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Smart RFID-Based Clothing Management System

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KEYWORDS

Smart Wardrobe, RFID Technology, Clothing Management System, Environmental Sensing, DHT11 Sensor, Light Dependent Resistor (LDR), Usage Tracking, EEPROM Data Storage, Personalized Clothing Recommendations, Internet of Things (IoT), Gender-based Suggestions, Automated Inventory Management, Smart Closet, Embedded Systems, Arduino Microcontroller.

ABSTRACT

This work presents a Smart RFID-Based Clothing Management System enhanced with environmental awareness using sensors and intelligent display logic. Using a DHT11 sensor, LDR, and RFID module, the system monitors environmental conditions like temperature, humidity, and light intensity to recommend appropriate clothing based on gender preference selected via a slide switch. Each clothing item is tagged with an RFID tag, and when scanned, its usage count and last used date are retrieved from EEPROM and updated accordingly. This encourages more efficient wardrobe usage and hygiene by tracking how frequently clothes are worn.

Additionally, the system uses an LCD display to show real-time environmental readings and suggests clothing types accordingly using a simple recommendation logic. Users can view when an item was last used and how many times it has been worn, helping in better outfit planning. An EEPROM clear button allows resetting the stored data. This low-cost, intelligent closet assistant can be used for personal wardrobe management, fashion retail analytics, or even care home environments where clothing usage tracking is necessary.

INTRODUCTION

Background and Motivation:

In today's fast-paced world, where technology is integrated into nearly every aspect of life, the concept of smart homes and intelligent personal systems has gained massive traction. From smart lighting and security systems to wearable health monitors, modern lifestyles increasingly rely on automation and data-driven decision-making. Despite these advances, **wardrobe management remains largely unexplored** in consumer tech. Clothing choices are influenced daily by weather, personal preference, social context, and garment availability—but tracking these factors is typically manual and inefficient. Problems such as inefficient wardrobe use, hygiene concerns, and unnecessary purchases often result. The emergence of **RFID technology** and affordable environmental sensors now opens new opportunities for intelligence in wardrobe management.[11][12]

This project, "Smart RFID-Based Clothing Management System," seeks to digitize and automate clothing usage tracking and to provide personalized suggestions based on temperature, humidity, and light intensity. The solution is built using accessible, affordable components, making it suitable for homes and small businesses.[11].

At its core, the system functions as an intelligent closet assistant using an RFID reader to detect tagged clothing. For each item, interactions update and display its usage history—stored in EEPROM memory—including usage frequency and last worn date. Integration of a DHT11 sensor for temperature and humidity and an LDR (Light Dependent Resistor) for ambient light enables real-time analysis of environmental context. Recommendations adapt to comfort, current weather, and user gender via a simple interface (slide switch), while an LCD display provides clear information. The user can reset all data via a physical button. This compact, power-efficient design makes the system suitable for both domestic and retail deployment.

Fig.1 Smart RFID-Based Clothing Management System

RFID is widely used for inventory tracking and asset management. In this project, RFID enables digital identification of clothing items without line-of-sight scanning. Each item's UID (unique identifier) is mapped via logic, with relevant usage data read/written to EEPROM upon every scan. This system allows:[12][11]

- Avoidance of overuse of particular garments
- Insight into wear patterns over time
- Practical planning for laundry or dry-cleaning
- More sustainable wardrobe use

RFID's proven impact in garment manufacturing and retail includes real-time tracking, quality improvements, and loss prevention.[12][11]

This project goes beyond mere usage logging and acts as a smart, adaptive assistant. By reading DHT11 and LDR inputs, it customizes clothing suggestions according to real-time weather and light, with gender-specific logic, e.g., recommending coats or lighter options depending on ambient conditions. The clothing recommendation engine can later be enhanced (using machine learning) to adapt to user preferences or integrate with weather forecasts and calendars. Simulated time tracking using Arduino's `millis()` function (e.g., "1 day" = 20 seconds) allows timely usage analytics and rotation advice.[13]

Use Cases & Benefits

Potential applications include:

