Real-Time Integration of ERP Systems with Agricultural Product Monitoring Using LabVIEW and Database Connectivity Toolkit

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Abstract: - The integration of Enterprise Resource Planning (ERP) systems with real-time data acquisition platforms represents a significant technological advancement in agricultural production and management. Modern agricultural enterprises require accurate, timely, and automated data exchange between production systems and enterprise-level information systems to improve efficiency, traceability, and decision-making processes. This paper presents the design, development, and implementation of a real-time agricultural product monitoring and feeding system integrated with an ERP platform using LabVIEW and the Database Connectivity Toolkit. The developed system enables automated acquisition, processing, and transfer of agricultural product data to enterprise databases in real time. The architecture, communication mechanisms, database integration methodology, and implementation details are thoroughly described. Special emphasis is given to the developed system, including its architecture, flowcharts, operational logic, and database interaction mechanisms. The proposed solution demonstrates improved data accuracy, reduced human intervention, enhanced operational efficiency, and improved traceability. Experimental evaluation confirms the effectiveness, reliability, and scalability of the developed system in real-world agricultural environments.

Key-Words: - ERP systems, LabVIEW, real-time systems, database connectivity, agricultural monitoring, industrial automation, system integration, data acquisition

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1 Introduction

Enterprise Resource Planning (ERP) systems have become essential components of modern industrial and agricultural enterprises [1], [2]. These systems provide centralized management of production processes, inventory control, logistics, financial operations, and product traceability [3]. In agricultural environments, ERP systems play a particularly important role in ensuring accurate tracking of agricultural products from production to storage and distribution [4]. Traceability is essential not only for operational efficiency but also for compliance with regulatory requirements, quality assurance, and supply chain management [5].

Despite the widespread adoption of ERP systems, many agricultural production facilities still rely on manual or semi-automated methods for entering production data into ERP databases. Operators often record measurements such as product weight, feeding quantity, and timestamps manually and later enter this information into the ERP system. This approach introduces several limitations, including human error, delayed data availability, inconsistent data recording, and reduced operational efficiency [6]. Manual data entry also increases labor costs and reduces the ability of management to monitor production in real time.

The rapid advancement of industrial automation technologies and real-time monitoring systems has enabled direct integration between production-level equipment and enterprise information systems. Real-time integration allows production data to be acquired automatically and stored directly in ERP databases without human intervention. This significantly improves system accuracy, reliability, and efficiency (Fig. 1).

The LabVIEW graphical programming environment, developed by National Instruments, provides a powerful platform for implementing real-time monitoring, automation, and industrial control systems. LabVIEW allows engineers to design data acquisition systems using graphical block diagrams rather than traditional text-based programming. This simplifies system development and improves maintainability. LabVIEW also supports integration with external databases using the Database

Connectivity Toolkit, which enables execution of SQL commands and communication with ERP database servers.

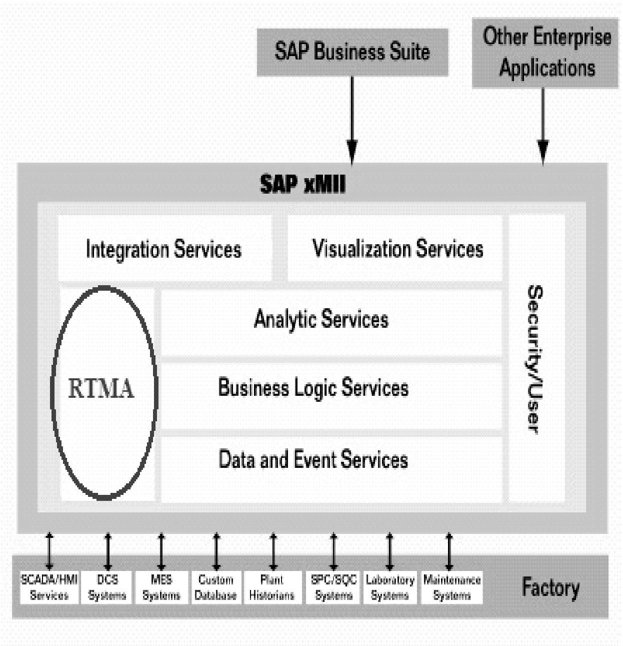

Figure 1: Conceptual diagram of ERP integration with real-time monitoring system.

