



UNIVERSITÀ DEGLI STUDI
DI GENOVA



ISTITUTO ITALIANO
DI TECNOLOGIA

TOWARDS AN AFFECTIVE COGNITIVE ARCHITECTURE FOR HUMAN-ROBOT INTERACTION FOR THE ICUB ROBOT

Ana Tanevska

Francesco Rea

Giulio Sandini

Alessandra Sciutti

Cognitive Robotics and Interaction lab

Department of Robotics, Brain and Cognitive Sciences

Istituto Italiano di Tecnologia (IIT), Genova, Italy

OVERVIEW

1. Motivation
2. Our Architecture
3. Methodology
4. Results
5. Discussion

MOTIVATION

- *...affective, cognitive architecture for HRI...*
- *...developing an affect-based architecture for the humanoid robot iCub with the purpose of having fully autonomous interactions with humans...*

MOTIVATION

- *...affective, cognitive architecture for HRI...*
- *...developing an affect-based architecture for the humanoid robot iCub with the purpose of having fully **autonomous** interactions with humans...*

MOTIVATION

MOTIVATION

- Autonomy in robotics

MOTIVATION

- Autonomy in robotics
- Cognition in robotics

MOTIVATION

- Autonomy in robotics
- Cognition in robotics
- Affect in robotics

AUTONOMY AND COGNITION IN HRI

AUTONOMY AND COGNITION IN HRI



AUTONOMY AND COGNITION IN HRI



MOTIVATION

MOTIVATION

- **Autonomous, cognitive human-robot interaction**

MOTIVATION

- **Autonomous, cognitive human-robot interaction**
- **Autonomy**
 - perceiving the environment
 - selecting the appropriate action
 - adapt to unpredicted scenarios

MOTIVATION

- **Autonomous, cognitive human-robot interaction**
- **Autonomy**
 - perceiving the environment
 - selecting the appropriate action
 - adapt to unpredicted scenarios
- **Cognition**
 - acting to fulfill some goals, driven by motivation
 - learning from the history of interaction
 - personalizing the interaction for each user

AUTONOMY AND COGNITION IN HRI

- *“Cognition – the ability to autonomously perceive the environment, learn from experience and history of interactions, anticipate the outcome of events, act to pursue internal goals and adapt to changing circumstances”¹*

REQUIREMENTS FOR COGNITIVE ROBOTS

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception
- Anticipation

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception
- Anticipation
- Action

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception
- Anticipation
- Action
- Adaptation

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception
- Anticipation
- Action
- Adaptation
- Learning

REQUIREMENTS FOR COGNITIVE ROBOTS

- Motivation
- Perception
- Anticipation
- Action
- Adaptation
- Learning



+ Autonomy

THE DUAL ROLE OF AFFECT IN COGNITION²

THE DUAL ROLE OF AFFECT IN COGNITION²

- As motivational drive and self-evaluation mechanism

THE DUAL ROLE OF AFFECT IN COGNITION²

- As motivational drive and self-evaluation mechanism
- As perceptual input from the human peers

STUDY GOAL

- Develop a cognitive architecture for iCub capable of:

STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive

STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive
 - ❖ autonomous perception of affective state of the human

STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive
 - ❖ autonomous perception of affective state of the human
 - ❖ anticipating the outcome of its actions on the human

STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive
 - ❖ autonomous perception of affective state of the human
 - ❖ anticipating the outcome of its actions on the human
 - ❖ autonomously selecting the best action

