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CAPRI project. Cognitive Solutions y Process Industry: Asphalt Use Case.

#ICA4point0

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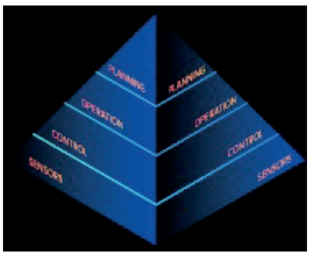
ABSTRACT

Keywords: Process Industry, Automation, Industry 4.0, IIoT, Cognitive Platform, Innovation, Digital Transformation, Industrial Plants, Smart Modules, Smart Industry, Open Data, Open Source, Open Science, Asphalt.

The CAPRI project is a H2020 project that develops ***Cognitive Solutions (CS) to the Process Industry and a Cognitive Automation Platform (CAP) towards the Digital Transformation of process industries.*** CAPRI enables cognitive tools to provide to the existing process industries flexibility of operation, improving the performance and quality assurance of its products and flows. CAPRI's consortium is composed by 12 partners across 7 European countries: a strong, experienced, and interdisciplinary cluster of research institutes and organizations, SMEs and process industry companies that are working together to achieve the objectives of the project.

CAPRI's project is demonstrating its applicability in three key process industries: asphalt mix production, pharmaceutical tablets, and steel billets & bars. This project foresees the development and testing of different cognitive solutions at each automation level, entaili



This article carries out a general description of the asphalt use case, followed by a more detailed analysis of its technologies and related developments.

1. INTRODUCTION

One of main challenges for process industry plants is to enable an efficient monitoring and control when the production or environments are complex, e.g., due to harsh conditions the system is operating in. The basic elements of process monitoring and control loops, including the models which can be used for supporting this task cannot be solved easily using nor traditional techniques from process monitoring (like Statistical Process Control) neither solely by using advanced AI techniques (like predictive analytics) (Cinar, Nuhu, Zeeshan, & Korhan, 2020). This problem requires a better understanding of the underlying data and processes, their contexts and their dynamics, similarly how human cognition is building a superior situational understanding and reasoning (Jacoby, Jovicic, Stojanovic, & Stojanović, 2021), even in very ambiguous cases. ***CAPRI uses the analogy of human cognition, based on cognitive architecture (Kaur & Sood, 2015), for addressing above challenges.***

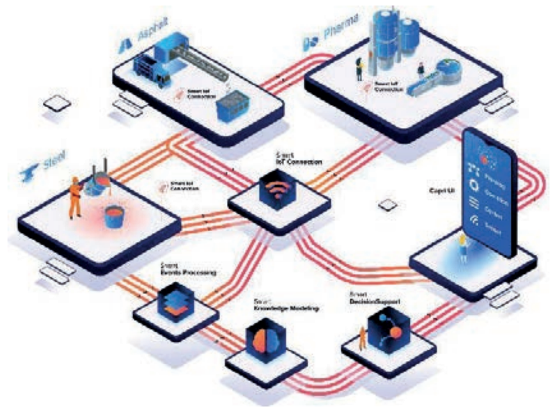


Figure 1. H2020 CAPRI project introduction.

The CAPRI project is a H2020 project that is developing cognitive solutions to the Process Industry and a Cognitive Automation Platform towards Digital Transformation. ***CAPRI enables cognitive tools to provide, to the existing process industries, flexibility of operation, improving the performance and state of the art quality control of its products and intermediate flows.***

The Asphalt Use Case of the H2020 CAPRI project is located in EIFFAGE Gerena plant (located in Seville, southern Spain). A general overview of the asphalt manufacturing process of the corresponding use case is shown in Figure 2.

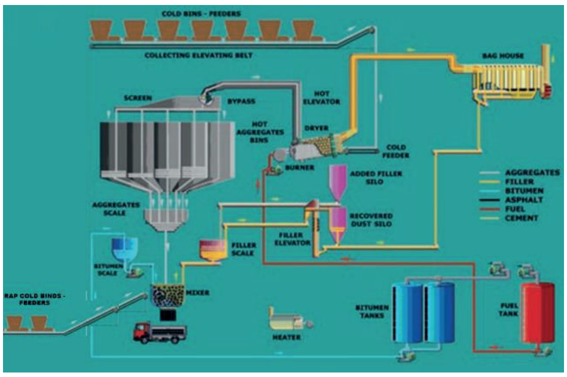


Figure 2. Asphalt manufacturing process diagram.

