# Special Session: Applied AI @ AGH University

## 1. Sensor-driven AI-based dynamic control of street lighting

**Sebastian Ernst, Leszek Kotulski, Igor Wojnicki, Adam Sędziwy**

The GRADIS research group was established at AGH University based on the observation that the properties and relationships between real-life objects, such as architectural features, lighting infrastructure, sensor networks or streets and roads can be efficiently modelled as graph structures. This allows them to be processed and analysed using graph transformations in order to prepare them for further optimisation or machine learning tasks.

The initial practical application of these methods, which still remains the primary focus of our interest, is road and street lighting. First, graph-based methods were used to optimise and automate the process of lighting infrastructure design, using a real-world testbed in Geel (Belgium) as part of the Alive and KICing research project. This was soon followed by a large project in our home city of Kraków, Poland, which involved deployment of almost 4,000 lamps under sensor-driven AI-based dynamic control.

However, especially the latter project emphasized the importance of data preparation; even the seemingly trivial task of assigning the lamps to the roads the illuminate turned out to be challenging in many situations. Thus, the research focus was shifted to data preparation. As the developed solutions started to gain market interest, an eponymous university spin-off company was founded to commercialise the solutions. A new large R&D project fast-forwarded the development of both the optimisation engine and a new flagship product, g.Inventory, aimed at integration of GIS (spatial) datasets.

Given several years of experience in designing outdoor lighting, our most recent efforts are aimed at rapid estimation of lighting efficiency using minimal input data (e.g., only publicly-available map datasets). The LightPASS project is aimed at developing machine learning models and look-up datasets for determination of the power requirements of lighting systems using the new Spatially-Triggered Graph Transformations (STGT) paradigm, which allows for easy modelling of detected relationships within datasets and using them for further inference.

## 2. Proportional Rules for Participatory Budgeting

**Piotr Faliszewski**

In this talk we will discuss Method of Equal Shares (MES) and its first real-life applications, by Wieliczka (near Kraków, Poland) and Aarau (in Switzerland). We will briefly describe the rules, the arguments for adopting the rule, and our research leading to adopting it in Wieliczka. We will also mention some new research issues that opened itself upon using the rule in practice. For example, we will discuss the issue of presenting election results to the participants.

## 3. Agent-based crowd dynamic modeling

**Jarosław Wąs, Dariusz Pałka**

From an individual point of view, a human in a crowd can be considered an agent who has abilities or knowledge at various levels. In reference to Adam Newell's notion of knowledge levels of artificial

agents, one can distinguish different levels of the pedestrian decision-making process including: social, rational, cognitive, reactive and physical levels pedestrian decision-making. Often, in practice, a simplified version of the decision-making levels is used, which comes down to a three-level scheme: strategic, tactical and operational levels. During the presentation, we will present a number of practical results from our projects: crowd dynamics modeling at sports stadiums (including Allianz Arena Munich), mass events, and public buildings. We will present an approach related to data driven modeling.

## 4. Machine learning and statistical models in cyber-physical system for integrated management of electric steel and rolling plants

**Łukasz Rauch, Krzysztof Bzowski, Monika Pernach, Piotr Hajder, Krzysztof Regulski, Andrzej Opaliński**

Cyber-Physical Systems (CPS) are systems of collaborating computational modules which are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the internet . In other words, these systems enable objects and processes residing in the physical world (e.g. manufacturing facility), to be tightly coupled with computing, communication and control systems in the cyber world. In industrial applications the CPS systems are usually called Cyber-Physical Production Systems (CPPS) and are one of the key technical enablers of 4th industrial revolution (often referred to as Industry 4.0). In the past years tremendous amount of work was done on implementing CPPS in many branches of industry. Many concepts like holonic or agent-based systems, cloud, fog, dew, edge computing, Wireless Sensor Network and many others were successfully implemented to address Industry 4.0 requirements.

This work presents results of the project aiming to create computer system integrating management of the electric steel and rolling mills producing billets and long products.

The main goal of the project was to conduct R&D works aimed at development of globally innovative, integrated with the infrastructure of steelmaking facility (Electric Arc Furnace “EAF” - Ladle Furnace “LF” – Continuous Casting Machine “CCM”), hybrid IT system for optimizing and modeling steel billets production process i.e. solution significantly contributing to the quality of CMC Poland Sp. z o.o. products by providing full control over liquid steel temperature, including superheating temperature.

