Proposal of a Empathic Multi-agent Robot Design based on Theory of Mind

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Summary

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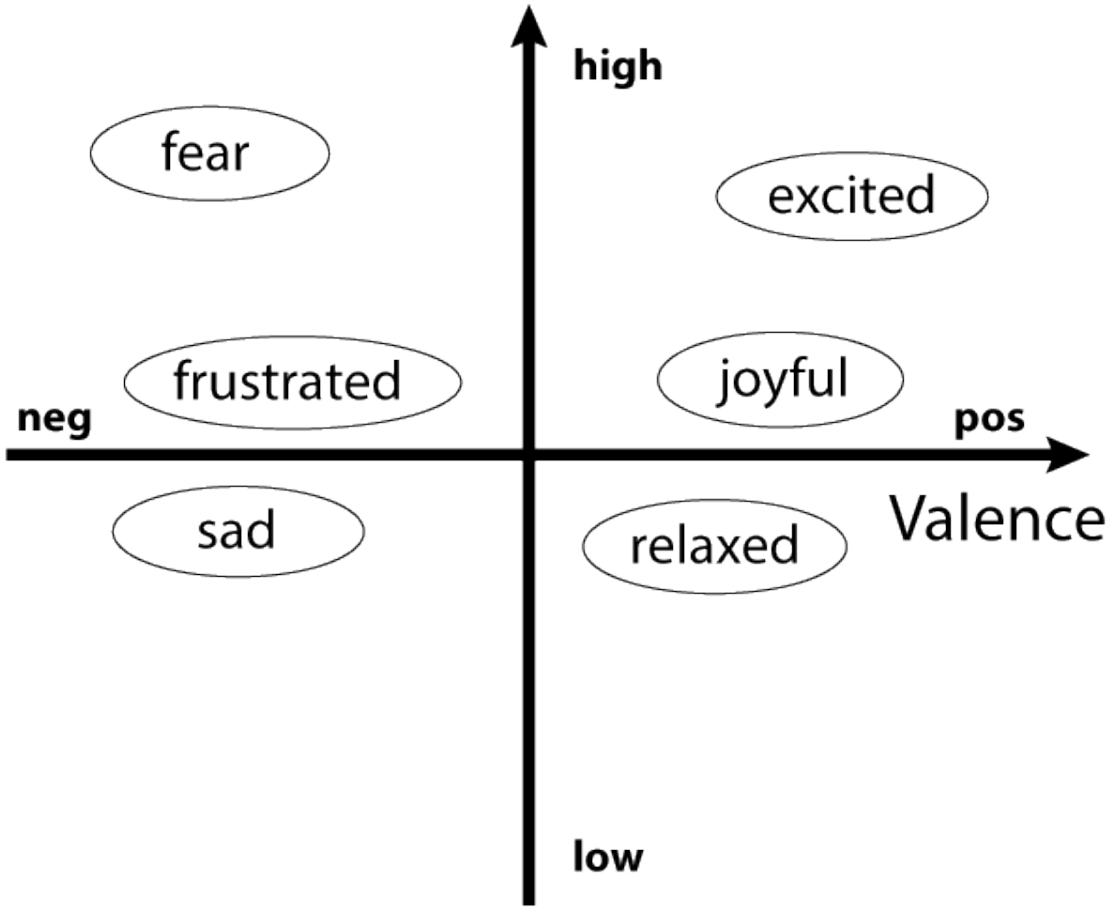

Figure: Some named emotions in the arousal-valence space by *Nakasone et al., 2005*

Introduction

- Multi-modal bidirectional communication model that is common among humans
- Emotional exchange
- Different channels: face muscles, body posture, voice modulation, skin responses, odors, etc.
- Exploit current level of technology
- Reason, plan, deliver emotionally intelligent action while interacting with human beings
- Emulate (as much as possible) human empathy

Introduction

But, what is exactly EMPATHY?

from the Oxford dictionary:

The ability to understand and share the feelings of another

Figure: Picture Courtesy of Emami Chisel Art blog

Multi-modal bidirectional communication model

VERBAL AND NON VERBAL CHANNELS:

- verbal
  - speech
  - text
- non-verbal
  - prosody : voice management
    - pitch, length, rate, intonation (tonality, tonicity, tone), loudness, tempo (rythm, pause, chunks)
  - paralanguage (gasp, sigh, throat-clear, mhm, etc.)
  - kinesics : body language
    - facial expression, oculesics (gaze, eye contact and movement), gestures, odors, tactility and skin response (haptics, color, humidity)
  - proxemics : space management
  - chronemics : time management

Human vs Robot emotion rendering

How emphatic are current robots in respect to humans?