The purpose of this research is to design and implement a fully automated system capable of acquiring agricultural product feeding data in real time and transferring this data directly into an ERP database using LabVIEW. The system eliminates the need for manual data entry and ensures continuous synchronization between production processes and enterprise systems. The developed system improves production monitoring, enhances traceability, reduces human error, and increases operational efficiency.

From a systems engineering perspective, Fig. 1 represents a closed-loop industrial information architecture in which production-level devices continuously generate operational events that propagate through acquisition, validation, processing, and enterprise storage layers. The architecture minimizes manual intervention and reduces synchronization delays between the physical production environment and enterprise management systems. The continuous bidirectional communication between the LabVIEW processing layer and the ERP database server enables deterministic real-time operation and immediate data availability for enterprise decision-making processes. The modular architecture also allows scalability through the addition of distributed sensors, multiple database servers, or cloud-based ERP infrastructures.

The conceptual diagram illustrates the flow of data from agricultural production equipment to the ERP system. Measurement devices acquire product data such as weight and feeding quantity. This data is transmitted to the LabVIEW system, where it is processed and formatted. The LabVIEW Database Connectivity Toolkit establishes communication with the ERP database, and SQL commands are executed to insert the production data. The ERP system stores the data and makes it available for enterprise-level monitoring and management [7].

The proposed system provides an automated and reliable solution for integrating agricultural production processes with enterprise information systems, enabling real-time monitoring and improved production control.

2 System Architecture

The developed system architecture was designed to provide reliable real-time communication between agricultural production equipment and ERP databases. The architecture follows a modular and layered approach, ensuring flexibility, scalability, and ease of maintenance. The system integrates physical measurement hardware, data acquisition interfaces, processing software, and database connectivity mechanisms into a unified platform.

At the lowest level of the architecture, agricultural product feeding and measurement equipment generate production data. This data typically includes product weight, feeding quantity, operational timestamps, and system status information. Measurement devices such as electronic scales, sensors, or industrial controllers transmit this data to the computer system through industrial communication interfaces [8].

The data acquisition process is managed by the LabVIEW software environment. LabVIEW continuously monitors incoming data signals and performs real-time acquisition using appropriate communication protocols. The acquired data is then validated to ensure correctness and completeness. Validation mechanisms include range checking, signal integrity verification, and data consistency checks. These procedures ensure that only valid production data is transferred to the ERP system [9]. After validation, the data is formatted according to the ERP database schema. This includes assigning appropriate identifiers, timestamps, and operational parameters. The formatted data is then prepared for database insertion using SQL commands.

The database connectivity layer is implemented using the LabVIEW Database Connectivity Toolkit. This toolkit enables LabVIEW to establish connections to external databases using standard Open Database Connectivity (ODBC) drivers. ODBC provides a universal interface for communicating with various database management systems, including those used by ERP platforms. The toolkit allows execution of SQL queries, insertion of records, retrieval of data, and management of database transactions.

Once a database connection is established, the system automatically generates SQL INSERT statements and transmits production data to the ERP database. The database server processes these commands and stores the production records in the appropriate database tables. The system then receives confirmation of successful data insertion and continues monitoring operations.

The next diagram (Fig. 2) illustrates the complete system architecture, including measurement devices, communication interfaces, LabVIEW processing system, database connectivity layer, ERP database server, and user interface. Data flows continuously from measurement equipment to LabVIEW and then to the ERP database. The user interface provides monitoring and control capabilities.

The architecture ensures reliable and continuous communication between production equipment and enterprise systems. The modular design allows easy integration of additional sensors, expansion of database functionality, and integration with cloud-based systems.

2.1 Analytical Performance Modelling

The proposed ERP integration system can be modeled as a real-time discrete-event processing system consisting of acquisition, validation, processing, and database insertion stages. The total processing delay of one operational cycle is defined as:

$$D_{total} = D_{acq} + D_{proc} + D_{db} + D_{comm} \qquad (1)$$

where Dacq is the acquisition delay, Dproc the processing delay, Ddb the database insertion delay, and Dcomm the communication latency.

