Enriched collaborative Human-Robot Interaction: going further using cognitive state characterization based on electrophysiological features

Context

This post-doctoral research position is part of the EPIIC project (ElectroPhysiological Involuntary Inputs for Collaborative robotics enhancement) funded by ANR (French national research agency). In human-machine interaction research, be it for driving, flying, gaming or medical teleoperation applications, user experience is still to this day under evaluated compared to other technical aspects, and particularly so in the human-robot interaction field. However, part of the community is now aware that there is a need for a richer and better evaluation of HRI, both at the metrics level and at the experimental design level (Hoffman, 2019; Hoffman and Zhao, 2020). In HRI research, the usual metrics to assess the quality of interaction (QoI) are subjective ones, i.e. users' reported feelings acquired through questionnaires, or – more recently – objective ones such as performance metrics (Mayima et al., 2020, 2021). Yet these metrics do not allow for a continuous and online assessment, nor for a direct assessment of the users' cognitive state.

In recent years, the development of physiological computing methods including that of brain-computer interfaces has enabled the rise of symbiotic systems that adapt the interaction using involuntary user inputs (Lotte and Roy, 2019; Roy et al., 2020). Yet, to our knowledge, this technology has never been applied to human-robot interaction (HRI) in the context of mobile and collaborative robotics. This project will provide the first evaluation of the usability of electrophysiological metrics from wearable sensors for a rich, out-of-the-lab and online quality of interaction (QoI) assessment for collaborative robotics.

The main objectives of this post-doctoral position will be to characterize the users' cognitive state -i.e. cognitive effort and automation surprise- during collaborative HRI using involuntary electrophysiological features elicited by a standard collaborative robotic task, i.e. an interactive manipulation task, using the PR2 LAAS' robot from the LAAS ADREAM facility (figures 1 and 2), along with existing robot architectures for both human-aware motion and task planning (Sisbot et al., 2007; Khambhaita and Alami, 2017), motion capture, and with wearable sensors from ISAE-SUPAERO's Neuroergonomics' lab (cerebral, ocular, cardiac and electrodermal activity acquisition devices).

Figure 1: The LAAS ADREAM facility equipped with various robots and sensors including motion capture.

Recent work by the interns and the current PhD student has highlighted that such a study requires a trade-off between a scenario complex enough to exhibit an interdependance between agents and brief enough to ensure the collection of a sufficient amount of electrophysiological data. Indeed, despite the robot being a physical device with speed constraints for both performance and safety considerations, mental state estimation needs many repetitions to be robust to intra-individual variability. A first experimental campaign has been conducted to address this challenge and classification of several levels of cognitive effort was performed. While this proves the feasibility of the project, additional efforts are still needed in protocol design, signal processing and mental state classification to build a retroactive physiological loop during human-robot collaboration.

Thus, further steps could include without being limited to:

- Designing a human-robot collaboration scenario with mental state-based adaptation
- Developing noise processing methods robust to both human and robot-generated artifacts
- Improving inter-session performance of the models by using transfer-learning techniques

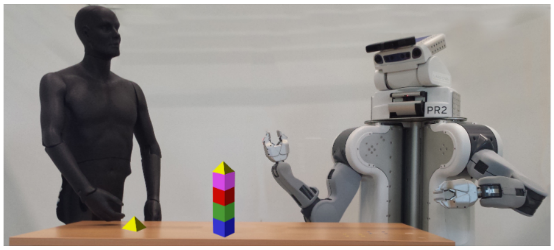

Figure 2: LAAS' PR2 robot from Willow Garage (figure from Clodic et al. (2017)).

Candidate's profile

- Currently completing or holding a PhD in Robotics, human-computer interaction, cognitive science or biomedical engineering;
- Strong programming skills;
- Autonomous, hard-working, problem-solver;
- Interested in Cognitive Science and Human Factors.

Additional information

- Salary: This post-doctoral position is financially supported by the ANR, it offers a net salary of at least 2 596.63 euros per month (depending on experience), and will increase to at least 2 703.66 in 2025.
- Nationality: Open, although security checks will be performed in compliance with the 'ZRR' procedure (restricted access zone).
- Starting date: May 2024
- Duration: 17 months (from May 2024 to September 2025)
- Supervisors: Dr Raphaëlle N. Roy, ISAE-SUPAERO, and Dr Aurélie Clodic, LAAS CNRS, Toulouse, France.
- Collaborators: Mr Mathias Rihet, doctoral student on the project, Dr Guillaume Sarthou, post-doctoral research fellow.

- Application procedure: Formal applications should include a detailed CV, a motivation letter, at least one reference letter, and pdf versions of several publications. The documents should be sent to: raphaelle.roy@isae-supaero.fr and aurelie.clodic@laas.fr
- Possibility of giving lessons within the master and engineering degree of ISAE-SUPAERO (extra funding).

References

Clodic, A., Pacherie, E., Alami, R., and Chatila, R. (2017). Key elements for human-robot joint action. In *Sociality and normativity for robots*, pages 159–177. Springer.

Hoffman, G. (2019). Evaluating fluency in human–robot collaboration. *IEEE Transactions on Human-Machine Systems*, 49(3):209–218.

Hoffman, G. and Zhao, X. (2020). A primer for conducting experiments in human–robot interaction. *ACM Transactions on Human-Robot Interaction (THRI)*, 10(1):1–31.

Khambhaita, H. and Alami, R. (2017). Assessing the social criteria for human-robot collaborative navigation: A comparison of human-aware navigation planners. In *2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN)*, pages 1140–1145. IEEE.

Lotte, F. and Roy, R. N. (2019). Brain–computer interface contributions to neuroergonomics. In *Neuroergonomics*, pages 43–48. Elsevier.

Mayima, A., Clodic, A., and Alami, R. (2020). Toward a robot computing an online estimation of the quality of its interaction with its human partner. In *2020 29th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 291–298. IEEE.

Mayima, A., Clodic, A., and Alami, R. (2021). Towards Robots able to Measure in Real-time the Quality of Interaction in HRI Contexts. *International Journal of Social Robotics*.

Roy, R. N., Drougard, N., Gateau, T., Dehais, F., and Chanel, C. P. (2020). How can physiological computing benefit human-robot interaction? *Robotics*, 9(4):100.

Sisbot, E. A., Marin-Urias, L. F., Alami, R., and Simeon, T. (2007). A human aware mobile robot motion planner. *IEEE Transactions on Robotics*, 23(5):874–883.