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Integration of Smart Machine Presence Using RFID E-Money Cards for Employee Attendance Management at Universitas Negeri Semarang

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Keywords

Smart Machine Presence, RFID, ID Card

Abstract

The study aims to improve the effectiveness of the online attendance system at Universitas Negeri Semarang (UNNES). The existing system, reliant on web-based input via tokens and employee identification numbers, suffers from inefficiencies and potential inaccuracies due to proxy attendance. These limitations hinder productivity and the accuracy of performance appraisals. To address these challenges, a Smart Machine Presence system was designed and implemented, utilize RFID e-money cards which become employee Identification cards (ID Card) to streamline the process and eliminate the need for manual input. This novel system employs Raspberry Pi 4 Model B technology, integrated with RFID readers and camera modules for robust authentication. The research utilized a three-stage approach: system needs analysis, prototype design, and system development. Usability testing conducted with 20 participants using the System Usability Scale (SUS) yielded a score of 86.8, indicating high user satisfaction and effectiveness. The proposed system demonstrated significant advantages, including improved data validity, enhanced operational efficiency, and reduced resource costs compared to traditional systems. This study concludes that the Smart Machine Presence system is a cost-effective, efficient, and scalable solution for modern attendance management systems.

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INTRODUCTION

Employee attendance is a critical component of organizational productivity and resource management. Accurate and detailed attendance records facilitate human resource operations such as performance evaluation, payroll, and overall workforce planning (Nailuvar & Nugroho, 2023). For institutions like Universitas Negeri Semarang (UNNES), maintaining accurate attendance data is essential for fostering an effective working environment and ensuring operational efficiency.

The existing online attendance system at UNNES operates on a web-based platform, requiring employees to input a token and their 18-digit Employee Identification Number into a desktop-based system. The system also uses a camera module to capture the employee's facial image for additional verification (Sasongko, Maulana, & Latifah, 2020). While functional, this system has notable shortcomings. Proxy attendance—where an employee's attendance is recorded by another individual—is a persistent problem that compromises data integrity and undermines performance assessments (Tahyudin & Sholihati, 2022). Additionally, the system's reliance on manual data input creates inefficiencies, particularly during peak hours, resulting in queues and delays. These issues detract from overall productivity and require a modernized approach to attendance management.

Another critical limitation is the high operational cost associated with the hardware requirements of the current system. A single setup, including a desktop computer, camera module, and peripherals, costs approximately IDR 10–15 million. This presents a financial burden for scaling the system across multiple units.

To address these challenges, this research proposes a Smart Machine Presence system that integrates RFID e-money cards with employee ID cards. By leveraging Raspberry Pi 4 Model B and camera modules, the new system eliminates the need for manual input while enhancing data accuracy and operational efficiency. RFID technology, compliant with ISO/IEC 14443 standards, enables contactless identification, ensuring quick and secure attendance recording. Furthermore, the camera module provides dual-layer validation by capturing the employee's facial image.

The objectives of this study are threefold, first, to design and develop a Smart Machine Presence prototype that improves data validity and operational efficiency. Second, to evaluate the usability and user acceptance of the system through systematic testing. Third, to provide a scalable solution for attendance management that reduces costs and enhances user experience. This paper outlines the methodology used to develop the Smart Machine Presence system, presents the results of its implementation at UNNES, and discusses its implications for attendance management in academic institutions.

METHODS

This study follows a structured approach encompassing three primary phases: system needs analysis, prototype design, and system development. Each phase is detailed below to ensure replicability and clarity in the implementation of the Smart Machine Presence system.

System Needs Analysis

The System Needs Analysis phase focused on identifying and addressing the limitations of the existing attendance system at Universitas Negeri Semarang (UNNES). The primary issues highlighted included inaccuracies in attendance data caused by proxy attendance, inefficiencies in manual data entry, and the high operational costs associated with the current system. Employees were required to input an 18-digit Employee Identification Number and a token, which often led to long queues during peak hours, causing delays and frustration. Additionally, the system's reliance on desktop computers, complete with peripherals and camera modules, made it cost-prohibitive to scale across multiple units. These factors necessitated the development of a streamlined, cost-effective, and reliable attendance management solution.