In the asphalt mix manufacturing process, most of the measured data is not usually exploited although it may provide very interesting information. There could be variables that are not known how to relate with the information obtained or whose relationship is unknown. Even more, some variables are not measured or measured only in the laboratory. CAPRI project addresses the challenge of integrating relevant information data sources as well as knowledge of the personnel of the plant, at all the levels: planning, operation, and control of the plant. Considering this challenge, within the scope of CAPRI Project Asphalt Use Case, five different cognitive solutions have been developed at different process levels: sensor, control, operation, and planning:

- Cognitive sensor for bitumen content in RAP [CAS1]: An innovative sensor that allows precise and automated measurement of the bitumen content in RAP in-line in real-time.
- Cognitive sensor of filler amount [CAS2]: Development of a new sensor to automated measurement of extracted filler flow from dry aggregates trough the baghouse pipe.
- Cognitive control of Asphalt Drum [CAC1]: A control algorithm where sensors and actuators are used to calculate the optimum values for the different variables that run the drier-drum.
- Predictive maintenance of the Baghouse [CAO1]: Deep Learning models for predicting the health state of the baghouse and abnormal behaviour.
- Planning & Control of Asphalt Production [CAP1]: Tool that helps in the decision making in the planning of the production process in the Asphalt plant thanks to a Mass and Thermal Balance to optimize asphalt production process.

2. CAPRI COGNITIVE SOLUTIONS

2.1.- Cognitive sensor for bitumen content in RAP (CAS1)

CAS1 is an automated sensor that measures the content of bitumen present in all Reclaimed Asphalt Pavement (RAP) added to an asphalt mix in real-time. This allows for a precise, automated, and timely measurement of the bitumen content present in RAP, allowing to adjust the asphalt mix formula accordingly in a timely manner. This sensor, besides allowing significant saves in raw materials and freeing the operators time, will also make the asphalt manufacturing process more flexible and automated, reducing decision-making times and improving productivity and product quality.

Figure 3. CAS1 installation details

The plant's prototype is already designed and installed at EIFFAGE's plant in Gerena (Sevilla, Spain) for deep tunning. Currently, the plant's full-scale prototype is under validation period 'reading' the bitumen content in RAP while it is being carried in the transporting belt to the asphalt mixer. This prototype will be fully automated, providing directly to EIFFAGE's plant the % of bitumen content with the correspondent time stamp, and complying with the limits set by the European Standards.

2.2.- Cognitive Sensor for Amount of Filler (CAS2)

Eventually CAS2 solution has two kinds of physical sensors, one is a commercial solution, that has never been used under these conditions. The second sensor is a custom sensor based on another commercial sensor, not intended to measure concentrations of particles, but to measure disturbances of the flow, which can then be used to estimate the amount of filler flow through the pipe of baghouse. This second sensor is a research and innovation action of this project. It is based on a vibration measurement that has been validated under laboratory conditions providing an actual measurement of filler flow at a smaller scale process.

Figure 4. Commercial sensor (left) and CAS1 sensor (right)

Thanks to the knowledge that this sensor will provide (actual mass flow of filler trough baghouse aspiration pipe), the needed filler addition and extracted will be minimized and added only if it is detected that there is less amount of filler than the final hot mix needs. This cognitive sensor is developed to estimate and measure the fine filler quantity that goes out of the aggregates drying to the baghouse filter (Figure 3 with position of CAS2 solution). The high-level outcome of this cognitive sensor is to obtain the real amount of filler present in the cold aggregates, which allows then wasting less energy in the rotary drying drum and in the filtering (baghouse) process.

2.3.- Cognitive Solution – Control of the Asphalt Drum (CAC1)

Within CAPRI project, CAC1 Cognitive Control Solution objectives are to obtain a dry product at an optimum temperature and fumes (combustion gases) at the possible lowest temperature, on one hand not to damage the baghouse filter and on the other to minimize energy consumption, thus increasing the efficiency of the drying process. The main objective is to decrease the consumption of electricity and fuel. This way, knowing the humidity and temperature in the input of the drum, adjustments will be made to obtain the best conditions of output, avoiding overheating of aggregates.

