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INFORMATION INTEGRATION IN MANUFACTURING PROCESSES BY USING IOT AND MICROSERVICES.

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The IoT technology is significatively contributing to enlarge the data available for many manufacturing processes. To the classical already collected dataset related to sensors located at the processing machines, now it becomes possible considering additional data coming from wearables, which enable describing processes in a more integrated way, including many more potential sources of variability Although advantages are rather evident, still there are significant challenges to be better identified and faced when new useful solutions regarding knowledge and management are foreseen. The goal of this paper is to discuss some use cases where challenges and advantages become evident, in a way that the experience can be useful for other applications and further research.

Keywords: IoT; Microservices; Data Integration; Process improvement.

INTEGRACIÓN DE INFORMACIÓN EN PROCESOS PRODUCTIVOS UTILIZANDO IOT Y MICROSERVICIOS.

Gracias a la tecnología de Internet de las cosas existen ahora muchos procesos productivos en los que se puede añadir a los datos provenientes de los sistemas de automatización y control de los equipos implicados, otros provenientes de sensores inteligentes vinculados al factor humano. Estas tecnologías proporcionan una visión mucho más integrada de esos procesos, permitiendo explicar mejor su variabilidad, al incorporar el comportamiento de operadores y no solo de sensores en equipos. Aunque las ventajas son bastante evidentes existen retos significativos que deben ser identificados y afrontados para desarrollar soluciones útiles desde el punto de vista del conocimiento y de la gestión. El objetivo del artículo es analizar algunos casos de uso que muestren tanto los retos de la integración como las potencialiades de la misma de modo que la experiencia resulte útil en otros casos de aplicación o en otras investigaciones.

Palabras claves: IoT; microservicios; integración de datos; mejora de procesos.

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1. Introduction

The IoT technology is significantly contributing to enlarge the data available for many manufacturing processes. To the classical already collected dataset related to sensors located at the processing machines, now it becomes possible considering additional data coming from wearables, which enable describing processes in a more integrated way, including many more potential sources of variability. Although advantages are rather evident, still there are significant challenges to be better identified and faced when new useful solutions regarding knowledge and management are foreseen.

The amount of edge devices that are currently developed to support fitness and health monitoring is enormous. Many of them aim at measuring body parameters to offer care related services. At the same time, a lot of smart health applications are developed, often making decisions or offering feedback based on sensor data processing. Application developers often struggle to integrate and plug in novel sensor technologies becoming available on the market at a fast pace (Bohé, Willocx, and Naessens 2019).

In the manufacturing domain, the I4.0 vision has promoted smart manufacturing and smart factories concepts by augmenting all assets with sensor-based connectivity (Grangel-González et al. 2016). These intelligent sensors generate a large volume of industrial data helping to create digital twins (defined as a digital replication of both living and inanimate entities that enable seamless data transfer between the physical and virtual worlds) as support for a live mirror of physical processes (El Saddik 2018; Tomko and Winter 2019). Within this approach the ambition is to capture the process variability, being able to process all the relevant information by big data analysis on cloud computing. Therefore, manufacturers could find the bottlenecks of manufacturing processes, identify causes and impacts of problems in such a way that effective implementation of measures become useful either for product design or for manufacturing engineering including maintenance, repair and overhaul (MRO) (Qi and Tao 2018).

According with Zhuang, Liu, and Xiong (2018) the interest is focused on monitoring, prediction, and optimization control of manufacturing resources, production activities, and production processes. Service/application platform provides real-time and predictive production management and control services for the physical assembly shop-floor. It should include a prediction service platform and a production management and control service platform. The prediction service platform incorporates functions of product quality prediction, work-hour prediction, production progress prediction, production bottleneck prediction, production disturbance prediction, equipment failure prediction, equipment life prediction, material requirement prediction, etc. The systems that support the service/application platform are enterprise information systems (e.g., MES, PLM, ERP, PDM), a big data-based prediction and analysis system, and a digital twin technology based prediction and analysis system.

