PROCEEDINGS OF THE III WORKSHOP ON DISRUPTIVE INFORMATION AND COMMUNICATION TECHNOLOGIES FOR INNOVATION AND DIGITAL TRANSFORMATION

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Talk:
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Pablo Chamoso
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Talk:
DeepInt as a tool to manage AI projects

JAVIER PARRA DOMÍNGUEZ, SARA RODRÍGUEZ GONZÁLEZ,
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PREFACE

The III workshop on Disruptive Information and Communication Technologies for Innovation and Digital transformation, organized under the scope of the DISRUPTIVE project (disruptive.usal.es) and held on December 18, 2020 in Salamanca (Hybrid Format), aims to discuss problems, challenges and benefits of using disruptive digital technologies, namely Internet of Things, Big data, cloud computing, multi-agent systems, machine learning, virtual and augmented reality, and collaborative robotics, to support the on-going digital transformation in society.

The main topics included:

- Intelligent Manufacturing Systems
- Industry 4.0 and digital transformation
- Internet of Things
- Cyber-security
- Collaborative and intelligent robotics
- Multi-Agent Systems
- Industrial Cyber-Physical Systems
- Virtualization and digital twins
- Predictive maintenance
- Virtual and augmented reality
- Big Data and advanced data analytics
- Edge and cloud computing
- Digital Transformation

This workshop was organized by BISITE Research Group (University of Salamanca) and mainly supported by the European Regional Development Fund (ERDF) through the Interreg Spain-Portugal V-A Program (POCTEP) under grant 0677_DISRUPTIVE_2_E (Intensifying the activity of Digital Innovation Hubs within the PocTep region to boost the development of disruptive and last generation ICTs through cross-border cooperation).

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PREDICTIVE MAINTENANCE THROUGH DATA-DRIVEN APPROACHES

MANTENIMIENTO PREDICTIVO MEDIANTE EL ENFOQUE BASADO EN DATOS

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Abstract: Nowadays, the Industrial Internet promises to transform our world. The melding of the global industrial system that was made possible because of the Industrial Revolution, with the open computing and communication systems developed as part of the Internet Revolution, opens new frontiers to accelerate productivity, reduce inefficiency and waste, and enhance the human work experience. With the emergence of Industry 4.0, smart systems, machine learning within artificial intelligence, predictive maintenance (PdM) approaches have been extensively applied in industries for handling the health status of industrial equipment. This paper focus on the PdM field, describing and specifying, its techniques, applications in the real world, methods and approaches widely used as such its challenges.

Keywords: predictive maintenance; anomaly detection; data-driven.

Resumen: Hoy en día, el Internet Industrial promete transformar nuestro mundo. La fusión del sistema industrial global que se realizó fruto de la Revolución Industrial, con los sistemas de comunicación e informáticos abiertos de comunicación desarrollados como parte de la revolución de Internet, abre nuevas fronteras para acelerar la productividad, reducir la ineficacia y el despilfarro, y mejorar la experiencia de trabajo del ser humano. Con la aparición de la Industria 4.0, los sistemas inteligentes y el aprendizaje automático dentro de la inteligencia artificial, los enfoques de mantenimiento predictivo se han aplicado ampliamente en las industrias para manejar el estado de salud de los equipos industriales. Este artículo se centra en el campo del mantenimiento predictivo, describiendo y especificando sus técnicas, aplicaciones en el mundo real, los métodos y enfoques ampliamente utilizados, así como sus desafíos.

Palabras clave: mantenimiento predictivo; detección de anomalías; data-driven

1 Introduction

Since the outset of the Industrial Revolution, maintenance of engineering equipment in the field has been a challenge. While impressive progress has been made in maintaining equipment in the field in an effective manner, maintenance of equipment is still a challenge due to factors such as size, cost, complexity, and competition [7]. The notions of prediction or prevention didn't exist, as we know in the present, so maintenance suffered from quite a bad image back then [7]. The industrial world, as well as the implications, were very different from the ones we know today. At that time, the industry was prospering, so the consequences on production lines weren't the same (e.g. equipment were not integrated to a more general system) [8, 6]. Several industrial managers overlooked the positive influence of proper maintenance management on their company's activity. Yet, it is a major performance factor and a cause for prompt gains within the company: in terms of productivity as well technology, suitable industrial maintenance management has positive consequences on organizations and their products [8]. In recent years, manufacturing industry has been facing a major shift of the manufacturing requirements (e.g. consumer demand for customized products continues to grow), resulting in a much shorter product life cycle, unlike the traditional mass production of standardized products [17]. These changes are impacting companies, rising the need for adaptation, driving all sectors of the manufacturing activity to move correspondingly. Maintenance activities can impact the entire manufacturing/production cost and quality, and consequently, customer satisfaction [17]. This shift in the maintenance paradigm has led to the research and development of new ways to execute maintenance by considering the operational state of assets and enabled the development of new maintenance approaches, such as, predictive maintenance, a proactive maintenance strategy that tries to predict when a piece of equipment might fail so that maintenance work can be performed just before that happens. Monitoring for future failure allows maintenance to be planned before the failure occurs.

The rest of the paper is organized as follows: Section 2 overviews the maintenance strategies, Sections 3 describes the predictive maintenance techniques and applications. Finally, Section 5 rounds up the paper with a discussion on the topic addressing the open challenges in this field.

2 Maintenance Strategies

Maintenance implementation requires organization, planning and control practices, in order so that it is possible to have a disciplined structure that supports a change of mentality and behavior in maintenance. The maintenance function involves all activities related to the maintenance of good working conditions of equipment, systems and installations, and the performance of corrective interventions whenever failures or breakdowns arise. According to the literature there are three main types of maintenance [12, 2], Reactive, Preventive and Predictive. To these three main types, two more can be added [11], these being, Condition-based and Pro-active maintenance. Figure 1 illustrates the taxonomy of the maintenance strategies.

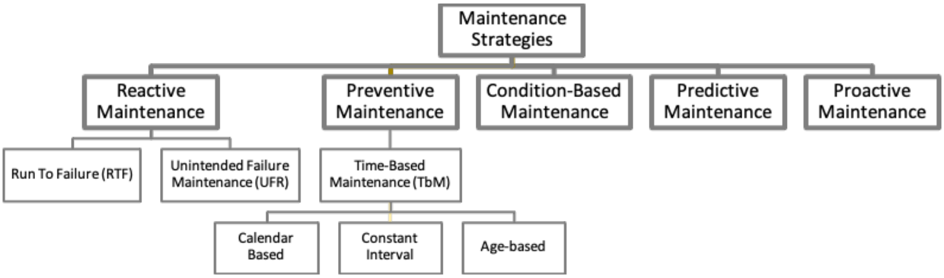

Fig. 1. Maintenance strategies Taxonomy.

- **Reactive Maintenance** (or Unplanned Maintenance): When equipment fails, it must be repaired, or replaced. Reactive Maintenance is the technical activity performed after the occurrence of a malfunction and aims to restore the asset to a condition where it can function as intended, either by repair or replacement. This type of maintenance often leads to worse and more regular breakdowns, as well as costly downtimes [22, 12].
- **Preventive Maintenance** (or Planned Maintenance): Instead of waiting for the malfunction to occur, this type of maintenance is aimed at preventing it from happening. It takes place in a cyclical and scheduled manner, regardless of the condition of the asset and with the aim of preventing damage and minimizing the consequences of equipment breakdowns. Examples of preventive maintenance actions include inspections, periodic overhauls, cleaning and lubricating parts [4, 12].
- **Predictive Maintenance** (PdM): This is the most recent and the one that requires the most technological investment. Concerns monitoring equipment conditions to predict when it is destined to fail. When certain undesirable conditions are detected a repair is scheduled before the equipment actually malfunctions, thus eliminating the need for costly corrective maintenance or unnecessary preventive maintenance. It is based on the physical and operational condition of the equipment, through regular monitoring and testing of the condition and performance of the equipment [12, 4].

To these three main types, two more can be added [11]:

- **Condition-based Maintenance** (CbM): Carried out by assessing the condition of the machine, normally carried out continuously. The component replacement process is based on predictive analysis. Concerns to monitoring the condition of the equipment to assess which maintenance needs to be performed. It occurs only when the data indicates a drop in performance or the first signs of failure. This differentiates it from preventive maintenance, where tasks are performed at regular intervals [20].
- **Pro-active Maintenance** (PbM): is any form of maintenance that is done before any significant breakdowns or failures occur. As opposed to reactive maintenance, it focuses on anticipating and managing machine failures before they take place. Is focused on by undertaking activities that avoid the underlying conditions that lead to machine faults and degradation. Requires to identify the root causes of a failure that can be removed, to determine potential failure locations and to avoid breakdowns caused by deteriorating equipment conditions [9].

3 PdM Techniques and Applications

3.1 PdM Techniques

PdM is a group of emerging scientific technologies that can be used to detect potential failures that may not be evident through a preventive maintenance program. If the equipment's failure characteristics are known, the PdM can detect the failure well in advance and the appropriate actions can be taken in a planned manner. The difficulty is in detecting faults, which are not always noticeable to the user in an initial state. That is why it is so important to find the indicated non-destructive tests to diagnose infrastructure failures [16]. Non-destructive tests are techniques that do not compromise or damage the analyzed equipment:

- **Thermographic and infrared analysis:** Infrared thermography uses special instruments to detect, identify, and measure the heat energy objects radiate in proportion to their temperature and emissivity. Is used to study everything from individual components of machinery to plant systems, roofs, and even entire buildings [10].

- **Oil analysis:** The purpose of oil analysis is to measure the number and size of particles in a given (oil) sample to determine wear and tear on the equipment. The full benefit of oil analysis can only be achieved by taking frequent samples and evaluating data from each machine in the program. Based on the results of the analysis, lubricants can be changed or updated to meet specific operational requirements [23].
- **Wear particle analysis:** While the oil analysis provides information about the lubricant itself, the wear particle analysis provides direct information about the wear conditions within the machinery. The wear particle morphologies of machine lubricants contain valuable information about the wear processes in operation and can reveal the condition of a machine [18].
- **Vibration analysis:** This type of analysis is ideal for equipment and rotating machines, such as compressors, water pumps and engines. Vibration monitoring of plant machinery can provide a direct correlation between mechanical condition and recorded vibration data for each machine in the plant. Used correctly, it can identify specific components of the degrading machine or the failure mode of plant machinery before serious damage occurs [21].
- **Ultrasonic testing:** The instruments intended for ultrasonic tests detect the ultrasonic waves produced by the operation of the machines, as well as the turbulent flow of leakage. It is designed to detect early leaks in compressed air transport systems. They provide quick and accurate diagnosis of problems such as valves in blowby mode, defective steam traps, vacuum and pressure leaks [19].

3.2 PdM Applications

Predictive maintenance can be applicable to all sectors where machines produce significant amounts of data and require maintenance or fine-tuning of their parameters. PdM applications is already gaining traction in some industries such as:

- **Airlines:** The aviation industry is grasping for opportunities to reduce costs. Airlines are no stranger to monitoring sensor data from planes.

Today's analytical capabilities allow them to analyze more data, increasing passenger safety.

- **Transportation:** Although airlines lead the group in terms of the complexity of their equipment, other means of transportation, such as trains, also involve complex machinery that can benefit from predictive maintenance.
- **Ports:** Exposed to adverse conditions, the conditions of port equipment deteriorate rapidly. For instance, cranes are critical components, but are subject to failure. Crane downtime means more waiting time for ships and less processing for ports. Reducing downtime improves service quality and reduces waste at ports [1].
- **Automotive:** Automotive companies operate some of the largest robot parks in the world. In order to reduce inventory costs, automotive companies have developed the Just-In-Time manufacturing methodology since the 1960s and 1970s. As a result, they have fully integrated supply chains. While tight supply chain integration allows for reduced inventory, any reduction in manufacturing efficiency results in a significant supply chain disruption. It is no surprise that automotive companies gain significantly from technology that reduces downtime.
- **High-tech manufacturing:** Operating complex equipment at optimal parameters is the main challenge for improving the efficiency of high-tech manufacturers, such as semiconductor manufacturers. Predictive maintenance systems allow them to operate at a level closer to the ideal parameters.
- **Oil and gas:** Despite the increase in green energy, oil and gas is still one of the largest industries. Both extraction and refining involve expensive equipment that can cause risks to health and the environment in the event of failure. For example, the Deepwater Horizon oil spill in 2010, which resulted in 11 deaths and 5 million barrels of spilled oil, was one of the worst disasters in the past decade [15]. The stakes are high to prevent such disasters with better analysis and maintenance.

4 PdM Data-Driven paradigm

In predictive maintenance scenarios, data should be collected over time to monitor the state of equipment. The goal is to find patterns that can help predict and ultimately prevent failures. There are two main paradigms to deal with this problem, Model-driven and Data-driven. Model-Driven fault prediction (or detection) implies the creation of a model of how the physical system works and how it can break. It is grounded in theory-based hypothesis formation and experiment-based testing.

Data-Driven fault prediction is a new way of thinking enabled by machine learning algorithms that can discover hidden patterns in OT data (sensors, PLCs, SCADA) and IT data (ERP, quality, MES, etc). Because of the continuous improvement of data acquisition ability [5], as well as the exponential growth of data volume [13], data-driven methods have achieved great success and received widespread attention regarding the PdM of industrial equipment. Data-driven PdM system consists of two phases [26]:

- The learning process consisting of the training phase of the model through historical data from the sensor signals;
- The prediction process consists of applying the trained model to predict targets and make decisions.

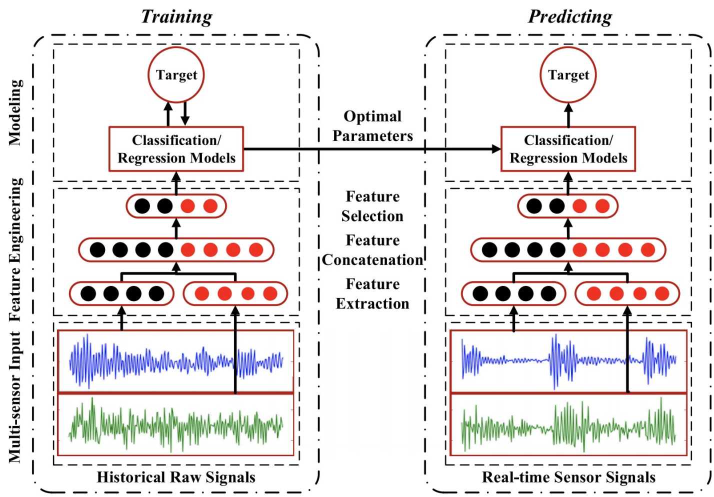

Fig. 2. Data-driven method for PdM from Zhang et al. [26].

In addition, each phase consists of the following three subprocesses:

1. Data acquisition and preprocessing;
2. feature engineering through processes such as feature extraction, concatenation, and selection;
3. model training and predicting, in which a well-trained model will be generated with the optimal parameters.

Most notably, data-driven methods make data acquisition an indispensable part of the PdM process [3], providing valuable information for specific tasks. However, for engineering applications, a customized data acquisition system needs to be established to meet specific requirements. It has been proven that Data analysis at different stages of the machine's life cycle can not only process data or information more effectively, but also achieve transparency of the health status of industrial equipment. Moreover, addressing the obtained data effectively (i.e., whether to use feature engineering or not) is a major challenge for algorithm selection.

The Model building is also a major part of data-driven process, and the selection, training and optimization of the model deserve more attention. In practice, supervised learning has achieved remarkable results in many fields, but it requires data to be recorded correctly, which is also a major challenge for the PdM. With the quantitative trend of industrial big data, and since the process of labeling data is hard and time consuming, unsupervised learning has naturally become a promising research direction.

Machine Learning has been widely used in computer science and other fields, such as the PdM of industrial equipment, which is one of the potential application fields for data-driven methods such as, Logistic Regression, Decision trees, Support Vector Machines and Neural Networks [14, 24]. As a result, although increasingly high-performance algorithms are continually developed, generally, employing simple and efficient methods is considered first. These methods have become a surefire solution for managing the health status of equipment with Remaining useful life (RUL) prediction given insights about when a machine will fail so maintenance can be scheduled in advance; flagging irregular behaviour through Anomaly detection time series analysis; failure diagnosis and recommendation of mitigation or maintenance actions after failure.

5 Discussion – Open Challenges

Predictive Maintenance enables more efficient, longer-term planning for maintenance operations and makes it easier to define operational maintenance goals and to allocate maintenance resources. Examining data from hundreds or thousands of sensors, gathered over months or even years, is well beyond the capabilities of human operators. Furthermore, the mathematical models, which describe an equipment's evolution (and predict potential faults) based on such a wealth of data, are generally prohibitively complex to be used by humans. For data scientists, predictive maintenance has several promising outcomes, including reducing machine downtime and avoiding unnecessary maintenance costs while adding revenue streams for equipment vendors with aftermarket services. However, engineers and scientists face challenges [25] around process and data when applying predictive maintenance technologies into their business operations:

- Being unaware of how to do predictive maintenance;
- Lacking data to create proper predictive maintenance systems;
- Lacking failure data to achieve accuracy;
- Understand failures but not being able to predict them;
- Unable to store or process large amounts of data.

The growing digitalization of companies marks the beginning of a new era for industrial maintenance: the emergence of predictive maintenance. A new generation of smart sensors appeals to an increasing number of manufacturers who wish to improve their maintenance methods. Companies should press well beyond one digital tool and think about how digital and advanced analytical techniques can transform their entire maintenance and reliability system. This means looking end to end for opportunities to make better use of data and apply user-centric design principles to digitize processes. The sustainable impact will require a blend of new digital tools, changes in asset strategy, and improved reliability practices.

Ongoing research into predictive maintenance techniques discussed in this paper promises to deliver technologies that may improve equipment reliability; predict failures before they occur; and contribute to process safety and efficiency. Integrating the predictive maintenance techniques will enable plants to avoid unnecessary equipment replacement, save costs, and improve process safety, availability, and efficiency.

Future work in this field is related to the development of algorithms to tackle predictive maintenance data-driven challenges such as: dealing with large amounts of data, allowing transparency in outputs and the ability to automatically adjust hyperparameters to data distributions.

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BLOCKCHAIN TECHNOLOGIES TO IMPLEMENT TRACEABILITY IN THE FARM TO FORK CHAINS

TECNOLOGÍAS BLOCKCHAIN PARA LA IMPLEMENTACIÓN DE LA TRAZABILIDAD EN LA CADENA DE VALOR DE LAS GRANJAS

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Abstract: Agriculture traceability demands a large volume of data that needs to be collected across the supply chain. Very early tracking and traceability systems used workers to record the information manually which entails risks, such as faulty information recording as well as inefficient resource usage. The implementation of tamper proof semi-automated digital ledgers will have a great impact on issues such as compliance with regulations, food provenance, food fraud, and many others, and therefore will gradually increase the trust within the supply chain. This paper provides an overview on the different stages of the AgriFood supply chain and of the fundamentals of a Distributed Ledger Technology, namely Blockchain, which can be used to mitigate some of the issues related to transparency and traceability of this sector. It also presents some solutions that already implement this technology to enable the traceability in the AgriFood sector. The authors also present the most important challenges and opportunities identify regarding the application of Blockchain based traceability systems for the AgriFood supply chain.

Keywords: blockchain; agrifood sector; traceability.

Resumen: La trazabilidad agrícola exige un gran volumen de datos que debe recopilarse en toda la cadena de suministro. Los primeros sistemas de seguimiento y trazabilidad utilizaban trabajadores para registrar la información manualmente, lo que conlleva riesgos como el registro defectuoso de la información, así como un uso ineficiente de los recursos. La implementación de libros de contabilidad digitales semiautomatizados a prueba de manipulaciones tendrá un gran impacto en cuestiones como el cumplimiento de la normativa, la procedencia de los alimentos, el fraude alimentario y muchos otros, por lo que aumentará gradualmente la confianza dentro de la cadena de suministro. Este documento ofrece una visión general de las diferentes etapas de la cadena de suministro agroalimentaria y de los fundamentos de una tecnología de que puede utilizarse para mitigar algunos de los problemas relacionados con la transparencia y la trazabilidad de este sector. También presenta algunas soluciones que ya implementan esta tecnología para permitir la trazabilidad en el sector agroalimentario. Los autores también presentan los retos más importantes y oportunidades identificados en relación con la aplicación de sistemas de trazabilidad basados en Blockchain para la cadena de suministro agroalimentaria.

Palabras clave: blockchain; sector agrifood; trazabilidad

1 Introduction

AgriFood Supply Chains are characterized for being ecosystems of high complexity and this is many times aggravated by the lack of transparency traceability. Existing systems lack in transparency and consumers' trust due to the unavailability of a fast and trustworthy way to retrieve information on the product's provenance. This problem can be mitigated by taking advantage of rapidly evolving technologies such as Information and Communication Technology (ICT), Radio-Frequency Identification (RFID), Internet of Things (IoT), Distributed Ledger Technology (DLT) and many more [4].

Additionally, today's consumer is a more informed, digital, and self-aware individual regarding the production conditions of the goods consumed. The nowadays consumer is interested in knowing, in a transparent and trustful way, about the practices used by the farmers (whether the farmers apply sustainable practices or not), the animal breed conditions, food provenance, and the transport conditions of the goods throughout the supply chain. This is true not only for the consumer, but transparent and trustful interactions between the different players of the AgriFood supply chain is also of great importance, facilitating the regulatory entities work and the prevention of fraud attempts.

The matters related to sustainable food systems are not only an interest of the consumers, the European Union has established the Farm to Fork Strategy which addresses comprehensively the challenges of sustainable food systems and recognises the relationships between healthy people, healthy societies and a healthy planet [6]. The Farm to Fork Strategy is at the heart of the Green Deal which offers a roadmap on how to make Europe the first climate-neutral continent by 2050. It maps a new, sustainable and inclusive growth strategy to boost the economy, improve people's health and quality of life, care for nature, and leave no one behind. In short, the Farm to Fork Strategy aims at building the food chain that works for consumers, producers, climate and environment by ensuring sustainable food production, food security, stimulating sustainable food processing, wholesale, retail, hospitality and food services practices, promoting sustainable food consumption, reducing food loss and waste and combating food fraud along the food supply chain.

Traceability systems can positively impact the AgriFood supply chain by allowing the decrease in the time needed to recall and withdraw products dangerous for the public health, thus improving consumers' safety and confidence. Additionally, traceability provides the agriculture supply chain with transparency and reliability, mandatory attributes considering the complexity of the food supply chain [4]. Despite the efforts of the different players of the AgriFood supply chain to developed technologies to track their products, in many cases the traceability systems are centralized, asymmetric and outdated in terms of data sharing and interoperability [4]. Leading the different stages of the AgriFood supply chain to continue to operate individually. In order to achieve a transparent and traceable system is mandatory to verify context data shared with third-parties, and guaranty the quality of data being stored in a distributed ledger. These are crucial requirements in applications the aim to certify the quality in food production, for example, the gathering of certain parameters of animal welfare on farms, or when public administrations strive to ensure transparency of their processes [7]. DLT offer a solution to many existing problems, but simultaneously pose new challenges as well.

For the above mentioned, DLT present great potential in the agriculture domain. The implementation of self-executing smart contracts together with automated payments would be the game changer. The role of smart contracts especially in agricultural insurance, green bonds, and traceability could be very effective [10].

In this paper the authors intend to present an overview on the importance of the traceability in the AgriFood sector and how DLT, particularly Blockchain, can be applied in this context, what are the challenges of its applications and what are the opportunities inherent for transparent and trustful traceability systems.

The rest of the paper is organized as follows: Section 2 introduces the AgriFood Supply Chain and the explains why the traceability is of great importance in this sector. Section 3 presents an overview of the Blockchain technologies, including the working principles, implementation technologies and some examples of application. The application of Blockchain technologies to the farm to fork chain is addressed in Section 4, where existing solutions for the AgriFood sector are presented. Additionally, the challenges and research opportunities inherent to the use of Blockchain technologies to the AgriFood supply chain are exposed as well. Finally, Section 5 rounds up the paper with conclusions and points out the future work.

2 Traceability in the Farm to Table Chain

Agrifood supply chains are characterize as a sequence of linked events associated to the agricultural production of food, including chain of events from production to processing, trading, distribution, and consumption [8].

The Agrifood supply chain includes, not only the producer and its suppliers, but also, depending on the logistic flows, transporters, warehouses, retailers, and consumers themselves [19].

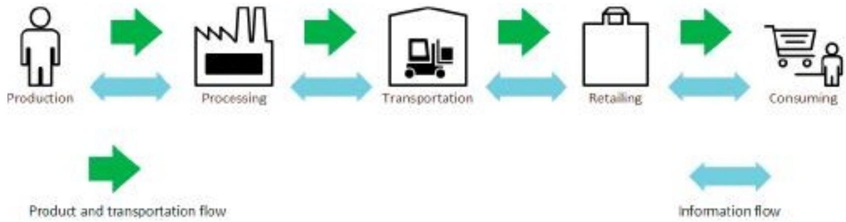

Fig. 1. AgriFood Supply Chain and its information flow [4].

The structure of the Agrifood chains are, as depited in Figure 1 initiated with the primary production of goods, which is diverse and includes production of crops, livestock, forestry, fisheries and aquaculture [9]. The resulting goods are then transported to the processing and packaging stage where the transformation industry intervenes. After this stage, the products are transported to the retail infrastructures (the goods can be stored in between these two stages) which sell the goods to the end user, constituting the last stage of the Agrifood chain.

