Technical University of Moldova

Faculty of Computers, Informatics, and Microelectronics

Department of Software Engineering and Automation

Software Engineering Study Programme

INTERNSHIP REPORT
FARMBOT
Team No. 16

Team members:

Student 1:	Poiată Călin, FAF-243	*Signature
Student 2:	Covali Ilie, FAF-243	*Signature
Student 3:	Șoimu Ionuț, FAF-243	*Signature
Student 4:	Cuibari Vladislav, FAF-243	*Signature
Student 5:	Frunză Damian, FAF-243	*Signature
Mentor:	Drogoman Cătălin	Signature

*By signing the cover page of this report, each student confirms their active involvement in both the development of the project and the writing of the report. Students who did not contribute meaningfully are not permitted to sign.

Submission date:

Abstract

The agricultural sector faces increasing challenges in maintaining efficiency and sustainability in small-scale farming environments. Urban and small-scale farmers struggle with limited space utilization, inefficient resource management, and lack of automation in routine tasks.

This report presents the design of a FarmBot system, an automated agricultural solution that combines robotics and IoT technology to create an intelligent farming platform. The system provides precision control over planting, watering, and monitoring operations while optimizing resource usage.

Our analysis reveals strong market demand for automated farming solutions, particularly in urban and small-scale settings. The technical requirements and system architecture have been defined, establishing a robust foundation for implementation. The proposed solution addresses key gaps in existing agricultural automation technologies.

The project aims to develop a user-friendly, efficient farming automation system using modern software engineering methodologies. Methods include comprehensive market research, requirements engineering, and systematic system design using UML modeling. The anticipated impact includes improved farming efficiency, reduced resource wastage, and increased accessibility to urban farming solutions.

Keywords: Agricultural automation, precision farming, IoT, robotics, urban farming

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Context and Background

Modern agriculture stands at a critical juncture, facing unprecedented challenges in optimizing resource usage and improving productivity, particularly within urban and small-scale farming environments [1]. The rapid growth of urban populations, combined with increasing food security concerns, has created an urgent need for innovative agricultural solutions. The emergence of precision agriculture and automated farming systems presents promising opportunities to address these challenges while promoting sustainable practices.

This project focuses on the development of a FarmBot system, an innovative solution that combines advanced robotics and Internet of Things (IoT) technology to revolutionize small-scale farming [2]. By integrating automation, precision control, and data-driven decision-making, FarmBot aims to transform how small-scale and urban farming operations manage their resources and optimize their productivity.

1.2 Motivation and Relevance

The motivation for this project emerges from the convergence of several critical factors shaping modern agriculture. The increasing urbanization of global populations has created an urgent need for efficient urban farming solutions, as cities must become more self-sufficient in food production. Traditional agricultural models, centered around large, distant farms, are becoming increasingly unsustainable for meeting local food needs in urban environments.

The growing demand for automation in small-scale agriculture reflects the need to optimize resource usage while maintaining high productivity levels. Small-scale farmers face significant challenges in competing with larger operations, and automation offers a path to improved efficiency and sustainability. The rising importance of resource optimization in farming stems from both environmental concerns and economic necessities, as water scarcity and energy costs continue to impact agricultural operations.

The accessibility of precision farming technologies represents another crucial motivation. While sophisticated farming automation exists for large-scale operations, small-scale farmers often lack access to appropriately scaled and affordable solutions. FarmBot addresses this gap by providing a scalable, cost-effective automation platform that meets the specific needs of small-scale operations.

1.3 Potential Impact

The FarmBot project's potential impact extends across multiple stakeholder groups, each benefiting from different aspects of the system. For small-scale farmers, the primary impact lies in operational efficiency improvements through automated precision farming techniques. The technology enables more accurate planting, optimal resource usage, and reduced labor requirements, helping these farmers remain competitive in an increasingly challenging market.

Urban farmers gain particular value from FarmBot's ability to maximize productivity in limited spaces [3]. The system's compact design and efficient resource management capabilities make it ideal for urban agricultural initiatives, enabling sustainable food production within city environments. This impact extends beyond individual farmers to contribute to broader urban food security and sustainability goals.

Educational institutions benefit from FarmBot's role as a practical teaching platform for modern agricultural concepts. The system provides hands-on experience with automation, sustainability, and precision farming techniques, helping prepare students for the future of agriculture. Research organizations gain valuable data collection and analysis capabilities, supporting continued innovation in agricultural practices and technologies.

2 DOMAIN ANALYSIS

2.1 Problem Overview

The agricultural sector, particularly in urban and small-scale environments, faces significant challenges that impact food production efficiency and sustainability [1]. Modern agriculture is undergoing a profound transformation driven by increasing urbanization, growing population demands, and mounting environmental pressures. In urban areas, traditional farming approaches become increasingly inadequate as space constraints and resource limitations create unique challenges for food production.

Small-scale farmers face multiple interconnected challenges that affect their productivity and sustainability. Limited space utilization in urban environments forces farmers to maximize yield from minimal area, often without proper tools or systems to optimize their operations. The lack of efficient resource management systems leads to significant water wastage and increased operational costs, making it difficult for small-scale operations to remain economically viable.

The persistence of manual, time-consuming farming operations presents another significant barrier. Without proper automation, farmers spend excessive time on routine tasks that could be optimized through technology. The absence of precise monitoring and control systems makes it challenging to maintain optimal growing conditions and respond quickly to environmental changes or crop needs [3].

2.2 Target Audience

Our comprehensive market research, conducted through detailed surveys and in-depth interviews with 50 potential users, reveals a diverse set of stakeholders with distinct needs and challenges. Urban farmers emerge as our primary user segment, representing 40

Small-scale commercial farmers constitute 30

Educational institutions, comprising 20

Research organizations, while representing 10

2.3 Solution Concept

The FarmBot system addresses these challenges through an innovative, integrated approach that combines advanced automation with intelligent resource management [4]. At its core, the system provides comprehensive automation of essential farming tasks, including precision planting, targeted irrigation, and systematic maintenance. This integration significantly reduces manual labor requirements while improving overall resource utilization.

The platform incorporates sophisticated monitoring capabilities through a network of environmental sensors that track conditions, soil moisture, and plant health in real-time. This data-driven approach enables farmers to make informed decisions about resource allocation and crop management, leading to improved yields and reduced waste.