Traditional factory-floor control and interconnection data management solutions are mainly based on centralized systems. The Open Platform Communications Unified Architecture (OPC UA)(Cavalieri and Chiacchio 2013) is the core communication standard for I4.0-compliant communications (Fraile et al. 2019). Due to the different requirements that different stakeholders have but also due to the different ways of processing such data, the convenience of integrating semantic meaning into the data itself has arisen. Different stakeholders can easily integrate data processing into their own workflows, and the whole process becomes more resilient to changes in format, the creation of new attributes or entities, and so on. These aspects are linked to data transparency, understood (Müller, Kiel, and Voigt 2018; Zhu 2002). The lack of interconnected data and shared meaning is a significant limitation which introduce disturbances in the whole process understanding.

A critical aspect to be considered when the previous interest is addressed is the human influence on the processes. There is a gap between the information collected by the IIoT devices and their capability to capture the causes influencing process variations, as far as it becomes relevant to describe process variability.

The goal of this paper is to discuss some use cases where challenges and advantages become evident, in a way that the experience can be useful for other applications and further research. It also proposes a vision about how to build IoT systems by reconceiving IoT's fundamental distributed "microservice" already familiar to web service engineering.

2. State of the art

The Human-Cyber-Physical Systems (H-CPS) integrate the operators into flexible and multi-purpose manufacturing processes. The primary enabling factor of the resultant Operator 4.0 paradigm is the integration of advanced sensor and actuator technologies and communications solutions.

Although the process automation reduces costs and improves productivity, human operators are still essential elements of manufacturing systems (Hancock et al. 2013). As discussed in (Romero, Stahre, et al. 2016), the degree of automation does not directly imply an enhanced operator performance, because handling human factors requires more complex dimensions related to human to machine interactions including robotics. The integration of workers into an Industry 4.0 system consisting of different skills, educational levels and cultural backgrounds is a significant challenge. The new concept of Operator 4.0 was created for the integrated analysis of these challenges (Ruppert et al. 2018). The new concept of Operator 4.0 was created for the integrated analysis of these challenges. The concept of Operator 4.0 is based on the so-called Human-Cyber-Physical Systems (H-CPSs) designed to facilitate cooperation between humans and machines (Romero, Bernus, et al. 2016).

Although specific contributions regarding different dimensions have been proposed by different authors (Kaasinen et al. 2020; Sun, Zheng, Gong, et al. 2020) still there is a significant room for improvement when an integrated perspective is required, because the available wearable devices lack of enough level of integration. In current industrial practice, most applications are developed in isolated circumstances aimed at addressing specific problems. Therefore, there is a gap in creating human-centred systems able to promote operators' learning context not only relying on single parameters but also providing a meaningful articulated set of relevant parameters both in the short and long term (Sun, Zheng, Gong, et al. 2020).

Data availability and transparency have been addressed by some other authors as well (Buhulaiga, Telukdarie, and Ramsangar 2019; Kumar et al. 2020; Sun, Zheng, Villalba-Díez, et al. 2020), but it becomes relevant to consider the cyber-security threats and information security challenges.

Industry 4.0 envisions a future of networked production where interconnected machines and business processes running in the cloud will communicate with one another to optimize production and enable more efficient and sustainable individualized/mass manufacturing. Inside such vision, there are different requirements to be considered, including cloud computing, data pseudo-anonymization, as well as data micro-services. The assembly shop-floor in virtual space is the reconstruction and digital mapping of the physical devices at shop-floor level. They exchange data/information/knowledge through by using a big data storage and management platform. By constructing a virtual shop-floor system, the working progress and working status of assembly stations, products, and manufacturing resources in the physical assembly shop-floor can be dynamically, realistically, and accurately mapped in the virtual space through the cloud services (Zhuang et al. 2018).