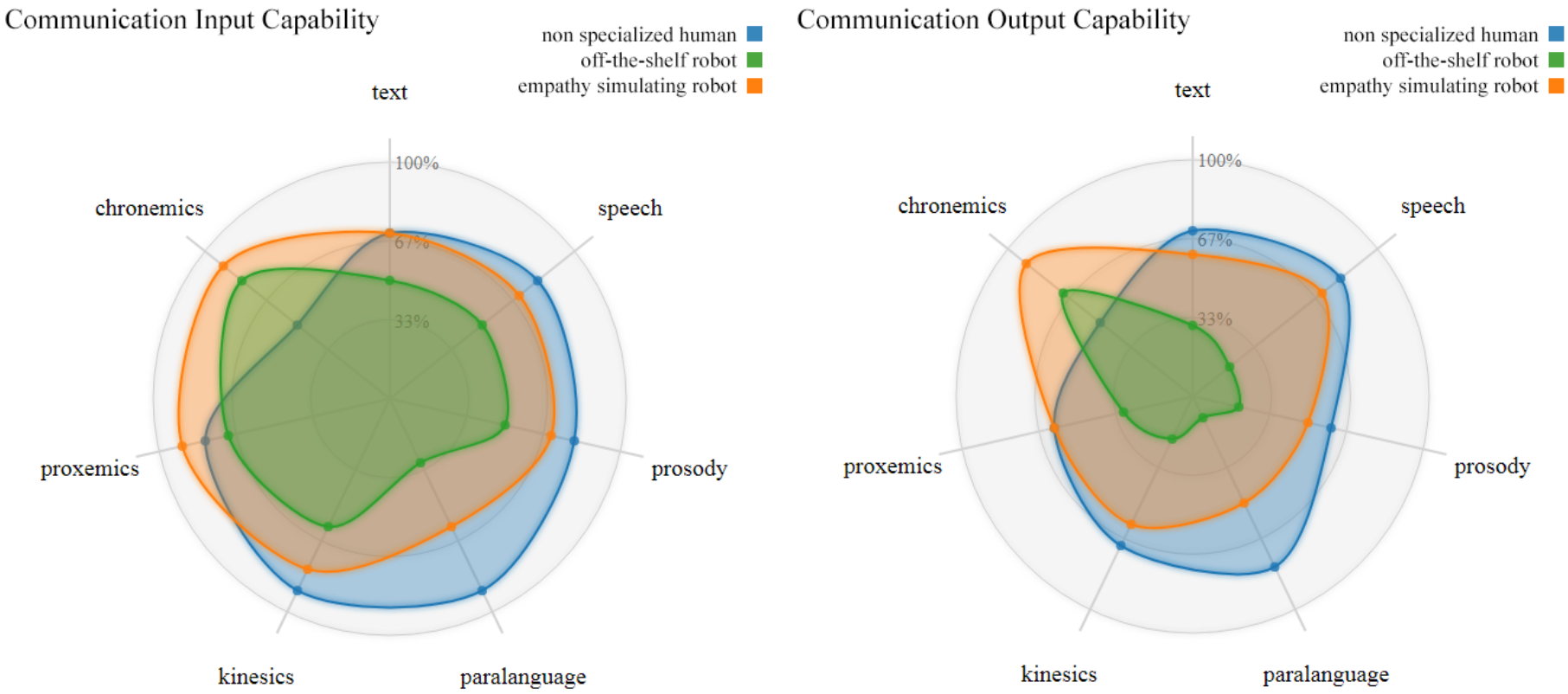

Figure: Emotional channels capabilities of humans (blue) vs robots

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Perception Technologies

Requirements and technological constraints

- Use *off-the-shelf* technology exploiting the Moore's Law [1]
- Prefer open standards vs. proprietary oriented platforms
- Prefer development frameworks that have a short learning curve for humans
- Do not overshoot, accomplish one step at a time

Figure: The NAO robotics platforms, GNU/Linux based, programmable in C, C++, Python, 26 degrees of freedom

[1] "the number of transistors in a dense integrated circuit doubles about every two years."

Perception Technologies - references

Speech perception sub-system

Available: Google speech API, Amazon Alexa, Mycroft, Mozilla Speech Project, Beyond Verbal. The Softbank NAO robot includes onboard speech recognition sub-system limited to keyword-spotting applications, or predefined question/answer dialog interactions.

Face and facial expression recognition sub-system

Available: Kairos Emotion Analysis, Amazon Rekognition, Google Vision, Microsoft Emotion, IBM Watson, Affectiva, OpenCV and Megvii Face++

Skin response estimation sub-system

Empatica E4, Polar H7, Biopac MP150

Body posture recognition

Microsoft Kinect, NAO onboard cameras

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Interaction Planning Technologies

How to design and implement the robot behaviour?

Multi-Agent System Software Engineering approach *(see GAIA)*

Procedural multi-agent system frameworks

- **SPADE**: It uses Jabber XMPP as communication protocol among agents, including an agent management console.
- **osBrain**: the most recent MAS framework based and the ZeroMQ approach to inter-agent communication, inspired by the Internet of Things (IOT) technology.

