Mobile Web Application for Durian Orchard Management and Geospatial Data Visualization Using Deep Learning

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Abstract **– Durian, a globally popular fruit, is primarily exported by Thailand, making it the foremost contributor to the world market. Nevertheless, there remains a notable absence of a comprehensive platform or application catering to both consumer tourists and businesses seeking domestic purchases. Prior research has highlighted several shortcomings, notably the inability of existing applications to provide location-based search functionality or automatically identify durian plantation plots from digital photographs. Consequently, this study proposes the development of a mobile web application aimed at managing, processing, and visualizing geospatial data pertaining to orchards and durian plantations. Through the integration of mobile technology, geospatial technology, and machine learning, the research endeavours to address these deficiencies. The findings indicate promising results, particularly in the accurate classification of durian plantations using four machine learning algorithms: convolutional neural network (CNN), support vector machine (SVM), random forest, and k-nearest neighbor (KNN). Among these algorithms, CNN exhibited the highest accuracy, achieving a value of 95%, with precision, recall, and f-measure values of 95.55%, 94.44%, and 94.97%, respectively.**

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1. Introduction

Durian, often referred to as the "king of fruits," holds a prominent position in the world market, with Thailand reigning as the foremost exporter globally [1], [2], [3]. To sustain the Thai durian consumer base over the long term and explore new agricultural market avenues, strategic planning is imperative. This planning encompasses not only cultivation and maintenance practices but also the establishment of accessible channels for consumers and businesses, both domestic and international, to access comprehensive information on durian production from farmers [4]. Current communication channels between consumers and farmers include traditional methods such as telephone communication and social media engagement, alongside direct visits to durian plantations [4]. However, reliance on these methods presents limitations, including uneven distribution of information across regions, necessitating travel to locate durian orchards, and the absence of a centralized platform for managing and disseminating durian plantation data [5], [6]. Advancements in various technologies, notably mobile technology, geographic information systems (GIS), global positioning system (GPS), digital image processing, and artificial intelligence, offer avenues for addressing these limitations [7]. Integration of these technologies holds the potential to develop a comprehensive platform or application for efficient management, processing, and visualization of durian plantation data, catering to the needs of both producers and consumers.

A comprehensive examination of relevant literature and research elucidates the prevalent utilization of digital image processing in tandem with machine learning methodologies for durian species classification [7], [8], [9].

Moreover, endeavors to diagnose diseases in durian trees leverage image processing techniques applied to durian leaves [10], [11], alongside efforts to discern the ripeness of durian fruits [12], [13]. Notably, these applications have demonstrated commendable accuracy in classification, as evidenced by high accuracy values. The integration of mobile technology has facilitated the development of applications designed to furnish information regarding distinct durian cultivars through augmented reality (AR) [14], as well as initiatives aimed at monitoring invasive species within durian plantations via image recognition [15]. Furthermore, geospatial technology, encompassing GIS, has been instrumental in durian plantation management, spanning tasks such as tree enumeration [16], yield trend analysis [17], and the creation of data management applications to delineate the geographical distribution of durian orchards [18].

Despite advancements, notable limitations persist, including challenges in retrieving GPS coordinates for durian plantation plots, thereby hindering precise localization. Moreover, extant applications lack automated verification mechanisms to ascertain the authenticity of reported plantation locations, necessitating on-site inspections. Furthermore, the inability to search for durian plantations based on users' current GPS coordinates underscores existing deficiencies. Consequently, this study proposes the development of a mobile web application platform harnessing mobile technology, GIS, and machine learning to effectively manage, process, and present durian plantation data. Such an endeavor seeks to furnish consumers and businesses with a robust platform or application for accessing pertinent durian plantation information, thereby facilitating informed decision-making regarding durian procurement for consumption and commercial purposes. Additionally, provision of platforms or channels for durian farmer groups to disseminate information pertaining to orchard locations, sales status, and contact details serves to enhance consumer and business awareness, thereby mitigating the monopolistic influence of intermediaries and positively impacting product pricing and farmer income levels.

2. Related Works

A comprehensive examination of literature and research pertaining to the management of durian plantation data utilizing mobile technology, image processing, machine learning, and GIS reveals three primary domains: the integration of image processing and machine learning in durian orchard management; the utilization of GIS or geospatial technology in durian orchard management; and the development of mobile applications for durian orchard management.

Notably, research endeavors applying image processing and machine learning techniques to durian orchard management have explored various facets. For instance, classification of durian fruit ripeness levels employing machine learning algorithms such as random forest (RF), support vector machine (SVM), and k-nearest neighbors (KNN) has been investigated, with SVM demonstrating the highest accuracy of 88.5%, followed by RF with an accuracy of 84.6%. Additionally, methodologies have been proposed for the assessment of durian fruit maturity utilizing Short Wavelength Near-Infrared (SWNIR) and Long Wavelength Near-Infrared (LWNIR) data, coupled with supervised machine learning algorithms like Linear Discriminant Analysis (LDA), SVM, and KNN, where LDA yielded the most accurate results with 97.28% and 100% accuracy for LWNIR and SWNIR, respectively. Furthermore, image processing techniques, particularly deep learning, have been applied for durian species classification, achieving high accuracy rates of 98.96%. Additionally, methods employing Gray Level Co-Occurrence Metrics (GLCM) in conjunction with machine learning algorithms like KNN have demonstrated classification accuracies of 93%. Mobile applications have also been developed for durian species detection, utilizing deep learning approaches such as convolutional neural networks (CNN), achieving training accuracy rates of 86%, although validation and testing data accuracy rates were slightly lower. Moreover, image processing techniques have been employed for durian disease classification, with a system utilizing the ResNet-9 machine learning algorithm achieving 99.1% accuracy, further validated by a mobile application employing the MobileNet algorithm, yielding disease classification accuracy of 90%. These findings underscore the potential of integrating advanced technologies in the management and maintenance of durian orchards, offering robust tools for farmers and stakeholders in the durian industry.

