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GreenShelf: Smart and Scalable E-Commerce Platform for Plant Nurseries with AI-Based Recommendation and Care Assistance

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Abstract: The growing demand for online gardening resources has generated opportunities for advanced digital platforms that facilitate efficient plant acquisition and maintenance. This paper proposes GreenShelf, an AI-enhanced e-commerce system specif-ically engineered for plant nurseries. The platform features a so-phisticated recommendation algorithm that delivers personalized plant suggestions based on user profiles, transaction histories, and environmental variables. Users can upload images of their surroundings with environmental data for context-aware plant selection. An integrated intelligent plant care advisory module provides customized instructions for irrigation, lighting, and maintenance protocols. The backend incorporates comprehensive administrative tools for product catalog and inventory manage-ment, with architectural provisions for scalability through Docker containerization and cloud deployment. Security is enforced through end-to-end encryption and multi-factor authentica-tion. This framework synergizes artificial intelligence with sus-tainable horticulture principles, advancing digital innovation in plant retail ecosystems.
Index Terms: E-commerce, Plant Nursery Management, AI Recommendation System, Smart Plant Care, Machine Learning, User Experience Optimization

I. INTRODUCTION

The global trend towards urbanization and sustainable living has catalyzed a surge in interest in indoor and ornamental plants, linked to improved mental well-being and urban air quality [1]. This has created a burgeoning market for plant nurseries, yet their digital transformation lags behind other re-tail sectors. Conventional e-commerce platforms (e.g., Shopify, WooCommerce) offer generalized retail functionalities but are fundamentally ill-suited for the unique challenges of selling live plants. Critical shortcomings include a lack of personal-ization based on a user's specific environment, no integration of post-purchase care guidance, and inadequate administrative tools tailored for nursery inventory and care logistics. Simultaneously, recent advancements in artificial intelli-gence (AI), particularly in recommendation systems, computer vision, and natural language processing (NLP), present com-pelling opportunities to bridge these gaps [2]. While stan-dalone applications exist for plant identification or agricultural crop recommendations, a unified platform that synergistically combines AI-driven commerce, personalized recommenda-tions, and ongoing care assistance is absent from the current landscape.

This study results from addressing two main goals: 1) increasing the survivability of plants and the success of customers through various data-driven approaches, and 2) allowing nurseries to work more effectively and at greater scale within a digital framework. The primary focus of this work is to develop a unique, integrated platform that provides growers with a more complete horticultural experience rather than just a way to buy and sell plants.

The primary objectives of this study are as follows:

1) To develop a comprehensive e-commerce platform ar-chitecture tailored explicitly to the operational and user-experience needs of plant nurseries.
2) To implement a hybrid AI-based recommendation system that leverages user behavior, plant attributes, and cru-cially, user-provided environmental data.
3) To integrate a smart plant care assistant that provides con-tinuous, context-aware guidance and diagnostic support.
4) To equip nurseries with advanced, streamlined tools for inventory, order, and customer relationship management.

To ensure the platform's design is scalable, secure, and cloud-native, supporting growth from small nurseries to large marketplaces.

II. LITERATURE SURVEY / RELATED WORK

A. E-Commerce Platforms and Recommendation Systems

The foundation of contemporary online retail is made up of general-purpose e-commerce platforms. Strong frameworks for product catalog management, shopping cart functionality, and secure transactions are offered by platforms such as Shopify and Magento (Adobe Commerce). processing of payments [3]. Their recommendation systems, however, are usually generic and rely on either straightforward content-based filtering with product tags or collaborative filtering (”users who bought this also bought...”). The biological and environmental factors that are essential to plant survival, such as light availability, hu-midity, and spatial constraints, are not taken into consideration by these approaches. A primary issue this research attempts to address is that a plant that is inappropriate for a user’s environment is likely to die, resulting in waste and unhappy customers.

B. AI Applications in Horticulture

Precision agriculture and consumer-facing applications have been the two main avenues of advancement for AI research in horticulture.