The main problem when assembly shop-floor in virtual spaces is addressed is the complexity of the IoT solutions, as they suffer of poor scalability, extensibility and maintainability. In response to those challenges, microservice architecture has been introduced in the field of IoT application, due to its flexibility, lightweight and loose coupling (Sun, Li, and Memon 2017).

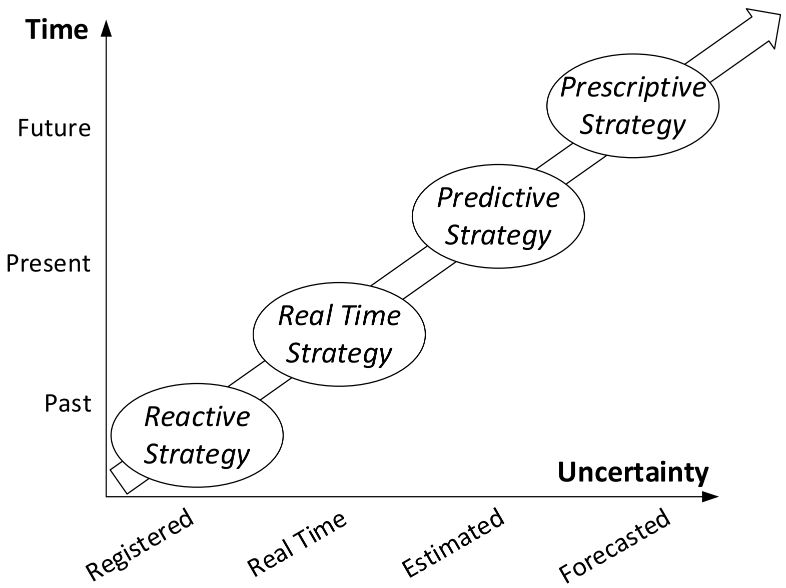
However, the existing IoT framework of microservice mainly focus on a specific domain, therefore, this greatly limits its application.

3. Reference framework

From a historical point of view, the dominant strategy was based on records coming from the shop floor, which can be considered a reactive strategy as it is based on collected evidences from the past. On the other hand, from the last thirty years the automation systems gained prevalence for implementing control actions regarding even complex processes and they have been considered as a useful source of information for understanding shop floor operations. This strategy was named as Real Time Strategy looks the floor shop in present time, while its major constraint for properly exploit the information from different control systems is the integration issues.

To keep the different information flows aligned the digital twin concept was introduced. Digital twin for processes and for products were defined, linking them inside the cloud, which enable as well the access to artificial intelligence (AI) techniques. Based on these technologies a Predictive Strategy can be identified, where based on the collected information models can be developed and updated to use them to estimate the behaviour of systems (Predictive Strategy).

