SSM
Scuola Superiore Meridionale

MERC PhD Project Proposal 2023/2024

Title of the research project:

Developing Explainable Models of Human Decision-Making in Team Contexts

Keywords (up to five)

Multiagent modeling, team behavior, machine- and deep-learning, decision-making, predictive modeling

Supervisors (at least two from two different areas):

Supervisor 1 (name, contact details, homepage, area of expertise)
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Supervisor 2 (name, contact details, homepage, area of expertise)
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Project description (max 5000 characters)

Please include a description of the work to be carried out. State of the art, key research questions and project objectives, workplan and the methodological and application aspects of the project.

Effective team behaviour requires that teammates reciprocally coordinate their actions with respect to one another and changing task demands. Pivotal to this coordination is the ability of teammates to effectively decide how and when to act, with robust *decision-making* (DM) often differentiating expert from novice performance. This is particularly true in team sports, or high-stakes military or first-responder operations, where every moment-to-moment decision can lead to success or failure. Identifying and understanding the DM processes that underly expert behaviour is therefore essential for assessing and enhancing skill development and maximizing team performance outcomes.

In contrast to practical reasoning or deliberative DM, where individuals evaluate all possibilities to determine optimal behaviour, action decisions during dynamic team behaviour are emergent and highly context dependent, with teammates spontaneously and continuously adapting their actions to achieve task goals. The efficacy of such action decisions is also a function of an individual's situational awareness, with expertise reflecting the trained attunement of an individual to the information that specifies what action possibilities might best lead to success. It is this dynamic and situational complexity, however, that makes predicting and understanding action decisions during team behaviour so challenging, with a validated and generalizable method for assessing expert DM yet to be identified.

Motivated by the latter need, the Auletta and collegues have provided preliminary evidence that the challenges associated with predicting and understanding human DM in team settings can be overcome using cutting-edge artificial intelligence (AI) techniques. Specifically, the Auletta et al., demonstrated how a type of artificial neural network (ANN), known as a Long Short-Term Memory (LSTM) network, could not only be trained to predict the future action decisions of individuals playing a two-person videogame, but that an analysis of the resultant models using explainable-AI techniques could identify and differentiate the sources of information that expert and novice players used to make action decisions. The significant and transformative implication is that these and more recent interpretable AI methods could provide the tools necessary to identify and understand expert DM processes in complex team settings. **Accordingly, *the objective of this project is to empirically investigate the potential of these AI methods by applying them to predict and understand the action decisions of expert and non-expert players in team sports and multiplayer video-gaming contexts.***

One aim of AI and computer vision research has been to develop machines that can recognize and predict human actions. Of the numerous AI architectures and algorithms capable of predicting human actions, LSTMs have been the preferred method However, newly developed Transformer models have recently been adapted from their original use in Natural Language Processing (NLP) to forecasting and action prediction tasks. Importantly, Transformers now supersede LSTMs in NLP, and underly the dramatic improvements in large language models (e.g., ChatGPT) in recent years. Although research exploring the utility of Transformer models for action prediction is still in its infancy, Transformers are likely to supersede LSTMs in this domain. Thus, ***this project will also investigate and compare the utility of LSTM and Transformer models for predicting and understanding human DM in complex team contexts.***

AIM 1: Determine the effectiveness of LSTM and Transformer techniques for ***modelling and predicting*** the action decisions of expert and non-expert players in team sports and multiplayer video-gaming. Aim 1 will be achieved by modelling the key action decisions of human players in three team contexts.

- Multiplayer Video-gaming: A multiplayer video game developed by the CIs called *Desert Herding*[12] will be employed. The game requires teams of 4 to 8 players to work together to identify, corral and contain target agents (autonomous robots) within a large game area with minimal visibility (15 meters). We will record game play data of *novice* and *expert* teams and develop predictive models of three key action decisions: (i) *heading direction decisions* **–** the direction a player chooses to move when searching for targets; (ii) *target selection decisions* – the target agent a player chooses to corral; and (iii) *verbal communication decisions* – when players communicate their movement direction and target location information to other teammates.
- Association Football (Soccer): We will extract player and ball position data, as well as player pose data from videos of competitive soccer games to develop predictive models of players' action decisions for three key football skills (i) *passing*, (ii) *dribbling* and (iii) *shooting*. Models will be pre-trained using data extracted from opensource SoccerNet videos (https://www.soccer-net.org/), which include over 500 annotated 30 second videos of professional soccer matches, and then fine-tuned on data extracted from 4-years of annotated videos of competition games of the *Youth* and *First (pro)* teams of the ***Parma Calcio, Italian professional football club***.