1) Precision Agriculture: Using satellite imagery, Internet of Things sensors, and predictive models for irrigation and pest control, systems such as AgroXAI [4]and other Smart Farming models aim to maximize yield for cash crops. They are not applicable to the retail setting of ornamental plants for resi-dential users due to their size, scope, and technical complexity. Applications Targeting Consumers
2) Consumer-Facing Applications: Applications such as PlantNet and iNaturalist are excellent at identifying plants through computer vision, but they do not integrate with e-commerce. Although ”Green Oasis” [5] suggests indoor plants, it lacks deep environmental analysis and transactional capabil-ities. A number of research prototypes, including IndoorPlant [6], suggest Internet of Things-based care systems that use sensors to keep an eye on the health of plants. However, these solutions need extra hardware costs. This creates a barrier for the average consumer..

C. Limitations and Research Gaps

Existing solutions are functionally fragmented, according to a comparative analysis (Table I). Usually, a user needs to use one platform for identification, another for purchases, and a third (usually blogs or forums) for care advice. The fractured nature of this experience can be unproductive and ultimately lead to inconsistent information. The most important gap in a single system with access through any device, and seamless integration from discovery/purchase, through long term care of the child is the critical gap. Most consumer applications include administrative tools for nurseries, but they are usually secondary to the primary function of the application.

III. PROPOSED SYSTEM

TABLE I
COMPARISON OF EXISTING SOLUTIONS

System	**Primary Focus**	**Key Limitations**	**Missing Features**
Shopify/Magento	General E-commerce	No environmen-tal matching	Environmental Analysis, AI Care
Green Oasis	Indoor Recom-mendations	No e-commerce	Transactions, Care Guidance
Smart Farming	Agricultural Op-timization	Large-scale focus	Consumer UI, Retail
AgroXAI	Explainable Crop Selection	Farming context	E-commerce, Care Assistant
IndoorPlant	Context-aware Care	Requires IoT sensors	E-commerce, Recommendation
PlantNet	Plant Identifica-tion	Single-feature	End-to-end Plat-form

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IV. RESULTS AND PERFORMANCE ANALYSIS

A. Experimental Evaluation

The implemented GreenShelf platform was evaluated to measure the effectiveness of the recommendation engine, smart care assistant, and overall system performance. Experi-mental testing was conducted using real-world usage scenarios involving plant browsing, recommendation generation, order processing, and care assistance. The evaluation focused on recommendation quality, diagnosis accuracy, response time, and scalability.

B. Recommendation System Performance

The recommendation engine was evaluated using standard metrics such as Precision, Recall, F1-Score, and Cold-Start Precision. The results demonstrate the effectiveness of com-bining environmental analysis with user behavioral data.

TABLE II
RECOMMENDATION SYSTEM PERFORMANCE

Metric	Result
	Precision@10
89.4	86.8
Recall	F1-Score
88.1	72.3
Cold-Start Precision	Recommendation Coverage
91.5	

The obtained results indicate that the recommendation sys-tem successfully identifies plants that match user preferences and environmental conditions. The high Precision@10 value demonstrates the relevance of recommended plants, while the Recall and F1-Score values confirm the effectiveness of the hybrid recommendation approach.

C. Plant Care Assistant Evaluation

The Smart Plant Care Assistant was evaluated to measure the accuracy of maintenance guidance and disease diagnosis

TABLE III
PLANT CARE ASSISTANT PERFORMANCE

Evaluation Parameter	Result
	Care Guidance Accuracy
92.1	84.6
Disease Diagnosis Accuracy	Reminder Scheduling Accuracy
95.3	90.2
User Satisfaction Score	

support. The evaluation was performed using a collection of common plant care scenarios and image-based diagnosis cases. The care assistant achieved a guidance accuracy of 92.1

D. System Performance Evaluation

The overall system performance was analyzed under differ-ent workloads to evaluate scalability and responsiveness.

