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E-Marketplace Solution for Coconut that Matches Crop Supply and Demand in Sri Lanka

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***Abstract* - This research paper presents an integrated emarketplace solution for the coconut industry, aiming to match crop supply efficiently. The system combines a coconut quality grading system using image processing, registration of farmers and collectors, algorithmic matching of buyers and sellers, supply visualization on a map, vehicle routing optimization, and a machine learning-based pricing and trend analysis dashboard. By integrating these functionalities, the solution enhances efficiency, transparency, and profitability in the coconut industry. This research contributes to advancing the industry in Sri Lanka by providing a comprehensive platform for seamless transactions, optimized transportation, and data-driven decision making. The proposed e-marketplace offers a holistic approach to connect stakeholders, streamline operations, and enable informed decision-making for sustainable growth in the coconut sector.**

Keywords: e-marketplace, crop supply matching, coconut quality grading, pricing estimates, routing optimization.

I. INTRODUCTION AND LITERATURE REVIEW

The agricultural sector plays a crucial role in guaranteeing Sri Lanka's food security and economic development. Nonetheless, ineffective distribution networks and insufficient market access frequently present considerable obstacles for cultivators and purchasers alike. To tackle these problems, we present an e-marketplace solution initially targeted to the coconut sector that can be subsequently broadened to other sectors as well, empowering cultivators to connect directly with purchasers and simplifying the commercial process. Our system utilizes cutting-edge technologies to enhance transparency, convenience, and effectiveness in the coconut trade ecosystem. The following are the main functionalities of this system. In many different domains and applications, image processing has been shown to be a useful tool for analysis. From the perspective of the farmers, the agricultural sector's key performance indicators included canopy, yield, and product quality. Most of the time image processing is used to identify coconut plant diseases. Bother invasions are seen as a major issue that agriculturists have been combating for numerous long times, much like supplement hardship. The vital components to be taken into consideration in any development are early recognizable proof, bug infections, recuperation from bother assaults, and utilization of pesticides[1].

In this research focusing how to categorize coconuts by their color and size weight with image processing. There is a huge request for coconut items nearby as well as international markets. Choosing the correct crop maturity improves quality. Choosing the appropriate crop to harvest is a crucial component of decision making. For the procedure to be automated, a powerful system vision model that assists in selecting the produce from the plant is mostly required. Internationally researchers used many technologies such as Color based K-Means clustering, Marker controlled watershed, grow cut, and Maximum Similarity based Region Blending (MSRM)[2]. India is the second largest fruit producer globally, but a significant amount of harvested fruit goes to waste due to a lack of qualified workers and inaccurate human grading. To tackle this, automation is being introduced in the fruit industry. Using image processing and machine learning, an automated system can accurately identify and classify fruits based on variety, type, maturity, and condition. The proposed method, called ISADH, outperforms other texture features and achieves an accuracy rate of 89.1 By gathering data from 1653 photographs of 18 fruit species and employing PCA for dimensionality reduction, the system shows promising results in reducing waste and improving efficiency in fruit production [3].

In previous research, has discovered a way to find the diameter of diagrams using this image-processing technology. They used HSV approach to identify the trunk, then evaluated different tree rings under sloping conditions. To estimate the tree diameter, they used an approach based on flat-area calculation and the area measuring principles of

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parallelograms and rectangles - making it simpler and faster than traditional methods [4]. This research explores the difficulties confronted by coconut producers in the Jaffna District, such as constrained resources, obsolete practices, and educational gaps. To enhance competitiveness, it emphasizes the significance of technological investment, collaborative efforts, and ensuring quality standards, thus fostering sustainable growth within the industry [5]. The following study describes how E-commerce in agriculture empowers farmers, improves practices, and provides market access. It offers a promising future, leveraging technology and networks for smallholder farmer's success [6]. When considering the development of the hybrid algorithm for vehicle routing for the shortest and most fuel-efficient path that can cater to multiple destinations, there are several research done related to this.

