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Design and Development of IIOT Based Prototype Model by Using Machine Learning Techniques for Workflow Management in Industry 4.0

Abstract: - Manufacturing is undergoing a revolutionary shift known as Industry 4.0 (I4.0), which unifies production and business operations through data-driven End-to-End digital integration. I4.0 goes beyond the digital ecosystem of the Third Industrial Revolution to include autonomous tech-human convergence and real-time data interchange. The Industrial Internet of Things (IIoT) and machine learning are driving breakthroughs in cyber-physical systems, which form the basis of this. In order to advance I4.0, technology and human talents must be balanced. It is essential to upskill the workforce and engage in coordinated transdisciplinary activities. A holistic approach, integrating human factors and tech advancements, ensures smooth automation transition. The proposed study introduces a cost-effective liquid filling system based on a Raspberry Pi, addressing automation challenges for smaller firms.

Keywords: Industry 4.0, transformative phase, manufacturing organizations, business functions, production systems, IT capabilities, human involvement

I. INTRODUCTION

The manufacturing industry is currently undergoing a transformative phase known as Industry 4.0 (I4.0), which aims to achieve "End-to-End Digital Integration," or the seamless integration of production systems and business operations through complete data integration throughout the whole lifecycle. The adoption of I4.0 extends beyond the technological advancement of future factories, encompassing broader organizational dimensions, including strategy, personnel, and cultural aspects [1].

The Third Industrial Revolution, often referred to as the era of "Digital Transformation," introduced the concept of a 'digital business ecosystem' leveraging the existing IT capabilities and analytics structure within a firm [2]. On the other hand, Industry 4.0 (I4.0) and its application transcend the concept of connectedness and move beyond the confines of a single company or a restricted range of information technologies. Rather, it emphasises the coming together of data-driven and self-governing technological ecosystems with human participation [3][4]. The primary goal of I4.0 is to amplify the interconnectedness and real-time exchange of production data among individuals, processes, services, intelligent products, and manufacturing equipment [5].

The Fourth Industrial Revolution focuses on autonomous systems collaborating between humans and machines. Industry 4.0 emphasizes analysis, communication, and human-machine interaction to optimize production processes [6]. Advancements like sensors and mobile devices have revolutionized human-computer interaction. As Industry 4.0 rapidly progresses, addressing human-machine interaction becomes crucial [7].

Advanced self-configuration, automation, informatization, and decentralised decision-making skills could be fostered by the effective integration of I4.0 [8]. Cyber-physical production systems that can perceive and adapt to their immediate surroundings efficiently are the means by which this enormous transition can be achieved. The integration of machine learning and the Industrial Internet of Things (IIoT) improves these systems and leads to the creation of a digital twin that simulates the production environment in a virtual world [9].

As automation and AI develop, striking a balance between technology and human skill is essential. To be ready for these changes and improve interaction with automated systems, the workforce must be upskilled [10]. In the era of Industry 4.0, interdisciplinary collaboration between engineers, data scientists, and domain experts is increasingly crucial[11]. A seamless shift towards automation and Industry 4.0 is guaranteed through a comprehensive strategy that encompasses both human elements and technological advancements. Automation minimizes human involvement through electronic control loops and remote control. While PLCs are used for automation in large

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sectors, they are costly for small firms. To overcome this limitation, the study proposes a low-cost automatic liquid filling system based on a Raspberry Pi.

1.1. Industry 4.0

A. Factory

The upcoming plant is positioned to include a revolutionary integrative approach as a key component within the Industry 4.0 framework. In addition to providing automated information sharing, this extends beyond simple connectivity of all production resources and includes sensors, actuators, machines, robots, conveyors, and more. The factory is intended to evolve beyond automation to a point of consciousness and intelligence where it can plan for and maintain machine maintenance, control production processes, and manage the entire factory system. In addition, many manufacturing processes will use a modular simulation approach, strongly interlinking in an end-to-end manner, ranging from product design and production planning to production engineering and subsequent services. This means that these processes will be interdependently controlled in addition to being directed by a decentralised system. The Smart Factory is a well-known name for this avant-garde factory idea [12].

