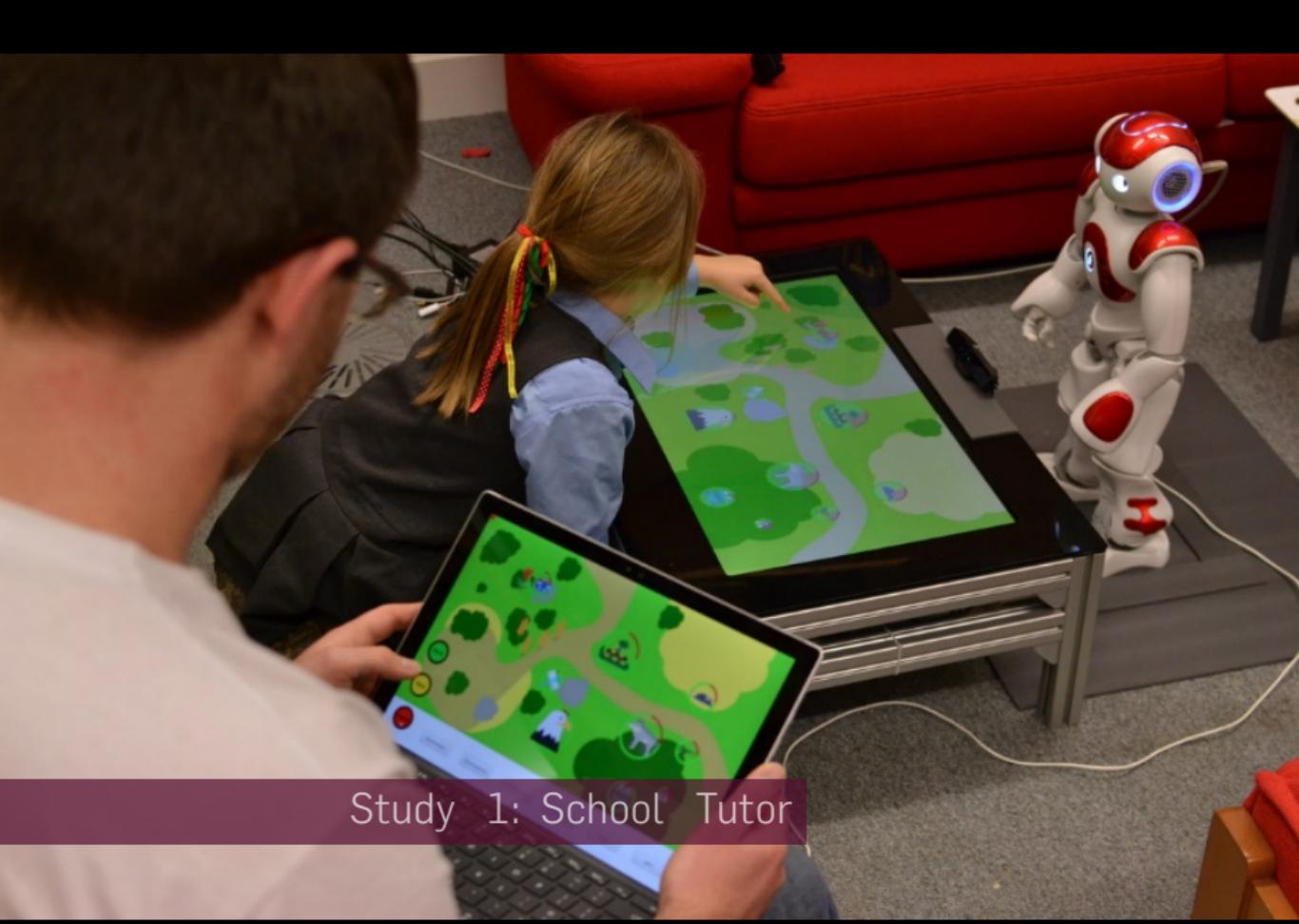
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Design & run a study with:

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- o a realistic task (**large state vector & action space**)
- o **in the wild**
- o also including **social behaviours & social dynamics**
- o ...and of course, the robot should be **autonomous**



Study 1: School Tutor

IRL APPLIED TO SOCIAL ROBOTICS



Emmanuel Senth

The children plays a game about food chains; the robot learns to guide them (*task-specific action policy*) and encourage them (*social action policy*)

Interactive Machine Learning (IRL) to teach the robot.

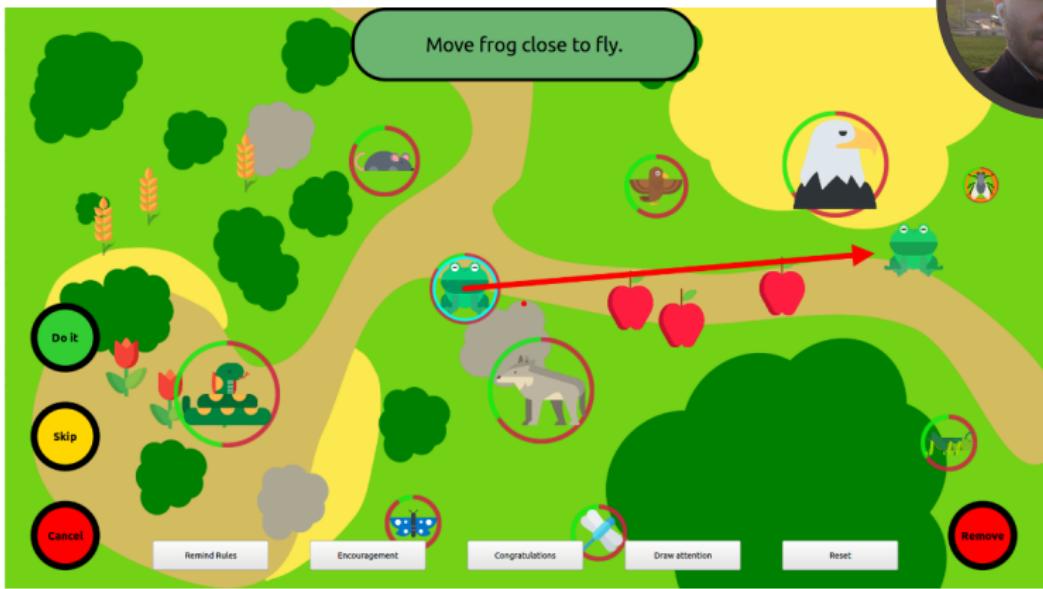
$$|state| = 210 \quad |action_space| = 655$$



TEACHER'S INTERFACE



Emmanuel Sennf



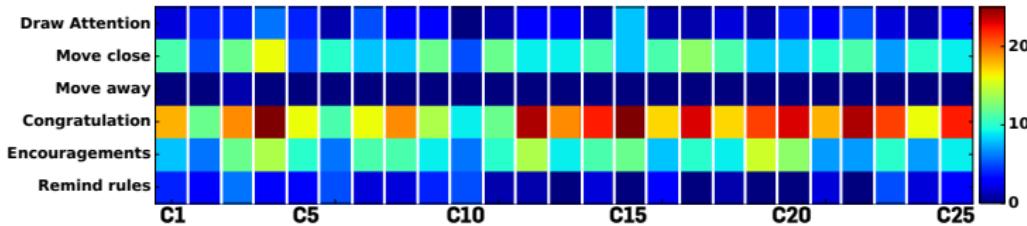
The robot's teacher (an end-user: might be the actual child's teacher) has a tablet interface that mirrors the child one, and adds robot's teleoperation and rewards.