Figure 1: Comparison of Strategies According to the Uncertainty and Time Frame

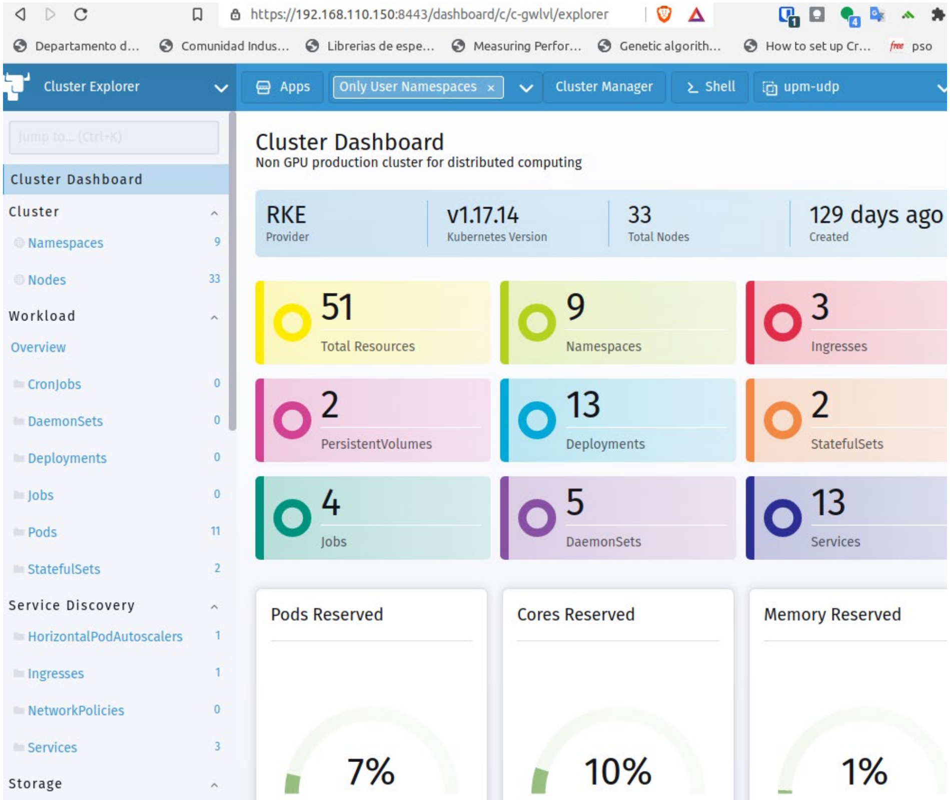


For the coming future it is expected that interconnection of models will increase because of every system component in the shop floor will look to gain self-awareness and analyse different scenarios. All these components increment the communications between different elements in order to estimate the effects, the potential demands and quality control outcome.

When all these systems interact monolithic applications face enormous challenges in dealing with all implied events, and to deal with such challenges a different architecture was introduced named microservice architecture (Namiot and Sneps-Sneppe 2014). This new architecture is based on the concept of large and complex applications should be divided into small manageable groups, where each group deals with the related services. According to its specific business responsibilities, each micro service is dedicated to single business function. Therefore, independent services can be easily deployed and released internally to the production environment in isolation and the modification of services would not affect the whole system. Any applicable tools and languages can quickly realize a specific service. Compared with the traditional monolithic architecture, the microservice architecture has obvious advantages, such as complexity under control, independent deployment, more choices for technology stack and fault tolerance, which will facilitate the development of IoT applications on large scale (Kravari and Bassiliades 2019; Krylovskiy, Jahn, and Patti 2015).

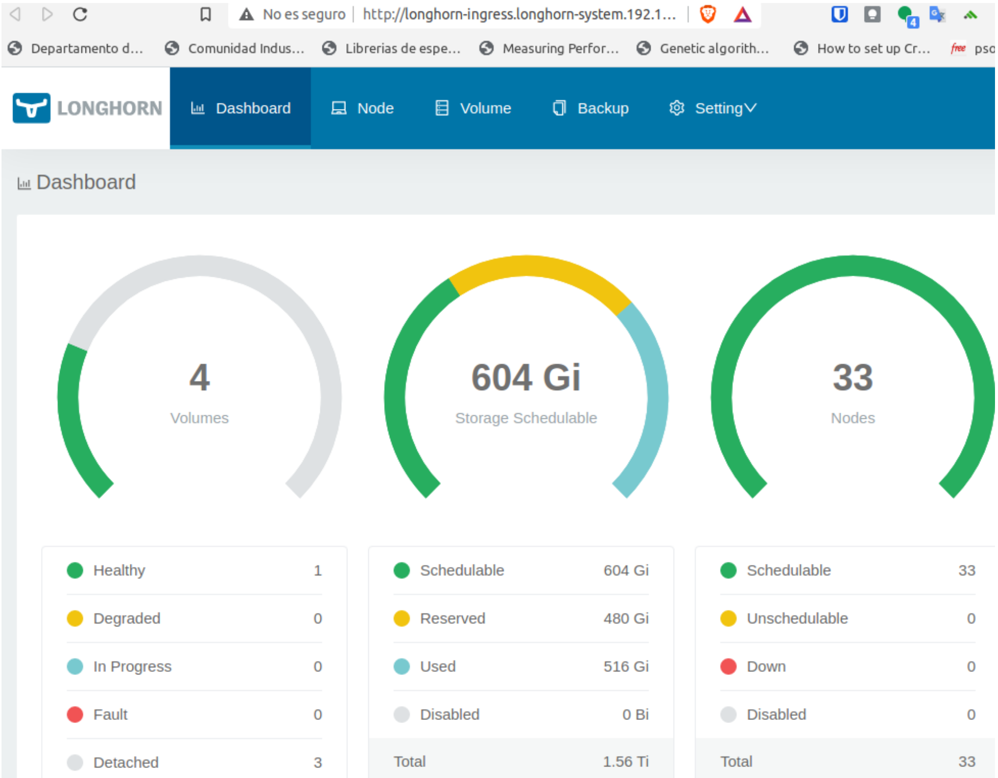
Interaction between microservices are driven using REST interfaces. It shall be possible also to implement publishable model on subscription to notify the clients about the interest events from their interesting topics.