B. Business

The term "industry 4.0" refers to the creation of a vast communication network that includes numerous different organisations, including businesses, factories, suppliers, logistics partners, resources, and customers. Each component of this network dynamically optimises its configuration in response to current demands and the condition of connected segments. This collective adaptation effectively uses pooled resources to increase earnings for all parties involved. Notably, this strategy helps to lower prices, pollution, raw material usage, CO2 emissions, and other things. The way the next business network functions basically involves each cooperating entity having an impact on the others, promoting a self-organizing state that allows for real-time response [13].

C. Products

Smart products will become a new product category in manufacturing as a result of Industry 4.0. These cutting-edge objects come with sensors, distinguishable parts, and CPUs. They work as information and knowledge carriers, providing clients with practical counsel and relaying user input to the production system. Numerous functionalities can be implemented into these goods through these integrated features. As an example, they possess the ability to evaluate both consumer conditions and product statuses, subsequently relaying this information. They can follow the progress of the product and evaluate results using the information acquired. These intelligent gadgets may also come with a thorough production information log. This record can be extremely helpful to product developers in optimising maintenance procedures, making forecasts, and designing better products [14].

II. RELATED WORK

The effects of integrating I4.0 go beyond the boundaries of the factory floor or "smart factory" as the application domains expand [16]. The internal support activities performed by organisations, such as Marketing, Human Resources, and Research and Development (R&D), are also included in this influence [17]. It also encompasses the network of cooperative supply chain partners [18]. In this context, as part of the path towards adopting I4.0, the implementation phase comes after the initial phases of readiness assessment and planning [19]. Any digital transformation strategy's results are greatly influenced by the strategy or method used throughout execution[20][21].

For some, pursuing I4.0 implementation has the potential to improve production performance. For others, I4.0 is used to support environmental sustainability and foster social responsibility. This implementation process simultaneously poses a significant barrier to both large enterprises and Small and Medium-sized Enterprises (SMEs). These organisations aim to capitalise on I4.0's advantages in order to develop cutting-edge human-machine work dynamics and new business models [22][23].

The area of I4.0 has been partially examined by previous evaluations, which mostly concentrated on specific but limiting aspects related to various business models, work arrangements, and the rising use of lean practises [24][25]. One noteworthy instance is when a thorough analysis of the management literature from 2010 to 2016 was carried out by a specific study [26]. Without delving extensively into the specifics of I4.0 implementation, this study underscored the pivotal importance of managers and the essential nature of management strategies in cultivating change and leadership.

In a similar vein [27], a different study examined literature published between 2014 and 2018 with the purpose of developing a management working definition for I4.0. This project had a limited investigation of the many resources, stages, and results of I4.0 implementation but sought to understand developments at the level of specific firms. Despite glimmers into particular organisational facets, the overall comprehension of implementation's extent is still fragmented [28]. It's crucial to remember that, depending on the implementation method chosen, the process of implementing I4.0 solutions is one that is always changing. However, I4.0's real-world applications haven't yet been successfully matched with organisational environments.

III. METHODOLOGY

The proposed system operates through a well-defined and interconnected flow, orchestrating various components to achieve its intended objectives. At the outset, a user initiates the process by attempting to access the designated area within the bottle manufacturing plant. This user's access is safeguarded through a dual-layer authentication process involving an RFID tag and One-Time Password (OTP) verification, ensuring heightened security.

Further enhancing security measures, a webcam conducts face identification, detecting the presence of masks and verifying the proper usage of helmets. This step ensures compliance with safety protocols and reinforces user access control.

Within the manufacturing process itself, real-time monitoring of bottle fill levels is maintained using Capacitance Level sensors. These sensors continuously track the liquid levels, ensuring precision and consistency in the production process.

The Internet of Things (IoT) takes center stage by collecting data from smart devices and sensors throughout the system. This data forms a crucial foundation for informed decision-making and system operations.

A pivotal aspect of the proposed system involves the utilization of machine learning models for workflow management. These models navigate complex decisions based on architectural considerations, algorithmic intricacies, and set parameters, optimizing the entire process.

Thorough testing is conducted to evaluate the efficacy of the machine learning model, using diverse datasets to gauge the model's capacity to generate text and make decisions effectively.

