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Smart warehouse management using IIoT to optimize inventory control

Gestión de un almacén inteligente usando IIoT para optimizar el control de inventario

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Abstract

Product flows within warehouses require detailed work in many ways, one of these is linked to fluctuations in demand, since this is uncertain, it is not possible to specifically predict the safety stocks that certify the supply. This can lead to production problems in different departments and consequently low productivity. This article proposes the optimization of merchandise warehouse flows by evaluating its inventory system, its integration and interoperation with emerging technologies based on the Industrial Internet of Things (IIoT) as well as artificial intelligence methods, with the aim of to know and adequately plan the stock needs, allowing to generate ideal inventory policies through an adequate prediction model, since a recurring problem is having outdated inventories among other reasons because the demand is uncertain, so it is not possible to predict from specific and timely manner security stocks. For this purpose, a methodology based on the experimental design of a management system is proposed that allows analysing inventory information through neural networks, being able to establish an automatic reorder point, with the aim of turning the warehouse into a dynamic unit that through self-learning allows you to create forecasts to make internal processes more efficient, improving decision-making.

Smart warehouses, Inventory control, Neural network

Resumen

Los flujos de los productos dentro de los almacenes requieren de un trabajo detallado en muchos sentidos, uno de éstos está ligado a las fluctuaciones de la demanda, dado que esta es incierta, no es posible predecir de manera específica las existencias de seguridad que certifiquen el abasto. Esto puede traducirse en problemas de producción en diferentes departamentos y, en consecuencia, una baja productividad. Este artículo propone la optimización de los flujos del almacén de mercancías mediante la evaluación de su sistema de inventario, su integración e interoperación con tecnologías emergentes basadas en el internet industrial de las cosas (IIoT) así como con métodos de inteligencia artificial, con el objetivo de conocer y planificar adecuadamente las necesidades de stock, permitiendo generar políticas ideales de inventario a través de un modelo de predicción adecuado, pues un problema recurrente es tener inventarios desactualizados entre otros motivos debido que la demanda es incierta, por lo no es posible predecir de manera específica y oportuna las existencias de seguridad. Para este fin se plantea una metodología basada en el diseño experimental de un sistema de gestión que permita analizar la información de inventarios mediante redes neuronales, pudiendo establecer un punto de reorden automático, con el objetivo de convertir al almacén en una unidad dinámica que mediante autoaprendizaje permita crear pronósticos para hacer más eficientes los procesos internos, mejorando la toma de decisiones.

Almacenes inteligentes, Control de inventarios, Redes neuronales

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Introduction

Different industries are facing great changes, caused by megatrends such as globalization, individualization, and demographic change. The boost in globally connected business activities increases complexity within industry networks, where volatile demand and customized products influence their planning and production processes (Bartodziej, 2017).

The supply chain management (SCM) aims to guarantee the appropriate interactions of the logistics elements to present optimal flows of products and information that allow cost reduction and an increase in customer satisfaction (Correa et al., 2010). As shown in Figure 1.

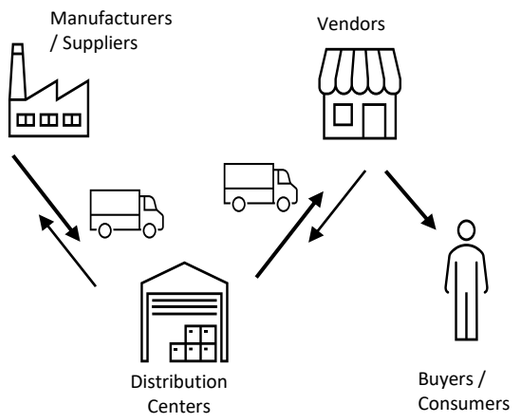

Figure 1 SCM flows
Source: Own elaboration

The rapid growth of online product transactions has revealed important areas of opportunity at the logistics level, especially in distribution operations, in this sense, the expansion of interconnected devices creates opportunities to obtain valuable information more quickly, so IIoT solutions create new routines and drive smarter operations from the data collected.

Warehouse management is a key activity of the SCM, because in addition to storage, the warehouse also provides custody, verification, and supply of merchandise within the supply chain (LD Logística Dinámica, 2020). The existence of volume and variety of merchandise makes it necessary to implement systems that allow effective asset management, with the aim of streamlining operations and minimizing human errors.

Among the resources available for warehouse management, in addition to handling equipment, the information systems stand out, which allow the registration, administration and control of the information generated by the processes (Figure 2). The term supply chain execution (SCE) reflects a shift toward comprehensive logistics applications where warehousing is one of its components. Always knowing the status of the merchandise in the warehouse is important because this constant supervision facilitates the planning and organization of flows and operational processes, to avoid product shortages, reduce improvised purchases, avoid uncertainty in the elaboration of the processes that are related to the supply of supplies, in this way it contributes to boost sales, promoting a reduction in delivery times and compliance with customer requirements.