To address these challenges, stakeholder consultations were conducted with IT staff, HR personnel, and employees to define the key requirements of the new system. The analysis revealed the need for enhanced data validity to eliminate proxy attendance, operational efficiency to reduce waiting times, and affordability to enable wider deployment. These needs informed the design of the Smart Machine Presence system, which leverages RFID e-money card technology and facial image verification for robust authentication. The integration of Raspberry Pi 4 Model B ensured a compact and cost-efficient hardware solution, while the repurposing of employee ID cards as RFID-enabled e-money cards added value to the existing system

infrastructure. This thorough needs analysis laid the foundation for a tailored system that aligns with the institution's goals and operational requirements.

Prototype Design

Based on the needs analysis, a prototype of the Smart Machine Presence system was developed. The design comprised two core components:

1. **Hardware Integration**:
   - **Raspberry Pi 4 Model B**: Selected for its compact design, high performance, and affordability.
   - **RFID Reader**: Configured to read ISO/IEC 14443-compliant cards, including e-money and tap-cash cards, integrated with employee ID cards.
   - **Camera Module**: A wide-angle, infrared-enabled camera was incorporated to capture facial images under various lighting conditions.
   - **Acrylic Box Cover**: Designed to house the components securely and allow for wall mounting.
2. **Software Development**:
   - **Attendance System Integration**: The existing UNNES online attendance system was modified to incorporate RFID and facial image validation.
   - **Programming Tools**: Python was used for RFID reader integration, while TinkerCAD and Ultimaker Cura supported the physical design process.
   - **Raspberry Pi OS**: The operating system was configured with Docker to virtualize the attendance application environment.

System Development

The prototype was developed iteratively, with each iteration addressing issues identified during testing. The system development phase was structured around three key stages: hardware assembly, software configuration, and database synchronization. During **hardware assembly**, the components, including the Raspberry Pi 4 Model B, RFID reader, camera module, and a custom acrylic housing, were integrated into a compact and modular design. This ensured the system's durability and adaptability for wall-mounted installations. In the **software configuration** stage, Python was used to program the RFID reader and synchronize it with the camera module, while the Raspberry Pi OS served as the operating system to run the attendance application within a Dockerized environment. This configuration enabled seamless data capture and system operations. Finally, in **database synchronization**, the attendance records, including the unique employee ID and captured facial image, were securely transmitted and stored in the UNNES online attendance system's database. Together, these stages ensured the system's functionality, reliability, and integration with existing institutional infrastructure.

The working diagram illustrates the operation of the Smart Machine Presence system for attendance recording. When an employee taps their RFID-enabled ID card on the machine, the RFID reader retrieves the unique card ID number and sends it to the Raspberry Pi for processing. Simultaneously, the camera module captures the employee's facial image for additional verification. These two data points—RFID card ID and facial image—are processed and validated by the Raspberry Pi, which serves as the system's central controller. Once verified, the attendance data, including the employee's unique identifier and timestamp, is securely transmitted and stored in the institution's attendance management system. This workflow ensures accuracy, efficiency, and robustness by combining RFID authentication with facial recognition, thus preventing proxy attendance and streamlining the entire process.

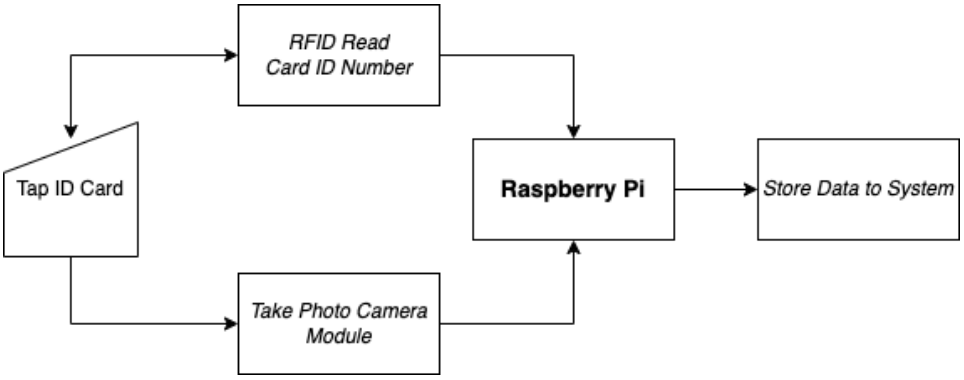

Figure 1. Smart Machine Presense Working Diagram

Figure 2. Smart Machine Presense Prototype

Testing and Validation

The final phase involved comprehensive testing of the system's functionality and usability. Lapao, da Silva, and Gregorio (2017) presented three test methods that can be used.

