Modeling joint action reinforcement learning under inter- and intra- personal variability

February 2025

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Keywords: Human-robot interaction, Joint Action, Joint Attention, Neural robotics, Bio-inspired modeling, Social cognition.

Image: Leibniz University of Hanover

1 Introduction

In human collaboration, assertiveness and timing in reciprocal interaction make all the difference for the achievement of shared goals. Thus, most collaborative tasks are based on direct social interaction where adaptation plays a major role, not only to handle inherent situational contingencies but also to acknowledge contextual and personality particularities, where information should be conveyed in adequate forms of expression, which often transcends the functional dimension of behavior. In this sense, motivation is indeed a very important dimension in human interaction which conditions the quality of a joint effort.

Building robotic agents according to the principles of human social interaction and ethics would help the adoption of this promising technology in our society, while being able to interact with such agents in an intuitive and understandable manner. An important aspect of research, which is an open problem to our days, is how providing social robots, not disposing of developmental background, with forms of knowledge representation which favors adaptation at a level of sensory-motor communication, for both conveying and "guessing" other's intention. This research problem is rooted in the philosophical study of intersubjectivity, grounding in developmental and social psychology the antagonist views between cognitivism and the so-named *4E cognition* perspective (e.g Newen et al., 2018, Gallagher, 2008).

2 Relevance, originality and objectives

Although recent studies in social robotics have addressed the problem of providing the robot with the ability to balance between motion expressiveness and function in achieving joint tasks (e.g. in Hu et al., 2025) using, for example, reinforcement learning, they do not consider the adaptability of the robot to the situation.

The approach adopted consists in endorsing the robot with a predefined behavior repertory, with may not be suitable when considering human inter-variability. Also, the approach does not consider intra-subject variability, in the sense that humans continuously fluctuate in mood, awareness, and motivation; which results in our opinion in a somewhat narrow perspective for social robotics in joint action interaction with humans.

Therefore, **the originality of the thesis work** we propose consists in investigating *online* human-robot co-adaptation in expressive interaction. We would like to explore using the general framework of Reinforcement Learning (Sutton and Barto, 1998) to model the adaptation problem as a stochastic optimization process, thus taking into account both inter- and intra-subject variability for joint action interaction scenarios.

3 Methodology

Interaction scenario. Based on the literature, the first phase of the work will consist in proposing an intuitive HRI scenario eliciting joint action between the partners. Ideally, this activity will take the form of a fun game, capable of inducing human engagement.

Mathematical modeling. The second phase of the project will aim at the construction of the real-time interaction model using the various available data sources. Several bio-inspired neural network architectures can be considered to develop the interaction model. Within dynamic neural fields theory research Amari, 1977, previous works have investigated two aspects directly related to the problem under study, such as modeling attention (at the individual Chame and Alami, 2024 and joint level Chame et al., 2023), and motivation Chame et al., 2019. Variational models could also be considered, based on the concept of active inference from free energy principle theory (e.g. Chame et al., 2020).

Experiment prototyping. Several sources could be considered in order to provide data to the interaction model, such that: behavioral (e.g. monitoring of position, direction of gaze), electrophysiological (e.g. electromyography, electroencephalogram), and data captured from the robot (proprioceptive and exteroceptive sensors). Ideally, the interaction prototype will consist of a distributed system, integrated to the Robot Operating System (ROS) middleware, and programmed in Python or C++.

Robotic platforms. Several robots are available in the LORIA laboratory, including: iCub (IIT), G1 (Unitree Robotics), Tiago (Pal Robotics), Panda (Franka), Pepper (Softbank Robotics), Furhat (Furhat Robotics).

4 Supervision and collaborations

The thesis will take place at LORIA laboratory between the teams BISCUIT and NeuroRhythms. Scientific collaboration with other members of both teams is expected and welcomed, as well as more general scientific discussions and collaborations with other members of the laboratory. The teams will provide a set of programming tools, robotics platforms and all the human support necessary to the technical aspects of the work, allowing the doctoral student to focus on scientific issues.

Other collaborations with external partners may be set up, drawing in particular on the networks of the "Drôles d'Objets" community and the "Organic Robotics" PEPR, in which the thesis supervisors participate.

5 Thesis details

- **Dates:** from September 2025 to August 2028.
- **Duration:** 36 months.
- **Laboratory:** LORIA (CNRS UMR 7503). Campus Scientifique, 615 Rue du Jardin-Botanique, 54506 Vandœuvre-lès-Nancy, France.
- **Department:** Complex Systems, Artificial Intelligence and Robotics.
- **Salary:** 2.200 € / month (gross salary)

6 Profile

- Equivalent degree to a French Master II diploma in robotics, computer science, mathematical modeling or cognitive science.
- Deep research interest in human-robot interaction, embodiment, cognitive sciences and bio-inspired modeling.

- Programming skills in Python language (skills in C++ would be a plus).
- Notions of classical geometric modeling and behavior regulation in robotics would be a plus.
- Level of French or English required: at least intermediate level. You can speak the language understandably, coherently and confidently on everyday topics that are familiar to you.

7 How to apply

As soon as possible, and **before the 2nd of may 2025**, please send your application pack including a motivation letter, CV and the most recent transcript of your academic records to:

- Prof. Hendry F. Chame, hendry.ferreira-chame@loria.fr
- Alain Dutech, alain.dutech@loria.fr

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