Logic multi-agent system frameworks

- **DALI**: enriched with the PyDALI extension, allows to exchange asynchronous events logic states by a shared Linda tuple space server.
- **QuLog/Teleor**: The agent behaviours can be described by universal planners that take perceptions as asynchronous events coming from a shared tuple space server.
- **JaCaMo**: Inherently a BDI multi agent model implemented in Java, with a complete Eclipse IDE

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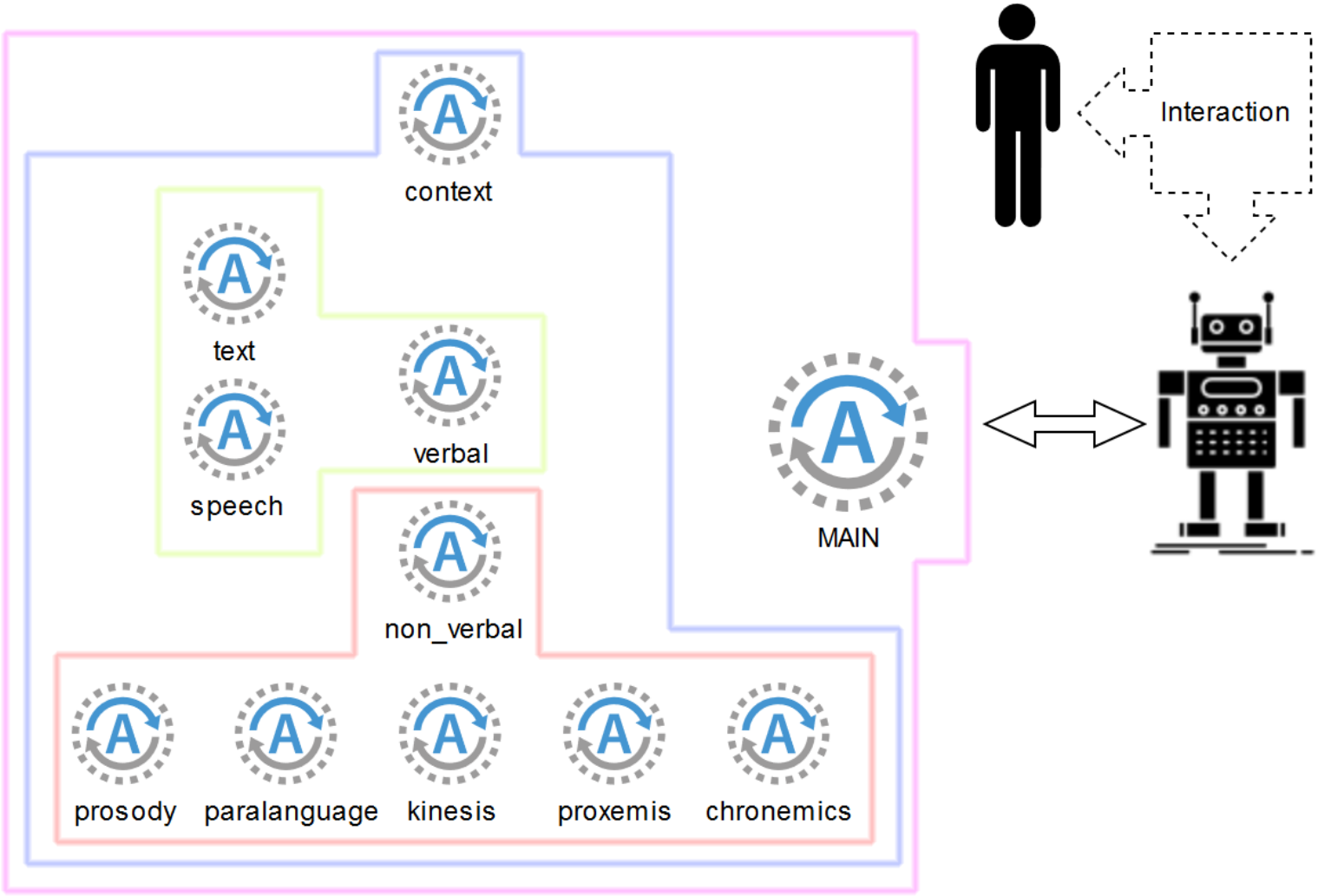
Multi-Agent System Framework