Figure 2: Example of micro service oriented cluster



Obviously, micro services need to be protected by user/group/role credentials, authentication and authorization, access control, single sign-on and federation, identity governance and administration, including monitoring, reporting and auditing. The architecture can support multitenant design, including different communication protocols and plugging services and/or callbacks. Usually a bigdata service provides support for many kinds of scalable persistence to store data. It interacts with storage implementations by a consistent encapsulated API set. By this way, it is easy to add new storage technologies to the system. When operating database, the system never directly manipulates database and it supports scalability and replicability, out of getting distributed filesystem to provide enough block replication capabilities, which is supported by the provided cloud.

Figure 3: Example of cloud file system storage based on Longhorn



The AI service based on the IoT bigdata, provides a series of Artificial Intelligence tools including machine learning through Apache Spark, data mining, graph computing, etc.

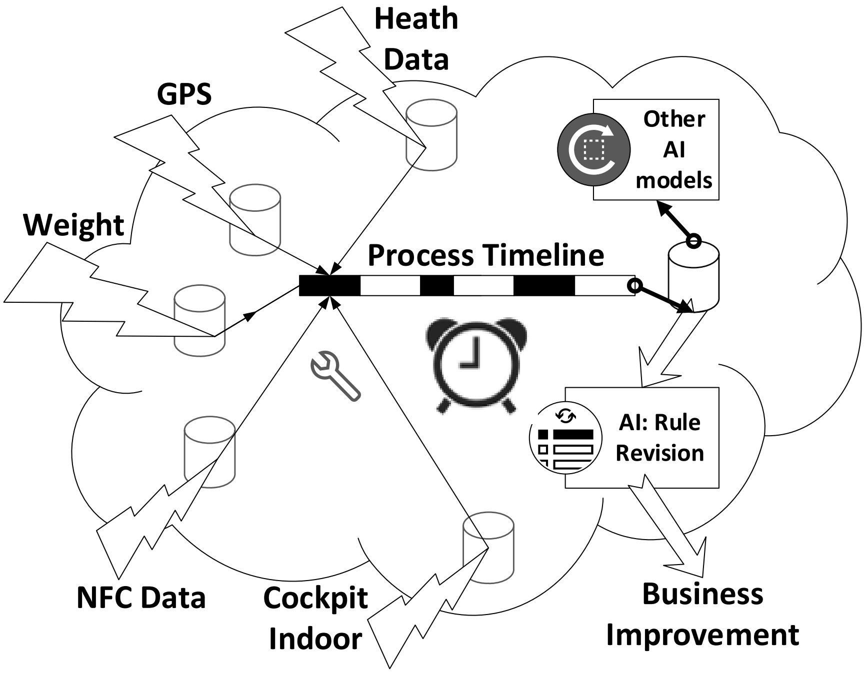
4. Use cases

Considering the introduced framework, the WISEST project uses it to integrate different microservices based on a kubernetes cluster (Fernandez, Vidal, and Valera 2019; Taherizadeh and Grobelnik 2020) managed by using Rancher (Buchanan, Rangama, and Bellavance 2020).