This solution has been developed based on a control algorithm where sensors and actuators are used to calculate the optimum values for the different variables that run the drum. Currently, a dynamic modelling of the rotary drum is being created through model-based identification methods running several experimental tests performed at the asphalt plant taking into account some of the main variables: temperatures, humidity, load to dry, burner, drum speed, combustion gas flow. This identified model will be required like an input for the Model Predictive Control (MPC), advanced method of process control that is used to control a process while satisfying a set of constraints. It is in this control solution where the rotary drum optimized control calculations are performed.

The Cognitive Algorithm will be executed in real time by providing the setpoints: drum burner power (%), drum rotation speed (%) and exhaust damper opening (%), to obtain the optimal temperature of the hot aggregates coming out of the drum and to guarantee in this way the desired temperature of the final asphalt mix and also the gas combustion temperature. In addition, this is intended to minimize the combustion gases temperature and to improve energy efficiency and reduce pollution.

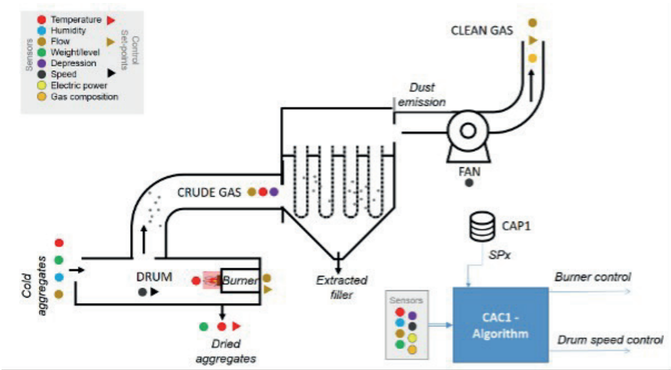


Figure 5. CAC1 Basic Architecture.

2.4.- Predictive maintenance of the Baghouse (CAO1)

The baghouse filter consists of a collector which removes dust, mainly filler content in dry aggregates during drying process from the drier drum. Baghouse performance is heavily depended on inlet and outlet gas temperature and flow speed as well as opacity climatic conditions and pressure drop in the bag house (temperature and humidity, the recipe of asphalt). The final user of this asset is the plant operator, which is interested in the predictive maintenance of the baghouse. In the context of the developed Cognitive Solution (CS), a prediction model has been developed. The model predicts if the baghouse is working properly by attempting to identify any abnormal behaviour. The former is utilized for generating a set of alarms based on the process measurements.

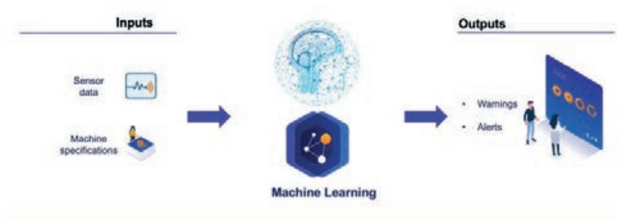


Figure 6. CAO1 Basic Scheme.

2.5.- Planning & Control of Asphalt Production (CAP1)

One of the main problems in asphalt production is knowing the correct composition of the raw materials as well as their relevant properties. The extraction of knowledge will allow the development of an expert system that generates the adjustments of the setpoints of the controllers, the amounts of material to be incorporated into the processes such as the mixer, and other data. The main objective is to generate a tool that helps in the decision making in the planning of the production process carried out in the Asphalt plant. This main objective can be divided into two specific objectives linked to two balances:

- To ensure the optimum temperature of the asphalt mix: Thermal Balance.
- To minimize the excess of asphalt material in the hot hoppers at the end of the day: Mass Balance.