Each agent role is dedicated to a communication channel



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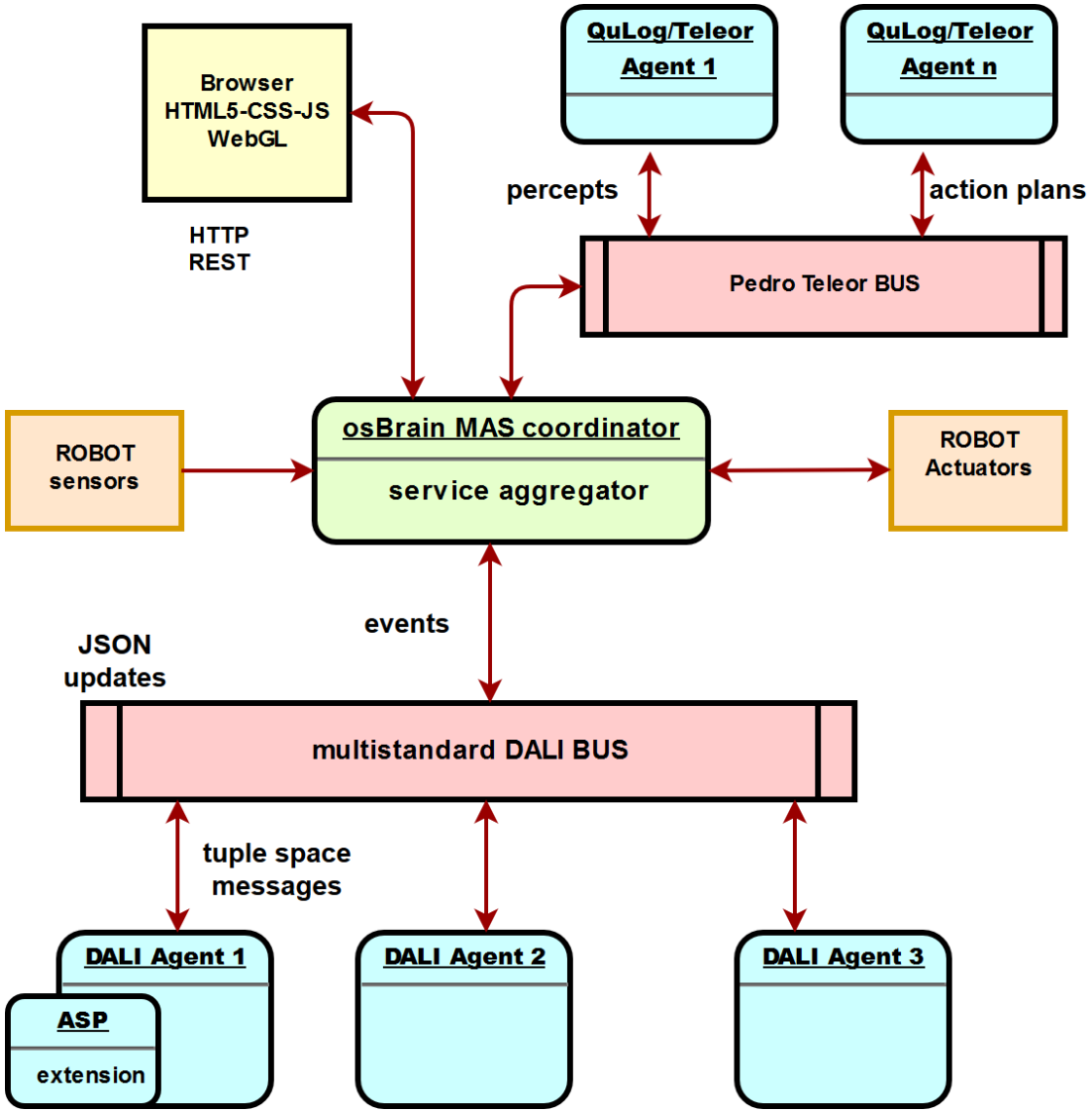
Architectural Design

Our aim for the complete emphatic robot



Teleor/QuLog Robot high-level controller

types definitions

Apri | teleor_agent.pl ~/AIKE2019 | Salva

```
% Possible actions:  pose(stand|sit|listen|explain),
%                        face_expression(neutral|happy|sad), take(Obj),
%                        wait_human(1..60)
% Percept Facts:         human_voice(loud|neutral|calm),
%                        human_face_expr(neutral|happy|sad), giving(Obj)

% INPUT DEFINITIONS

% EMOTIONS
def emotion_type ::= neutral|happy|sad

% POSES
def pose_type    ::= stand|sit|listen|explain

% VOICE
def voice_type   ::= calm|normal|loud

% HUMAN STATE
def human_state  ::= quiet|troubled|aroused|awake|sleeping

% HUMAN IDENTIFICATION
def person_id    ::= 0..9999

% OBJECT IDENTIFICATION
def object_id    ::= 0..9999

% ROBOT STATE
def durative ::= face_expression( emotion_type ) | pose( pose_type ) |
                 take_obj( object_id ) | wait_human( num )
```

