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IoT Integration in CNC Machine for Production Rate Monitoring

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Abstract: *In the era of Industry 4.0, integrating and implementing Internet of Things (IoT) technologies into manufacturing processes is critical for increasing efficiency and reducing machine failures. From last 15 years, Internet of Things (IoT) is the main application which is extended from smart connected homes to wearable to healthcare. Industry 4.0 is the recent revolution in the industry. It contains cyber-physical systems(CPS) monitor the production and manufacturing process of the factory and make independent decisions. In a wireless sensor network, the sensor senses the data from the device and that collected data will be sent to the router. That Sensor may be different as per its applications. As So many devices will be connected to the Internet of Things(IoT), it will generate massive data. To extract hidden information from the generated data we have to apply different types of algorithms. A large amount of data can be monitor and controlled with the use of Wi-Fi, internet of things (IoT), cloud computing (CC) This study addresses the lack of real-time monitoring systems in CNC machines. In this study, the ESP32 microcontroller has used as primary data acquisition and transmission units. Data is collected using advanced sensors such as the Inductive Sensor for the live count. From last 15 years, Internet of Things (IoT) is the main application which is extended from smart connected homes to wearable to healthcare. Industry 4.0 is the recent revolution in the industry. It contains cyber-physical systems(CPS) monitor the production and manufacturing process of the factory and make independent decisions. In a wireless sensor network, the sensor senses the data from the device and that collected data will be sent to the router. That Sensor may be different as per its applications. As So many devices will be connected to the Internet of Things(IoT), it will generate massive data. To extract hidden information from the generated data we have to apply different types of algorithms. A large amount of data can be monitor and controlled with the use of Wi-Fi, internet of things (IoT), cloud computing (CC) .This study highlights the importance of real-time monitoring in CNC machine and provides a cost-effective IoT-based real-time monitoring solution for CNC machines.*

Keywords: Internet of Things

I. INTRODUCTION

The integration of the Internet of Things (IoT) into Industry 4.0 has significantly transformed manufacturing processes, with the goal of increasing efficiency and speed. IoT's primary goal is to create self-reporting devices that allow for real-time communication, which includes key components such as IoT platforms, sensors, unique identifiers, and internet connectivity. This network of physical devices within manufacturing systems allows for more efficient control and monitoring. The key benefits of IoT include cost-effectiveness, minimal space requirements, low power consumption, and system portability during implementation [1]. The advent of IoT presents exceptional opportunities for the manufacturing sector, facilitating real-time resource monitoring and elevating safety and performance [2]. Over the past five decades, machine tools have evolved from basic equipment to complicated computer numerical control (CNC) technology, proving economically viable in various production cases [3]. CNC machining, which is controlled by pre-programmed software, has made significant advances with technologies such as G-code, M-code, CAD, and CAM software. The use of CAD/CAM software not only increases production Research Progress in Mechanical and

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Manufacturing EngineeringVol. 5 No. 2 (2024) p. 49-58 50 rates but also ensures accuracy and saves time when compared to manual programming, resulting in high repeatability and efficient production of complex components [4]. In precision manufacturing, high vibrations in CNC machines present significant operational challenges. These vibrations, with unknown amplitude and frequency, complicate efforts to maintain optimal machine performance, risking both the longevity and quality of CNC operations. Unwanted vibrations during machine operation can cause system disruptions, leading to faults such as imbalance, wear, and misalignment [5]. Effective solutions require integrating technological innovation with an understanding of CNC machine dynamics, with vibration monitoring emerging as a key strategy [6]. Additionally, temperature and humidity fluctuations can affect CNC machine performance by compromising precision, inducing tool wear, and impacting sensitive electronic components. Machine tool precision and accuracy are influenced by a variety of issues, including geometric faults in the fuselage structure, clearances, servo control errors, and, most significantly, temperature and humidity deformations [7]. Therefore, monitoring of temperature, humidity, and vibration is very important. Condition Monitoring (CM) addresses challenges such as inefficiencies, product quality compromises, and higher operating expenses, with a rising emphasis on continual structural health monitoring to mitigate unplanned failures [8]. The benefit of real-time monitoring is enabling industries to prevent unscheduled downtime, implement preventive maintenance, and gather diagnostic data [9]. By leveraging IoT technology, various manufacturing resources and their statuses are effectively captured [10]. Real-time monitoring of live sensory data is critical for continuously assessing the health of machines, significantly lowering the risk of unexpected failure [11]. Consequently, there is a need for a device capable of monitoring CNC machine condition and providing real-time data to operators. To sum up, this study aims to explore a cost-effective IoT-based real-time monitoring solution for CNC machines. The primary objective is to seamlessly integrate IoT capabilities into CNC machines, with a particular emphasis on monitoring in real-time.