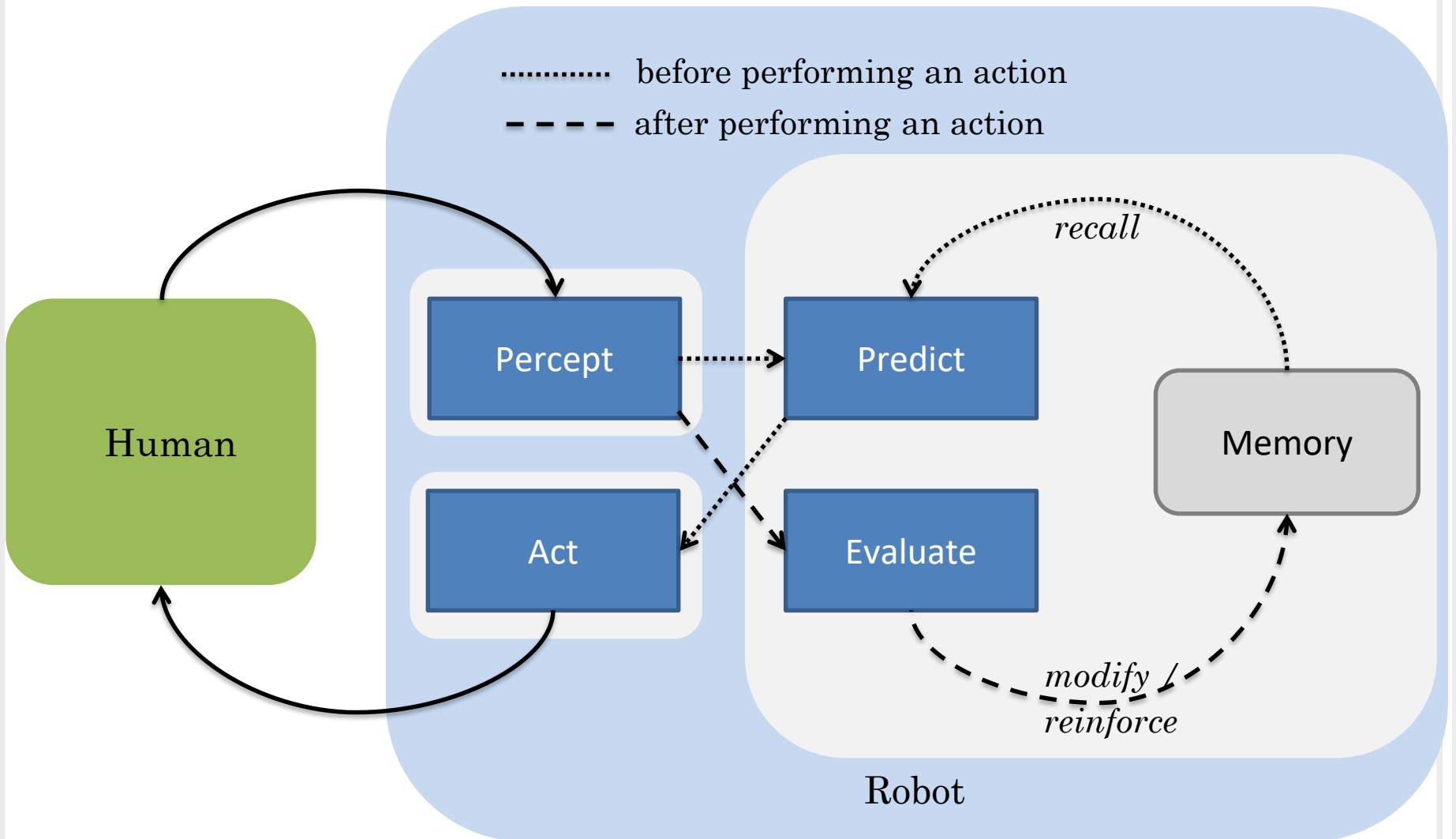
STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive
 - ❖ autonomous perception of affective state of the human
 - ❖ anticipating the outcome of its actions on the human
 - ❖ autonomously selecting the best action
 - ❖ adapting to unpredicted feedback from the human