The selected application case describes the reverse logistics application, where trucks are monitored through an external fleet control, but additional information need to be collected through a specific android based app, collecting NFC process relevant information. It was also relevant to know specific stress levels for truck drivers as well as the indoor aspects from the truck cockpit.

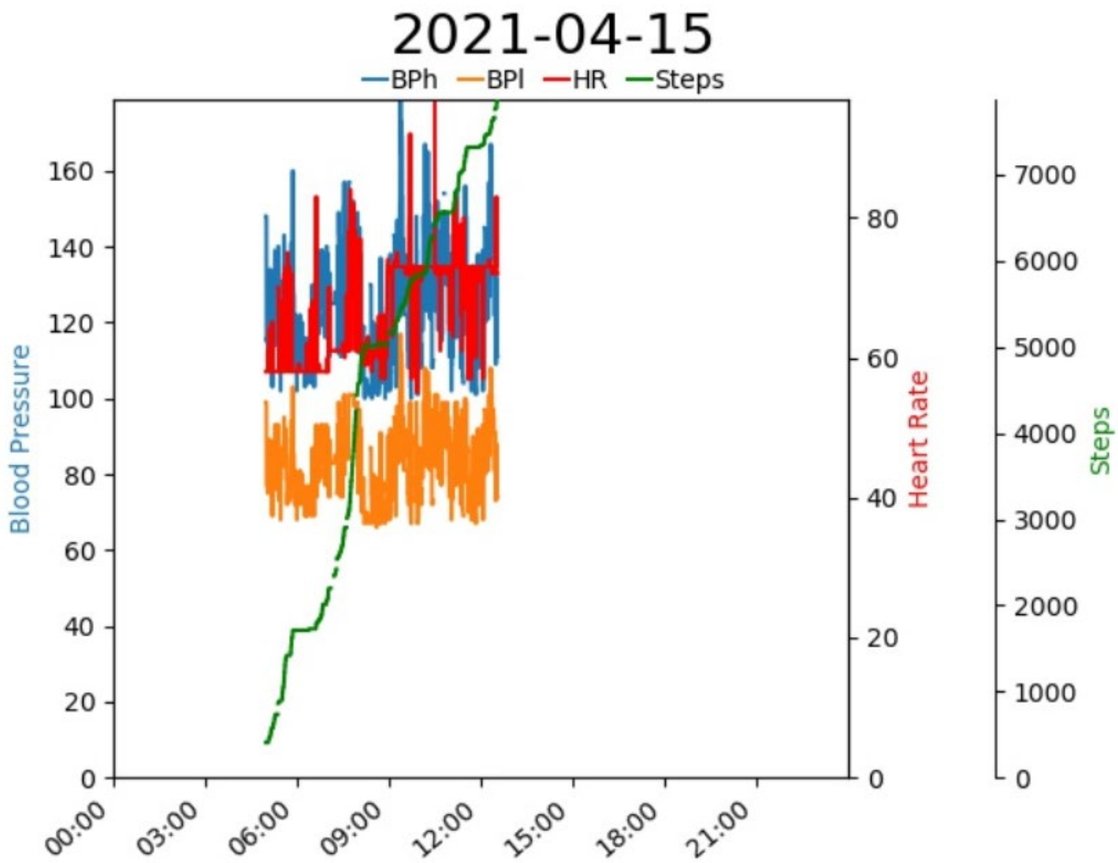
Collection of geolocation data for cloud ingestion is fired every two minutes and collection of human body parameters every minute as per truck driver. The adopted frequency for the indoor cockpit is established in two minutes. Because of the business logic at the end of every day different KPI requiring to merge the different data flows through specific python based tools, where those daily based KPI are stored inside the database, able to feed the AI models, mainly association rules looking for relationships related to significant variations. The whole system can be seen in Figure 4.

