

An Integrated Automation Framework for Monitoring and Control of Material Processes

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INTRODUCTION & AIM

The continuous growth of logistics operations has elevated the importance of reliable and automated material management systems. In warehouse and industrial environments, the accurate registration of inbound materials is a fundamental requirement for maintaining supply chain integrity and operational efficiency [1]. Manual processes at the receiving stage are susceptible to human errors, data inconsistency, and lack of real-time visibility, which can propagate throughout downstream operations.

Industrial automation, particularly in the context of smart manufacturing and Industry 4.0, has provided technological foundations for addressing these challenges. The integration of mobile computing, cloud-based platforms, and discrete event control has opened new possibilities for automating complex logistic workflows [2]. However, the specific challenge of inbound material registration — encompassing document capture, structured data entry, and real-time monitoring — remains an underexplored area in terms of systematic automation frameworks.

This paper presents an integrated automation framework for the monitoring and control of material entry processes in warehouse environments. The proposed system combines a mobile application for material intake registration with a centralized web-based platform that handles data storage, validation, and monitoring. The framework was designed according to automation and control engineering principles, emphasizing modularity, process standardization, and information flow consistency.

METHOD

The proposed framework follows a client-server architecture composed of two primary subsystems: a mobile application for inbound material registration and a centralized web-based platform for data management and monitoring. Figure 1 illustrates the high-level system architecture. Both subsystems communicate through a RESTful API layer, ensuring loose coupling and facilitating independent evolution of each component. The mobile application was developed to support data capture activities during the material receiving process. It operates on standard Android devices deployed at the receiving dock, providing functionalities for document scanning through optical capture and parsing of shipping documents, invoices, and delivery notes using on-device OCR processing. It also enables image recording, allowing photographic documentation of received items, packaging conditions, and visible defects, as illustrated in Figure 2.

In addition, the application offers structured input fields through guided data entry forms, covering attributes such as quantity, unit, supplier code, and lot identification. To ensure operational continuity, the system supports offline operation by implementing local data buffering, with automatic synchronization once network connectivity is restored.