Research carried out in 2022 on solving the traveling salesman problem by applying a meta-heuristic algorithm based on ant colony optimization theory has proposed an algorithm that can be used for finding the shortest possible route for visiting a number of nodes in a graph [7]. Similarly in 2016, a clustering-based genetic algorithm was introduced by a group of students at the International Islamic University Malaysia (IIUM), for solving a robot route navigation problem, which is a variant of the traveling salesman problem [8]. There are a few research conducted on combining the shortest path routing and fuel-efficient routing. For example, research conducted in 2018 has proposed a genetic algorithm based co-optimization method that is able to provide both fuel-economic routes and reference speed profiles for vehicles to improve fuel economy and in turn, reduce transportation costs [9]. A group from the University of Michigan has developed a non-parametric fuel consumption model which has been used for the development of the Eco-routing algorithm developed by them [10]. They have compared this Eco-routing model with an Eco-route, which factors only the fuel consumption, and the fastest route, which factors only the travel time, and found out that this model has been able to save 5.16fuel while only incurring a 0.91Furthermore, a research article published in 2021 contains a method for computing the efficient fastest path for road maps by using an algorithm [11]. The coconut industry is a significant economic force in Sri Lanka, accounting for 15 which could have a negative impact on coconut yields and prices, resulting in significant financial losses. To address these issues, farmers, traders, and decision-makers must forecast coconut prices accurately. Machine learning algorithms have proven to be an effective tool for forecasting agricultural prices, including coconut prices. Notably, Long Short-Term Memory (LSTM) and multivariate time-series models with promising success rates to forecast Sri Lankan coconut prices and export prices of coconut products, respectively[12][13]. The coconut industry in Sri Lanka is also vulnerable to the effects of climate change, which include rising temperatures, altered precipitation patterns, and extreme weather events. The study by E. Pathiraja, G. R. Griffith, and R. Faggian emphasizes the importance of these climate-related factors on coconut growth, yield, and production [14]. Financial studies on climate variability's effects on the coconut industry, have shown that climate variations have a negative impact on coconut yields and farm-level profitability [15]. As a result, there is a growing body of research that not only forecasts coconut prices but also investigates the profound effects of climate change on Sri Lanka's coconut business. Google Trends is one tool for keeping an eye on market trends for coconut-related products.

Users of Google Trends can view the evolution of a given search term's popularity over time, giving them knowledge about the most popular products [16]. For instance, a Google Trends search for "coconut oil" reveals a consistent rise in interest over the previous ten years, with a peak in popularity in early 2021.

II. METHODOLOGY

A) Bold Grading System for Coconut Quality Analysis using Image Processing Techniques

The Grading system combined of two modules. a) Colour detection b) Size detection. Combination of these 2 modules gives the final output grade of each coconut. Below diagram shows the main architecture of the system.

1) Colour detection: The first step in developing a comprehensive coconut color detection system involves collecting a data set of coconut images with known color values. Tensor-Flow will be used to train a machine learning model on this data set, enabling it to recognize coconut husk colors based on pixel values. The next phase involves integrating this model into a mobile app, allowing users to capture coconut images for color analysis.

The app's variety identification model processes the captured images, identifying the predominant coconut husk tones. It assigns an appropriate grade based on predefined criteria. Importantly, the machine learning model can be continuously updated with new data, ensuring ongoing improvement and accuracy in color grading. Overall, this system offers an automated and robust solution for coconut husk color detection and grading, enhancing productivity and accuracy in coconut processing and related industries.

2) Size detection: A system is developed for coconut size detection and grading using machine learning. It starts by collecting a dataset of coconut photos with known size values. TensorFlow is used to train a model to detect coconut size

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based on pixel values. This model is integrated into a Progressive Web Application (PWA) for user convenience. When users take a picture of a coconut with the app, the PWA sends the image to the model, which calculates the coconut's diameter and circumference.

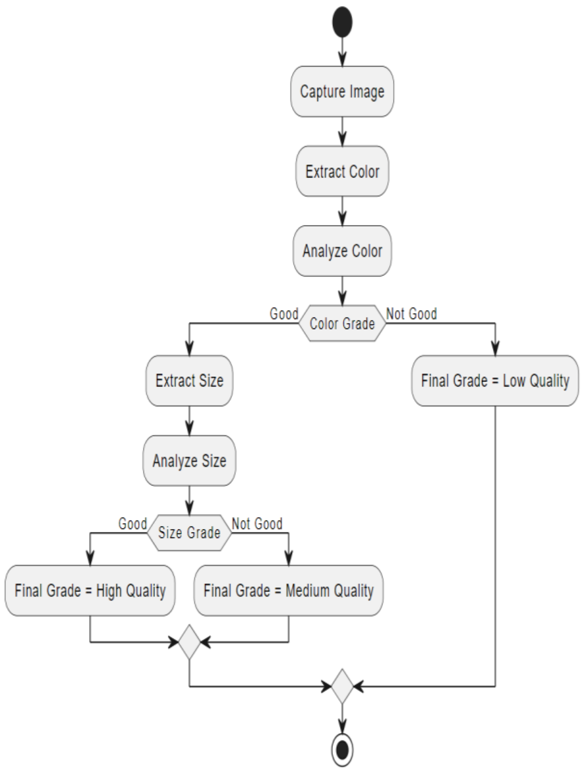

Figure 1: Quality Analysis architecture

The coconut is then assigned a size grade based on predefined standards. The system continues to learn and improve as it processes more coconut photos, updating the machine learning model. This technology offers an automated and accurate solution for industries requiring precise coconut size measurements, enhancing efficiency and decision-making.