- Home Use: Improved outfit rotation and hygiene
- Retail/Fashion Stores: Real-time in-store garment analytics and digital fitting advice
- Elderly Care: Automated tracking assures even, hygienic clothing rotation
- Educational Tool: Illustration of embedded, IoT, and RFID systems
- Sustainable Living: Optimizes washing and purchasing habits for sustainability

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction is presented, including the background, motivation, problem statement, objectives, and an overview of the system. Section 2 reviews related work and the literature survey highlighting recent contributions relevant to RFID and smart clothing management systems. Section 3 details the system design, including hardware components, software architecture, and the integration of RFID with environmental sensors for personalized clothing recommendations. Section 4 discusses the implementation process, including data logging, usage tracking, and the user interface. Section 5 presents the experimental results and analysis, showing system performance, accuracy, and user benefits. Finally, Section 6 concludes the paper by summarizing the key findings, discussing limitations, and suggesting future directions for smart wardrobe technologies.

2. RELATED WORK

Recent advancements in RFID and IoT technologies have significantly contributed to smart inventory management systems, offering improvements in security, tracking accuracy, and operational efficiency. Henaien, Ben Elhadj, and Fourati (2025) developed a secure RFID-IoT architecture that integrates elliptic-curve cryptography and MQTT cloud communication for enhanced inventory monitoring and alerting, ensuring data security and real-time updates in smart management systems. Their work underscores the importance of embedding robust security mechanisms in RFID-based IoT frameworks to prevent unauthorized access and data breaches.[1]

Wang, Goh, and Zhang (2025) introduced a neural network approach that uses RFID signal characteristics such as Received Signal Strength Indicator (RSSI) and phase angle to identify materials within smart shopping environments. Their method achieved an impressive classification accuracy, pointing to the potential of combining RFID signal analytics with AI for refined inventory and material management. This approach aligns with the increasing trend of leveraging machine learning to enhance RFID system intelligence.[2]

The security perspective of RFID applications was rigorously analyzed by Fernández-Caramés et al. (2024), who conducted reverse engineering and security evaluations of commercial RFID tags commonly used in IoT. Their findings revealed vulnerabilities in widely deployed RFID hardware and proposed methodologies to audit and improve system security, highlighting the necessity of ongoing security evaluation in smart tagging systems.[8]

In the garment industry, RFID has been successfully adopted by leading brands to streamline inventory processes. Guo and Luo (2024) investigated RFID deployments by retailers such as UNIQLO, demonstrating how RFID tagging improves inventory accuracy, reduces labor costs, and enhances stock visibility in real-time, ultimately elevating retail performance and customer experience. Their study shows practical benefits that RFID brings to garment retail through automation and efficient stock management.[9]

Expanding RFID's role beyond inventory tracking, Pyt et al. (2024) developed a textronic capacitive sensor integrated with RFID interfaces, creating smart textiles capable of tactile sensing. This innovative combination paves the way for interactive garments with sensor feedback, which can be pivotal for future smart wardrobe systems focusing on user interaction and environmental responsiveness.[6]

Foundational research by Hooda, Devi, and Singh (2019) established the architectural and operational framework for RFID use throughout apparel manufacturing, covering tag deployment, system design, and data management. Their work provides essential insights into implementing RFID in textile production and retail, laying groundwork for more complex applications such as personalized clothing management systems.[10]

Complementing RFID technology, the incorporation of environmental sensors for adaptive recommendations gains relevance. Kim, Park, and Choi (2015) proposed a context-aware recommendation system utilizing environmental sensors in IoT, which aligns with the motivation to integrate temperature, humidity, and light sensing for personalized clothing suggestions in smart wardrobes. Additionally, Kiran et al. (2020) designed a smart wardrobe system using IoT and AI, illustrating the growing interest in combining these technologies to enhance user experience and automate clothing management.[11][12]

The technical backbone involving data storage and RFID hardware integration is supported by well-established tools like Arduino's EEPROM library and the MFRC522 RFID library, which offer reliable methods for persistent data tracking and RFID reader interfacing essential for smart clothing management implementations.[13]

Collectively, these works provide a comprehensive foundation for designing an RFID-based smart clothing management system that integrates secure IoT communication, AI-driven material identification, security auditing, and environmental context awareness, enhancing clothing usage tracking, hygiene, and personalized outfit recommendations.