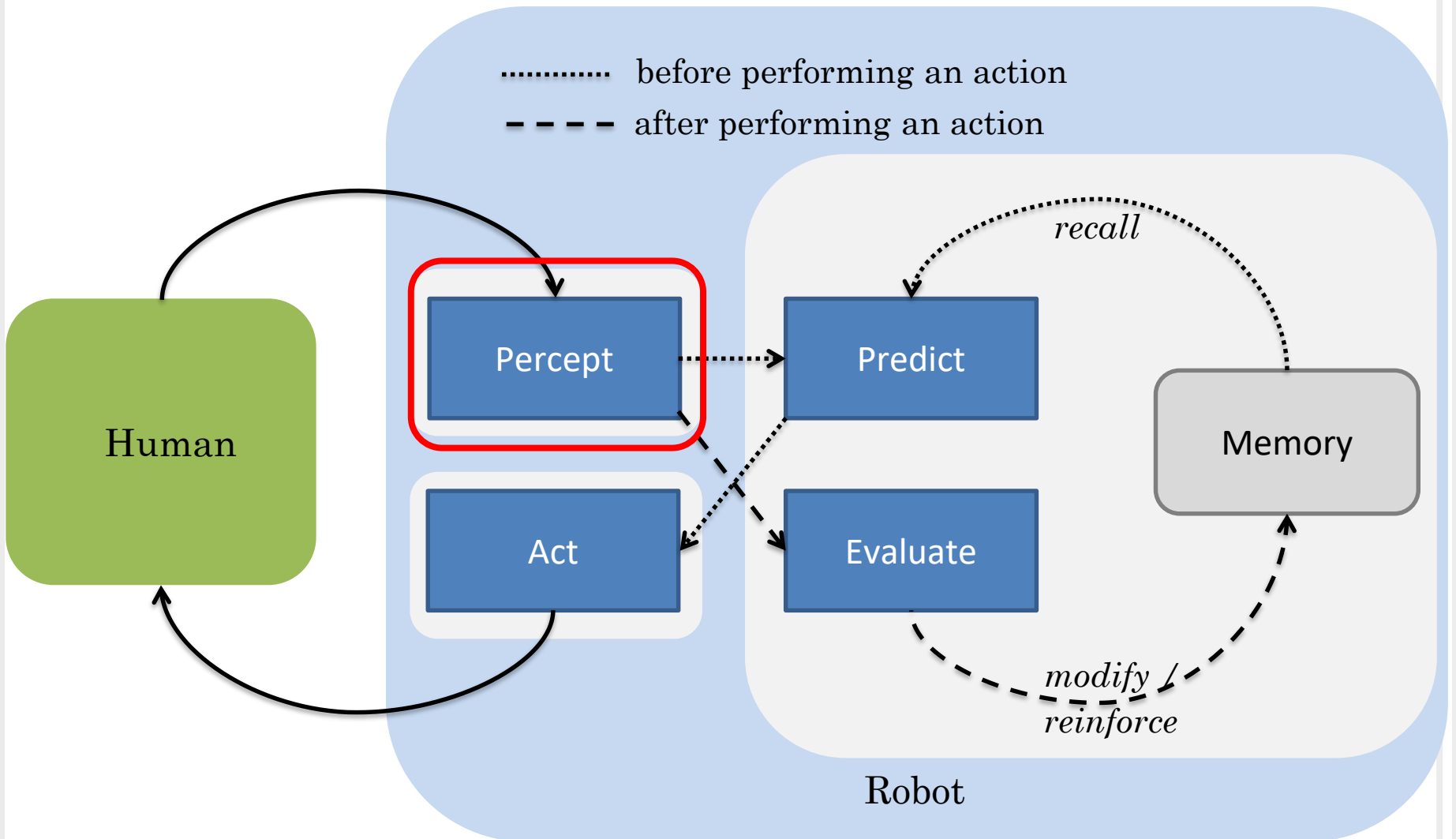
STUDY GOAL

- Develop a cognitive architecture for iCub capable of:
 - ❖ having an affect-based motivational drive
 - ❖ autonomous perception of affective state of the human
 - ❖ anticipating the outcome of its actions on the human
 - ❖ autonomously selecting the best action
 - ❖ adapting to unpredicted feedback from the human
 - ❖ learning from its past experience