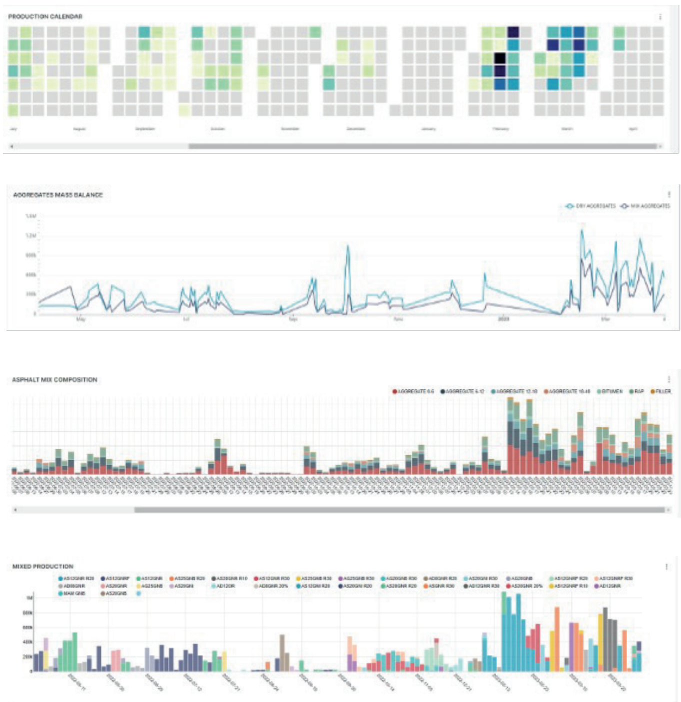


Figure 7. Different dashboards of the CAP1 cognitive solution

3. CAP REFERENCE ARCHITECTURE

In process industries, due to harsh conditions the system is operating in, some sensors might be operating improperly (de-calibrated), or some parameters might be very deviating (instable) in a period of time. On the other hand, the production processes have to be under strict control ensuring stability - otherwise some small issues might be escalating very quickly.

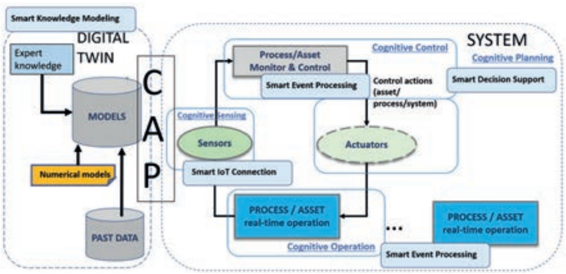


Figure 8. Cognition-driven process monitoring and control loop (cognitive plant) (ToBe).

Therefore, the analogy of human cognition for resolving above-mentioned challenges is used for an efficient process control in process industry plants. Since one of the most critical issues in understanding/analysing process stability is to observe variations, this artificial (or machine) cognition should be based on a complex, comprehensive but yet very efficient sensing, analysing and understanding variations, including their root causes, as well as their impacts. This is exactly how CAPRI envisions the monitoring/sensing and controlling/reacting in cognitive process plants.

In a cognitive plant, there is a need for monitoring a broader context of the data that is collected and processed in, as well as for a deep multivariate analysis of the variation in data, to be able to detect and react properly to unexpected events. The realization of the cognitive plant is supported by Cognitive components as depicted in Figure 8 (cf. light-blue and blue coloured boxes).

CONCLUSIONS

This article has carried out a brief description of the CAPRI project Cognitive Solutions, emphasizing the technologies developed in the Asphalt Use Case. H2020 CAPRI project develops and promotes digital transformation through a CAP involving a Reference Architecture (mainly based on the FIWARE framework) with four levels of cognitive human-machine interactions and a set of reference implementations both commercial and open source. This CAP coordinates a set of specific CS's at the various levels of functional organization of the automation (from planning to sensors).

The asphalt domain shows as one of the main process industry sectors where the CAP provides flexibility of operation, improvement of performance across different indicators (KPIs) and state of the art quality control of its products and intermediate flows. The CAP architecture and their different modules have been presented in this domain and the CS's which are under refinement, have been explained.

From here, next steps involve the final validation to be developed at last project stages, addressing manufacturing challenges in industrial operational environments and providing useful feedbacks and lessons learnt.

Different KPI's will be calculated and deployed to see if initial target objectives are met with an evaluation period (6-month minimum) of the performance improvements thanks to the different implemented CS's. This will provide effective stories for replication purposes and dissemination. It is expected that results like the reference architecture will be replicated in other sectors with similar challenges from the point of view of CS's applied to similar unitary processes.

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