1. **Internal Testing**: Conducted by the UNNES IT infrastructure team to verify system responsiveness and accuracy in reading employee ID cards.
2. **Expert Validation**: Feedback from IT and HR experts was gathered through questionnaires to evaluate system performance and reliability.
3. **Black-Box Testing**: Focused on ensuring all system functions operated as intended without knowledge of the internal code structure.

In addition, usability testing was carried out using the System Usability Scale (SUS). A total of 20 participants (Sharfina and Santoso, 2016) were given an instrument consisting of 10 questions as in Table 1 and filled them in after using a smart machine presence. This provides quantitative insight into user satisfaction and system effectiveness.

Tabel 1: Questions for SUS

Code	Statement
S1	I want to use the smart machine presence
S2	I think smart machine presence is easy to use.
S3	I found smart machine presence read the Id cards correctly
S4	I found smart machine presence reads cards quickly

S5	I feel very confident using smart machine presence
S6	I found the implementation too complicated.
S7	I think I need technical support to use smart machine presence
S8	I have difficulty making presence if I don't bring an ID card
S9	I'm skeptical about smart machine presence
S10	I need to learn a lot of things before using smart machine presence

Ethical Considerations

The ethical considerations in this study focused on ensuring the privacy and security of employee data while adhering to best practices in the development and implementation of the Smart Machine Presence system. The system collects sensitive information, including the unique identifiers of RFID cards and employees' facial images. To address potential privacy concerns, all collected data were securely stored in the institutional database, with access restricted to authorized personnel only. Encryption methods were employed to safeguard the transmission of data between the hardware devices and the server, preventing unauthorized interception or tampering. Additionally, stringent access controls were implemented, ensuring that only designated IT and HR personnel could retrieve or process the stored attendance records.

Informed consent was obtained from all participants involved in usability testing and system trials. They were provided with a clear explanation of the purpose, methods, and potential impacts of the study, along with assurances that their data would be used solely for research and system development purposes. No personally identifiable information, apart from what was necessary for the system's operation, was collected or analyzed. Furthermore, the study complied with institutional and national regulations regarding the use of biometric data, ensuring ethical integrity throughout the research and development process. By prioritizing these ethical considerations, the study aimed to build trust among employees and stakeholders while establishing a foundation for the responsible use of technology in attendance management.

RESULTS AND DISCUSSION

Results

The Smart Machine Presence system was developed and tested to address the challenges of the existing attendance system at Universitas Negeri Semarang (UNNES). The results are presented in terms of system functionality, usability, and key performance metrics.

Functional Testing

Functional testing was a critical phase in validating the performance and reliability of the Smart Machine Presence system. This testing phase was conducted to ensure that the system met its primary objectives, including data accuracy, operational efficiency, and seamless integration with the existing attendance infrastructure at Universitas Negeri Semarang (UNNES). Each component of the system was tested individually and as part of the integrated setup to identify and address potential issues. One of the most significant improvements validated during functional testing was the system's ability to enhance data accuracy. The integration of RFID-based authentication and facial recognition eliminated proxy attendance, a common issue in the previous system. The dual-layer verification ensured that only authorized employees could mark their attendance, significantly improving the validity and reliability of attendance records. Each transaction was securely logged, linking the unique RFID card identifier with the employee's facial image and timestamp, thus preventing manipulation or errors in data entry.

The system's operational efficiency was also a key focus of functional testing. Employees could complete the attendance process in less than 3 seconds, as opposed to the manual entry system, which required several seconds for typing and verifying the 18-digit Employee Identification Number (NIP). This improvement

eliminated long queues during peak hours and ensured a smooth attendance experience, even in high-traffic periods. The system's ability to process a large number of employees in a short time demonstrated its scalability and suitability for institution-wide implementation. Hardware performance was evaluated to ensure the system's reliability under various conditions. The Raspberry Pi 4 Model B, equipped with an RFID reader and a camera module, consistently delivered high-speed and accurate performance. The infrared-enabled camera ensured reliable facial recognition even in low-light conditions, while the RFID reader adhered to ISO/IEC 14443 standards, allowing for compatibility with various types of smart cards, including employee ID cards integrated with e-money functionality. The modular design also allowed for easy maintenance and scalability.

