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Empowering Pregnant Women with Tailored Food Recommendations through K-Nearest Neighbors in Android Application

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ABSTRACT

When at a restaurant, pregnant women often face difficulties in choosing healthy and appropriate foods during pregnancy, primarily due to lack of knowledge, uncertainty about food ingredients, and difficulty in remembering the list of foods to avoid. This research aims to assist restaurants and pregnant women in avoiding consuming foods containing unhealthy ingredients for pregnant women. Our solution is to develop an Android-based application that can detect foods containing ingredients that pregnant women should not consume and then offer alternative foods that are similar to those foods. The application is developed using the Rapid Application Development method, and the algorithm used is the K-nearest Neighbor. The application has been tested with a User Acceptance Test with an 84-90% acceptance rate.

ABSTRAK

Pada saat di restaurant, ibu hamil seringkali mengalami kesulitan dalam memilih makanan sehat dan sesuai selama kehamilan, terutama karena kurangnya pengetahuan, ketidakpastian tentang bahan makanan, dan sulitnya mengingat daftar makanan yang sebaiknya dihindari. Penelitian ini bertujuan membantu pihak restoran dan ibu hamil untuk menghindari ibu hamil mengonsumsi makanan yang mengandung bahan-bahan tidak sehat untuk ibu hamil. Solusi yang kami tawarkan adalah dengan mengembangkan sebuah aplikasi berbasis Android yang dapat mendeteksi makanan yang mengandung bahan-bahan yang sebaiknya dihindari oleh ibu hamil, dan kemudian menawarkan alternatif makanan yang memiliki kemiripan dengan makanan tersebut. Aplikasi ini dikembangkan menggunakan metode Rapid Application Development dan algoritma K-nearest Neighbor. Aplikasi telah diuji melalui *User Acceptance Test* dengan tingkat penerimaan sebesar 84-90%.

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INTRODUCTION

Food is one of the crucial aspects of human life. Besides serving as an energy source, food also plays a role in maintaining health and the balance of bodily nutrients (Thirumdas et al., 2021).

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Humans have diverse nutritional needs, including protein, carbohydrates, fats, vitamins, and minerals, which must be met through a balanced and varied diet (Ofoedu et al., 2021). Pregnant women must maintain a balanced diet and meet their bodies' nutritional needs because insufficient nutrition during pregnancy often results from consuming foods that do not meet the required dietary standards (Jardí et al., 2019).

All the food and beverages consumed by pregnant women have a significant impact on the health of their unborn babies (Tobing et al., 2019). Therefore, it becomes crucial to identify the foods and drinks that should be avoided during this period. Firstly, caution should be exercised when consuming raw or undercooked food (de Seymour et al., 2022). Additionally, extra care should be taken when consuming dairy products, and dairy products should be approached with caution as well (Rehman et al., 2020). Certain fruits and vegetables must also be avoided (Tufail et al., 2023). It includes unripe papaya, pineapple, and durian fruit. Furthermore, specific vegetables such as chili peppers, bitter gourd, raw bean sprouts, and potatoes should be kept off the pregnant woman's menu (Seal, 2023).

However, pregnant women often struggle to remember foods that should be avoided and feel uncertain about the ingredients used in restaurant dishes. Several practical solutions can be implemented to assist pregnant women in remembering foods to avoid during pregnancy. Firstly, using a mobile application or website that provides a list of safe and unsafe foods and creating a shopping list containing permitted and non-permitted foods can help pregnant women remember the types of foods to avoid and select foods that meet their nutritional needs. Additionally, collaborating with restaurants to obtain information about the ingredients used in their dishes can also help pregnant women choose safe and healthy menu options. Furthermore, reminders or alarms on mobile phones or other devices can be a practical solution to remind pregnant women about foods to avoid regularly. Combining these solutions allows pregnant women to maintain a healthy and safe eating pattern during pregnancy more easily. This research aims to develop an Android-based application in a restaurant that can remind pregnant women and restaurant staff to avoid food orders containing unhealthy ingredients for pregnancy.