Regarding research employing GIS or geospatial technology, an investigation featured a classification methodology aimed at enumerating durian trees within plantations utilizing unmanned aerial vehicle (UAV) imagery, accompanied by the analysis of diverse indices such as vegetation indices (VIS), visible-band difference vegetation index (VDVI), visible atmospherically resistant index (VARI), normalized green-red difference index (NGRDI), red-green ratio index (RGRI), modified green-red difference index (MGRVI), excess green index (ExG), color index of vegetation (CIVE), and vegetation (VEG). However, the evaluation of classification accuracy remains unreported [16].

Furthermore, an investigation delved into analyzing the durian yield trend from 2000 to 2007 utilizing GIS for strategic planning and management of durian cultivation areas and production in Malaysia. The findings delineated a spatial distribution map of durian cultivation areas and production, facilitating an analysis of aggregate durian production across distinct temporal and spatial domains. Such insights enable the identification and evaluation of factors influencing yields within each region [17]. Additionally, GIS and remote sensing methodologies were employed to manage durian orchards, leveraging UAV imagery for durian plant classification and geotagging, alongside height and slope analysis to optimize incision placement for water management or irrigation, thereby influencing durian growth and production quantity [19]. Moreover, methodologies for assessing the health of durian within planting plots were elucidated through the analysis of various index values, including vegetation index (VI), normalized difference vegetation index (NDVI), normalized difference red-edge (NDRE), chlorophyll index-green (CIG), and chlorophyll index-red-edge (CIRE). The study reported a classification accuracy of 92% [20].

The review of literature and research concerning the development of applications and mobile applications reveals several pertinent findings. Firstly, mobile applications have been developed to disseminate durian-related information encompassing various aspects such as fruit and pulp characteristics of different durian varieties, as well as guidelines for preparing and maintaining durian orchards using augmented reality (AR) technology, offering data visualization in both 2D and 3D formats. This approach enhances the appeal of presented content to both consumers and farmers, surpassing conventional methods reliant solely on textual information and images [14]. Additionally, a mobile application has been introduced for monitoring animal intrusions into gardens or durian plantations utilizing image recognition technology, with supplementary features including location information for durian planting plots and details on durian species. However, notable limitations persist in terms of managing and displaying durian planting plot location data, as the application lacks mechanisms to verify the authenticity of user-added coordinates and does not support data retrieval based on the user's current coordinates [15]. Furthermore, a system has been developed for managing durian varieties within planting plots utilizing GIS technology, empowering users or farmers to input coordinates and corresponding durian varieties.

Notably, the system facilitates real-time data management and visualization. However, limitations remain, as the system solely focuses on displaying data related to durian species and tree counts, neglecting crucial information concerning the status of durian plantations such as retail and wholesale availability. This oversight hampers the application's utility in augmenting income generation opportunities for farmers and providing consumers with decision-making information. Additionally, the application lacks automated accuracy verification for durian planting location information, necessitating manual inspection through on-site surveys. Moreover, the inability to search for durian plantations in proximity to the user's current location further diminishes its practical utility [18] owing to limitations inherent in previous research endeavors. To address these deficiencies, this study proposes the development of a mobile web application leveraging mobile technology, GIS, and deep learning methodologies to effectively manage, process, and visualize durian plantation data. This holistic approach aims to rectify existing challenges and mitigate limitations, thereby enhancing the utility and accessibility of durian-related information for stakeholders.

3. Materials and Method

This study introduces the creation of a mobile web application platform tailored for the management, processing, and visualization of data pertaining to durian orchards, integrating mobile technology, geographic information systems (GIS), and machine learning. The research methodology encompasses several key components, including the formulation of a classification model for identifying durian planting plots from photographs, the assessment of model accuracy, system analysis and design, as well as mobile web application development.

3.1. Durian Plantation Image Classification

In this study, a model was developed to discern durian from non-durian plots in photographs utilizing various machine learning algorithms, namely SVM, RF, KNN, and CNN. The dataset comprised 1,000 images, evenly divided into 500 instances of durian plantation class and 500 instances of non-durian plantation class. Four distinct machine learning algorithms were employed to assess classification accuracy and precision, facilitating the identification of the most effective methodology for incorporation into the development of mobile web applications.

3.2. Accuracy Assessment

This study assesses the accuracy and precision of classifying images depicting durian and non-durian plots by computing several metrics, including accuracy, precision, recall, and f-measure. The evaluation process encompasses two distinct datasets: the training dataset, comprising a total of 1,000 images, utilized in conjunction with a 10-fold cross-validation technique, and the testing or validation dataset, consisting of 300 images, segregated into 150 instances of durian plantation class and 150 instances of non-durian plantation class.

3.3. System Analysis and Design

This study encompasses system analysis and design, elucidated through a use case diagram depicted in Figure 1, delineating three distinct user groups: user, farmer, and administrator. Users, primarily consumers, can utilize map visualization features to access information regarding the location of durian planting plots, species details, and the status of these plots. Additionally, users have the capability to search for information based on their current coordinates, with distance specifications presented in an online map format. Farmer users, on the other hand, possess functionalities enabling the management of durian planting plot information and associated data. This entails the extraction of plot location coordinates, facilitated by GPS integration via Google API on users' smartphones or tablets. Furthermore, farmers can verify the accuracy of plot locations by uploading images, subsequently subjecting them to image classification using machine learning techniques. Notably, only data pertaining to verified durian planting plots are recorded into the database. Administrator users have analogous system access as regular users and farmers, along with additional capabilities such as generating diverse data reports. These reports, available in both dashboard and Microsoft Excel formats, serve as invaluable resources for presentation to relevant agencies, aiding in management and decision-making processes, including zoning considerations for durian cultivation areas. Moreover, the study supplements the system analysis and design presentation with a comprehensive overview of the system's operational workflow, depicted through a use case diagram in Figure 2, further elucidating the functionality and processes inherent to the developed system or mobile web application platform.