Figure 4: Application Framework for the Use Case



As already mentioned, major issue to be dealt with is related to the integrative dimension of independent data flows in a robust way.

Figure 5: Personal information shared individually through Trello® dashboards



The data is collected over different data services supported by different databases, some of them relational such as MySQL (The Galera version for scalability) as well as some non SQL oriented, storing data blocks from different sensors such as MongoDB collections.

Mash-up and problem related integration is carried out by specific tailor made python tools, extracting and summarizing relevant information as per day and user, etc. It does include to cope with requirements from different stakeholders, such as providing relevant personal information regarding health parameters for increasing self-awareness (see Figure 5), where daily information is provided for BPh (High blood pressure), BPl (Low blood pressure), as well as HR (Heart rate) and steps during the shift.

Another case study accomplished during the project is related to the manufacturing of steel rebars, where the implemented automation level is high in the initial parts of the production but the inner logistics for truck loading of products as well as their heterogeneity makes the tracking complex enough and hinders the process related information as a whole. Indeed, performance and safety strongly depends on personal knowledge and attitudes from crane operators, where it becomes essential to collect information about crane operations depending on orders under process.

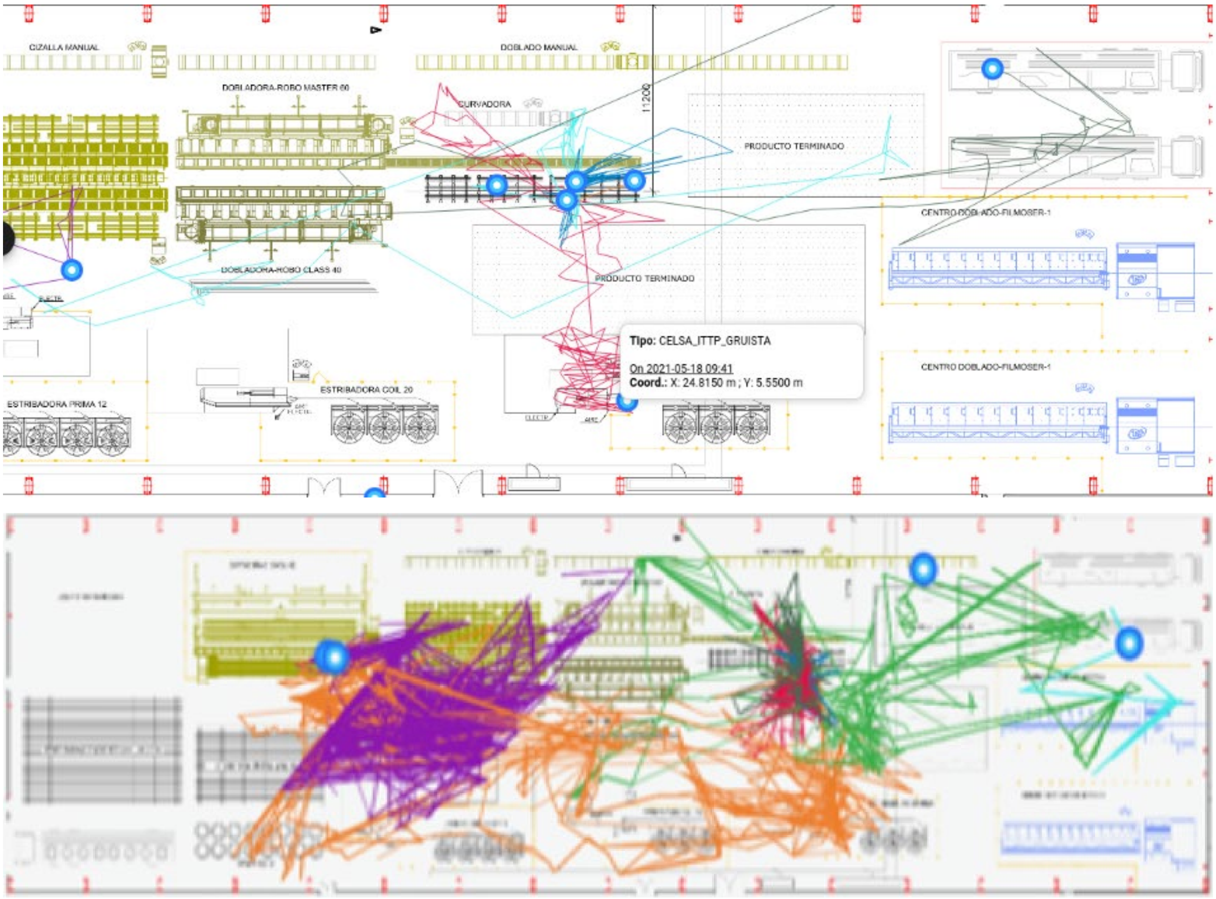
On this case study it becomes relevant to track trajectories from cranes but also from crane-operators, in particular crane loading goods into trucks, as they can explain the required time, movements, which mean energy, as well as source of variability and risk because moving items over workers' head (see Figure 6).

