Ph.D. in Information Technology
Thesis Defenses

February 8th, 2022
at 9:00
online by Teams

Alessandro BRUSAFERRI – XXXIII Cycle

Machine learning for optimization of energy intensive industrial processes

Supervisor: Prof. **Matteo Matteucci**

Abstract:

This work targets the investigation of novel machine learning approaches to support the energy-aware optimization of energy intensive industries, thus fostering more sustainable consumption patterns. In particular, we focus the on the development of two major functional components needed to realize such implementations, namely the integration of reliable short-term energy price/load forecasting, and data-driven behavioral models of discrete/hybrid processes. Specifically, we first study a novel probabilistic forecasting approach, based on a Bayesian Mixture Density Network architecture, inferring general conditional densities within an end-to-end learning framework including features selection. Both aleatoric and epistemic uncertainty sources are encompassed within the overall predictive distribution, to enable what-if scenario/consumption analysis before trading, enhanced risk evaluation and the ability to plan multiple production strategies for the range of possible prices outcomes. Afterwards, we target the identification of behavioral models of discrete systems through Recurrent Neural Networks (RNN). The goal here is to increase explainability, as the rationale behind the network responses is encoded in an implicit way, which is difficult to be interpreted by practitioners. Hence, we propose a new approach based on the introduction of a Gaussian Mixture-based clustering layer, constraining the network to operate on a discrete latent state representation. By processing context-input conditioned transitions between clusters, a human interpretable Moore Machine based characterizing the RNN computations is extracted. The identification of hybrid patterns over the measured data sequences is a further key issue to be address, to properly represent the heterogeneous interactions occurring between control logic/rules and continuous process dynamics, including sharp changes in operating points, plants regimes, constraints on values of system inputs/outputs, etc. In this context, we focus on two general classes of hybrid systems, proposing specialized model architectures. Besides the

complementary utilities provided to the realization of energy-aware optimization tools, the approaches developed in this thesis shares a further leitmotif. In fact, they constitute multiple extensions to probabilistic mixtures models, especially implemented to achieve flexible conditional density estimation, probabilistic latent space clustering and enhanced Mixture of Expert architectures.

Sergio Luis HERRERA GONZALES – XXXIV Cycle

Software engineering methods for distributed and model-driven development

Supervisor: Prof. **Piero Fraternali**

Abstract:

Persuasive and game elements have become more common in utilitarian applications in recent years. Persuasive applications focus on engagement and user experience to attract users and induce behavioural changes. The development of gamified applications is a complex and challenging task. It requires a multi-disciplinary group of experts to generate prototypes as fast as possible, test them, evaluate their effects. This cycle of activities should be carried on continuously during the project's life-cycle. Model-driven development could bring the needed agility to the development process of these applications. However, current MDD methods need to be adapted to cover the complex requirements of gamification, many of which can not be modelled, such as usability, presentation, etc. Such non-modelled requirements are typically covered by integrating hand-written code into the code generated by the MDD tool, causing conflicts at each iteration of the development cycle.

This thesis proposes methods, architectures, and components to integrate the non-modelled requirements that characterize gamified applications into the model-driven development life-cycle. We will present a model-driven pattern-based methodology for gamified applications, which separates the game logic from the presentation layer by introducing a gamification data model and a gamification engine in charge of keeping the game status and executing the rules.

We will introduce a novel MDD work-flow to enable the collaboration between MDD tools and human developers with a model and code co-evolution approach. A reference implementation of the approach is presented and evaluated. We will discuss how it impacts the integration effort by reducing the collision between the hand-written and the generated code.

We will describe a data-driven approach for automatic conflict resolution based on the synthesis of conflict resolution rules from similar conflicts observed in previous iterations integration process. A references implementation is presented and evaluated on a large dataset of conflicts.

The experiment's results show how the proposed methods and components can reduce the effort needed to develop real-life gamified applications by using reusable patterns and components and reducing the integration effort of the non-modelled requirements.

Simone MENTASTI – XXXIII Cycle

Embedded AI and Sensor Fusion for Autonomous Vehicles

Supervisor: Prof. **Matteo Matteucci**

Abstract:

One of the main requirements of an autonomous vehicle is the ability to sense the area around itself and retrieve a uniform representation of the surrounding. A standard setup for a self-driving car consists of multiple sensors (i.e., Lidar, radar, cameras, IMUs, Encoders). The goal of sensor fusion is to collect the heterogeneous information provided by these sensors and merge it to give the control algorithm a rich, but concise, representation. Furthermore, each sensor offers a specific feature of the surrounding obstacles; cameras are used for classification, Lidar provides accurate position and radar relative speed. Moreover, Lidars and radars are less effected by the changes of illumination between day and night compared to cameras. Adverse weather is also an important aspect to consider, indeed heavy rain and fog can degrade the quality of radars and cameras detection. Aggregating all those information and contexting the obstacle's position (i.e., on the street, on the ego-vehicle trajectory, parked on the roadside) requires accurate synchronization between the sensors and high computational power to perform fusion in real-time. This is particularly important in an highly dynamic environment like urban roads, where the rapid changes in the surrounding requires constant and fast responses from the vehicle. My thesis focuses on realizing a sensor fusion pipeline for a development platform equipped with limited computational power and soft synchronization between sensors. Through the thesis, I present multiple solutions to process each single sensor and retrieve information on the state of the autonomous vehicle and the surroundings. Then I propose different techniques to combine those data, using late fusion algorithms and hybrid architectures to retrieve a concise list of obstacles, which can be processed in real-time by the vehicle's planner. Due to the limited computational power available on the car, and the low resolution of the sensors if compared to a more traditional autonomous vehicle development platform, ad-hoc solutions needed to be implemented. In particular, the fusion process has been performed asynchronously, employing less traditional data representation, like a 2D occupancy grid, generally used in robotics systems, characterized by limited computational

power, but not in the autonomous driving field. Each of the proposed solutions has been validated in a real environment, using the developed platform, and in simulation using data acquired from our vehicle in a controlled scenario.

Rocio Nahime TORRES – XXXIII Cycle

Analysis of Geographic Data for Environmental Monitoring

Supervisor: Prof. **Piero Fraternali**

Abstract:

Environmental monitoring processes and investigations are essential to understand the conditions of the environment and the changes it undergoes (by natural processes or by human interventions) with their associated impact. One of the main contemporary problems is waste crimes, in other terms, activities that violate the waste management laws. A particular case is illegal waste dumping, which threatens the environment and public safety and health. Discovering them as early as possible is essential for preventing hazards such as fire pollution and leakage. Before the digital era, the only means to detect illegal waste dumps was the on-site inspection of potentially suspicious sites, a procedure extremely costly and impossible to scale to a vast territory. With the advent of Earth Observation technology, scanning the territory via aerial images has become possible. However, manual image interpretation remains a complex and time-consuming task that requires expert skills. This research aims to exploit Artificial Intelligence methods and remote sensing imagery to embed expert knowledge within data-driven classifiers that can help partially automate the photo interpretation process. For such purposes, methods have been selected to train different CNNs classifiers, and tools to evaluate and use them have been proposed. The results proved the feasibility of applying Convolutional Neural Networks for scene classification in this scenario to optimize the process of waste dumps detection.

PhD Committee

Prof. **Francesco Amigoni**, Politecnico di Milano
Prof. **Alexandre Bernardino**, University of Lisbon
Prof. **Alessandro Bozzon**, TU Delft
Prof. **José Nuno Moura Marques Fidalgo**, University of Porto