Previous research has developed an application that recommends food using a genetic algorithm (Hermawan et al., 2021). Other studies have created tailored diet guidelines for pregnant women (Kim et al., 2013). What sets this research apart from previous studies is its focus on assisting pregnant women in choosing healthy foods during pregnancy. This study differs in that it will develop an Android-based application that both restaurants and pregnant women can use to avoid foods containing harmful ingredients for pregnancy. It will utilize clustering algorithms to recommend foods similar to those avoided. This study employs the K-Nearest Neighbor (K-NN) algorithm to achieve this goal. The K-NN algorithm is a machine-learning technique categorized as lazy learning (Sinaga & Suwilo, 2020). It operates by finding the k-nearest training data points in a feature space that closely resembles the new or testing data points being analyzed. In this study, the K-NN algorithm recommends suitable food options for pregnant women based on similarities to known safe and nutritious choices. By leveraging the K-NN algorithm, this study aims to simplify the food selection process for pregnant women. The hope is that both pregnant women and restaurants can collaborate effectively so that pregnant women can avoid consuming foods that are unhealthy for pregnancy.

METHODS

Research Object and Data Collection

This research examines the array of culinary offerings at Port Five Six restaurant. Established in January 2017 and located in Gading Serpong, it is renowned for its diverse dishes. Embracing the concept of an Australian brunch and coffee shop, the restaurant primarily specializes in Western-style cuisine. However, it also accommodates the preferences of Indonesian residents by featuring rice dishes complemented by a variety of side dishes. This amalgamation of culinary styles enables the restaurant to cater to a broad clientele, offering traditional Indonesian cuisine and unique Western-inspired delicacies.

After data is gathered from the restaurant, it is partitioned into two sets for analysis and evaluation. The more significant portion, constituting 80% of the dataset, is allocated to the training set. This portion trains machine learning models or algorithms, allowing them to learn patterns and relationships inherent within the data. The remaining 20% of the data is allocated to the testing set, an independent dataset used to assess the performance and generalization capability of the trained models.

Rapid Application Development (RAD)

The chosen approach for designing and developing this application is RAD. RAD is an object-oriented method that reduces the time typically required in traditional system development (Wiratama et al., 2022). It focuses on meeting rapidly changing business requirements. As shown in Figure 1, the RAD methodology includes phases such as Requirement Planning, User Design, Construction, and Cutover (Oetama & Andila, 2023). During Requirement Planning, stakeholders are consulted to identify user requirements. The User Design phase involves creating, testing, and refining Unified Modelling Language (UML) prototypes. The Construction phase uses the Android operating system to build mobile device applications. Meanwhile, in Cutover, testing includes user acceptance testing.

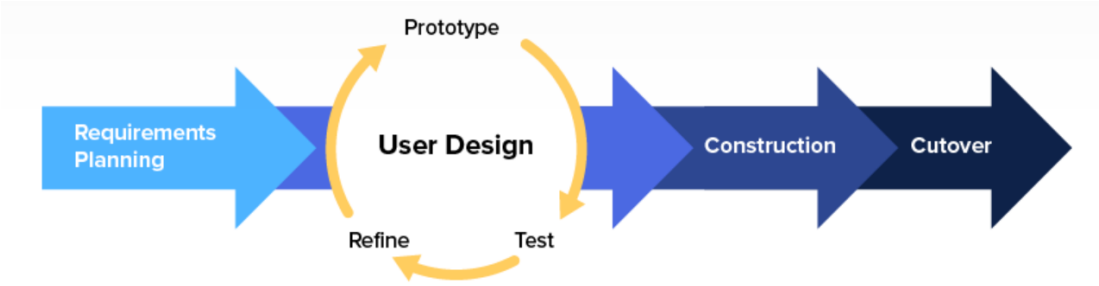


Figure 1. Rapid Application Development (Oetama & Andila, 2023)