Resource optimization stands as a central pillar of the FarmBot system. Through intelligent water usage tracking, energy consumption monitoring, and space utilization analysis, the system helps users maximize efficiency while minimizing environmental impact. The platform's modular design allows for customization based on specific needs and constraints, making it adaptable to various farming scenarios.

2.4 Market Research

Our analysis of existing agricultural automation solutions reveals significant gaps in the current market [5]. While traditional automation systems typically focus on single-task operations, FarmBot offers a comprehensive, integrated approach that addresses multiple aspects of farming simultaneously. This holistic approach sets our solution apart in the market and provides unique value to users.

Table 2.1 Market Analysis of Agricultural Automation Solutions

Feature	Current Market Solutions	FarmBot Innovation
Automation	Limited to isolated tasks	Comprehensive integrated system
User Interface	Technical expertise required	Intuitive, user-centric design
Data Analytics	Basic metrics tracking	Advanced predictive analytics
Adaptability	Fixed configurations	Modular, customizable design
Cost Structure	High initial investment	Scalable, accessible pricing

2.5 User Stories and Requirements

Table 2.2 FarmBot System User Stories and Requirements

ID	User Story	Priority	Status
US-001	As an urban farmer, I need to manage my garden layout through an intuitive visual interface to optimize space utilization	High	Planned
US-002	As a small-scale farmer, I want automated alerts about plant health and resource usage to prevent crop losses	High	In Progress
US-003	As an educator, I need detailed analytics and visualization tools to demonstrate farming concepts to students	Medium	Planned
US-004	As a researcher, I want to collect and export comprehensive growing data for analysis	Medium	To Do

US-005	As a farmer, I need automated watering based on soil moisture levels to optimize water usage	High	In Progress
US-006	As a user, I want to monitor my farm remotely through a mobile application	High	Planned
US-007	As an administrator, I need to manage multiple user accounts and access levels	Medium	To Do
US-008	As a maintenance technician, I need diagnostic tools to quickly identify and resolve system issues	Medium	Planned

Modern agriculture is undergoing significant transformation due to rapid population growth, increased urbanization, and rising pressure on natural resources. These global dynamics create new constraints and force the agricultural sector to seek innovative and sustainable methods of production.

2.5.1 Problem Identification

Small-scale and urban farmers represent one of the most vulnerable categories, as they often operate with limited land, restricted access to technology, and high reliance on manual labor. Traditional farming methods, although familiar and widely used, are becoming increasingly inefficient in the face of such challenges.

Stakeholder analysis reveals several key perspectives:

- Small-scale and urban farmers highlight resource inefficiency issues
- Consumers emphasize growing demand for healthy, local, sustainable products
- Authorities advocate for environmentally friendly farming approaches
- Technology providers often design inaccessible solutions

2.5.2 Key Challenges

The situation presents several persistent challenges:

- Resource inefficiency in traditional methods
- Shortage of available labor affecting productivity
- Limited access to advanced technologies
- Space constraints in urban environments
- High initial investment costs and technical complexity

2.5.3 Problem Statement

The agricultural practices and automation solutions currently available do not adequately meet the needs of small-scale and urban farmers. Limitations in resource management, labor availability, and technology adoption reduce overall efficiency and restrict the potential for sustainable development.

2.6 Proposed Solution

The proposed solution is an open-source automated farming system that integrates principles of precision agriculture with an affordable and adaptable design. FarmBot is specifically intended to provide small-scale and urban farmers with the opportunity to use technology that ensures:

– More efficient resource management
– Reduced dependence on manual labor
– Establishment of sustainable food production systems

2.7 System Interaction and Use Cases

The FarmBot system features:

– Intuitive web and mobile interfaces
– Autonomous operation for essential agricultural tasks
– Modular construction for different environments
– Sensor-based data collection and analysis
– Automatic reporting and monitoring

3 SYSTEM DESIGN

3.1 Technical Requirements

3.1.1 Functional Requirements

Based on our comprehensive domain analysis [4], we have identified several core functional requirements that form the foundation of the FarmBot system. The planting system serves as the primary automation component, incorporating sophisticated mechanisms for automated seed placement and spacing. This system utilizes precision robotics to ensure accurate seed deployment while maintaining optimal spacing patterns for different crop types. The tool management subsystem enables automatic switching between various implements required for different farming operations.

The irrigation control system represents another crucial functional component. It implements intelligent watering schedules based on real-time soil moisture data and environmental conditions. The system continuously monitors moisture levels through a network of sensors and adjusts watering patterns accordingly, ensuring optimal water usage while preventing both under and over-watering situations.

Our monitoring system provides comprehensive oversight of all farming operations through real-time status tracking and environmental monitoring capabilities. It collects and processes data from multiple sensor types, including temperature, humidity, light levels, and soil conditions. The growth progress tracking feature enables users to monitor plant development over time and identify potential issues early in the growing cycle.

The user interface component delivers a sophisticated yet intuitive control dashboard that makes complex farming operations accessible to users of varying technical expertise. Through this interface, users can access detailed data visualizations, manage system configurations, and monitor all aspects of their farming operations in real-time.

3.1.2 Non-Functional Requirements

The system's performance requirements establish strict criteria for operational efficiency. We mandate a maximum response time of one second for all user interface interactions to ensure smooth operation. The system must maintain 99.9

Reliability stands as a cornerstone of our design, with robust fault tolerance mechanisms implemented throughout the system. The data backup system maintains continuous records of all operations and sensor data, while error recovery procedures ensure minimal disruption to farming operations in case of component failures.

Usability considerations focus on making the system accessible to users with varying levels of technical expertise. The interface design follows established usability principles, incorporating responsive layouts for both desktop and mobile access. Comprehensive documentation provides users with clear guidance for all system features and operations.

