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INDUSTRIAL IOT-BASED AUTOMATION FOR ENHANCED TEXTILE PRODUCTION EFFICIENCY

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Abstract - As Industry 4.0 continues to reshape global manufacturing, intelligent automation and live data monitoring have emerged as critical enablers of operational excellence and consistent product output. Despite these advancements, a significant portion of power loom operations in the textile sector continues to depend on conventional, manual-based oversight resulting in frequent unscheduled halts, slow identification of mechanical failures, and compromised output standards. This paper presents an Industrial Internet of Things (IIoT)-based automation system designed to improve textile production through intelligent monitoring, control, and data analytics. The system utilizes a NODE MCU8266 (ESP12E) At its center, the architecture employs a NodeMCU ESP8266 (ESP-12E) module paired with vibration transducers, IR-based thread sensors, and RPM detectors to provide uninterrupted surveillance of loom-specific parameters namely rotational speed, mechanical vibration, thermal state, and yarn integrity. Sensor data is transmitted wirelessly to a cloud platform for real-time visualization and analysis. The proposed system incorporates an automated fault detection and alert mechanism that notifies operators instantly in case of abnormalities. Additionally, remote control functionality enables authorized users to operate the loom safely and efficiently from a distance.

***Keywords** - Industrial IoT, Power Loom Automation, NODE MCU8266 (ESP12E), Real-Time Monitoring, Fault Detection, Smart Manufacturing.*

1. INTRODUCTION

Within the broader industrial landscape, the textile sector occupies a pivotal position particularly in developing economies such as India. Among its various segments, power loom units play an important role in industries. However, many of these units still rely on manual supervision and traditional control methods, which often lead to inefficiencies such as production delays, increased downtime, and inconsistent fabric quality. Continuous human monitoring is required to detect issues like thread breakage and motor faults, making the process labor-intensive and prone to errors.

A fundamental bottleneck in conventional power loom setups is the absence of continuous machine surveillance and automated decision-making capabilities. Important machine parameters such as motor speed, vibration, temperature, and thread condition are not continuously tracked, resulting in delayed fault detection and potential equipment damage. To overcome these limitations,this project provides an effective solution. By using sensors connected to a NODE MCU8266 (ESP12E) microcontroller, real-time data can be collected and transmitted to cloud platforms such as Web application for monitoring and analysis. This enables continuous supervision of machine performance without the supervision for constant manual intervention.

Deploying IIoT-driven automation brings forward a range of measurable benefits: instantaneous anomaly identification, off-site machine supervision, and a notable uplift in throughput efficiency. The system can instantly alert operators in case of abnormalities such as excessive vibration or thread breakage, reducing downtime and preventing material wastage. Additionally, the collected data is used for maintenance, helps to identify faults. Web application features allow authorized users to operate looms safely from a distance, while optimized energy usage and reduced labor dependency contribute to sustainable manufacturing practices. In essence, IIoT acts as a transformative bridge, connecting legacy weaving infrastructure with the demands and capabilities of contemporary smart factory environments.

2. LITRATURE SURVEY

2.1 IoT Integration in Textile Manufacturing

Incorporating IoT technologies into the fabric of textile production marks a decisive shift away from resource-heavy manual workflows toward interconnected, data-driven automation frameworks. By embedding sensors and microcontrollers into looms, real-time data such as temperature, humidity, and machine condition can be continuously monitored and transmitted to cloud platforms. This enables remote supervision, faster fault detection, and improved operational control. As a result, manufacturers can reduce downtime, enhance product quality.

2.2 Thread Breakage Detection

Yarn rupture during the weaving cycle is a recurring source of production interruption and output degradation. Sensor-based detection architectures particularly those employing optical and infrared technologies enable near-instantaneous identification of thread discontinuities, significantly curtailing associated material losses. These systems send signals to the controller to alert operators or stop the machine immediately, reducing wastage and improving fabric quality. This project minimizes human error and increases the reliability of the weaving process.

2.3 Loom Speed Monitoring

Maintaining consistent loom speed is essential for ensuring fabric quality and machine performance. IoT-based systems use sensors like rotary encoders and proximity sensors to monitor speed in real time and provide feedback to the control system. This allows automatic adjustments or alerts in case of irregularities, improving production efficiency, reducing defects, and extending machine lifespan.