Although the Agrifood sector has been adapting to all production, manufacturing and presentation standards, there is another characteristic that is strongly dictating trends in the markets: a more demanding, more informed, and digital end consumer. The main trends that will mark the future of the Agrifood sector worldwide are directly linked to product quality and environmental concerns. The search for new products, unique and innovative, has been an interest on the part of consumers, which has driven the evolution of the sector and companies. In parallel, the Agrifood value chain has to face consumer demands, norms and regulations for production, manufacture, labeling and food safety. On the other hand, international food law encourages the preservation of the history of production data, which led to the appearance of some traceability solutions resulting, for example, from regulatory and food safety requirements (DOP, BIO products, etc.). According to [2], food traceability can be definied as the ability to identify the origin of food and feed ingredients and food sources, particularly when products are found to be faulty. A traceability system allows an organization to document and/or to locate a product through the stages and operations involved in the manufacture, processing, distribution and handling of feed and food, from primary production to consumption.

However, these solutions and the information contained within these are disconnected throughout the Agrifood value chain, barely accessible to the other stages of the chain and, due to the fact that they are performed/registered mainly manually, result in a difficult consultation by the various economic agents throughout the Agrifood value chain and also by the end consumer. This difficulty penalizes quick action for example in situations of fraud. In this context, the BIOma project intends to address the challenges identified and promote the benefits of product traceability throughout the Agrifood value chain, by creating a digital, integrated and interoperable traceability solution that connects the different phases of the Agrifood value chain.

3 An Overview of Blockchain Technologies

This section aims to overview the Blockchain concept and working principles, providing also a fast snap-shoot on its technologies and applications.

3.1 Concept and Working Principles

Blockchain is a disruptive technology for building consensus and trust in a peer-to-peer network without centralized control and it takes advantage of the DLT, which is a decentralized system for recording transactions with mechanisms for processing, validating and authorizing transactions that are then recorded on an immutable ledger [21].

A simple analogy for understanding Blockchain technology is a Google Doc. When a document is created and shared with a group of people, the document is distributed instead of copied or transferred. This creates a decentralized distribution chain that gives everyone access to the document at the same time. Non of users is locked out awaiting changes from another user, while all modifications to the document are being recorded in real-time, making changes completely transparent and it demonstrate tree critical ideas of technology:

1. Digital assets are distributed instead of copied or transferred.
2. The asset is decentralized, allowing full real-time access.
3. A transparent ledger of changes preserves integrity of the document, which creates trust in the asset.

Blockchain consensus algorithms ensure each new block added to the network is the only version of the truth, which is agreed by all the nodes in a decentralized computing network. There are four primary types of blockchains: Private and Public Blockchain and Consortium and Hybrid Blockchains which are variations of the first ones. Every Blockchain consists of a cluster of nodes functioning on a peer-to-peer (P2P) network system. Every node in a network has a copy of the shared ledger which gets updated timely. Each node can verify transactions, initiate or receive transactions, and create blocks. Publick Blockchain allow anyone to participate as users, miners, developers, or community members. All transactions that take place on public Blockchains are fully transparent, meaning that anyone can examine the transaction details [13].

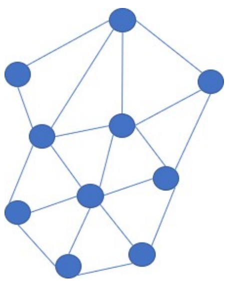

Fig. 2. Distributed structure.

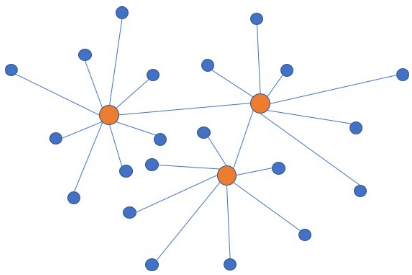

Fig. 3. Decentralized structure.

Before a transaction is considered valid, it must be authorized by each of its constituent nodes via the chain's consensus process. As long as each node abides by the specific stipulations of the protocol, their transactions can be validated, and thus add to the chain. Since each node on a public Blockchain has as much transmission and receipt power as any other, they are not only decentralized but fully distributed. The difference between distributed and decentralized structures is demonstrated in Figure 2 and Figure 3. Private Blockchains, also known as permissioned Blockchains, has a number of notable differences from public Blockchains. Private Blockchains are more centralized than public Blockchains so participants need consent to join the networks. Another difference of private Blockchain is that the transactions are private and are only available to ecosystem participants that have been given permission to join the network [5].

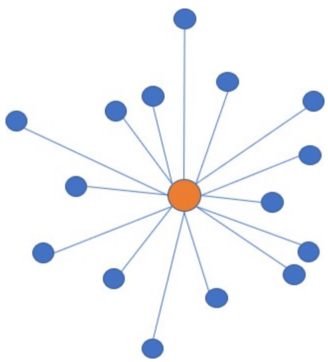

Fig. 4. Centralized structure.

In a centralized setup, a single entity has power over the system. In most cases, they can make changes at their discretion as there isn't some complex governance system for reaching consensus amongst many administrators. Meanwhile, in a decentralized setup, appearing challenges of agreement among entries in a distributed database.

Blockchain overcomes this challenge by resolving the trust issue between entities. Further, we'll be discussed how consensus algorithms are vital to the functioning of cryptocurrencies and distributed ledgers.

3.2 Blockchain Consensus Algorithms

As Blockchain functions in a decentralized manner and records large volume transactions in real-time, there may be the complexity of what the truth is. The key is to get consensus one way or another, or else double-spending attacks can occur. This is where the consensus algorithm comes in.

A consensus algorithm is a protocol through which all the parties of the Bockchain network come to a common agreement on the present data state of the ledger and be able to trust unknown peers in a distributed computing environment. For Blockchain networks, they are an essential element to maintain the integrity and security of these distributed computing systems [3].

In Blockchain networks, there is a wide variety of consensus algorithms, all with their own advantages and disadvantages. The two main kinds of consensus algorithms for arriving at a consensus in a distributed manner are Proof of Work (PoW) and Proof of Stake (PoS).

PoW is the first viable consensus algorithm and currently is the most common and one of the most robust consensus mechanism for Blockchain technology. In Blockchain, this algorithm is used to confirm transactions and produce new blocks to the chain. With PoW, miners compete against each other to complete transactions on the network and get rewarded [17].

The PoW method defines that the nodes must adopt the fork which carries work, and it is very unlikely that the two competing forks will generate the next block together. Blockchain core network protects against double-spending by the verification of each transaction with the use of PoW mechanism [18].

PoS is a substitute approach for PoW which requires fewer CPU computations for mining. Though this is also an algorithm, and the purpose is the same as PoW, the process is quite different here, especially during the validation of new blocks on the Blockchain network.

In PoS systems, the creator of a new block is chosen in a deterministic way, depending on its stake, or degree of commitment in the network. This means that in the PoS mechanism, there is no block reward. So, the miners take the transaction fees.

3.3 Example Applications

The Industrial Internet of Things (IIoT) plays a central role in the Fourth Industrial Revolution, with many specialists working towards implementing large scalable, reliable, and secure industrial environments. However, existing environments are lacking security standards and have limited resources per component which results in various security breaches. Due to the resilience and its security properties, combining Blockchain-based solutions with IIoT environments is gaining popularity [16].

Blockchain provides a way to securely and efficiently create a tamper-proof log of sensitive activity. This makes it excellent for international payments and money transfers. One of first applications based on Blockchain technologies are Bitcoin and other cryptocurrencies. It uses fully peer-to-peer networking technology to operate with no central authority or banks. Blockchain simply combines cryptography, distributed system technology and other well-known technologies. Besides, it also provides a secure framework for the cryptocurrencies, in which anyone cannot tamper the content of transactions and all the nodes participate in transactions anonymously [20]. Blockchain can be used to immutable record any number of data points as in the form of transactions, votes in an election, product inventories, state identifications, deeds to homes, and much more.

Similar to a transfer of value on a Blockchain, deployment of a smart contract on a Blockchain occurs by sending a transaction from a wallet for the Blockchain. A smart contract is a computer code that can be built into the Blockchain to facilitate, verify, or negotiate a contract agreement. Smart contracts operate under a set of conditions that users agree upon. When those conditions are met, the terms of the agreement are automatically carried out. Smart contracts permit trusted transactions and agreements to be carried out among disparate, anonymous parties without the need for a central authority, legal system, or external enforcement mechanism [11].

There are many other applications that can be built, all leveraging the benefits of Blockchain. From supply chain to accounting, to identity management, and more.

4 Application of Blockchain Technologies for the Farm to Fork Chains

This section presents the most interesting, in the authors perspective, Blockchain solutions for the AgriFood sector and what are the main challenges and research opportunities inherent to this research topic.

4.1 Existing Blockchain Solutions for AgriFood Sector

Enhancing traceability in the food supply chain is one known preventative measure and its wider implementation could help to check the spread of foodborne illnesses. The means and methods of increasing traceability exist and are in widespread use in many supply chains.

Walmart cooperating with IBM has launched a food safety Blockchain solution to add transparency to the decentralized food supply ecosystem by digitizing the food supply chain process. The food traceability system was created based on Hyperledger Fabric, the open-source ledger technology. By placing a supply chain on the Blockchain, it allows making the process more transparent and traceable. Each node on the Blockchain represents an entity that has handled the food on the way to the store, making it a lot easier and faster to see if one of the farms has sold an infected batch to a specific location [12].

Provenance uses Blockchain technology to track products through the AgriFood supply chain: materials, ingredients, and impact, in order to provide consumers with greater transparency about a product's authenticity and origin. Its use of the technology allows the end user to see each step of the journey the product has taken: where it is, who has it, and for how long? Producers can also benefit from this increased authenticity when telling the story of goods they produce [14].

Skuchain applies the cryptographic principles developed in the Bitcoin network to provide security and visibility for the global supply chain. As goods travel through the supply chain, from manufacturers to distributors to consumers, the crucial electronic information about what the item is and where it came from becomes disconnected from the stock keeping unit (SKU) itself. A Blockchain offers a universal, secure ledger by which SKUs can attest digitally to their origins and attributes. Skuchain is building a system of next generation identifiers in the form of both barcodes and radio frequency identification devices (RFID) tags to digitally secure the transfer of goods across the entire global economy. Whereas most anti-counterfeiting systems rely on copy resistant labels, holograms etc., Skuchain relies on the uncopyable nature of a Blockchain ledger to solve the problem of supply chain integrity. Skuchain's system will provide cryptographic proof of each SKU's origin and supply chain that can be verified all the way to the point of consumption [15].

Arc-net connects every step of a product's journey to deliver supply chain transparency and product security. The Arc-net toolset provides an easy to use scalable platform, powering the strategic insights that unlock profit. [1]

All the example provided above take advantage of the Blockchain technology in order to increase transparency throughout the AgriFood supply chain.

4.2 Challenges and Research Opportunities

Throughout the state of the art performed several challenges related to the implementation of Blockchain the AgriFood sector were identified. These challenges were organized in different groups as depicted in Figure 5.

There are several challenges to be addressed in order improve maturity and acceptance of this technology, some of the identified challenges are connected to technologies that are related to, and support, the use of Blockchain apply to the AgriFood sector. The most important challenges are divided into four main groups, namely technological, methodological, legislation and behavioural challenges.

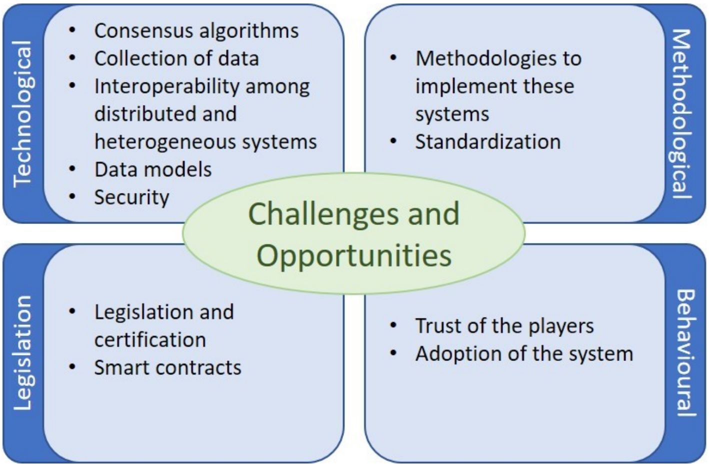

Fig. 5. Identified challenges and opportunities.

Regarding the technological challenges, the authors have identified the need to perform a benchmarking of existing technologies for the AgriFood requirements in order to understand how to take advantage of the best approaches and customize them for the AgriFood sector according the application requirements and constraints. The benchmarking must include a thorough study of the existing consensus algorithms to understand if the existing ones are compliant with the requirements of the AgriFood sector. These system are required to guarantee interoperability among distributed and heterogeneous systems, which can be a great challenge considering that such systems need to integrate data collected from different sources and formats. IoT nodes and communication protocols need to be considered to make sure that the collection of data is perform in accordance to their requirements. This leads to the study of the data models and the security on data transference from and to the Blockchain services. From a technological perspective the systems must be tamper proof as well as flexible and financially viable in order to improve acceptance.

The development and implementation of Blockchain is still in the early stages of its maturity and there are several methodologies to implement these systems creating a sense of uncertainty. Another issue that need urgent action is the lack of standardization. The authors have grouped these challenges under the methodological group.

The implementation of traceability systems in the AgriFood sector needs to be a subject of legislation and certification of the solutions. Also the implementation of the smart contracts is not yet regulated adding another layer of mistrust and contributing to the resistance to adoption of these systems.

All the challenges identified previously leads to the last group, the behavioural challenges group, which includes the lack of trust by the AgriFood chain players and the resistance in implementing Blockchain traceability system in their businesses.

Addressing the challenges presented in the other groups will contribute to the resolution of the lack of trust and consequently the increase the willing to adopt these systems. Last but not least, it is of great importance to increase the Technology Readiness Levels (TRL) level of the systems in order to move the prototypes and laboratory solutions from the experimental environments to the market.

5 Conclusions

Traceability systems are currently widely studied and considered to be applied to AgriFood supply chain since it can positively impact the sector by allowing the decrease in the time needed to recall and withdraw products dangerous for the public health, thus improving consumers' safety and confidence.

This paper presented an overview on the topics related to the application of DLT to the AgriFood sector, such as the description of the supply chain and how it would benefit of the application of traceability systems. Several topics regarding in inner works of Blockchain are exposed, namely the working principles and technologies used to implement it. Addicionally, the authors identified several existing solutions that take advantage of this technology to implement traceability in the AgriFood sector. All this work has converged in the identification of the several existing challenges of the application of Blockchain technology in the AgriFood sector. From the identified challenges was possible to recognize research opportunities.

Future work will be devoted to the structuring of a research work intended to contribute to further develop maturity of the Blockchain based AgriFood traceability systems.

Acknowledgments

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MULTI-AGENT SYSTEMS TO REALIZE INTELLIGENT ASSET ADMINISTRATION SHELLS

SISTEMAS MULTIAGENTES PARA UNA ADMINISTRACIÓN INTELIGENTE DE ACTIVOS

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ABSTRACT: The digital transformation driven by the fourth industrial revolution is promoting the transition of traditional manufacturing systems towards flexible, reconfigurable and intelligent factories based on Cyber-Physical Systems (CPS), bringing new opportunities and innovative solutions for modern manufacturing systems. However, this condition imposes complex planning across the production chain and lifecycle of the industry. In this context, the Reference Architecture Model Industrie 4.0 (RAMI4.0) provides guidelines to develop Industry 4.0 (I4.0) compliant solutions based on industrial standards. As the main specification of RAMI4.0, the Asset Administration Shell (AAS) is a standardized digital representation of an asset that represents an object of value for the industry. This paper discusses how Multi-Agent Systems (MAS) technology can be used to realize the AAS, mapping their inherits characteristics into AAS functionalities and also extending them, introducing intelligence and data analytics capabilities.

Moreover, it explores the necessity to develop a light and industrial oriented MAS framework to attend the industry requirements, showing the gaps in existing frameworks and some ideas of how to fulfil these requirements.

KEYWORDS: multi-agent systems; cyber-physical systems; asset administration shell.

RESUMEN: La transformación digital impulsada por la cuarta revolución industrial está promoviendo la transición de los sistemas de fabricación tradicionales hacia fábricas flexibles, reconfigurables e inteligentes basadas en sistemas sistemas físicos (CPS), lo que aporta nuevas oportunidades y soluciones innovadoras para los sistemas de fabricación modernos. Sin embargo, esta condición impone una planificación compleja en toda la cadena de producción y el ciclo de vida de la industria. En este contexto, el Modelo de Arquitectura de Referencia de la Industria 4.0 (RAMI4.0) proporciona directrices para desarrollar soluciones conformes con la Industria 4.0 (I4.0) basadas en estándares industriales. Como especificación principal de RAMI4.0, AAS es una representación digital estandarizada de un activo que representa un objeto de valor para la industria. En este documento se analiza cómo puede utilizarse la tecnología de los sistemas multiagentes (MAS) para realizar el AAS mapeando sus características heredadas en funcionalidades AAS y también ampliándolas, introduciendo capacidades de inteligencia y análisis de datos. Además, explora la necesidad de desarrollar un marco de trabajo más ligero y orientado a la industria para atender los requisitos de la misma.

PALABRAS CLAVE: sistemas multiagente; sistemas ciber-físicos; administración de activos.

1 Introduction

The digital transformation driven by the fourth industrial revolution is promoting the transition of traditional manufacturing systems towards flexible, reconfigurable and intelligent factories based on Cyber-Physical Systems (CPS) [22]. As a backbone of the Industry 4.0 (I4.0), CPS creates digital ecosystems through the combination and coordination between the cyber and physical counterparts, supported by the information communication technologies (ICT) to develop complex large-scale and intelligent systems [3]. However, the development of these I4.0 systems is not a straightforward task, requiring the adoption of new production system architectures as a key enabler to reduce complexity and achieve interoperability in the industry [11].

A set of specifications for proceeding digitalizing industrial system is offered by the Reference Architecture Model Industrie 4.0 (RAMI4.0) [23]. RAMI4.0 is a three-dimensional model that provides guidelines to develop I4.0 compliant solutions based on industrial standards. As the main specification of RAMI4.0, the Asset Administration Shell (AAS) is a standardized digital representation of an asset that represents an object of value for the industry. The AAS encapsulates the logic/physical asset, transforming it into an I4.0 component, allowing the access and control of the asset information, and provides an interface communication with other I4.0 components based on the Service-Oriented Architecture (SOA) [16, 22, 23].

In this context, Multi-Agent System (MAS) [21] is a suitable approach to realize CPS and particularly AAS, providing means to implement the key functionalities of AAS, such as providing a digital representation of the asset, collecting data and enabling I4.0 components interactions [11], as well as embed and decentralize the intelligence over the system. MAS comprises a society of autonomous, proactive and cooperatives entities, called agents, that represents physical/logical objects in the system. The agents are endowed with communication and self-x capabilities in order to exchange information and make decisions according to the conditions changes.

Having this in mind, this work discusses how MAS can be used to realize the AAS, mapping their inherits characteristics into AAS functionalities and also providing new functionalities. Moreover, it explores the necessity to develop a light and industrial oriented MAS framework to attend the industry requirements, showing the gaps in existing frameworks and some ideas of how to fulfil these requirements.

The rest of this paper is organized as follows. Section 2 overviews the related work related to the development of emergent industrial CPS, namely regarding Industry 4.0 compliant solutions. For this purpose, the RAMI4.0 architecture is re-visited, as well as its main specification, i.e. the Asset Administration Shell (AAS). Section 3 discusses how MAS can be used to realize AAS by mapping their inherent functionalities and extending with new functionalities, e.g., decision-making capabilities. Section 4 describes the need to develop a light and industrial oriented MAS framework that can support a wider adoption of agentbased AAS solutions. Finally, Section 5 rounds up the paper with the conclusions and points out future work.

2 Related Work

2.1 RAMI4.0

RAMI4.0 is a three-dimensional layer model that provides a flexible serviceoriented framework, combining services and data to facilitate and address different aspects of the I4.0 systems. RAMI4.0 classifies existing standards along three dimensions, namely, Lifecycle and Value Stream, Hierarchy Levels, and Layers [23].

The *Layers* represents various properties of an I4.0 component through six layers, namely, asset, integration, communication, information, functional and business. The *asset* reflects the physical world such as physical and non-physical objects (e.g., machines, services or documents), managed by the upper layers, which are in the digital world. The *integration* represents the transition from the real to the digital world, providing the assets information in a form which can be processed by a computer. The *communication* provides a standard communication, using uniform data format to the *information* level, and services to the *integration* level. The *information* describes the information that is used and exchanged between functionalities, services and components, using a common semantic definition. The *functional* describes the functionalities of an asset according to its role in the I4.0 system. The *business* includes information regarding the business-related features of the assets under the legal and regulatory constraints [4, 18, 23].

The *Lifecycle and Value Stream* follow the IEC 62890 standard and describes the asset lifecycle throughout the supply chain, since an asset can perform different functions and different data can be collected during its lifecycle. This recorded information may be used to make corrections and improvements during the asset lifecycle. The *Hierarchy Levels* follows the IEC 62264 and IEC 61512 standards, and describes the different functionalities within factories or facilities, namely product, field device, control device, station, work center, enterprise and connected word, based on the so-called automation pyramid [23].

As a reference model, the descriptions of RAMI4.0 are implemented through the I4.0 components, a specific case of CPS [22]. The I4.0 components combine the assets with their digital representation, called Asset Administration Shell (AAS), the main specification of RAMI4.0. The asset is a physical or nonphysical component with value for a company, which needs to be connected to create I4.0 compliant solutions. In this context, the AAS provides means to integrate the asset into I4.0 environment, allow the access to the asset information, provides a standardized and secure communication interface, and covers the asset lifecycle. Furthermore, the AAS structure illustrated in Figure 1, consists of a number of submodels in which all the information and functionalities of the asset, including the manifest, i.e., a list of properties, are described and managed by the component manager [16, 22, 24].

The Industrial Internet Reference Architecture (IIRA) [8] is another reference standards-based open architecture for Industrial IoT systems, which may be used to complement missing aspects in RAMI4.0. Unlike RAMI4.0, which develops a solid base of service-oriented interoperability, focusing on the digitization of manufacturing, through the I4.0 component, in particular the AAS. The IIRA focuses on industrial analytics, highlighting the collection and analysis of machine data, applying analytical insights in decision making, which would be beneficial for building intelligent I4.0 systems [9].

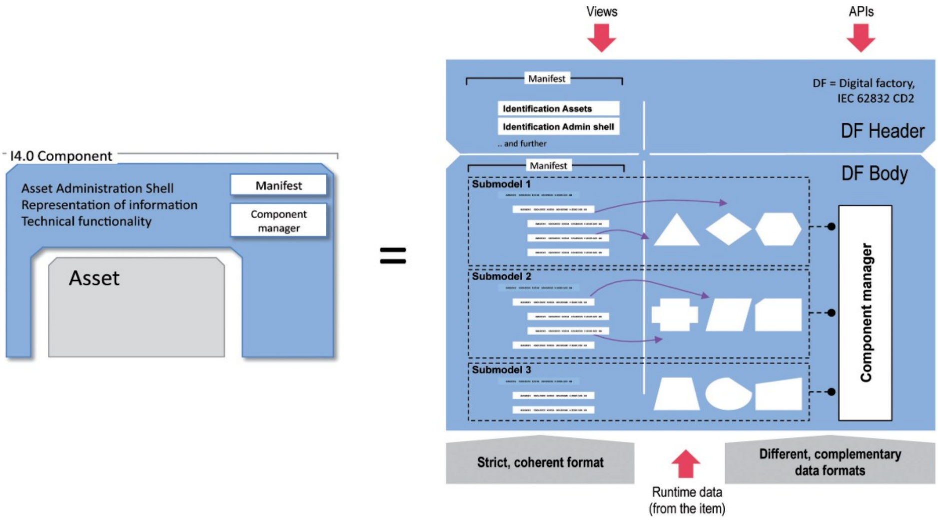

Fig. 1. Asset Administration Shell structure [24].

2.2 Multi-Agent Systems

Derived from the area of distributed AI, MAS comprises a society of autonomous and intelligent entities, named agents, which represent physical or logical objects in the system [21]. The global functioning of these systems emerges from the interaction between the different agents, whose autonomy, cooperativeness and proactivity play a fundamental role in the agents behaviour, promoting modularity, reconfigurability and flexibility to the system.

MAS are a suitable technology for decentralized architecture in industrial environments, as well as embedding intelligence in the system. The agents are distributed over the environment, interacting with each other and the environment, in order to reach a particular or a common goal, exchanging information, making decisions and adapting their behaviour according to condition changes [2,21]. Furthermore, MAS and more specifically industrial agents can be used for realizing industrial CPS. The industrial agents expand the potential application domains of MAS, having the inherits characteristics of traditional agents and the capability to interface low-level control of industrial automation systems, addressing industry requirements [10].

3 MAS to Realize AAS

Due to their characteristics, MAS are a promising technology to realize AAS. The agents can encapsulate the AAS structure, access the asset information, and enable I4.0 interactions with other AAS. Some of the MAS characteristics, such as encapsulation, reusability, reactivity, social ability, learning ability, proactivity, cooperation, autonomy and service-orientation, can be mapping to implement the AAS functionalities associated with the RAMI4.0 layers as illustrated in Table 1.

The encapsulation allows the agent knows the properties and functions of the asset, which is solely accessible by the agent itself, since not all information of asset must be visible and changed from outside [20]. As a software component, some generic structures and functionalities of agents can be reused to encapsulate the assets, making only adaptations to meet the specifics of the asset when necessary. The reactivity of agents allows establishing a bridge with the digital world, perceiving the real-world by sensors and low-level control devices, and acting to achieve their goals. These interfaces can be assisted by the IEEE 2660.1 standard [7], which provides recommended practices to interconnect software agents with low-level automation functions.