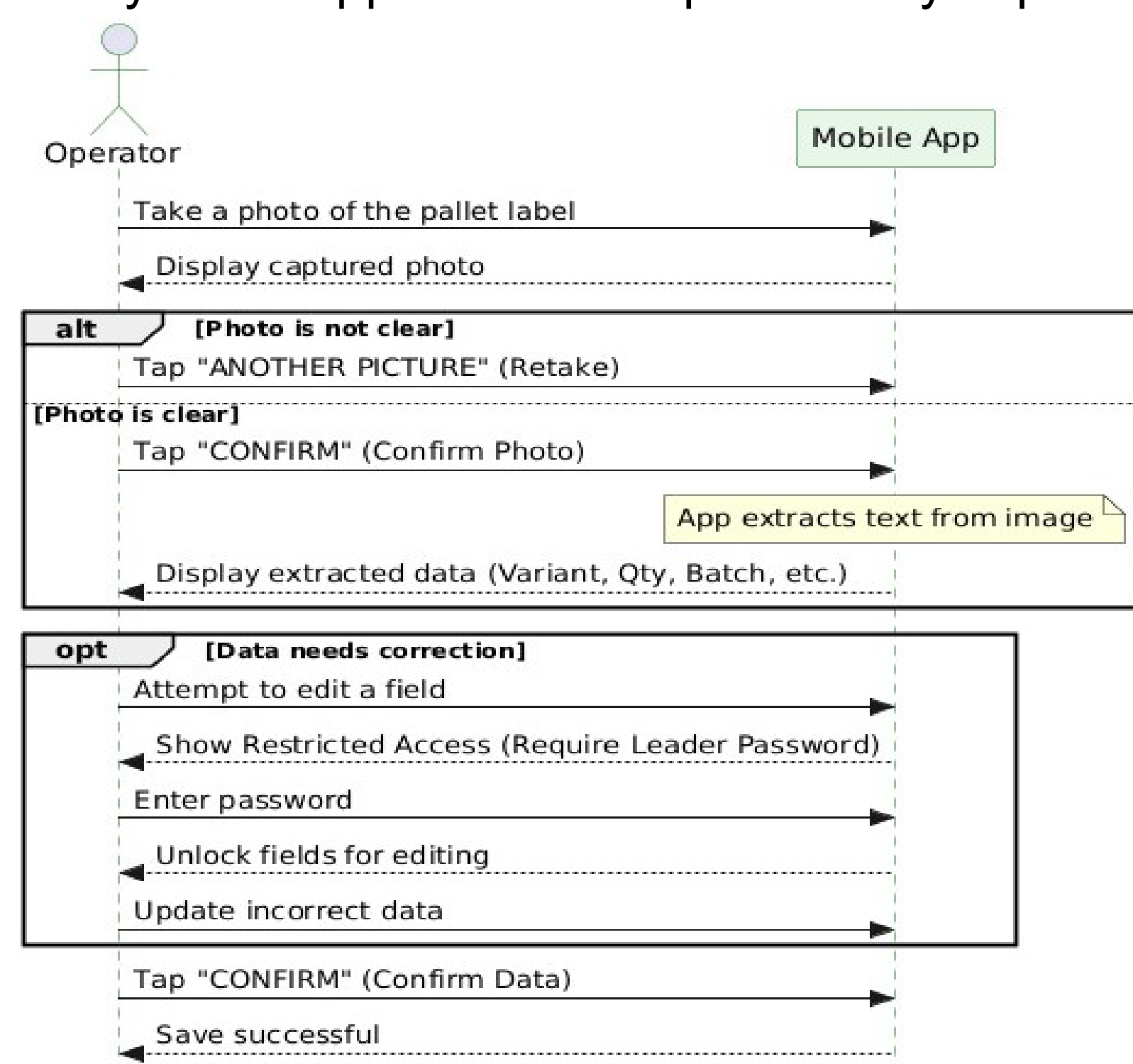


Figure 1. High-level system architecture

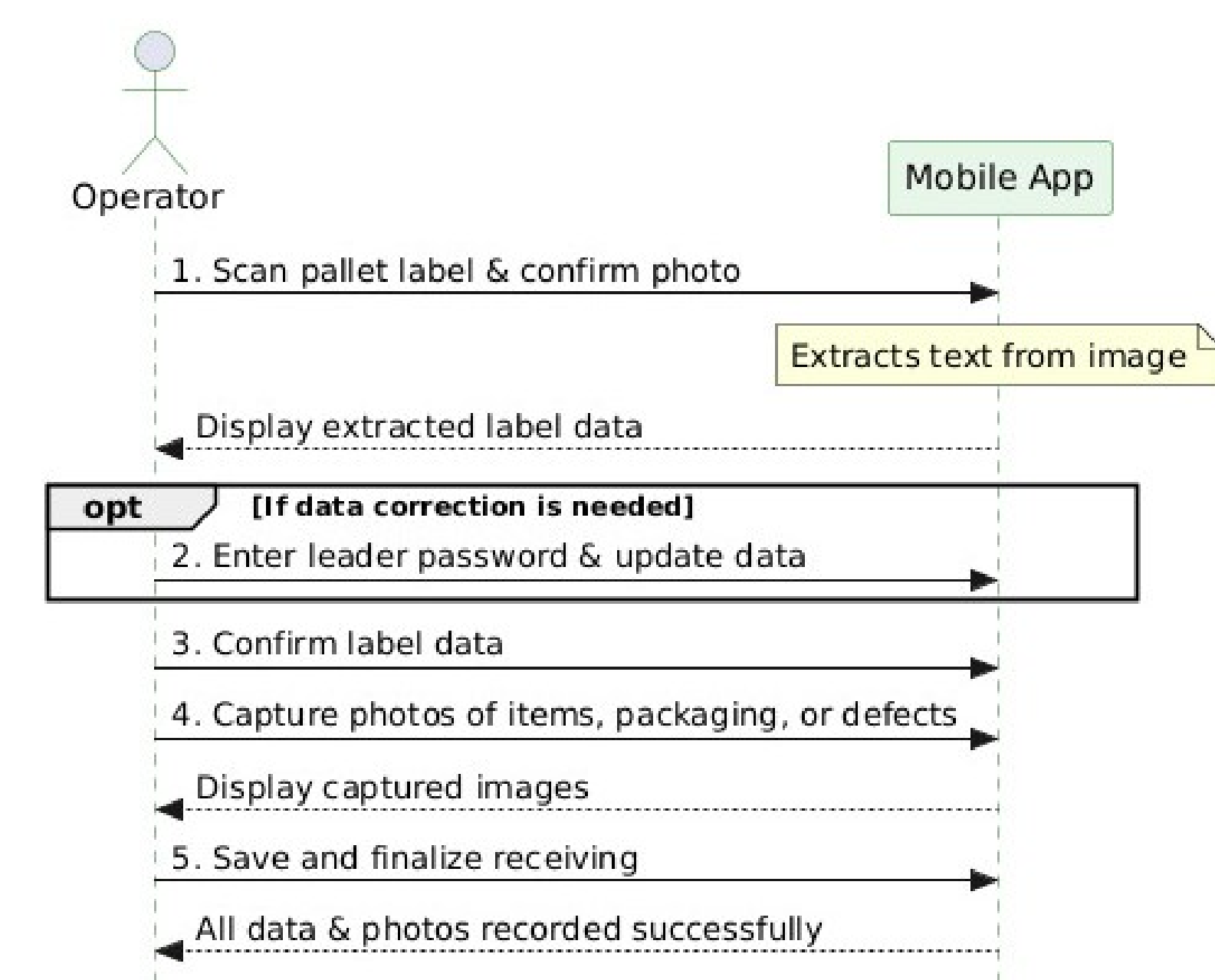


Figure 2. Mobile Registration Application

RESULTS & DISCUSSION

The experimental deployment yielded consistent improvements across all evaluated metrics. Table 1 summarizes the comparative results between the manual baseline period and the automated framework deployment period. The registration completeness rate increased from 71.4% (manual) to 98.7% (automated), demonstrating the effectiveness of mandatory field enforcement and mobile-guided data entry. The information gap rate — a proxy for post-registration correction effort — was reduced from 18.2% to 1.3%, indicating a substantial reduction in downstream data quality issues.

Average registration time per entry decreased from 4.8 to 2.1 minutes, a 56% reduction attributed to streamlined data capture flows and the elimination of paper-based transcription. Traceability event logging reached 100% coverage under the framework, compared to 43% under manual procedures, where traceability was dependent on individual operator diligence.

Metric	Manual	Framework
Completeness rate	71.4%	98.7%
Information gap rate	18.2%	1.3%
Avg. registration time	4.8 min	2.1 min
Traceability events logged	43%	100%

Table 1. Comparative performance metrics: manual baseline vs. automated framework.

CONCLUSIONS

This paper presented an integrated automation framework for the monitoring and control of inbound material registration processes in warehouse environments. The framework combines a mobile application for structured data capture with a centralized web platform for validation, storage, and real-time monitoring. The system architecture was grounded in automation and control engineering principles, incorporating Discrete Event Systems modeling to enforce process compliance.

Experimental deployment demonstrated significant improvements in registration completeness, information gap reduction, and traceability coverage. The results position the proposed framework as a practical and theoretically grounded reference model for future developments in warehouse automation.

FUTURE WORK/ REFERENCES

Future work will focus on the integration of computer vision-based automated identification, extension of the framework to outbound logistics operations, and the development of predictive analytics capabilities based on accumulated registration data.

[1] FLORIDO-BENÍTEZ, L. et al. Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review. *Logistics*, v. 7, n. 2, art. 24, abr. 2023. DOI: 10.3390/logistics7020024.

[2] TUBIS, A. A.; ROHMAN, J. Intelligent Warehouse in Industry 4.0 — Systematic Literature Review. *Sensors*, v. 23, n. 8, art. 4105, abr. 2023. DOI: 10.3390/s23084105.