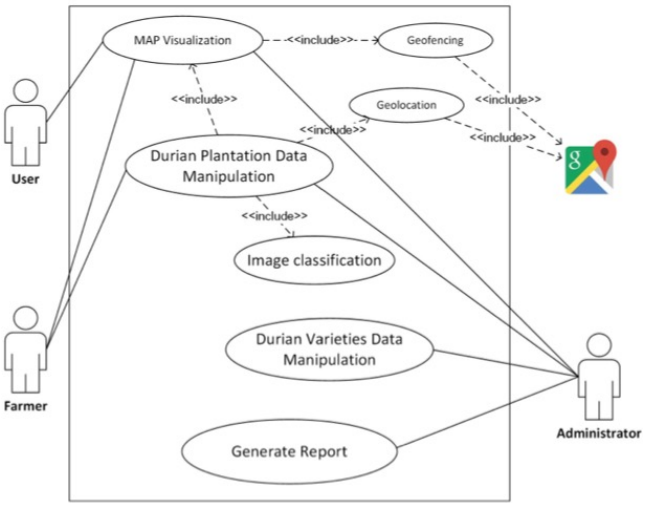

Figure 1. Use case diagram

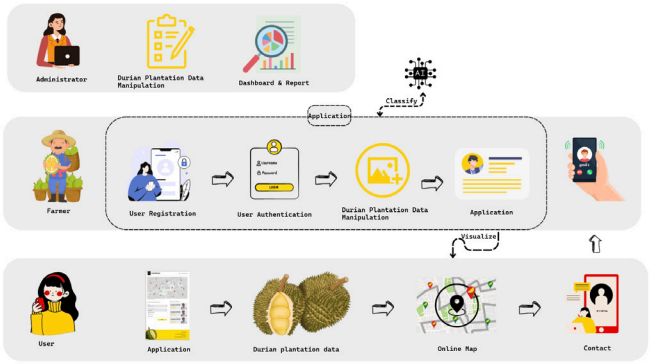

Figure 2. User journey diagram

3.4. Mobile Web Application Platform Development

The application developed in this research takes the form of a mobile web application to ensure compatibility across various operating systems, including Microsoft Windows, Mac OS, Android, iOS, and iPadOS. This approach facilitates the utilization of GPS functionalities for retrieving latitude and longitude values, essential for user and farmer location tracking. The diverse hardware and software requirements for application development and utilization are comprehensively outlined in Table 1. The software stack employed encompasses a range of programming languages such as PHP, Python, SQL, and JavaScript. Development tools include the Apache Web Server, MySQL, Microsoft Visual Studio Code, and standard web browsers. Furthermore, spatial data processing and visualization are facilitated through the integration of Google Maps. Key APIs employed within the application encompass functionalities crucial for managing durian planting plot data, including attribute and spatial data, as well as image processing capabilities for durian plot classification.

Additionally, the application supports durian variety data management, distribution type, and status data handling, alongside functionalities for searching durian planting plot locations based on user-defined distance criteria. Lastly, the application provides robust reporting capabilities, enabling data presentation through dashboards and exportation in Microsoft Excel file formats.

Table 1. Hardware and software

User	Hardware	Software
User	• Smartphone/Tablet • Laptop	• Web Browser
Farmer	• Smartphone/Tablet	• Web Browser
Administrator	• Microcomputer • Laptop • Mobile Devices	• Web Browser • Microsoft Excel • PDF Reader
Developer	• Server • Laptop • Mobile Devices • Camera	• Apache • MySQL • Microsoft Visual Studio Code • PHP • Python • JavaScript • Google Map API • Web Browser

4. Results and Discussion

The research findings are structured into two main sections: the outcomes of classifying durian planting plots through machine learning utilizing photographic data, and the results stemming from the development of a mobile web application platform. Each section delineates specific details pertaining to its respective domain.

4.1. Durian Plantation Classification Result

In this study, a model was developed to classify durian plantations utilizing digital photographs employing four machine learning algorithms: CNN, SVM, RF, and KNN. The experimental outcomes revealed CNN as the most accurate classifier, yielding an accuracy value of 95.00%. Precision, recall, and f-measure values for CNN were recorded at 99.55%, 94.44%, and 94.97%, respectively. Subsequent algorithms, SVM, KNN, and RF, exhibited decreasing levels of accuracy, with respective accuracy values of 93.50%, 91.40%, and 89.70%. Detailed performance evaluation results of the model are presented in Table 2 and Figure 3. The accuracy assessment considered 1,000 training images utilizing the 10-fold cross-validation method.

Moreover, the accuracy evaluation compares the performance of each algorithm across both Durian Plantation Class and Non-Durian Plantation Class, as depicted in Figures 4(a) to 4(d). Specifically, utilizing the CNN algorithm, the accuracy for Durian Plantation Class was 95.5%, while for Non-Durian Plantation Class, it was 94.5%. Employing SVM for classification yielded accuracies of 91.1% for Durian Plantation Class and 96.2% for Non-Durian Plantation Class. Similarly, the KNN algorithm achieved accuracies of 91.6% for Durian Plantation Class and 88% for Non-Durian Plantation Class. Conversely, the RF algorithm exhibited accuracies of 87.4% for Durian Plantation Class and 96.4% for Non-Durian Plantation Class. Comparative analysis revealed CNN's superior accuracy, particularly in its ability to classify both classes with consistently high accuracy levels. Therefore, the subsequent application development in this research prioritizes models created utilizing the CNN algorithm.