AIM 2: Investigate whether Explainable-AI techniques and Interpretable Transformer Models can be used to ***identify and understand*** the action decisions of expert and non-expert players in team sports and multiplayer video-gaming. Explainable-AI techniques make the internal processes of ANN models (e.g., LSTMs) interpretable by quantifying the importance of input variables on output predictions. Transformer models provide explainability via the *attention mechanisms* that underly their core functionality. Using architecture-agnostic explainable-AI techniques and the attention mechanism of Transformer models, we will analyse the models developed in AIM1 to identify the importance of state input features for predicting player action decisions. Of interest will be whether the outcomes of this analysis explicate theoretically grounded differences in the perceptual information that players use to make action decisions as a function of expertise (novice vs. expert gamers; youth- vs first-team football players) and team success.

Relevance to the MERC PhD Program (max 2000 characters)

Briefly describe how this project fits within the scope of the MERC PhD program describing its interdisciplinary aspects, relevance in application and beneficiaries.

The ability to effectively understand and model the DM behaviour of players in team sports has broad ***applications*** for the development of new sport analytics, coaching, and athlete assessment and training techniques, including new ways of identifying and assessing the (un)predictability of players, tactical game strategies, and set-plays. In addition to project outcomes potentially increasing the competitive advantage of Australian (and International) sports teams and athletes, the proposed AI based modelling framework could also be employed for the selection, assessment, and training of personnel in the defence and emergency service sectors. For example, the methods developed for this project could be used to create autonomous, human-like virtual agents for simulated team training exercises to increased training opportunities and reduce the logistic and financial costs associated with team training exercises. Project outcomes could also be used to develop real-time monitoring systems to track and augment human DM in complex task contexts, maximizing personnel efficiency, while also safeguarding against human error.

Key references

Auletta, F., Kallen, R. W., di Bernardo, M., & Richardson, M. J. (2023). Predicting and understanding human action decisions during skillful joint-action using supervised machine learning and explainable-AI. *Scientific Reports*, *13*(1), 4992.

Auletta, F., Fiore, D., Richardson, M. J., & di Bernardo, M. (2022). Herding stochastic autonomous agents via local control rules and online target selection strategies. *Autonomous Robots*, *46*(3), 469-481

Nalepka, P., Lamb, M., Kallen, R. W., Shockley, K., Chemero, A., Saltzman, E., & Richardson, M. J. (2019). Human social motor solutions for human–machine interaction in dynamical task contexts. *Proceedings of the National Academy of Sciences*, *116*(4), 1437-1446.

Nalepka, P., Prants, M., Stening, H., Simpson, J., Kallen, R. W., Dras, M., ... & Richardson, M. J. (2022). Assessing Team Effectiveness by How Players Structure Their Search in a First-Person Multiplayer Video Game. *Cognitive Science*, *46*(10), e13204.

Auletta, F., Patil, G., Kallen, R. W., Di Bernardo, M., & Richardson, M. J. (2022, December). Modeling and Understanding Future Action Decisions of Players during Online Gaming. In *Proceedings of the 10th International Conference on Human-Agent Interaction* (pp. 324-326).

Joint supervision arrangements

Describe joint supervision arrangements, e.g. weekly/monthly meetings with one or both supervisors, how will the joint supervision be split etc.

Weekly meetings with Prof. Richardson. Monthly meetings with Prof. Richardson and di Bernardo.

Location and length of the study period abroad (min 12 months)

Give details of the foreign research institution where the student will be host together with the full name and contacts of the foreign host. Please indicate if the foreign institution has already agreed to host the student and when the student is expected to travel abroad.

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Any other useful information

E.g. involvement of stakeholders, industrial partners, other research institutions etc, funded research projects related to the proposed activity etc

Please return this form via email by no later than 9th February 2024 to merc@ssmeridionale.it