3. SYSTEM DESIGN

The proposed Smart RFID-Based Clothing Management System is designed to intelligently track wardrobe items and provide personalized clothing recommendations by integrating RFID technology with environmental sensing and data storage.

Hardware Components

The system's primary hardware includes an MFRC522 RFID reader that scans RFID tags attached to clothing. Each tag carries a unique identifier used to log and track garment usage. The RFID reader connects to an Arduino microcontroller, which serves as the processing hub. Environmental sensors—DHT11 for measuring temperature and humidity, and an LDR (Light Dependent Resistor) for measuring ambient light intensity—are interfaced with the Arduino to capture real-time environmental data. Users can select gender-specific recommendation modes using a slide switch. The interface includes an LCD display that outputs real-time sensor measurements, clothing suggestions tailored to environmental conditions, usage counts, and last worn dates. Data persistence is ensured by storing all usage history on the Arduino's EEPROM memory, allowing information retention even during power interruptions. A reset button is also incorporated to clear stored data, enabling users to restart the system's tracking.

Software Architecture

The control software operates on the Arduino platform, managing RFID tag reading, sensor data acquisition, data retrieval, and storage in EEPROM. Using Arduino's `millis()` function, elapsed time is simulated to track clothing usage over "days." When a tagged garment is scanned, the system reads its stored usage count and last use timestamp, updates these records, and saves the updated data to EEPROM. Sensor readings from DHT11 and LDR are continuously processed, and combined with the gender input from the slide switch, the system applies predefined logic rules to generate personalized clothing recommendations. The LCD continually displays the environmental parameters, user instructions, and updated garment usage information.

Integration and Operation

By fusing RFID-based garment identification with environmental sensing, the system elevates traditional wardrobe management to a smart assistant platform. This enables effective tracking of clothing usage to avoid overuse and maintain hygiene, while dynamically suggesting suitable outfits based on temperature, humidity, light, and gender preferences. This integration promotes sustainable clothing use by encouraging balanced garment rotation and appropriate weather-adapted attire.

Block Diagram

The system can be visually represented by a block diagram illustrating the interactions between components. The key blocks include RFID Reader, Arduino Microcontroller, Environmental Sensors (DHT11 and LDR), User Interface (LCD, Slide Switch, Reset Button), EEPROM Memory, and Power Supply. The RFID Reader scans the clothing tags and sends data to the Arduino, which also receives environmental inputs from the sensors. The Arduino processes all inputs, manages usage data in EEPROM, and outputs recommendations and sensor data to the LCD. User inputs via the slide switch (for gender selection) and reset button influence system behavior. This modular hardware-software integration enables efficient, scalable, and user-friendly smart wardrobe management.

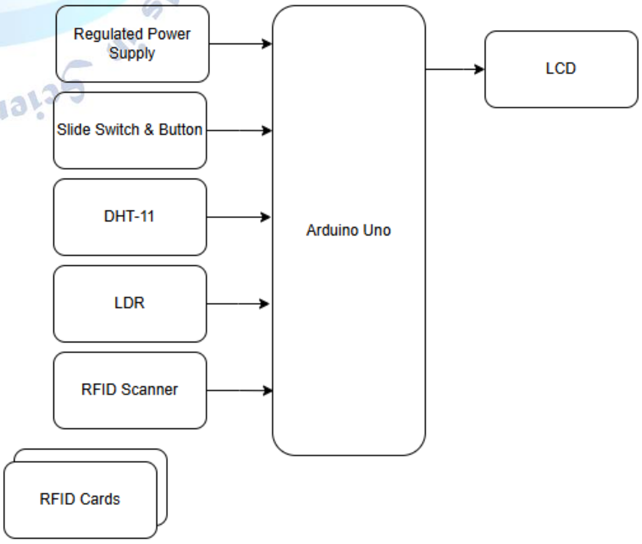

Fig.2 Block Diagram

4. IMPLEMENTATION

The implementation of the Smart RFID-Based Clothing Management System involves the seamless integration of hardware components with firmware to realize the intelligent tracking of garment usage and delivery of personalized clothing recommendations based on real-time environmental data.