LEARNT ROBOT'S BEHAVIOUR



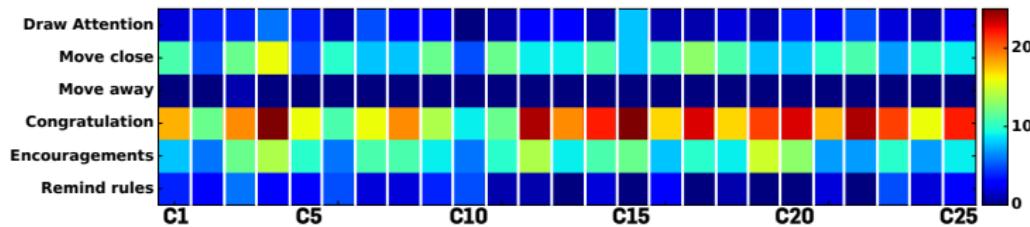
Emmanuel Sennf

Distribution of actions for the 25 children participants:
Supervised

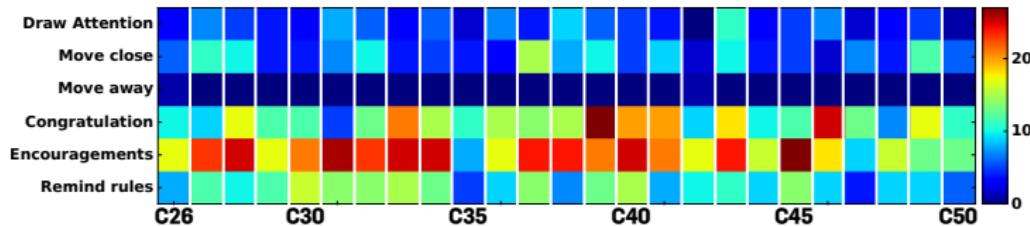


LEARNT ROBOT'S BEHAVIOUR

Distribution of actions for the 25 children participants:
Supervised



Autonomous



→ the robot personalises its action policies to the child's behaviour.

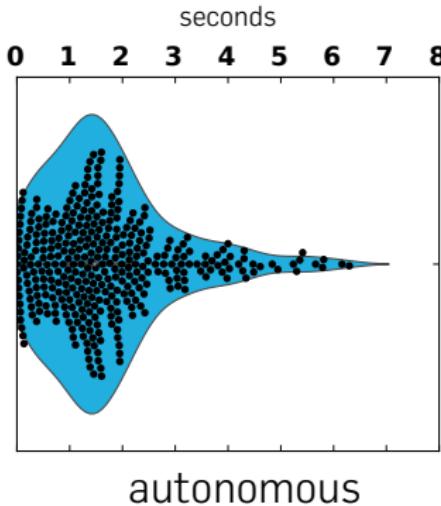
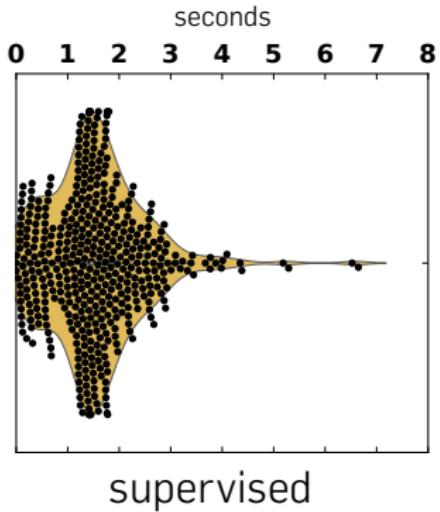


LEARNT ROBOT'S BEHAVIOUR



Emmanuel Sennf

Time between a child's successful action and a praise:



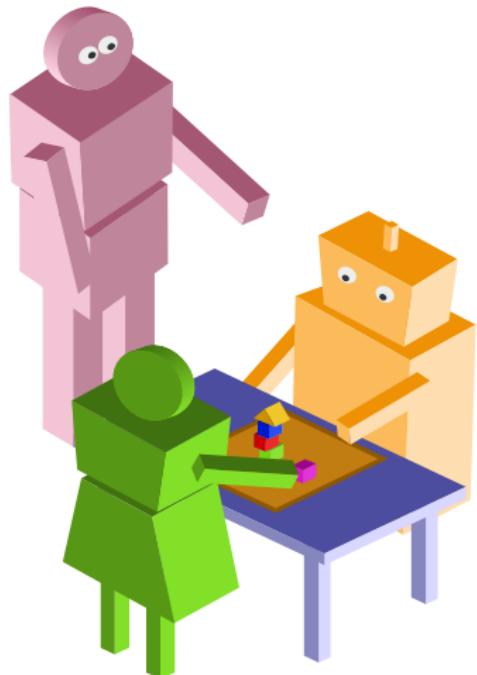
→ the robot has also learnt an appropriate social timing.

WHAT DOES THAT MEANS FOR THE EXPERT/TEACHER-END-USER?



- **Progressively transferring autonomy** demonstrably works in non-trivial tutoring scenarios
- (it also learns some elements of **social behaviours** and **social timing**)

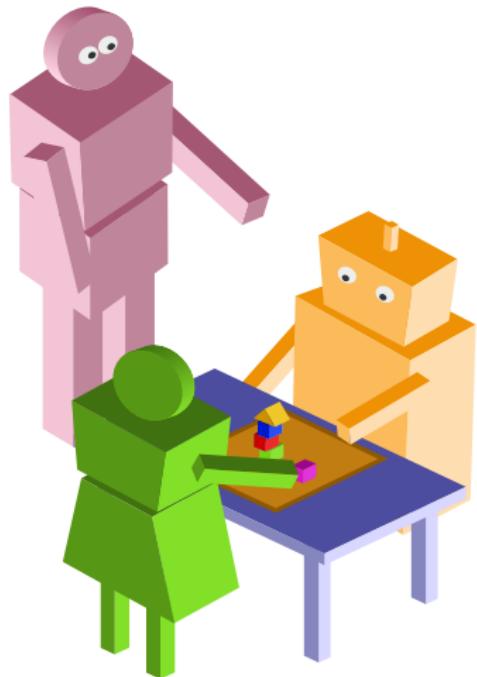
WHAT DOES THAT MEANS FOR THE EXPERT/TEACHER-END-USER?



Key properties:

- **progressive autonomy** yet **transparency** of the behaviour;
 - **observability** and possibility to **take over**;
 - because the training takes place in-situ, the robot behaviours are **situated** and **co-constructed** by the teacher and the child
- ⇒ good characteristics from a ethics/responsible AI perspective

WHAT DOES THAT MEANS FOR THE EXPERT/TEACHER-END-USER?



Yet:

- Design of the input state tricky and largely task dependent;
- What about more complex social behaviours?
- Would that sustain long-term interactions?



Study 2: gym coach

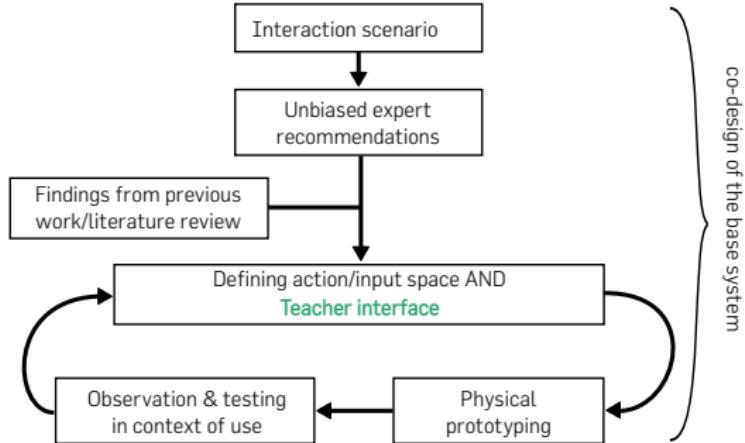
COUCH-TO-5K STUDY

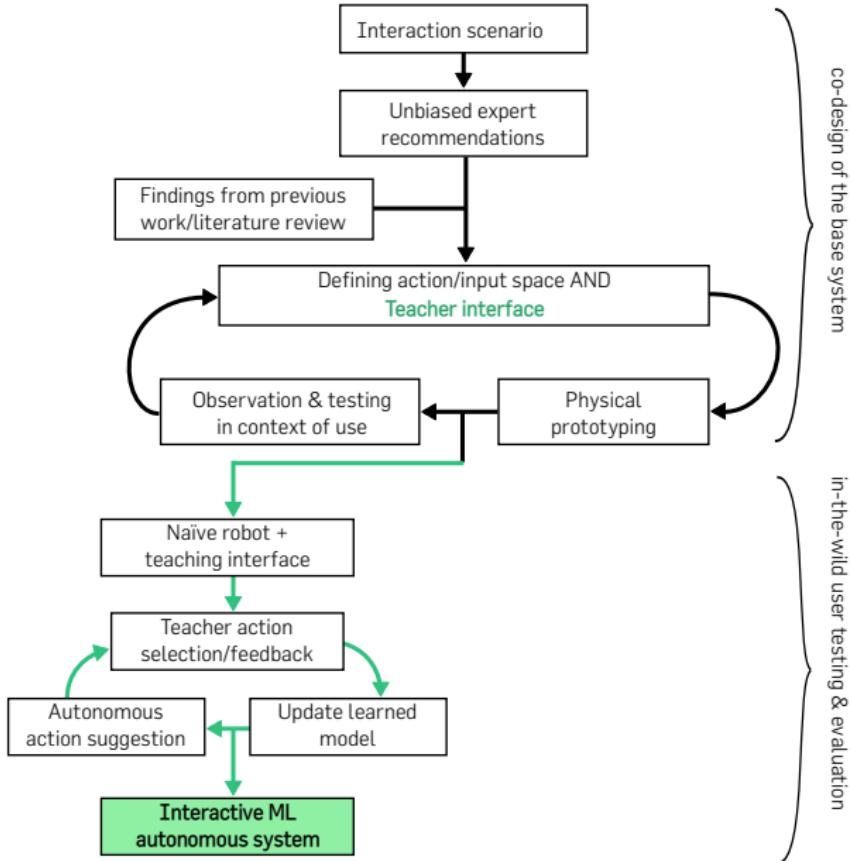


- 9 participants
- 3 months; 27 one-hour sessions per participants
- $|state| = 20$; $|action_space| = 11$
- Includes participants' personality (Big-5) as input feature