Table 2. Model evaluation results

Algorithms	Accuracy	Precision	Recall	F-measure
CNN	95.00	95.55	94.44	94.97
SVM	93.50	91.12	96.18	93.68
RF	89.70	91.61	87.95	89.46
KNN	91.40	96.80	87.36	91.84

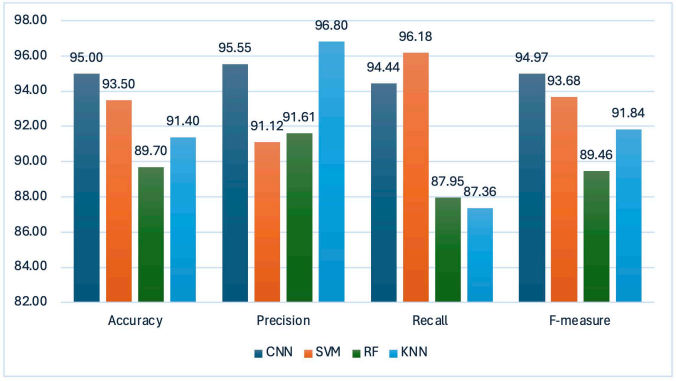

Figure 3. Model performance evaluation results

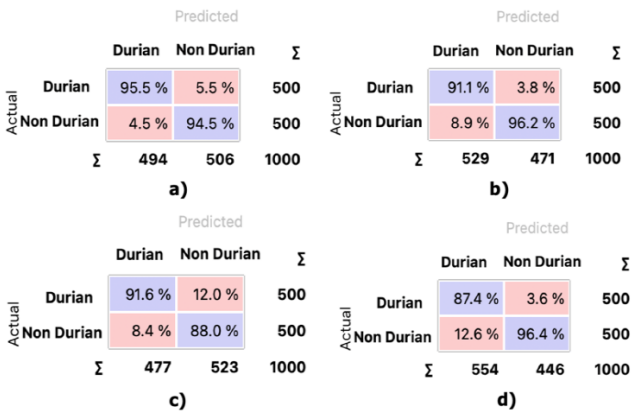

Figure 4. Accuracy results a) CNN b) SVM c) KNN and d) RF

The outcomes of classifying digital images to discern between durian and non-durian plots are illustrated through exemplary classification results presented in Figures 5 and 6. Figure 5 depicts an image representative of a durian plantation plot, while Figure 6 portrays a plot cultivating alternative fruit varieties. Upon scrutiny of the classification results showcased in Figure 5, it is evident that durian plots are accurately classified, encompassing images featuring durian trees in various developmental stages, including those yet to bear fruit and those bearing mature fruit. Conversely, the classification outcomes presented in Figure 6 demonstrate the model's proficiency in accurately discerning plots designated for non-durian fruit cultivation. Noteworthy examples within Figure 6 include plots cultivated with bananas, rambutans, and oranges. These classification results collectively underscore the efficacy of the proposed model in effectively distinguishing between durian and non-durian plots with a high degree of accuracy. Consequently, the model holds promise for integration within an application framework to facilitate automated scrutiny of durian plantation data submitted by users or farmers, thereby obviating the necessity for human inspectors. Such implementation stands to yield reductions in costs and processing time associated with manual inspection procedures.