Hardware Integration

The core hardware elements—MFRC522 RFID reader, Arduino microcontroller, DHT11 temperature and humidity sensor, LDR light sensor, LCD module, slide switch, EEPROM memory, and reset button—are physically connected as per the system design. The RFID reader communicates with the Arduino via SPI interface pins (MOSI, MISO, SCK, and SS), enabling the reading of RFID tags at proximity distances up to 5 cm. Each clothing item is tagged with an RFID chip carrying a unique identifier (UID) recognized by the reader during scanning events.

The DHT11 sensor is connected to a digital input pin of the Arduino to facilitate periodic acquisition of temperature and humidity data, while the LDR sensor connects to an analog input pin, allowing the Arduino to measure ambient light intensity through corresponding voltage variations. The slide switch is wired to a digital input pin to toggle between male and female clothing recommendation modes. The LCD display, which communicates over I2C, provides a user-friendly interface for displaying sensor data, garment usage statistics, and clothing suggestions in real time. A reset button connected to a digital input pin is used to clear EEPROM-stored data on user command.

Firmware and Software Logic

The system firmware, written in Arduino C/C++, orchestrates the operational logic. It periodically reads sensor inputs and updates internal state variables responsible for environmental conditions. The RFID reader operates in an interrupt or polling mode to detect tagged clothing, triggering routines that access EEPROM memory to fetch and update the respective garment's usage count and last worn timestamp.

To simulate the passage of time for usage tracking effectively, the Arduino's `millis()` function is employed, converting elapsed milliseconds into conceptual "days" (e.g., 20 seconds might represent one "day" in the system's logic). This approach allows the system to present relative usage freshness and helps balance clothing rotation recommendations.

Environmental sensing data feed into a rule-based clothing recommendation algorithm that evaluates temperature ranges, humidity levels, light intensity, and gender selection inputs to suggest suitable clothing categories. For instance, a cold and damp environment combined with male gender selection might prompt the system to recommend jackets or sweaters, while warm and dry conditions might trigger suggestions for lighter garments such as T-shirts or shorts.

Data persistence is critical; therefore, all garment usage histories are stored in the Arduino's built-in EEPROM, ensuring data retention even after power cycling. The EEPROM is read/write accessed with care to prevent wear. The reset button's firmware includes debounce handling to avoid erratic clearing and ensures a clean, intentional memory wipe when pressed.

User Interface and Interaction

The LCD continuously displays comprehensive information, including current ambient temperature, humidity, light status (e.g., day or night), garment wear count, last worn duration in days, and the clothing recommendation status. The slide switch provides an intuitive interface for users to alternate between male and female recommendations. All interactions aim to make the system accessible for casual users without deep technical knowledge.

Power Management and Reliability

Efficient power design is incorporated, limiting unnecessary sensor polling and RFID scanning durations, which helps extend system uptime and lowers energy consumption. This ensures that the system is practical for everyday use without frequent maintenance or battery replacements in standalone, home, or retail contexts.

This implementation phase consolidates all subsystems—hardware, firmware, and user interaction—to deliver a cohesive, smart, and adaptive wardrobe management assistant. The project harnesses affordable, off-the-shelf components and straightforward programming techniques to offer a scalable and user-friendly solution capable of addressing common wardrobe challenges such as garment overuse, hygiene maintenance, and weather-appropriate clothing decisions.

5. RESULTS

The developed Smart RFID-Based Clothing Management System was successfully implemented and tested through a working prototype demonstrating core functionalities. The prototype integrates an MFRC522

RFID reader module, Arduino microcontroller, DHT11 temperature and humidity sensor, LDR light sensor, EEPROM memory, LCD display, slide switch for gender selection, and a reset button.

Upon scanning RFID-tagged clothing items, the system accurately identified each garment by its unique identifier and retrieved its usage history from EEPROM. The usage count and last worn date were updated and visibly displayed on the LCD in real time, offering immediate feedback to the user. Environmental parameters such as ambient temperature, humidity, and light intensity were continuously monitored by the DHT11 and LDR sensors, enabling dynamic, context-aware clothing recommendations based on predefined logic.