K-Nearest Neighbors (KNN) Algorithm

Evelyn Fix and Joseph Hodges are recognized for their initial contributions to the concept of the KNN model in 1951 (Mladenova & Valova, 2022). Thomas Cover further developed their ideas in his research. The KNN model is precious in situations where obtaining labeled data is costly or not feasible (Killamsetty et al., 2021), and it demonstrates high accuracy in various prediction problems (Itoo et al., 2021), (Uddin et al., 2022). KNN is a straightforward algorithm that relies on identifying the local minimum of the target function to learn an unknown function with the desired precision and accuracy. The K-Nearest Neighbors algorithm measures the distances between instances and selects the closest neighbors. Suppose we have menu(a) with a set of ingredient flags $\{i_{1a}, i_{2a}, i_{3a}, \ldots i_{na}\}$ and menu(b) with a set of ingredient flags menu(b) with ingredient flags $\{i_{1b}, i_{2b}, i_{3b}, \ldots i_{nb}\}$. The Euclidean distance between two menus is calculated using formula (1).

$$E(a,b) = \sqrt{(i_{1a} - i_{1b})^2 + (i_{2a} - i_{2b})^2 + (i_{3a} - i_{3b})^2 + \cdots + (i_{na} - i_{nb})^2} \quad (1)$$

The Pseudocode of KNN is shown in Figure 2. Following is an explanation of the steps involved in the KNN algorithm in this study:

1. **Determining the Value of k**: The parameter k in KNN represents the number of nearest neighbors to consider when making predictions. It needs to be resolved before running the algorithm. The choice of k can significantly impact the model's accuracy and performance. In this study, k is 4, meaning the food options for pregnant women consist of 4 healthy menus.

2. **Calculating Euclidean Distance**: For each sample in the testing set, the KNN algorithm calculates the Euclidean distance between that sample and all samples in the training set. The Euclidean distance measures the straight-line distance between two points in a multidimensional space. It is used to quantify the similarity or dissimilarity between samples.
3. **Selecting the Nearest Neighbors**: After calculating the distances, the algorithm determines the k-training samples closest to the current testing sample. These samples are the "nearest neighbors" and will be used to predict the future of the testing sample.
4. **Prioritizing Based on Distance**: The nearest neighbors are prioritized based on the order of their distances. Typically, neighbors within smaller distances are given higher Priority. This prioritization is crucial for accurate predictions since closer neighbors are considered more like the current testing sample.
5. **Displaying Prioritized Training Data**: the algorithm shows the training data that has obtained priorities from 1 to k as healthy food options for pregnant women.

```
function KNN (training_data, testing_data, k):
    // Collect data
    data= collect_data()
    testing_data = select_harmlessFood(data)
    training_data = select_harmFood(data)
    // Initialize a list to store the prediction results
    predictions = []
    for each_test in test_data:
        // Calculate Euclidean distance to all training data
        distances = []
        for each_train in train_data:
            distance = calculate_euclidean_distance(each_test, each_train)
            distances.append((distance, each_train))
        // Sort the training data based on the smallest to largest distance
        distances.sort(key=lambda x: x[0])
        // Select the k nearest training data
        nearest_neighbors = distances[:k]
        // Create priorities based on the order of smallest to largest distance
        priorities = [x[1] for x in nearest_neighbors]
        // Add priorities to the prediction results
        predictions.append(priorities)
    // Show the training data that have obtained priorities from 1 to k
    for i in range(k):
        print(predictions[i])
    return predictions
```

Figure 2. KNN pseudocode to show healthy food options for pregnant women.