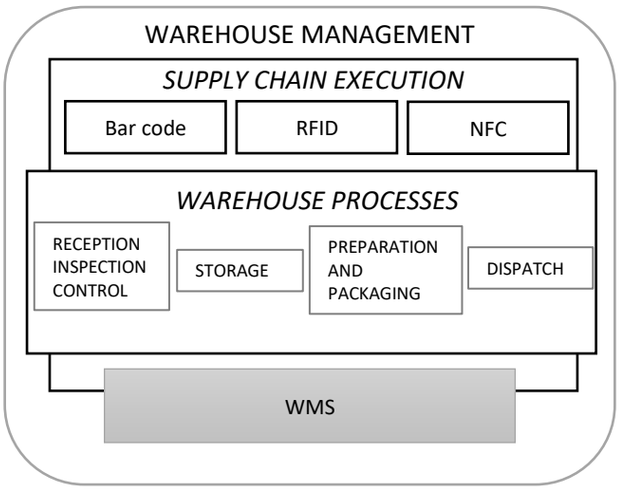

Figure 2 Technologies in warehouse management
Source: Own elaboration

Although RFID technology-based techniques have been available for a long time that allow for an interconnection between information management systems and goods found in warehouses or circulating through supply chains. The IIoT, in logistics 4.0, condescends the implementation of real-time systems that allow to automate and efficiently manage the entire logistics process, from the manufacture of the product to its final delivery, through storage and distribution tasks (IAT, 2021).

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Thus, IIoT is constituted as a non-deterministic and open network in which self-organized intelligent entities and virtual objects are interoperable and capable of acting independently pursuing their own objectives (or shared objectives) depending on the context, circumstances, or the environments. According to the ISO/IEC 2382 Information Technology Vocabulary (ISO, 2000), interoperability is defined as the "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units".

Interoperability in the IoT facilitates communication and data exchange between objects regardless of their brand. According to Yzquierdo & González (2009), the guarantee that the systems are interoperable means that you can access more information and useful functionalities from a single environment in a practical and reliable way. In this way, efficiency and profitability are possible, by guaranteeing open connections of the company's products. So, a company need all systems to communicate with, and understand, each other to be able to leverage the advantages of technology solutions.

The warehouse, presents constant challenges, being technological innovations a tool to face them, which is why the move towards an "intelligent" entity based on automation is evident both to integrate and manage inventories (Ruiz et al., 2021). It is important to note that inventories are integrated into the financial statements of the company as a reflection of its economic operation, therefore, determining the optimal quantity of orders is one of the main aspects in inventory management that can facilitate this run at optimal cost (Senthilnathan, 2019).

Artificial intelligence (AI) is related to the development of mechanisms that behave intelligently. These systems that think have programming that accumulates information that can then autonomously use this knowledge (Transped, 2021). Platforms with AI engines may also influence logistics, automating routine tasks, extracting data and insights, interacting with customers significantly and influence decision-making.

This article presents a model for a smart warehouse architecture that combines neural networks as a learning system on product information, and RFID system for an inventory management system. The study closes by mention the advantages brought by this possible solution that allow the different systems to automatically manage the input and output of warehouse data based on the user demand in order to increase the productivity and its control, being able to share strategic information.

Methodology

This research shows the results of warehouse processes analysis, in this way, a balance can be made between the items that enter and leave the warehouse to know their availability. Inventory control requires considering fluctuations in demand, delivery time and the operation of the business to define the number of products that are needed to properly serve the customer.

This work is done in two stages. The first part consists in an IIoT-based system that uses RFID, to identify and track the labels attached to products, it is complemented by a microcontroller that will track the inventory movements, recording the entry and exit of merchandise in real time using and IoT platform.

The second part will use AI technologies because they can provide real-time visibility and analysis by training machine learning (ML) models with supply chain data. AI-driven logistics optimization enables companies to solve complex cost and delivery constraints by utilizing in-depth insights and analytics (Malhotra, 2020).

1. WMS

The WMS as a software application that controls inventory and warehouse labour resources in real time.

2. ANN

ML is based on learning algorithms, artificial neural networks (ANN), as a part of ML, are computational models that are connected to each other to transmit signals obtaining the prediction of the possible desired output, this technology has been successfully applied in many business areas.

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ANN are interconnection structures among artificial neurons that are modelled to mimic biological neurons using activation functions.

3. Inventory control

In this article, we propose an ANN enabled IIoT architecture with the vision of manage the warehouse stock from any device, for quick access.