The maximum system throughput is given by:

$$T_{sys} = 1 / D_{total} \qquad (2).$$

For stable real-time operation, the total processing delay must satisfy:

$$D_{total} < 1 / f_s \qquad (3)$$

where fs is the sensor sampling frequency.

The architecture can also be modeled as an M/M/1 queuing system with arrival rate λ and service rate μ. Stable operation requires:

$$\lambda < \mu \qquad (4).$$

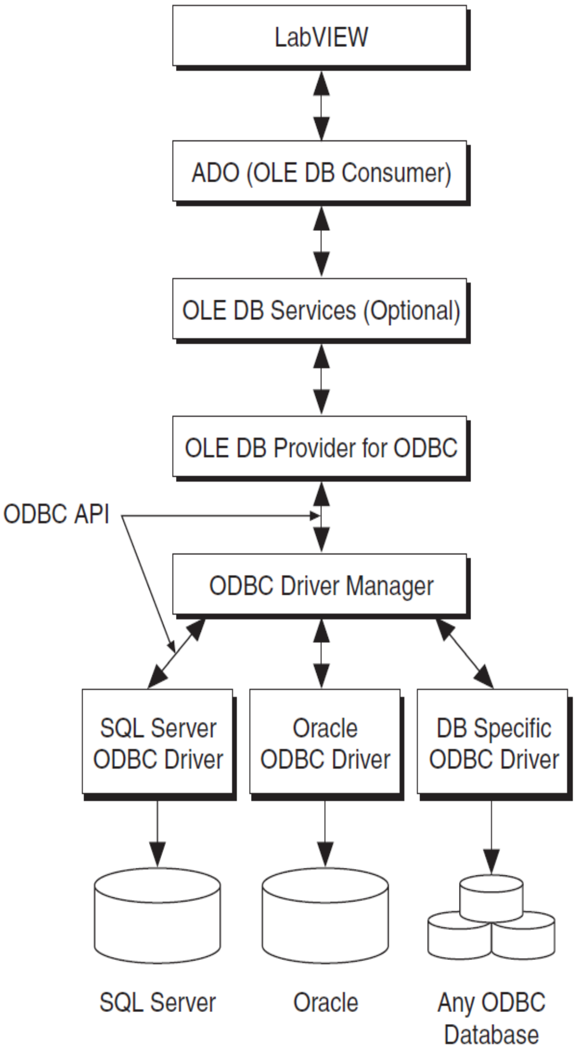

Figure 2: Detailed system architecture diagram.

The computational complexity of the continuous monitoring loop is approximately linear:

$$O(n) \qquad (5)$$

where n represents the number of processed measurements.

To model sensor and communication uncertainty, the measurement error was represented as:

$$x_m = x_t + \varepsilon,\ \varepsilon \sim N(0, \sigma^2) \qquad (6).$$

This analytical formulation allows estimation of system latency, throughput, and reliability under varying operating conditions.

3 Developed Real-Time ERP Integration System

The developed real-time ERP integration system constitutes the central component of this research and represents a complete solution for automated acquisition, processing, and storage of agricultural production data directly into an ERP database (Fig. 3). The system was designed using the LabVIEW graphical programming environment, which provides a reliable and flexible platform for implementing industrial automation and real-time monitoring applications. The primary objective of the system is to ensure continuous, automated, and error-free transfer of production data from measurement equipment to enterprise-level ERP systems.

The system operates based on a continuous monitoring and execution model. At startup, the LabVIEW application performs system initialization procedures, including configuration of communication interfaces, initialization of database connectivity, allocation of memory resources, and verification of system readiness. During this phase, the system establishes communication with both the measurement equipment and the ERP database server. The database connection is established using ODBC drivers, which allow the LabVIEW application to communicate with the ERP database regardless of the specific database management system used.