Throughout the flow, the outcomes remain consistently positive. The filling machine operates seamlessly, accurate bottle detection and precise filling are upheld, and the system aligns seamlessly with its intended functionality.

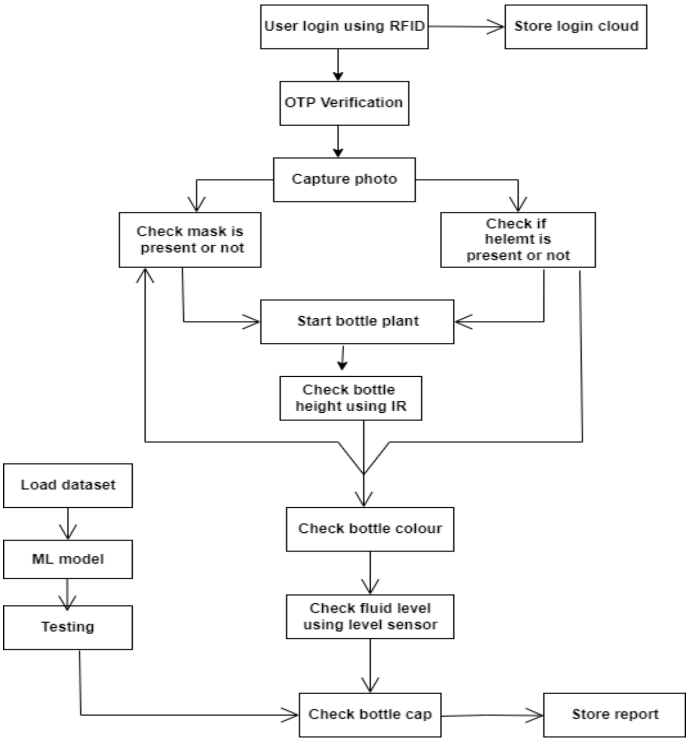


Fig 1. Proposed system of bottle manufacturing plant

Overall, the proposed system follows a well-structured flow that seamlessly integrates authentication measures, IoT data collection, real-time monitoring, and advanced machine learning. This holistic approach aims to enhance user access control, security, and overall manufacturing efficiency within the bottle manufacturing plant.

IV. HARDWARE SPECIFICATIONS

1) Raspberry Pi: The research project encompasses various technological components, including the utilization of a Raspberry Pi Model 3 B. This Single Board Computer (SBC) is chosen due to its cost-efficiency, making it an optimal choice compared to other alternatives. Its compatibility with complex task management aligns well with the multifunctional requirements of the proposed multimodal security system for the bottle manufacturing plant.

Fig 2. Raspberry Pi

2) IR (Infrared) Sensors: Within the context of the research model aiming to design a multimodal security system for enhanced user access control in the bottle manufacturing plant, IR Sensors play a significant role. These sensors are employed to facilitate certain functionalities within the security system. IR Sensors operate on a basic principle: they utilize a specialized light sensor capable of detecting a specific light wavelength within the Infra-Red (IR) range. In the context of the research, these sensors can be integrated into the security system to detect specific aspects, such as the presence of individuals wearing masks or helmets.

