Internship Proposition:
Temporal Rules in Activity Recognition for Explainable AI

Internship for Spring-Summer 2025

1 Motivation

The fields of activity recognition and sequential event-based decision making allow multiple applications ranging from monitoring and assisting in smart environments to enhance user convenience and safety, to automating cybersecurity protocols for real-time threat detection and response, and applying control in industrial settings to improve operational efficiency. However, the development of robust and reliable models for these domains has been challenged by the inherent complexity of their associated environments and the limited availability of suitable test-beds for evaluation. Furthermore, in critical environments, it is crucial to guarantee functionality and trust. This internship builds upon clear reasoning and interpretability so as to ensure that a system's behavior can be understood and trusted by operators and regulators, promoting reliability and compliance.

2 Summary

Understanding external events to interpret the behaviour of humans is crucial for smart environments to provide automated services such as automated power management in smart homes [1] or protection against threats in secure buildings. These services are related to the fields of activity recognition and sequential event-based decision making, which identify and interpret behaviors as they occur and the optimization of subsequent choices of reaction.

While recent artificial intelligence algorithms seem to have improved the performance of these systems, their robustness and reliability, as well as the guarantee of functionality and trust still needs to be improved. Our approach combines reinforcement learning of data-efficient learning and rule-based methods for better explainability. For the latter, this project focuses on temporal-logic methods for better understanding and reasoning of complex sequence models.

The intern will implement algorithms for event-based environments, with a focus on capturing and managing complex historical dependencies between events and actions. The intern will work on testing and improving these models using real smart home data, where a range of activities and events are monitored over time.

3 Internship Objectives

The goal of this internship is to explore the application of interpretable temporal-logic-based algorithms on real data. Specifically, it will involve using algorithms based on Allen's Temporal Interval Algebra [2] to learn interpretable rules, which enable the recognition of activities and the selection of actions in a structured manner. We will work on 2 application cases : recognition of activity in smart homes with the Smart Home dataset collected by the team in a living lab [3], and data generated by a simulator for sequential event-based decision making, designed to facilitate Reinforcement Learning experiments in simulated event-based environments, OpenTheChests [4].

For our comparison, we aim to focus on three categories of algorithms: First, algorithms that integrate temporal logic rule learning with reinforcement learning, inspired by approaches such as those in [5]. Next, algorithms designed for Partially Observable Markov Decision Processes (POMDPs), such as POMCP [6], which excel in handling uncertainty and partial observability in dynamic environments. Finally, methods incorporating Transofrmer architectures, such as Deep Q-Networks (DTQN) [7], which are particularly adept at capturing long-term dependencies and modeling complex temporal relationships in sequential data.

The intern will be responsible for evaluating these algorithms and assessing their performance across various metrics. The objective is to highlight the advantages of interpretable algorithms, especially in settings where transparency and trustworthiness are paramount, and to understand setbacks such as potential limitations in the flexibility or scalability of these interpretable models when applied to complex, real-world scenarios.

4 Context

Principal Investigator (PI): Sao Mai Nguyen is an Associate Professor at the U2IS laboratory at ENSTA Paris, part of IP Paris, a world-class Institute of science and technology encompassing 5 prestigious French engineering Schools: École Polytechnique, ENSTA Paris, ENSAE Paris, Télécom Paris, Télécom SudParis. ENSTA Paris research laboratory "Computer Science and System Engineering Department" (U2IS) studies mobile robot navigation, perception, embedded vision, machine learning and human-robot interaction. Its emphasis is on applying machine learning to real-world applications, such as assistive and service robotics, intelligent vehicles, defence and security. Sao Mai Nguyen specialises in robot learning, active learning, imitation learning and reinforcement learning with applications in assistive technologies.

Co-Investigators :

- David Filliat, Autonomous Systems and Robotics team, Computer Science and Systems Engineering Laboratory (U2IS), ENSTA.
- Ivelina Stoyanova, Thales.

To apply, please send to Sao Mai Nguyen (sao-mai.nguyen@ensta-paris.fr) an email with the subject containing the tag [Temporal Rules intership]: your CV, a cover letter and a link to a git repository of an example code project.