Table 1. Mapping MAS into AAS functionalities [17]

RAMI4.0 Layers	AAS Functionalities	MAS Characteristics	MAS Support Functionalities
Asset	Provide a digital representation of the asset	Encapsulation Reusability	JADE framework to develop the MAS-based solution compliant with FIPA
Integration	Establish a connection between the asset and its digital representation	Reactivity	Recommended practices by IEEE 2660.1. standard of how to interconnect software agents with low-level automation functions
Communication	Access the asset information and establish the communication with the other assets	Socialability	Communication by FIPA-ACL messages Client-Server or Publish-Subscribe schema Lightweight IoT protocols, e.g., MQTT
Information	Provide data in a structured and integrated manner	Learningability	Combine MAS with data models, such as AutomationML, to support the exchange of data in a structured and integrated manner
Functional	Provide functions based on the collected information	Proactivity Cooperation	Combine MAS with ML algorithms, IoT technologies, data analytics, computational processing layer (edge, fog and cloud) and Intelligent Products
Business	Provide services based on the AAS functions	Autonomy Service-orientation	Combine MAS with Service-Oriented Architecture The Directory Facilitator from the agent platform allows the registration and discovery services

Agents are also endowed with social abilities, which enable the interaction with other agents. These interactions are based on a semantic definition and ontologies, following a client-server or publish-subscribe schema. In this sense, the communication between AAS may be perfectly realized by agents following the standardized FIPA-ACL communication language or using lightweight IoT communication protocols, e.g., Message Queuing Telemetry Transport (MQTT). Furthermore, from the learning abilities of agents, their knowledge can be provided in a structured and integrated manner to other

I4.0 components, recurring the adoption of standard approaches for data exchange, e.g., AutomationML.

The proactivity and cooperation enable agents starts their tasks itself in order to reach the asset objectives, cooperating or not with other agents. For this purpose, the agents can extend the AAS functionalities, acting as intelligent products to cover the asset lifecycle, and vessels for ML algorithms and data analytics capabilities to support monitoring, diagnosis, prediction and optimization. Moreover, the agent may enable the distributed intelligence process on the cloud, fog and edge. Lastly, the autonomy and service-orientation allow agents formulate strategies based on the business-related features and provided the asset functionalities as a service, implementing the concept of directory facilitator (DF) for registration and discovery services, following FIPA specifications, and combining MAS with SOA.

The mapping of MAS characteristics into AAS functionalities provides an overview of how MAS technology fulfils the requirements to realize AAS. However, other aspects also need to be considering, such as the concepts involved, the technologies to complement MAS, the methodology to digitizing assets, and the MAS-based framework to implement the AAS. Figure 2 illustrates a conceptual map with all these aspects.

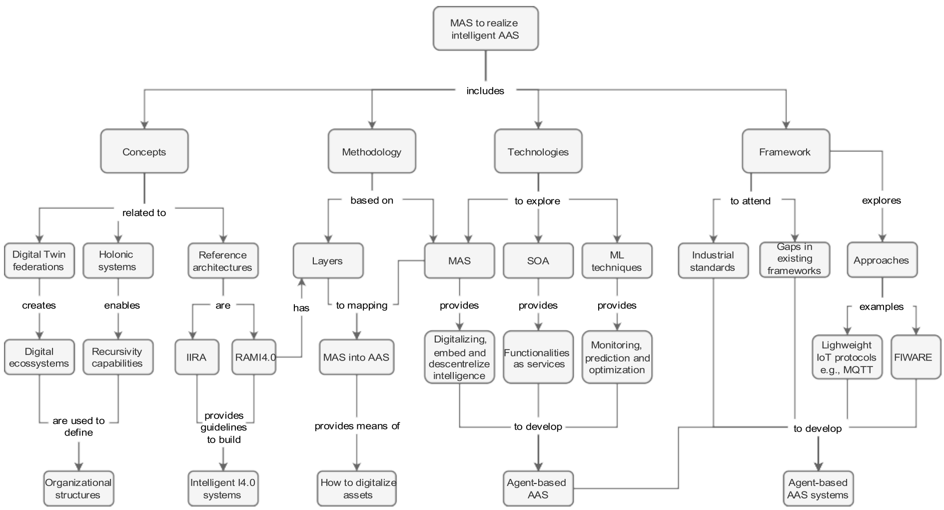

Fig. 2. Conceptual map with the aspects to consider to realize the AAS using MAS.

The first aspect to consider is the concepts included, which will provide the basis for realising the agent-based AAS. In this context, references architectures like RAMI4.0 and IIRA may support compliance with I4.0 solutions, providing guidelines based on industry standards to develop intelligent I4.0 systems. The RAMI4.0 focusing on the AAS specification to develop an interoperable network between I4.0 components and systems. In the other hand, the IIRA focusing on industrial analytics, processing and analysing data from assets to build intelligent components. Furthermore, the holonic principles and Digital Twin federations are another important concepts to develop organisational structures, taking the advantages of recursivity capabilities, e.g., in cases that one asset is composed by other assets, or even a factory can represent an asset and have its AAS, but also each asset within the factory can have its own AAS.

Besides MAS, the main technology used to realizing the AAS, other technologies need to be considered to support the implementation and extend the AAS functionalities. For instance, ML techniques may be used to support the analysis of collected data aiming monitoring, diagnosis, prediction and optimization, which combined with SOA enables to offer these functionalities in the form of services accessible for all I4.0 components. Moreover, the development of a methodology to digitalize assets is required to guide the stakeholders about the prerequisites and analysis to determine why, what and how to digitalize the assets, since this process has to bring added value to the industry. In this context, the mapping of MAS characteristics into AAS functionalities based on RAMI4.0 layers may assist in answering how digitalizing the assets. In the other hand, to answer what and why, the business-related features based on the industry strategies and the customer demands need to be deeply analyzed.

Another aspect to taking account is the development of a light framework for agent-based AAS systems, since the currently MAS-based frameworks do not support the development of I4.0 compliant solutions, which restrict the wide adoption of MAS solutions in these scenarios. Section 4 will deeply address this topic, showing the gaps in existing frameworks and some ideas of how to fulfil these requirements.

4 Need for a Light and Industrial Oriented MAS Framework

The development of a MAS-based system should follow existing standards in this field. The Foundation for Intelligent Physical Agents (FIPA) [1] provides a set of specifications for the development of heterogeneous agent-oriented systems. FIPA specifications represent a collection of standards that are grouped in different categories (see Figure 3) [1, 14]:

- Applications: refer to the application areas where FIPA agents can be deployed, representing ontology and service descriptions specifications for a particular domain.
- Abstract architecture: provides entities which are required to build agent services and agent environments.
- Agent communication: deals with Agent Communication Language (ACL) messages, interaction protocols, speech act theory-based communicative acts and content language representations, to support the exchange of messages between agents.
- Agent management: specifies a reference model for the creation, registration, location, communication, migration and retirement of agents.
- Agent message transport: deals with the transport and representation of messages across different network transport protocols.

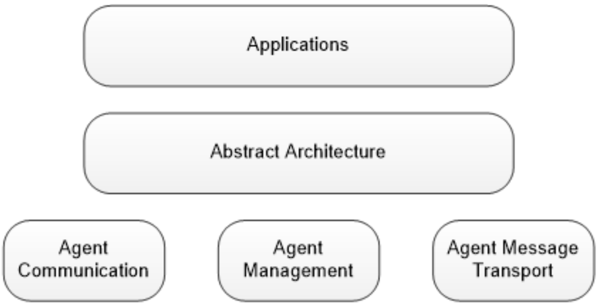

Fig. 3. Categories of the FIPA specifications [1].

Due to the high popularity of the FIPA-compliant Java Agent DEvelopment (JADE) framework [2], FIPA is usually adopted by the agent developers community. JADE aims to simplify the development of MAS by providing a set of services and agents in compliance with the FIPA specifications, e.g. naming service and yellow-page service, message transport and parsing service, and a library of FIPA interaction protocols ready to be used [2, 13]. JADE is a Java-based architecture that uses the Java Remote Method Invocation (RMI) to support the creation of distributed Java technology-based applications. Each agent is implemented with Java «threads» and associated with a container, using the concept of behaviours to model concurrent tasks in agent programming [2]. Aiming to simplify the debug of developed applications, JADE provides a set of useful tools, e.g., Dummy, Sniffer and Introspector.

Industrial applications, and particularly the industrial CPS environments, impose strong requirements that may affect the adequacy of the existing MAS frameworks, and particularly the JADE framework, for the adoption of the agent technology. Examples of these requirements are the integration with hardware devices, industrial standard compliance, reliability, fault-tolerance, scalability, quality assurance, resilience, manageability and maintainability [6, 12, 19].

In particular, the JADE framework presents the following limitations [14]:

– Need for real-time interaction protocols for industrial and large-scale systems, ensuring scalability and latency.
– Need to adopt IoT technologies for the interconnection among the agents, and particularly a publish-subscribe schema that ensures loosely coupled integration.
– Need for distributed yellow pages service and discovery mechanism to improve the system robustness.
– Need to combine agents and services to support interoperability, allowing to agents to encapsulate their functionalities as services that are offered, discovered and consumed by other agents (acting as service consumers).
– Need to integrate agents and low-level automation functions, as well as legacy systems, using standard interfaces, e.g., the recent established IEEE 2660.12020 standard.
– Need to simplify the debug and maintenance of agent-based applications (note that in the essence, the agents developed using the JADE platform are Java Threads, which makes the debugging of multi-threading very difficult).

In this context, the development of a light and industrial oriented MAS framework is fundamental to attend the industrial requirements, considering the communication between I4.0 components, the structure to interconnect all the modules and the integration with hardware devices. Figure 4 illustrates some aspects to consider in this framework, mainly the MQTT protocol, FIWARE [5] and service-orientation. For communication, the use of lightweight IoT protocols, e.g., MQTT that is based on the publish-subscribe paradigm, is a suitable alternative to provide highly scalable solutions. Instead of client-server protocols which demand communication directly, the publish-subscribe does not rely on a direct connection between the data producers and the data consumers, having a message broker to deliver the messages. Furthermore, MQTT provides small message headers to optimize network bandwidth, reliable message delivery and security aspects [15].

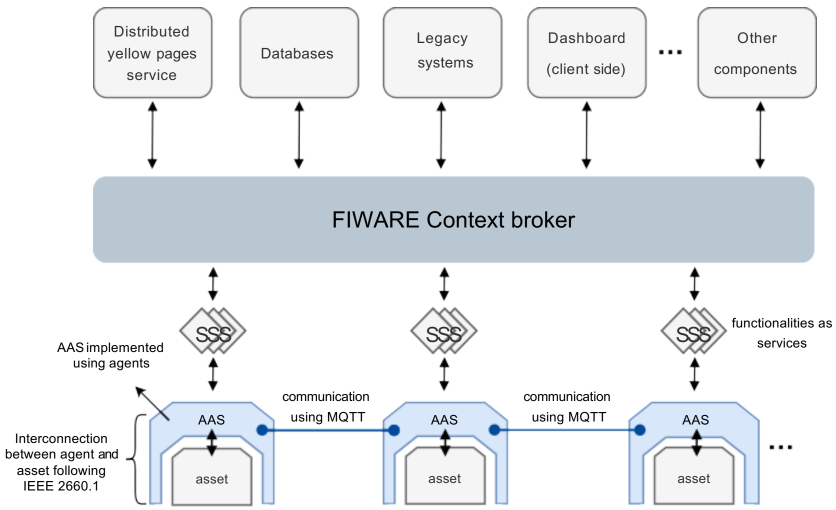

Fig. 4. Aspects to consider in the framework for agent-based AAS systems.

Another pertinent issue is related to create an interoperable network of I4.0 components. For this purpose, FIWARE [5] is an open-source platform that enables the integration of components (including legacy systems) and provides the conditions for the development of smart solutions. FIWARE has the context broker as the core component, which enables the interfacing with

IoT devices, robots and third-party systems, and also the processing, analysis, and manage of context information in a highly decentralized manner. These interfaces are realized by entities, called IoT Agents, that facilitates the interface with devices using protocols like HTTP, MQTT and OPC UA. In this sense, the recommended practices from IEEE 2660.1 standard may also assist and complement these interfaces realized by the IoT Agents from FIWARE.

Additionally, other aspects can be considered, for instance, the adoption of SOA to provide the AAS functionalities as services, as well as the ML techniques, where each I4.0 component can require these services from a distributed yellow pages service and discovery mechanisms. Also, the strategies to distribute the intelligence among edge, fog and cloud computing layers, since each layer presents differences in terms of functional, data analysis, technological and implementation aspects.

5 Conclusions and Future Work

The digitalization associated with Industry 4.0 brings several benefits and opportunities for innovative solutions based on Cyber-Physical Systems, but also new challenges for modern manufacturing systems. RAMI4.0 is a reference architecture that provides guidelines to develop I4.0 compliant solutions based on industrial standards, aiming to reduce the complexity and achieve interoperability in these systems. As a reference model, the I4.0 components implement this model in practice, combining the asset with its digital representation, the AAS. In this context, MAS is a suitable approach to implement the key functionalities of AAS, as well as to embed intelligence in the system.

This paper discusses how MAS technology can be used to realize the AAS, mapping their characteristics into AAS functionalities and also extending them, introducing intelligence and data analytics capabilities. Additionally, also considered other aspects involved, as the fundamental concepts to support the development of an agent-based AAS, namely the references architectures compliant with I4.0 solutions like RAMI4.0 and IIRA, and Holonic principles and Digital Twin federations to build organizational structures. Furthermore, the paper discussed the needs of developing a methodology to digitalize assets aiming to provide guidelines for stakeholders of why, what and how to digitalize. Lastly, the gaps in existing frameworks to attend the industrial requirements were analyzed, showing some ideas of how to fulfil these requirements using the MQTT protocol, FIWARE and industrial standards.

Future work will be devoted to developing a methodology to digitize assets based on the mapping of MAS characteristics into AAS functionalities, as well as the development of a light framework for agent-based AAS systems.

Acknowledgments

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MULTI-ACCESS EDGE COMPUTING: CARACTERÍSTICAS Y APLICACIÓN EN ENTORNOS RURALES DE BAJA DENSIDAD DE POBLACIÓN

MULTI-ACCESS EDGE COMPUTING: CHARACTERISTICS AND APPLICATION IN LOW POPULATION DENSITY RURAL ENVIRONMENTS POPULATION

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Resumen: Con la aparición de tecnologías disruptivas como Internet de las Cosas (IoT), Industria 4.0 o Realidad Virtual (VR), entre otras, cada vez hay más servicios y dispositivos con diferentes características que se interconectan mediante redes de comunicaciones y necesitan capacidades de computación y almacenamiento con las que, en principio, no cuentan. Para superar este problema se propuso la solución de computación en la nube (*cloud computing*), que consiste básicamente en confiar las tareas más pesadas a un servidor central con alta potencia computacional. A primera vista este enfoque resuelve el problema, pero, como generalmente estos servidores centrales (*data centers*) se encuentran lejos de los dispositivos finales, aparecen nuevos problemas, especialmente con respecto al aumento de la latencia. La siguiente propuesta es el MEC (*Multiaccess Edge Computing*, o computación de acceso múltiple en el borde), que es similar a la computación en la nube, pero se basa en servidores más cercanos a los usuarios, esto es, «en el borde» de la red de acceso, en lugar de servidores lejanos «en la nube». Este artículo ofrece una revisión de las principales características, de MEC, haciendo énfasis en su aplicación en escenarios como muchas regiones hispano-portuguesas, con baja densidad de población, grandes distancias entre ciudades o pueblos, y con un importante porcentaje de entornos rurales.

Palabras clave: MEC; multi-access edge computing; tecnologías disruptivas; internet of things; (Iot); latencia; 5g; virtualización.

Abstract: With the emergence of disruptive technologies such as the Internet of Things (IoT), Industry 4.0 or Virtual Reality (VR), among others, there are more and more services and devices with different more and more services and devices with different characteristics that are interconnected through communication networks and require computing and storage capacities with which, in principle, they do not have. The cloud computing solution was proposed to overcome this problem by entrusting the heaviest tasks to a central server with high computational power. At first glance, this approach solves the problem, but as these central servers (data centres) are usually located far away from the end devices, especially concerning increased latency. The following proposal is MEC (Multiaccess Edge Computing), which is similar to MEC (Multiaccess Edge Computing), which is identical to MEC (Multiaccess Edge Computing), which is similar to cloud computing but relies on servers closer to the users, i.e. «at the edge» of the access network, instead of distant servers «at the edge» of the access network. This article provides a review of the main features of SCM, with an emphasis on its application in scenarios such as many Spanish-Portuguese regions, with low population density, large distances between cities or population, large distances between cities or towns, and with a significant percentage of rural environments.

Keywords: multi-access edge computing; disruptive technologies; internet of things (IoT); latency; 5G; virtualisation.

1 Introducción

La evolución de Internet en las últimas décadas ha sido evidentemente rápida y acelerada, pasando de unas pocas conexiones al inicio, a los miles de millones de dispositivos diferentes que envían y solicitan datos hacia y desde la red que vemos hoy en día. Además del crecimiento en el número de conexiones, la conectividad de Internet se ha vuelto considerablemente diversa, incluyendo no solo computadoras y servidores personales tradicionales, sino también un conjunto muy variado de dispositivos con diferentes y muchas veces altos requisitos. La Fig. 1 ilustra la evolución de Internet de las conexiones desde las redes de igual a igual (P2P), al nuevo concepto llamado Internet táctil, que tiene como objetivo incluir sensaciones táctiles y hápticas en las telecomunicaciones, permitiendo que los humanos y las máquinas interactúen con su entorno en tiempo real.

La mencionada evolución de las conexiones ha hecho posible la aparición y difusión de nuevas tecnologías y aplicaciones relacionadas con la Internet de las Cosas (IoT). La evolución de IoT se ha visto impulsada con la aparición de tecnologías relacionadas con la quinta generación de comunicaciones móviles (5G) [1], lo que hace posible cumplir con nuevos requisitos como velocidades de datos más altas, latencia muy baja, permitir un número muy alto de dispositivos conectados y alta eficiencia espectral.

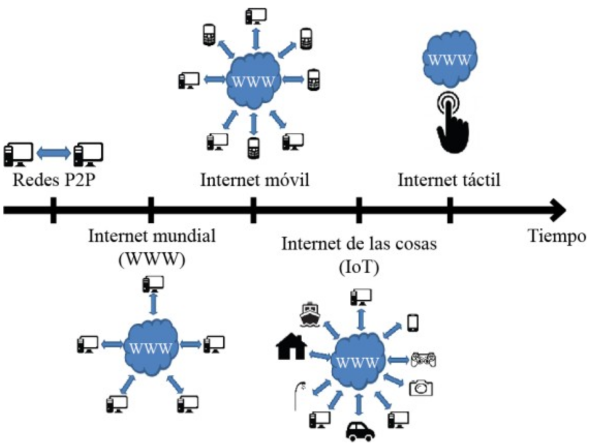

Fig. 1. Línea del tiempo de Internet.

Con estas tecnologías disruptivas, aparecen nuevos desafíos y problemas. Uno de estos desafíos surge de la existencia de dispositivos con diversas características que se interconectan mediante redes de comunicaciones y necesitan capacidades de computación y almacenamiento con las que, en principio, no cuentan. Por ejemplo, muchos dispositivos IoT tienen recursos limitados de almacenamiento, procesamiento y comunicación. Para superar este problema se propuso una nueva área de investigación denominada *Mobile Cloud Computing* (MCC) [2], que consiste básicamente en delegar las tareas más pesadas a un servidor externo con alta potencia computacional. La conexión de ambos dispositivos se hace a través de la red de comunicaciones, Internet. A primera vista, este enfoque resuelve el problema, pero, dado que generalmente estos servidores se encuentran en *data centers* lejos de los dispositivos finales, aparecen nuevos problemas, especialmente con respecto al aumento de latencia y la congestión de la red. Una representación gráfica general de la arquitectura de MCC se aprecia en la Fig. 2, en donde la información debe atravesar el borde (*edge*), y luego pasar por Internet hasta llegar al servidor *cloud*.

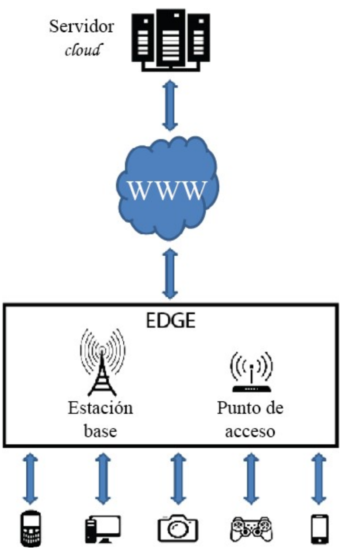

Fig. 2. Arquitectura de MCC.

Para tratar los problemas mencionados de MCC, en 2015, el Grupo de Especificación de la Industria (ISG, por sus siglas *Industry Specification Group*) del Instituto Europeo de Estándares de Telecomunicaciones (ETSI, *European Telecommunications Standards Institute*), introdujo el concepto de *Mobile Edge Computing* (MEC) [3]; destinado a transferir la mayoría de las funcionalidades de computación y almacenamiento de MCC al borde (*edge*) de las redes móviles (esto es, en servidores localizados en estaciones base). De esta manera, el retardo del sistema se reduce considerablemente en comparación con MCC, además, la congestión para la red de *backhaul* también disminuye ya que muchas peticiones pueden ser resueltas por los servidores MEC sin traspasar el borde (*edge*).

En 2017, la ETSI cambió la palabra «*Mobile*» en las siglas por «*Multi-Access*», de tal manera que MEC pasó a significar *Multi-Access Edge Computing*. El objetivo de este cambio de nombre era incluir no solo tecnologías móviles en el MEC, sino también otras como redes fijas y Wi-Fi.

Al igual que las tecnologías 5G impulsaron a IoT a mejorar, MEC está demostrando ser una tecnología útil que complementa a ambas. Hay varias aplicaciones que utilizan MEC en el ámbito de la industria 4.0, robótica, telepresencia, realidad aumentada (AR), realidad virtual (VR), agricultura inteligente, atención médica, conducción autónoma, ciudades inteligentes y vehículos inteligentes, por nombrar solo algunas.

La motivación de este artículo es contextualizar y presentar la tecnología MEC junto con sus principales características y aplicaciones, y evaluar sus ventajas si se implementa en zonas rurales de escasa densidad de población, como muchas regiones de España y Portugal. El resto del artículo está organizado de la siguiente manera. La sección 2 presenta una descripción general de la tecnología MEC, incluidas sus principales características, tecnologías y aplicaciones. En la sección 3 se ofrece un análisis de la relación entre la densidad de población de una zona y la cobertura de las redes de telecomunicaciones en la misma. La sección 4 presenta algunas ideas y reflexiones sobre la aplicabilidad de MEC a entornos rurales y escasamente poblados.

2 Visión general de MEC

El objetivo de esta sección es establecer un contexto para evaluar, en las siguientes secciones, la aplicabilidad de las tecnologías MEC en áreas rurales con baja densidad de población y largas distancias. En [4], se realiza un estudio completo sobre MEC hacia la inteligencia de borde (*edge intelligence*) en el contexto de 5G e IoT y se propone un caso de uso. En [5], los autores expresan la asociatividad tanto de MEC como de IoT como factores esenciales para la realización de 5G en términos de escenarios de aplicación y atributos técnicos clave (KPI, *Key Performance Indicators*). Además, el trabajo de [6] presenta un estudio sobre MEC y se centra en las tecnologías clave fundamentales que habilitan el 5G.

2.1 Principales características

Para tener una perspectiva más clara de las características y posibles ventajas o desventajas de MEC, mostramos en la Tabla 1 una comparación entre MEC y las dos principales alternativas: MCC y computación local. La computación local se caracteriza por ser los dispositivos finales los que realizan todas las operaciones requeridas por sí mismos, incluidas las tareas de computación y almacenamiento, sin delegar ninguna responsabilidad a fuentes externas de MEC o MCC. Definimos seis parámetros para evaluar y comparar las tres tecnologías: latencia, coste, disponibilidad, capacidad, flexibilidad y seguridad.

Latencia. En cuanto a la latencia, la computación local es el enfoque más conveniente, ya que todos los procesos se realizan dentro del mismo dispositivo. El problema de esta solución es que solo es factible si el equipo local cuenta con todos los requisitos de la aplicación en particular: capacidad de computación, capacidad de almacenamiento y autonomía energética. De lo contrario, es mejor utilizar MCC o MEC. Por otro lado, MCC ofrece generalmente un buen desempeño en términos de capacidades informáticas y energéticas, pero la latencia puede llegar a ser alta ya que los servidores en la nube pueden ubicarse a grandes distancias del usuario (cientos de kilómetros o incluso más). Finalmente, MEC se presenta como un punto intermedio, en el que existen servidores externos que dan soporte a los usuarios finales que lo necesitan, pero estos servidores no son dispositivos centralizados en algún centro de datos lejano, sino dispositivos más cercanos, generalmente en el borde de la red de acceso de radio (RAN, *Radio Access Network*), por ejemplo, en estaciones base, proporcionando baja latencia y alto ancho de banda a las aplicaciones sin necesidad de que el usuario posea equipos costosos capaces de realizar todas las tareas requeridas.

Coste. En la computación local, los dispositivos finales deben poder realizar todas las tareas requeridas por sí mismos, lo que se traduce en la necesidad de un hardware más potente y, por lo tanto, mayores costes para el usuario. Este no es el caso de MCC y MEC, donde los servidores pueden ofrecer soporte a los dispositivos finales con una gran carga sin importantes inversiones en hardware por parte del usuario. Además, las tareas más pesadas suelen consumir grandes cantidades de energía, y muchas aplicaciones, como la instrumentación IoT, están muy limitadas por la batería.

