Designing an Affective Cognitive Architecture for Human-Humanoid Interaction

Ana Tanevska
Robotics Brain and Cognitive Sciences Dept, Italian Institute of Technology
Genoa, Italy
ana.tanevska@iit.it

Francesco Rea
Robotics Brain and Cognitive Sciences Dept, Italian Institute of Technology
Genoa, Italy
francesco.rea@iit.it

Giulio Sandini
Robotics Brain and Cognitive Sciences Dept, Italian Institute of Technology
Genoa, Italy
giulio.sandini@iit.it

Alessandra Sciutti
Robotics Brain and Cognitive Sciences Dept, Italian Institute of Technology
Genoa, Italy
alessandra.sciutti@iit.it

ABSTRACT

Robots involved in HRI should be able to adapt to their partners by learning to select autonomously the behaviors that maximize the pleasantness of the interaction for them. To this aim, affect could play two important roles: serve as perceptual input to infer the emotional status and reactions of the human partner; and act as internal motivation system for the robot, supporting reasoning and action selection. In this perspective, we propose to develop an affect-based architecture for the humanoid robot iCub with the purpose of fully autonomous personalized HRI. This base framework can be generalized to fit many different contexts -social, educational, collaborative and assistive – allowing for natural, long-term, and adaptive interaction.

ACM Reference format:
A. Tanevska, F. Rea, G. Sandini, and A. Sciutti. 2018. Designing an Affective Cognitive Architecture for Human-Humanoid Interaction. In *HRI'18 Companion: Conference on ACM/IEEE International Conference on Human-Robot Interaction, March 5-8, 2018, Chicago, IL, USA.* ACM, NY, NY, USA, 2 pages. DOI: https://doi.org/10.1145/3173386.3177035

1 INTRODUCTION

Humans are so good at interacting with each other because they naturally adapt their behavior to their partners, modifying their actions, tones and speech according to the needs of the other person. In fact, humans not only can perceive the emotional state of others, but during multiple interactions they learn which behaviors are the most appropriate for each of them. In our work, we propose to endow the robot with a similar ability, enabling it to perceive the state of the person it is interacting with and to autonomously decide how to act, guided by an affect-driven motivational drive. Although affect is sometimes not included in cognitive architectures [1], there are several studies showing that emotions could represent a crucial component of human-inspired cognitive systems for HRI [2]. In particular affect could play two roles in a cognitive architecture for HRI: 1) serve as perceptual input to infer the status of the partner and 2) constitute a motivation system for the robot. Indeed, by implementing a range of pseudo-emotions (e.g. happy, sad, neutral…), it is possible to make them a part of the anticipation and decision phases in the robot's reasoning, supporting learning, adaptation and action selection. There are several examples of these two affect-based functionalities (e.g. [2,3]), but their combination into a fully autonomous affect-based HRI is not yet common, in particular for humanoid platforms. This is due to specific challenges entailed, such as the heightened human expectations for the robot's performance, as well as the complexity of the control. In this work we aim at filling this gap, by developing a cognitive, self-learning architecture for social interaction for the humanoid robot iCub.

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.
HRI '18 Companion, March 5–8, 2018, Chicago, IL, USA
© 2018 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-5615-2/18/03.
https://doi.org/10.1145/3173386.3177035

2 ARCHITECTURE AND METHODS

Our cognitive architecture would provide iCub with the primary supportive functionalities necessary for autonomous HRI, including perception, action, adaptation, anticipation, learning and motivation. We propose a motivational system based on affect, where the robot's emotional state changes as a function of the perceived change in the person's affective state. Additionally, the robot stores in its memory the affective reactions of each partner to its behaviors and updates this map whenever it learns some new information about the person's reactions. Thus, before performing an action, the robot uses the affective input (measured through its *perception module*) to predict which behavior will be most beneficial- i.e., which action will most probably improve the human and robot's affective states. After action execution, the robot will evaluate from its perceptual input if the person's reaction is as predicted and will update accordingly its belief values (with its *internal evaluation/learning module*), either modifying them if wrong, or reinforcing them if right (see Fig.1).

The **perception module** detects a face, extracts facial landmarks and derives the facial action units (AUs) [4] which can be associated with the expression of certain emotions. The activation of the AUs is first determined by using linear-kernel SVM and coding their appearance (1/0). Then the intensity (0-5) of each AUs is computed by using a linear-kernel SVR. The multiplication of these two factors allows to define the most active AUs, which are then associated to separate affective states (i.e. anger, happiness,...). The **learning module** is in charge of anticipating the outcome of the future actions, as well as learning whether its beliefs about human reactions are true. This evaluation occurs in steps: 1) every change in the person's affective state impacts the robot's emotions; 2) the internal goal of the robot is to maximize its own happiness, by making sure the person's affective state changes for the better; 3) a basic memory system is responsible of storing the robot's knowledge about what each person prefers in the interaction, and adapts its values on the basis of the observed reactions. The value system used for these functionalities is implemented in the form of Markov chains of transitional probabilities, with a separate group of graphs for each partner of the robot.