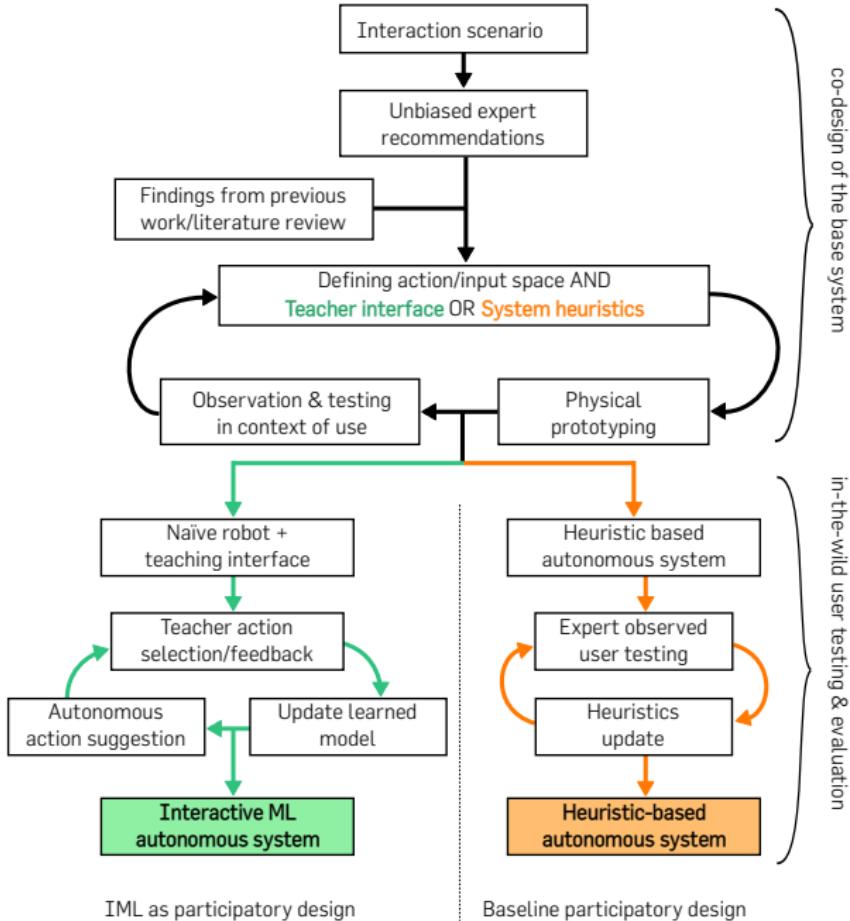
CO-DESIGN FOR REAL-WORLD + LONG-TERM



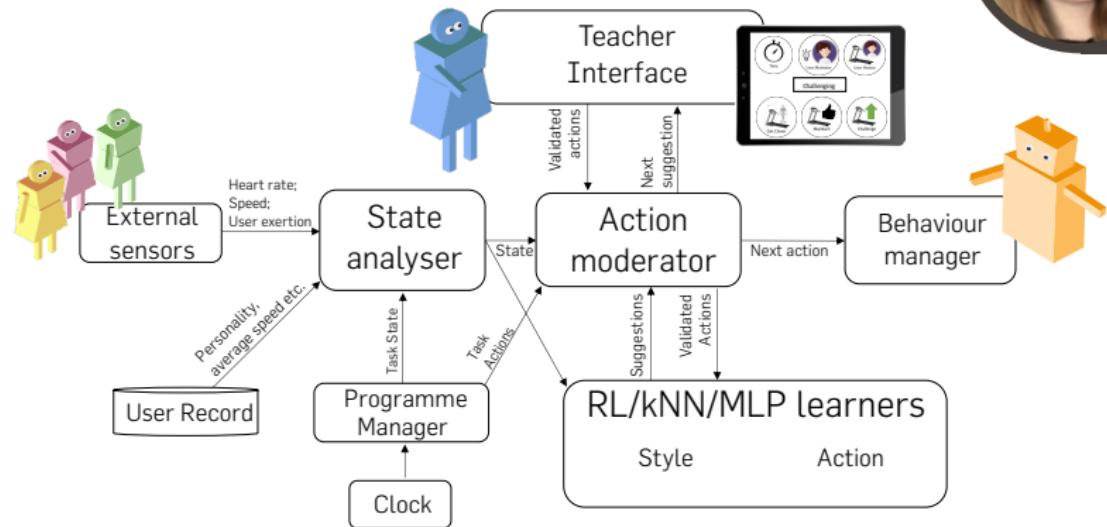




IML as participatory design



COUCH-TO-5K: ARCHITECTURE



Katie Winkle

INPUT & OUTPUT SPACES: MOSTLY TASK-SPECIFIC

Type	Feature	Values	Description
(Dynamic) Task State	Task Action Type	0, 0.5, 1	Whether participant is in warm-up, walk or run
	Session Progress	0-1	Time spent in session/session duration
	Programme Progress	0-1	Time spent on programme/programme duration
	Programme Action Progress	0-1	Time spent on current walk or run action/action duration
	Programme Action Duration	0, 0.5, 1	Current walk/run action length as \leq 3 mins, \geq 20 mins or other
	Time Since Last Action	0-1	Time since last action/60; capped at 1
Dynamic Performance	Relative Speed: Average	0-1	Current speed/(2 x average speed)
	Relative Speed: Best	0-1	Current speed/(2 x personal best speed)
Dynamic Engagement	Heart Rate	0-1	Heart rate/2x resting heart rate capped at 1
	Motivation/Effort	0, 0.5, 1	Self-reported measure in warmup/on check PRE action
	Facial Expression: Lip Pull*	0-1	Normalised action unit returned by OpenFace
	Facial Expression: Mouth Open*	0-1	Normalised action unit returned by OpenFace
Static Engagement	Elaboration level (self)	0-1	Normalised sum of 3 Likert questions
	Elaboration level (expert)	0-1	As above but rated by fitness instructor
	Activity Level	0-1	Likert question response
Static Personality	Extroversion	0-1	Big Five measure normalised with respect to max score
	Agreeableness	0-1	Big Five measure normalised with respect to max score
	Conscientiousness	0-1	Big Five measure normalised with respect to max score
	Emotional Stability	0-1	Big Five measure normalised with respect to max score
	Openness to Experience	0-1	Big Five measure normalised with respect to max score

Features followed by * were ultimately removed due to unreliable detection.