Disponibilidad. Entendiendo la disponibilidad como la posibilidad de acceder a los recursos en cualquier momento, los tres enfoques ofrecen buenos resultados, pero dependiendo del punto de vista, la computación local podría ser mejor o peor, dado que, al poseer todos los recursos y tenerlos todos en un dispositivo local, siempre están disponibles, incluso cuando falla la conexión a internet o el servidor, pero por otro lado, si el dispositivo local es el que falla o falta, el usuario no podrá acceder a la información, lo que hace que MEC y MCC tengan una mejor disponibilidad. Si se produce un fallo en la conexión o en el servidor usando MEC o MCC, el sistema fallará, pero sin embargo, hoy en día este tipo de fallos son poco probables en la mayoría de escenarios (debido a mecanismos de restauración y redundancia). Por lo tanto, la disponibilidad de MCC y MEC también se considera alta.

Capacidad. En términos de capacidad o potencia computacional, en computación local tenemos valores muy bajos, a menos que el usuario final posea equipos muy sofisticados, lo cual no es tan frecuente, principalmente teniendo en cuenta que muchas aplicaciones modernas son sistemas IoT compuestos por una gran cantidad de pequeños sensores o actuadores sin capacidades informáticas destacadas. El caso contrario es MCC, en el que, generalmente, el servidor en la nube cuenta con una alta potencia de procesamiento y almacenamiento. Un punto intermedio podría ser MEC. Los servidores *edge* generalmente no tienen capacidades tan altas como los servidores en la nube, pero resultan útiles y suficientes para numerosas aplicaciones.

Flexibilidad. En este contexto, consideramos la flexibilidad como la capacidad del servicio para ser modificado sin importantes esfuerzos o inversiones. Cuando el servicio está basado en MEC, en caso de que los requisitos cambien en algún aspecto, o incluso si se convierte en un servicio completamente diferente, no es un problema reorganizar los recursos destinados a este servicio en el servidor MEC, e incluso es posible redistribuir la carga entre múltiples servidores en caso de que sea necesario [7]. También hay propuestas que combinan de forma cooperativa los recursos de la nube y del borde para realizar la descarga de cálculo (*offloading*) [8]. Gracias a tecnologías como máquinas virtuales (VM), virtualización de funciones de red (NFV) y contenedores [6], es muy fácil asignar solo los recursos necesarios a cada servicio, y eliminarlos o modificarlos sin esfuerzos considerables y sin ningún cambio de hardware. Estas técnicas de virtualización están disponibles tanto en MCC como en MEC. MCC comparte la mayoría de las ventajas de flexibilidad de MEC, pero como es un sistema más centralizado que MEC, es un poco menos flexible.

Tabla 1. Comparación cualitativa entre Computación local, MEC y MCC.

	Computación local	MEC	MCC
Latencia	Muy baja	Baja	Alta
Coste	Alta	Baja	Baja
Disponibilidad	Alta	Alta	Alta
Capacidad	Baja	Media	Alta
Flexibilidad	Baja	Muy alta	Alta
Seguridad	Alta	Alta	Media

Seguridad. En materia de seguridad, la computación local tiene ventaja desde el punto de vista de que la información no se transmite al exterior, evitando cualquier posibilidad de fuga o corrupción de datos. Por otro lado, MEC y MCC ofrecen un aspecto positivo si los dispositivos finales fallan o pierden la información, pues los servidores suelen tener una copia y no sería un problema mayor. MEC también es más seguro que MCC en términos de que, debido a que los servidores MEC están más cerca del usuario que los servidores MCC, reduciendo la probabilidad de fuga o corrupción de datos. Además, MCC usualmente presenta gran concentración de la información dado que se basa en grandes servidores centralizados, mientras que MEC utiliza servidores distribuidos y de menor escala, disminuyendo la probabilidad de ataques [4].

2.2 Tecnologías principales

En este apartado revisamos algunas tecnologías importantes para el desarrollo de sistemas basados en MEC.

Virtualización de funciones de red (NFV, *Network Function Virtualization***).** Una de las principales ventajas de MEC es la capacidad de los servidores de ser «independientes del hardware», lo que significa que los dispositivos no tienen que estar especializados físicamente para realizar una función en particular, sino que se utilizan plataformas de computación universales. NFV permite descomponer un servicio dado en funciones de red virtual (VNF, *Virtual Network Functions*), de tal manera que cada VNF realice una tarea específica, y para un servicio en particular, se instancia un conjunto específico de VNF, que se pueden modificar, mezclar o eliminar si necesario, ofreciendo un alto nivel de flexibilidad [9].

Slicing **(rebanado) de red.** Al igual que NFV, el *slicing* de red tiene como objetivo aumentar la flexibilidad y escalabilidad de los servicios ofrecidos, ofreciendo la posibilidad de admitir servicios personalizados bajo demanda en una red física compartida. El *slicing* de red puede asignar porciones o *slices* de recursos de red de forma dinámica y eficiente [6]. Un *slice* se conoce como una instancia de red optimizada para una aplicación o servicio específico [10].

Offloading **(descarga) de cómputo.** Una de las principales ventajas de MEC es la capacidad de hacer uso de los servidores *edge* para «descargar» los dispositivos finales. Con el *offloading* de cómputo surgen múltiples ventajas, como el ahorro de energía y la no necesidad de tener dispositivos finales potentes [11].

Internet de las cosas de banda estrecha (NB-IoT, ***NarrowBand IoT*****).** NB-IoT es una nueva y prometedora tecnología de acceso por radio que puede coexistir con las implementaciones existentes de GSM, UMTS y LTE. De hecho, las especificaciones NB-IoT se han integrado en los estándares LTE [12]. NB-IoT funciona muy bien para dispositivos que tienen un bajo consumo de energía, bajas demandas de transferencia de datos y están geográficamente dispersos o remotos.

2.3 Aplicaciones de MEC

Gracias a las ventajas de MEC y las múltiples tecnologías habilitadoras que lo respaldan, se pueden lograr diversas aplicaciones. La Fig. 3 representa gráficamente algunas de las ramas o aplicaciones que se benefician de MEC, que se describen brevemente a continuación, junto con algunas menciones de trabajos relacionados.

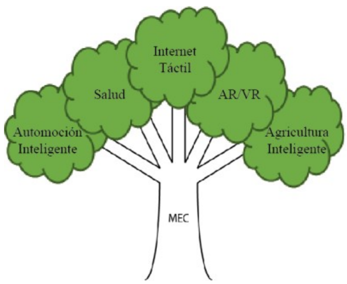

Fig. 3. Campos de aplicación de MEC.

Automoción inteligente. Un campo de aplicación importante de MEC es el sector de la automoción. Por ejemplo, en [13], los autores demuestran cómo las aplicaciones de conducción remota y autónoma, como el rastreo de carriles y la detección de objetos, pueden descargarse a una red 5G habilitada para MEC. Además, la sensorización virtual extendida, o *Extended Virtual Sensing* (EVS), integrada en los automóviles, les permite acceder a sensores externos de una ciudad inteligente, brindando una mayor seguridad y comodidad a los pasajeros, así como a otros actores viales. Este tipo de aplicaciones son especialmente sensibles a la latencia, por lo que el uso de tecnologías MEC es adecuado. Un ejemplo de sistema EVS que utiliza MEC se presenta en [14].

Internet táctil. La Unión Internacional de Telecomunicaciones (ITU) define Internet táctil como el próximo salto evolutivo después de IoT, en el que la alta disponibilidad y seguridad, los tiempos de reacción ultrarrápidos y la confiabilidad de nivel de operador agregarán una nueva dimensión a la interacción entre humanos y máquinas al permitir la interacción táctil y sensaciones hápticas, que permiten a los humanos y las máquinas interactuar con su entorno en tiempo real [15]. Evidentemente, MEC es un habilitador clave para las tecnologías táctiles de Internet, como se describe en [16].

AR/VR. Debido a su naturaleza en tiempo real, la realidad aumentada y la realidad virtual (AR y VR) exigen latencias bajas para ofrecer una experiencia inmersiva y realista. El uso de MEC en aplicaciones AR/VR ya ha sido estudiado. En [17], los autores diseñan un sistema de almacenamiento en caché de realidad virtual de 360° sobre la red de acceso de radio a la nube (C-RAN), donde se implementa un servidor MEC con capacidades de almacenamiento y síntesis de vistas, de tal manera que si el contenido solicitado de una vista de realidad virtual específica está almacenado en el *edge* o se puede sintetizar con la ayuda de las vistas adyacentes almacenadas en caché, no es necesario solicitar el contenido del servidor de fuente de video VR remoto.

Agricultura inteligente. La agricultura inteligente tiene como objetivo mejorar muchos procesos de la agricultura y la ganadería tradicionales mediante la aplicación de tecnologías de la información y la comunicación (TIC). Actualmente existen muchas tecnologías operativas de agricultura inteligente, y muchos otros proyectos y propuestas aún se encuentran en fases de investigación o desarrollo y parecen tener un futuro muy prometedor. En la producción de cultivos se han propuesto tecnologías IoT y MEC. En [18], por ejemplo, se muestra una arquitectura general centrada en la nube, con un nodo *edge* que se utiliza para recopilar datos de una red de sensores distribuidos con el fin de monitorear y predecir algunas enfermedades de los viñedos.

Cuidado de la salud. La implementación de tecnologías sanitarias también está muy relacionada con IoT, 5G y MEC. Hay muchas aplicaciones que ya se están ejecutando y otras están en etapa de investigación. Las tecnologías sanitarias también están relacionadas con algunas otras aplicaciones mencionadas anteriormente, como AR, VR e Internet táctil. Las aplicaciones tecnológicas en el cuidado de la salud incluyen la monitorización de signos vitales y la prevención automática de enfermedades. También se han estudiado propuestas futuristas como la cirugía remota [19]. Gracias a la cirugía remota, en muchos casos en los que se necesita una cirugía de alta dificultad y el especialista adecuado está lejos, será posible realizar la operación sin la necesidad de que el especialista sea trasladado, potencialmente salvando muchas vidas.

3 Impacto de la densidad de población en la infraestructura de telecomunicaciones

Para poder establecer las características y solucionar los retos del despliegue de redes de telecomunicaciones en zonas rurales poco pobladas y con grandes distancias entre ellas, como la región transfronteriza de España y Portugal, evaluaremos la densidad de población, y la calidad de las redes desplegadas en las respectivas zonas.

A continuación se muestra una comparación entre un mapa de densidad de población de España en 2015 (ver Fig. 4) y dos mapas de cobertura de un proveedor de servicios (ver Fig. 5) a fecha de noviembre de 2020. Los mapas de cobertura incluyen el estado real de la implementación de las redes de 4G+ y 5G de un proveedor de servicios específico [21].

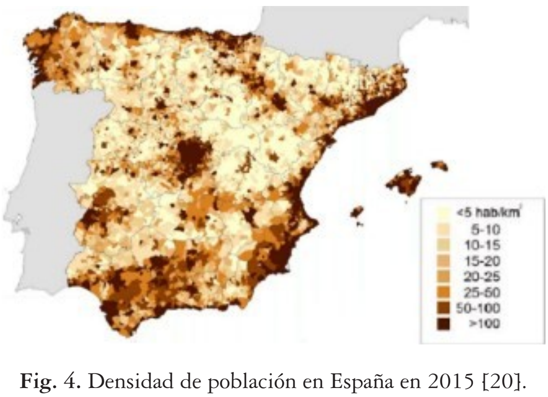

Fig. 4. Densidad de población en España en 2015 [20].

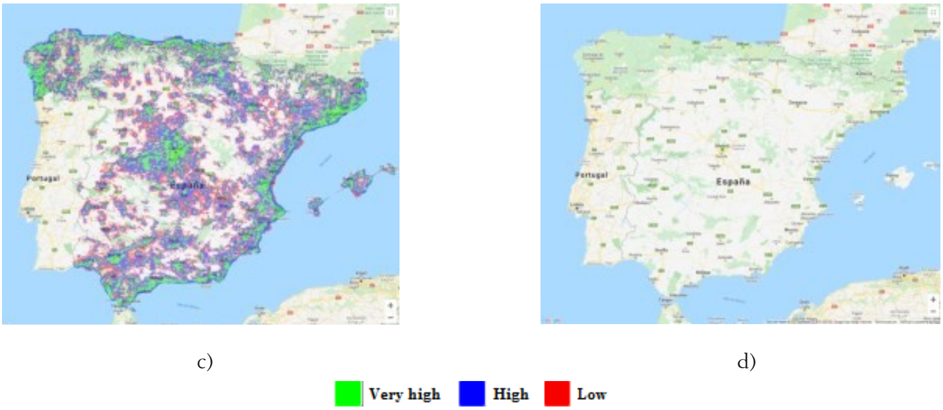

Fig. 5. Cobertura de red de un proveedor de servicio específico: a) 4G+, b) 5G [21].

A primera vista existe una clara correlación entre la densidad de población y una mejor cobertura. Además, según el Tribunal de Cuentas Europeo [22], existe una discrepancia significativa entre la cobertura en las zonas urbanas y rurales. En toda la UE, la cobertura en las zonas rurales fue del 47% de los hogares en 2016, frente a la media general del 80%. A pesar de la aparente correlación, hay algunos estudios que sugieren que la densidad de población no está correlacionada con la calidad de la infraestructura móvil [23]. Sin embargo, independientemente de la correlación causal de la densidad de población con la infraestructura, es un hecho que existen múltiples zonas de baja densidad de población, en las que la cobertura de los sistemas de telecomunicaciones 4G+ y 5G es baja. Una descripción de 4G+ se ofrece en [24].

4 Reflexiones finales: MEC aplicado a áreas de baja densidad de población

Dado que las distancias para interconectar áreas de baja densidad de población suelen ser grandes, la latencia introducida puede ser mayor de lo esperado para muchas aplicaciones. Además, con la aparición de IoT, los dispositivos conectados no están necesariamente en manos de un humano, lo que significa que no es estrictamente necesario que exista una gran población en una zona para que haya muchas conexiones.

El crecimiento en la cantidad de conexiones representa un desafío importante, sumado a la falta de conectividad estable de muchas regiones rurales. Sin embargo, es interesante examinar los proyectos e inversiones actuales que se están llevando a cabo en materia de infraestructuras TIC. Por ejemplo, en julio de 2020, la Junta de Castilla y León (España) aportó 4 millones de euros a la convocatoria estatal de subvenciones para la extensión de Internet en el medio rural [25].

A pesar de las dificultades de acceso a Internet en entornos mayoritariamente rurales, tecnologías como la agricultura inteligente son muy útiles y están creciendo. Además, en regiones donde hay que recorrer grandes distancias, el transporte en coche está muy valorado y, por tanto, las nuevas tecnologías de automoción inteligente también tienen una gran demanda. Otro campo de acción importante de MEC en este tipo de entornos es el cuidado de la salud, que no distingue entre ubicación o densidad de población. Si una persona necesita atención médica en un lugar remoto, la atención médica remota podría incluso salvarle la vida. Resulta importante también que con la implementación de MEC, los problemas causados por una conexión a Internet intermitente y/o baja capacidad, frecuente en áreas rurales, se pueden aliviar porque, en ciertas aplicaciones los servidores MEC se pueden usar para atender solicitudes sin necesidad estricta de tener una conexión a Internet estable y de alta capacidad.

El Foro Económico Mundial (WEF) estimó que si las soluciones de IoT se implementaran en el 50-75% de las cadenas de suministro en los países desarrollados para 2020, se generarían ahorros de 10 a 50 millones de toneladas de alimentos [26]. Esta cadena de suministro involucra el trabajo realizado en áreas rurales, donde generalmente se producen los alimentos para las ciudades. Gracias a las tecnologías de Internet táctil, se podrán controlar dispositivos desde ubicaciones diferentes, esto puede mejorar la productividad de áreas escasamente pobladas al disminuir la necesidad de desplazamiento físico humano, por ejemplo, en la recolección de cultivos, el mantenimiento de infraestructura y tareas tan importantes como cirugías remotas.

En regiones rurales de escasa densidad de población, las tecnologías MEC tienen un gran potencial y muchas aplicaciones. La mayoría de estas aplicaciones se complementan con tecnologías de 5G y, como vimos en la Fig. 5, el despliegue comercial de 5G está básicamente empezando. Eso quiere decir que hay mucho trabajo por hacer para implementar este tipo de tecnologías, pero también significa una gran oportunidad de progreso y desarrollo si el trabajo se hace bien.

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EXPERIENCES IN DEVELOPING PREDICTIVE MAINTENANCE SOLUTIONS

EXPERIENCIAS EN EL DESARROLLO DE SOLUCIONES BASADAS EN EL MATENIMIENTO PREDICTIVO

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ABSTRACT: In industrial manufacturing environments, a regular maintenance is crucial to ensure the production efficiency, since the occurrence of unexpected disturbances leads to a degradation of the system performance, causing the loss of productivity and business opportunities. In this context, the purpose of predictive maintenance has been receiving increasingly more attention, which when well performed, can be a strategic factor in achieving corporate goals. The predictive maintenance, framed as an important issue in Industry 4.0, is able to anticipate problems or emergencies before they happen, bringing huge advantages to industries that allow them to optimize their results and obtain greater efficiency and profitability of equipment. For that reason, more and more Companies are understanding that the equipment conservation and conditionbased maintenance can contribute to increase their competitiveness. This paper focuses on the topic of predictive maintenance, its benefits, applications and challenges, complemented with the description of predictive maintenance applications, illustrated with two examples of real-world applications resulting from the experiences of the Instituto Superior de Engenharia do Porto (ISEP) and the Instituto Politécnico de Bragança (IPB) in previous R&D projects.

KEYWORDS: predictive maintenance; industrial maintenance; advanced data analysis.

RESUMEN: En los entornos de fabricación industrial, el mantenimiento es crucial para garantizar la eficiencia de la producción, ya que la aparición de perturbaciones inesperadas conduce a una degradación del rendimiento del sistema provocando la pérdida de productividad y de oportunidades de negocio. En este contexto el propósito del mantenimiento predictivo ha recibido cada vez más atención, que cuando es bien realizado, puede ser un factor estratégico para alcanzar objetivos corporativos. El mantenimiento predictivo, enmarcado como una cuestión importante en la Industria 4.0, es capaz de anticiparse a los problemas o emergencias antes de que ocurran, aportando enormes ventajas a las industrias que les permiten optimizar sus resultados y obtener una mayor eficiencia y rentabilidad de los equipos. Por ello, cada vez son más las empresas que entienden que el equipo de conservación y el mantenimiento basado en la condición pueden contribuir a aumentar su competitividad. Este documento se centra en el mantenimiento predictivo, sus beneficios, aplicaciones y retos, complementado con la descripción de las aplicaciones de mantenimiento predictivo, ilustradas con dos ejemplos de aplicaciones del mundo real reales resultantes de las experiencias del Instituto Superior de Engenharia do Porto (ISEP) y del Instituto Politécnico de Bragança (IPB) en anteriores proyectos de I+D.

PALABRAS CLAVE: mantenimiento predictivo; mantenimiento industrial; análisis avanzado de datos.

1 Introduction

Nowadays, industrial maintenance is mainly reactive and preventive, being the predictive strategy only applied for critical situations [22]. Traditionally, these maintenance strategies are not taking into consideration the huge amount of data being generated on the shop floor and the available emergent Information and Communication Technologies (ICT), e.g., Internet of Things (IoT), Big data, advanced data analytics and cloud computing. However, the maintenance paradigm is changing and industrial maintenance is now understood as a strategical factor and a profit contributor to ensuring productivity in industrial systems [9, 17]. This shift in the maintenance 4.0 paradigm has led to the research and development of new ways to execute maintenance by considering the operational state of assets and enabled the development of new maintenance approaches, such as, predictive maintenance (PM) to improve system reliability [19], the Prognostic and Health Management (PHM), the condition-based maintenance (CBM), amongst others [11].

In this sense and considering problematic situations resulting from the manufacturing operation and stability are usually hard to detect, and contribute, in a critical manner, to the reduction of Overall Equipment Effectiveness (OEE), this work aims to report the development of predictive maintenance applications, illustrated with two examples resulting from the participation and experiences in industrial maintenance projects by ISEP and IPB. For this purpose, approaches and architectures with advanced data analysis support for monitoring the «machine» health status and the early detection of possible emergencies to mitigate the occurrence of such problems are exemplified.

The rest of the paper is organized as follows: Section 2 overviews the concept of predictive maintenance and Sections 3 and 4 describes two examples of developed predictive maintenance solutions. Finally, Section 5 rounds up the paper with the conclusions.

2 Predictive Maintenance

Predictive maintenance applications predict failure sufficiently ahead of time so that decision makers can take appropriate actions such as maintenance, replacement or even a planned shutdown [15]. These applications facilitate savings on machine maintenance and increase productivity by ensuring the maximum uptime of machines. Basically, predictive maintenance uses time-based information and knowledge to report a possible failure avoiding downtime [22].

Predictive maintenance approaches are considered one of the crucial datadriven analytical applications for large-scale manufacturing industries and Industry 4.0 environments. Considering real cases in the area of predictive maintenance, it was identified that the requirements for a big data processing pipeline in the different phases of data processing such as data collection, analytics, querying, and storage [15]. Therefore, the data comes from different sources and formats. In this way, the data complexity in terms of its size, variety, and uncertainty is difficult to be analyzed using traditional techniques. Consequently, knowledge processing approaches including machine learning (ML), data mining, and deep learning techniques have extensively been used in many industry 4.0 applications (e.g., pattern recognition, product identification, product steering, predictive maintenance, scheduling, material flow control, and predictive analytics in supply chains) [18]. The use of ML algorithms is capable of fulfilling the task of prognostics and prediction of failures, for example, estimating the lifetime of a machine using a large amount of data to train a ML algorithm [16], in addition to being used to diagnose failures [1]. On the other hand, overcoming challenges include the need to integrate data from various sources and systems within a facility, which is important to gather accurate information to create prediction models [12]. In this sense, the predictive maintenance in Industry 4.0 and its applications, the several predictive maintenance uses cases, needs to utilize knowledge processing approaches for accurate failure predictions to enhance decision-making and maximize profit.

The ability to collect and analyze data to accurately predict failure patterns is crucial to a successful predictive maintenance strategy. However, engineers and scientists face challenges [8, 20] around process and data when applying predictive maintenance technologies into their business operations, such as, lacking data to create proper predictive maintenance systems, understanding failures but not being able to predict them, lacking failure data in order to improve the predictive models accuracy. Also, PdM can be expensive. A solid PdM setup requires a variety of different technologies to run efficiently. It may require significant investment to upgrade old equipment with smart assets or to integrate predictive technology into these aging machines [14].

3 InValue Experience

ISEP has acquired experience in the field of predictive maintenance through its involvement in the InValue project. The InValue project aims to develop a platform that, through an integrated set of technological solutions and processes, facilitates the adoption of good organizational practices and the implementation of predictive maintenance in the manufacturing industry.

The GECAD research center of ISEP and the companies SISTRADE, EVOLEO Technologies, FACORT and ISQ, collaborate in this project. Given the complexity of the problem, the development of the platform requires a multidisciplinary approach that involves concepts and technologies such as sensor technology, Big Data, intelligent data analysis and human-machine interfaces, among others.

The InValue platform was designed to facilitate the implementation of Predictive Maintenance approaches and is currently installed in a metallurgical company, specialized in custom precision parts production, which has begun its digitalization process. The platform is comprised of three layers (Fig. 1): (1) Data acquisition, (2) Data Processing and (3) Information delivery.

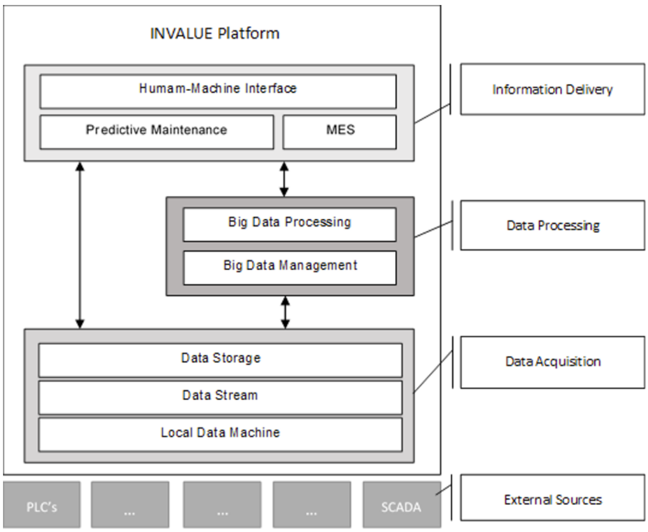

Fig. 1. InValue system's architecture [7].

The Data Acquisition module is capable of monitoring machines of different ages and technologies. The data generated by the machine (production data or provided by the machine's own sensors) are made available through a bus with the described protocol; Additional information of interest about the state of the machine that is not provided by the machines themselves is captured by a series of sensors previously installed for this purpose in mind. Moreover, relevant information can be provided by external systems, such as production management software, local SCADAs, etc. The Data Processing module is responsible for both data pre-processing and the use of ML and Data Mining techniques in order to identify components that may be approaching failure, diagnose failures and propose possible corrective measures. This information is delivered by the Information Delivery module not only to the end users concerned, but also to the Manufacturing Execution Systems (MES) in use.

InValue's Data Acquisition module captures large amounts of data at great speeds. The challenges that arise from the need to process this data can be tackled by the use of distributed architectures such as the Cloudera's distribution of Apache Hadoop. To satisfy the processing needs of the data extracted from InValue's relational warehouse, a small cluster (without high availability) comprised of four nodes, was set up. This particular set up is meant for development/testing purposes.