The manufacturing industry is undergoing a transformation with the convergence of Computer Numerical Control (CNC) machines and the Internet of Things (IoT). This integration enables unprecedented automation, efficiency, and precision, revolutionizing shop floor operations.

CNC machines have long been the backbone of manufacturing, offering high accuracy and repeatability. However, traditional CNC machines operated as standalone units, requiring manual monitoring and servicing. With IoT, CNC machines are now smart, interconnected systems, capable of real-time data analysis and automated decision-making.

Objectives:

- Integration of esp32 with CNC machine.
- Using inductive sensor to monitor the production rate of each machine.
- Implementation to 2 machine.
- Data storage on cloud library & open access to customer.
- Utilizing think speak platform.

II. METHODOLOGY

2.1 Framework of the Study

This study consists of 5 layers, each contributing to the seamless functionality of an IoT-based real-time monitoring system for CNC machines. The sensor layer's foundation consists of inductive sensors that capture vital data of counted inspected parts. The data acquisition and processing layer uses ESP32 microcontroller to collect and process data efficiently. The communication layer uses Wi-Fi connectivity to facilitate seamless communication. The core security and optimisation layer protect data integrity and system efficiency through encryption, authentication, and power optimisation. At the top tier, the application and user interface layer prioritise MATLAB and ThingSpeak IoT Interface optimisation to provide a user-friendly experience. These layers work together to create a real-time monitoring system that is efficient, secure, and easy to use.

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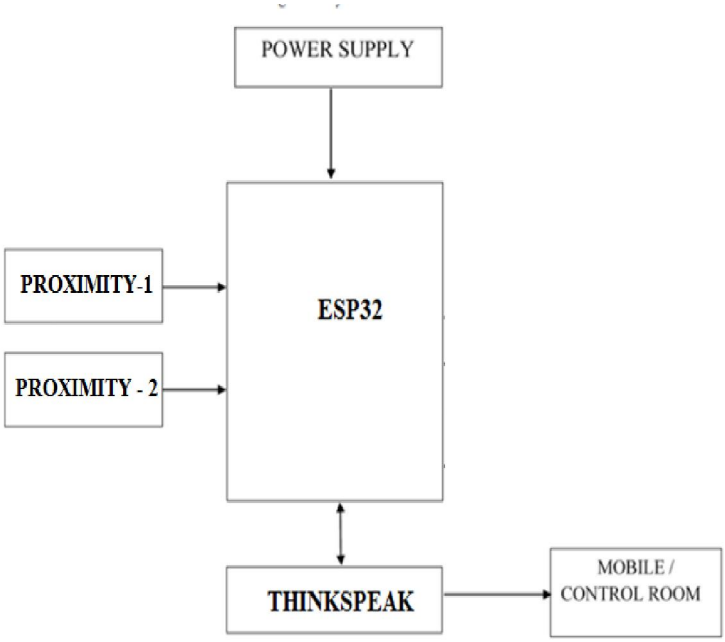
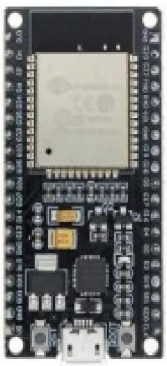
2.2 Block Diagram of the Study

The CNC machine serves as the central hub for real-time monitoring, with the inductive sensor for . ESP32 microcontrollers process this data, acting as intelligent hubs for accurate data acquisition and analysis. A dependable power supply ensures uninterrupted operation, which is critical for maintaining system efficiency. The MATLAB and ThingSpeak IoT app simplify data transmission by providing user-friendly, real-time monitoring on laptops or smartphones, allowing for complete oversight of the CNC machine's production rate.