B) Optimizing the Coconut Supply Chain: An Analysis of Distance Matching Algorithms and Data Visualization Techniques for Connecting Buyers with Nearest Sellers

This section describes the approach and the techniques that followed to develop the Matching algorithm and Data visualization techniques that can be used to optimize coconut supply chain. The following characteristics were selected to examine the behavior of customers and sellers in the coconut supply chain.

1) Price of Coconuts
2) Distance between customer and sellers
3) Medium of interaction
4) Coconuts supply and demand

For the identified characteristics, main factors have been identified using a conducted survey results. Depending on the type of seller or customer requirements, any of the selected factors can be removed, new factors can be added, or both can be combined in the future.

• Price of Coconuts

The coconut market in Sri Lanka is experiencing price volatility due to strong demand and low supply, which is exacerbated by edible oil imports. This system support for coconut farmers, price stability, and efficient transportation, as well as the enforcement of price regulations to ensure fair pricing for customers and sellers.

• Distance between customer and sellers

Customers and coconut sellers must be close to one other for cost-effective transactions. With adjustable filtering options, the use of mapping and location-based algorithms simplifies supply chains, improving efficiency and communication.

• Medium of interaction

This system improves user experience by utilizing web and mobile apps, phone calls, and emails for coconut market communication, as well as an interactive map for location based seller identification.

• Coconuts supply and demand

The coconut supply and demand dynamics play a crucial role in the optimization of the coconut supply chain. Fluctuating market demands and insufficient supply can result in price breaches and affect overall industry stability. By analyzing and addressing these factors, this system aims to create a more balanced and efficient coconut market, benefiting both buyers and sellers in the industry.

Distance Matching Algorithm and Data Visualization

The distance matching technique, powered by the Haversine formula and MongoDB spatial queries, improves efficiency in linking clients with nearby coconut suppliers. The data visualization component, which is powered by Leaflet.js and OpenStreetMap, provides an interactive map interface for users to explore seller distribution, inspect details, and make informed decisions in the coconut market, enhancing the entire user experience.

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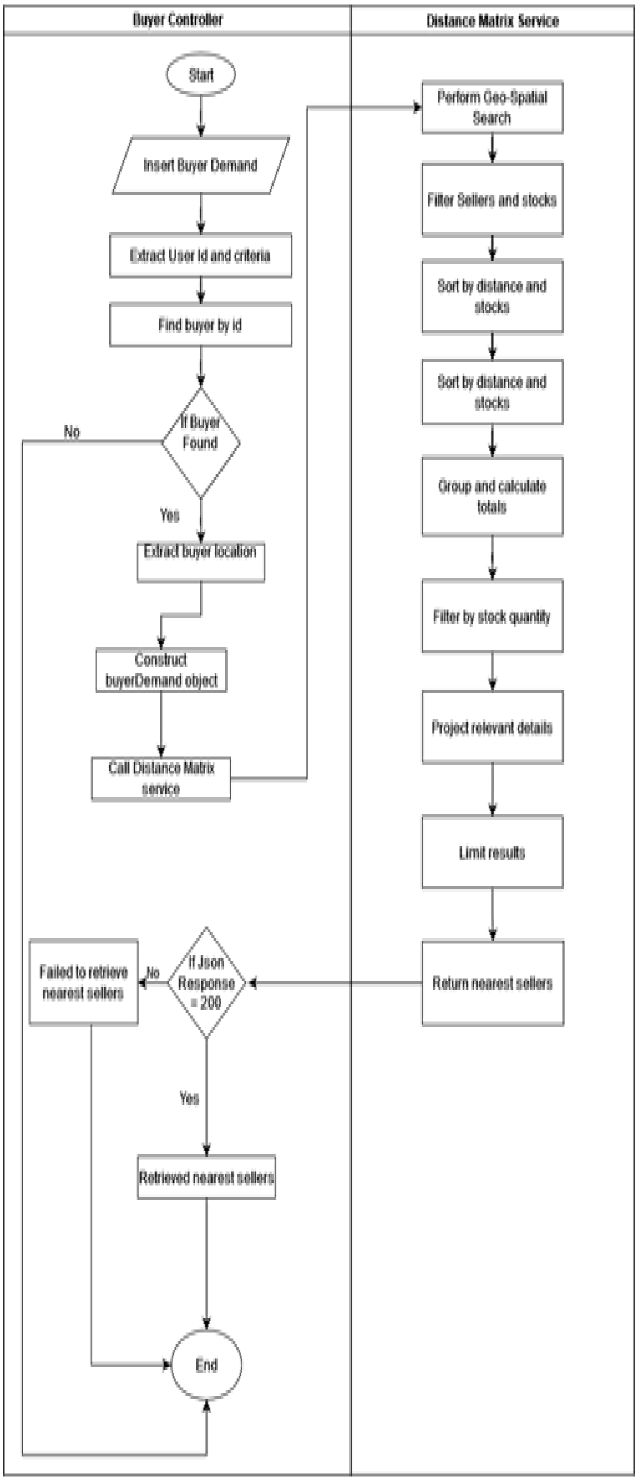