Considering the needs of SQL queries in a distributed environment for data analytics and the need to schedule diverse tasks, the following services were added: Hive, Hue, Yarn, Sqoop, Oozie, Zookeeper and Impala. Fig. 2, presents a simplified view of the distribution of roles and services through the nodes.

A small cluster without high availability must assign roles to three types of hosts: Master hosts, Utility/Edge hosts and Worker hosts. However, due to the very small size of the InValue cluster, composed of only four hosts, the responsibilities of the master host and the utility/Edge hosts are aggregated on Node 1, with the exception of the secondary NameNode, which is delegated to Node 4. As such, Node 1 is the NameNode and ResourceManager/JobHistoryServer, responsible for dividing data and assigning tasks through DataNodes/NodeManagers (Nodes 2 to 4). Work hosts include work responsibilities for Impala, Hive and Zookeeper. Regarding the InValue Big Data Analytics platform's, it is divided into two workflows: (a) batch processing for predictive model generation and (b) stream processing for real-time statistics and alerts. These two different scenarios are represented in Fig. 3.

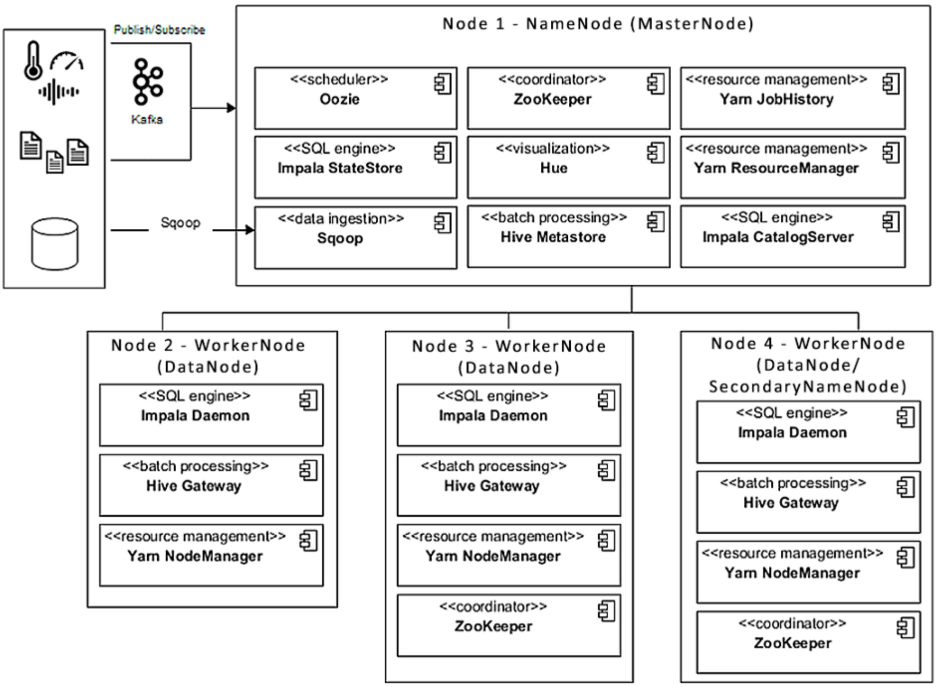

Fig. 2. InValue's Hadoop Cluster [6].

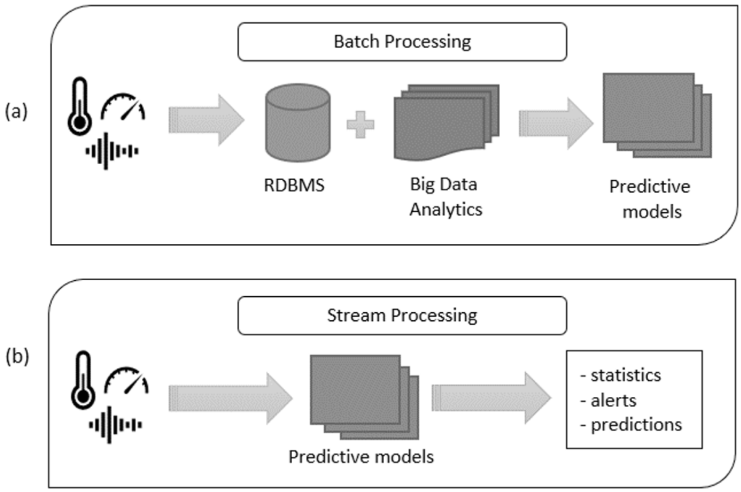

Fig. 3. InValue's Big Data Analytics platform workflows [6].

In an initial approach, data will be extracted from the relational database and processed in batch to generate a series of predictive models. These models will be used in a second future phase, where they will be executed in data flows to generate statistics, alerts and forecasts in real time.

4 Maintenance 4.0 Experience

The experience obtained by IPB, and particularly the CeDRI research center, in the topic of predictive maintenance is exemplified by the participation in the Maintenance 4.0 project, which is related to an intelligent and predictive maintenance system, aligned with an end-user interface for visualization and monitoring in a manufacturing enterprise. The Maintenance 4.0 project was oriented to the requirements of Catraport Lda company, located in Bragança, where the environment volatility is higher due to ts production system that produces components and accessories for the automobile industry using metallic stamping machines, which served as an experimental proof-of-concept of new applications in a real case.

A proper system architecture for condition-based maintenance was designed, comprising the cooperation of several modules, namely data acquisition and treatment, decision, communication and visualization, as illustrated in Fig. 4.

The ability to successfully integrating these modules is essential to create a functional system that allows the implementation of intelligent and predictive maintenance, taking advantage of a broad spectrum of technologies, such as IoT, ML and advanced data analysis [5].

Briefly, the data collection module is responsible for the automatic and manual collection of data, being able to retrieve data from several sources and store it in a database using IoT technologies. The database will feed the offline data analysis module, where the knowledge is generated through the use of advanced data analytics and ML techniques, e.g., rules to correlate different parameters to trigger the earlier identification of needs for maintenance interventions. The generated knowledge is used by the dynamic monitoring module that is responsible to apply the generated rules to the collected data, supporting the visualization of the machine health along the time but also the detection in advance of needs for maintenance interventions. Finally, the intelligent decision support module is responsible to provide a decision support guidance to the technician during the execution of maintenance interventions comprising human-machine interfaces (HMI) and augmented reality technologies.

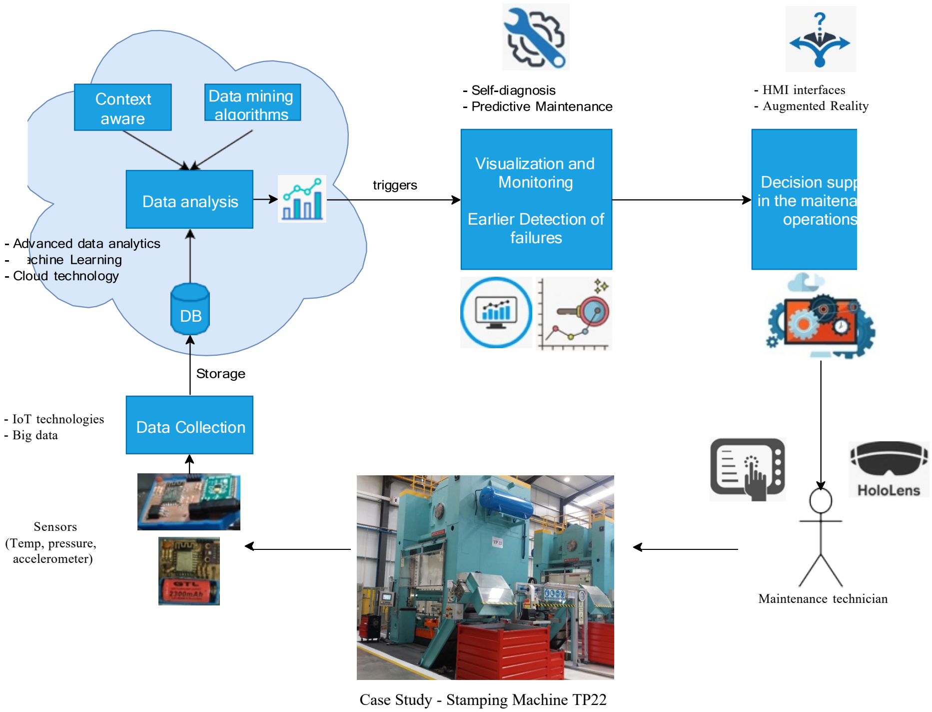

Fig. 4. Intelligent and predictive maintenance system architecture (adapted from [2]).

This basis of this experience considers the online analysis of the collected data where the production managers or supervisors could view and monitor the various parameters collected from the machine in real-time, as well as the statistical data relating to products, product failures or machine warnings reports. In addition, they can also monitor the probability of occurrence of some events, such as machine failures, according to models and forecasting algorithms that could help a timely decision-making. For this purpose, the data acquired and transmitted by all modules is visualized through a computational application developed according to a flow programming approach using the Node-RED platform [10].

Dashboards were developed, but one of them related regarding the display of data regarding failures or warnings, whether from product quality or machine health condition, providing monitoring and statistical information. In this way, the production manager uses this dashboard, (Fig. 5), to get a deeper insight of the current product quality (data regarding defects) or the machine operation health (machine failures).

Regarding the products quality, the dashboard displays for each type of defect, the total number of occurrences, the last occurrence of such defect (date), the time without defect (in days), the Mean Time Between Failure (MTBF) for a specific product defect, which is a crucial industry parameter to be taken into consideration, and is related to the average time between the occurrence of two consecutive failures.

Concerning an important research topic in this experiment, it was the development of an advanced data analysis module, for predicting events, failures or warnings, on the theme of predictive maintenance (bottom of the monitoring system presented in Fig. 5). This module takes advantage of several technologies, namely advanced data analytics, machine learning and cloud technologies, to extract knowledge from the collected data in order to create new monitoring rules and procedures or update the existing ones. For this purpose, a machine learning approach with supervised learning for the early fault prediction and predictive maintenance was developed, concerning the advantage of detecting underling patterns that may not be detected by a human operator/programmer [4]. The algorithm was trained from the input data of previous events/faults, labeled accordingly to the type of event (fault or operation), rather than being explicitly programmed by a set of static rules.

Initially, the data analysis focused mainly on machine internal events, e.g., the log of machine errors, being proposed an evaluation of one machine learning approach, a type of recurrent neural networks (RNN), the long short-term memory (LSTM) network [13, 21, 3], that can correctly predict a fault in the next 5 minutes' block. After analysing the dataset regarding the machine failures (coming in.csv files), with more than 43.000 previous events, we started to integrate the early failure/warning prediction inference engine according to the collected files, which was codified in python. The Fig. 6 shows the overall model architecture that LSTM layer will feed with all sequences of events through each internal layer and the final LSTM state encodes the machine behaviour, including relations between past and recent events, in this case as a supervised problem up to 5 previous samples.

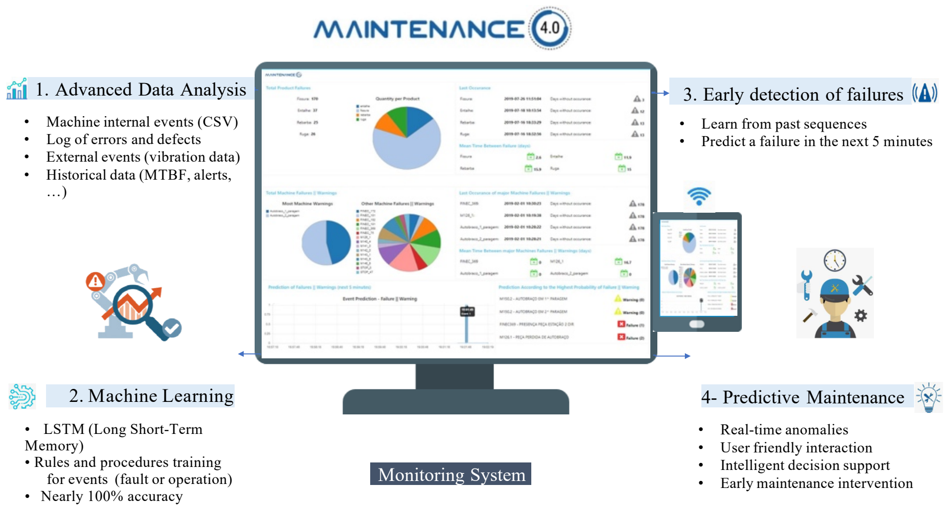

Fig. 5. Dashboard for the visualization and monitoring of the statistical data related to product's defects, machine's failures and early fault prediction.

The implemented network was configured with 50 up to 150 cells, the Adam optimizer and binary cross entropy as loss function through 30 epochs. The algorithm was trained using as input data the previous events collected, classified and labeled accordingly to the type of event (failure as 1 or warning as 0), rather than being explicitly programmed and harmonized by a set of static rules. Since the majority of the events are not related to fails, i.e. almost 98% of the original machine events are warnings, resulting in an imbalanced dataset, the model was designed to group events in 5 minutes blocks and thus predict the type of event that may arise in the next 5 minutes (failure or not) [2].

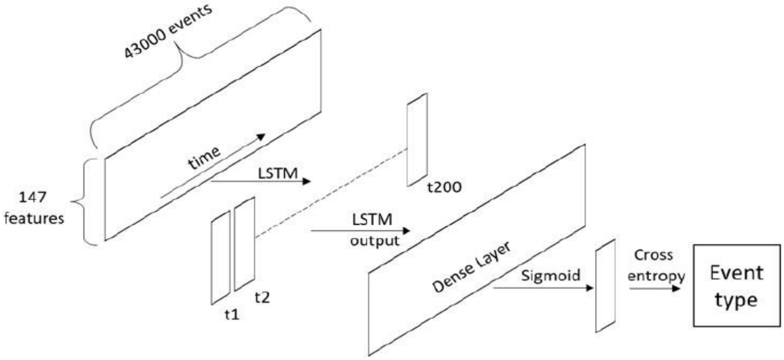

Fig. 6. Proposed RNN model architecture based on a LSTM layer to predict the next failure/event type [5].

Fig. 7 represents the results for the training and validation accuracy and loss for the 150 neuron configuration and considering the range up to 30 epochs.

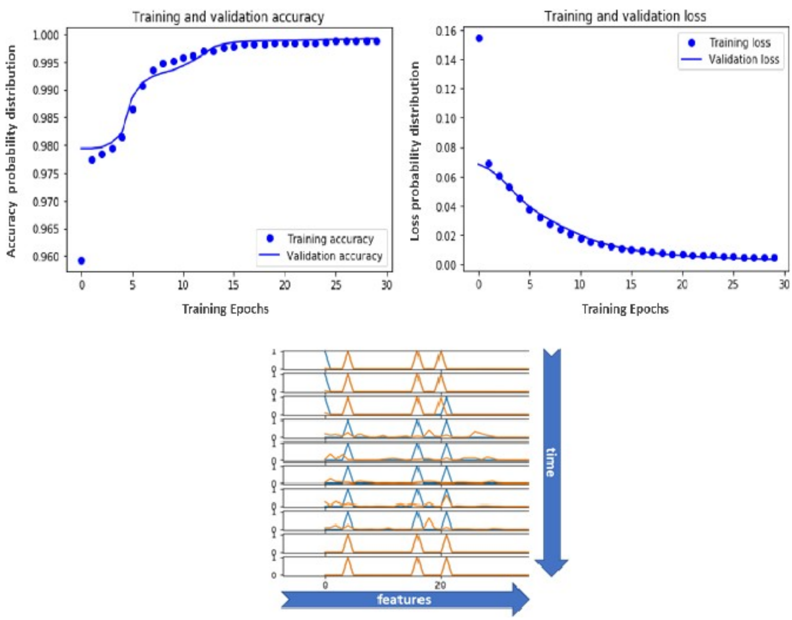

Fig. 7. Top Training and validation accuracy and loss for 150 neurons; Bottom Sample of prediction vector (orange line), with probability of anomaly at index 0 of feature axis, the following index are the type of event.

The results show an increase in the accuracy with a steady decrease in loss, reaching a value of 99% accuracy after 15 epochs, which suggests that the network is able to properly learn patterns or new features. At the bottom of the Fig. 7, the orange line represents probability of an event and the blue line the ground-truth. The left most feature (index 0) is the overall fault probability and the following are types of events (including from faults types to normal operational events).

The output is interpreted, communicated and represented in real-time through the graph shown at the bottom of the monitoring system (Node-RED dashboard) in the bottom of the monitoring system, from Fig. 5. The probability of fault is being predicted for the next 5 minutes, in a graph, when vertical lines with the value 1 on the y-axis appear, it represents the type of failure that can occur, which is accessed in dynamic way to the type and name of the failure to be predicted. In overall, the proposed algorithm was able to predict and detect anomalies from internal and external data sources, showing that is possible to improve the device/system availability by performing earlier the maintenance interventions.

In addition to the dashboard application for visualization and monitoring, an Android mobile application was developed, to support the remote monitoring, and provide to the user the ability to check the machines' status, that, either by WiFi or VPN and will have the ability to access via the dashboard's IP.

5 Conclusions

This work presents two intelligence maintenance solutions integrating artificial intelligence algorithms for prediction to support the industrial maintenance, further minimizing the effects and impact of unexpected failures in the production system, and consequently increasing the competitiveness of manufacturing enterprises, provided and researched by two Higher Institutes in Portugal, IPB in Bragança and ISEP in Porto.

Within the scope of the INVALUE project, wich ISEP was involved, a predictive maintenance platform was developed capable of supporting the companies decision making, collecting data from industrial machines and using ML techniques to extract useful knowledge from them. A pilot version of the platform was tested at the end user's facilities, whose predictive system uses predictive models to analyze the monitoring data of the machines in real time and detect the occurrence of early failures. The predictive system is complemented by a system of rules whose purpose is to assist in the detection of failures and provide information that can be used by the management team to optimize production. The use of the INVALUE platform in a real environment has demonstrated its ability to improve the company's operations and thus increase its competitiveness.

In relation to IPB, the proposed system architecture considers the advanced and online analysis of the collected data for the earlier detection of the occurrence of possible machine failures, dynamic monitoring and supports technicians during the maintenance interventions by providing a guided intelligent decision support. Additionally, the collected data is analysed by a ML algorithm that allows to predicts earlier the problems, and generate warnings for the implementation of maintenance interventions that will mitigate their occurrence.

Although, several limitations still exist either due to data availability, the process digitalization or technician learning curve, this work enabled the development and validation of the several architectural modules in practice, i.e. in a real industrial production unit for metal stamping for the automotive sector. The partnership with an automotive industry and application in real context, showed that the experience developed in the Maintenance 4.0 project leveraged an importance of maintenance management that has generated an increasing interest in the development and implementation of efficient maintenance strategies that are able to improve the system reliability, prevent system failures, and reduce maintenance costs.

The Industry 4.0 will continue to evolve and certainly more contributions and experiences in predictive maintenance will be applied continuously to support manufacturing systems or other interventions. The experience gained in these reports will provide the knowledge and expertise for more projects in the future.

Acknowledgments

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Digital Innovation Hubs within the PocTep region to boost the development of disruptive and last generation ICTs through cross-border cooperation).

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ARTIFICIAL INTELLIGENCE FOR OPTIMIZATION AND INDOOR REAL-TIME LOCATING SYSTEMS. A CASE STUDY IN WINERY LOGISTICS

INTELIGENCIA ARTIFICIAL PARA LA OPTIMIZACIÓN EN LOS SISTEMAS DE LOCALIZACIÓN EN TIEMPO REAL. UN CASO DE ESTUDIO EN LA LOGÍSTICA EN BODEGAS

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Abstract: Spain is the EU country with the largest area of cultivated vineyards. However, it experiences a phenomenon of disaggregation and smallholdings, making it complicated for winegrowers to invest in technification. This paper describes an experiment that will be conducted in the Spanish wine company Pago de Carraovejas. The experiment aims at optimising storage and decision-making when packaging for shipment by developing an Artificial Intelligence system. A module will be created for the improvement of the arrangement of products in the warehouse. This way, the efficiency of the warehous0e and productivity of the winery will increase.

Keywords: agri-food industry; winery logistics; storage and packaging; internet of things; artificial intelligence; smart warehousing system.

Resumen: España es el país de la Unión Europea con mayor superficie de viñedos. Sin embargo, experimenta un fenómeno de desagregación y minifundismo, lo que complica la inversión de los viticultores en tecnificación. Este trabajo describe un experimento que se llevará a cabo en la empresa vinícola española Pago de Carraovejas. El experimento tiene como objetivo optimizar el almacenamiento y la toma de decisiones a la hora de envasar para su envío mediante el desarrollo de un sistema de Inteligencia Artificial. Se creará un módulo para la mejora de la disposición de los productos en el almacén. De esta forma, se incrementará la eficiencia del almacén y la productividad de la bodega.

Palabras clave: industria agri-food; logística en bodegas; almacenamiento y embalaje; Internet of things; inteligencia artificial; sistemas de almacenamiento inteligentes.

1 Introduction

The digitisation of the Spanish industry has accelerated in recent years, representing 30% of the total growth of the Spanish economy since 2015 [1]. The technologies driving this change include the use of Internet of Things (IoT) devices, an improvement in communications, and the generalisation of new architectures [2] which had made possible to store and process vast amounts of data. As a result, the increase in processing capacity caused the development of new techniques that have represented a significant advance for Artificial Intelligence (AI) [3].

Still, the conversion of the Spanish industry towards digitalisation is not reaching the expected pace. According to the PwC Industry 4.0 report [4], only 8% of Spanish companies are at an advanced level of digitalisation. Far from being a handicap, this behaviour presents a great opportunity. The industrial sectors need to be encouraged to continue growing, and it is essential to invest in new technological solutions for the digitalisation of the whole value chain. Until now, most of these solutions have been limited to a descriptive analysis of the data to detect anomalies or to identify the optimum modes of operation. Yet, few solutions provide support in decision-making and use predictive models that evolve and adapt to processes over time to support and guide workers on their tasks.

The wine industry is included in the agri-food sector. Its production is subject to the natural environment where it is placed, and its processing part involves a complex transformation industry, affected by the diverse distribution channels. The food and beverage industry is a leading Spanish sector in terms of turnover and a significant generator of employment [5]. However, most businesses are small, making the processes of innovation and internationalisation challenging.

Focusing on the wine sector, Spain is the EU country with the largest area of cultivated vineyards [6]. Still, comparing the average size of the cultivated area per producer with the competing countries, Italy and France, Spain experiences a phenomenon of disaggregation and smallholdings, which make complicated for winegrowers to invest in technification. Spain exports most of its wine; however, and despite the excellent quality of the product, its sales price does not reach the level of the competing countries. Hence, the current challenge of the sector is not in the market shares, but in increasing the market value.

This paper describes an experiment conducted in the Spanish wine company Pago de Carraovejas. The experiment aims at optimising storage and decision-making when packaging for shipment by developing an AI system that manages the processes of storage, packaging and palletising. The rest of the paper is organised as follows: *Section 2* describes the proposed solution; *Section 3* draws the main conclusions and future research lines.

2 Case study: Pago de Carraovejas S.A.

Pago de Carraovejas [7] is a wine company established in the 70s and located in the province of Valladolid (Spain). It has built an image of quality in the winery industry thanks to its effort in controlling all its production processes, from the vineyard to the bottle, both in the production of wines and in the preparation of orders. Its facilities cover more than 26,000 m^2, and a 200-hectare vineyard. Vinification is made up of a unique system that combines work by gravity, the use of yeasts and bacteria, and the delicate work with wood for ageing. However, maintaining a high level of quality until the wine reaches the consumer requires management that goes beyond the internal operations of the company.

The DIH-World is a Horizon 2020 project which aims to stimulate the uptake of advanced digital technologies by European manufacturing SMEs and to strengthen the capacities of regional Digital Innovation Hubs (DIH) by providing them with access to harmonised tools, well-proven technologies, effective methodologies, and knowledge, etc. [8]. As a representative of the agri-food industry, Pago de Carraovejas will participate in an experiment that will apply AI for optimisation and indoor real-time locating systems to build a smart warehousing system.

Pago de Carraovejas is engaged in the process of digitalisation of the different stages of the wine value chain, from the vineyard itself to the consumers. To optimise resources, reduce costs and improve quality and safety, Pago de Carraovejas has implemented a platform for the traceability of its product. One of the stages where the company has detected the most significant margin for improvement is the warehousing. Once a bottle is produced, it is packed in a box. When there are sufficient boxes of a product, a pallet is prepared and stored in the corresponding place of the winery warehouse. It is possible that, during the production and storage processes, a client places an order made of different types of products. In this case, there are two possibilities: dismantle several pallets to create one with the specifications of the order or prepare a new pallet.

The current traceability system implemented in Pago de Carraovejas tracks all bottles that are processed. Each bottle labelled includes a Radio Frequency Identification (RFID) tag, allowing to identify each bottle univocally in the system. In addition to the RFID label, a QR code is printed on the bottle. Both the RFID tag and the QR code are associated with each other and stored in a MongoDB database. Another QR code is printed on each box. The ID of each box is associated with all the IDs of each of the bottles inside it, allowing the operators to know the state of each bottle and box in the value chain always. When a client (distributor, supermarket, restaurant, etc.) places an order, it is received in the Enterprise Resource Planning (ERP) of Pago de Carraovejas. It generates a request consisting of a combination of boxes of different units of different products. Each order involves the formation of one or more pallets, which contains a variety of packages with different volumes, weights, and levels of fragility during the picking process before loading and transport it to the purchaser.