Finally, the integration of the Smart Machine Presence system with the existing UNNES online attendance system was thoroughly tested. Data captured by the hardware components were transmitted and stored in the institutional database without any loss or delay. The synchronization between the hardware and software components was seamless, ensuring that the system operated as an efficient extension of the current infrastructure. Overall, functional testing validated that the Smart Machine Presence system not only addressed the limitations of the previous system but also introduced significant enhancements in accuracy, efficiency, and user experience.

Usability Testing

A System Usability Scale (SUS) evaluation was conducted with 20 participants, yielding a score of 86.8, which exceeds the industry benchmark of 68 for good usability. Key insights from the SUS evaluation include:

- Positive Responses (82.5%): Most participants found the system easy to use, accurate, and efficient. Statements such as “The system is quick and precise in reading cards” received high agreement.
- Negative Responses (6%): Some participants expressed concerns about the system's reliance on RFID cards, noting difficulty if the card was misplaced or forgotten. However, backup solutions, such as manual entry systems, were available to address this issue.
- Neutral Responses (11.5%): A small percentage of responses indicated neither strong satisfaction nor dissatisfaction.

Efficiency Metrics

The implementation of the Smart Machine Presence system significantly improved the efficiency of attendance management at Universitas Negeri Semarang (UNNES). Efficiency metrics were evaluated based on time savings, queue reduction, and cost-effectiveness, each demonstrating the practical benefits of transitioning from the traditional manual system to the RFID-based automated system.

First, Time Savings. One of the most critical efficiency metrics was the time required to record attendance. The traditional system relied on employees manually entering an 18-digit Employee Identification Number (NIP) into a desktop interface, which often took several seconds per entry. In contrast, the Smart Machine Presence system reduced this process to under three seconds by using an RFID-enabled ID card and facial recognition. Employees only needed to tap their ID cards on the RFID reader and briefly align their faces with the camera. This rapid authentication method streamlined the attendance process, especially during peak hours, and minimized the time employees spent on administrative tasks, allowing them to focus on their core responsibilities.

Second, Queue Reduction. The time efficiency of the system directly contributed to the reduction of queues during peak attendance periods, such as the start and end of work shifts. The previous manual system often created bottlenecks, as the process of typing in the NIP and verifying attendance was slow and error-prone, particularly during high-traffic times. The new system processed employees in a fraction of the time, eliminating congestion and ensuring a smoother flow of attendees. This improvement was especially beneficial in large administrative buildings where a high volume of employees needed to record attendance simultaneously.

Third, Cost-Effectiveness. Another critical efficiency metric was the cost of hardware and maintenance. The traditional system required a complete desktop setup, including a computer, keyboard, and camera module, for each attendance station, with an estimated cost of IDR 10–15 million per unit. In contrast, the Smart Machine Presence system utilized compact and cost-efficient components, such as Raspberry Pi 4 Model B and modular RFID and camera units. This configuration reduced hardware costs by 60–70%, making it more affordable to deploy across multiple units within the institution. Furthermore, the system's modular design simplified maintenance and upgrades, further reducing operational expenses.

Fourth, User Experience and Scalability. Efficiency metrics also extended to user experience and system scalability. The rapid and user-friendly process of the new system ensured high user satisfaction, as evidenced by positive feedback during usability testing. Additionally, the compact design of the Smart Machine Presence system allowed for easy installation in various locations, making it scalable for widespread use across all units at UNNES. These improvements in efficiency metrics collectively demonstrated the system’s ability to meet the institution's needs effectively while optimizing resources.

significantly improving time efficiency, reducing operational costs, and ensuring scalability, the Smart Machine Presence system established itself as a highly efficient solution for modern attendance management in academic institutions. These metrics highlighted the practical advantages of transitioning to an automated system and underscored its potential for broader implementation.

User Feedback

Participants highlighted several benefits of the system:

1. Ease of Use: The system was intuitive, requiring minimal training for first-time users.
2. Aesthetic Design: The compact and wall-mounted design was appreciated for saving space and improving workplace aesthetics.
3. Reliability: The system performed consistently across different environments and lighting conditions, thanks to the infrared-enabled camera module.

