Call for candidates for post-doctoral or engineering positions in computer science and applied math for cognitive sciences

Title : Toward model-based, automated, quantitative psychometry: application of the Projective Consciousness Model to virtual reality to study social cognition and behaviors

Topic: Conception, design, implementation and validation of solutions for advanced multi-agents real-time interactions and inferences in virtual reality, to study social cognition and behaviors

Institution: Université Paris-Saclay

City and country: Orsay, France

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

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

Host laboratory: the research will take place at the CIAMS (Complexity, Innovation, Motor and Sport Activity; Dir: Michel-Ange Amorim), 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.

Context

The CIAMS (Complexity, Innovation, Motor and Sport Activity) is a multidisciplinary laboratory (SDV and SHS). It plays a key role in the FéDev, a federation of institutions and laboratories promoting interdisciplinary research across SDV, SHS and Engineering sciences. David Rudrauf recently joined the CIAMS in the context of a Junior Professor Chair (CPJ) on a project entitled: « Cognitive, Affective and Social Generative Models, and Simulation of Behaviours for STAPS 2.0: ». 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). Alain Finkel (LMF, ENS Paris-Saclay), a computer scientist, collaborates with David Rudrauf on computational modeling-based psychology and behavioral science. The collaboration also involves mathematician Grégoire Sergeant-Perthuis (Inria).

The project builds upon the Projective Consciousness Model (PCM) (Rudrauf et al., 2017, Rudrauf, Bennequin, & Williford, 2020; Rudrauf et al., 2022; Rudrauf et al., 2023; Rabeyron, & Finkel, 2020), an integrative psychological model that combines active (Bayesian) inference (Friston et al., 2017) and 3D projective geometry to simulate human consciousness, which is operationalized as a subjective perspective integrating and appraising information to program actions as part of a Global Workspace (see Dehaene et al., 2017).

The model is implemented in multi agent systems, embodied in virtual humans, to enable experiments in virtual reality in which real human participants interact with virtual humans. Artificial agents use the model to infer in real-time the beliefs, preferences and states of other agents to predict their behaviors and control their own behavior accordingly.

The project will leverage a new innovative, high-tech platform of research at the CIAMS 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 overarching aim is to develop interpretable, model-based, automated, quantitative psychometry. The project focuses on the role of emotion, empathy and social cognition in adaptive and maladaptive behaviors.

We are actively developing the platform and infrastructures at the CIAMS for this project, and are looking for a candidate that will be able to take a leadership role in this endeavor encompassing basic science, technical design, implementation, and technological innovation, as well as experimental research.

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Job description

The successful candidate will contribute to the design, development, implementation and validation of the software infrastructure, with a focus on the implementation of the PCM.

Background. We have developed an initial version in C# that is interfaced with the game engine Unity (Rudrauf et al, 2023), and virtual humans capable of complex emotion expression relating to voluntary and involuntary expressive features (Tisserand et al., 2020). The project is grappling with several current limitations. The current software is suboptimal and do not run well in real-time when highly recursive and deep advanced multiagent inferences are involved, which is desirable for the application. The interfacing and message passing between the game engine and the running simulations are also too limited in their current version. Likewise, the integration of signals from the human participant leveraging and using new virtual reality technology needs to be further developed. Furthermore, solutions for multimodal quantifications of behaviors, multivariate statistical inferences, and comparisons with model predictions need to be designed and implemented. Finally, the software infrastructure will need to be validated through data quality control tools and experimental tests, in an agile manner, with efficient development-validation cycles.

Role. The successful candidate will be a key personnel for the success of the project. The specific tasks will encompass:

- *Optimization and parallelization.* The current C# version of the PCM simulator should be rebuilt and rethought in a parallel computing-friendly environment such as Tensorflow or PyTorch. For integration with the planned overall infrastructure, Python should be used as a high-level language (although some interfaces in C# will be involved for interactions with the game engine). Moreover, the current PCM algorithm could certainly be improved and enriched above and beyond the need for parallelization, which will entail not only implementation considerations but also theoretical reflections.

- *Interfacing and message passing between the game engine and the running simulations.* The current version of the interface and message passing is only preliminary. An new version is needed that will have to be well thought, designed and implemented, which will entails both theoretical and practical considerations. The research will entail design and implementation of solutions for data structures, agents multimodal 3D awareness and information integration, two-way a-synchronous message passing and updates through servers, real-time data stream storage in and access from a database, monitoring and analytics tools for data quality control and assessment.

- *Leveraging new virtual reality technologies (e.g. Meta Quest Pro), and (Qualisys) motion capture systems*, to capture multimodal information from human participants, process it in real-time and forward data structures that can be interpreted and used by the artificial agents. Data type will encompass facial expression encoded as Action Units (see Matsumoto & Ekman, 2008), eye fixation, facial expression tracking, and full body tracking controlling a skeletal rig humans representing the participants. Data will have to be processed to extract useful metrics, represented in standardized data structures and ontologies, which will be rendered available in the game engine and in the PCM simulator for further processing.

- *Multimodal quantifications of behaviors, multivariate statistical inferences, and comparisons with model predictions.* The artificial agents include internal states and output behaviors, including orientation, position, motion, and facial expressions. Data are time series and fixed parameters. Similar behavioral measures will be quantified on real human participants, leveraging virtual reality and motion capture technologies. The objective will be to design and implement solutions of data processing, metrics, statistical inference and data representation, in order to compare data that will be collected in real human participants and predictions of the model. The tools will also serve in purely simulated situations between artificial agents.