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Features followed by * were ultimately removed due to unreliable detection. **Non-task specific features.**

INPUT & OUTPUT SPACES: MOSTLY TASK-SPECIFIC

Full listing of actions as *{action-type, style-modifier}*:

Social-Supporting Actions							Task Actions		Low Level	
Time	Social	Performance	Reward	Check User	Animation	Get Closer	Back Off	Run	Walk	Eye Colour

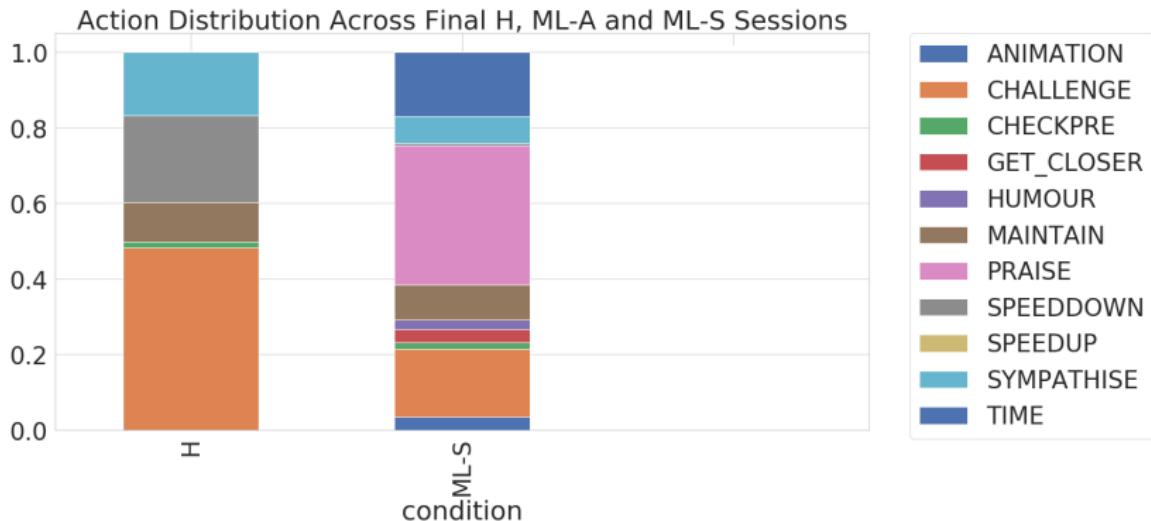
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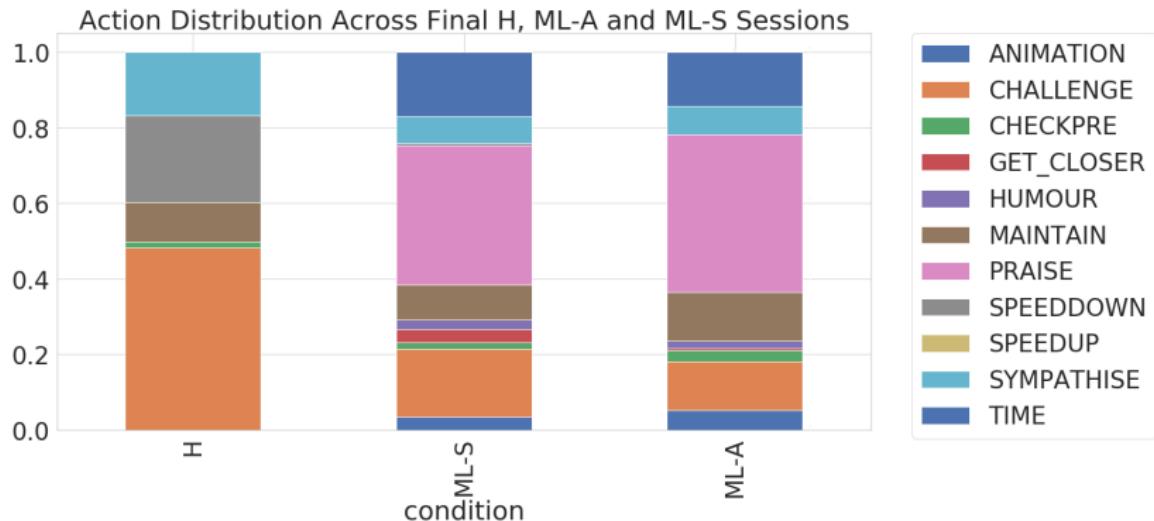
	Social-Supporting Actions							Task Actions		Low Level	
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P	Time	Humour	Maintain	Praise	-	Animation	-	-	Run	Walk	Green
C	Time	Challenge	Speed Up	-	-	-	-	-	Run	Walk	Yellow
S	Time	Challenge Sympathise	Speed Down	Praise	Check PRE	-	-	-	Run	Walk	Blue
N	-	-	-	-	-	-	Get Closer	Back Off	Run	Walk	White

Style modifiers: P = Positive; C = Challenging; S = Sympathetic; N = Neutral.

LEARNT POLICIES



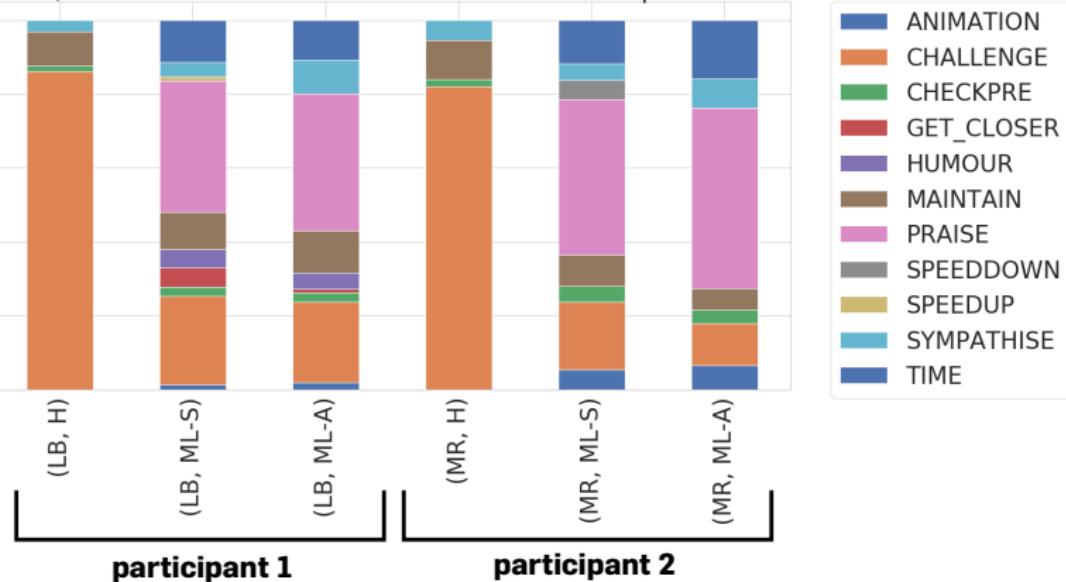
LEARNT POLICIES



(another nail in the expert systems coffin!)

LEARNT POLICIES

Phase 3 H, ML-A and ML-S Action Distribution for Participants LB and MR



LEADOR: END-TO-END PARTICIPATORY METHODOLOGY

In retrospect:

- a successful technical solution to replace the wizard;
- but equally important, a **end-to-end** participatory design methodology

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From a technique:

SPARC: Supervised progressively autonomous robot competencies

to a methodology:

LEADOR: Led-by-Experts Automation and Design Of Robots

[Senft et al. **SPARC: Supervised progressively autonomous robot competencies**, ICSR 2015;

Winkle, Senft, Lemaignan **LEADOR: End-to-End Participatory Design of Autonomous Social Robots** FrontiersIn AI & Robotics 2021]

LET'S REVISIT OUR CHALLENGE

Studies with...

- ✓ real robots

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- ✓ real interactions with humans

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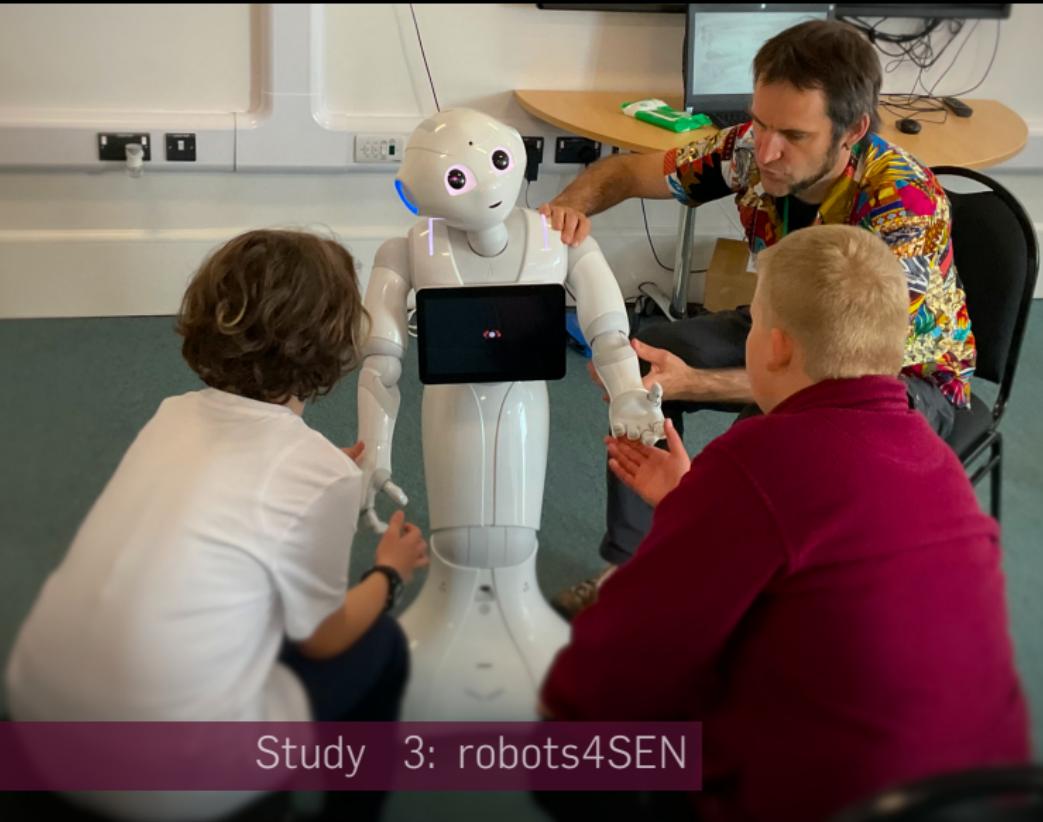
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- ~ real-world robustness