5 Tasks and Responsibilities

The expected results and deliverables are:

- A scientific article reporting the algorithm implemented and the results.
- Code and documentation of the algorithm implemented in the form of a shareable docker.
- Datasets cleaned and documented: we will work on 2 application cases : recognition of activity in smart homes with the Smart Home dataset collected by the team in a living lab, and data generated by a simulator for sequential event-based decision making, OpenTheChests.

In more detail, the intern will work on several key tasks:

- **Data Analysis and Preprocessing**: Understand and preprocess the Smart Home Data to ensure it is suitable for algorithm development and simulation.
- **Algorithm Implementation**: Understand and fine-tune interpretable temporal-logic-based models for the provided datasets.
- **Simulator Development**: Develop a simulation mechanism using the OpenTheChests environment to replicate real-world data scenarios.
- **Performance Evaluation**: Compare the developed algorithms with existing models to assess their efficiency and interpretability.
- **Documentation and Reporting**: Document the development process and results, providing insights into the performance of the models.

During the internship, the intern will develop the following Skills and Qualifications:

- **Technical Skills**: Proficiency in Python and familiarity with data analysis libraries (such as pandas, NumPy). Experience with machine learning frameworks (e.g., TensorFlow or PyTorch) and reinforcement learning libraries for simulation (gym). Experience with classical methods involving temporal logic and modeling sequential behaviors.
- **Analytical Skills**: Ability to understand complex data and derive meaningful insights, with a focus on interpretability and reliability.
- **Presentation Skills**: Capacity to represent results and clearly communicate insights and conclusions. Present advancements in written form and prepare presentations.

6 Internship Milestones

- **Milestone 1: Research and Preparation**
  - Familiarize with the project scope, objectives, and tools, including OpenTheChests.
  - Conduct a literature review on interpretable temporal-logic-based algorithms and Reinforcement Learning.
  - Explore and preprocess the Smart Home dataset to ensure it is ready for temporal analysis.
- **Milestone 2: Algorithm and Simulator Development**
  - Adapt an interpretable temporal-logic-based algorithm using Allen's Temporal Interval Algebra.
  - Develop or adapt any models needed for comparison.
  - Implement a module in the OpenTheChests environment to replicate real-world scenarios.
- **Milestone 3: Testing and Evaluation**
  - Test and refine the algorithms, focusing on interpretability, accuracy, and integration with the simulator.
  - Compare performance with state of the art models to highlight strengths and weaknesses.
- **Milestone 4: Algorithm for Activity of Daily Living Recognition**
  - Adapt the temporal-logic-based algorithm for activity recognition of the Smart Home Dataset.
  - Compare it with state-of-the art algorithms, including the algorithm basaed on GPT developped in our group [8]
- **Milestone 5: Reporting and Final Deliverables**
  - Compile findings into a comprehensive report, under the form of a scientific article, and prepare a final presentation.
  - Provide all code, datasets, and documentation in a reproducible format.

References

[1] Damien Bouchabou et al. “A survey of human activity recognition in smart homes based on IoT sensors algorithms: Taxonomies, challenges, and opportunities with deep learning”. In: *Sensors* 21.18 (2021), p. 6037.

[2] James F Allen and George Ferguson. “Actions and events in interval temporal logic”. In: *Journal of logic and computation* 4.5 (1994), pp. 531–579.

[3] Damien Bouchabou et al. “A Smart Home Digital Twin to Support the Recognition of Activities of Daily Living”. In: *Sensors* 23.17 (Sept. 2023), p. 7586.

[4] Ivelina Stoyanova et al. “Open the Chests: An environment for Activity Recognition and Sequential Decision Problems Using Temporal Logic”. In: (2024).

[5] Chengzhi Cao et al. “Discovering intrinsic spatial-temporal logic rules to explain human actions”. In: *Advances in Neural Information Processing Systems* 36 (2024).

[6] David Silver and Joel Veness. “Monte-Carlo planning in large POMDPs”. In: *Advances in neural information processing systems* 23 (2010).

[7] Kevin Esslinger, Robert Platt, and Christopher Amato. “Deep transformer q-networks for partially observable reinforcement learning”. In: *arXiv preprint arXiv:2206.01078* (2022).

[8] Damien Bouchabou and Sao Mai Nguyen. “Generative Pretrained Embedding and Hierarchical Irregular Time Series Representation for Daily Living Activity Recognition”. In: IOS Press, Oct. 2024, pp. 4764–4771.