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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 technifica-

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tion. 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.

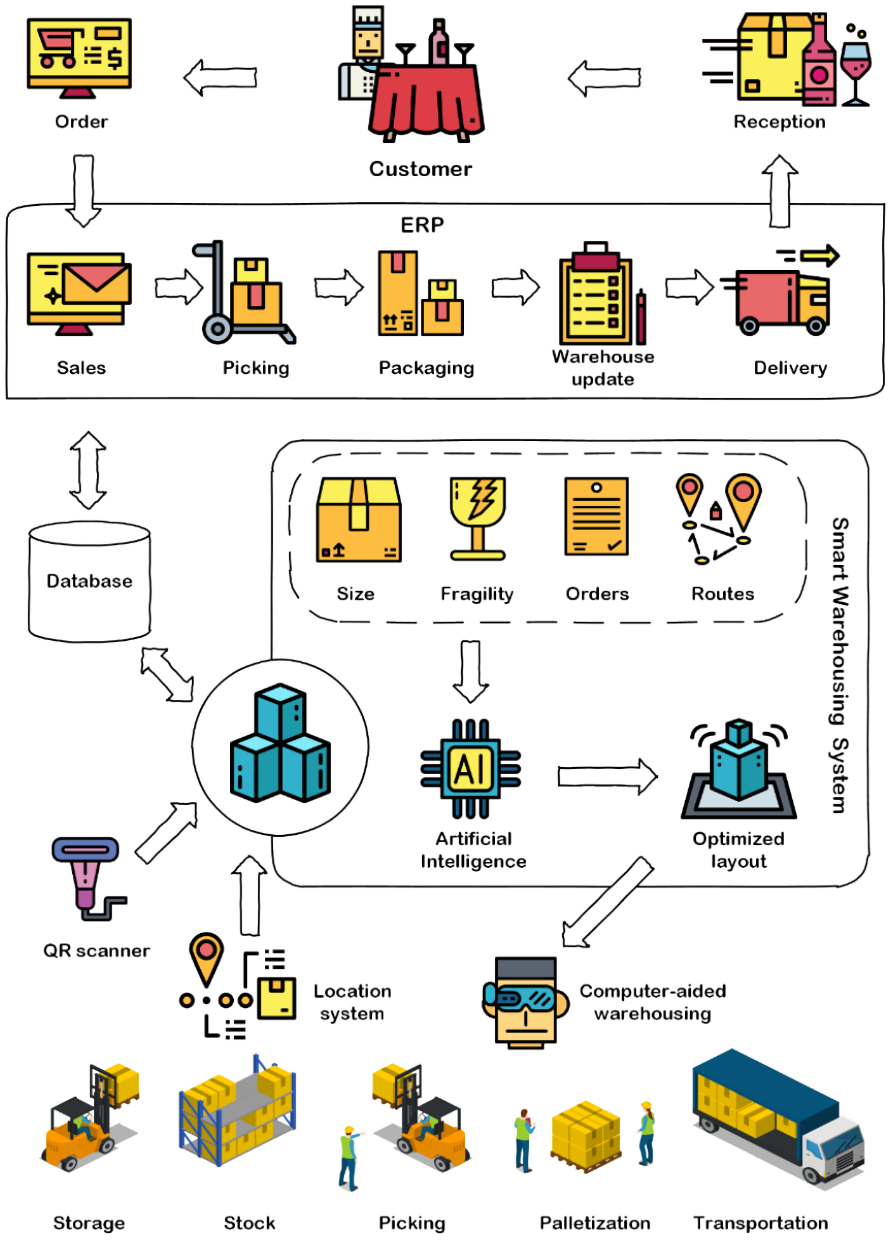

Fig. 1. Smart warehousing system for the optimisation and indoor real-time location in winery logistics.

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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