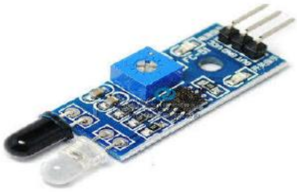


Fig 3. IR Sensor

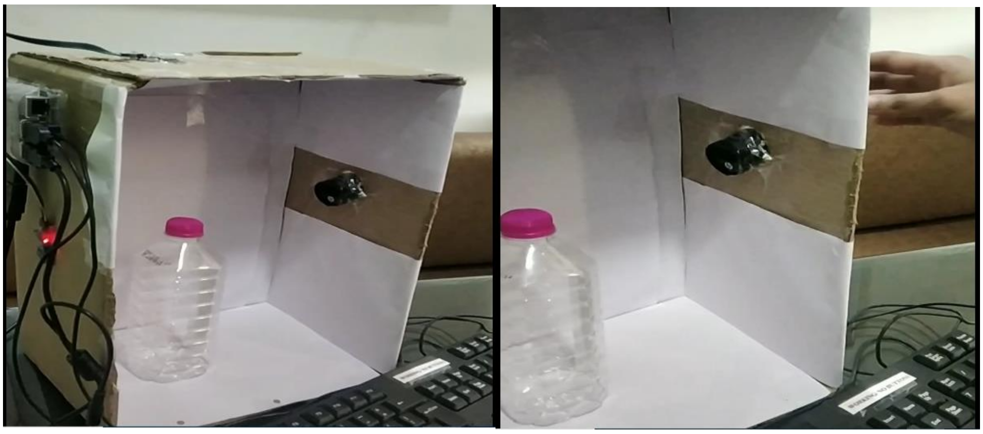
3) Level sensor: The incorporation of a Level Sensor serves a critical purpose. This sensor plays a pivotal role in the monitoring and management of liquid levels within the manufacturing process. The Level Sensor functions by gauging and assessing the amount of liquid present within the water tank. This data is then transmitted to the system. In the specific context of the research, the Level Sensor can be integrated into the manufacturing process to ensure that the bottle fill levels are accurately monitored and controlled.

Fig 4. Level sensor

V. RESULTS:

Positive outcomes are achieved by the filling device's smooth integration of the Raspberry Pi and sensor. It continuousnly accomplishes exact filling and accurate bottle detection. The device perfectly carries out the purpose for which it was designed.

The outcomes of the suggested system are listed below:



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Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