RESULT AND DISCUSSION

Requirement and Planning

During the initial phase, a thorough analysis of The Company's business processes was conducted to identify the needs and challenges associated with user requirements. Direct interviews were conducted with the company owners to gather insights. The interviews revealed that The Company faced specific issues, and several proposed solutions were agreed upon, as indicated in Table 1. The PIECES analysis method was applied to categorize the identified problems based on specific indicators. Consequently, several key features were identified as necessary for the system, including User Management, Customer Management, Sales Report Management, Stock Management, Sales Transaction Management, and Customer Management.

Table 1. PIECES Analysis

PIECES	Current Issues in The Company	Proposed Solution
Performance	The process is still manual	Manage Users: The Admin can add, edit, and delete users who access the system.
Information	The manual searching menu is time-consuming.	Search Menu: the search menu will help make searching for food and drink easier and faster
Economics	Manual order notes cause time consumption and wrong order.	Make an order: Able to create and export reports.
Control	Manual control by memorizing menu categories causes the potential for wrong information.	Manage Menu: Able to perform adding and editing menu categories and menu data.
Efficiency	Payment is calculated manually, inefficient in recording costs and time, and the risk of human error.	Make Payment: Able to show billing and pay action to confirm payments.
Service	There is no recommendation menu for a pregnant woman	Show Recommendation: The system can show four menus for a pregnant woman

User Design

Use case diagrams are drawn from the Proposed Solution, as seen in Figure 3. The restaurant system's use case diagram involves two main actors: the Admin and the User. The Admin has several responsibilities, including managing users, creating, editing, and deleting user accounts, assigning roles and permissions, and viewing and updating user information. Another critical task for the Admin is managing the menu, which includes adding, editing, and deleting menu items, updating their availability and prices, and categorizing them for better organization. The Admin can also search for and quickly retrieve relevant menu items.

Figure 3. Use Case Diagram

Additionally, the Admin can provide recommendations for pregnant women, notifying them of foods unsuitable for pregnancy and suggesting other options. The Admin can make orders on behalf of customers, creating and modifying customer orders. Once an order is completed, the

Admin can process customer payments, including generating receipts and handling payment transactions. On the other hand, users also have capabilities similar to the Admin, but limited to the search menu, showing recommendations, making orders, and making payment functionalities. Users can search the menu, view recommendations, create orders, and process payments for completed orders.

Construction

The step-by-step KNN in the prototype is shown in Figure 4. Figure 4(a) shows the menu broken down to its ingredients in the restaurant. The Salted Egg Yolk Chicken menu contains Rice, Sunny Side Up, Fried Chicken, and Salted Egg Yolk Sauce in the first row. Afterward, four menu examples comprised Smash Chicken, Chasu Don, Ontama Grill Chicken, and Classic Gyudon. There are various homemade sauces prepared by the staff in the kitchen, but not all sauces are safe for pregnant women to consume. Some sauces at the restaurant are made with undercooked egg yolks, which can harm pregnant women. Sauces with undercooked egg yolks as their main Ingredient include aioli, salted egg yolk sauce, and hollandaise sauce. Because they contain undercooked egg yolks, pregnant women are not recommended to consume dishes that include these sauces (de Silva et al., 2020). Since Salted Egg Yolk Chicken contains harmful ingredients for pregnant women, it is highlighted in gray.

Furthermore, if a customer chooses Salted Egg Yolk Chicken, the system will set a warning flag to true. The system will then provide alternative healthy menus for pregnant women. The Euclidean distance will be calculated from each training data to the Salted Egg Yolk Chicken, as shown in Figure 4(b). The distance from Salted Egg Yolk Chicken to Chasu Don is 1.41 until reaching Smash Chicken at 2.00. Next, the priority order will be determined based on the smallest to most considerable distances. Thus, the healthy menu options for pregnant women are Chasu Don as the First Priority, Smash Chicken as the second Priority, Classic Gyudon as the third, and Ontama Grill Chicken as the last Priority.