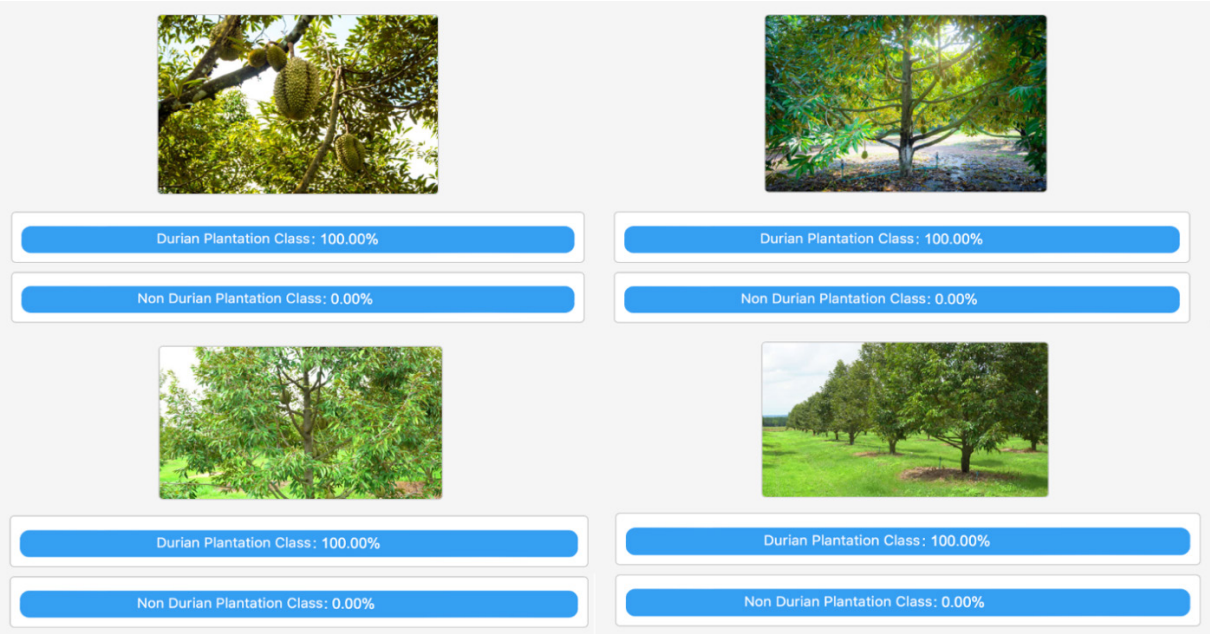

Figure 5. Durian plantation classification result

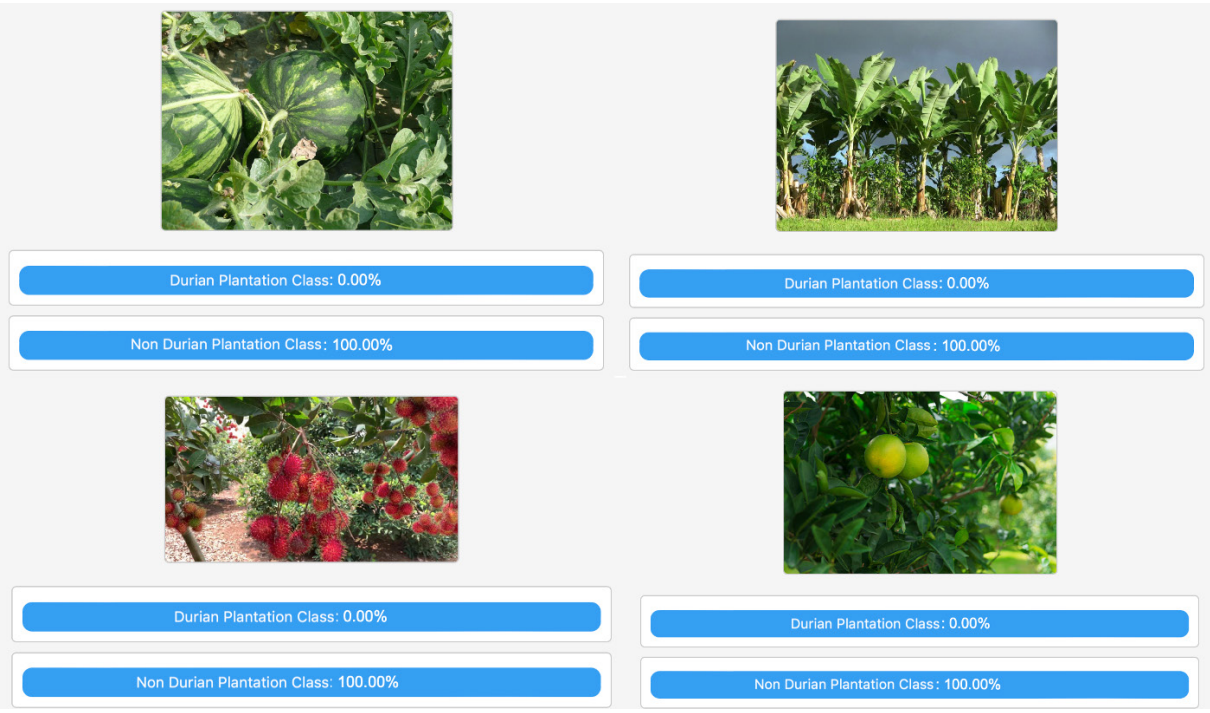

Figure 6. Non-durian plantation classification result

4.2. Mobile Application Platform Development Result

The outcomes of developing a mobile web application for the management, processing, and visualization of durian plantation data, integrating various technologies such as mobile technology, geospatial technology, and machine learning or deep learning, are delineated. The initial phase of development involves user verification, wherein each user group is endowed with permissions to delineate the scope and functionality of the application. An illustrative example of the user interface is depicted in Figure 7. Within this segment, users from each group may log in utilizing their respective credentials. However, users lacking a pre-existing account may request access by accessing the user register link. Subsequently, the development outcomes pertaining to data management within farmers' durian planting plots are elucidated, as depicted in Figure 8. Data management is compartmentalized into three distinct categories: attribute data management, encompassing fields such as Plantation Name, Number of Durian Trees, Telephone Number, Sale Type, Durian Plantation Status, and Durian Type or Varieties; spatial data management, comprising Latitude and Longitude coordinates; and image management, incorporating Durian Plantation Image. Users are empowered to populate attribute data fields accordingly. In the spatial data section, upon tapping the Durian Plantation Location button, the application automatically retrieves latitude and longitude coordinates from the GPS module embedded within the user's smartphone or mobile device. Furthermore, users may capture and upload images of durian plantations by tapping the Choose File button. Subsequently, the application undertakes image processing and executes a classification model to discern durian plantations. If the classification outcome indicates Non-Durian Plantation Class, the user interface omits the provision for data submission, precluding the appearance of a Submit button. Conversely, if the classification outcome identifies a Durian Plantation Class, a Submit button is rendered available, enabling users to save pertinent information.