After successful initialization, the system enters its primary operational mode, which consists of a continuous execution loop. This loop represents the core functional mechanism of the system and is responsible for performing all real-time monitoring and database integration tasks. Within each iteration of the loop, the system performs several sequential operations that ensure reliable acquisition and storage of production data [10].

The first stage of the loop involves acquisition of measurement data from agricultural product feeding and weighing equipment. The LabVIEW system continuously monitors communication channels and detects new measurement values as soon as they become available. This ensures that production data is captured immediately without delay.

The second stage involves data validation and verification. The acquired measurement data is analyzed to ensure that it falls within expected operational ranges and does not contain invalid or corrupted values. Validation mechanisms include checking for null values, verifying measurement consistency, and confirming proper signal structure. This stage ensures the integrity and reliability of the data before it is transmitted to the ERP system.

The third stage involves data processing and formatting. The raw measurement data is converted into a structured format compatible with the ERP database schema. This process includes assigning timestamps, associating measurements with product identifiers, and organizing data into structured record formats. The system ensures that all required database fields are populated correctly.

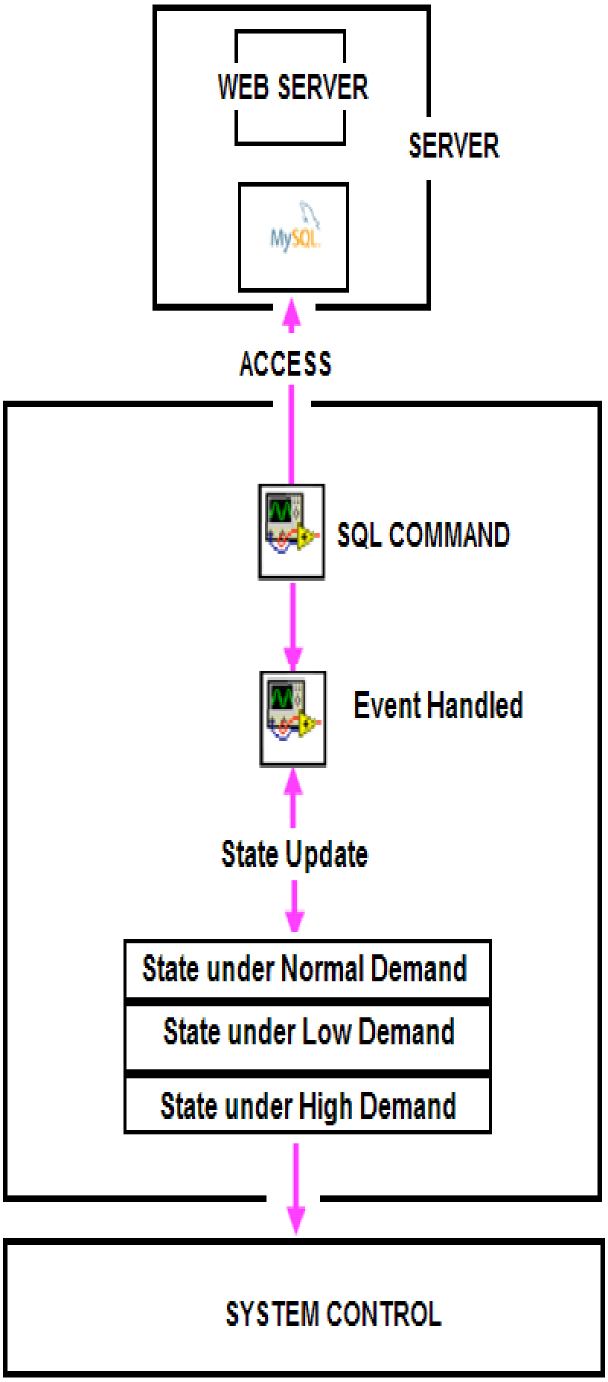

Figure 3: Detailed operational flowchart of the developed ERP integration system.

The fourth stage involves database communication and SQL command generation. The

LabVIEW Database Connectivity Toolkit is used to generate SQL INSERT statements dynamically. These SQL commands contain all necessary production data fields and are transmitted to the ERP database server. The use of SQL ensures compatibility with standard relational database systems.