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Supervision. The successful candidate will tackle the issue under the supervision of David Rudrauf, with co-supervision by Alain Finkel, assisted by collaborators mathematician Grégoire Sergeant-Perthuis (Inria), and computer scientist Yvain Tisserand (University of Geneva). He/she will have privileged access to software and hardware infrastructures available to the project at the CIAMS.

Mentoring role. He/she will contribute to the supervision of a Ph.D. student who will contribute to implementations but with a stronger focus on experimental research in VR leveraging the simulation framework. He/she will also contribute to the recruitment and supervision of master students from math and physics departments, engineering and technical schools (e.g. Polytechnique, ENS, Centrale-Supélec), and from the master programs of the Faculty of Sport Sciences at Université Paris Saclay. The students will work on the specific project related to this recruitment, and thus be of direct relevance for the research project under the responsibility of the successful candidate.

Innovative training role. The successful candidate will also assist David Rudrauf in the organization and running of hackathons to stimulate interdisciplinary research in our academic environment.

Academic output role. He/she will be responsible for writing and publishing technical reports and scientific articles relating to the research project, and deliver oral communications.

Overall organization and schedule. In the early phase of the project, the successful candidate will pursue bibliographic research and integration, familiarization with the tools, environments and code, choices of design and implementation and the development of a workplan. In the second main phase of the project, the successful candidate will implement and test the design according to the workplan, with an agile mindset to adapt to ongoing challenges.

Your profile

- A master degree from engineering schools and/or computer science, and/or applied math programs
- (required for postdocs) A Ph.D. in computer science or applied math or equivalent
- Solid computer science/software engineering skills, ideally with basic knowledge in: optimization, parallelization, algorithmics, real-time processing, C#, Python, Tensorflow and/or PyTorch, data structures, ontologies, computer graphics/game engines, virtual reality, networking, message passing algorithms, databases, asynchronous updates, Linux and Windows
- Solid background in math, ideally with basic knowledge in: classical & stochastic control, geometry/group theory, game theory, multiagent systems, (Bayesian) inference, multivariate data analysis and machine learning
- Strong interest in cognitive science, virtual reality, game engines/video games, complex scientific and technological challenges
- A mindset that enjoys linking basic abstract theoretical conceptualization with concrete, hands-on, practical and agile implementations
- Willingness to learn and pursue serious experimental research and user experience assessments

Salary and duration :

- The gross salary will be around 2500 euros/month.
- The contract will be for 2.5 years, with possibilities of prolongation depending on budget and performance of the recruited candidate.

Application submission and recruitment process :

The application must contain:

- A CV/Resume (2 pages max.)
- A letter of motivation (2 pages max.)

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- A transcript of undergraduate and graduate grades
- One or two references letters from senior scholars (academia) and/or professionals (e.g. industry) with direct experience with the candidate

The application should be sent by email to: david.rudrauf@universite-paris-saclay.fr, and alain.finkel@ens-paris-saclay.fr, with '[Job Application PCM/VR]' in the subject
The application deadline is **25/05/2023**
The recruitment process will be as follow:

1. Assessment and preselection of submitted applications (by 10/06/2023)

2. Interview of candidates, on site or via remote video conference (between the 01/07/2023 and 15/07/2023)

3. The successful candidate will be expected to start by 01/09/2023 depending on administrative constraints (start date may be discussed)

*References***:**

Dehaene, S., Lau, H., & Kouider S. (2017), "What is consciousness, and could machines have it?," Science, 358(6362), 486–492.

Friston, K., FitzGerald, T., Rigoli, F., Schwartenbeck, P., & Pezzulo, G. (2017). Active inference: a process theory. Neural computation, 29(1), 1-49.

Matsumoto, D., & Ekman, P. (2008). Facial expression analysis. Scholarpedia, 3(5), 4237.

Rudrauf, D., Bennequin, D., Granic, I., Landini, G., Friston, K., & Williford, K. (2017). A mathematical model of embodied consciousness. Journal of theoretical biology, 428, 106-131.

Rudrauf, D., Bennequin, D., & Williford, K. (2020). The moon illusion explained by the projective consciousness model. Journal of theoretical biology, 507, 110455.

Rudrauf, D., Sergeant-Perthuis, G., Belli, O., Tisserand, Y., & Serugendo, G. D. M. (2022). Modeling the subjective perspective of consciousness and its role in the control of behaviours. Journal of Theoretical Biology, 534, 110957.

Rudrauf, D., Sergeant-Perhtuis, G., Tisserand, Y., Monnor, T., De Gevigney, V., & Belli, O. (2023). Combining the Projective Consciousness Model and Virtual Humans for immersive psychological research: a proof-of-concept simulating a ToM assessment. ACM Transactions on Interactive Intelligent Systems.

Rabeyron, T., & Finkel, A. (2020). Consciousness, free energy and cognitive algorithms. Frontiers in Psychology, 11, 1675.

Tisserand, Y., Aylett, R., Mortillaro, M., & Rudrauf, D. (2020, October). Real-time simulation of virtual humans' emotional facial expressions, harnessing autonomic physiological and musculoskeletal control. In Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents, 1-8.