Figure 7. User authentication interface

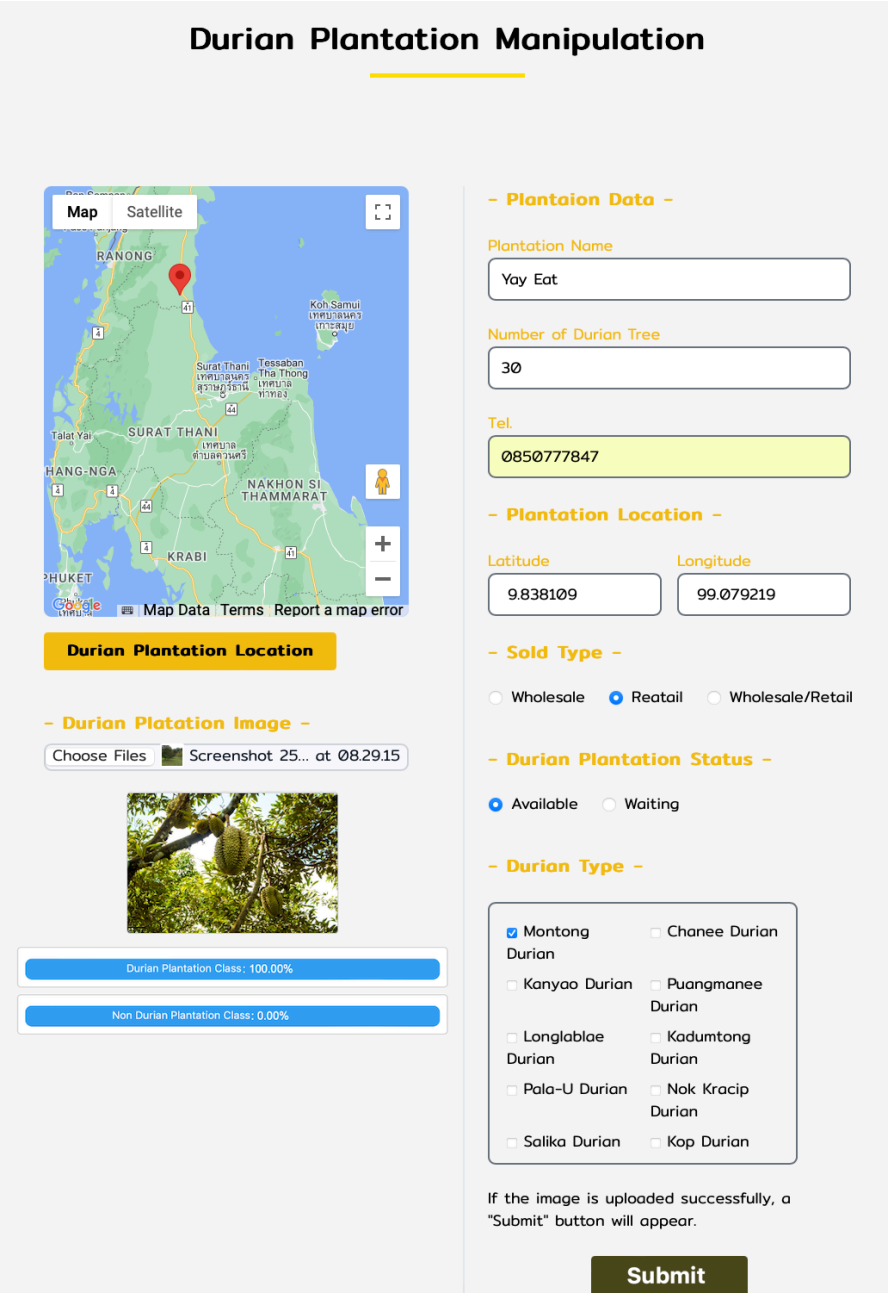

Figure 8. Durian plantation manipulation interface

The outcomes of displaying data concerning durian planting plots in this study are portrayed through spatial data visualization via an online map, as illustrated in Figure 9. The map delineates the locations of durian planting plots utilizing markers, wherein green markers signify plots currently engaged in durian fruit production or sale, while red markers denote plots without ongoing production or available durian fruit for sale. This visualization facilitates user or consumer access to information regarding durian plantations offering durian fruit for sale, thereby supporting real-time data accessibility. Furthermore, upon selecting a marker, users can ascertain the orchard's sale status, delineating whether durian is available for retail, wholesale, or both.

This feature caters to consumers and businesses interested in durian consumption or commercial transactions. Additionally, the display functionality enables users to search for durian plantations based on their location coordinates within a specified distance, exemplified in Figure 10. To retrieve user coordinates, the application leverages the Geofencing API provided by Google. Upon tapping the Current Location button, the application invokes the GPS functionality of the user's mobile device. Subsequently, upon initiating a search by tapping the Search button, a circular boundary is generated based on the specified radius (e.g., 100 kilometers), within which markers are displayed. Detailed information pertaining to durian plantations within this radius is presented alongside the map.

Such information includes Plantation Name, Telephone Number, Latitude, Longitude, and the types or varieties of durians cultivated at each plot. Additionally, the display provides the distance from the user's current coordinates, thereby furnishing users with pertinent information to aid in their selection of durian orchards for purchase. This functionality is equally beneficial to the private sector in planning trips to procure durian within desired locales.

The outcomes of developing the dashboard display, depicted in Figure 11, entail the presentation of diverse information encompassing the Number of Durian Planting Plots distributed across Retail, Wholesale, and Wholesale/Retail categories. Additionally, the dashboard provides a breakdown of durian plots by varieties, presented both numerically and graphically. The utilization of a dashboard format enables facile application of the data by pertinent government agencies for durian orchard management purposes. Furthermore, the creation and issuance of reports under specific conditions are exemplified in Figure 12. The reports are categorized into three types, facilitating data filtration based on sales status, distribution type, and durian species. Each section enables the exportation of files in Microsoft Excel format, thereby furnishing management agencies with actionable data for informed decision-making.