Figure 2: Flow Chart Diagram Distance matching algorithm

C) Development of a Hybrid Algorithm and delivery system for Vehicle Routing with Shortest and Fuel-Efficient Path

This section includes the methodology used in the development of a hybrid routing algorithm that calculates the shortest and most fuel-efficient path for the delivery system. The methodology contains the following key steps,

- Data collection
- Algorithm design
- System implementation
- Evaluation

Data collection

In the data collection phase, Opensource resources such as OpenStreetmap data is used to obtain accurate and up-to-date map information that has road network data, landmarks, road inclination/declination data and vehicle traffic data relevant to the system.

Algorithm design

The algorithm designing phase focuses on developing the route calculation algorithm that calculates the shortest path and fuel-efficient path from a starting point to a destination. For this graph theory is used and for graph traversal, Dijkstra's algorithm is used with weighted edges. The edges include factors such as distance, road traffic conditions, road inclination/declination, climate data. The following equation is used in calculating the value of an edge of the graph.

$$E = \sum_{i=1}^{n} W_i F_i$$

E = Value of the edge
W_i = Weight of the factor i
F_i = Value of the factor i
n = number of factors

System implementation

The stage of implementing the system includes creating the user interface using React JS and Leaflet JS, allowing transporters to sign up, see available orders, and access the calculated routes. The application's back end is developed using Node.js with Express.js, which helps with the logical operations and communication between the user interface and the database. MongoDB is used as the database, ensuring efficient storage and retrieval of data related to coconut transporters, delivery orders, and route calculations. The different elements, such as the user interface, server, and database, are integrated to create a cohesive and functional delivery system.

Evaluation

The evaluation and testing stage seeks to measure the efficiency and effectiveness of the developed system. Thorough testing is carried out to guarantee the functionality, precision, and execution of the algorithm and the overall system.

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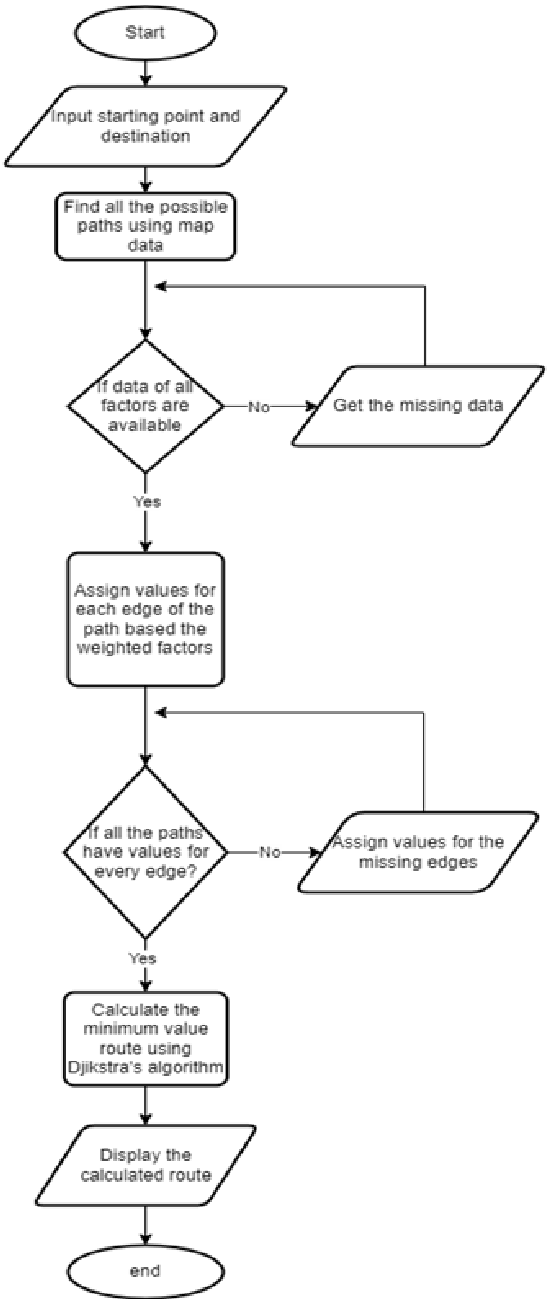