After labelling and packaging, the arrangement of the boxes in the warehouse is a task that workers performed manually, based on their experience. At present, there is no optimisation system implemented that suggests the best arrangement of the products. The warehouse consists of several shelves with rails where the operators introduce and push the pallets. To take out a pallet, they must take out all the ones in front of it first, causing a waste of time and a risk of falls and breaks. Pago de Carraovejas is looking for a solution to optimise the disposition of the products within its warehouse, so the storage capacity in the allocated space is maximised, and the number of movements required for making the pallets is minimised, reducing the time spent on these tasks before delivery. This way, the efficiency of the warehouse and productivity of the winery increase. Such a solution should provide the optimum arrangement of boxes on each area and shelf for workers.

3 Proposed solution: Smart warehousing system for the optimisation in winery logistics

Several studies have proven that it is possible to optimise different tasks during production processes, including warehousing, with the assistance of computer-aided technologies [9]. The application of location technologies and AI techniques allow the optimisation of the routes during storage, reducing the time invested and increasing efficiency and productivity [10]. Also, the introduction of this type of systems minimises the stress of workers and improve health and ergonomics [11]. Within the scope of AI, hybrid genetic algorithms have been used to optimise packaging dimensions and composition [12], and the mapping route in warehousing environments [13]. Generating plans for the reduction of incidents is a challenge that requires intelligent systems with the capacity for learning and adapting. One possibility is using AI techniques through Case-Based Planning (CBP) systems. To implement this type of systems, Multi-Agent Systems (MAS) can provide advanced reasoning skills and solve new issues by making use of past experiences based on artificial neural networks [14]. The latest techniques for the implementation of planning systems in industrial environments are those based on evolutionary computing [15], including genetic algorithms, particle-swarming algorithms [16], differential evolutionary techniques [17], neuroevolutionary techniques and deep neuroevolutionary techniques [18].

The experiment that will be conducted in Pago de Carraovejas aims to optimise storage and decision-making when packaging for shipment. One of the main advantages of automated warehouses is their ability to improve productivity, prevent hazards during activity peaks and reduce the harsh working conditions. The technical objectives that will be explored are the development of an AI system that manages the order of the storage process as well as the packaging and palletising process. A module will be developed for the improvement of the arrangement of products in the warehouse. A set of smart algorithms will be designed and implemented to optimise the layout of the boxes and pallets in the shelves, striving to increase the storage capacity and to reduce the time spent for the subsequent composition of pallets. These algorithms will consider the dimensions and weights of each box and pallet, the capacity available in each shelf, the probabilities of exit from the warehouse of each product depending on the planning and prediction of expected orders and the routes to follow for the collection of each product.

The module will communicate with the ERP of Pago de Carraovejas. On the one hand, when the bottling, labelling, and packaging line generates a set of products to be stored, the ERP will be informed of these new products; and the algorithms will calculate the optimum position of the boxes and pallets according to the expected future orders. On the other hand, when an order is placed by a customer, the ERP will read the composition of it in terms of the number of boxes and presentation of each product; and the algorithms will calculate the optimal routes to pick the different boxes, minimising the total time. The location of the elements in the warehouse will also be considered to facilitate their monitoring using real-time identification and location technologies, such as RFID or beacons. *Figure 1* presents an overview of the solution proposed.

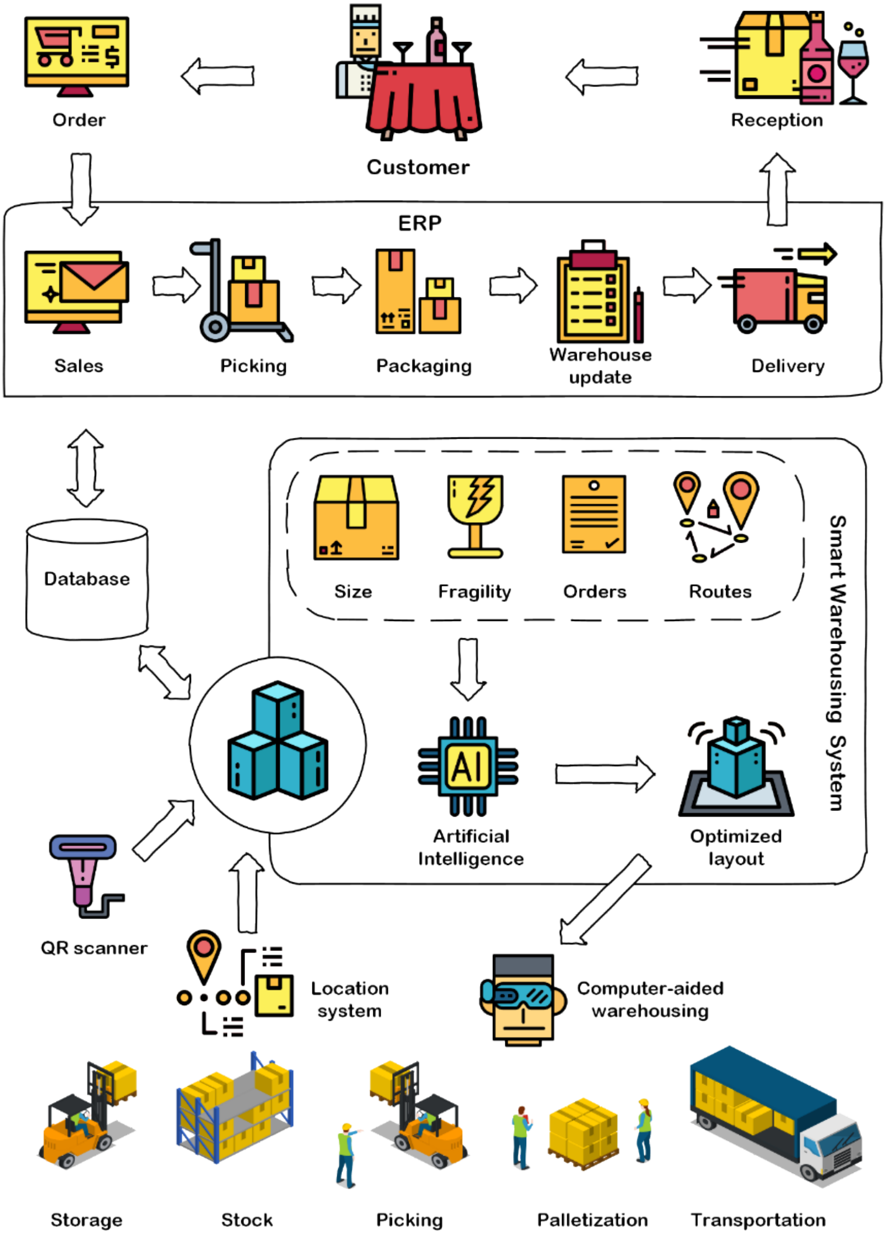

Fig. 1. Smart warehousing system for the optimisation and indoor real-time location in winery logistics.

IoT is considered one of the leading gateway technologies to digital transformation [19], especially in the transportation and logistics sectors, which requires an intensive and efficient exchange of data for effective management and decision-making [20]. The different IoT devices involved in this experiment will include the implementation of RFID tags and QR codes to identify the boxes and the rows of the warehouse. Software connectors will be created for the communication between the smart devices and the reading peripherals (RFID readers and QR cameras). Appropriate user interfaces will be developed for use on mobile devices anchored to the forklifts.

During storage, the system will indicate to the operator what type of product need to be collected. The operator will pick up a product of that type and read it with his smart device. In this way, the system will know which box and bottles are being handled at each moment. The system will indicate to the operator in which aisle and at what height he has to store the product. To do this, it will take into account its weight, volume, fragility and information from the ERP in terms of future planned orders. The operator will mark with his device in which aisle and height he leaves the product, thus confirming the operation. The same process in reverse is carried out in the picking operations. When a new order arrives at the ERP, the system calculates the optimal combination of movements to pick the product from the warehouse. A battery of tests will be conducted in a selected area, avoiding interfering with the daily tasks of the warehouse. Lastly, the system will be implemented in the entire warehouse and will be tested for use during the actual warehouse operation.

4 Conclusion and future work

Today, IoT, Big Data and Machine Learning are presented as the most suitable technologies for prediction-making and the improvement of the quality of services. Pago de Carraovejas is looking for a solution to optimise the disposition of the products within its warehouse. The experiment aims to optimise storage and decision-making when packaging for shipment. A set of smart algorithms will be developed and implemented to optimise the layout of the boxes and pallets in the shelves, striving to increase the storage capacity and to reduce the time spent. The expected impact of the experiment includes an increase in the average storage capacity of each warehouse by 25%; a reduction of the average time invested in storing and picking operations by 25% and 30%, respectively; and a reduction of the average workload of workers by 10%, improving their occupational health and ergonomics.

After the implementation of the new smart warehousing system in the different warehouses of Pago de Carraovejas, another step will be taken towards digitalisation in the different stages of its value chain.

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DISRUPCIÓN TECNOLÓGICA EN FORMA DE INNOVACIÓN Y AVANCES EN LA CALIDAD DEL EMPLEO: UNA APROXIMACIÓN TEÓRICA

TECHNOLOGICAL DISRUPTION IN THE FORM OF INNOVATION AND ADVANCES IN JOB QUALITY: A THEORETICAL APPROACH

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Resumen: «Innovación tecnológica es el complejo proceso que lleva las ideas al mercado en forma de nuevos o mejorados productos o servicios». A causa de la mayor liberalización de los mercados, en los últimos tiempos el mundo, así como las relaciones económicas internacionales, se han convertido en un conjunto de redes interconectadas, lo cual ha fomentado los efectos derivados de Internet. La llegada de la Industria 4.0 con tecnologías como Big Data, la impresora 3D o la inteligencia artificial, la domótica o la quinta generación de telefonía móvil –5G– han supuesto cambios disruptivos. El reto presente del mercado laboral es hacer frente a estas novedades, motivando la adaptación del sistema educativo bajo la finalidad de otorgar herramientas a la sociedad para ser capaz de satisfacer la demanda de nuevas habilidades, paliar el posible incremento de la desigualdad por medio de políticas o encontrar un equilibrio para evitar la polarización sectorial. El presente artículo se enfoca en analizar –dentro de un margen temporal determinado– y, desde un punto de vista teórico, si la implementación de nuevas innovaciones en el proceso productivo ha derivado en una mejora de la calidad del empleo.

Palabras clave: innovación; tecnología disruptiva; empleo; desempleo tecnológico; productividad; salarios; calidad en el empleo.

Abstract: «Technological innovation is the complex process of bringing ideas to the market in the form of new or improved products or services». Due to the increased liberalisation of markets, in recent times, the world, as well as international economic relations, has the earth, and global economic ties have recently become a set of interconnected networks, which has fostered Internet spill-over effects. The advent of Industry 4.0 with technologies such as Big Data, the 3D printer or artificial intelligence, domotics or the fifth generation of mobile telephony – 5G have brought disruptive changes. The current challenge of the labour market is to face up to these new developments, motivating the adaptation of the education system to provide society with the tools to be able to satisfy the demand for the community to be able to meet the demand for new skills, mitigate the possible increase in inequality by the potential rise of inequality through policies, or finding a balance to avoid sectoral balance to avoid sectoral polarisation. This article focuses on analysing – within a given timeframe and from a theoretical point of view – whether the theoretical point of view of implementing innovations in the production process has led to an improvement in the quality of employment.

Keyword: innovation; disruptive techonlogy; labour; technological unemployment; productivity; wages; quality in employment.

1 Innovación y empleo

La escuela neoclásica parte del supuesto de considerar a los empleados como mano de obra disponible para ser utilizada en cualquier empleo o sector, por tanto, no existe la especialización. Se introduce el concepto de mecanismos de compensación donde la destrucción de empleo inducida por la innovación es compensada por efectos positivos, como la creación de este, pues a medio plazo el mercado tiende a una situación de pleno empleo.

En 1930, John Maynard Keynes manifestó su preocupación acerca de la automatización de mano de obra empleada, por ello acuñó el término technological employment, donde trabajadores son expulsados de su empleo habitual, al mismo tiempo que se produce «*unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour*» [20]. Esta visión es apoyada en Zimmermann en 1991 [38], donde se encuentra como motivo del desempleo en Estados Unidos en la década de 80s, al avance vivido en cuanto a tecnología, pero Entorf et al en 1990 [8] no aprueban esa evidencia.

Otra visión pesimista fue abordada por el premio Nobel de Economía en 1982, Wassily Leontief, en «*The Distribution of Work and Income*» donde referencia que las nuevas tendencias asociadas a la automatización de parte de los procesos productivos propiciaban el desplazamiento de los puestos de trabajo. Por su parte, la perspectiva post-schumpeteriana define el desempleo como aquella situación de desequilibrio propiciada por la incapacidad de absorción del factor trabajo que ha perdido un empleo tradicional por parte del capital humano disponible de los sectores innovadores nacientes [13].

Responder a la pregunta acerca de si el cambio tecnológico da lugar a incremento del empleo o conduce a la generación de desempleo tecnológico; lleva a distinguir entre innovación en proceso e innovación en producto [13]. Desde el punto de vista teórico, se habla de la existencia de mecanismos de compensación también en la innovación de procesos, cuya efectividad está sujeta a políticas como la reducción de barreras de entrada que no favorezcan la conformación de mercados monopolísticos, al tiempo que es alentada la demanda final e intermedia en cuanto a nuevos productos [37].

Desde una perspectiva empresarial, se han presentado multitud de estudios empíricos, no obstante; no existe unanimidad acerca de los resultados por la disparidad de modelos empleados. Un breve repaso bibliográfico sería el siguiente:

En el caso de Blechinger et al. en 1998 [5], Van Reenen et al. den 2002 [36]; Entorf et al. en 1990 [9]; Greenanand et al. en 2000 [11]; Rottmann et al. en 1998 [31]; Van Reenen, en 1997 [35] se afirma hallar correlación positiva entre innovación en producto y la creación de empleo en el sector industrial. En cuanto a la innovación en procesos, no existe unanimidad; en algunos casos como Van Reenen en 1997 [35], se apoya que la innovación respecto al empleo no tiene un efecto significativo; en tanto que, en Lachenmaierandet al. en 2011 [21] y Greenan et al. en 2000 [11] aseguran que la generación de empleo en este caso es superior a la alcanzada en la innovación de producto [28].

Aportando una perspectiva geográfica, hay contribuciones en Alemania y Países Bajos, que concluyen que existe una relación positiva entre innovación en proceso, producto y generación de empleo [5]; no obstante, estudios anteriores basados en encuestas realizadas en Alemania y Países Bajos concluyen que sí existe relación positiva entre innovación en producto y empleo, pero no con respecto a la innovación en general [6, 4].

En el caso de Reino Unido o Australia, se ratifica una correlación positiva entre innovación y el crecimiento del empleo, mientras que en el caso de Noruega [17] en ningún caso se puede estatuir ninguna relación entre innovación y empleo [28].

Sectorialmente, la automatización de la mano de obra se encuentra concentrada en el sector industrial, ocupando en las economías desarrolladas el 80%; esta cifra en el periodo 2010-2015 aumentó un 9% anualmente hasta alcanzar 14 robots por cada 1.000 habitantes en 2015, en cuanto a las economías emergentes esta cifra es de 2 por cada 1.000 habitantes [15].

Existe algo que no se puede obviar y es la caída de aquellos trabajos considerados como rutinarios. El mercado demanda personal especializado capaz de satisfacer tareas muy concretas; al tiempo, que el empleo de baja cualificación ha ascendido; produciéndose la llamada polarización del trabajo [1].

1.1. La importancia del nivel de cualificación

El nivel de cualificación guarda relación con la tasa de desempleo; en términos generales, existe una correlación negativa; cuanto menor sea el nivel de especialización, mayor será la tasa de desempleo.

En el gráfico 1 podemos observara cómo ha evolucionado la tasa de desempleo según el nivel de educación, el cual permite comparar cómo influye el desempeño de habilidades a la hora de encontrar empleo.

Las personas con estudios universitarios presentan una tasa menor en relación con aquellas que poseen estudios de secundaria o por debajo. En el año 2019, el paro asociado a la educación universitaria era un 10% menor en cuanto a personas con estudios básicos –4,7% vs.13,8%–. En términos generales, el paro es mayor, durante todo el periodo, cuanto menor nivel de educación por la destrucción de empleo de aquella población cuyo trabajo puede ser automatizado; el estudio de Oxford Economics cifra que en el periodo 2000-2016 han sido destruidos en Europa 400.000 puestos de trabajo. Durante la recesión de 2008, es posible observar que el desempleo aumentó sobre todo para personas sin estudios pasando de 11,5% –2008– a 20,5% –2013–.

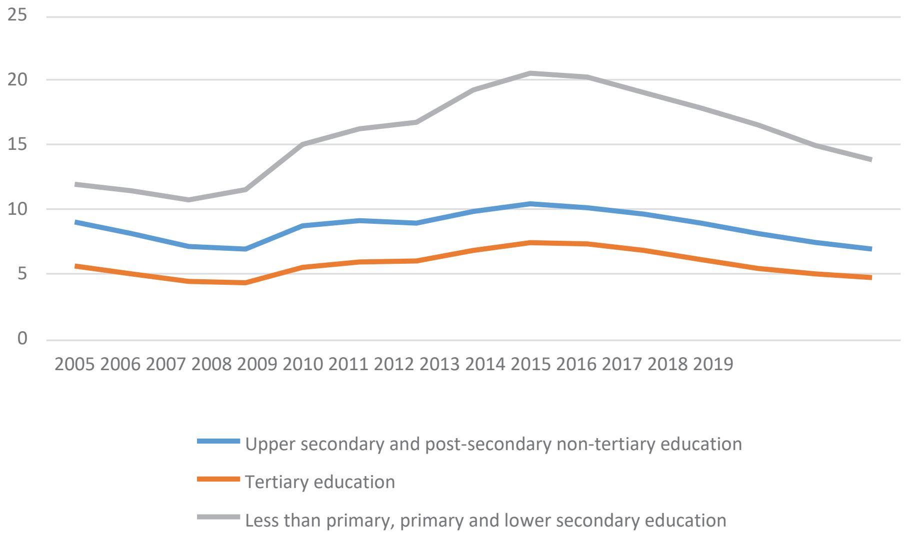

Fig. 1. Desempleo por nivel de educación (2005-2019) EU-28 personas entre 15-74. Elaboración propia basado en información de Eurostat.

1.2. +Innovación y productividad

En cifras, la productividad ha aumentado al tiempo que la automatización de tareas ha agilizado los procesos productivos; para producir la cantidad de algodón a la que da lugar hoy en día una jornada semanal de 40 horas, en el año 1790 se requerían de 1.000 horas y antes de la Revolución Industrial 50.000 horas [13].

A raíz de un modelo de demanda industrial focalizado en el mercado industrial norteamericano el aumento de la productividad unido a una demanda muy elástica propiciará que la implementación de las nuevas tecnologías desencadene un aumento del empleo [3]; la automatización eliminará puestos de trabajo y permitirá establecer precios más competitivos; en caso de que se cumpla el supuesto de demanda muy elástica (>1), el ahorro derivado de necesitar menos mano de obra quedará en un segundo plano. Por ello, las tecnologías alentarán el empleo en aquellos mercados en los que se consiga aumentos de productividad orientados a las preferencias de los consumidores. Respecto a la afirmación de la ley de Moore, si la demanda es elástica, un cambio técnico más rápido creará un crecimiento más rápido del empleo. Sin embargo, un cambio técnico más rápido también acelerará el día en que la demanda ya no sea tan elástica y la desindustrialización se establezca.

Tomando como objeto de estudio el sector industrial español se concluye, tras comprobarlo empíricamente, la existencia de una relación positiva entre la inversión en I+D y la consecución de mayores cotas de innovaciones en proceso y producto conlleva a una mayor productividad total de los factores –FTP– [14]. Y se trata explicar por qué en la segunda mitad de la década de 2000-2010; esa citada productividad total de los factores no creció, encontrando los motivos en la disminución de la proporción de empresas que realizaban actividades vinculadas a I+D y, por otro, la caída de la capacidad de conseguir productos y, especialmente, innovaciones de procesos a partir de la inversión tecnológica.

El crecimiento de la productividad es el indicador económico clave de la innovación. El crecimiento económico puede tener lugar sin innovación a través de la aplicación reiterada de tecnologías existentes. Utilizando la inversión aumenta para motivar disponibilidad de estas tecnologías, mientras que la fuerza de trabajo se expande a medida que la población crece. Con sólo la replicación y sin la innovación, la producción aumentará en proporción a los insumos de capital y mano de obra, como sugirió Schultz [15].

En caso de que sean introducidos nuevos productos y procesos –cambio tecnológico– es ocasionado un incremento de la producción que excede el crecimiento de maquinaria y mano de obra; lo cual deriva en un incremento de la productividad por unidad de insumo. Este razonamiento es patentado por Robert Solow (Premio Nobel, 1987) donde considera como esencia del crecimiento económico a largo plazo al cambio tecnológico como mecanismo potenciador de un aumento de la productividad.

A nivel de organizacional en función del ámbito geográfico, existen estudios como los de Lichtenberg et al. en 1991 [23] sobre EE.UU., Mairesse et al. en 2005 [26] en cuanto a Francia, Harhoff en 1998 [12] vinculado a Alemania, Klette et al. en 1996 [19] respecto a Noruega, Loof et al. en 2002 [25] sobre Suecia, o Parisi et al. en 2006 [29] orientado en Italia; todos concluyen en hallar evidencias que prueban un impacto positivo del gasto en I+D en la productividad, aunque algunos han sugerido que la ganancia derivada de I+D pierde fuerza con el tiempo [18]. De manera plural, los estudios empíricos encuentran su fundamento en la inclusión de una función de productividad que introduce una variable que refleja I+D, constituyendo un insumo más de la producción.

En nuestros días, cabe decir que no toda implementación de innovación propulsa un aumento en la productividad; aquellas que sí lo hacen son las asociadas a innovaciones disruptivas como, sin duda fueron, las novedades surgidas en la Revolución Industrial. En la actualidad, un símil sería el microprocesador, o la inteligencia artificial. La razón reside según, Clayton Christensen –profesor en Harvard, que acuñó el concepto innovación disruptiva– en «*invertir en proyectos corporativos que maximicen beneficio en el corto plazo, manteniendo costes bajos y cash-flow positivo, pero renunciando a la innovación disruptiva*», apostando por una economía con visión a corto plazo en la que se da más importancia a la eficiencia productiva –mayores márgenes empresariales y menores costes de producción y distribución–, pero que realmente no es generadora de valor ni cuenta con un potencial transformador. Una solución pasaría por promover una cooperación entre la esfera público-privada, bajo una perspectiva de largo plazo, para potenciar el llamado *technology push* [10].

2 Implicación teórica de la calidad del empleo

Si bien se han introducido aspectos teóricos relevantes en cuanto a la innovación y la productividad, a este punto es importante delimitar la implicación y la importancia de la calidad del empleo. El término calidad del empleo fue acuñado en la Conferencia Internacional del Trabajo celebrada en 1972; su importancia recae en la visibilidad que otorga a la importancia de respetar los derechos humanos en el trabajo [2].

En España, tras la llamada Gran Recesión, y sus consecuencias en el auge de la tasa de desempleo –20%–; en términos generales, se implementaron políticas que promovieran la creación de empleo sin tener en cuenta la calidad del mismo.

No existe unanimidad acerca de qué atributos permiten considerar un empleo como empleo de calidad. La medición del bienestar de los trabajadores puede ser medido acorde a la calidad del empleo, el cual resultaría de medir las múltiples circunstancias que rodean al mismo. En segundo lugar –visión subjetiva–, puede ser estimada de acuerdo con la utilidad que obtienen los empleados de su trabajo, derivada de aquellas características que los empleados elogian de su puesto de trabajo. Por último, la visión objetiva propone medir la calidad según qué nivel de necesidades el trabajador consigue satisfacer a través de este [27].

En cualquier caso, dadas las múltiples dimensiones desde las que puede ser abordada o planteada la calidad del empleo, en el presente estudio se ha optado por utilizar la perspectiva vista desde los ingresos y beneficios reportados por el empleo [9], para llegar a comprender qué relación subyace entre ambos conceptos.

2.1 Ingresos del empleo

Se entiende por ingresos derivados del empleo aquellas ganancias –en efectivo y en especie– recibidas como contraprestación por la realización de un trabajo; dicho concepto fue definido en 1973, en «*Resolution concerning an integrated system of wages*» por ICLS-International Conference of Labour Statisticians. Incluye aspectos como pagos en especie, bonos y propinas, vacaciones –pago por tiempo no trabajado–, sueldos y salario directos [34].

El poder adquisitivo derivado de la remuneración conseguida como resultado del empleo, condiciona en gran medida la calidad de vida; pues dependen aspectos como la satisfacción de necesidades básicas y materiales o la posibilidad de acceso a una cobertura médica.

La teoría de los salarios de eficiencia –modelo Shapiro –Stiglitz– [32], promulga que los efectos derivados de pagar un salario por encima del dado por la situación de equilibrio fijada por la oferta y la demanda, deriva en un nivel socioeconómico mayor, así como una mayor motivación.

Un buen ejemplo de lo anterior se da en 1914, cuando Henry Ford decidió implementar una práctica revolucionaria en el seno de su empresa; entre las medidas se encontraba la duplicación del sueldo. La idea detrás de esta iniciativa era mejorar el nivel de vida de sus empleados, pues les consideraba potenciales clientes. Las cifras avalan el éxito de esta política, la tasa de absentismo se redujo al 2'5 %, la tasa de rotación disminuyó hasta el 54% y en 1915 hasta el 16% [33].