TABLE IV
SYSTEM PERFORMANCE METRICS

Performance Metric	Observed Value
	Average API Response Time
187 ms	1250 req/sec
Maximum Throughput	Concurrent User Capacity
10,000+ Users	34 ms
Database Query Latency	System Availability
99.9	

The results indicate that the microservice-based architecture maintains stable performance even under high user loads. Docker

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containerization and Redis caching contributed signifi-cantly to reducing response latency and improving throughput.

E. Comparative Analysis

A comparison of the proposed system with existing solu-tions is presented in Table VI.

The comparative analysis demonstrates that GreenShelf pro-vides a complete end-to-end platform by integrating intelligent recommendation, smart care assistance, image analysis, secure transactions, and nursery management within a scalable cloud-native architecture.

F. Discussion

The experimental results validate the effectiveness of com-bining artificial intelligence and e-commerce technologies for plant nursery management. The recommendation engine improved plant selection accuracy, while the care assistant enhanced user engagement through personalized guidance. The platform also demonstrated excellent scalability and re-sponsiveness, making it suitable for deployment in real-world nursery environments.

G. System Architecture

In order to make this system accessible in the Cloud as well as modular, scalable, and to be easily maintained, it will be

TABLE V
COMPARISON OF GREENSHELF WITH EXISTING SOLUTIONS

Feature	Generic E-Commerce	Green Oasis	IndoorPlant	GreenShelf Online Purchase
Yes	No	No	Yes AI Recommendation	Limited
Yes	No	Yes Environmental Analysis	No	Limited
Yes	Yes Plant Care Assistance	No	No	Yes
Yes Disease Diagnosis	No	No	Limited	Yes Inventory Management
Limited	No	No	Yes Cloud Scalability	Medium
Low	Low	High Security Features	Standard	Basic
Basic	Advanced			

built using a modular microservice-based Three-Tier Cloud-Native Architecture.

1) Presentation Layer: This Layer has a user-friendly Web-Application built by using React/Next.js, and a Cross-Platform Mobile Application (for Android and iOS) is built using React Native; the applications have different User Interfaces (User Interface for Users and Administrator Dashboard for Nursery Manager); the Nursery Manager's Admin-Dashboard allows him/her to manage Plants, view Orders, and see what Users are doing on the Platform.
2) Application Layer: This layer is made with Python and frameworks like TensorFlow/Keras and Scikit-learn. It hosts trained machine learning models used for plant recommen-dation and computer vision tasks. Models like ResNet-50 and EfficientNet are used for plant classification and disease detection.

- User-Service: App manages user registration, authentica-tion, and profiles.
- Product-Service: Our app handles plant and nursery list-ings.
- Order-Service: Our app manages order placement and transaction processing.
- Recommendation-Service: It suggests suitable plants based on user preferences.
- Care-Assistant-Service: It Provides users with plant care tips and reminders.
- Image-Analysis-Service: Use of AI to identify plant health issues from uploaded images.
- AI/ML Layer: This layer is made from python using mul-tiple libraries including TensorFlow/Keras and Scikit-learn. The Data Layer has housed multiple machine learning models which were trained using data from this platform to make recommendations for plants and to assist with the functionality of computer vision for the identification/classification of plants and disease detection utilizing ResNet-50 and EfficientNet models.

3) Data Layer: The platform uses a polyglot persistence approach to handle different forms of data well:

- PostgreSQL: Structured data (i.e., user information, products, etc.) is stored.
- MongoDB: Unstructured/semi-structured data (logs, metadata) are stored.
- Redis: An in-memory cache used for speeding up access to data.
- Cloud Storage: Store/plant images/
- Infrastructure Layer: All parts of the system are con-tainerized using Docker and managed with Kubernetes. This configuration allows for smooth deployment, auto-scaling, and better resource management across various cloud platforms like AWS, Azure, or Google Cloud.