Study 3: robots4SEN

Intro
oo

Social autonomy @school
oooooo

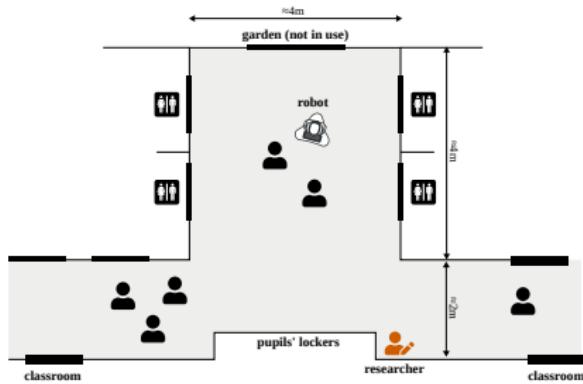
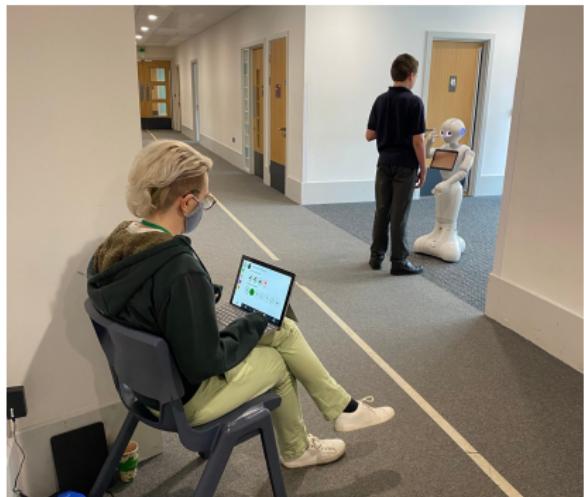
Social autonomy @gym
oooooooo

Conclusion?
oo

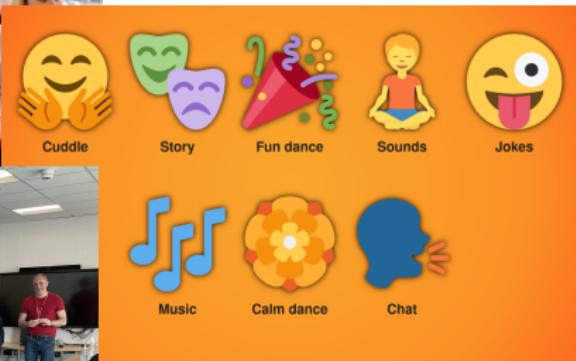
Social autonomy @SEN
o●oooo

ROS4HRI: brief introduction
oooooooooooo

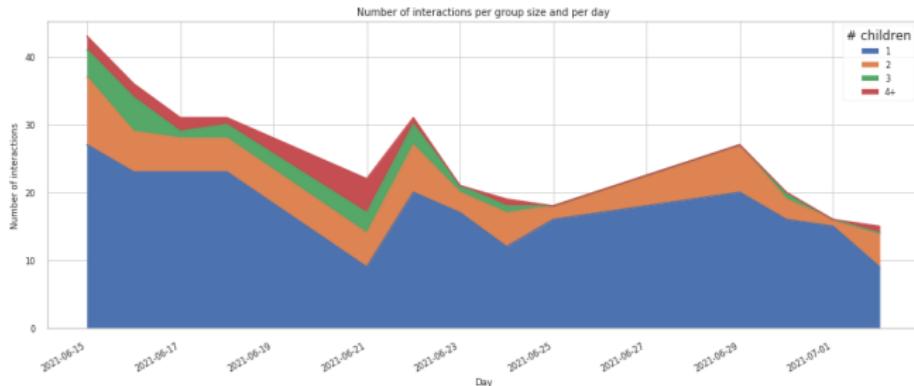
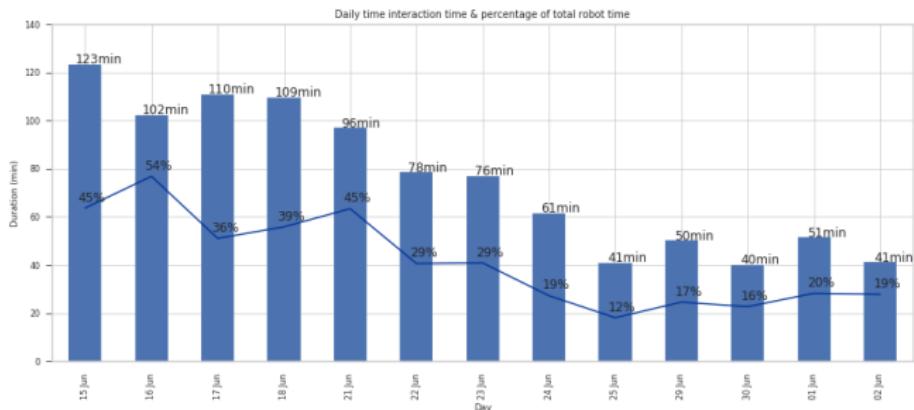
WELL-BEING AND AUTISM



PARTICIPATORY DESIGN WITH AUTISTIC CHILDREN



ENGAGEMENT OVER 3 WEEKS



SOCIAL COMPANIONS TO SUPPORT CHILDREN'S WELL-BEING

- open-ended, underspecified situations
- rich semantics
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But limited autonomy! Interactions child-led!

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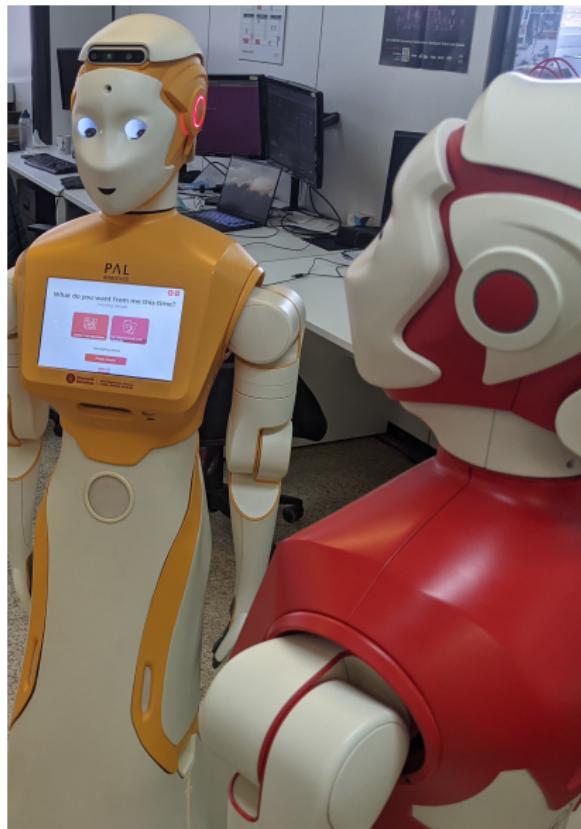
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⇒ The next frontier

NEXT STEPS AT PAL

Can we turn the LEADOR paradigm into a generic & robust enough technique for broad usage?