Figure 3: Algorithm Flowchart

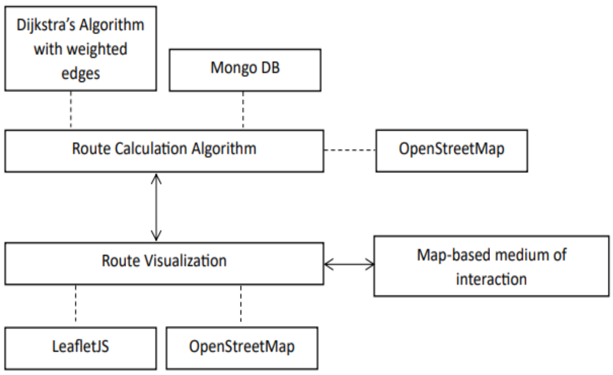

Figure 4: System diagram

D) Optimizing Coconut Trade in the Face of Climate Change: A Dashboard-based Solution for Price Prediction and Trend Analysis using Machine Learning

Coconut price prediction and trending coconut products can be categorized as current and future predictions using machine learning. Current predictions inform users about the present coconut market prices. Future predictions aid farmers in maximizing profits, planning crops, managing finances, and gaining a competitive edge. The goal is to help the coconut industry cope with climate change challenges. A dashboard based system enhances market transparency, risk management, and trading efficiency by providing accurate price forecasts and trend analysis.

- Data collection
- Pre-Process Data
- Training the model

Data collection

To optimize Sri Lanka's coconut trade, this study uses recent local historical data for current price prediction and weekly data for future price prediction. It also incorporates data on coconut export product sales, demand, weather, and inflation. Information sources include agricultural departments, government organizations, market reports, and registered Sri Lankan websites. Weather data, including temperature, rainfall, and humidity, were sourced from the Department of Meteorology and online weather APIs. Data collection spans ten different Sri Lankan districts over a twenty-five-year period to account for regional variations and long-term trends.

Pre Process Data

The collected datasets, comprising coconut prices, export product data, and meteorological info, undergo rigorous preprocessing. This involves rectifying missing data, outliers, and inconsistencies. Integration techniques are employed to link coconut pricing with weather conditions based on shared attributes. Feature selection reduces dimensionality, enhancing computational efficiency by identifying crucial variables. Additionally, data normalization techniques ensure variables are on a consistent scale, facilitating analysis and modeling.

Training the model

The price prediction dashboard employs machine learning, specifically Random Forest Regression, for coconut price forecasts, considering climate change factors. Random Forest Regression, adept at managing complex relationships and both numerical and categorical features, outperforms alternatives like gradient boosting and linear regression. It

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exhibits lower mean absolute error and root mean square error values during cross-validation, demonstrating improved accuracy and resistance to overfitting.