Teleor/QuLog Robot high-level controller

behaviours declarations

Apri — teleor_agent.pl — ~/AIKE2019 — Salva

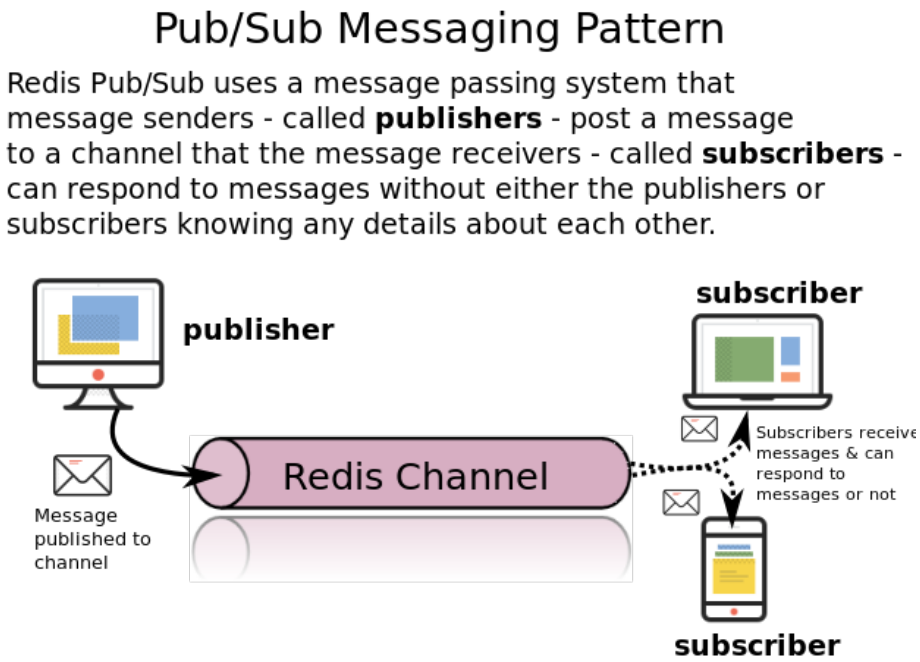
```
% ACQUIRE HUMAN INPUT
percept human_voice( person_id, voice_type ), human_face_expr( person_id, emotion_type ),
        human_giving( person_id, object_id )

% CONTEXT DEFINITION BY HUMAN INPUTS
rel situation(human_state)
situation(quiet) <=
        not human_voice(_, loud) & not human_face_expr(_, sad)
situation(troubled) <=
        not human_voice(_, calm) & not human_face_expr(_, happy)
situation(aroused) <=
        human_voice(_, loud)

% OBJECT EXCHANGE DETECTION
rel object_given()
object_given() <=
        human_giving(_, _)

% ROBOT REACTION BEHAVIORS
tel react_emotion(), exchange_object(), assume_pose()

% ROBOT REACTION TO HUMAN EMOTIONS
react_emotion() {
        situation(troubled) ~> [face_expression(sad):1, pose(sit):3, wait_human(30)]
        situation(quiet) ~> [pose(stand):3, face_expression(neutral)]
}

% OBJECT EXCHANGE ACT
exchange_object() {
        situation(quiet) & object_given() ~> [face_expression(happy):1, pose(stand):3, take_obj(_)]
        situation(aroused) ~> [pose(stand):3, take_obj(_)]
        true ~> pose(sit)
}

% EXECUTE ACTION
act go()
go() ~>
    start_agent( emprobot, all ) ;
    start_task( emotion_engine, react_emotion() )
\end{verbatim}
}
```

Perl — Larg. tab.: 8 — Rg 31, Col 22 — INS

Message Broker-based Multi-Process System

Lower level message passing and synchronization tool

For the pilot project implementation we adopted the open source tool **REDIS** message broker and NO-SQL key-value datastore, for the interprocess-cross-OS communication. [2]



Picture countersy from `intro2libsys.info`

[2] `http://redis.io`

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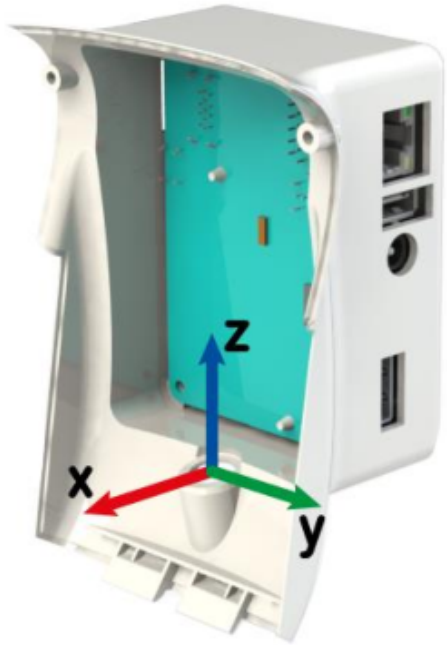
Prototype: the NAO robotic platform