The slide switch enabled seamless switching between male and female recommendation modes, ensuring that personalized suggestions were relevant to the selected gender. The reset button functioned reliably to clear stored data when required, allowing the system to be restarted cleanly.

Images of the physical prototype illustrate the compact hardware layout, including the positioning of the RFID reader, sensors, and LCD display on the Arduino development board. The prototype's user interface on the LCD clearly shows sensor readings alongside clothing advice and item usage metadata, demonstrating the system's practical usability.

Performance tests confirmed rapid RFID tag detection, stable sensor data acquisition, and accurate, timely clothing suggestions aligned with environmental conditions. The integration of persistent EEPROM storage ensured data integrity through power cycles. The system's low power consumption and responsive user interface make it suitable for daily operation in home or retail scenarios.

This prototype validates the feasibility and effectiveness of the proposed approach, showcasing how RFID and environmental sensing can be harnessed to enable intelligent, automated wardrobe management that supports hygiene, convenience, and sustainable clothing usage.

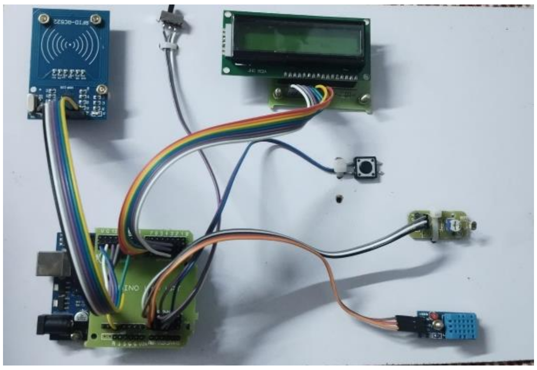

Fig.3 Proposed system Prototype

Fig.4 Prototype Output in 16X2 LCD

6. FUTURE SCOPE AND CONCLUSION

Conclusion

This project presents a novel, affordable, and practical Smart RFID-Based Clothing Management System that combines RFID technology with environmental sensing and persistent data storage to enable intelligent wardrobe tracking and personalized clothing recommendations. The system effectively tracks garment usage history, monitors real-time temperature, humidity, and light conditions, and provides gender-specific outfit suggestions via a simple interface. Its design facilitates improved clothing hygiene, balanced wardrobe utilization, and day-to-day decision support, contributing to sustainable clothing habits.

The prototype implementation demonstrates accurate RFID scanning, reliable environmental sensing, persistent usage logging, and an intuitive user interface. The system's modular and low-power design makes it suitable for both home users and small retail applications. By automating and personalizing clothing management, this solution addresses common wardrobe challenges and enhances user convenience.

Future work will focus on incorporating machine learning, expanding sensor integration, enhancing security, and developing remote management capabilities to create a fully realized smart wardrobe ecosystem. This research lays a foundation for advancing intelligent personal systems leveraging RFID and IoT to transform everyday lifestyle management.

Future Scope

The Smart RFID-Based Clothing Management System holds significant potential for further development and expansion. Future enhancements could integrate advanced machine learning algorithms to refine clothing recommendation accuracy by learning individual preferences and incorporating weather forecasts or calendar events. The system can be extended to support multiple users simultaneously, enabling families or retail environments to track a broader range of clothing items efficiently.

Integration with mobile applications or cloud platforms could facilitate remote wardrobe management, push notifications for garment care reminders, or customized fashion advice. Further incorporation of additional environmental sensors, such as air quality or UV radiation detectors, can enrich contextual awareness to better serve user needs. The use of advanced RFID tags embedded directly within textile fibers can improve durability and enable seamless monitoring throughout garment lifecycles, including washing and repair tracking.

Privacy and security enhancements, inspired by cryptographic protocols demonstrated in recent research, will be essential as such systems become more interconnected and data-sensitive. Additionally, integrating blockchain technologies could provide transparency and traceability in garment supply chains, promoting sustainability goals.

Overall, the system could evolve into a comprehensive smart wardrobe assistant that enhances convenience, sustainability, and consumer engagement in fashion retail and personal apparel management.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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