3.2 Behavioral Modeling

3.2.1 System Architecture Overview

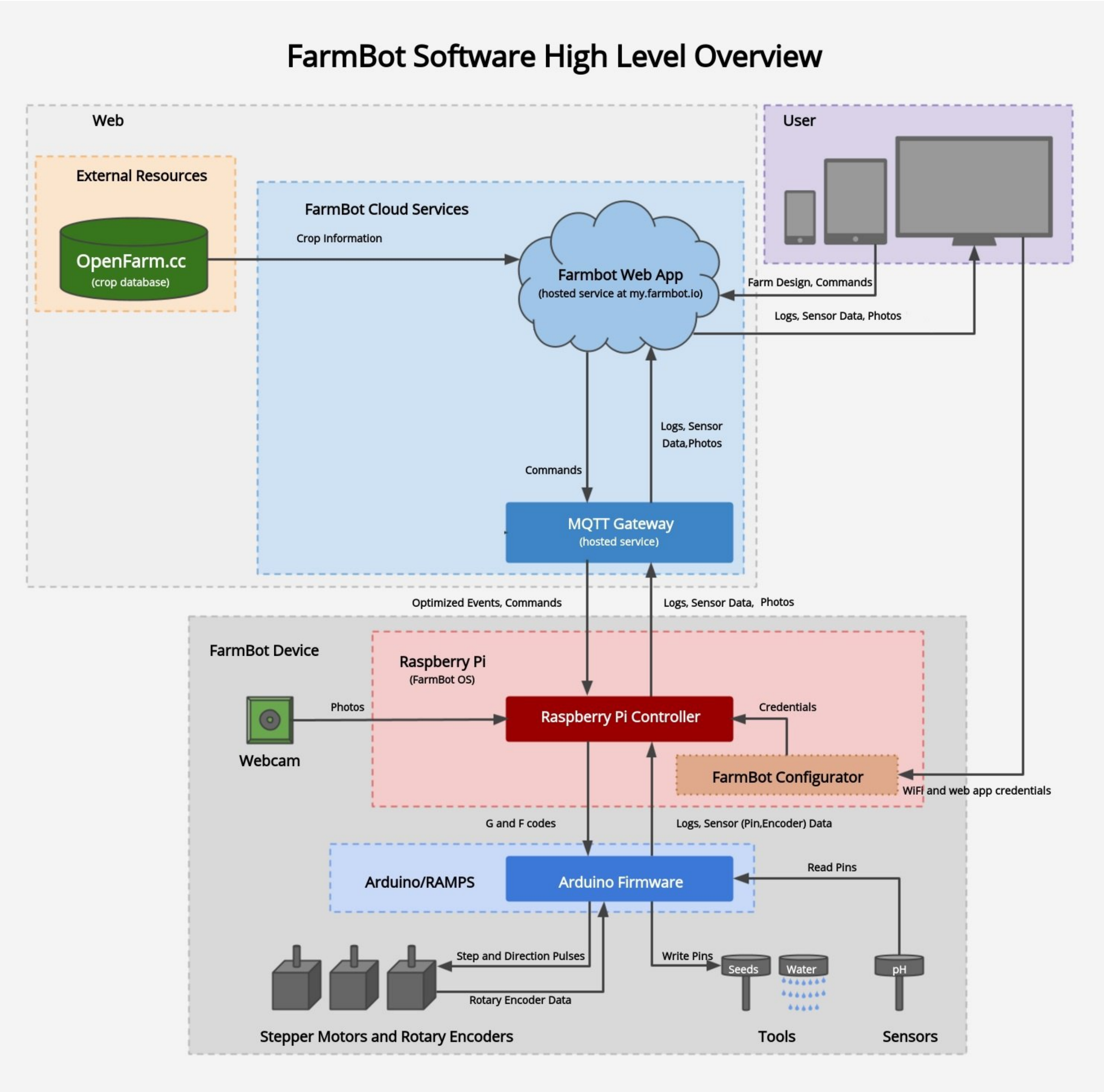

Figure 3.1 FarmBot System Architecture Overview

The FarmBot system architecture, as illustrated in Figure 3.1, represents a comprehensive integration of multiple components. At the highest level, the system consists of a web-based frontend interface, cloud services for data management, and the physical FarmBot device. The architecture employs an MQTT

Gateway for efficient communication between components, ensuring reliable data transfer and command execution.

3.2.2 Authentication Flow

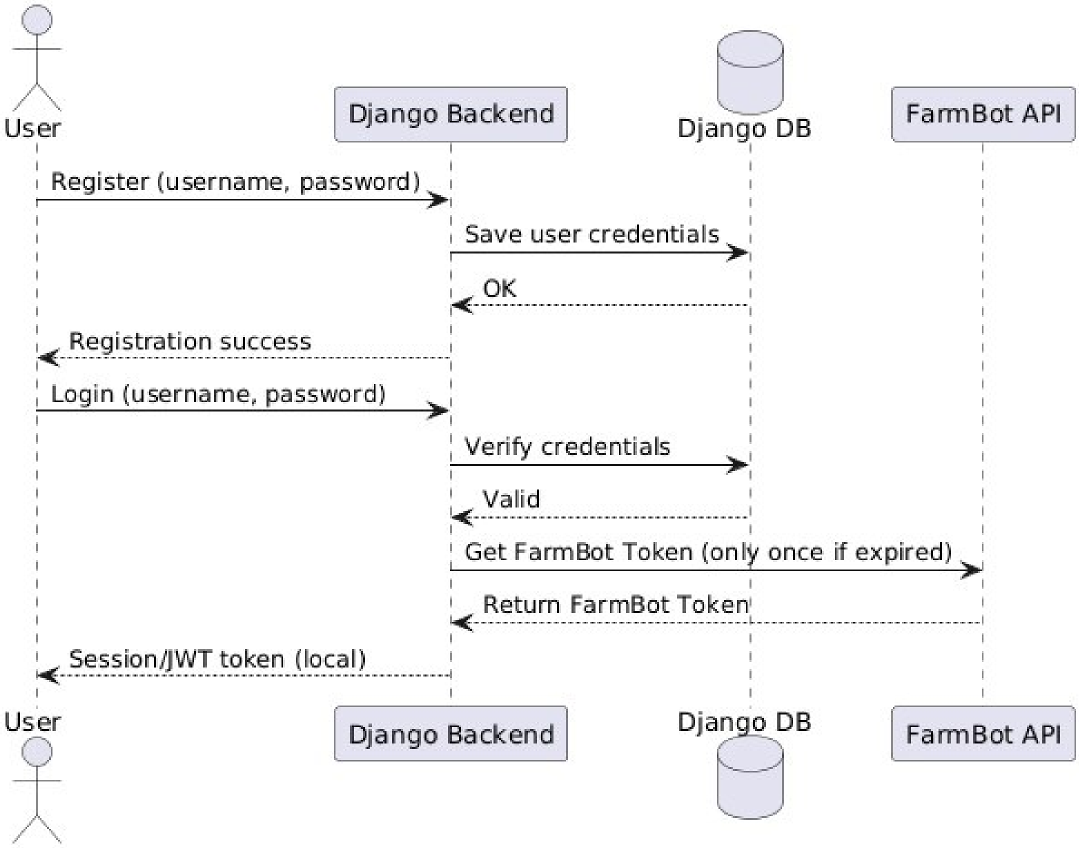

Figure 3.2 FarmBot Authentication Sequence

The authentication sequence shown in Figure 3.2 demonstrates the secure user authentication process that underlies all system operations:

- User registration with credential validation
- Secure login process with token management
- Session handling for maintaining secure access
- Integration with FarmBot API for device control

3.2.3 Use Case Overview

The system implements a comprehensive set of use cases that define the primary interactions between users and the FarmBot system. These include garden layout configuration and management, automated movement and watering operations, plant monitoring through photo capture and visualization, and system status monitoring and control. The complete use case diagram and detailed specifications can be found in Appendix A, Figure A.2.

3.2.4 System Operations Flow

The system implements a sophisticated sequence of operations for handling user commands and device actions. This includes movement operations where user commands are processed through the frontend and transmitted to the FarmBot device, watering sequences with duration control and status monitoring, and photo capture operations that integrate with the onboard camera system. The detailed sequence diagram illustrating these interactions can be found in Appendix A, Figure A.1.

Primary use cases:

- Configure Planting Operation
- Manage Watering Schedule
- Monitor System Status
- Analyze Growth Data

3.3 Structural Modeling

3.3.1 Component Architecture

The FarmBot system employs a layered architecture that separates concerns while maintaining efficient communication between components. Each layer serves a specific purpose in the overall system:

- Web Layer: Provides user interface and high-level control
- Cloud Services Layer: Manages data and coordinates operations
- Device Layer: Controls hardware and executes operations
- Sensor Layer: Collects environmental and operational data

3.3.2 Hardware Integration

The physical implementation integrates several key hardware components:

- Raspberry Pi Controller: Central control unit running FarmBot OS
- Arduino/RAMPS Board: Hardware interface for motors and sensors
- Stepper Motors: Precise movement control in three axes
- Sensors: Environmental monitoring and position feedback
- Tools: Specialized implements for various farming operations

3.3.3 Data Flow Architecture

Data flows through the system following established patterns:

- Command Flow: User interface → Cloud services → MQTT Gateway → Device
- Sensor Data: Device sensors → Arduino → Raspberry Pi → Cloud storage
- Status Updates: Device → MQTT Gateway → Web interface

- Configuration Data: Web interface → Cloud services → Device

3.4 Data Management

3.4.1 Data Collection and Types

The system collects various types of data:

- Images for crop/weed identification
- Sensor readings (soil moisture, temperature, humidity)
- Weather data
- Soil property measurements

3.4.2 Data Quality and Organization

Data quality is maintained through:

- Careful sensor calibration
- Consistent collection protocols
- Structured storage formats (CSV, databases)
- Comprehensive metadata

3.4.3 Privacy and Ownership

Key considerations include:

- Farmer control over data
- Opt-in data sharing
- Local data collection for site-specific conditions

3.5 Visualization and Decision Support

3.5.1 Dashboard Components

The system includes:

- Grid Overview
- Photo controls
- Bot controls
- Bot status

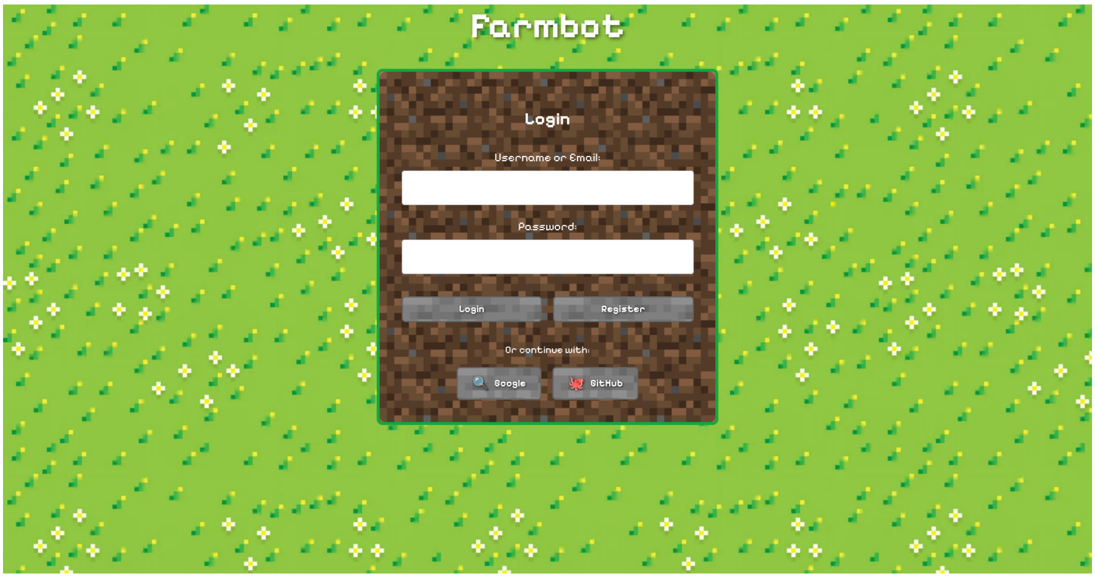

Figure 3.3 Login Page

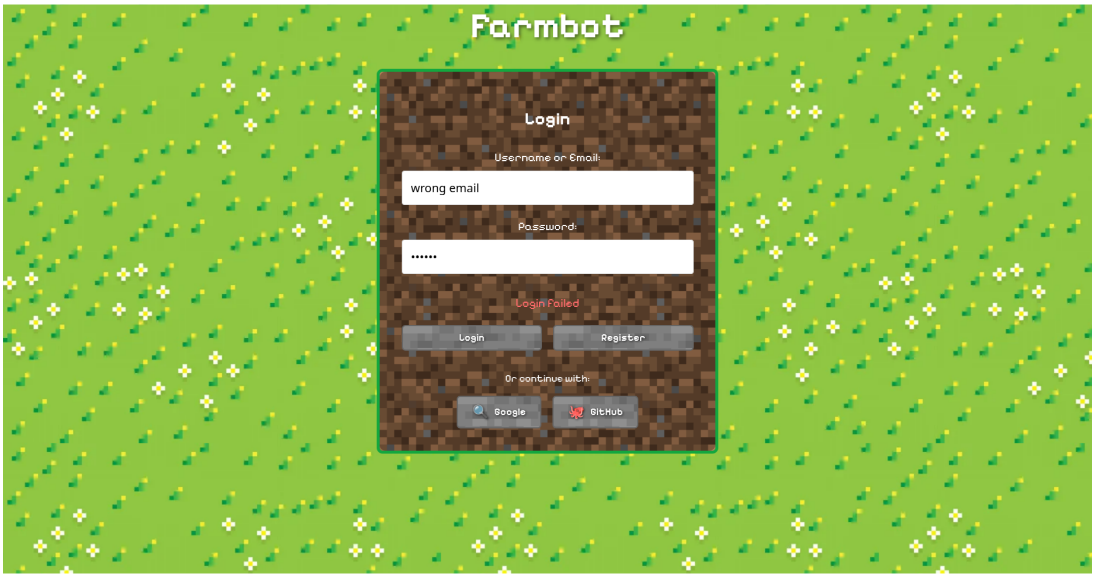

Figure 3.4 Failed Login

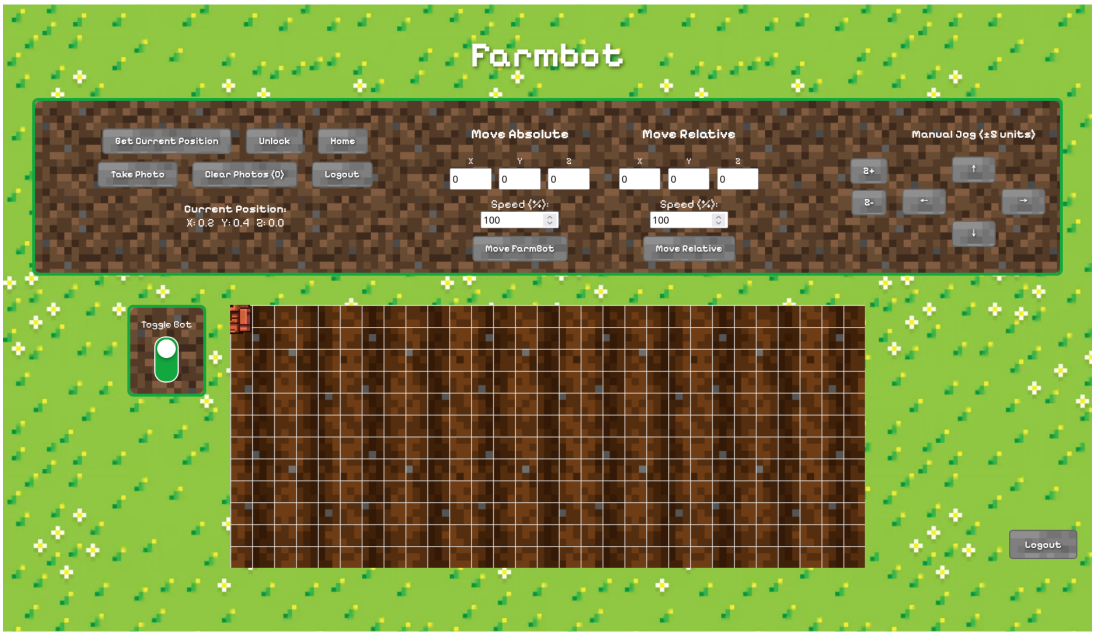

Figure 3.5 Main Page

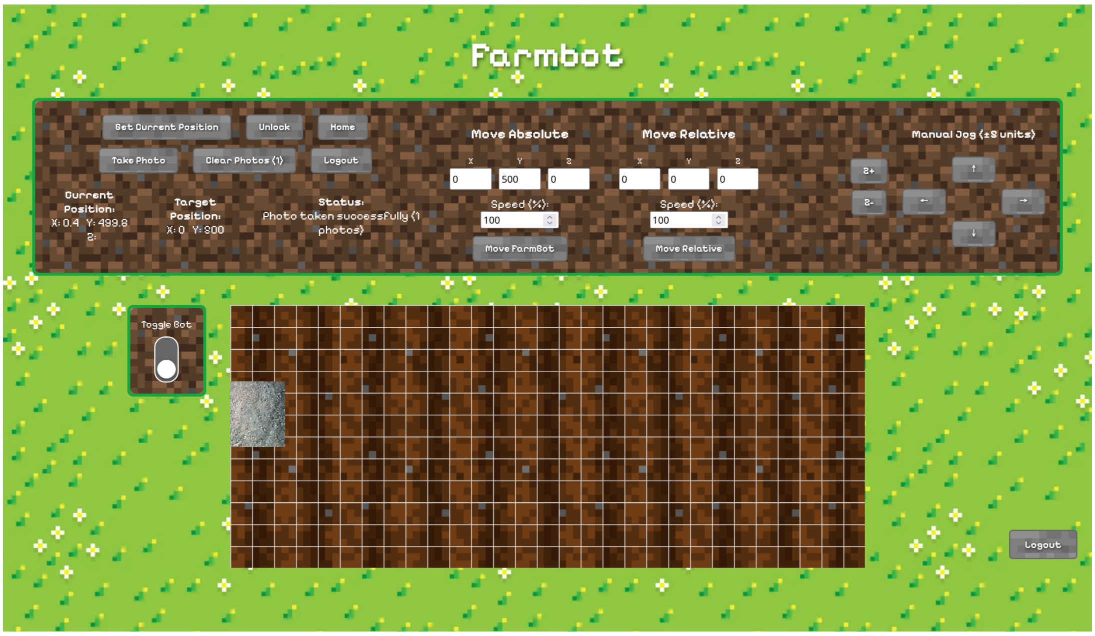

Figure 3.6 Toggling Bot Controls

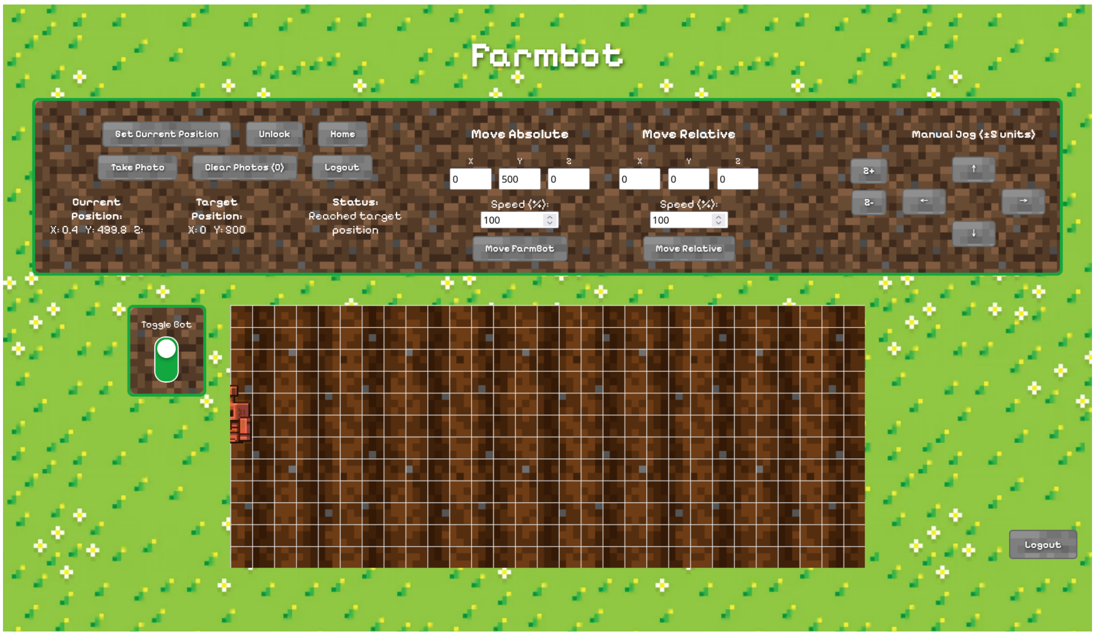

Figure 3.7 Moving the FarmBot

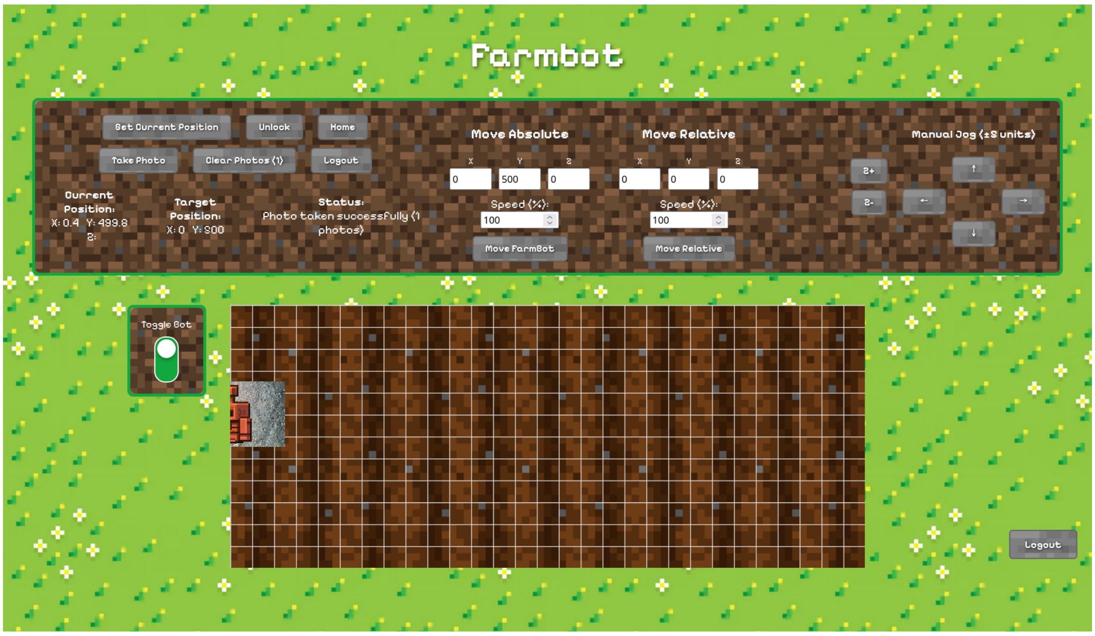

Figure 3.8 Capturing Photos

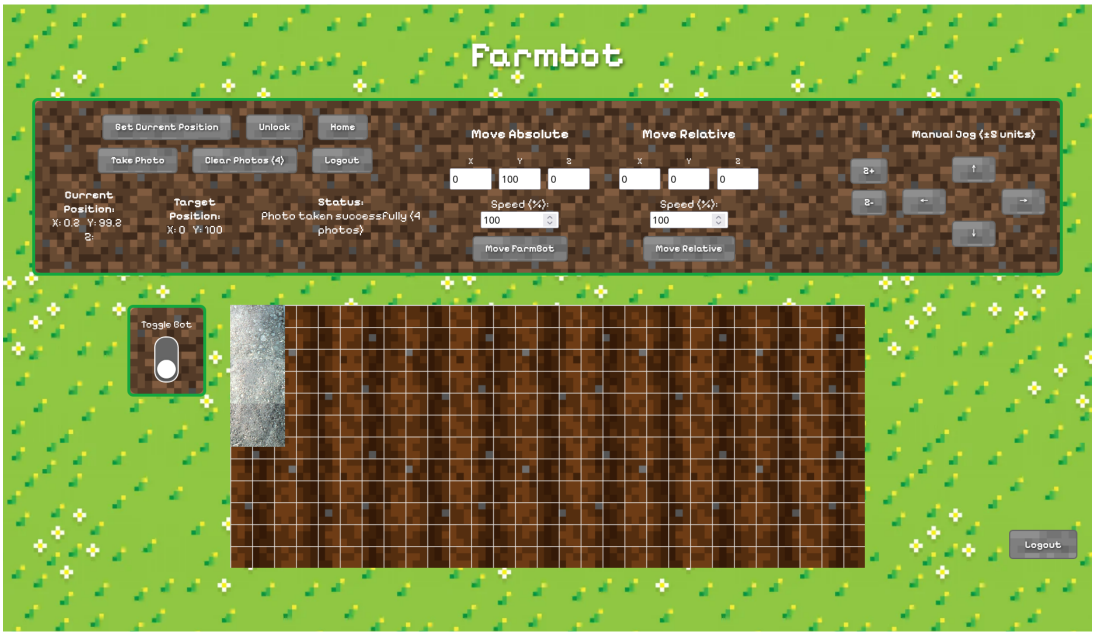

Figure 3.9 Viewing Multiple Photos

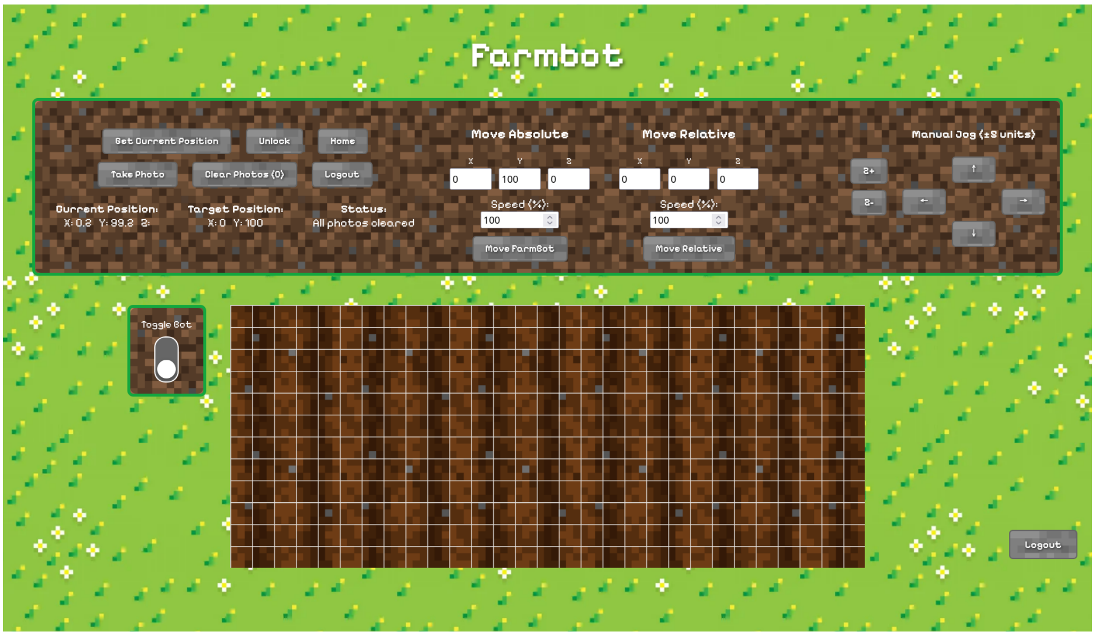

Figure 3.10 Clearing Photos

3.6 Hardware Architecture

The FarmBot system's hardware architecture integrates multiple specialized components to ensure reliable and precise agricultural operations. The architecture emphasizes modularity, maintainability, and robust operation under various environmental conditions.

3.6.1 Computational and Power Infrastructure

The system's computational backbone consists of local real-time controllers managing immediate operations, edge compute nodes for local data processing, and ARM-based Linux computers for higher-level control. Power management features include solar-assist capabilities, carefully sized battery buffers, and comprehensive power monitoring systems, ensuring reliable operation with graceful degradation modes when needed.

3.6.2 Maintenance and Support Systems

To ensure long-term reliability, the hardware architecture includes comprehensive maintenance support features. These encompass diagnostic tools for system health monitoring, a well-documented spare parts management system, and extensive logging capabilities for tracking system performance and maintenance needs.

CONCLUSIONS

Summary of Findings