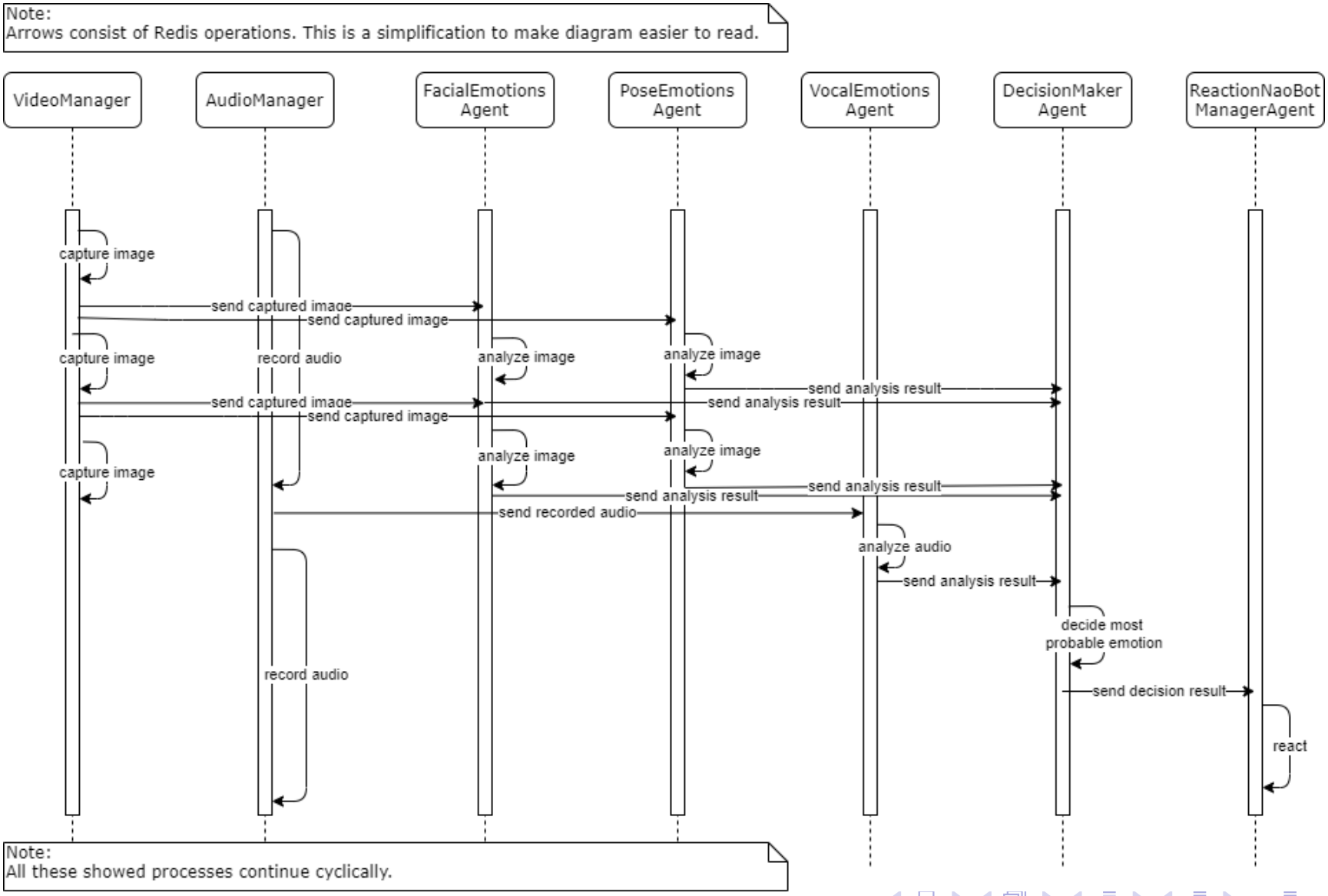


The 3D printed back pack mountable on the humanoid NAO robot that originally encapsulate the ODROID-XU 32bit single board computer with Android OS. Proposed by Mattamala et al, 2017 [3]

[3] https://arxiv.org/abs/1706.06696

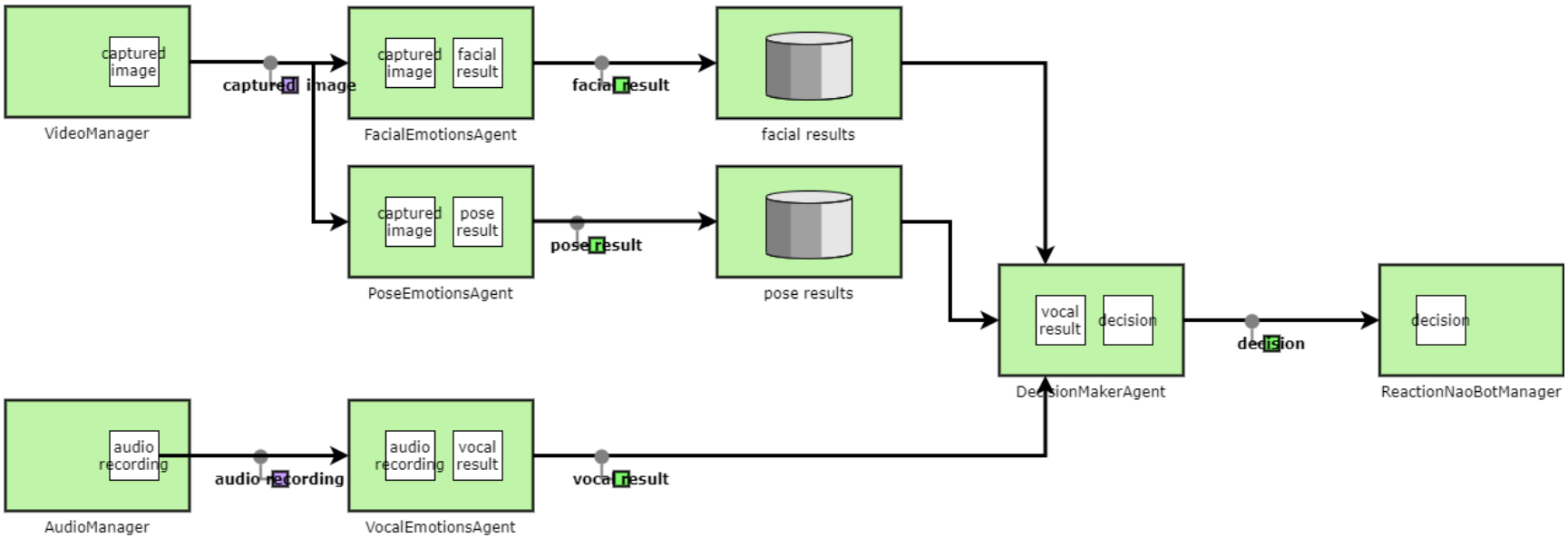
BlocksBOT: the three channel subset prototype