OUR ARCHITECTURE



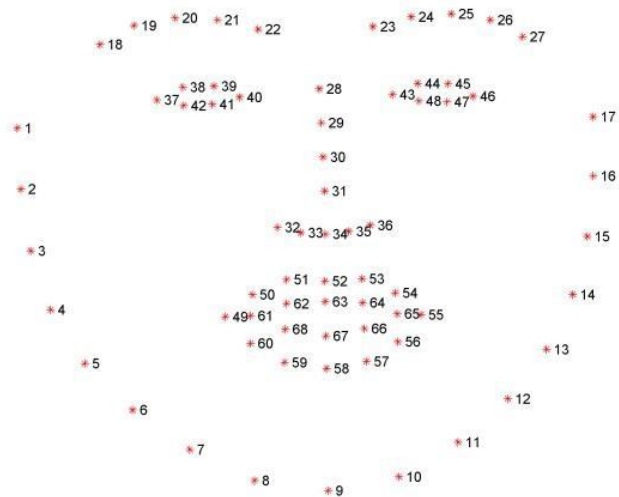
OUR ARCHITECTURE



PERCEPTION

- Process visual information about the environment
- Monocular input from iCub's camera, high resolution (1280x768 px)
- Extract information about affective state from facial features

AFFECT DETECTION FROM FACIAL FEATURES



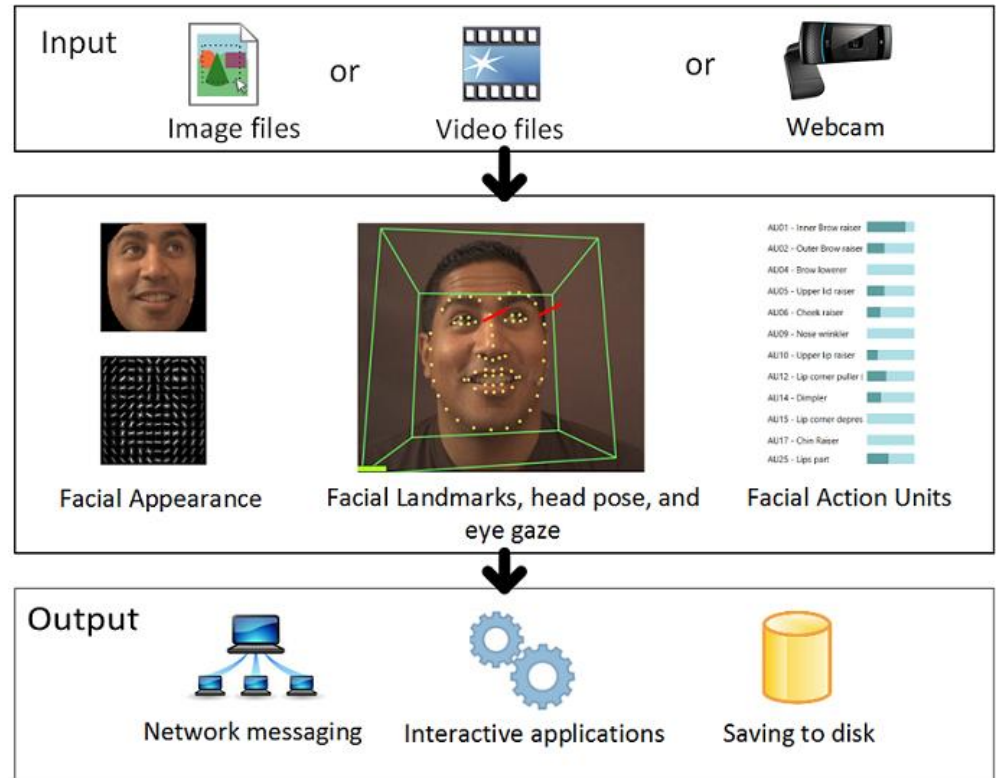
Facial landmarks



Action units (AUs)

THE OPENFACE³ FRAMEWORK

- Open-source, using dlib, OpenCV and CLM methods
- Extraction of AUs, facial information, head pose and 3D orientation, eye gaze