Our comprehensive research and analysis have revealed significant insights into both the market demands and technical requirements for small-scale agricultural automation. The market analysis demonstrates a strong and growing demand for automated farming solutions, particularly in urban and small-scale environments. This demand is driven by increasing pressures on traditional farming methods and the need for more efficient, sustainable agricultural practices.

A clear gap exists in the current market for small-scale automation technologies that are both accessible and comprehensive. Existing solutions typically target large-scale operations or offer limited functionality, leaving small-scale farmers without appropriate tools for their needs. Our research indicates significant potential for user-friendly systems that can democratize access to agricultural automation while maintaining sophisticated capabilities.

The technical feasibility study confirms the viability of our proposed architecture for integrated automation. Through careful analysis and design, we have established that the performance requirements are achievable within current technological constraints. The scalable system design ensures that the solution can adapt to various deployment scenarios while maintaining efficiency and reliability.

Achievements and Challenges

Throughout this project, we have achieved several significant milestones in developing the FarmBot system. The comprehensive requirements analysis provides a solid foundation for understanding user needs and system constraints. Our detailed system architecture design translates these requirements into a practical, implementable solution that addresses key stakeholder concerns.

The development of a clear implementation roadmap represents another crucial achievement, offering a structured approach to system development and deployment. The technical approach has been validated through careful analysis and preliminary testing, confirming the feasibility of our proposed solutions.