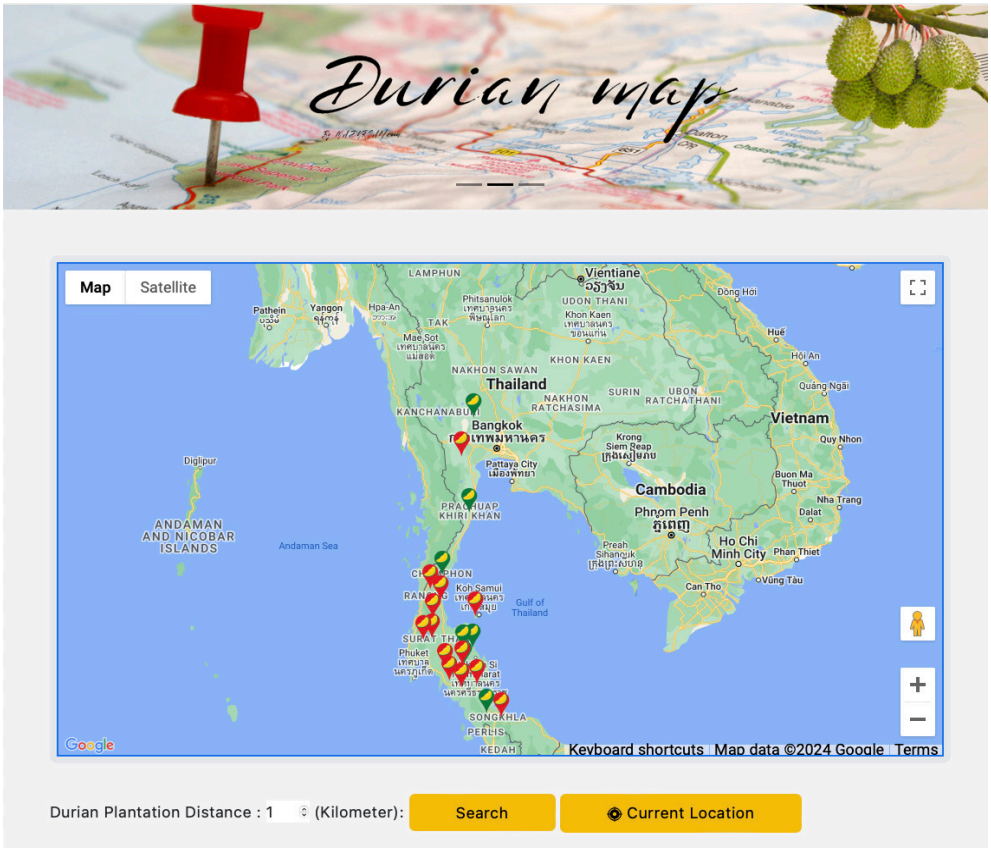

Figure 9. Durian plantation location via an online map

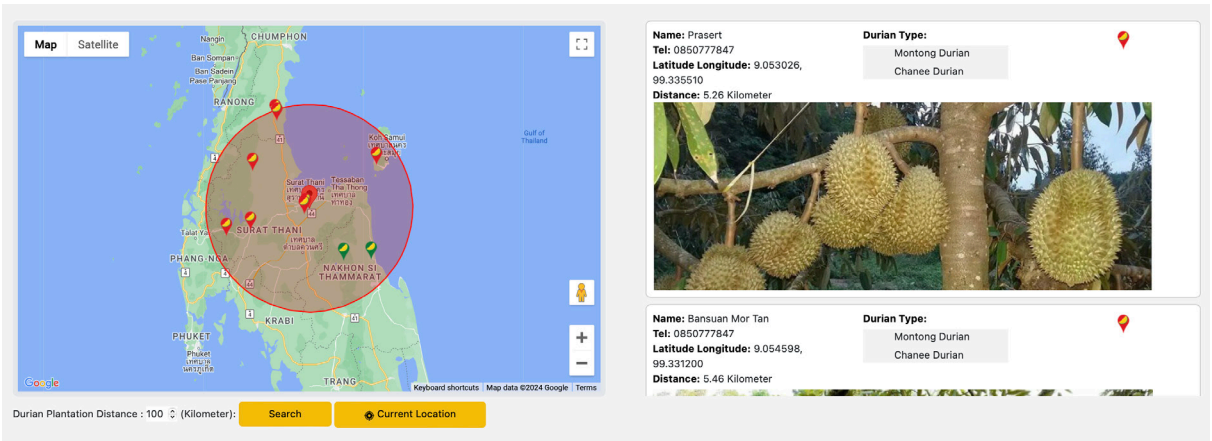

Figure 10. Durian plantation data using geofencing

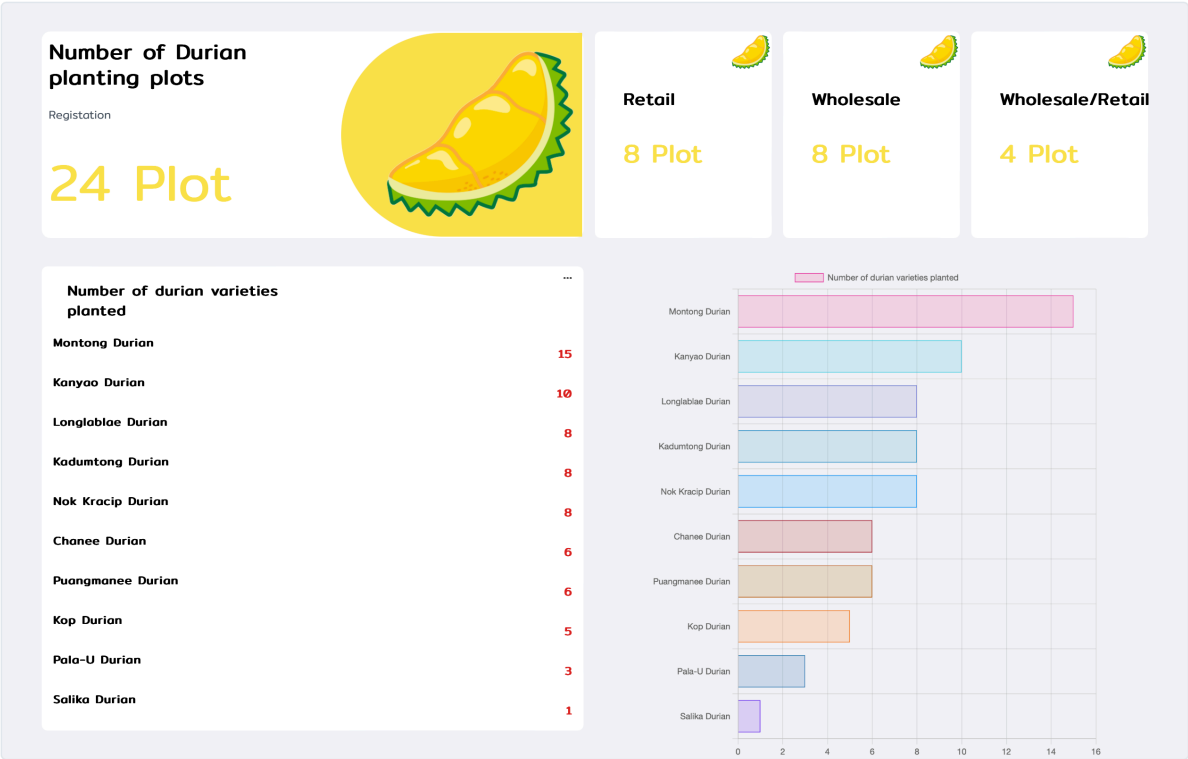

Figure 11. Dashboard

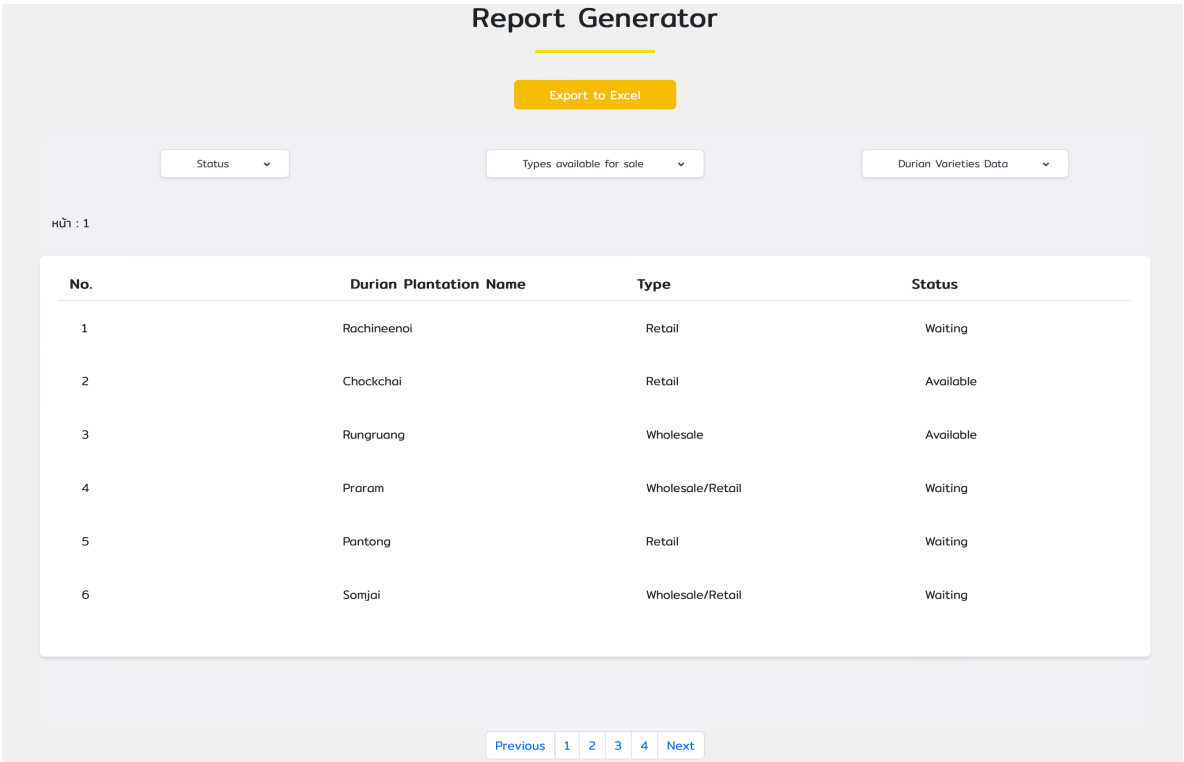

Figure 12. Report generator interface

5. Discussion

The development of a mobile web application platform for processing, managing, and displaying information regarding durian plantations, utilizing an amalgamation of mobile technology, geospatial technology, and machine learning, has resulted in a versatile channel for disseminating information from farmers to consumers and businesses alike. This platform also facilitates the management of data pertaining to the geographical locations of durian cultivation areas.

Notably, this approach aligns with previous research endeavors employing GIS technology, enabling real-time display of location coordinate data [18]. However, the present study advances upon prior limitations by leveraging GPS functionality from users' and farmers' smartphones or mobile devices during data management, thereby facilitating the precise determination of durian plantation locations. Moreover, this research incorporates deep learning techniques to process images of durian plantations, mirroring previous efforts employing digital image processing coupled with machine learning for various tasks such as classifying durian species, diseases, and fruit ripeness [7], [8], [9], [10], [11]. Notably, this research distinguishes itself by developing a model for classifying durian plantation photos, subsequently integrated into a mobile web application for real-time access via smartphones or mobile devices, obviating the need for pre-collected data. This approach contrasts with prior studies applying mobile technology [14], [15], which have encountered consistent challenges in real-time data management and display. Crucially, the utilization of geospatial technology in this research facilitates the processing and display of data based on user location coordinates, enabling spatial data retrieval according to user-defined distance or radius parameters. Additionally, the development of this application or platform empowers diverse stakeholders—including consumers, farmers, private enterprises, and governmental agencies—to leverage the platform and associated data for informed decision-making in orchard and durian plantation management endeavours.