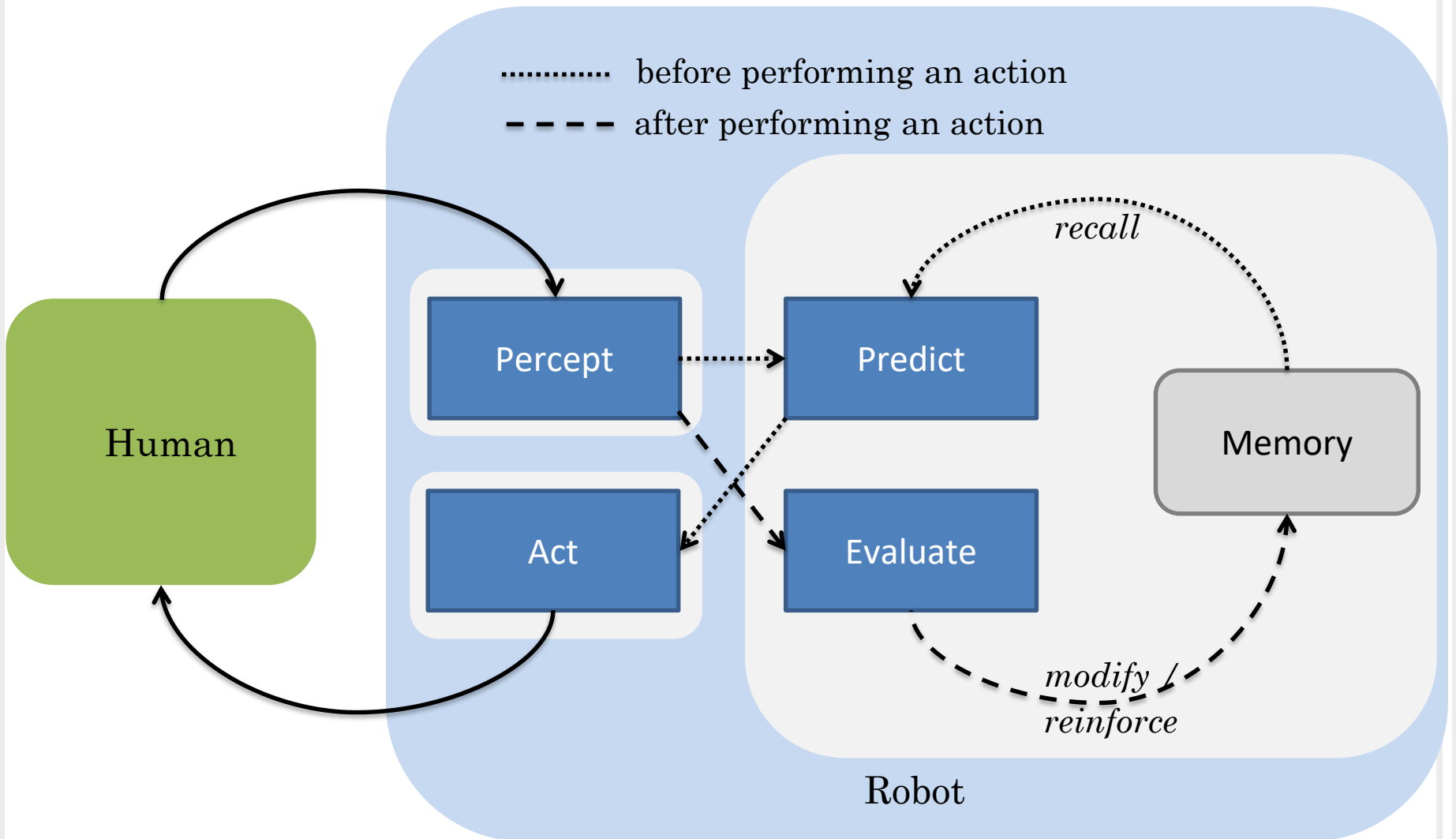


AFFECT DETECTION FROM FACIAL FEATURES

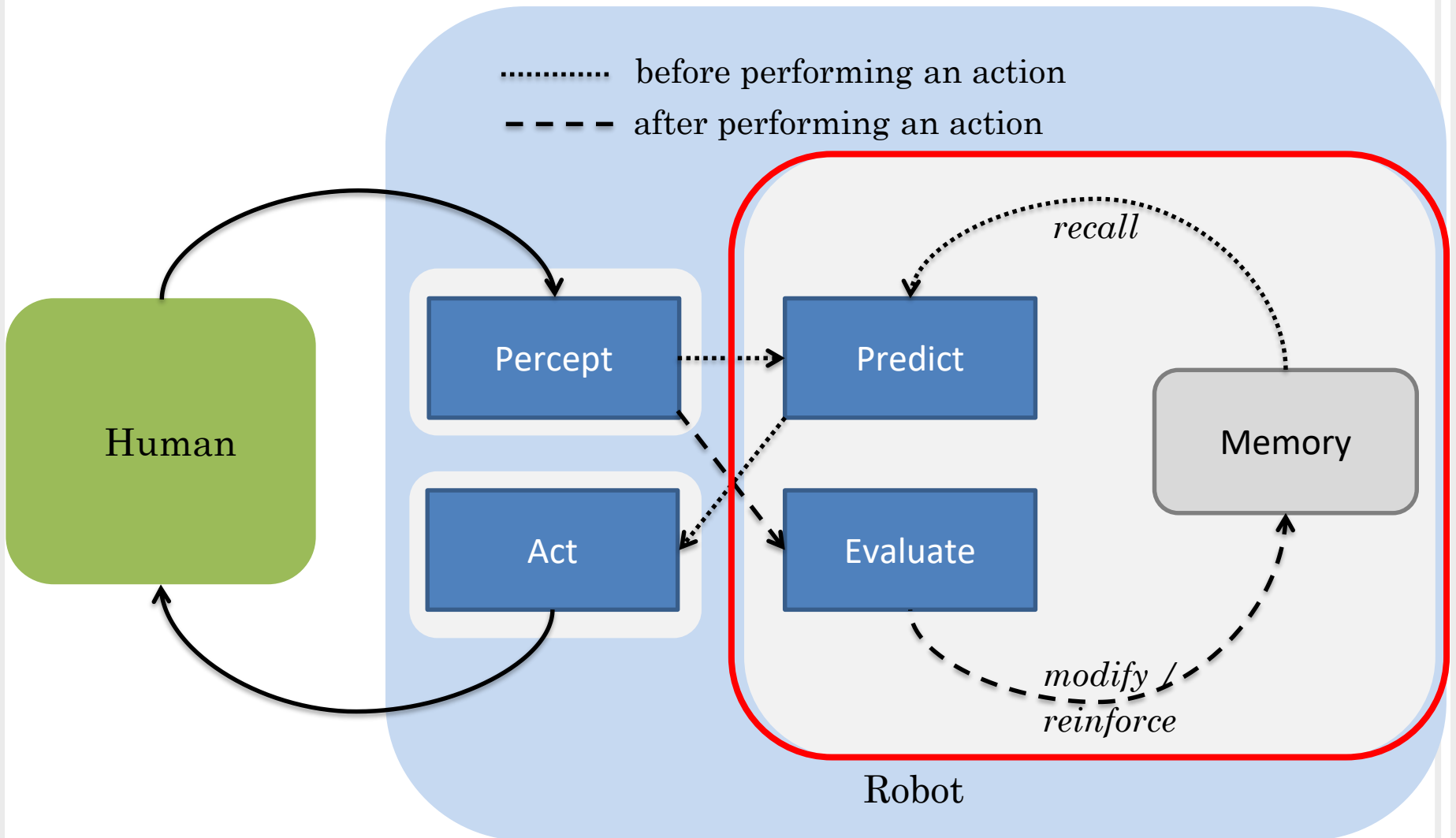
- Frame-by-frame detection and extraction of AUs
- Relying on subsets of highly-salient AUs characteristic for individual emotions



OUR ARCHITECTURE



OUR ARCHITECTURE



MEMORY, PREDICTION AND EVALUATION

- iCub needs to be able to decide and act by itself
- Concept – implementation of pseudo-emotions dependent on the interaction with the humans
- Motivation – maximize own positive state by maximizing the humans' interest in the interaction

MEMORY, PREDICTION AND EVALUATION

- Probability graphs storing the estimation of the positive or negative effect of a given action
- Individualized graphs for each user and each type of action
- Calculate most beneficial action w.r.t. the “mood” of the robot and the state of the human peer