Body Pose, Face Emotion, Voice Intonation



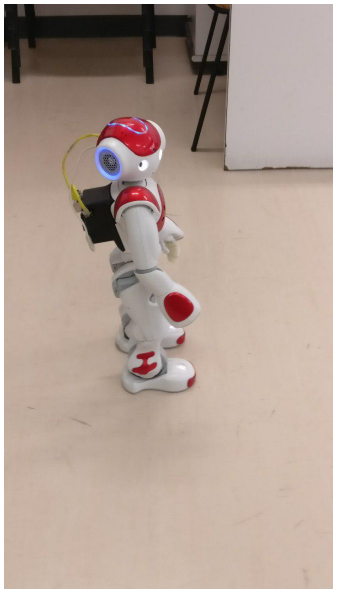
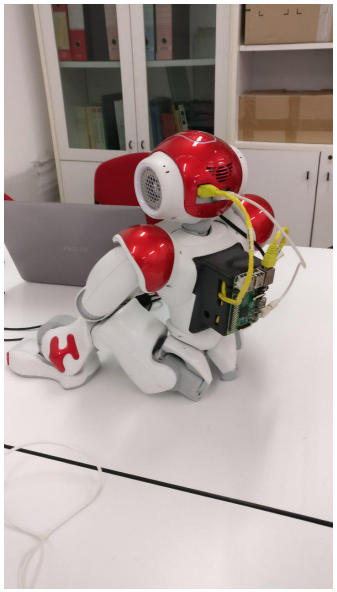
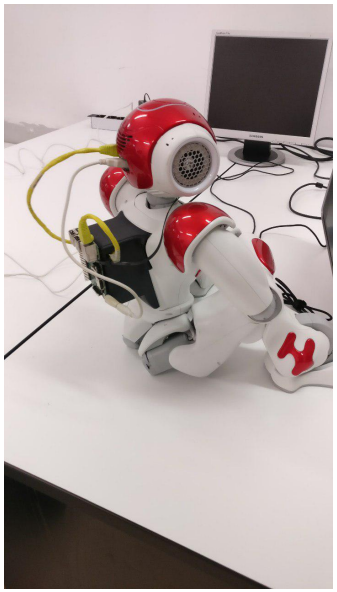
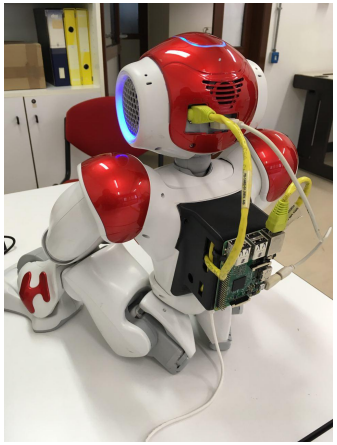
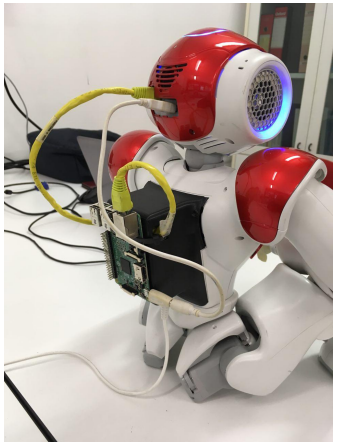
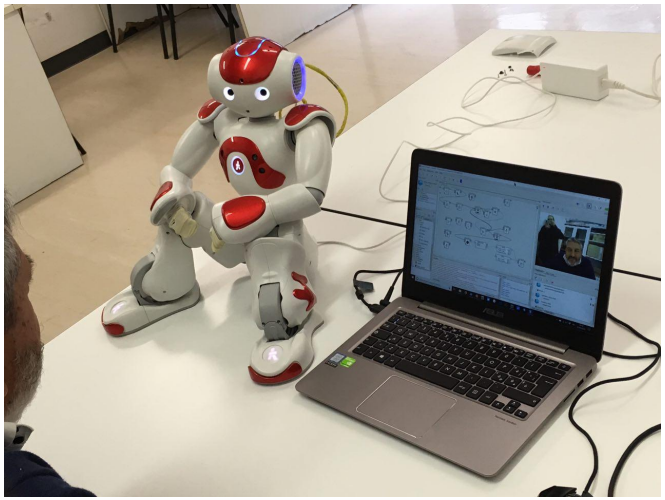
BlocksBOT MB-MPS