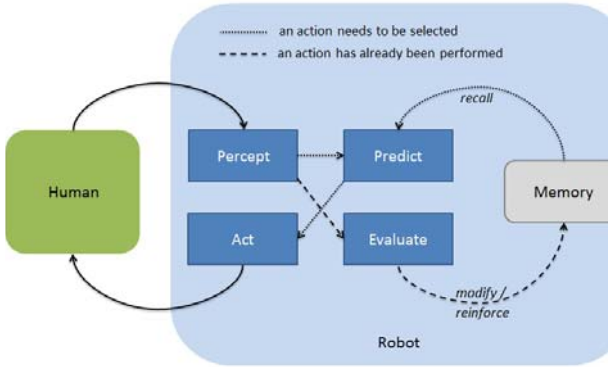

Figure 1: The layout of our architecture.

3 RESULTS AND DISCUSSION

While the system described is still a work-in progress, we already have implemented and qualitatively tested the different components. To validate the affect detection functionality, we devised an "emotional mimicry" module designed to have the iCub express the same affective facial expression as the person interacting with it. As the face of the iCub has controllable LED components only for the mouth and eyebrows, the action units corresponding to the facial muscles of the eyes, eyebrows and upper cheeks were processed to obtain a value for iCub's eyebrow expressions, and the action units of the mouth, chin and lower cheeks were processed for iCub's mouth expression. The module was tested during demos with both adults and children with positive reactions from the audience (see Fig.2) and has now been implemented as part of a greater interactive demo. The learning component has not yet been tested in an HRI experiment with the iCub robot. However, the same framework has already been validated in a child-robot scenario with the NAO humanoid robot, proving that it enables a robot to learn the preferences of each child during the interactive sessions [5].

Figure 2: Examples of the iCub detecting the face and facial expression of its partner (A) and of the robot exhibiting an expression with its LED displays (B).

4 CONCLUSIONS

Our goal is to equip humanoid robots with the cognitive abilities needed for an autonomous personalized interaction with humans. Through detecting and tracking the affective state of the partners, while simultaneously developing and maintaining its own internal evaluation system, a humanoid robot will be able to evaluate the desirability of each possible action at a time, by calculating which action would make it happier with the highest probability. The next step in this work will be to quantitatively evaluate both the affect detection component and the learning module in a structured interactive scenario with iCub. Further, we will exploit the tracking of the partners' gaze [6] as a measure of their level of engagement. Our hope is that this architecture will allow for a more natural, long-term, adaptive interaction between humans and robots.

ACKNOWLEDGEMENTS

The research presented here has been supported by the European CODEFROR project (FP7-PIRSES-2013-612555).

REFERENCES

[1] Lemaignan, S., Warnier, M., Sisbot, E. A., Clodic, A.,and Alami, R. Artificial cognition for social human–robot interaction: An implementation. Artificial Intelligence (2016).

[2] Dias, J., Mascarenhas, S., and Paiva, A. Fatima modular:Towards an agent architecture with a generic appraisal framework. In Emotion Modeling. Springer, 2014,44–56..

[3] McColl, D., Hong, A., Hatakeyama, N., Nejat, G., and Benhabib, B. A survey of autonomous human affect detection methods for social robots engaged in natural
hri. Journal of Intelligent & Robotic Systems 82, 1 (2016), 101–133.

[4] Baltru˘saitis, T., Robinson, P., and Morency, L.-P. Openface: an open source facial behavior analysis toolkit. In Applications of Computer Vision (WACV), 2016 IEEE Winter Conference on, IEEE (2016), 1–10..

[5] Tanevska, A., Rea, F., Sandini, G., and Sciutti, A. Can emotions enhance the robot's cognitive abilities: a study in autonomous HRI with an emotional robot. In Proceedings of AISB Convention 2017: Symposium on Computational Modelling of emotion (2017).

[6] Palinko O., Rea F., Sandini G. & Sciutti A. 2016, 'Robot Reading Human Gaze: Why Eye Tracking Is Better Than Head Tracking for Human-Robot Collaboration', IEEE/RSJ International Conference on Intelligent Robots and Systems, Deajeon, Korea, October (2016)