To implement the inventory control, the gather data will be concentrated into an ANN model, the results will be sent to the cloud allowing its concentration and access to it from any location and by any device connected to the internet.

Numerical analysis software (Scilab) will be used to measure, collect, analyse and report the data, and the toolbox Local Linear Model Trees (LOLIMOT) is a model from the neural network family able to learn every kind of non-linear relationship (Figure 3).

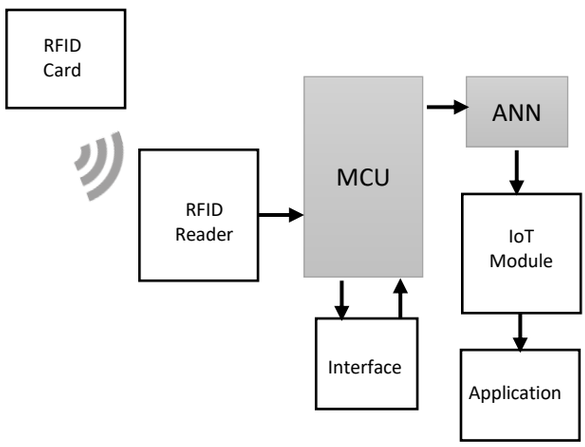

Figure 3 Block diagram
Source: Own elaboration

It is convenient to develop the solution using an inventory model, in this case, Economic Order Quantity (EOQ).

4. EOQ

EOQ is a set point designed to help companies minimize the cost of ordering and holding inventory. The cost of ordering inventory falls with the increase in ordering volume due to purchasing on economies of scale. However, as the size of inventory grows, the cost of holding the inventory rises. EOQ is the exact point that minimizes both inversely related costs (CFI, 2021).

The model considers a known a priori demand that is constant, and based on this it tries to know by the cost of maintaining an inventory and the cost of ordering the order, the optimal quantities to be ordered, all this minimizing the inventory cost to the max, as follows (Abdullah, et al., 2020):

$$Q * EOQ = \sqrt{2DS}/C \quad (1)$$

Where, Q * = the quantity of goods at each order, D = Number of requests for raw materials in a period, S = Cost every time you order, and C = Storage cost per unit.

Implementation

This model will work with a software application capable of joining data that is not typically combined. A lot of scenarios are simulated for each request, obtaining the best solutions for specific management in real-time. Thus, the warehouse can obtain valuable information on the evolution of demand and the prediction of stock optimal levels.

The proposed architecture comprises of monitoring the inventory goods of a warehouse using an MCU-RFID, categorizing using ANN to enhance a reorder point accuracy and analysing with Scilab (Figure 4).

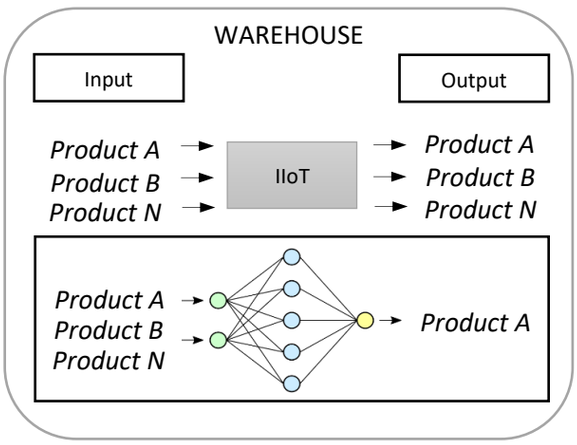

Figure 4 IIoT inventory control with ANN
Source: Own elaboration

The purpose of doing a maximum inventory calculation is so that the company can avoid the occurrence of shortages or excess inventory. A visible and transparent, thanks to the large amount of information available, warehouse processes improve efficiency, reduce waste, and enable traceability.

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The constant flow of data through the ANN allows verifying the status of the warehouse through indicators that describe its operation, such as: inputs, outputs, registrations, cancellations, income, costs, etc. which are interpreted in a personalized environment using descriptive statistics.

Various ANN configurations are studied taking as input variables the daily series of the movements of entries and exits in the merchandise warehouse. Different ANN structures are trained using the historical data series, where a part of it is used for training and the rest for prediction (Figure 5).