Ingredients	Salted Egg Yolk Chicken	Chasu Don	Classic Gyudon	Ontama Grill Chicken	Smash Chicken
Rice	1	1	1	1	1
Sauce Vide Egg 62.5	0	0	1	1	0
Sunny Side Up	1	1	0	0	1
Fried Chicken	1	1	0	0	1
Steak	0	0	0	0	0
Beef	0	0	1	0	0
Chicken Teriyaki	0	0	0	1	0
Tomato	0	0	0	0	1
Coriander	0	1	0	0	0
Cucumber	0	0	0	0	1
Salted Egg Yolk Sauce	1	0	0	0	0
Sambal	0	0	0	0	1

(a)

Ingredients	Salted Egg Yolk Chicken	Chasu Don	Classic Gyudon	Ontama Grill Chicken	Smash Chicken
Rice	0	0	0	0	0
Sauce Vide Egg 62.5	0	0	1	1	0
Sunny Side Up	0	0	1	1	0
Fried Chicken	0	0	1	1	0
Steak	0	0	0	0	0
Beef	0	0	1	0	0
Chicken Teriyaki	0	0	0	1	0
Tomato	0	0	0	0	1
Coriander	0	1	0	0	0
Cucumber	0	0	0	0	1
Salted Egg Yolk Sauce	0	1	1	1	1
Sambal	0	0	0	0	1
Eucledian Distance	0	1.41	2.24	2.24	2.00
Priority	0	1	3	4	2

(b)

Figure 4. Menu and Ingredient consist of (a) original and (b) added with Euclidean distance and Priority.

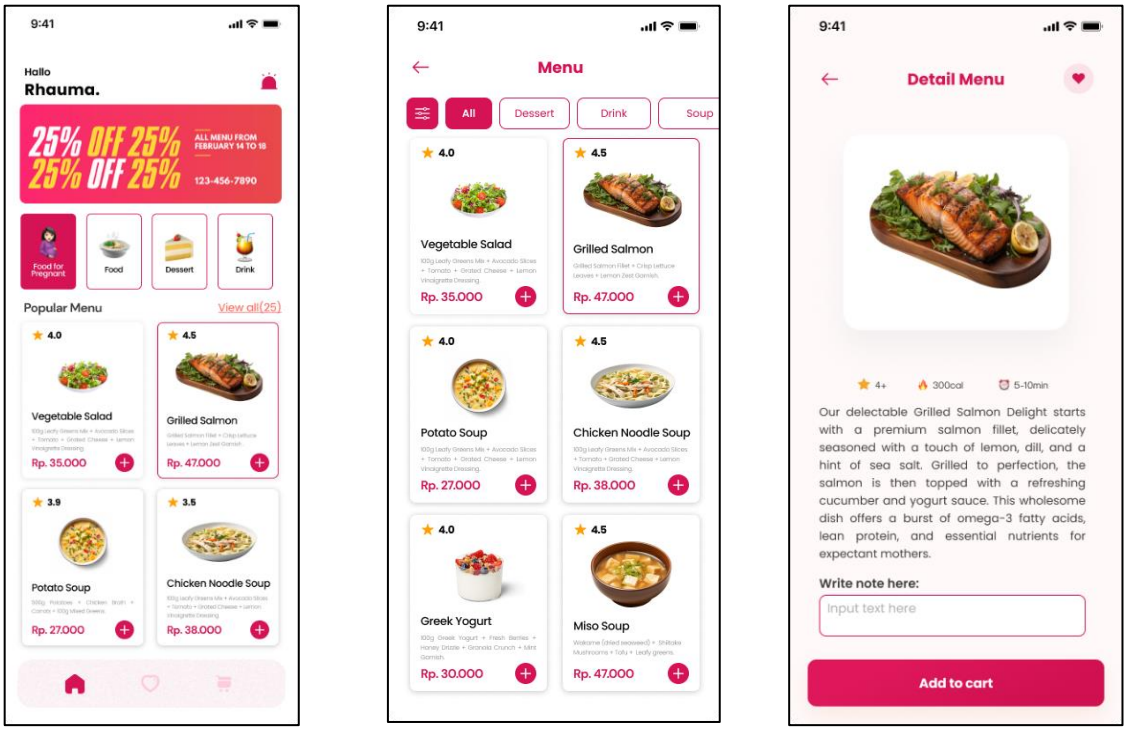
Furthermore, the process continues with other unhealthy food menus as new testing data. The results are shown in Table 2. The salted egg yolk chicken choices are Chasu Don until Ontama Grill Chicken. Alternative options from Port Five Six to Aglio Olio are provided for the Big Breakfast menu. In contrast, the Breaky Croissant menu offers choices from Toasted Brioche