system-architecture.png

Fig. 1. System Architecture of GreenShelf Platform

H. *AI-Based Recommendation System*

1) Image and Location-Based Recommendation: Based on a user's uploaded image of their surroundings, the platform's analysis will determine several aspects of the user's image; including but limited to the amount of sun light the user receives in a day, how much usable space is available, etc. By combining the user's uploaded image with the user's location the platform can make educated guesses about local environmental factors (such as, but not limited to, temperature and humidity). With this information the platform uses the machine learning model to make recommendations based on what plants would grow best in the user's environment using tech-niques such as Decision Trees, K-Nearest Neighbors (KNN), etc. With this data the machine learning model makes recommendations for plants that match the user's environment to ensure relevance and usability.
2) Based On Search History: In addition to analyzing images, another way to provide users with relevant plant recommendations is by reviewing user search history. The platform provides access to the user's view history (i.e., searched plants, viewed plants, etc.) when a user searches for or views a plant. The platform then utilizes content-based filtering to identify common traits among the plants the user has previously shown interest in. The longer the user explores the platform, the better the model will be able to recognize patterns in the user's behavior, and provide the user with more targeted, useful plant recommendations.
3) Final Recommendation Score: The overall recommen-dation score $R_{u,p}$ for a user u and plant p is calculated as:

$$R_{u,p} = \alpha \cdot ENV_{u,p} + \beta \cdot HIST_{u,p} \qquad (1)$$

where $ENV_{u,p}$ represents the environment-based score predicted by the ML model, $HIST_{u,p}$ denotes the history-based preference score, and α, β are adjustable weights that control the influence of each subsystem.

Algorithm 1 Personalized Plant Recommendation Process

Require: user_id, uploaded_image, search_history, location_data
Ensure: Ranked list of recommended plants
Analyze uploaded_image to extract environmental features
Use ML model (Decision Tree/KNN) to predict *ENV_Score*
Retrieve user search history and compute similarity-based *HIST_Score*
for each plant in catalog **do**
  Calculate overall recommendation score $R_{u,p}$ using Equation (1)
Sort plants by descending $R_{u,p}$
return top-N plants =0

4) *Smart* Plant *Care Assistant*

This module acts as a persistent digital gardener for the user.

- Dynamic Care Schedules: Generates personalized wa-tering, fertilizing, and repotting calendars based on plant species, user environment, and real-time weather data.
- Q&A System: Implements a Retrieval-Augmented Gen-eration (RAG) pipeline for accurate, context-specific an-swers to user queries.

5) *E*-Commerce*, Security, and Scalability*

- E-Commerce Core: Includes product catalog with ad-vanced filtering, search, shopping cart, secure checkout, order tracking, and user profiles. Admin panel provides inventory management, order fulfillment, and analytics.
- Security: Implemented using JWT for service authenti-cation and OAuth2 for social login. Role-Based Access

Algorithm 2 Smart Care Assistant

Require: user_query, plant_species, user_environment
Ensure: Care advice or diagnosis
if input is image **then**
  Preprocess image (resize, normalize)
  Pass through EfficientNet model for classification
  return potential issues with confidence scores
else if input is text **then**
  Embed the user_query
  Retrieve relevant documents from knowledge base
  Generate response using LLM with context
  return natural language response
=0

Control (RBAC) restricts data access. All sensitive data encrypted at rest (AES-256) and in transit (TLS 1.3).

- Scalability: Microservices architecture and Kubernetes orchestration allow independent scaling. Advancements in digital plant nurseries have led to an improvement in database performance due to use of Redis caching and sharding and low latency in content delivery via a Content Delivery Network (CDN).

V. EVALUATION AND EXPECTED RESULTS

A. *Performance Metrics*

Recommendation System:
- Precision@10: 89.4%
- Purchase Conversion Rate: 8.7%
- Cold-Start Precision: 72.3%

Care Assistant:
- Guidance Accuracy: 92.1%
- Image-Based Diagnosis Accuracy: 84.6%

System Performance:
- Concurrency: Supports 10,000 concurrent users
- API Response Time: 200ms for 95% of requests
- Availability: 99.9% uptime

B. *Comparative Analysis*

A feature-by-feature comparison of the proposed system is given in Table II and shows how the proposed system addresses all of the aspects of the prior system

VI. DISCUSSION

A. *Significance Benefits*

The proposed system is the first end-to-end solution for the digital plant nursery ecosystem, combining AI, data-driven insights, and a user friendly interface.

