Call for candidates to pursue an interdisciplinary Ph.D. combining cognitive science, applied mathematics, computer science and behavioral sciences

***Project title*: Simulating psychology to predict human behavior by combining computational modeling and virtual reality: application of the Projective Consciousness Model to study the role of emotion and social cognition in behavior**

Topic : Implementation and validation of tools for advanced multi-agents real-time interactions and inferences in virtual reality to study social cognition and interactions

Host laboratory & institution : the Ph.D. will take place at the CIAMS (Complexity, Innovation, Motor and Sport Activity), an interdisciplinary laboratory combining Life Science, Social and Human Sciences and engineering at the University Paris-Saclay ; and involve the LMF (Formal Methods Laboratory) at the ENS Paris-Saclay.

Principal investigator & main supervisor : Prof. (CPJ) David Rudrauf, Ph.D., H.D.R. (CIAMS)

Co-direction: Prof. Alain Finkel, Ph.D., H.D.R. (LMF, ENS Paris-Saclay).

Keywords : artificial agents, virtual reality, virtual humans, mathematical psychology, decision making, optimal control, technology, behavioral science, consciousness, empathy, active inference, emotion, social interactions

Context

• The CIAMS is developing a new interdisciplinary axis of research on mathematical psychology and the simulation and prediction of behaviors, spearheaded by David Rudrauf and Michel-Ange Amorim (CIAMS Director). David Rudrauf develops a research program based on his ANR-funded CPJ (Junior Professor Chair) project entitled: Generative Cognitive, Affective and Social Models and Simulation of Behaviors for STAPS 2.0.

• The axis will leverage a new innovative, high-tech platform of research combining the following. 1) The simulation of psychology on the basis of computational models of active inference for the prediction of behavior, based on a set of computation servers intended for real-time simulations, with models implemented as artificial agents and embodied in virtual humans. 2) Human-machine interfacing via immersive virtual reality (VR), allowing human participants to interact in real time with artificial agents in 3D space. 3) The quantification of behavior via: motion capture systems at the CIAMS; new immersive virtual reality technologies (Meta Quest Pro) to quantify the facial expressions (face tracking) and gaze (eye-tracking) of human participants; and wireless physiology, e.g. to quantify cardiovascular activity and sweating.

• The approach will be fuelled by implementations of the Projective Consciousness Model (see Scientific background below), a novel integrative model of human psychology, which combines projective geometry, active inference, and machine learning to control interactive artificial agents, and predict and explain human behaviors.

• The CIAMS is part of the Fédèv at the University Paris-Saclay, which is a large interdisciplinary federation of institutions and laboratories aiming at bridging research between engineering sciences and psychological, biological and behavioral sciences.

• The Ph.D. will be pursued within the Doctoral School Sciences of sport, motor control and human motion (SSMMH).

• The successful candidate will be directed by David Rudrauf, in co-direction with Alain Finkel, with co-supervisions and mentoring by mathematician Grégoire Sergeant-Perthuis (INRIA) and a post doctoral scholar in the process of being recruited. Local and international collaborators will also contribute to advise the student, including VR and software engineers. Master students will also be involved for implementation and data collection throughout the Ph.D.

Scientific background

The Projective Consciousness Model [1, see also 7] yields a testable framework to understand the relationships between consciousness, cognition, and adaptive behaviors. The model aims at offering a formal account of the phenomenology of consciousness that subsumes: multimodal perception, perspective taking through the imagination, the evaluation of the affective and

epistemic value of different possible perspectives, and the emergence of "drives" underlying the motivation of action, in non-social and social contexts. The space of conscious experience is conceived of as an internal workspace for representation and action planning (see [3]). The model uses 3D projective geometry to account for the subjective perspective of agents, as a method of (conscious) access of an unconscious world model, encoding objects and their relations in a componential manner. The approach leverages group theory, which we integrate to structure the agents' internal space of representation for active inference or more generally (stochastic) optimal control. In [2], we proposed a first version of the model that focused on visual perception to account for perceptual illusions such as the moon illusion. The model predictions were validated in a virtual reality experiment. In [3,4], we introduced a more encompassing model and software implementation to study how mechanisms of perspective-taking in social-affective agents can account for adaptive and maladaptive social behaviors. The action of the projective group directly contributed to maximize expectation satisfaction and information gain, resulting in different strategies of action, combining exploration and exploitation. Through projective geometry, social agents could communicate and infer key information about their environment. They could simulate each others' minds, relying on their spatial and affective behaviors, in a manner that fostered the transfer of information localization. Perspective-taking through projective geometry entailed homogeneity in the agents' variety of representations and phenomenal experiences of the world. In [5] we proved theoretical results demonstrating how changing the group that structures the world model of the agents influences their exploratory behavior. These exploratory behaviors relied on a cycle of prior updates from observations followed by the maximization of « epistemic value » (see [6] for definition) over the group. The model deals with the variety of partial world models encoded by different agents with different experiences, and allows agents to build a shared representation through perspective-taking. The approach relates to the general problem of how structured representations, such as conscious ones, enable agents, which live in a common environment, to interact socially and minimize the cost of behaviors. The model provides us with a scientific framework to design experiments with human participants, which are necessary to falsify or validate the predictions of the model as a whole. One of the overarching goals of our approach is not only to build a theory of consciousness and its relations to behaviors, but also to provide theoretical foundations for the control of autonomous systems such as social robots and virtual agents.

Research project

The research project entails both methodological research and basic science.

1) *Methodological research*: the successful candidate will play a central role in the design, implementation and testing of the PCM in the CIAMS platform, involving: coding in Python and C#; optimization and parallelization; game engine control (Unity) and VR integration; real time simulations for prediction of empirical behaviors; statistical inference and metrics for comparisons between model prediction and human behaviors. The research will leverage existing code.

2) *Basic research*: the successful candidate will pursue empirical research, with a strong focus on social cognition and interactions, based on the platform and modeling tools, encompassing the following themes :

• The assessment of hypotheses about the role of projective geometry in non-social and social inference, the appraisal of affective and epistemic value of situations, and the motivation of behaviors;

• The mechanisms of empathy and Theory of Mind;

• The strategic control of voluntary versus involuntary emotion expression and intention detection

• The role of these processes and mechanisms in the control of behaviors of orientation, approach and avoidance and emotion expressions.

Profile of candidate

Required:

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• Master degree in engineering science and/or computer science and/or applied mathematics and/or physics

• Strong interest in cognitive science, behavioral science, technology, modeling and VR

• Experience in coding in Python

• A mindset that enjoys linking basic abstract theoretical conceptualization with concrete, hands-on, practical and agile implementations

• Willingness to learn and pursue rigorous and challenging experimental research and user experience assessments

Advantageous:

• Experience in coding in C#, PyTorch and/or Tensorflow

• Experience with Unity game engine and VR

• Skills in optimization, parallelization, algorithmics, real-time processing, data structures, ontologies, computer graphics, networking, message passing algorithms, SQL databases, asynchronous updates, Linux and Windows

• Solid background in mathematics, with basic knowledge in: classical & stochastic control, geometry/group theory, game theory, multiagent systems, (Bayesian) inference, multivariate data analysis and machine learning

Application submission

The application must contain:

• A CV/Resume (2 pages max.)

• A letter of motivation (2 pages max.)

• A transcript of undergraduate and graduate grades

• One or two reference letters from senior scholars (academia) and/or professionals (e.g. industry) with direct experience with the candidate

The submission deadline is 12/05/2023.

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Please also submit your application via: https://adum.fr

References

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