3 Marco conceptual

En el actual apartado se establecerá el marco teórico que establece una aproximación a la existencia de algún tipo de correlación entre la introducción de métodos innovadores en la organización y un aumento de la retribución percibida por los asalariados, y, por consiguiente, en la calidad de empleo.

En términos generales, como ha sido presentado con anterioridad, a mayor innovación mayor aumento de la productividad, correspondiéndose con mayor cota de beneficios empresariales, los cuales llegan a los empleados en forma de aumento salariales. Por tanto, habría un aumento de las rentas como consecuencia de las mayores ganancias derivadas de la productividad [24].

A continuación, se presenta la ecuación de salarios inspirada en Martínez-Ros y Fumás Salas de 1999 [24] y en el modelo de Layard de 1991 [22]:

$$W = F\ (ro,\ s,\ /,\ X) \quad (1)$$

Donde W hace referencia al salario observado –variable dependiente–, ro es el salario de oportunidad, s es el poder de negociación de los trabajadores, I referencia el proceso de innovación y X recogería el mayor o menor poder de mercado de la empresa. El salario de oportunidad muestra la posible disimilitud entre las finalmente rentas de los asalariados y las que en un principio fueron las esperadas, pues existen aspectos que intervienen como el tipo de empresa o el sector en el que está localizada.

Dicha variable independiente no guarda relación con el gasto en I+D, sino una variable expresada en porcentaje que refleja qué probabilidad existe de que la empresa inicie una actividad innovadora –proceso o producto–, dado un gasto en I+D.

Por otro lado, hemos introducido el poder negociación por parte de la organización sindical [7]. Considerando que, a mayor poder sindical, menores beneficios empresariales, y por tanto menor actividad innovadora para un cierto gasto en I+D.

X se apoya en la conocida investigación de Schumpeter en 1942 [30], donde se afirma que el clima de innovación es alentado en un ambiente ciertamente competitivo. Por su parte, Arrow en «Economic welfare and the allocation of resources for invention» argumenta que definitivamente sí se beneficia a la innovación bajo un mercado competitivo y cuanto mayor sea mejor, pues existen mayores incentivos a implementar una política innovadora en el seno empresarial.

4 Conclusiones

En el presente estudio se ha establecido la relación teórica entre la implementación de nuevas innovaciones en el proceso productivo y una mejora en la calidad en el empleo. Si bien el componente de influencia en la calidad del empleo (denotado por el nivel salarial) no recoge la implicación directa derivada de la incorporación de la innovación, con la formulación desarrollada sí se puede observar la relación teórica entre ambas variables.

Es importante resaltar que la innovación, históricamente ha derivado en incrementos en la productividad y, la misma, ha sido propiciada a su vez por mejoras en el nivel de cualificación de los trabajadores. Estas mejoras implícitas incorporadas en el actual estudio, habida cuenta de la revisión bibliográfica realizada, se ven abrigadas por la motivación de la participación en innovación teniendo en cuenta su implicación teórica, aquí planteada, en el nivel salarial.

El modelo teórico aquí planteado incorpora la influencia de la conjunción de dos modelos como son los de Martínez-Ros y Fumás Salas de 1999 [24] y en el modelo de Layard de 1991 [22] incidiendo en la relación de la innovación sobre el denominado salario observado.

Con todo lo anterior se puede concluir de la importancia de la innovación en el desarrollo del mercado de trabajo con la mejora del nivel salarial además de las que ya incorpora per sé la propia innovación con la contemplación en la misma de productividad y alto nivel de cualificación de los empleados.

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EL BIG DATA; OPORTUNIDADES, CASOS DE USO Y RETOS

BIG DATA; 0PP0RTUNITIES, USE CASES AND CHALLENGES

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Resumen: Cada año aumentan el número de artículos e investigaciones realizadas en el campo del Big Data, así como el impacto que ha tenido en las diferentes industrias. Además de todos los avances que ha permitido esta nueva forma de utilizar los datos, también se recogen los diferentes retos que plantea esta nueva forma de captura y uso de los datos y de la información.

Palabras clave: big data; captura de datos; procesamiento de datos.

Abstract: Every year, the number of articles and research in the field of Big Data is increasing, as is the impact it has had in the area of Big Data, as well as the impact it has had on different industries, are growing every year. In addition to all the advances in this new way of using data, the various challenges this new way of capturing and using data are also this new way of capturing and using data and information.

Keywords: big data; captura de datos; minería de datos.

1 Introducción

En el siguiente documento se describe cómo el big data y otros factores que intervienen en el crecimiento de los determinados sectores de la economía. Jin et al [1] recogieron los principales retos que afronta el big data en diferentes ámbitos, tanto en mercados e industrias que fomentan el desarrollo nacional como a nivel investigación. O'Neil [2] incluso afirmó que «el futuro pertenece a las empresas y personas que convierten los datos en productos». En el presente documento, a partir de la cuestión principal de identificar si el big data es útil para todos los sectores, se analizan diferentes palancas que convergen en este nuevo paradigma. Una posible aplicación de los datos del sector privado es la creación de estadísticas sobre la actividad económica agregada que pueden utilizarse para hacer un seguimiento de la economía o como insumos para otras investigaciones [3].

Como se recogió en el documento de IBM ya en 2013 [4], se han registrado más datos en los últimos dos años que en toda la historia humana anterior. Desde la perspectiva de la industria de la información, el Big Data constituye un fuerte impulso para la próxima generación de la industria de la tecnología de la información, que se basa esencialmente en la tercera plataforma, y se refiere principalmente a los grandes datos, la computación en nube, la Internet móvil y los negocios sociales.

El big data y las diferentes arquitecturas, así como posibilidades de tratar la información ha evolucionado desde sus inicios hasta ahora como se muestra en la figura 1.

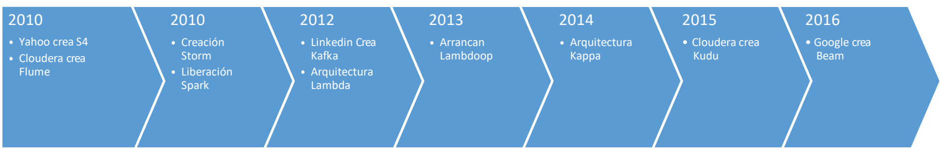

Fig 1. Evolución Big Data.

Hay diferentes sectores que han sufrido muchos cambios y han aumentado su potencial de crecimiento debido al big data [5]. Entre ellos, en este artículo se destacan sectores que de forma diferente hacen uso del big data; como el supply chain[6], el Healthcare [7], el Retail [8] y casos de uso concretos en el financiero y construcción [9].

El presente documento se organiza de la siguiente forma; en el apartado 2 se recogen diferentes casos de uso y estudios realizados en sectores de actividad concretos, el punto 3 los desafíos y retos generales que plantea el Big data y finalmente el último apartado recoge las conclusiones derivadas de los apartados anteriores.

2 Principales Industrias

El presente documento se organiza de la siguiente forma; en el apartado 2 se recogen diferentes casos de uso y estudios realizados en sectores de actividad concretos, el punto 3 los desafíos y retos generales que plantea el Big data y finalmente el último apartado recoge las conclusiones derivadas de los apartados anteriores.

2.1 Supply Chain

El *supply chain*, también denominado cadena de suministro, ha progresado hacia un entendimiento común de la Resiliencia [10]. MacCarthy et al, definieron el ciclo de vida de la cadena de suministro e identificaron seis factores que interactúan y pueden afectar a una cadena de suministro a lo largo de su ciclo de vida: la tecnología y la innovación, la economía, los mercados y la competencia, la política y la reglamentación, la adquisición y el abastecimiento, las estrategias de la cadena de suministro y la reingeniería [11]. Por otro lado, autores como Waller et al [12] sugieren que; El análisis predictivo de la logística utiliza métodos cuantitativos y cualitativos para estimar el comportamiento pasado y futuro del flujo y el almacenamiento del inventario, así como los costos asociados y los niveles de servicio. El análisis predictivo de Supply Chain Management utiliza métodos tanto cuantitativos como cualitativos para mejorar el diseño de la cadena de suministro y la competitividad mediante la estimación de los niveles pasados y futuros de integración de los procesos empresariales entre las funciones o empresas, así como los costos asociados y los niveles de servicio.

2.2 Healthcare

En una revisión del estado del arte e investigación en el campo del big data en healthcare llevada a cabo en 2017, se concluyó que; «*a) En la etapa inicial, los investigadores de los Estados Unidos, la República Popular China, el Reino Unido y Alemania fueron los que más contribuyeron a la bibliografía relacionada con la investigación de grandes datos sobre la atención de la salud y la vía de la innovación en este ámbito. b) La vía de la innovación en los grandes datos de la atención de la salud consta de tres etapas: la fase de detección temprana, diagnóstico, tratamiento y pronóstico de la enfermedad, la fase de promoción de la vida y la salud, y la fase de enfermería. c) Los puntos calientes de la investigación se concentran principalmente en tres dimensiones: la dimensión de la enfermedad» [13]*.

Por otro lado, [14] desarrollaron un estudio en el que se elaboró un marco que pudiera utilizarse para orientar el análisis que puede traducir y transformar grandes datos en un recurso más útil y útil para los profesionales de la salud, mejorando así los servicios que prestan a los pacientes. Como Margolis definió «Los grandes datos no son sólo una nueva realidad para el científico biomédico, sino un imperativo que debe ser comprendido y utilizado eficazmente en la búsqueda de nuevos conocimientos» [15].

2.3 Retail

La venta al por menor es una de las actividades comerciales más destacadas y diversificadas del mundo, que ha transformado considerablemente las estrategias comerciales para obtener más beneficios. Hoy en día, la definición de venta al por menor es sinónimo de tiendas de mercancías atractivas y adecuadamente gestionadas con una comodidad y un ambiente increíbles, en lugar de las tiendas tradicionales apiladas al azar. Además, el cliente moderno está enfocado hacia la calidad/marcas y espera que los servicios que le entregan los diferentes vendedores le lleguen a su casa con un solo clic. Como resultado, los clientes prefieren comprar en varios sitios web de compras en línea en lugar de trasladarse físicamente a una tienda minorista, lo que a su vez lleva a la caída de las ventas de los minoristas que se ha convertido en una importante amenaza para ellos.

McArthur et al [16] realizaron una revisión de la literatura en cuanto a las diferentes aplicaciones del big data en retail. Esta revisión de la literatura aplica un enfoque macro y teoría de sistemas a la literatura multidisciplinaria, y vincula los cuerpos de trabajo que, hasta ahora, han permanecido conceptualmente desconectados. Esto proporciona una meta tipología de seis factores que podrían explicar el cambio en la venta al por menor: eficiencias económicas, patrones cíclicos, desigualdades de poder, comportamiento innovador, influencias ambientales y partes interdependientes del sistema en co-evolución.

3 Retos del Big Data

El paradigma del big data aún tiene muchas incógnitas y retos a los que sobreponerse. Sivarajah et al [17] condujeron un estudio en el que se ponían de manifiesto los diferentes retos y oportunidades que presentaba el big data en la actualidad. Así mismo, Hairi et al [18] recoge los temas relacionados con las cinco V de los grandes datos, sin embargo, existen muchas otras V. En términos de la investigación existente, se ha prestado mucha atención al volumen, variedad, velocidad y veracidad de los datos, con menos trabajo disponible en valor (por ejemplo, los datos relacionados con los intereses corporativos y la toma de decisiones en dominios específicos).

3.1 Seguridad y Privacidad

A pesar de las grandes ganancias en materia de datos, existen también numerosos desafíos y entre ellos el de mantener la privacidad de los datos es la preocupación más importante en las grandes aplicaciones de extracción de datos, ya que el procesamiento en gran escala de conjuntos de datos delicados, como los registros de salud y los registros de transacciones bancarias, debe mantenerse de manera que los datos privados no se revelen a ninguna persona no autorizada. Sharma et al [19] recogen y examinan los problemas que plantea el big data así como los problemas que plantea la extracción de datos en gran escala y la preocupación por la privacidad de los grandes datos.

4. Conclusiones

Como se muestra a lo largo del documento, hay diferentes factores que contribuyen al uso del big data, así como el uso óptimo de los recursos ofrecidos. Siendo una nueva forma de entender los datos, y habiendo aparecido hace más de 10 años, todavía se encuentra en una fase muy temprana en la que sigue habiendo muchos retos y desafíos por solventar, así como diferentes formas para poder alcanzar máximos rendimientos.

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INNOVACIÓN Y CLÚSTERES TECNOLÓGICOS

INNOVATION AND TECHNOLOGY CLUSTERS

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Resumen: En el presente artículo se recogen diferentes factores que afectan al incremento de la competitividad en empresas, así como la vinculación de éstas con los clústeres tecnológicos. Se recogen las ideas de los principales economistas y análisis de campo realizados en relación con las ventajas competitivas y los diferentes modelos de colaboración y cooperación para el desarrollo. En el presente artículo se ha podido identificar que las políticas en cada región son determinantes a la hora de fomentar dichos clústeres.

Palabras clave: clúster; innovación; ventaja competitiva; tecnología.

Abstract: In this article, different factors that affect the increase of competitiveness in companies and the increase of competitiveness in companies and the link between them and with technology clusters. The ideas of the prominent economists and field economists and field analyses carried out concerning competitive advantages and the different collaboration models competitive advantages and the other models of collaboration and cooperation for development. This article has identified that the policies in each region are determinant in each area and are decisive in promoting such clusters.

Keywords: clusters; innovation; competitive advantage; tecnology.

1 Introducción

Este artículo explora la relación entre la innovación y las colaboraciones empresariales y cómo éstas afectan a la competitividad y el crecimiento de las Pequeñas y Medianas Empresas (PYMEs). A lo largo de los años se ha demostrado que los clústeres de empresas tienen un impacto positivo en el campo de la innovación. Las redes de innovación son la regla y no la excepción, y en la mayoría de las actividades innovadoras intervienen múltiples actores y en las que ha estado fomentando y analizando durante más de 20 años la OCDE [1]. Los clústeres innovadores de actividad económica se están convirtiendo en imanes para la nueva tecnología, el personal cualificado y la inversión en investigación. Además de resultar determinante la creación de estos centros tecnológicos para la mejora en innovación en términos tecnológicos. Estas acciones orientadas a las creaciones de clúster han sido determinantes en las regiones menos desarrolladas de Europa [2]. Estos clústeres surgen con mayor frecuencia cuando hay una masa crítica de empresas que permite economías de escala y alcance, una base científica y tecnológica sólida y una cultura que propicia la innovación y el espíritu empresarial. Dichas agrupaciones también pueden basarse en factores como los recursos naturales o las ventajas geográficas. Muchas agrupaciones exitosas tienen largas raíces históricas, y la aparición de nuevas agrupaciones lleva tiempo como demostraron Roetlandt et al [3]. Actualmente, nos encontramos en una economía basada en el conocimiento, en la que la generación y la explotación de los conocimientos desempeñan un papel fundamental en el proceso de creación de riqueza, la ventaja competitiva se acumula gracias a los conocimientos únicos y a la capacidad de aprender más rápido que el competidor según Grant [4]. Este hecho de la capacidad de obtención de recursos de conocimiento juega por tanto un rol determinante y por ello la importancia del acceso a los clúster tecnológicos por parte de las empresas PYMEs[5].

A lo largo de los años se han determinado diferentes indicadores para medir la importancia y la efectividad de las colaboraciones en diferentes tipos de entornos macroeconómicos [6] así como también han aparecido nuevas medidas para medir la digitalización de los entornos [7][8]. Las teorías de negocios tienen dos teorías distintas para explicar la competencia. Keynes y los seguidores de la teoría neoliberal basada en la teoría de las ventajas comparativas dicen que el mercado mitiga automáticamente las diferencias de desigualdad de ingresos, por lo que todos pueden participar en la economía y el comercio internacional explotando sus propias ventajas comparativas [9]. Las teorías de Porter definen la competitividad más bien a nivel de empresa y ponen la productividad en el centro del análisis. Dentro de las teorías de Porter una de las formas más utilizadas para elaborar este tipo de análisis, es la de la red de diamantes de Porter [10] como se muestra en la figura 1.

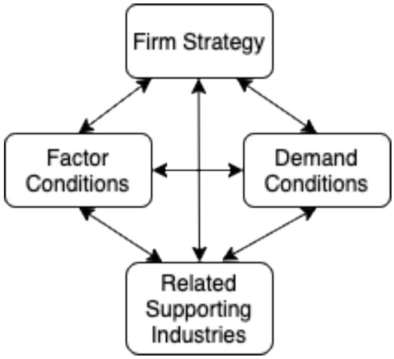

Fig 1. Modelo de diamante Porter.

Otras de las formas que aparecen en la literatura y que se han utilizado para hacer los análisis de la efectividad y eficiencia de diferentes tipos de clúster son los que se describen en la Figura 2 y la Figura 3. En ambos casos aparece el factor gobierno e industria, siendo cierto que son dos de los principales motores para el funcionamiento y creación de cualquier tipo de cluster en innovación. En la Figura 2 se utiliza el «Triple Helix» y en la Figura 3 la *« four-leaf clover innovation»*, ambos métodos utilizados para analizar distintas situaciones que incluyen los clúster.

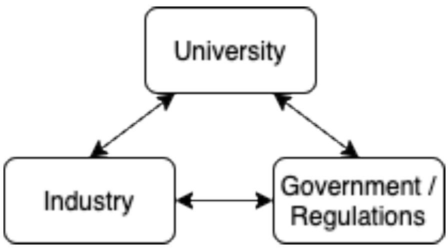

Fig 2. Triple Helix. Fuente: Elaboración propia en base al modelo «Triple Helix».

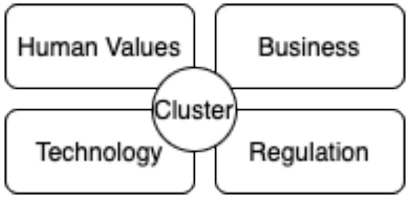

Fig 3. Four leaf-clover innovation. Fuente: Elaboración propia en base al modelo «Four leaf-clover».

En la bibliografía se encuentra una larga lista de factores individuales que afectan a la competitividad de la empresa. Estos factores difieren en su impacto actual en la productividad potencial basada en el conjunto específico de condiciones locales presentes [10].

El artículo se estructura de la siguiente forma; en la sección 2 se hace referencia al estado del arte, la sección 3 analiza los diferentes casos de éxito y en la sección 4 las conclusiones derivadas del análisis.

2 Estado del arte

El interés en la relación entre la innovación y el desarrollo regional también ha surgido debido al desempeño de algunas agrupaciones industriales clave, las denominadas «nuevas zonas industriales» que parecen generar un alto grado de innovaciones industriales, como Sillicon Valley [12][13]. Estas agrupaciones industriales se caracterizan principalmente por las PYMES que generan una gama de nuevos productos. Las agrupaciones se centran en diferentes grados en el desarrollo de productos de alta tecnología y/o en la mejora tecnológica de las actividades artesanales. El avance de estas zonas y la innovación demuestran la importancia de la ubicación de una nueva empresa y sus determinaciones por los clústeres [14]. La observación de estas agrupaciones industriales ha dado lugar a evidencias de buen desempeño de las empresas y desarrollo de esas regiones. El economista Michael Porter introdujo varios conceptos, entre ellos; el concepto de teoría de la estrategia competitiva [15] y ventaja competitiva [16]. El concepto de ventaja competitiva fue uno de los principales focos de estudio e investigación de Porter. Desarrolló diferentes teorías para evaluar el estado de los clústeres, su papel en la competencia y sus implicaciones. Describe la teoría del proceso por el cual crecen y decrecen, los papeles apropiados del sector privado, el gobierno y otras instituciones en la de la mejora de los clústeres [17]. La ventaja competitiva, el rendimiento económico y la prosperidad de una empresa surgen de las interdependencias entre actividades complementarias; incluye la disponibilidad de recursos iniciales, el intercambio de tecnología común, conocimientos específicos, insumos y productos en todos los sectores industriales [18].

2.1 Tipo de clúster

En este apartado se clasifican los tipos de clúster por tipología de los actores implicados, así como de los sectores en los que operan. Existen diferentes formas de entender el funcionamiento de los clústeres y sus agrupaciones. En este caso se ha hecho referencia al modelo propuesto por Roelandt et al [3]. En su libro, definen los diferentes tipos de clúster existentes y la influencia de las políticas gubernamentales que existan en cada momento y que se apliquen sobre ellos. Es decir, si los gobiernos invierten en Innovación y Desarrollo a nivel regional. Roelandt et al [3] proponen una clasificación por nivel de análisis (macro, meso y micro).

- Macro – Son a nivel nacional, como el caso de Taiwán [19].
- Meso – Son a nivel de una industria en concreto, como el caso de Silicon Valley[12][13]
- Micro – Son a nivel de una empresa en concreto y potenciales proveedores.

En este caso, el presente estudio recoge sobre todo los clústeres a nivel macro y meso ya que el análisis de estos tipos de clústeres, permiten elaborar enfoques para analizar la competitividad de la estructura de producción local. La importancia de los clústeres no reside únicamente ni afecta a que sea un conglomerado de empresas, sino que el sector al que pertenecen es igual de importante que dicha asociación. Es por ello por lo que hay sectores que se beneficiarán más de pertenecer a un clúster que otro. En el caso del sector del turismo, por ejemplo, en Brasil se propuso un modelo para fomentar el crecimiento en dicho sector [20]. Otro caso de tipos de clústeres crecientes son los orientados a la agricultura, denominados agribusiness y que han sido determinantes para la innovación y crecimiento en diferentes zonas de Europa [21].

3 Casos de uso

Además de los clústeres tecnológicos mencionados anteriormente, hay diferentes casos de éxito en el que se ha demostrado que los clústeres tienen un alto impacto en innovación tanto sobre las empresas como en la zona en la que se concentran. Por ejemplo, el caso de Taiwán [19] es una de las historias de éxito en el desarrollo mundial de la innovación y los clústeres industriales. Para analizar la situación se analizaron las zonas económicas especiales y se realizó un estudio empírico sobre las agrupaciones industriales y la competitividad de las empresas. Además de la creación e impulso de la economía de Taiwán de referencia son las zonas económicas especiales.

Por otro lado, [23] analizó la competitividad nacida de la creación de diferentes clústeres, los resultados indicaron que los clústeres regionales suelen ser competitivos a nivel internacional, y el análisis revela que las agrupaciones regionales de Noruega, con algunas excepciones importantes, experimentan una tendencia positiva en materia de empleo en comparación con los sectores correspondientes en todo el país.

Simmie et al [24]recogen la importancia de los clústeres en Londres y cómo estos han afectado de forma global a la economía, no únicamente local. Siendo el clúster en industria de Londres uno de los más grandes a nivel mundial.

Molema et al [22] recogen las diferentes implicaciones y los resultados derivados de las creaciones de los clústeres en el campo de la agricultura en las zonas más deprimidas económicamente en regiones de Europa. Los diferentes casos de uso recogidos en este apartado son un reflejo a nivel mundial de que la creación de los clústeres es positiva a nivel mundial independiente del modelo organizacional que predomine en una u otra región.

4 Conclusiones

Las conclusiones recogidas en este artículo destacan la importancia de la aparición de los clústeres como palanca para mejorar las economías locales como a nivel internacional. Además de ser una palanca para mejorar la economía y reducción de costes por transferencia de conocimiento, también resultan indudablemente un motor para la creación de empleo e innovación en campos diversos. Siendo muy importante las políticas económicas de los países u órganos encargados de fomentar la innovación y el desarrollo. Las líneas de trabajo futuro se enfocarán hacia cómo están apareciendo nuevos modelos de colaboración y cómo los clústeres tecnológicos también pueden fomentar y transferir innovación entre ellos.

Agradecimientos

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DESARROLLO Y COMPETITIVIDAD EN TERRITORIOS FRONTERA Y PERIFÉRICOS

DEVELOPMENT AND COMPETITIVENESS IN BORDER AND PERIPHERAL TERRITORIES

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RESUMEN: El presente artículo recoge las diferentes implicaciones que tienen los incentivos económicos externos en determinadas regiones frontera y periféricas. En el estudio se detallan casos de éxito en el que la inversión por parte de la UE ha sido clave para el desarrollo de la economía en esas zonas. Los resultados de este estudio conducen a concluir que aún siendo difícil medir dichas implicaciones económicas, la inversión y fondos como el INTERREG con previsiones a largo plazo resultan claves para el desarrollo.

PALABRAS CLAVE: competitividad; innovación; desarrollo.

Abstract: This article discusses the implications of external economic incentives in specific external financial incentives in particular border and peripheral regions. The study details successful cases in which EU investment has been key to developing the economy in these areas. Investment by the EU has been key to the development of the economy in these areas. This study concludes that while it is difficult to measure the economic implications, investment and funds such as INTERREG, with long-term forecasts, are with long-term forecasts are crucial to development.

Keywords: competitiveness; innovation; development.

1 Introducción

Un cambio básico de la teoría económica del siglo XXI ha sido el flujo de capital a nivel global y en el caso de Europa los movimientos libres dentro de ciertas regiones. Este capital global y a las actividades comerciales sobre la concentración espacial de las actividades económicas y la reconsideración de las teorías de competitividad conexas ha sido un foco de interés en los últimos años. A nivel práctico, la competencia territorial, es un fenómeno que se explica por los crecientes rendimientos de escala y la explotación de los beneficios de la aglomeración por parte de la literatura de la economía regional [1].