The proposed System (SWP) supporting complex production process management plays important role in IT infrastructure of the company, communicating at least three of the most important systems i.e. SAP, AMI and SWT. SAP system is responsible for management of sales gathering data of customers, orders, dates of contracts and material indexes with tonnage of sales. The data are exported to SWP system automatically every two hours in form of external database. The records of contracts are used further for purposes of rolling campaigns planning and scheduling of the wok in steel mill.

The plans of rolling campaigns are proposed automatically according to specific rules delivered by the rolling mill and department of sales. On the basis of each campaign as well as contract dates the System schedules casting sequences for steel mill according to metallurgical knowledge about joining of particular heats in each sequence, working calendar and rules delivered by steel plant managers. On the other hand SWT system delivers information on technological instructions, which are crucial for chemical composition of the casted steel and all the technological issues related to the way of heat preparation and casting. These data are also important for steel plant work scheduling, but also for prediction of liquid steel cooling rate inside the main ladles, what is the most interesting between LF and CCM to maintain casting temperature regimes for each grade of steel. The information needed for such prediction is supported also by AMI system, which is responsible for gathering all the data related to production processes including static as well as time-dependent parameters of production devices. The data are copied redundantly and gathered in external database to be used also for monitoring process and support of process operator by prediction and suggestion of energy usage. One of the modules is responsible for monitoring of electric steel mill, especially ladles with about 150t of melted steel by using images

from CCTV system. The module is based on machine learning approach which will be also described in details in this presentation with discussion on obtained results, computational efficiency and every day usage.

## 5. Long-lived particles reconstruction in real-time trigger system of LHCb experiment using machine learning approach

**Tomasz Szumlak**

The LHCb (Large Hadron Collider beauty) experiment at CERN is a high-energy physics experiment conducted at the European Organization for Nuclear Research (CERN) in Switzerland. It is specifically designed to study the properties of a type of fundamental particle known as the beauty quark. The LHCb experiment focuses on understanding the subtle differences between matter and antimatter and the phenomenon called CP violation. By examining the behaviour of particles containing beauty quarks, scientists aim to shed light on why the universe is predominantly composed of matter rather than antimatter.

The experiment utilises the Large Hadron Collider (LHC), which accelerates particles to nearly the speed of light before colliding them. These high-energy collisions produce secondary particles, including those containing beauty quarks, which are then meticulously analysed by the LHCb detector. The LHCb detector is a complex apparatus consisting of various sub-detectors that allow researchers to precisely measure and track the trajectories of particles. By studying these particles' properties and decay patterns, scientists can explore the fundamental forces and particles that govern our universe at the smallest scales. The core physics programme of LHCb experiment is precise tracking and vertexing. AGH group was responsible for providing real-time procedures for long-lived particle decay reconstruction enhanced with machine learning components. The final system consists of a cascade classifier based on boosted decision tree using xgboost learning algorithm and shallow neural network. Since the time budget of the trigger (online event selection system) was about 400 ms, we faced a considerable task of speeding up the model response. In order to fit into the stringent time requirements we used a novel approach of discretising the feature space. Also, we performed one of the first interpretability studies in the field of high-energy physics.

## 6. Cosmic-Ray Extremely Distributed Observatory- application of AI in high-energy particles detection, filtering, recognition and analysis

**Marcin Piekarczyk, Tomasz Hachaj**

The Cosmic-Ray Extremely Distributed Observatory (CREDO) is formed by an international research group comprising 49 institutions from 20 countries. It brings together specialists in astrophysics, computer science, and electronics. CREDO's areas of interest include observation and study of cosmic rays (CR) and cosmic ray assemblies (CRE). For this purpose, CREDO uses a dedicated fully operational observational infrastructure, which includes, among other devices, a network of CMOS-based vision sensors. A unique feature of the projects is the exploitation of a distributed network of mobile devices utilizing the citizen science paradigm. Through the use of AI modules, it is possible to detect, filter, recognize and analyse the acquired signals of both CR and CRE. AGH employees are the core of the Machine Learning research group in this project. This talk will present selected achievements of the research team and ongoing project work.