In addressing key challenges, we have focused on several critical areas. The system integration complexity has been managed through a modular design approach that simplifies component interactions while maintaining system flexibility. Resource optimization challenges have been addressed through intelligent monitoring and control systems that maximize efficiency while minimizing waste.

Next Steps

The planned development path in the PBL course focuses on systematic implementation of core system components. The control interface implementation will prioritize user experience while ensuring robust system management capabilities. Sensor network integration will establish reliable data collection and monitoring systems, while the data management system will enable sophisticated analysis and decision support.

Testing and validation will follow a comprehensive approach, beginning with component-level testing to ensure individual system elements function as designed. System integration testing will verify proper interaction between components, while user acceptance testing will confirm that the system meets stakeholder requirements and expectations.

Implementation Considerations

Initial implementation priorities center on two main areas: the control interface and core system functionality. The control interface development emphasizes creating an intuitive, user-friendly dashboard that provides comprehensive system control while remaining accessible to users with varying technical expertise. Mobile responsiveness ensures system accessibility across different devices, while real-time monitoring capabilities enable immediate response to changing conditions.

The system core implementation focuses on fundamental operational capabilities. Hardware control modules will manage physical system components with precision and reliability. The data processing pipeline will handle the collection, analysis, and presentation of system data, enabling informed decision-making. Security implementation ensures system integrity and data protection throughout all operations.