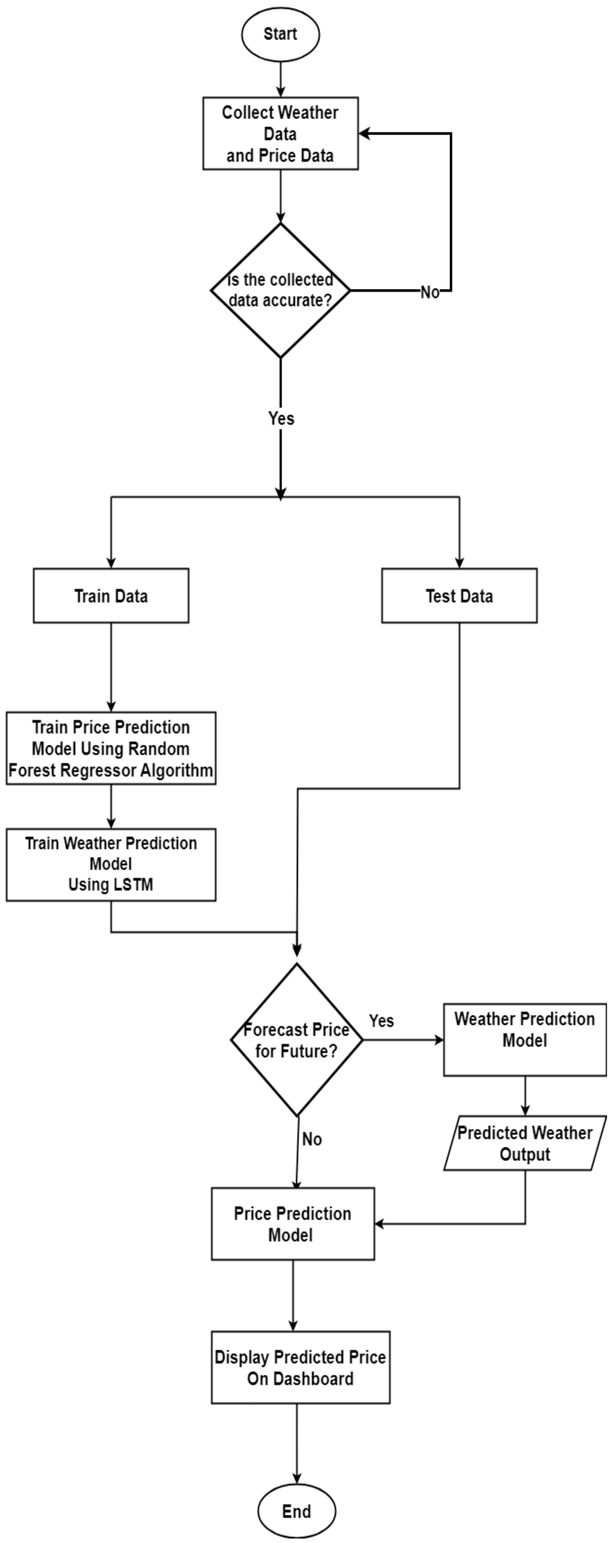

Figure 5: Price Prediction Flowchart

This model effectively captures the non-linear dynamics of coconut prices, incorporating climate variables and relevant factors for precise predictions.

The second dashboard forecasts trending coconut products using linear regression, chosen for its ability to handle both categorical and numerical features. Performance metrics include mean squared error, root mean squared error, and R-squared. Model selection depends on data characteristics, product nature, and study goals. Proper references and citations are essential when utilizing the linear regression algorithm and other models in the analysis of sales data.

III. RESULTS AND DISCUSSION

In this part, we show the outcomes of the coconut grading system we established using size and color criteria. On a data set of coconut photos captured under regulated lighting settings, the system was assessed. To ensure precise feature extraction, the photos underwent prepossessing to increase contrast and remove noise.

To assess the system's accuracy in grading coconuts by size, we performed a comparison between the manually measured sizes and the sizes predicted by our system. The system achieved an average size prediction accuracy of 90% across the data set. This indicates a high improvement over traditional manual grading methods, highlighting the efficiency and precision of our image processing approach. Furthermore, we calculated the Mean Absolute Error (MAE) between the manually measured sizes and the predicted sizes.

The color-based grading performance of our system was evaluated by comparing the color grades assigned by our system with those assigned by human graders. We used RGB values to determine color grades.

The results showed that our system achieved an average accuracy of 95% in predicting the correct color grade. This accuracy surpasses the human grading accuracy, underscoring the system's capability to effectively and consistently classify coconuts based on their color.

While our image processing system shows promising results, there are certain limitations that need to be acknowledged. Variability in lighting conditions and image quality can impact the accuracy of the system. Additionally, the system's performance might vary when presented with coconuts from different regions or varieties. In the future, refining the system's algorithms to account for these variations and conducting tests on diverse data sets could further enhance its accuracy and applicability. In below diagram shows the final mapping of the color and size.

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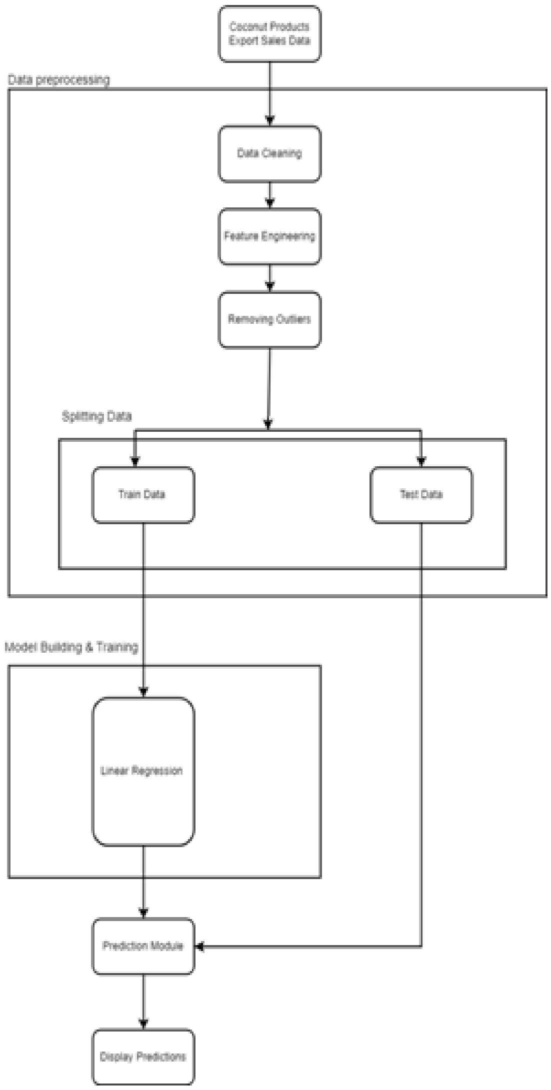