Figure 6: Rebar operations by crane

Indeed, linking such information to crane operator health parameters can also make links between performance, operator's health and item references. The information related to operator's heath is collected by using the same mongodb environment and position of cranes and operators are collected by continuous requesting a REST based data service, where trajectories can be seen in Figure 7 for both cranes and crane operators, where it is easy to see specific areas where concentration of routes are visible.

Therefore, for this use case it becomes relevant to integrate real time position of devices and operators (which can be independent), as well as production data flows and health parameters, and items loaded in trucks, as part as of the complete process, when different sources of variability are concerned.

Figure 7: Crane trajectories collected form the indoor tracking system



5. Conclusions

The work carried out within the WISEST project allow to introduce flexible and scalable architecture by combining an on premise cloud based on several nodes. It was discussed how such architecture works for IoT based deployment for mobile oriented businesses.

The analysis of the different clock based processes starting by ingestions in different databases such as MySQL Galera and MongoDB and running micro processes for daily reports. Indeed, other integrative micro processes were setup to align the different stages in the process timeline as per driver and operation cycle. The business process stages attend the different operations, such as driving to the customer facilities, inhouse navigation, loading process, way out and driving back, to end up with unloading at the headquarters. The tested implementation shows convenient characteristics through API REST interfaces, enabling modularity, while the whole configuration was presented in Figure 4, introduced from a proper timeline context presented in Figure 3.

A key aspect found during this research is that none of the individual streams of data are good enough to provide business significance, however, the integration of dataflows coming from different sources can bring a valuable contribution. Just as an example, the process operations are based on cycles as per working day, but no enough attention is given to effectiveness depending on the day because of traffic conditions, or even because of shift peculiarities or operator's behaviour. Such effectiveness is based on time performance and weight amount of material processed in the case of this particular application, while it can vary from business to business or case to case. Another significant learning is that to consolidate operating rules enough collected data is required, which means a significant period of time to collect the data. If the time scale is the day of the week, it is needed to collect information from long series of weeks, while if the interest are months, significant amount of data lasting for several years are needed.

Another valuable learning rule is that for such long term data collection involving human participation, it is needed to define strict quality and quantity monitoring as per shift or day, making it possible to provide advice to managers in such a way they avoid creeping of rules. Otherwise, the whole dataset will lose quality very quickly. This effect does not happen when data are collected automatically, while still some quality validations are indeed needed.

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Communication aligned with the Sustainable Development Objectives