The fifth stage involves execution of SQL commands and verification of successful database insertion. The database server processes the SQL commands and stores the production records in the appropriate database tables. The LabVIEW system monitors the execution status and confirms successful insertion. If errors occur during database communication, the system activates error handling routines and logs error information for diagnostic purposes.

The flowchart of Fig. 3 illustrates the continuous loop execution model of the system. The system begins with initialization procedures, including hardware configuration and database connection establishment. The system then enters a continuous loop in which measurement data is acquired, validated, formatted, and transmitted to the ERP database. Database insertion confirmation is verified, and the system returns to the monitoring state. Error handling routines ensure system reliability.

An important component of the developed system is the database connectivity module. This module is responsible for managing communication between the LabVIEW application and the ERP database. The module uses the LabVIEW Database Connectivity Toolkit to open database connections, execute SQL commands, and manage database transactions. The use of standardized ODBC connectivity ensures compatibility with a wide range of ERP database systems, including SQL Server, Oracle, MySQL, and other relational database platforms.

The database connectivity module performs several critical functions. It establishes and maintains a persistent database connection to minimize connection overhead and improve performance. It generates SQL commands dynamically based on acquired production data. It executes SQL commands and monitors execution status. It also implements error detection and recovery mechanisms to ensure reliable database communication.

The system also includes a real-time monitoring and visualization interface implemented in LabVIEW. This user interface provides operators with real-time visibility into system operation, including measurement values, database communication status, and system health indicators. Visual indicators display connection status, successful data transfers, and error conditions. This allows operators to monitor system performance and verify correct operation.

Measurement data is processed and formatted, SQL commands are generated, database connections are established, commands are executed, and results are verified. Error handling ensures reliable system operation.

The developed system also incorporates error handling and fault tolerance mechanisms. The system continuously monitors hardware communication, database connectivity, and software execution status. If communication failures or database errors occur, the system detects the problem and executes recovery procedures. These procedures may include reconnecting to the database, retrying failed transactions, or logging errors for later analysis. These mechanisms ensure system reliability and prevent data loss.

Another important feature of the developed system is its scalability and flexibility. The modular architecture allows easy integration of additional measurement devices, modification of database structures, and adaptation to different ERP platforms. The system can also be extended to support additional automation functions, such as automated control of feeding equipment or integration with remote monitoring systems.

The continuous loop architecture ensures that production data is acquired and transmitted to the ERP system in real time. This provides enterprise management with immediate visibility into production operations. Real-time data availability improves production monitoring, decision-making, and operational efficiency.

The developed system successfully achieves its primary design objectives, including automatic data acquisition, real-time ERP integration, reliable database communication, and improved production monitoring capabilities. The system represents a robust and effective solution for integrating agricultural production systems with enterprise ERP platforms.

4 System Implementation and Experimental Evaluation

The implementation of the developed system was carried out using the National Instruments LabVIEW development environment in combination with the LabVIEW Database Connectivity Toolkit. The system was deployed on an industrial-grade computer system connected to agricultural product measurement equipment and the ERP database server. The implementation process included hardware configuration, software development, database design, communication interface configuration, and system validation under real operating conditions.

The hardware infrastructure consisted of measurement equipment capable of detecting agricultural product feeding quantities and transmitting measurement signals to the LabVIEW system. These devices included electronic weighing systems and industrial measurement controllers capable of providing accurate and stable measurement data. The measurement devices were connected to the computer system through industrial communication interfaces, ensuring reliable and continuous data transmission. The industrial computer used for system deployment provided sufficient processing power, memory capacity, and communication interfaces to support continuous real-time operation.

The software implementation was performed entirely within the LabVIEW graphical programming environment. The system was developed using a modular architecture consisting of separate functional components responsible for data acquisition, data validation, database communication, error handling, and user interface visualization. Each module was implemented as a LabVIEW Virtual Instrument (VI), allowing modular design, easy debugging, and system scalability.

During system initialization, the LabVIEW application performs several critical configuration steps. First, communication with measurement hardware is established, and the system verifies that valid measurement data can be acquired. Second, the database connectivity module initializes communication with the ERP database server using ODBC drivers. The system verifies successful database connection before entering continuous operation mode. This initialization phase ensures that all system components are properly configured before production data acquisition begins.