 Bottle size OK
Calculating level.....
Measured Level = 15.1 CM

Detecing Bottle colour..
color_detected:  White

Detecting Bottle Cap..
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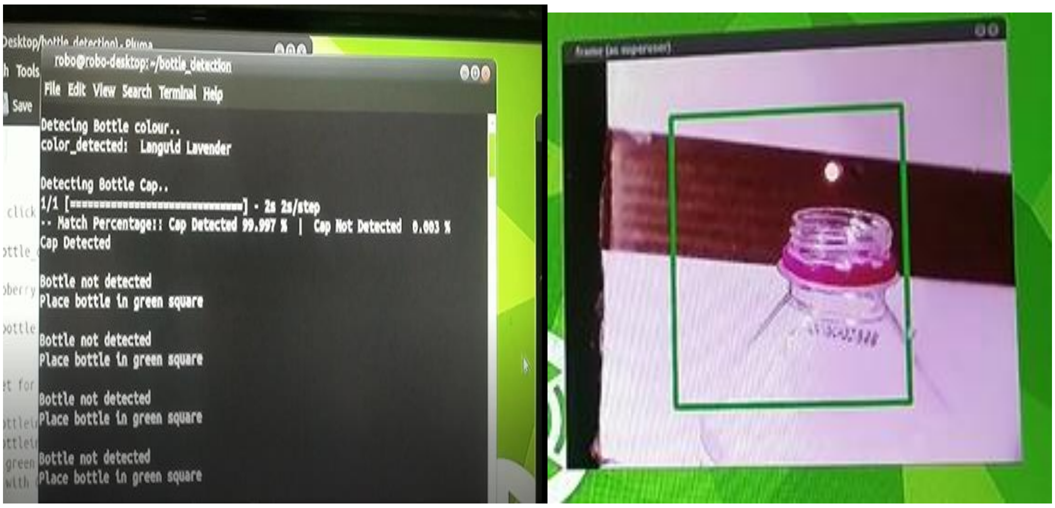


```
Detecing Bottle colour..
color_detected:  Languid Lavender

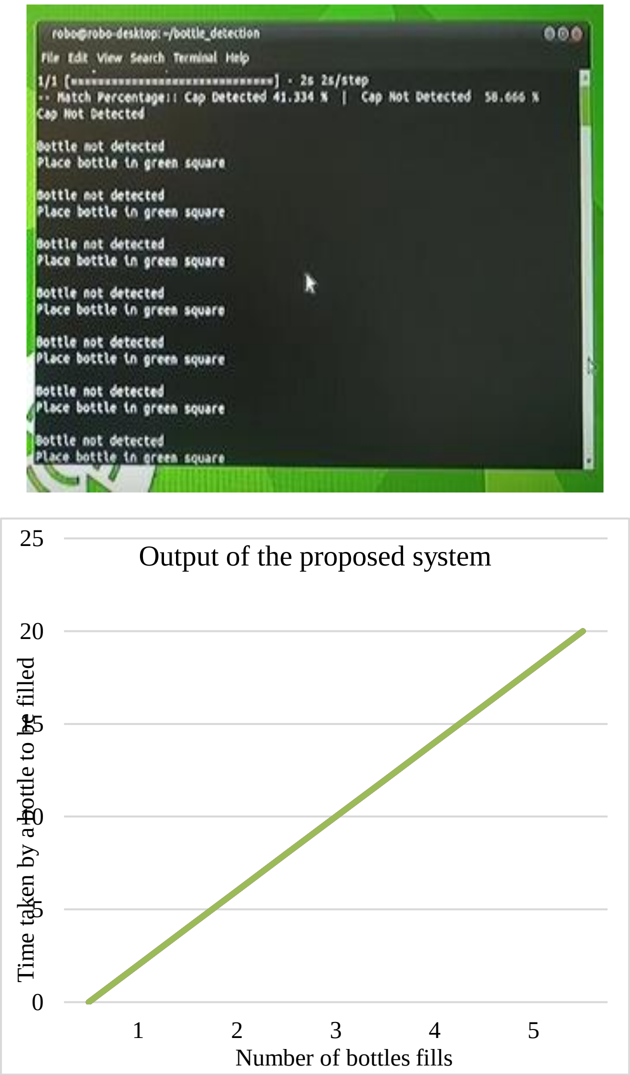
Detecting Bottle Cap..
1/1 [==============================] - 2s 2s/step
-- Match Percentage:: Cap Detected 99.997 % | Cap Not Detected  0.003 %
Cap Detected

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square
```



```
1/1 [==============================] - 2s 2s/step
-- Match Percentage:: Cap Detected 41.334 %  |  Cap Not Detected  58.666 %
Cap Not Detected

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square

Bottle not detected
Place bottle in green square
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Fig 5. Output of bottle filling process

Figure 5 shows the following results:
The results of the research experimentation and analysis have yielded several noteworthy findings:

1. The Filling Machine Performance: The investigation of the filling machine's functionality revealed that it operates effectively and efficiently. The machine successfully fulfils its intended purpose, which is to facilitate the filling process within the manufacturing plant. This outcome signifies that the machine's design and implementation align well with the objectives of the research, ensuring seamless and reliable operations.

2. Time-Based Control Efficiency: One of the significant achievements is the successful implementation of a time-based control mechanism. Through meticulous calibration and programming, the system is capable of consistently filling at an impressive rate of 67 millilitres per second. This finding underscores the precision and accuracy achieved in the manufacturing process, contributing to optimized productivity and quality assurance.

3. Positive Practical Research Outcome: The culmination of this research effort has led to a distinctly positive practical outcome. The various components and technologies integrated into the security and monitoring system have demonstrated their functionality in a real-world manufacturing environment. This outcome serves as a validation of the research's theoretical framework and practical implementation, reinforcing the potential benefits that such systems can offer to industrial settings.

Collectively, these findings highlight the seamless integration of technology and methodologies in the bottle manufacturing plant. The operational Filling Machine, coupled with efficient time-based control, and the encompassing positive practical outcome, collectively exemplify the research's profound influence on refining manufacturing processes, boosting efficiency, and elevating quality control. These results offer valuable insights into the potential strides achievable through the fusion of contemporary technologies and inventive approaches within industrial contexts. Furthermore, enhancing security through real-time alert mechanisms, designed to detect anomalies like unexpected access attempts or sensor irregularities, would provide an additional layer of protection and facilitate prompt corrective actions.

VI. CONCLUSION:

The proposed automation system for the bottle manufacturing plant presents a significant advancement in the manufacturing industry. By introducing automation, the system effectively addresses concerns related to cold drink misuse, thereby enhancing product quality and minimizing economic losses stemming from hardware failures or damages. Additionally, the system's reduced reliance on human interaction contributes to preventing potential employee fraud. Through these combined benefits, the automation system not only streamlines production processes but also improves overall security and operational integrity within the manufacturing environment. Elsewhere, the effectiveness of the system heavily relies on the accuracy and reliability of sensors. Sensor malfunctions or inaccuracies could potentially lead to erroneous data, affecting the overall system performance.

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