Discussion

The implementation of the Smart Machine Presence system at Universitas Negeri Semarang (UNNES) represents a significant advancement in attendance management technology, addressing critical shortcomings of the previous system. This section contextualizes the findings within the broader literature, highlights the theoretical and practical implications, and discusses the system's limitations and potential areas for improvement.

Theoretical Implications

This study contributes to the growing body of research on attendance management systems by demonstrating the effectiveness of combining Radio Frequency Identification (RFID) technology with facial recognition for enhanced data validity. Prior studies have highlighted the limitations of manual input systems, such as inefficiencies and vulnerability to proxy attendance (Tahyudin & Sholihati, 2022). By integrating RFID e-money cards, this system ensures unique identification for each employee, eliminating such vulnerabilities. Furthermore, the use of Raspberry Pi 4 Model B and modular hardware components aligns with sustainable design practices, as the system is cost-efficient and scalable (Francis-Mezger & Weaver, 2018).

Practical Significance

The Smart Machine Presence system introduces a range of practical benefits:

1. Operational Efficiency: The significant reduction in attendance recording time and elimination of peak-hour queues directly enhance workplace productivity. Employees can complete the attendance process in 2-3 seconds, compared to the manual entry system, which often caused delays.
2. Cost Savings: The system's hardware costs are 60-70% lower than the desktop-based setup previously used. This makes it a viable solution for widespread implementation across multiple units within UNNES.
3. Enhanced User Experience: The high usability score (SUS: 86.8) indicates strong user satisfaction and ease of adoption, which are critical for successful technology implementation.

These findings align with similar studies that emphasize the importance of usability and efficiency in attendance systems (Sasongko, Maulana, & Latifah, 2020).

Comparison with Existing Systems

Compared to existing systems, such as fingerprint-based authentication or earlier RFID implementations, the Smart Machine Presence system offers distinct advantages. Dual Layer Authentication makes the integration of RFID card scanning with facial image verification higher data security and reduces the risk of identity manipulation. Beside that, adaptability of smart presence machines Unlike fingerprint systems, which can be affected by environmental conditions or physical damage to the sensor, these systems work consistently across a variety of settings. Additionally, the system leverages existing employee ID cards, repurposing them as e-money cards, thereby increasing their functionality and value.

CONCLUSION

This study successfully developed and implemented a Smart Machine Presence system at Universitas Negeri Semarang (UNNES) to address the limitations of the existing attendance management system. The new system, which integrates RFID e-money card technology with facial recognition, provides a robust solution to ensure data validity, operational efficiency, and cost-effectiveness.

The research demonstrated several key contributions:

1. **Improved Data Accuracy**: By employing dual-layer authentication through RFID and facial

recognition, the system eliminates the possibility of proxy attendance and ensures accurate attendance records.

2. **Enhanced Efficiency**: Attendance recording time was reduced significantly, eliminating queues during peak hours and improving the overall user experience.
3. **Cost Reduction**: The system's reliance on Raspberry Pi 4 Model B and modular components reduced hardware costs by 60-70% compared to traditional desktop-based setups.
4. **High User Acceptance**: Usability testing with a SUS score of 86.8 indicated that the system is user-friendly and highly satisfactory for employees.

Novel Contributions

The integration of existing employee ID cards with e-money functionality introduces a unique value proposition, enhancing the practicality and utility of employee cards. Furthermore, the compact, wall-mounted design of the Smart Machine Presence system allows for space-saving deployment, making it adaptable for diverse institutional environments.

Recommendations

To maximize the potential of the Smart Machine Presence system, the following recommendations are proposed:

1. System Expansion: Deploy the system across all units at UNNES to achieve consistent and institution-wide benefits.
2. Employee Training: Conduct regular training sessions to ensure that all users are familiar with the system's features and operations.
3. Continuous Evaluation: Perform periodic evaluations to identify potential areas for improvement and to maintain system performance.
4. Enhanced Data Security: Strengthen data protection measures to safeguard sensitive information from breaches or misuse.
5. Integration with HR Systems: Expand the system's functionalities to integrate with human resource management systems for automated payroll and performance evaluations.

The Smart Machine Presence system represents a scalable and innovative solution to modern attendance management challenges. With further refinement and broader implementation, this system has the potential to become a standard model for attendance systems in academic and professional settings.

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