Estas regiones que tienen diferentes competencias políticas diferentes pero mismas características territoriales cada vez juegan un papel más importante a nivel de competición entre países. En el caso de la UE hay diferentes órganos dedicados al desarrollo de estas zonas transfronterizas. Las inversiones en I+D han aumentado la capacidad de innovación, impulsado el crecimiento económico o mejorado los resultados del mercado laboral en las regiones periféricas de la UE [2]. La cuestión de las contribuciones a turismo y a diferencias industrias en las zonas transfronterizas ha sido un tema en el que ha habido mucho interés desde el acuerdo de la Organización Mundial del Comercio (OMC), 1993 [3].

El presente artículo se ha organizado de la siguiente forma; en la sección 2 se indican los factores externos que conducen a la innovación en las empresas, en la sección 3 y 4 la situación y palancas para el desarrollo de territorios frontera y periféricos, finalmente la sección 5 cubre diferentes casos de éxito y la sección 6 las conclusiones derivadas del estudio.

2 Factores Externos para la innovación en las empresas

Varios investigadores han descubierto que los nuevos conocimientos, puntos de vista e ideas que provienen de fuera de las propias organizaciones dan lugar a más innovaciones que la que se puedan dar dentro de las empresas [4]. Los diferentes estudios concluyen que la innovación y las nuevas ideas provienen de factores de fuera de la organización [5]. Los estudios en el campo de la economía parten de la hipótesis de que el nivel de innovación en una empresa puede explicarse en términos de las características estructurales de la industria en la que compite, y que es posible encontrar patrones generales de cambios tecnológico asociados con industrias específicas o, en su defecto, con amplias categorías industriales [6]. Por tanto, además de los factores externos, la industria a la que pertenece una empresa será también clave para fomentar la innovación.

En la literatura, diferentes autores han hecho referencia a modelos y tipos de innovación. En la Fig1 se han representado los factores definidos por la OECD como clave para la innovación. El modelo que se El Manual de Oslo, [7] define cuatro tipos de innovaciones que incluyen una amplia gama de cambios en la empresa: innovaciones en el producto, el proceso, la organización y la comercialización. Dichas categorias se recogen en la Fig 1.

Fig 1: Tipos de Innovación definidos.

En cuanto a las empresas hay diferentes estudios que evidencian las diferencias en los factores que afectan a la innovación en una empresa, a continuación, se describen algunos de ellos:

- La zonificación influye en el alcance y la calidad de las actividades de innovación, que varían en las distintas regiones [8] y a fuentes de conocimiento externas. Las empresas pueden beneficiarse de su ubicación y proximidad a los facilitadores de la innovación [9].

– La existencia de centros de investigación en el entorno de una empresa, con los que pueden mantener un contacto constante, creando valores y capital social que, a su vez, aumentan la confianza y la interacción entre los diferentes elementos de la red, mejora la capacidad de innovación de una organización [10].

3 Medidas para el desarrollo de territorios frontera

3.1 Contextualización en desarrollo de territorios frontera

En los últimos años, las zonas fronterizas han adquirido gran importancia en el escenario internacional en lo que respecta a su potencial y funciones integradoras, como se ejemplifica a lo largo de la unificación de Europa [11]. Sin embargo, la transformación progresiva de los paisajes urbanos y rurales junto con las zonas fronterizas ha suscitado inquietudes a nivel mundial, lo que aumenta la necesidad de replantearse no sólo la forma en que deben crecer las ciudades [12], sino también la forma en que los países deberían cooperar entre sí para reforzar los beneficios de posibles proyectos de cooperación transfronteriza a distintos niveles [13].

El hecho de que más de un tercio de la población europea vive en zonas fronterizas, que son las más afectadas por las políticas de la UE, así como de las lagunas que estas políticas aún muestran [14], destaca que aún queda un largo camino por recorrer para aplicar plenamente las ideas expuestas por Emil Gött a finales del siglo XIX, según las cuales las fronteras no deben ser consideradas como factores limitantes, sino como algo que significa crecimiento y prosperidad entre las naciones.

3.2 Políticas implantadas por la UE en programas de cooperación transfronteriza

Europa ha financiado diferentes proyectos para la cooperación transfronteriza, los programas de cooperación transfronteriza de la UE se establecieron oficialmente con la puesta en marcha de la primera Iniciativa Comunitaria INTERREG [15][16]. La mayoría de los proyectos se engloban en un marco horizonte temporal hasta 2020, al mismo tiempo, apoya un nuevo paradigma estratégico para estos programas en la fase programática post-2020, enfocado a reducir los efectos barrera en todas las dimensiones, creando un potencial nuevo horizonte con planes hasta 2027 [17].

Estos proyectos han sido analizados y su eficacia a través del análisis del impacto y en general, se puede observar que los contextos regionales y nacionales tienen un gran impacto en la implementación y adopción de las mejores prácticas, así como en el establecimiento de estructuras de cooperación comunes [18].

Cooperación Sostenible. Algunos estudios como el llevado a cabo por Kurowska-Pysz [19] identificaron los factores que contribuyen a la cooperación transfronteriza sostenible y que afectan a la motivación para aumentar la cooperación entre los socios transfronterizos sobre la zona fronteriza polaca-lituana para realizar un análisis comparativo, útil para identificar y evaluar los factores que motivan la cooperación transfronteriza sostenible en la zona fronteriza [19]. La cooperación sostenible, transfronteriza e interinstitucional en las tierras fronterizas es el resultado de la interacción simultánea de tres grupos de factores: personas e instituciones, planificación transfronteriza, procedimientos y mecanismos de apoyo (por ejemplo, la posibilidad de planificar conjuntamente la cooperación transfronteriza y obtener fondos de la Unión Europea para el desarrollo de las tierras fronterizas, así como la disponibilidad de otros fondos útiles para este tipo de cooperación); y la afinidad histórica y proximidad geográfica de las regiones fronterizas vecinas, apoyo del sistema a nivel regional y local en los países vecinos [19]. A lo largo de los años ha habido múltiples estudios que han medido la eficiencia y los diferentes planes de acción llevados a cabo con las políticas y planes propuestos por la Unión Europea en el marco de INTERREG. Por ejemplo, otras zonas como la alemana-polaca [20] o bien la zona de Escandinavia [21].

4 Medidas para el desarrollo en zonas periféricas

Las regiones fronterizas se consideran zonas periféricas. Las diferencias en las regiones periféricas son muy acentuadas. Por ejemplo, en el caso de España, García-Cortijo et al [22], analizaron las diferentes palancas que conllevan a la innovación en las regiones del sur de Europa, en concreto de España. En dicho estudio revelaron que la innovación se predice principalmente por factores internos relacionados con las empresas. En el estudio de García-Cortijo et al [22], la forma jurídica de la empresa también es importante; las cooperativas surgen como agentes de cambio que promueven la innovación, y las variables relacionadas con el medio ambiente también desempeñan un papel, pero no son suficientemente significativas.

Entre las razones del menor nivel de innovación en las regiones periféricas, diferentes estudios han evaluado y han encontrado diferentes denominadores comunes [23][24]. Algunos de los denominadores mencionados anteriormente son; son zonas que se encuentran aisladas geográficamente, hay un tejido empresarial ya existente de pequeñas y medianas empresas dedicadas a las industrias tradicionales, el limitado desarrollo de agrupaciones y asociaciones de empresas, la escasa contribución de conocimientos y los escasos vínculos con centros de innovación y tecnológicos. Otra medida y para las cuales se están desarrollando diferentes mecanismos es el poder predecir la bancarrota a tiempo también como una medida para el desarrollo [25].

5 Casos de éxito

En la actualidad hay diferentes casos de éxito recientes en los que los incentivos externos han contribuido positivamente al desarrollo de las zonas.

Rechnitzer et al [1] realizaron un estudio en el que se apoyaron numéricamente para la suposición de que existen diferencias de competitividad tanto entre los de la capital y el campo y las regiones del norte y del sur de los países. Aunque la desviación de la tasa de empleo y la proporción de la población en edad de trabajar son relativamente bajas, si se considera la productividad laboral, las entidades individuales difieren de la media, en un promedio del 47%. Podemos concluir que las desigualdades regionales en materia de ingresos se deben principalmente a la mano de obra utilizada para producir una unidad de producción, mientras que la tasa de empleo y la proporción de población activa no explican esta ventaja competitiva [1].

Uno de los casos de éxito mencionados anteriormente y relacionado con el desarrollo de zonas periféricas y transfronterizas es el caso del valle del jerte (zona Extremadura), es un ejemplo en el que las estructuras de redes contribuyen a la creación de un destino cohesivo, en el que el intercambio de recursos permite dar respuestas locales innovadoras a los desafíos del mercado mundial [26].

6 Conclusiones

En el presente documento se recogen diferentes casos en los que se han llevado a cabo políticas de innovación por parte de órganos gubernamentales en los que se pretendía fomentar la transferencia de conocimiento y tecnología en zonas periféricas y fronterizas. En el caso de las zonas transfronterizas además tienen el hándicap de que tienen legislaciones de dos países y por tanto que existan proyectos como INTERREG a escala europea, fomentan el desarrollo de dichas zonas. La inversión monetaria por parte del exterior en estas zonas constituye una pieza clave para el desarrollo de estas.

Agradecimientos

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HOW DIGITAL INNOVATION HUBS CAN HELP THE SMES DIGITALISATION, PORTUGUESE AND SPANISH EXAMPLES

¿CÓMO LOS CENTROS DE INNOVACIÓN DIGITAL PUEDEN AYUDAR A LA DIGITALIZACIÓN DE LAS PYMES? EJEMPLOS PORTUGUESES Y ESPAÑOLES

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Abstract: This article introduces the different DIHs that currently operate in the Castile and Leon region in Spain and the Norte region in Portugal and presents some success stories involving SMEs from both countries.

A brief presentation on the status of digital adoption in both countries per sector and per technology is made.

Keywords: DIH-Digital Innovation Hub; Digitalisation; Digital Technologies.

Resumen: Este artículo presenta los diferentes DIH que actualmente que operan en la región de Castilla y León en España y en la región Norte en Portugal y presenta algunos casos de éxito de las PYME de ambos países.

Se presenta brevemente el estado de la adopción digital en ambos países por sector y por tecnología.

Palabras clave: DIH – Digital Innovation Hubs; digitalización; tecnologías digitales.

1 Digitalisation and Digital Innovation Hubs within the European policy

1.1 Background

Digitalisation is an enormous opportunity and challenge for the current generation. It is revolutionising the world of work, business structures and value chains as well as innovation and market structures. The recent COVID-19 pandemic is a sombre reminder of the relevance —and the necessity— of digital technology for a variety of businesses and sectors: from health to retail, from manufacturing to education [1].

In what regards the manufacturing sector the Digitising European Industry Initiative [2], adopted in April 2016, identified the Digital Innovation Hubs as gateways to link the existing digital innovation capacity of Europe in order for traditional sectors and small and medium enterprises (SMEs) to be able to access the knowledge from high-tech sectors that face strong competition from other parts of the world.

According to the European Commission (EC) the Digital Innovation Hubs (DIHs) are not-for-profit, one-stop-shops that support companies —in particular small and medium-size enterprises (SMEs)— and public organisations in their digital transformation, offering them services such as:

- Test before invest. Experimentation with new digital technologies —software and hardware— to understand new opportunities and return on investments, also including demonstration facilities and piloting;

- Skills and training to make the most of digital innovations: train-the-trainer programmes, boot camps, traineeships, exchange of curricula and training material;
- Support to find investments: feasibility studies, develop business plans, incubation & acceleration programmes;
- An innovation ecosystem and networking opportunities through marketplaces and brokerage activities [3].

Within Horizon 2020 500 million EUR was for Digital Innovation Hubs (2016-2020) activities, namely to support more than 2000 Start-ups, SMEs and mid-caps to test digital innovations in collaboration with more than 200 DIHs networked across the European Union [3]. These projects typically cascade funding through open calls by engaging SMEs in innovative experiments with DIHs in a cross-border context.

1.2 The digitising current status

Three years after the launch of the Digitising European Industry Strategy the economy has made significant progress. The level of digitalisation however remains uneven, depending on the sector, country and size of company: only 20% of SMEs in the EU are highly digitised [4].

According to the Study «Who is prepared for the new digital age?» from the European Investment Bank Investment Survey (EIBIS) [1] only 66% of manufacturing firms in the European Union report having adopted at least one digital technology. Digitalisation is associated with better firm performance. Digital firms tend to have higher productivity than non-digital firms, have better management practices, be more innovative, grow faster and create higher-paying jobs. A major barrier that is identified in Europe towards the increase in digital adoption is the high percentage of small firms that do not invest in digital technologies, that reinforces the important role of the DIHs.

EIBIS presented some comparison data between the EU and the US, in regards to digital adoption per sector, that is also disaggregated per country. In Figure 1 the data are presented including Portugal and Spain, the two countries involved in the DISRUPTIVE project.

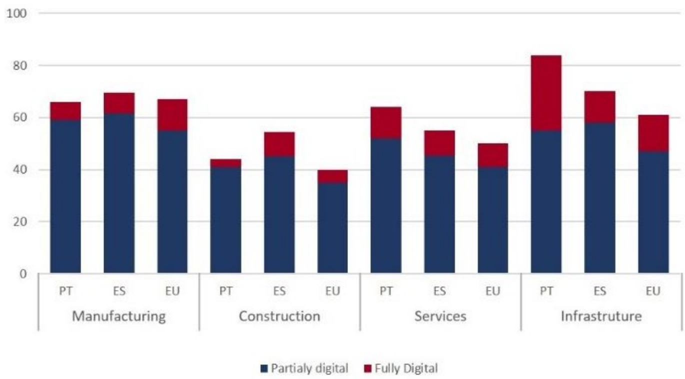

Fig. 1. Digital adoption per sector in Portugal, Spain and the EU (in % of all firms) SOURCE: Adapted from EIBIS wave 2019. Note. A firm is identified as partially digital if at least one digital technology was implemented in parts of the business and fully digital if the entire business is organized around at least one digital technology. Firms are weighted using value added.

Analysing the data in terms of digital adoption in the manufacturing sector, it can be observed that both Portuguese and Spanish companies are above the EU in the minimum digitalization, meaning with at least one digital technology implemented in parts of the business, but the number of fully digital companies in EU is higher than in either Portugal or Spain. On the other sectors in overall terms both Portugal and Spain are above the average EU companies.

Concerning the two countries involved in the DISRUPTIVE project, Portugal and Spain the adoption of different digital technologies by sector is given in Figure 2.

In what concerns the technologies most implemented they differ per sector being IoT the only one that is commonly used, followed by 3D Printing that is only absent in Services. Focusing on the manufacturing sector and analysing by technology, the EU integration of 3D printing is more expressive than in PT or ES and is quite similar on robotics; In IoT and Big data and AI both countries are above the EU with Spain presenting slightly higher values. In the other sectors Spain is higher or equivalent to the average of the EU companies, while Portuguese construction companies are behind in 3D printing and virtual reality, service companies slightly below in virtual reality and big data and AI. In Infrastructure PT and ES are slightly below the EU.

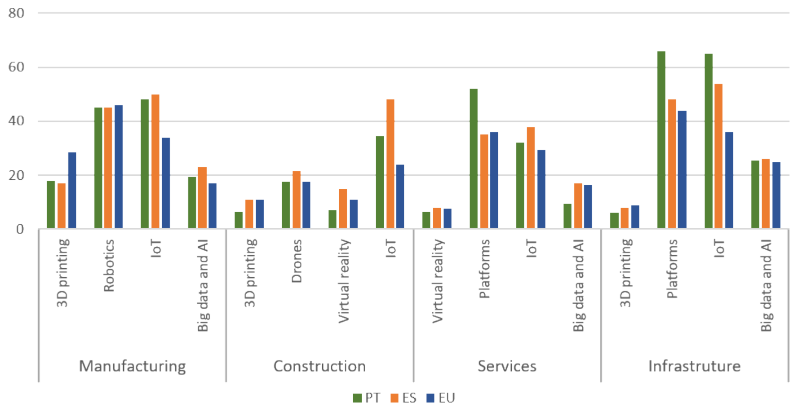

Fig. 2. Adoption of different digital technologies per sector in PT, ES and the EU (in % of all firms) SOURCE: Adapted from EIBIS wave 2019. Note. IoT: Internet of Things, AI: Artificial Intelligence. Firms are weighted using value added.

1.3 The upcoming EC financial framework 2021-2027

Within the new EC financial framework for 2021-2027, DIH will continue to play a key role, as they will be part of both the «Horizon Europe» and «Digital Europe» programmes. On the one hand, the «Horizon Europe» programme will support experiments where highly innovative companies work together with DIH to develop innovative digital solutions to improve their business. And on the other hand, the «Digital Europe» programme aims to increase the capacity of DIH to enable all businesses, SMEs and the public sector to benefit from strategic digital technologies and advanced digital skills [3].

2. DIHs in Castilla y Léon (Spain) and Norte (Portugal)

In the Portuguese Norte region, 2 fully functional DIHs are identified:

- PRODUTECH Digital Innovation Hub Platform (http://www.produtech.org), coordinated by PRODUTECH and located in Porto. The mission is to promote the digitization of the manufacturing industry, by establishing a critical mass of capacities, articulating and networking the relevant actors and by stimulating the ecosystem, presenting a portfolio of support services that enable and enhance the modernization of the industry.

- iMan Norte Hub-Digital Innovation Hub for Customer-Driven Manufacturing @ Norte (https://www.imannortehub.com/), co-coordinated by PRODUTECH and located in Porto. The main objective is to facilitate and foster manufacturing technology adoption and diffusion in the areas of cyberphysical production systems and robotics.

Currently, the Spanish region of Castilla y León has 4 regional DIHs, three of which are fully operational and one in preparation:

- DIH IoT (https://www.innovationhub.es/), coordinated by AIR Institute and located in Salamanca. The objective of the IoT-DIH is to help companies become more competitive through the adoption of Internet of Things (IoT) Technologies in their business or production processes.
- DIH Ciberseguridad (https://www.cybersecuritydih.es/), coordinated by Cluster of Cybersecurity and Advanced Technologies and by INCIBE. Located in León. The objective of this DIH is to bring cybersecurity and other advanced technologies closer to companies. Improve the knowledge that companies have of the active security policies that they must adopt.
- DIHBU Industria 4.0 (http://www.dihbu40.es/), a private non-profit association with legal personality. Located in Burgos. The DIHBU objective is to incorporate different 4.0 Technologies into the SMEs ecosystem. As well as guiding administrations in the implementation of digital solutions.
- Smart City Valladolid y Palencia (http://www.smartcity-vyp.es/), is under preparation under the coordination of CARTIF. Located in Valladolid. This DIH is a novel Project since it considers two cities, close and with different characteristics, this adding transport from one city to another as one more which is an added problem within a Smart City.

3 Projects participated by the Castilla y Léon and Norte DIHs

Within Horizon 2020 several activities boosted by DIH networks to support Start-ups, SMEs and mid-caps to test digital innovations where implemented.

3.1 Portugal and Norte region

Within the Norte Region and within the PRODUTECH ecosystem two projects are on-going DIH2 – A Pan-European Network of Robotics DIHs for Agile Production and DIH4CPS – Fostering DIHs for Embedding Interoperability in Cyber-Physical Systems of European SMEs.

The DIH^2 project (http://www.dih-squared.eu/) establishes a network of 26 Digital Innovation Hubs, from equivalent number of European countries including Portugal and Spain, with the objective to trigger incremental and disruptive innovation processes in industrial companies, supporting SMEs in their agile production challenges and promoting their digitalization through more cost-efficient robotic solutions for small batch productions. Within this project 26 pilots and innovative experiences with the potential to become open standards for agile production will be selected from an open competition and financed. A total of 96 applications were submitted to the Open Call, 5 proposals were Portuguese. In total 11 projects were selected for funding by an external panel, 2 of which Portuguese projects, FIREFIT and FEATS. The FIREFIT – *Fiware Ready Quality Control for packaging Systems in the Food Industry*, is being developed by INTROSYS and applied in A. Pires Lourenço & Filhos S.A. company. FEATS – *FIWARE Enabled Autonomous Transport System* is being developed by DALMASYS Lda. and implemented in DURIT – Metalurgia Portuguesa do Tungsténio, Lda.. The implementation of these experiments lasts 8 months and includes the support from the responsible DIH, PRODUTECH in the case of the Portuguese projects; financial support up to €248,000; technical support; mentoring and training and support on ethical, data privacy and cyber-security issues by EU experts. Currently the experiments finished the «Experimental setup» and the «Implementation of Smart Factory services» phases and are starting the «Experiment execution» on manufacturing companies and the «Business development» for the new technologies.

The DIH4CPS project (http://dih4cps.eu) aims to support the European strategy of industry digitisation, so that any company in Europe has access to a DIH, supporting it in its digital transformation. In this sense, the DIH4CPS project aims to leverage the network of Digital Innovation Hubs and solutions providers on an European scale, focused on cyber-physical systems and embedded systems (CPS). The project started with 13 DIHs from 10 countries and this network of DIHs is expected to grow to 33 through the financing of two open calls. Within DIH4CPS, Application Experiments (AE), formed by a group of partners that, with different skills and specific competences, will put in practice the aimed solutions, demonstrating how the DIH become available to address specific and otherwise complex business needs. It started with 11 initial AEs, with a DIH in each, to support the research centres, suppliers and end-users of CPS. PRODUTECH takes part of AE 7 – Safety and wellbeing of workers – CPS for security and wellbeing of shopfloor workers. The AE involves also UNINOVA, in the Data Collection setup, KnowledgeBiz, in Data Analysis integration and development, and PRODUTECH, providing the real setup places and enrolment of its members in the activities. For that PRODUTECH started with a survey to 30 SMEs to clarify their main difficulties on occupational health at productive sections. At this AE companies will benefit from the experience of using CPS technology to warn operators about their incorrect posture during work execution. We are currently selecting SMEs with common worker well-being concerns to develop the technology and implement the experiment.

3.2 Spain and Castilla y León region

The IoT-DIH has led different projects in the field of Internet of things applied to different environments and multiple European partners. The scope of work ranges from agricultural to manufacturing industry and the application of IoT solutions in cooperation of multiple partners.

A success case and example is the project GRACE (http://grace-project.org) which was has been developed by different partners. This project included the participation of universities and research centres in the northern region of Portugal and Spain, among other European countries. The partners of the project were: Universita Politecnica delle Marche (Italy), SINTEF (Norway), IPB (Portugal), AEA-Loccioni Group (Italy), Whirlpool Europe and Siemens AG. It consisted on the development of distributed production control systems integrating process and quality control levels using multi-agent systems principles and self-adaptation procedures to support variation and fluctuation in processes and products.

Another example of a success case in a project developed jointly with partners of the northern Portugal and Castilla y León is the 19K-INOVKIVI project. The 19K was developed by the following partners: IPN (Portugal), APK (Portugal), Universidade de Coimbra (Portugal), Direção-Geral de Alimentação e Veterinária (DGAV) (Portugal), Kiwicoop (Portugal), KiwiGreenSun (Portugal), Kiwi d'Ouro (Portugal), Produção e Marketing do Noroeste, Lda (PMNI) (Portugal), Fuverg, Lda, Kiwi1000, Lda (Portugal), Actiglabro (Portugal). The project consisted on the development of strategies for the sustainability of the Kiwi industry through the creation of a Value-added product. The aim of the project was to stimulate the adoption of measures based on new product, practices, processes and innovative technologies to combat Pseudomonassyringae pv. Actinidiae – (Psa), which is a disease of kiwi culture. The solution consisted in the implementation of different IoT sensors for the collection and treatment of crop data, to monitor the plant growth and to enable the detection of harmful agents.

4 Conclusions

Within Horizon 2020 several activities boosted by DIH networks to support Start-ups, SMEs and Mid-caps to test digital innovations were implemented.

Within the Norte Region and within the PRODUTECH ecosystem two projects are ongoing, DIH^2 and DIH4CPS.

The DIH^2 is allowing Portuguese technological companies to have high within a Pan European community to shape the future of standardization in robotics, access to potential customers offering customised agile and robotic solutions, publish in the COPRA AP Catalogue in the Marketplace and to interact with companies from other European countries. On the other hand, it allows PRODUTECH to enlarge its network and knowledge on Robotics and Agile production new technologies, as well as finding potential partners and new opportunities for its members.

DIH4CPS project is allowing DIHs to promote the interaction between manufacturing companies and technology providers in order to solve concrete problems, at the same time integrates SMEs in a network of entities focused on CPS technologies with enormous future cooperation and business potential.

After several years operating as a reference on IoT projects implemented in the region of Castilla y León and northern Portugal, the IoT DIH also provides different range of services. From technical advice and mentoring to access to funding opportunities for SMEs. Being also key the fact that the IoT offers events for the technological entrepreneurial ecosystem and allows building relationships with the right connections as accelerators, Universities and Investors among others. The IoT DIH, per year, on average works in more than 20 projects with SMEs. The GRACE project, which was previously mentioned as an example, after three years of research, concluded with a proper solution implemented in the Whirlpool production line and improving the process efficiency.

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The exchange of ideas between scientists and technicians, from both academic and business areas, is essential in order to ease the development of systems which can meet the demands of today's society. Technology transfer in this field is still a challenge and, for that reason, this type of contributions are notably considered in this compilation. This book brings in discussions and publications concerning the development of innovative techniques of IoT complex problems. The technical program focuses both on high quality and diversity, with contributions in well-established and evolving areas of research. Specifically, 10 chapters were submitted to this book. The editors particularly encouraged and welcomed contributions on AI and distributed computing in IoT applications. The editors are specially grateful for the funding supporting by the project "Virtual-Ledgers-Tecnologías DLT/Blockchain y Cripto-IOT sobre organizaciones virtuales de agentes ligeros y su aplicación en la eficiencia en el transporte de última milla", ID SA267P18, financed by regional government of Castilla y León and FEDER funds.

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