NEXT STEPS AT PAL

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Two use-cases:

- robots that know when to help in public administrations
- robot-supported Human-Human Interaction (rHHI) to address elderly isolation



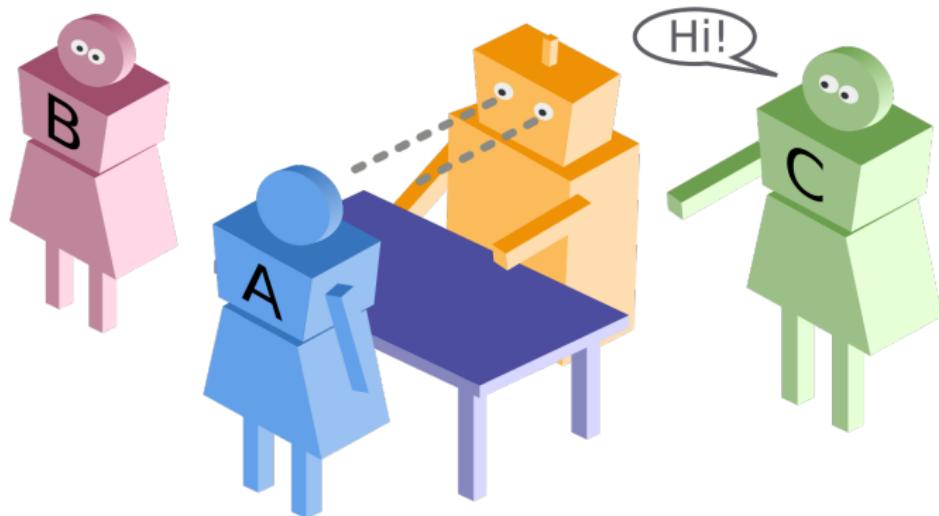
...and now for something more technical
(time permitting...?)

ROS4HRI: BRIEF INTRODUCTION

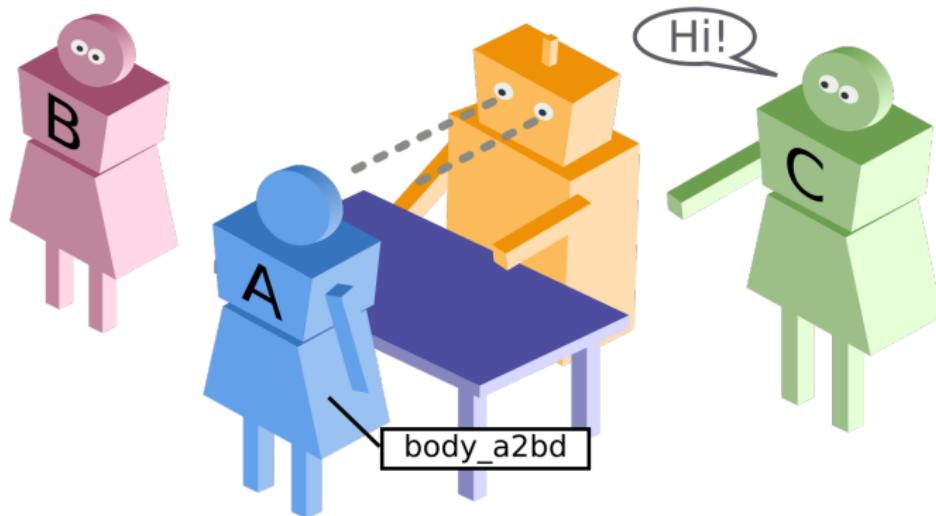
WHY ROS4HRI?

- dealing with humans is actually hard: they keep on disappearing/reappearing; hard to predict where/when; 'shape' known at run-time only, etc.
- widely different requirements depending on application: from '2D points' to full online kinematic model.
- no ROS standard for HRI (nothing, nada, rien!)

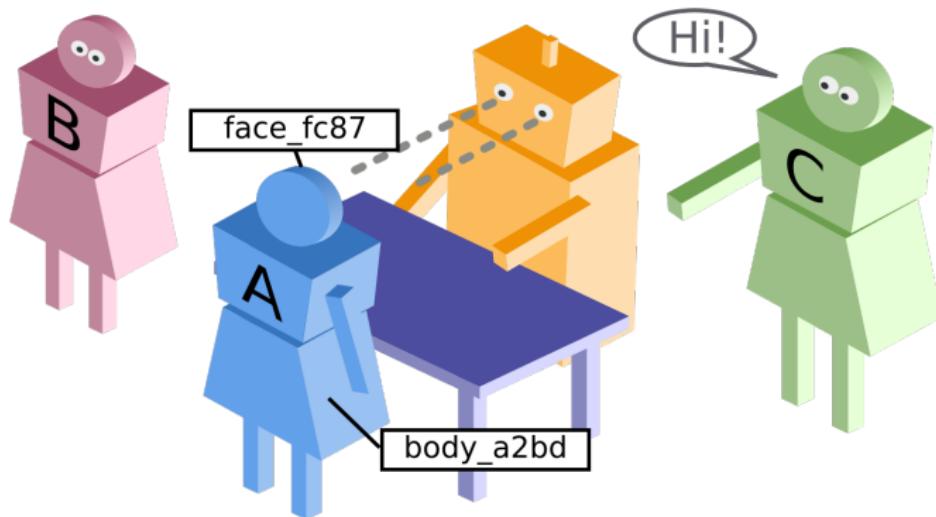
HUMAN REPRESENTATION: PERMANENT VS TRANSIENT IDS



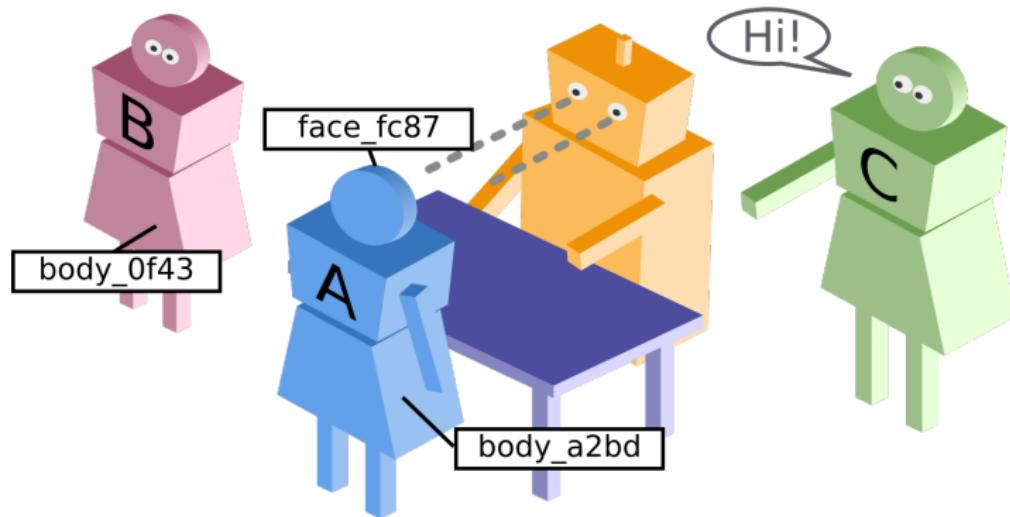
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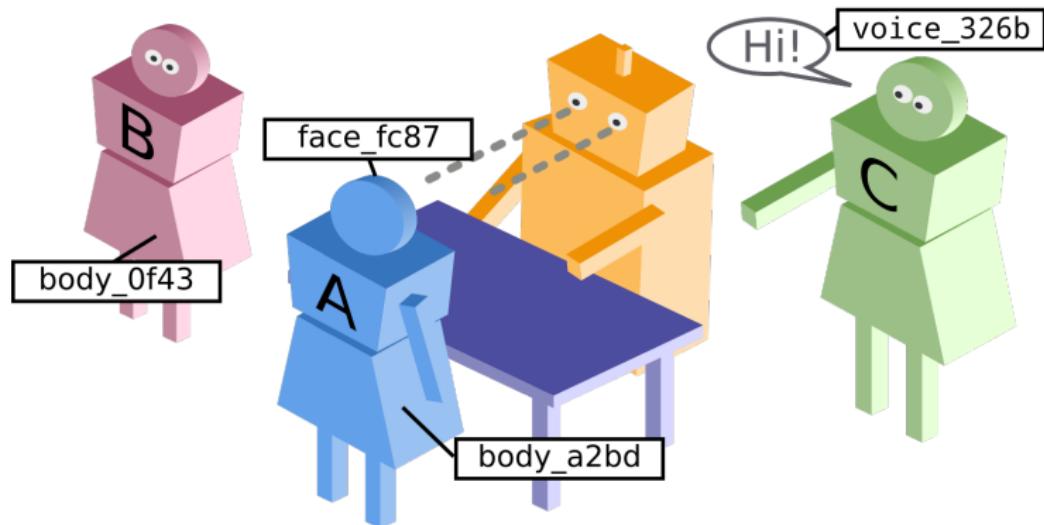
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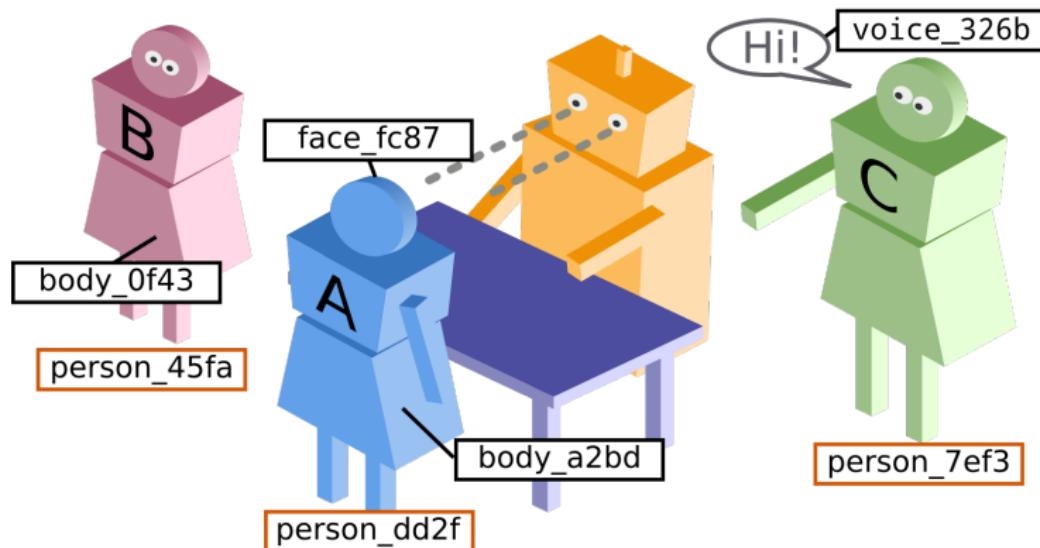
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TOPICS STRUCTURE: FACES