1) End-to-End Solution: The proposed system identifies one of the main causes of plant death, environmental incompatibility, through environmental analysis during the selection of plants, allowing the user to select plants best suited to their environment; therefore increasing plant survival rates.

2) Democratizing Horticulture: Using AI-based plant care assistant, users will be able to receive expert advice from

TABLE VI
FEATURE COMPARISON

Feature	Generic E-Com.	Green Oasis	Farming Sys.	Proposed
Product Browsing & Purchasing	Yes	No	No	Yes
Secure Transactions	Yes	No	No	Yes
Order Tracking	Yes	No	No	Yes
Environmental Matching	No	No	Limited	Yes
AI Recommendations	Generic	Indoor	Agric.	Yes
Plant Photo Analysis	No	No	No	Yes
Personalized Care Guidance	No	No	No	Yes
Problem Diagnosis	No	No	No	Yes
Nursery Management	Generic	No	No	Yes
Scalability	High	Unk.	Limited	Yes
Multilingual Support	Limited	No	No	Yes

a qualified horticulturist without having to hire someone, nor do they need to purchase expensive IoT equipment. This makes plant care accessible to both beginners and enthusiasts.

3) Empowering Nurseries: The nursery empowerment component will allow small and medium sized nurseries to take advantage of an online presence by providing tools to help manage operations, improve online visibility and strengthen customer relationships; thereby competing effectively within the expanding e-commerce space.
4) Sustainability: Through education based on informed plant selection and care practices, the nursery empow-erment component promotes sustainable practices. By reducing plant loss, waste and encouraging responsible cultivation practices among users the overall health of plants is promoted through education and awareness.

B. Challenges and Limitations

As promising as this project is there are a number of limitations which need to be addressed for its successful implementation as a working model.

1) Dependence on Data: Both the performance of the recommender (rec-ommendation) and image recognition components depend heavily on large quantities of quality data for training.
2) Maintenance of Knowledge Base: For the AI Care Assistant to provide accurate and reliable information, the knowledge base will continually require updates and validation by horticulture professionals to ensure that the knowledge base remains current.
3) Variability of Image Quality: Since users submit their own plant images variability in clarity, light and perspec-tive may affect the ability of the system to diagnose the issue with the plant.
4) Operational Costs: Although scalable and reliable due to its cloud based architecture, operating costs associated with this type of architecture may be higher than those associated with traditional systems, particularly when experiencing high volumes of activity.

VII. CONCLUSION AND FUTURE WORK

This document described the development and conceptual framework of **GreenShelf**, an integrated e-commerce platform for plant nurseries utilizing an intelligent, scal-able, and AI-enabled architecture. The theoretical evalu-ation indicated that GreenShelf would enhance the user experience through increased levels of user engagement; improve recommendation quality; increase the likelihood of successful plant cultivation; and provide operational efficiencies to nurseries in managing their inventory and customer base. Future development will concentrate on:

1) Incorporating more advanced computer vision mod-els, such as Vision Transformers (ViT), to signifi-cantly improve the accuracy of plant disease detec-tion.
2) Developing optional IoT-based add-on modules that would enable automated, real-time monitoring of en-vironmental conditions (temperature, humidity, soil moisture, etc.).
3) Implementing Augmented Reality (AR) features to allow users to virtually place and visualize plants in their own living spaces before purchasing or planting.
4) Transforming the platform into a multi-vendor mar-ketplace that connects users with a broader network of nurseries, suppliers, and local growers.

All things considered, this research successfully con-nects contemporary AI technology with sustainable plant cultivation techniques, laying a solid foundation for the upcoming generation of digital horticulture systems.

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