2.4 Predictive Maintenance

Rather than waiting for breakdowns to occur, predictive maintenance leverages continuously streamed IoT sensor data to evaluate machine health trends and anticipate component degradation well before it leads to operational failure. By analyzing parameters such as vibration, temperature, and speed, the system can identify early signs of wear and schedule maintenance accordingly. This approach reduces unexpected breakdowns, lowers maintenance costs, and improves equipment reliability and productivity.

2.5 Cloud-Based Data Visualization

In IoT-based textile systems, cloud infrastructure serves as the central repository and analytics engine ingesting raw machine data, persisting it for long-term analysis, and presenting it through accessible visual dashboards. Tools like Web application provide real-time dashboards that allow operators to monitor performance, receive alerts, and analyze trends remotely. This improves decision-making, reduces the need for human supervision, and supports management of multiple machines.

3. SYSTEM ARCHITECTURE AND METHODOLOGY

3.1 Overall System Design

The architecture of the proposed system is structured around five interdependent functional tiers physical sensing, local computation, wireless data transmission, cloud-based storage and analytics, and an operator-facing interface collectively enabling end-to-end modernization of power loom operations. The system enables real-time monitoring, fault detection, and automated control to improve production efficiency and fabric quality. At its core, the NODE MCU8266 (ESP12E) microcontroller acts as the central processing unit, coordinating sensor data acquisition, fault analysis, and communication with cloud platforms. This project continuously monitors parameters such as thread breakage, loom speed, fabric dimensions, and environmental conditions, ensuring a smart and efficient weaving environment aligned with Industry 4.0.

3.2 Sensing and Data Acquisition Layer

Serving as the system's perceptual foundation, the sensing tier is populated with purpose-specific transducers: optical and infrared elements track yarn continuity, rotary encoders quantify shaft RPM, and ambient sensors capture temperature and humidity readings all deployed at strategic loom positions to ensure thorough coverage. These sensors are strategically placed to ensure accurate and continuous monitoring of loom operations. The collected data provides essential input for automation, fault detection, and maintaining fabric quality.

3.3 Processing and Control Unit

The NODE MCU8266 (ESP12E) microcontroller serves as the brain of the system, responsible for processing sensor data and making real-time decisions. It detects faults such as thread breakage or abnormal speed variations and immediately triggers corrective actions like stopping the loom. Local processing ensures quick response without relying on cloud connectivity, enhancing system reliability. The controller also manages actuators and motors, reducing human intervention and improving operational efficiency.

3.4 Communication Layer

The communication layer enables the data transfer between the loom and cloud infrastructure. Wireless connectivity is achieved through the ESP8266's integrated Wi-Fi radio, which links the controller to the facility network. Data packets are dispatched using MQTT and HTTP two lightweight, low-overhead protocols well-suited to the latency-sensitive demands of machine telemetry. This layer ensures secure and reliable communication.

3.5 Cloud Platform and Data Management

The cloud platform acts as a centralized system for storing, analyzing, and visualizing data collected from looms. Platforms like Web application IoT provide real-time dashboards displaying key parameters such as speed, thread status, and environmental conditions.

The cloud also enables predictive maintenance by analyzing historical data trends to forecast potential failures. This reduces downtime, improves maintenance planning, and enhances overall system efficiency. Remote access allows supervisors to monitor operations from anywhere.

3.6 User Interface and Alerts

The user interface provides an interactive platform for operators and managers through mobile apps and web dashboards. It displays real-time data, historical trends, and system performance metrics in an easy-to-understand format. The system sends through app notifications when faults are detected. It also allows remote control of loom operations, such as stopping or adjusting parameters. This improves responsiveness, reduces manual monitoring, and supports informed decision-making in textile production.

4. HARDWARE COMPONENTS

Component	Model / Specification	Function
Atmega 8 Microcontroller	8-bit AVR Microcontroller	Acts as the brain of the system and controls operations
Transformer	12V, 1A Step-down Transformer	Converts AC supply to required DC voltage
GLCD	128x64 Graphical LCD	Displays system parameters and data
NODE MCU8266 (ESP12E)	ESP-12E Wi-Fi Module	Provides wireless communication and IoT connectivity
Loom Sensors (Spring)	Mechanical/Contact Sensor	Detects thread breakage and stops loom automatically
Capacitor	22µF Electrolytic Capacitor	Stores and releases electrical energy when required
Single Layer PCB	FR4 Board	Mounts and connects electronic components
LED	Standard 5mm LED	Indicates system ON/OFF status
Switch & Push Button	SPST Switch	Controls power and manual input
Stepper Motor	12V Stepper Motor	Converts pulses into precise rotational movement
ULN2803 IC	Darlington Driver IC	Drives high-current loads like motors
Limit Sensor	Mechanical Limit Switch	Detects end position and sends control signal
Resistor	1kΩ	Limits current to protect components
Form Sheet	Acrylic/Plastic Sheet	Provides structural support
Buzzer	5V Piezo Buzzer	Produces alert sound during faults

