Integrating Blockchain, IoT and Robotics into a Reliable Production System

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I. Introduction

Reliable production systems, which deliver high-quality products or services while minimizing disruptions and errors, are essential for companies seeking to meet customer demands, maintain competitiveness, and adapt to changing market conditions. Such systems involve a holistic approach that combines engineering, management, and technology to achieve the desired level of quality, efficiency, and dependability in manufacturing and production operations. This theme encompasses various aspects related to ensuring the dependable and efficient operation of production systems, including supply chain management, quality assurance, process automation, data analytics, predictive maintenance, and much more.

By integrating blockchain, IoT, and robotics into reliable production systems, manufacturers can achieve increased efficiency, reduced operational costs, enhanced quality control, and improved transparency, ultimately leading to more competitive and reliable production processes.

The manufacturing industry has been significantly impacted by digitalization, which has allowed companies to streamline operations, raise standards, and reduce prices. The fourth industrial revolution, commonly referred to as "Industry 4.0", is the most recent stage of the digital transformation of the manufacturing sector. It incorporates cutting-edge technologies with an organization's production processes, including Blockchain technology (BCT), the Internet of Things (IoT), artificial intelligence (AI), and robotics. At the same time, there is a growing demand for transparency across the supply chain from both customers and governments. The adoption of blockchain technology to enable secure traceability for supply chain management can provide information such as the provenance of a product and prevent fraud due to its inherent trust and inalterability. In this work we present the design concept of an integrated agri-food supply chain management system implemented through Blockchain technology, Artificial Intelligence and IoT devices, mobile devices, robotic arms. We also present a brief use case to better understand how these technologies can interact together to enhance the digitalization of a SME, leading to a more competitive and reliable production processes.

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II. Design Concept for Reliable Production System

An initial design concept of the platform is reported in Figure 1. The figure draws a schematic picture of the Operative Infrastructure as well as two associated workflows, one regarding the infrastructure itself and the other depicting the workflow of the associated reliable production system. The various blocks represent interconnected modules to make explicit the modular architecture of the solution so that each module can be enhanced and tuned according to needs without influencing other modules and avoiding a complete refactoring of the overall structure in case of changes.

The platform consists of the operative infrastructure and of the above mentioned workflows. The operative infrastructure receives data in input from different sources such as IoT devices in a sensor network, data from the industrial robots operating in the system, data from the supply chain. Examples of the first kind of input can be measures of humidity or temperatures performed by IoT devices set in specific points of the supply chain, or location and speed of the carrier of a product and so on. Industrial robots can communicate data about their present status, the operation they have just performed or those they are going to perform in the next future. Finally, data originating from the supply chain can be again data obtained from IoT devices in the sensor network but also data inserted by the operators along the supply chain, such as amount of products transferred or transformed, or data regarding a specific certification on a product.

All the input data is first stored in the platform and then preprocessed and eventually integrated with other data. Two well distinguished modules receive the data in the next step, the AI module and the Blockchain module. The first one will perform business intelligence analysis in order to detect bottlenecks or weaknesses in the system and to find and suggest optimal solutions to overcome the problems. The second one will take care of all the registrations and notarizations needed to enhance transparency and trust in the supply chain, such as timestamps registration, notarization of specific documents, identification of actors by means of signatures and so on, exposing all the data in a traceability board to be used by all the actors in the system and by the final customers as well. The proposed infrastructure can enhance production systems in different aspects. First of all, traceability and

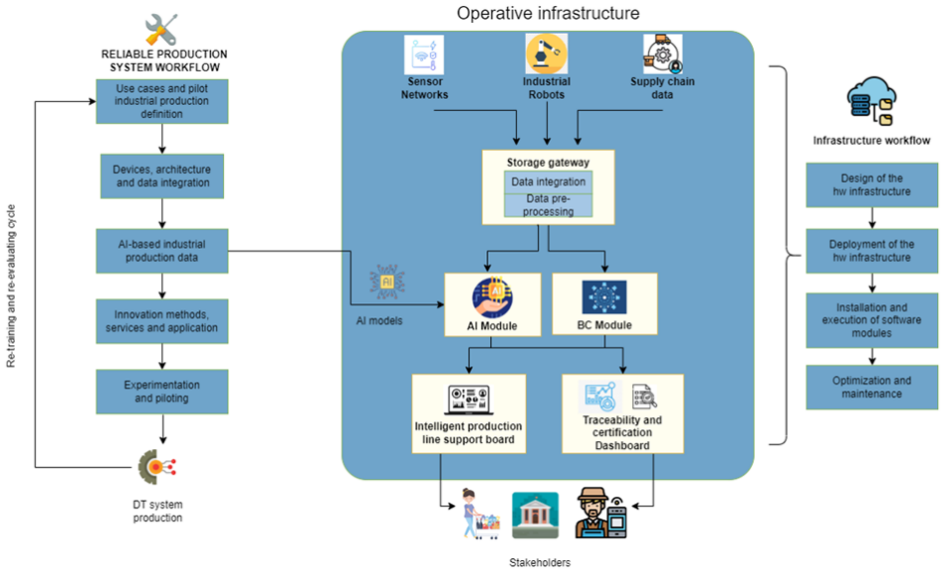

Fig. 1. Design Concept of the technology solution.

transparency of all steps in the supply chain are granted by the blockchain module. Every action (harvesting, production, transformation, etc.) is recorded in an immutable way in the form of blockchain transactions so that it is possible to recover all previous steps and all actors (producers, certifiers, retailers, etc.) involved in the process. This information cannot be altered or removed. Second, the use of industrial robots can help in the automation of different operations along the supply chain. Third, IoT devices and robots can be directly used to perform transactions in the blockchain avoiding bottlenecks or mistakes related to human operators. Finally, the AI module can suggest specific optimization along the different steps of the supply chain. In summary, the main outcomes will be increased efficiency, reduced operational costs, enhanced quality control, and improved transparency, leading to more competitive and reliable production processes.

III. Use Case

The object of the case study is the integration of blockchain technology and of robotics arms into the production line of a typical take away pizzeria. The idea behind the use case presented is to exploit the capabilities of the robotic arms, with AI plugins, to optimize resources (time and cost). Moreover, to exploit blockchain characteristics to provide unalterable and public, transparent records about the process. The two main functionalities we included are:

- to automate the pizza slice cutting and then, notarize the number of cuts for optimising the maintenance management of the arm and its components too.
- to recognise the dirty areas in the pizza boxes and to discriminate them from the clean ones and automate the separation in a specific garbage binder. Then, to notarize the dry waste fraction on the blockchain

In both cases, once the pizza boxes have been positioned, in the right work area, the arm employs dedicated modules (which eventually include the use of a camera), allowing it to proceed with the slices' cutting and later to recognize the dirty areas.

We used two robots produced by Universal Robots, the UR3e and the UR5e. Using the simulation software, we tested various scenarios to analyze and understand the UR language necessary for development. Simulations were also conducted to test behaviors for interaction with sensors, for measuring the surrounding environment, and actuators for pick-and-place applications. Such activities targets the preliminary and potential objectives for the system defined with the stakeholder. We decided to target a pizza shop because it represents an ideal case of food production and sale in which certification of the agri-food production chain can be exploited to determining the quality of the final product. The same is valid for the production process. In addition it is a particularly widespread activity, and it can be generalized to other production and sales activities of similar food products.