ARCHITECTURES AND DIGITAL PLATFORMS

IoT (Internet-of-Things) platforms have been enhancers of a close connection between the elements present on the shop floor and production management systems. This article presents INESC TEC's framework in the development of solutions for the operational management of flexible production systems.

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IoT (Internet-of-Things) platforms have been enhancers of a close connection between the elements present on the shop floor and production management systems. This article presents INESC TEC's framework in the development of solutions for the operational management of flexible production systems.
The creation of the movement Industrie 4.0 (i4.0) in Germany had as its main element a reference model, called RAMI 4.0[1], where the fundamental principles of the movement were identified. The concepts of Cyber-Physical System and Component i4.0 gave form to the model, and the notion adopted of a close interconnection between the real world (elements existing on the shop floor), and the virtual world, the digital representation of those real elements, had been worked on for some years. So, it is not surprising that at that time there were already solutions (e.g. OPC-UA) for connecting equipment on the shop floor with production management applications (e.g. Manufacturing Execution System - MES). However, the various initiatives that were subsequently created around the world, gave strength to what started to be called IoT (Internet of Things) platforms, in the context of the development of solutions around intelligent/smart production, predictive maintenance and optimization of production systems, amongst others. Both in the commercial world and the open source community, solutions have been established that aim to capture data in real time from different elements on the shop floor, through different communication protocols (e.g. MQTT, ROS, AMQP, REST) and the development of concepts such as intelligent/smart objects. The term IIOT (Industrial IoT) started to be in fashion. Data processing functions, for filtering, annotation and format conversion started to be made available on these platforms. Lately, the concept of Digital Twin has been heavily emphasized. The trend in the coming years is to extend these integration features to the communication of information between organisations.
In this context and following a collaboration between the INESC TEC Centre for Enterprise Systems Engineering (CESE) and the INESC TEC Centre for Enterprise Systems Engineering (CRIIS) on the European project STAMINA "Sustainable and Reliable Robotics for Part Handling in Manufacturing Automation"[2], these two centres began to define a generic application framework, OSPS - Open Scalable Production System, for the operational management of flexible production systems, and supported on an IIoT Platform. This system (Figure 1) defines a set of production resources, comprising of robotic manipulators, 3D printers, automatic conveyors of material in progress, and automatic storage units. For the first two cases, a control system (TaskManager) was defined that allows logistical operations (e.g. transportation of logistic units, construction of parts kits), assembly and additive production to be carried out. This element has as its fundamental pillar the APM Advanced Plant Model system (centre of Figure 1), defined as a data model responsible for maintaining a virtual representation, in three dimensions, of all the physical elements available in a specific physical area of

production or logistics. (e.g. logistical shelves and pallets, workstations, assembly lines). This model contextualizes the production plan defined by a typical production management system (MES), linking the temporal definition of operations, their allocation to production resources and the definition of product routes with the physical and geometric representations of the elements that comprise the physical area of production.
Production management features are also defined in the APM, in order to control and monitor the execution of the operations defined in the production plan in the supported production resources, namely robotic manipulators and 3D printers.
At a more tacit level, the OSPS architecture identifies a set of tools to support human decision-making (Figure 1) regarding the best organisation of a manufacturing system. The simulation of discrete events is the main instrument, used to analyse various production scenarios and estimate the value for several performance indicators[3]. This analysis results in importance levels to be assigned to several criteria such as minimising setup times, minimising delays, waiting times, or increasing the level of use of production resources, criteria that aim to change the way the plan of production is generated by the MES system.

The interaction between the elements of the OSPS architecture is performed by a set of messages that, through communication protocols specific to each element, allow the system to function as a whole.
This architecture was implemented and demonstrated in different cases, with different IIoT platforms, in two international projects, FASTEN (www.fastenmanufacturing.eu) and ScalABLE 4.0 (www.scalable40.eu)[4]. In FASTEN, a demonstrator of IIoT technologies between Europe and Brazil (involving INESC P&D Brasil), an IIoT platform was defined around the open source ecosystem Apache Kafka. Kafka acts as the main decoupling element between physical production resources and production management systems.
This system was demonstrated in two industrial scenarios: in Portugal, in a logistics warehouse where parts of various types are stored. The challenge was to develop a mobile robotic manipulator, capable of moving autonomously in the space occupied by the warehouse, moving to the place where the parts are stored, and collecting a set of parts for building a kit, then transporting that kit to the workstation on the assembly line where the kit is needed at any given time. In Brazil, the challenge consisted of the development of an additive production unit of components produced for solving part faults in elevators with some antiquity, for which there is no longer the production of parts.
A second implementation of the OSPS architecture took place in the European project ScalABLE 4.0. The prototype of the system was demonstrated on an engine assembly line in the automotive industry, where diesel and gasoline engines were subjected to robotic operations, carried out by fixed robotic manipulators, installed in some workstations along the line, and by mobile robotic manipulators, able to move to certain workstations on the line.
These two examples demonstrate the major objective of an IIoT Platform, the integration of a wide range of systems, from the equipment with activity in a certain manufacturing area to the management of the operations, providing adapters and converters to deal with the different possibilities of interaction.

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Figure 1- OSPS architecture