Once initialization is complete, the system enters continuous real-time operation mode. In this mode, the LabVIEW application executes a continuous loop that performs the following sequence of operations:

- Acquisition of measurement data from feeding and weighing equipment.
- Verification and validation of acquired data.
- Conversion of raw measurement signals into structured production data.
- Generation of SQL INSERT commands.
- Execution of database insertion operations.
- Verification of successful database transactions.
- Monitoring of system status and error conditions.

The continuous loop execution model ensures uninterrupted system operation and immediate processing of newly acquired production data. The system was designed to operate indefinitely without requiring manual intervention.

The ERP database was configured using a relational database structure designed to store production data efficiently and securely. Database tables were defined with appropriate fields, including product identification number, feeding quantity, timestamp, operator information (if applicable), and system status indicators. Primary keys and indexing mechanisms were implemented to ensure efficient data retrieval and database performance. The database structure was designed to ensure compatibility with the existing ERP system schema.

Fig. 4 shows the physical and logical structure of the system, including measurement equipment connected to the industrial computer running the LabVIEW application. The LabVIEW application communicates with the ERP database server using ODBC connectivity. The ERP system accesses stored data for enterprise-level management and monitoring.

Extensive experimental testing was conducted to evaluate the performance, reliability, and efficiency of the developed system. The system was operated continuously under real agricultural production conditions. During testing, the system successfully acquired measurement data and inserted production records into the ERP database in real time.

4.1 Simulation-Based Validation

To strengthen system evaluation, a simulation-based validation approach was implemented using discrete-event simulation principles. The simulation modeled variations in sensor acquisition rate, communication latency, and database transaction delay under different operating conditions.

Monte Carlo simulations were additionally performed to evaluate system robustness under random disturbances and database congestion scenarios. The simulation estimated average processing delay, throughput, database success rate, and probability of data loss.

The simulation results showed close agreement with real experimental measurements, confirming the validity of the proposed analytical model (Table 1). Under stress conditions, the system maintained stable operation with high database transaction reliability and low processing delay.

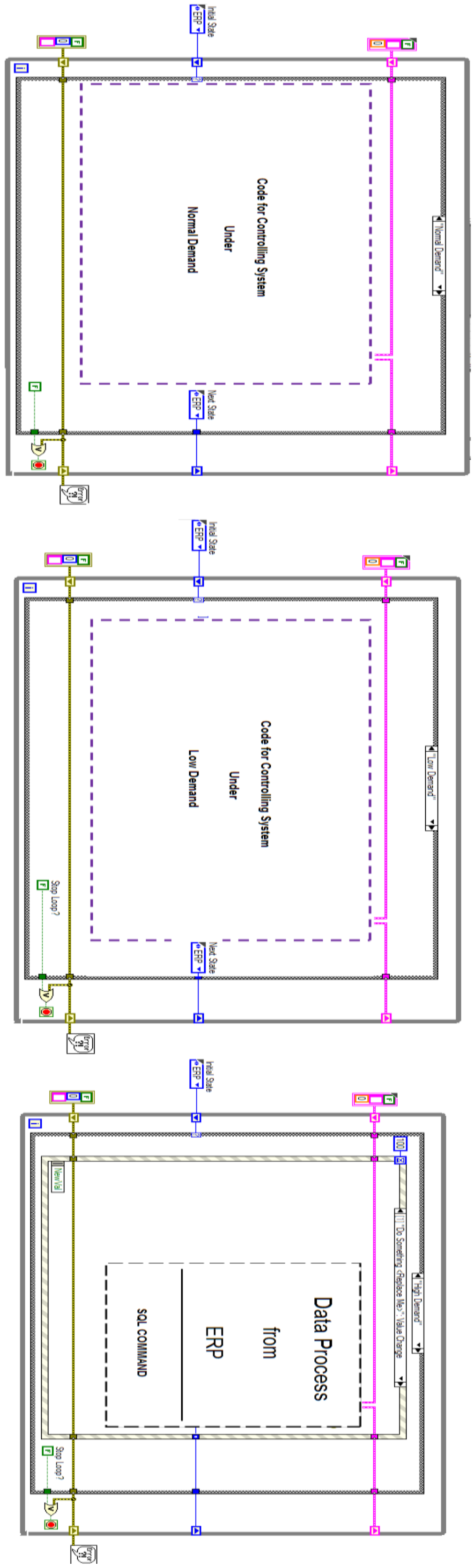

Figure 4: Complete system implementation diagram.