Figure 6: Trending Product Flowchart

In this section, we discussed the performance of our image processing system for grading coconuts based on size and color parameters. The system demonstrated impressive accuracy in both size and color grading, outperforming traditional manual methods. Furthermore, its ability to handle variations in both parameters and its potential to enhance grading efficiency were highlighted. Although certain limitations exist, our findings suggest that automated image processing holds great promise for revolutionizing the coconut grading industry.

The developed system's distance matching algorithm and map-based data visualization technique successfully utilized the Haversine formula, MongoDB spatial queries and leaflet JS with open street maps to enable efficient location-based matching using an map-based interface. As depicted in Fig 3, the interactive map interface displayed the nearest coconut sellers according to the buyer's demand.

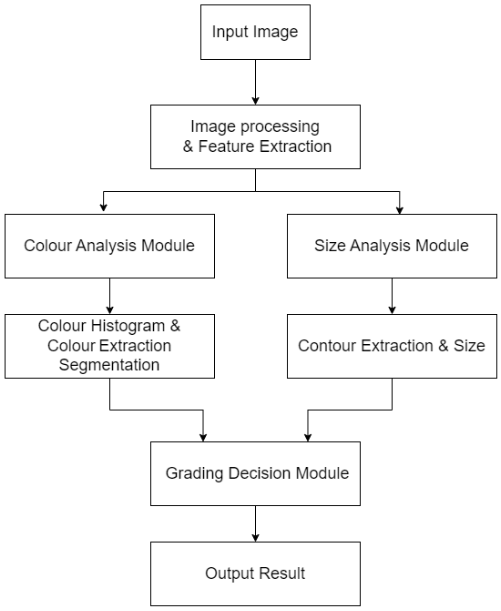

Figure 7: Main workflow

Color Grade	Size Grade	Final Grade
A	S	B
A	M	A
A	L	A
B	S	B
B	M	B
B	L	A
C	S	C
C	M	C
C	L	C

Figure 8: Mapping of Final Grades

The algorithm's accuracy was enhanced through spatial indexing, resulting in precise matching between customers and sellers.

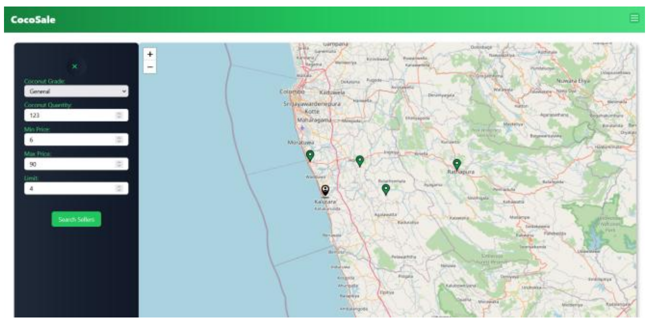

Figure 9: Screen Capture Interactive map

Route Calculation Performance

The implemented hybrid route calculation algorithm has shown promising results in optimizing coconut transportation routes in Sri Lanka. The algorithm considers both the shortest path and fuel efficiency, aiming to minimize distance and fuel

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consumption. Through extensive testing and evaluation, the performance of the algorithm was assessed using real-world scenarios and data.

In terms of route accuracy, the algorithm successfully calculated routes that closely aligned with the actual road networks and landmarks in Sri Lanka. By leveraging OpenStreetMap data, the algorithm utilized up-to-date map information, ensuring accurate and reliable route calculations. As an example the coordinates given in "Table. I" were selected as the starting and ending point coordinates. The hybrid route calculation algorithm demonstrated its effectiveness in optimizing fuel efficiency.