2.3 Hardware Requirement:

1. ESP32
2. 4GHz Dual-Mode WiFi + Bluetooth Development Board, 38PIN
2. Ultra-Low power consumption works perfectly with the IDE
3. Support LWIP protocol, Freertos
4. Support Three Modes: AP, STA, and AP+STA
5. ESP 32 is safe, reliable, and scalable to a variety of applications



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2. OMRON Inductive Proximity sensor:

a sensing device that detects metal targets using electromagnetic energy and without contact

3. POWER SUPPLY 12 V 2 AMP

- Input Voltage (V): 100 ~ 280 VAC @50 ~ 60Hz.
- Input current (mA): 100.
- Output Power: 12V 2A.
- Input Plug: 2-Pin EU type.
- Output Plug: 5.5mm DC plug.

4. Conveyor belt :

A conveyor belt uses a wide belt and pulleys and is supported by rollers or a flat pan along its path. Conveyors are durable and reliable components used in automated distribution and warehousing, as well as manufacturing and production facilities.

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2.4 Software Requirements:

ThingSpeak IoT:

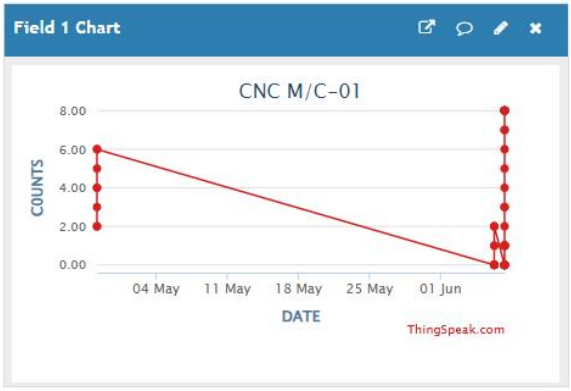
ThingSpeak is a cloud-based Internet of Things (IoT) platform that allows you to collect, store, and visualize data from your sensors and devices. You can use ThingSpeak to create sensor logging applications, location tracking applications, and more. It offers instant visualizations of your data and can be integrated with MATLAB for analysis and data processing.

III. EXPERIMENTAL MODEL

Result of the IoT Based Real Time Production Monitoring System:

MATLAB and ThingSpeak IoT are used to perform advanced visualization and analysis on data collected from the sensors. These visualizations provide immediate insight into the machine's real-time production rate. The robust data handling capabilities of MATLAB and ThingSpeak IoT enable detailed analysis, efficient storage, and thorough documentation of the collected data, ensuring comprehensive monitoring of the CNC machine's live production count.