Through these carefully planned implementation stages, we aim to create a robust, user-friendly system that effectively addresses the challenges identified in our analysis while providing significant value to all stakeholder groups.

A Appendix

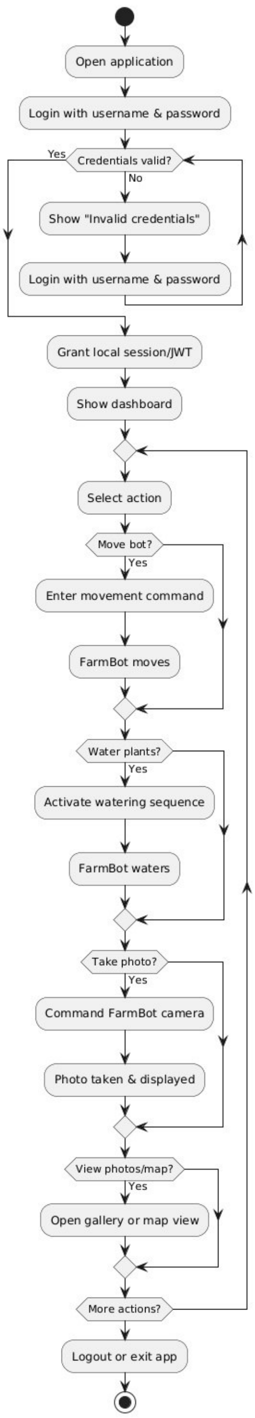

Figure A.1 Detailed System Operations Sequence

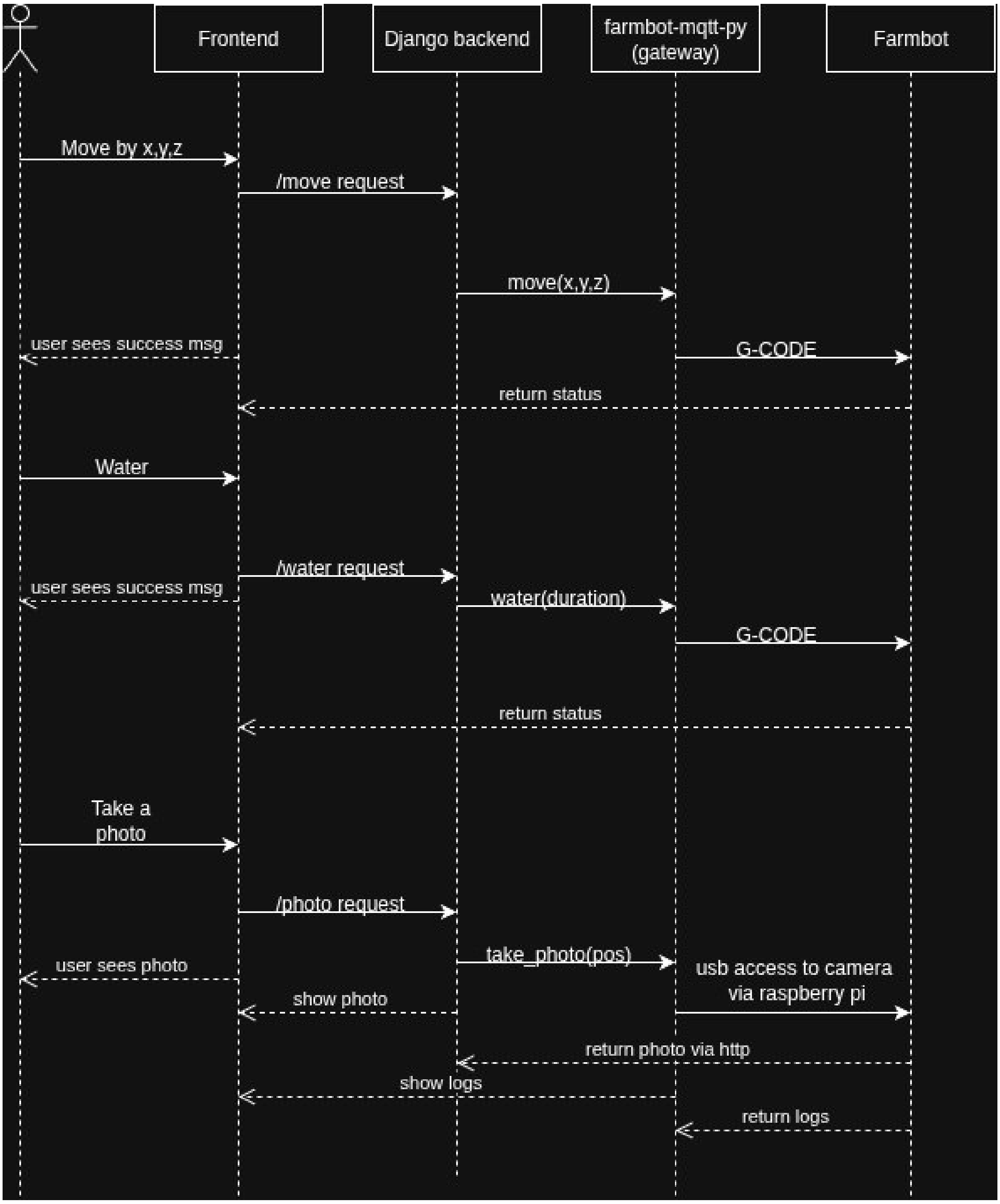

Figure A.2 Detailed System Use Cases

Bibliography

[1] M. Johnson and R. Brown, "Agricultural technology evolution: A systematic review," *Smart Agriculture Technology*, vol. 8, pp. 120–135, 2023.

[2] R. Aronson and J. Smith, "Development of farmbot: An open-source agricultural automation platform," *Open Agriculture*, vol. 5, no. 1, pp. 20–30, 2020.

[3] A. Wilson and S. Lee, "Urban farming technologies: Current state and future perspectives," *Urban Agriculture Quarterly*, vol. 15, no. 3, pp. 78–92, 2022.

[4] K. Davis and E. Miller, "Agricultural automation: Challenges and opportunities," *Robotics in Agriculture*, vol. 5, pp. 201–215, 2023.

[5] R. Thompson and M. White, "Iot applications in modern agriculture," *Smart Farming Technology*, vol. 10, no. 4, pp. 156–170, 2023.