Under `/humans/faces/<faceID>/` (eg `/humans/faces/bf3d`):

Name	Message type	Description
<code>/roi</code>	<code>sensor_msgs/RegionOfInterest</code>	Region of the face in the source image
<code>/cropped</code>	<code>sensor_msgs/Image</code>	Cropped face
<code>/frontalized</code>	<code>sensor_msgs/Image</code>	Frontalised face
<code>/landmarks</code>	<code>hri_msgs/FacialLandmarks</code>	The 2D facial landmarks extracted from the face
<code>/facs</code>	<code>hri_msgs/FacialActionUnits</code>	The presence and intensity of facial action units found in the face
<code>/expression</code>	<code>hri_msgs/Expression</code>	The expression recognised from the face

TOPICS STRUCTURE: BODIES

Under `/humans/bodies/<bodyID>/` (eg `/humans/bodies/5e4d/`):

Name	Message type	Description
<code>/roi</code>	<code>sensor_msgs/RegionOfInterest</code>	Region of the whole body in the source image
<code>/cropped</code>	<code>sensor_msgs/Image</code>	Cropped image of the body
<code>/skeleton2d</code>	<code>hri_msgs/Skeleton2D</code>	The 2D points of the detected skeleton
<code>/attitude</code>	<code>hri_msgs/BodyAttitude</code>	Recognised body attitude or gesture

TOPICS STRUCTURE: VOICES

Under `/humans/voices/<voiceID>/`
(eg `/humans/voices/dde2`):

Name	Message type	Description
<code>/audio</code>	<code>audio_msgs/AudioData</code>	Separated audio stream for this voice
<code>/features</code>	<code>hri_msgs/AudioFeatures</code>	INTERSPEECH'09 Emotion challenge low-level audio features
<code>/isSpeaking</code>	<code>std_msgs/Bool</code>	Whether or not speech is recognised from this voice
<code>/speech</code>	<code>std_msgs/String</code>	The live stream of speech recognized via an ASR engine

TOPICS STRUCTURE: PERSONS

Under `/humans/persons/<personID>/`
(eg `/humans/persons/45ff`):

Name	Message type	Description
<code>/face_id</code>	<code>std_msgs/String</code> (latched)	Face matched to that person (if any)
<code>/body_id</code>	<code>std_msgs/String</code> (latched)	Body matched to that person (if any)
<code>/voice_id</code>	<code>std_msgs/String</code> (latched)	Voice matched to that person (if any)
<code>/location_confidence</code>	<code>std_msgs/Float32</code>	Location confidence; 1 means 'person currently seen', 0 means 'person location unknown'
<code>/softbiometrics</code>	<code>hri_msgs/SoftBiometrics</code>	Soft biometrics like age and gender of the person
<code>/name</code>	<code>std_msgs/String</code>	Name, if known
<code>/native_language</code>	<code>std_msgs/String</code>	IETF language codes like EN_gb, if known

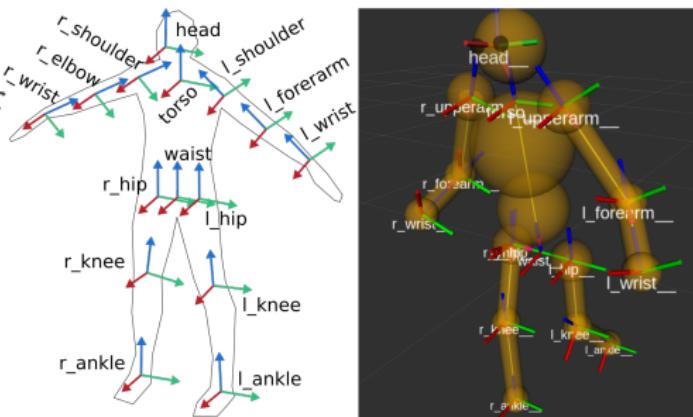
TOPICS STRUCTURE: INTERACTIONS

Under `/humans/interactions/`:

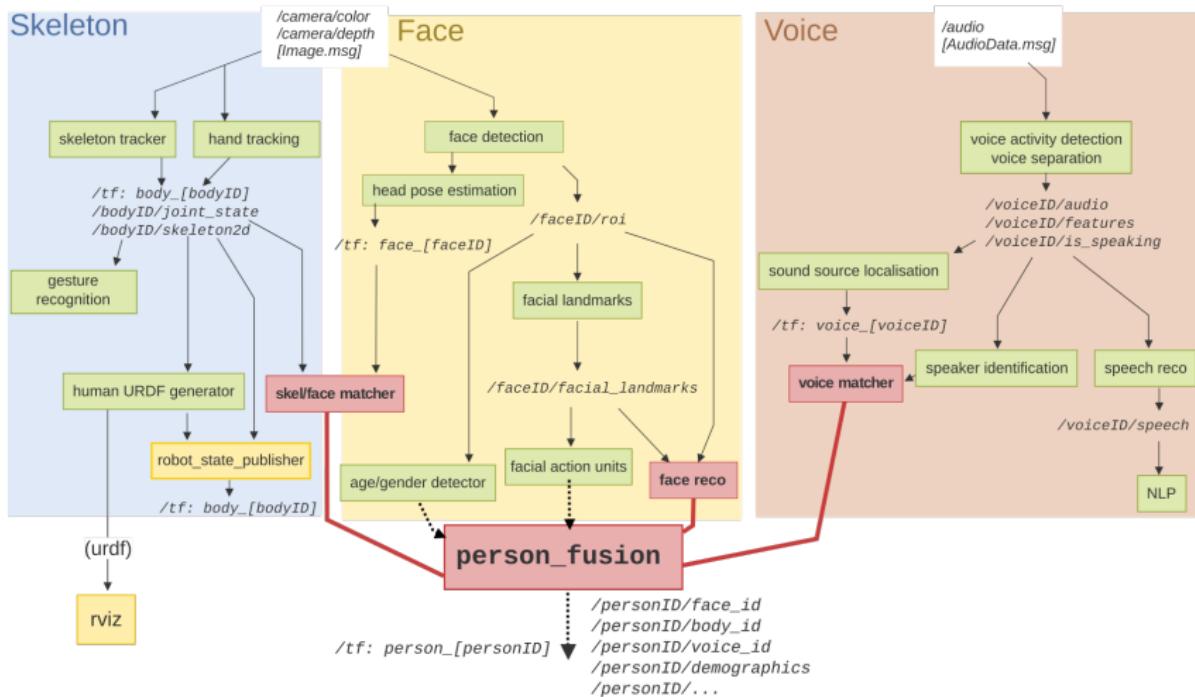
Name	Message type	Description
<code>/groups</code>	<code>hri_msgs/GroupsStamped</code>	Estimated social groups
<code>/gaze</code>	<code>hri_msgs/GazesStamped</code>	estimated gazing behaviours

HUMAN PHYSICAL REPRESENTATION

- standard ROS pipeline: joint state (eg OpenPose) -> `robot_state_publisher` + URDF
- URDF generated on the fly, based on person's height (xacro params)
- Follows REP-120 as much as possible.