Table I: Coordinates of Selected Locations

	Latitude	Longitude	Location description
Start	6.9173013	79.8648130	Colombo10(Town hall), Sri Lanka
End	6.9357027	79.9843311	Kaduwela, Sri Lanka

By incorporating factors such as road conditions, traffic congestion, and vehicle specifications, the algorithm accurately estimated fuel consumption along different route segments. "Fig. 3" shows the resulting route that has been calculated by the routing algorithm.

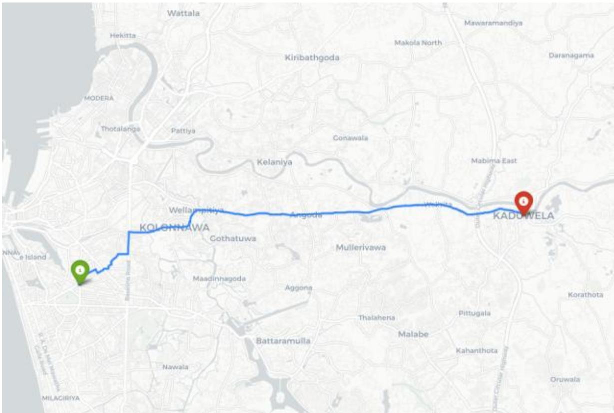

Figure 10: Resulted route

System Performance

The implemented delivery system, consisting of the front-end interface, back-end server, and database, exhibited satisfactory performance during testing and evaluation. The user interface, developed using React JS and Leaflet JS, provided a seamless and intuitive experience for coconut transporters. It allowed them to register, view available orders, and access the calculated routes easily. The real-time map visualization, powered by OpenStreetMap and Leaflet JS, enhanced the transporters' navigation capabilities and facilitated efficient route tracking

Additionally, the system as it is now implemented does not take dynamic elements like weather or road closures into account. Real-time data feeds could be incorporated in future improvements to allow the system to change routes in response to changing conditions. Route estimates would be more precise and adaptive if integration with external APIs or services that give weather updates and traffic information were implemented.

Finally, expanding the system's capabilities to include features like real-time tracking of coconut transporters, automated order allocation, and intelligent route adjustments would further enhance the system's functionality and value proposition.

IV. CONCLUSION

In conclusion, the development and implementation of the coconut grading system using image processing techniques represent a significant advancement in the field of agricultural automation. The integration of size and color parameters for grading purposes has proven to be effective in accurately categorizing coconuts based on their quality and market value. This research successfully demonstrated that image processing technology can greatly enhance the efficiency and precision of traditional coconut grading methods.

Through the course of this study, it has become evident that the size and color parameters, when combined, offer a more comprehensive evaluation of coconut quality compared to individual parameters alone. The accuracy achieved by our developed system indicates its potential for widespread adoption within the coconut industry, leading to increased productivity and reduced labor costs. By automating the grading process, coconut farmers and distributors can minimize human error and subjectivity, resulting in consistent and reliable grading outcomes.

Additionally, the utilization of image processing technology offers scalability and adaptability, enabling the system to accommodate variations in coconut size and color across different geographical regions and varieties. This adaptability enhances its potential for global implementation and contributes to the sustainable growth of the coconut industry.

However, as with any technological innovation, there are avenues for further research and improvement. The current system's accuracy could be further refined through the incorporation of machine learning algorithms, enabling the system to learn and adapt to subtle variations in size and color. Moreover, exploring the integration of additional parameters such as shape and texture could potentially enhance the grading system's robustness and precision.

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In conclusion, the coconut grading system developed in this research holds promise for revolutionizing the coconut industry by streamlining the grading process and improving overall efficiency. As technology continues to advance, there is ample opportunity for collaboration between agricultural experts, image processing specialists, and machine learning practitioners to further refine and optimize the system. This research paves the way for a future where technology and agriculture seamlessly converge, resulting in higher-quality products, increased profitability for farmers, and enhanced consumer satisfaction.

In conclusion, the hybrid route calculation algorithm and delivery system presented in this research paper have shown promising results for optimizing coconut transportation routes in Sri Lanka. The algorithm's ability to consider both the shortest path and fuel efficiency has led to efficient and cost effective route planning for coconut transporters.

The system's usability, productivity, and customer satisfaction were assessed through testing and user feedback. However, there are still room for advancements, such as adding real-time data, sharpening fuel usage projections, and boosting system capabilities. The findings of this study show that the hybrid route calculation algorithm and the created delivery system have the potential to considerably increase the efficiency and effectiveness of coconut transportation in Sri Lanka. The findings open the way for future study and breakthroughs in logistics and transportation system optimization for specific sectors and geographical contexts.

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