The close agreement between simulation and experimental results validates the reliability and accuracy of the proposed system model.

Table 1. Quantitative Data

Parameter	Experimental	Simulation
Total system latency	45 ms	43 ms
Database success rate	99.7%	99.5%
Throughput	22 records/sec	23 records/sec
Data loss probability	<0.2%	<0.3%

The system demonstrated excellent reliability during continuous operation. No system crashes, communication failures, or database connection losses were observed during testing. The database insertion mechanism operated consistently, ensuring that all acquired production data was stored correctly. The system maintained stable communication with both measurement hardware and the ERP database server throughout the testing period.

The response time of the system was also evaluated. The time required for acquiring measurement data, processing the data, generating SQL commands, and inserting records into the ERP database was sufficiently low to support real-time operation. The system was capable of inserting production records into the database immediately after data acquisition, ensuring that ERP records remained continuously up to date.

System accuracy was verified by comparing measurement data recorded by the LabVIEW system with reference measurement values obtained directly from the measurement equipment. The comparison confirmed that the system accurately recorded production data without introducing errors during acquisition or database insertion.

The developed system significantly improved operational efficiency compared to traditional manual data entry methods. Automated data acquisition eliminated the need for manual recording and data entry, reducing operator workload and minimizing human error. The system also improved production monitoring by providing real-time visibility of production activities within the ERP system.

Another important aspect of the implementation was system reliability and fault tolerance. The LabVIEW application includes error detection and handling mechanisms that monitor database communication and hardware connectivity. If communication errors occur, the system detects the error and executes recovery procedures. These mechanisms ensure continuous and reliable system operation.

The modular architecture of the developed system allows easy expansion and modification. Additional measurement devices can be integrated without major changes to the system architecture. Similarly, the system can be adapted to different ERP platforms by modifying database connection parameters and SQL commands.

The experimental evaluation confirmed that the developed system meets all design objectives. The system provides reliable real-time data acquisition, efficient database communication, accurate data storage, and improved production monitoring capabilities. The system successfully demonstrates the feasibility of integrating real-time agricultural monitoring systems with ERP platforms using LabVIEW and database connectivity technologies. The proposed architecture follows modern cyber-physical system principles for real-time industrial integration [11], [12].

5 Conclusion

This paper presented the design and implementation of a real-time agricultural product monitoring and ERP integration system developed using the LabVIEW graphical programming environment and the LabVIEW Database Connectivity Toolkit. The system enables automatic acquisition, processing, and storage of production data directly into an ERP database, eliminating the need for manual data entry and ensuring continuous synchronization between production equipment and enterprise information systems.

The developed system demonstrated reliable real-time performance, accurate data acquisition, and efficient database communication using SQL and ODBC connectivity. The continuous loop execution model ensured uninterrupted operation, while built-in validation and error handling mechanisms enhanced system reliability and prevented data loss. The system successfully operated under real production conditions and provided immediate availability of production data within the ERP system.

The integration of real-time monitoring with ERP platforms significantly improves production traceability, operational efficiency, and data accuracy. The modular architecture of the system allows easy scalability and adaptation to different ERP platforms and production environments. The addition of analytical modeling and simulation-based validation strengthens the scientific contribution of the proposed system. The mathematical formulation successfully describes the relationship between processing delay, sampling frequency, database latency, and system throughput, while simulation results confirm system robustness and real-time operational stability.

The results confirm that the proposed system provides a robust, flexible, and efficient solution for integrating agricultural production processes with enterprise ERP systems. Future enhancements may include integration with IoT devices, cloud-based ERP platforms, and advanced data analytics to further improve automation and intelligent production management.

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