Body Pose, Face Emotion, Voice Intonation coordination



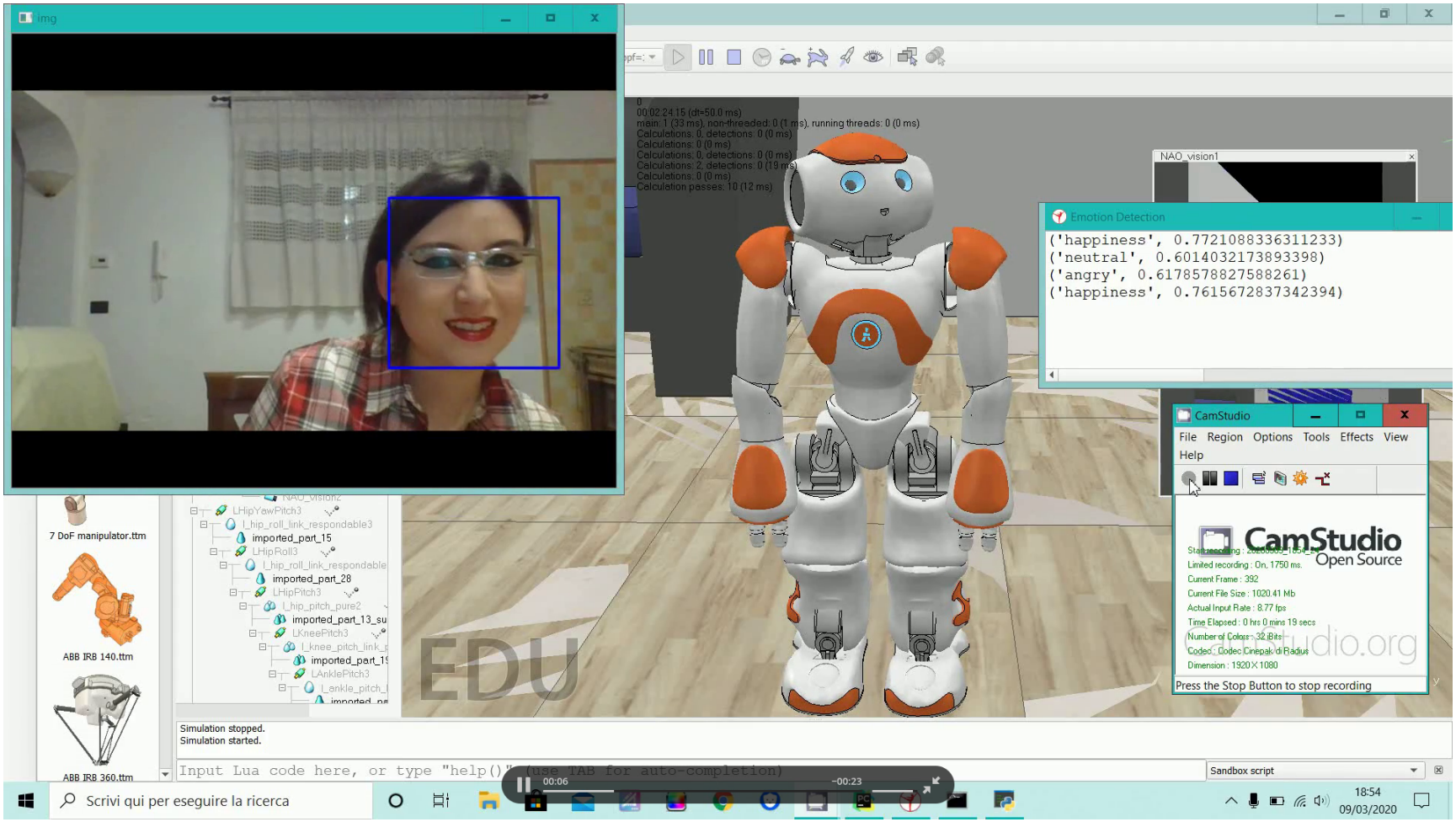
Prototype: the expanded NAO robotic platform

Expanded with the Raspberry-Pi3 backpack in our laboratory @UnivAQ, L'Aquila

Prototype: simulated BlocksBot NAO in CoppeliaSim [4]

Video Demo



[4] https://www.coppeliarobotics.com/

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Conclusions

Given the progress level of current technology and what is expected to happen in the near future, we can argue the proposed goal is **reachable**:

Emphatic Robot Design Goal

A robot design which can manage a communication with humans showing what is considered to be an "emphatic interaction" by the meaning of recognizing and showing emotions.

Acknowledgements

We thank Prof. Keith Clark and Prof. Rafael Bordini for their insightful seminars held at University of L'Aquila in Academic year 2016-19 about the "Theory and Practice of Logic Robotic Programming" and "Theory of Mind".

Prof. Keith Clark

Prof. Rafael Bordini

References I

Keith Clark Peter Robinson.
Qulog/teleor home - 0.7 qu-prolog extension for robotics.
http://staff.itee.uq.edu.au/pjr/HomePages/QulogHome.html, 2020.
[Online; accessed 14-March-2020].

Ştefan Sarkadi, Alison R Panisson, Rafael H Bordini, Peter McBurney, Simon Parsons, and Martin Chapman.
Modelling deception using theory of mind in multi-agent systems.
AI Communications, 32(4):287–302, 2019.

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