6. Conclusion

This research introduces the development of a mobile web application platform designed to enhance information communication channels among farmers, consumers interested in durian consumption, and businesses engaged in durian distribution or processing. The platform integrates multiple technologies, including mobile technology, GIS (Geographic Information Systems) or geospatial technology, and deep learning, aiming to address and mitigate limitations encountered in previous research endeavors. Key advancements offered by the developed application or platform include real-time management, processing, and display of durian plantation information, alongside the ability to automatically verify the accuracy of durian plantation data and locations through photo processing. Furthermore, the platform facilitates the search for durian plantations near the user's current location.

Notably, the method employed for classifying durian planting plots via image processing demonstrates high accuracy, thereby reducing the time and costs associated with manual verification processes. Moreover, the proposed methodology exhibits versatility and applicability across various domains, without spatial constraints, thereby extending its utility beyond durian plantation management to encompass other types of fruit cultivation plots.

In forthcoming research endeavors, the integration of additional technologies, such as the Internet of Things (IoT), holds promise for advancing the management of durian orchards. Incorporating IoT capabilities into the development of a platform for durian orchard management could encompass functionalities such as environmental monitoring within the orchard premises. Such monitoring could aid in ensuring optimal environmental conditions for durian tree growth and facilitate timely detection of diseases. By leveraging IoT technology, farmers could access a comprehensive platform encompassing various stages of the planting process, maintenance protocols, and distribution logistics. Furthermore, the envisioned platform could be adapted for application in diverse agricultural contexts beyond durian orchards.

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