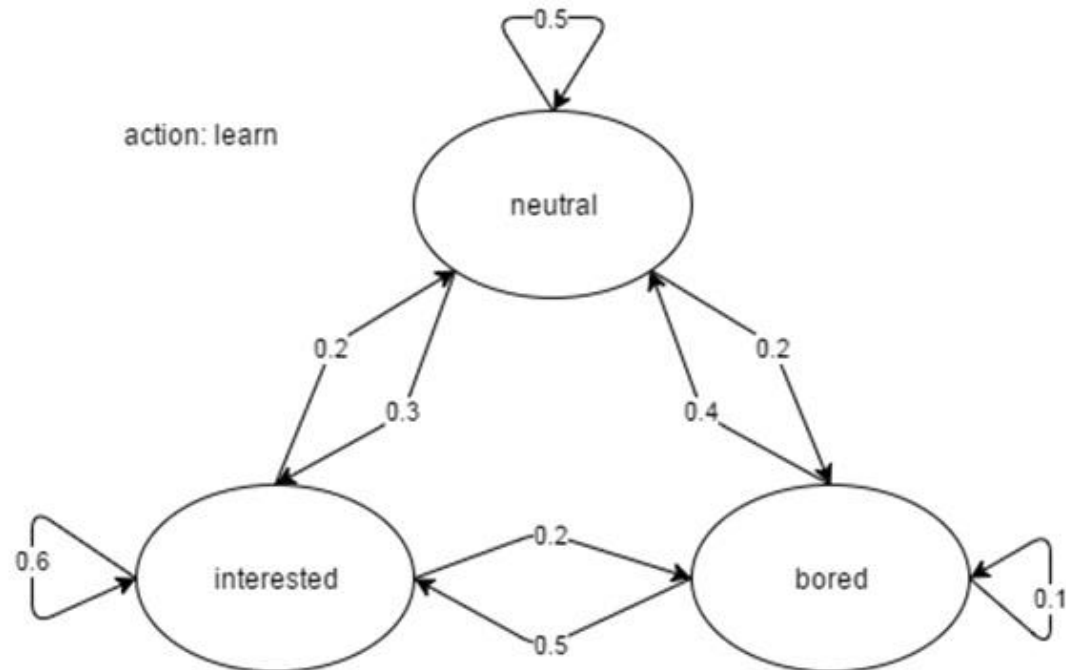
MEMORY, PREDICTION AND EVALUATION

- Implementation in python using Markov networks of transitional probabilities for the state of the users
- Porting in C++ to be integrated as an iCub module after the development of the actions

MEMORY, PREDICTION AND EVALUATION

$$P(r1 = m1) = \sum_{c1} P(r1 = m1 | r0, u1) P(u1)$$

$$P(u1 = n1) = P(u1 = n1 | u0, a1)$$



RESULTS

- Affect detection module
 - ❖ Implemented both as a standalone module and as emotional mimicry module (with the iCub mimicking the facial expression of the person)
- Tested in demos with both adults and children



RESULTS

- Engagement detection module
 - ❖ Training with AM-FED⁴ database of videos

[4] <https://www.affectiva.com/facial-expression-dataset/>

RESULTS



RESULTS

- Engagement detection module
 - ❖ Training with AM-FED⁴ database of videos
 - ❖ Testing with prerecorded data with the iCub from a tower-building experiment⁵
 - ❖ Insufficiently accurate to detect changes in engagement level of the human peers, human judges also had difficulties

[4] <https://www.affectiva.com/facial-expression-dataset/>

[5] Palinko et al. Intelligent Robots and Systems (IROS), 2016.

FUTURE WORK

- Use datasets of facial expressions to train model for affect classification
- Implement gaze-tracking and possibly multimodal processing for the engagement-detection module
- Develop several groups of actions to be integrated in the learning module
- Design experiments with human peers to test the autonomous behavior and the architecture

THANK YOU FOR YOUR ATTENTION!



Cognitive Robotics and Interaction laboratory
RBCS department, IIT Genova

Questions?



UNIVERSITÀ DEGLI STUDI
DI GENOVA