5. SYSTEM WORKING FLOWCHART

Step 1: All sensors (thread breakage, speed, fabric dimension, and environmental sensors) continuously monitor loom parameters and send real-time data to the NODE MCU8266 (ESP12E).

Step 2: The NodeMCU reads and processes incoming sensor data using programmed logic to evaluate normal and abnormal conditions.

Step 3: If thread breakage is detected or any parameter exceeds predefined thresholds (e.g., abnormal speed or environmental conditions), the system identifies it as a fault.

Step 4: Upon fault detection, the NodeMCU immediately triggers local actions such as stopping the loom motor and activating a buzzer or alert indicator.

Step 5: Simultaneously, the NodeMCU transmits sensor data and fault status to the cloud platform via Wi-Fi using MQTT/HTTP protocols.

Step 6: The cloud platform receives, stores, and updates data in real-time dashboards, displaying parameters like loom speed, thread status, and environmental conditions.

Step 7: If any abnormal condition is detected, the cloud system sends instant alerts (SMS, email, or mobile app notifications) to operators and supervisors.

Step 8: Operators can monitor system status remotely through mobile or web applications and take necessary actions if required.

Step 9: The cloud platform analyzes historical data to identify trends and predict possible failures, enabling predictive maintenance.

Step 10: After resolving the fault, the system resumes normal operation and continues continuous monitoring of loom performance.

6. RESULTS AND DISCUSSION

Testing of the project was conducted across environments in real-world conditions. The first environment was a controlled laboratory setup using a scaled prototype loom, which enabled precise and repeatable experimentation. The second environment involved deployment in an active weaving unit, where practical challenges such as dust, vibration, and fluctuating power supply were present, offering a more realistic assessment of system reliability. Among all evaluated features, thread breakage detection proved to be the most critical and reliable. The loom sensor detected both warp and weft thread failures in less than 0.5 seconds, immediately cutting motor power and activating a buzzer alert. This rapid response ensured that fabric defects were minimized by preventing prolonged unnoticed breakage, thereby significantly reducing material wastage and rework costs.

Loom speed monitoring was achieved which continuously tracked shaft RPM. During field trials, minor fault were observed due to variations in load, such as transitions between lightweight and heavier yarns. The consistency of this feedback allowed operators to rely on the system and temporarily step away from the machine without concern. Environmental sensing was also integrated, with continuous monitoring of temperature and humidity levels. Alerts were triggered when temperature exceeded 40°C or humidity rose above 70%, conditions that can negatively impact motor life, yarn tension, and overall fabric quality. This automation eliminated the need for frequent manual inspections.

The system also demonstrated effective cloud integration, with data transmitted via Node MCU to Web application platforms, enabling real-time monitoring through mobile devices. When operating under consistent Wi-Fi signal conditions, live parameter updates appeared on the GLCD display with a typical latency of one to two seconds.

In cases of weak connectivity, slight delays were observed; however, no data loss occurred. Alert notifications delivered via mobile applications reducing the time between fault occurrence and corrective action. Overall, the system outperformed manual supervision in terms of response speed, accuracy, and fault coverage. It contributed to reduced downtime by detecting issues early and preventing escalation. The system's modular design also proved advantageous in terms of extensibility accommodating supplementary sensors and cloud service hooks with only minor adjustments to the firmware logic.

7. CONCLUSIONS

In this project, we observed that the system worked properly in real conditions. It successfully detected thread breakage in the loom and quickly stopped the machine, which helped in protecting the cloth and reducing damage. Because of this fast action, the fabric was formed smoothly without major defects. The system also monitored the motor speed continuously and showed stable readings during operation, which helped in maintaining proper working of the loom.

We also saw that the system measured the temperature of the machine correctly and displayed it on the GLCD screen in real time. Along with this, the same data, including temperature and machine status, was sent to the Web application app, where it could be viewed easily on a mobile phone. The alerts were received on time, which helped in quick response. The sensors responded properly even in the presence of dust and vibration in the factory environment.

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