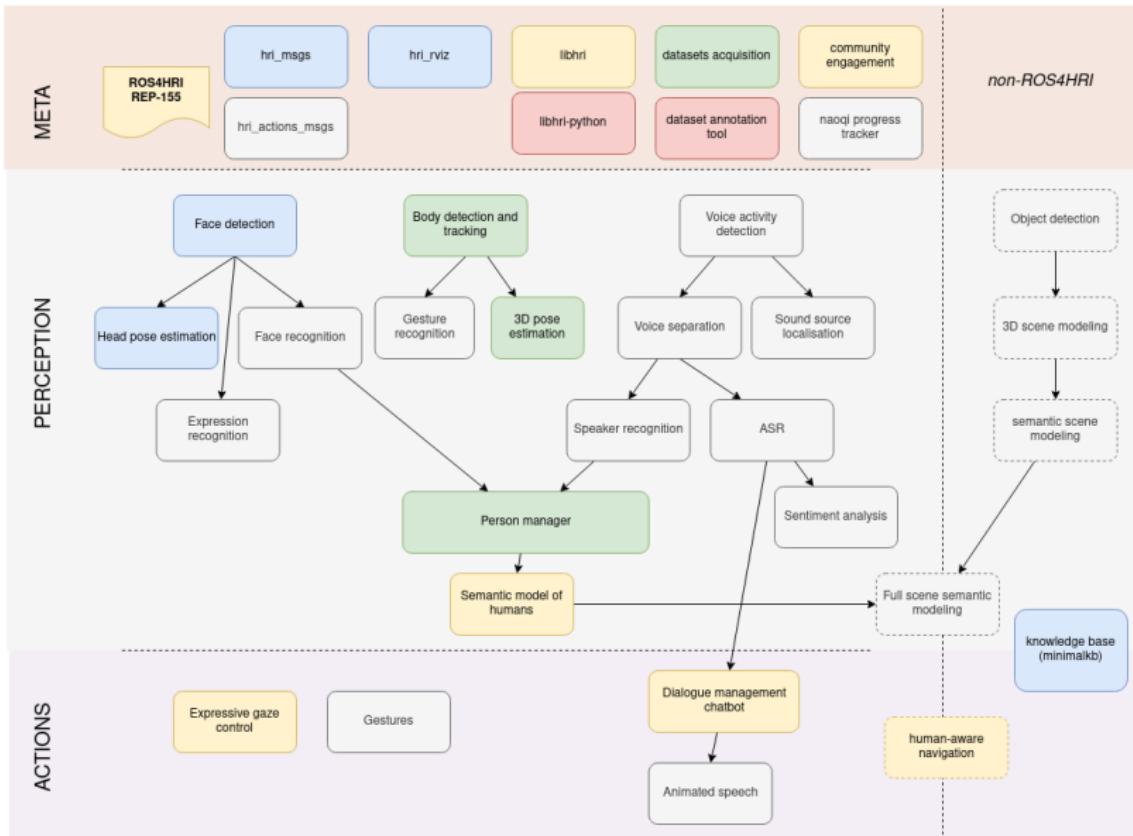


ONE POSSIBLE PIPELINE (BUT OTHER ARE POSSIBLE!)

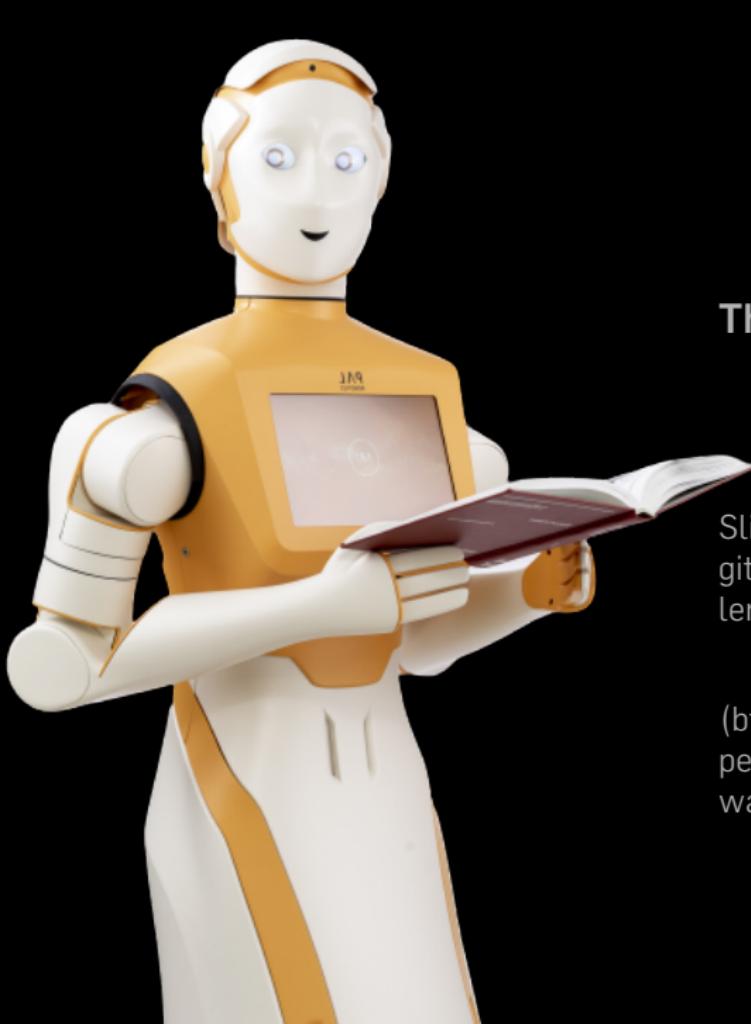


ROS4HRI to become REP-155

Currently under public consultation here:
github.com/ros-infrastructure/rep/pull/338



package released	code working	in progress	not started	stalled
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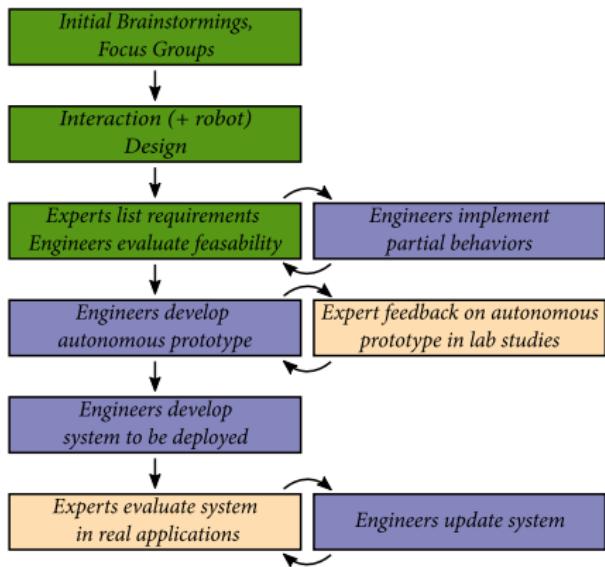
A yellow and white humanoid robot, specifically a PAL Robotics model, is positioned on the left side of the frame. It is holding a silver laptop in its left arm and an open book in its right hand, extending it towards the center of the image. The robot has a white face with blue eyes and a small smile. Its body is primarily yellow with white accents on the arms and legs.

Thank you!

Slides:
github.com/severin-lemaignan/presentation-codesign

(btw, we are always looking for great people to join us: drop me line if you want to know more!)

Classic PD



End-to-end PD