CNC MACHINE-01 READING



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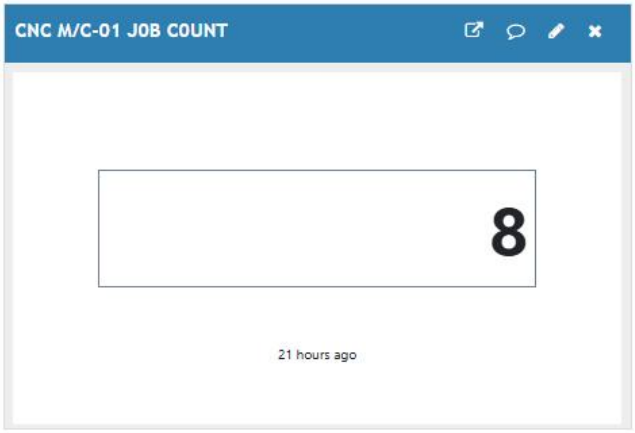
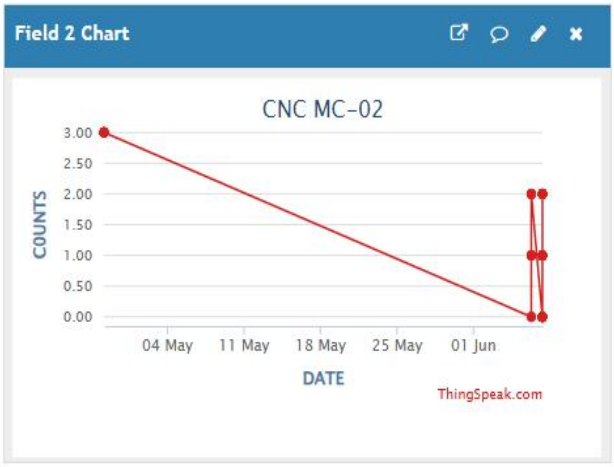
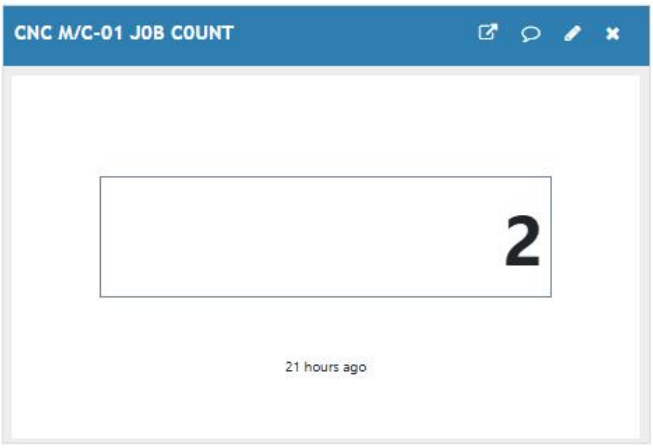


CNC MACHINE-02 READING





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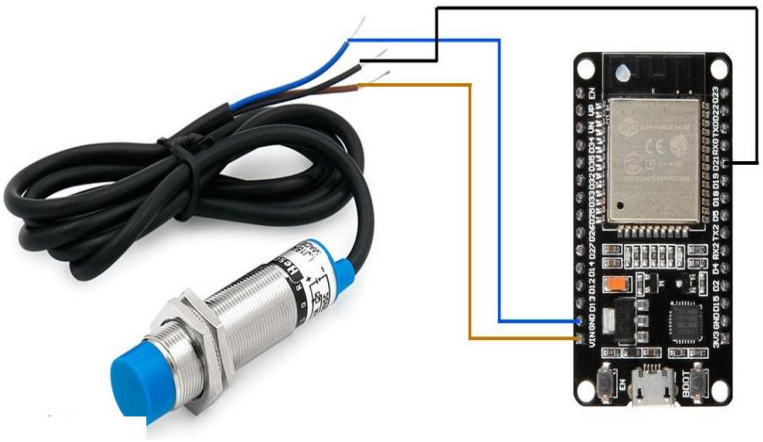
CIRCUIT DIAGRAM :



IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

It was clearly concluded that this cloud service can be put to maximum benefit if the mechanized devices can be automated to interlink them. This study has successfully developed and implemented an IoT-based real-time production rate monitoring system for CNC machines. This system uses advance sensors, including the OMRON inductive proximity sensor. The ESP32 were the primary data acquisition and transmission units respectively. Data visualisation and analysis were facilitated by MATLAB and the ThingSpeak IoT interface, which provided a comprehensive and user-friendly interface for monitoring machine conditions. The results demonstrated the system's ability to consistently and accurately monitor live count of inspected parts and production rate between two or more CNC machines, ensuring the reliable operation of CNC machines. Despite its successes, the monitoring system has some weaknesses. The system currently lacks a dependable long-term cloud storage solution, as ThingSpeak IoT's free version only keeps data for a limited time. Based on the outcomes of this project, several recommendations can be made for future improvements and applications. Firstly, for accurate data collection, utilize 3D printing or other manufacturing processes to produce suitable mounts for sensors, ensuring proper sensor placement. Secondly, ensure solid wire connections by using high-quality, shielded wires of appropriate length to prevent sensor disconnection, thereby enhancing data integrity and preventing signal loss. Thirdly, integrate a reliable cloud storage solution for long-term data archiving, facilitating easier analysis of historical data and trend identification.

4.2 Future Scope

This paper based on IoT can be further expanded by providing additional facility to the industry person with the help of Android app for achieving better control and monitoring of industry.

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