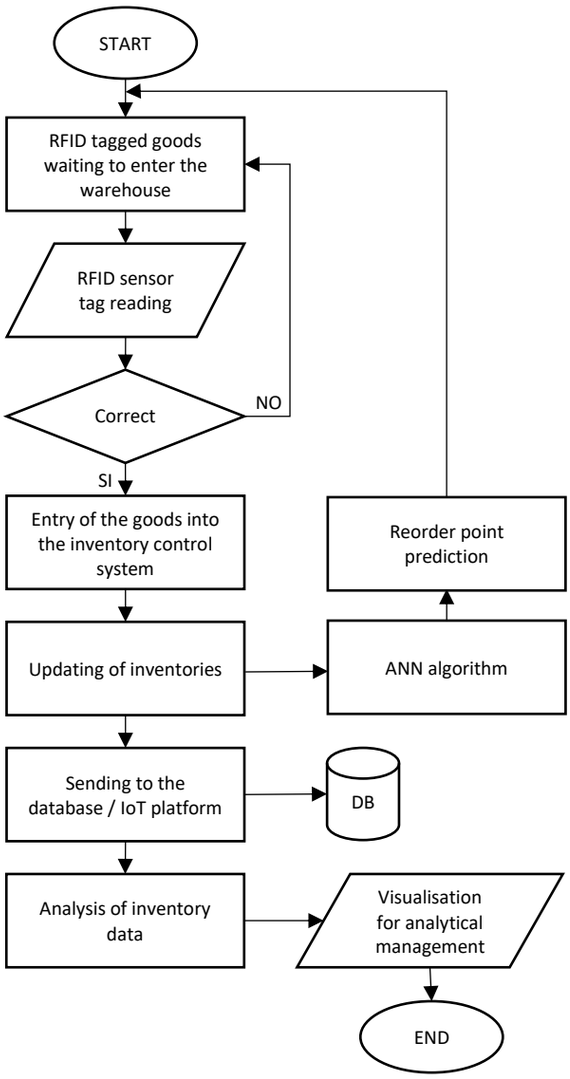

Figure 5 Process flow diagram of the proposed model
Source: Own elaboration

The models for inventory control are diverse, however, an intelligent control based on IIoT and AI linked with other WMS provide optimization in the model, being able to predict reorder points that minimize costs in inventory management.

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Conclusions

The WMS applications will be derived from expansion into other business operations, so it touches intralogistcs, supply chain and even retail store operations.

In the supply chain, using IIoT managers will be able to monitor the status of shipments and with sensors, RFID tags and RFID readers, sees in real time the exact location of the box within the warehouse, the point of origin and other physical factors of interest.

Thanks to the ability of objects to report data in real time, users can make decisions more quickly and accurately, through offering continuous remote monitoring facilities inventory control. The results of the application of new trends technologies have repercussions not only in the logistics sector but also in society.

References

Abdullah, R., Bahar, S., Dja'wa, A., & Abdullah, L. (2020). Inventory Control Analysis Using Economic Order Quantity Method.

Bartodziej, C. (2017). The concept industry 4.0. An empirical analysis of technologies and applications in production logistics. Berlin: Springer.

CFI. (2021). EOQ. Recovered: december 1st, 2021, from https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-eoq-formula/

IAT. (2021). IOT en Logística, Gestión de Almacenes y Transporte. Recovered: december 1st, 2021, from https://iat.es/tecnologias/internet-de-las-cosas-iot/logistica/

ISO. (2000). ISO/IEC 2382-7:2000. Recovered: december 1st, 2021, from https://www.iso.org/standard/7241.html

Gharehbaghi, K. (2016) Artificial Neural Network for Transportation Infrastructure Systems, MATEC Web Conf., vol. 81, p. 05001.

LD logística Dinámica (july 2nd, 2020). Cómo Hacer una Gestión Inteligente de nuestro Almacén. LD Logística Flexible. Recovered: november 27th, 2021, from https://www.ld.com.mx/blog/noticias/como-hacer-una-gestion-inteligente-de-nuestro-almacen/

Malhotra, S. (2020). Sizing the Potential Value of Artificial Intelligence in Logistics. november 24th, 2021, from OodlesAI Web site: https://artificialintelligence.oodles.io/blogs/artificial-intelligence-in-logistics/#!

Mbida, M. (2019). Smart Warehouse Management using Hybrid Architecture of Neural Network with Barcode Reader 1D / 2D Vision Technology. International Journal of Intelligent Systems and Applications. 11. 16-24.

Ruiz, J., Martínez, I., Juárez, C., & Huitrón, A. (june, 2021). Management system of smart warehouses using IIoT for optimize inventory control. Journal of Technologies in Industrial Processes, 5, 1-8. ECORFAN-México.

Senthilnathan, S. (november, 2019) Economic Order Quantity (EOQ). SSRN Electronic Journal.

Transped (september 14th, 2021). Artificial Intelligence in Logistics. Recovered: november 25th, 2021 from https://www.transped.com/en/artificial-intelligence-in-logistics/

Yzquierdo, R. & González, H. (june, 2009). Interoperabilidad entre los Sistemas Informáticos. ResearchGate.

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