Cendol/Honey to PBJ Waffle. All these options will be stored in the database to facilitate the application of other healthy food menu choices for pregnant women.

Table 2. KNN Results

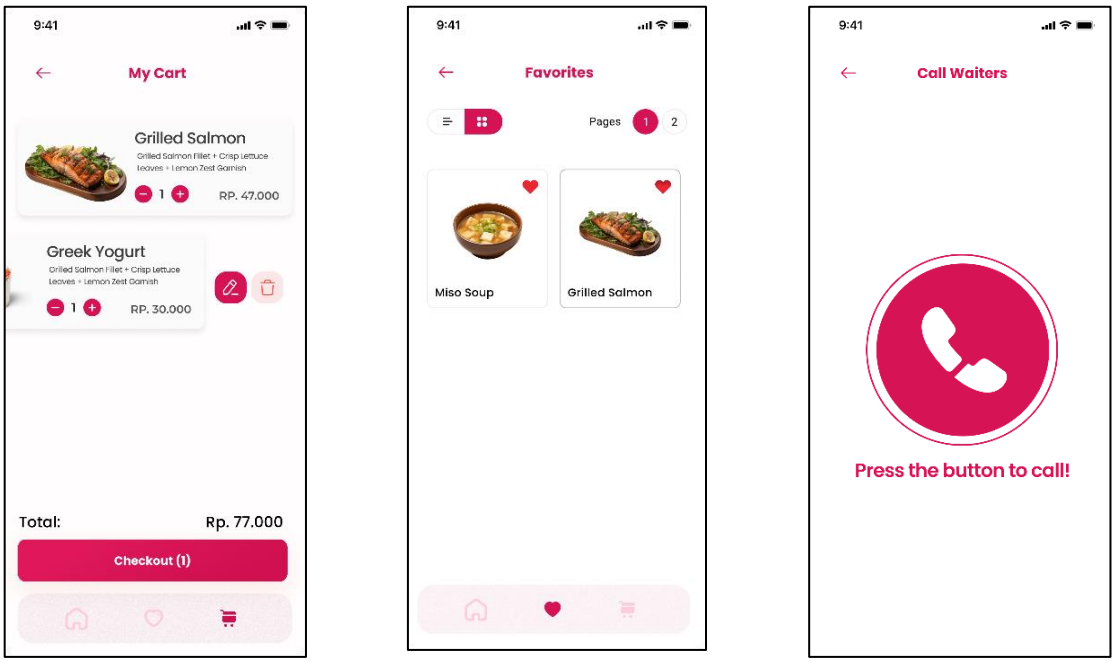
Priority	Group-1	Group-2	Group-3
Zero (unhealthy)	Salted Egg Yolk Chicken	Big Breakfast	Breaky Croissant
First	Chasu Don	Port Five Six	Toasted Brioche Cendol/ honey
Second	Smashed Chicken	Steak & egg	Cendol Croissant
Third	Classic Gyudon	Beef&mushroom	Chicken Waffle
Fourth	Ontama Grill Chicken	Aglio Olio	PBJ Waffle

The User interfaces shown in Figure 5 and Figure 6 depict the application's main features seamlessly integrated into a tablet interface, facilitating interactions between users, waiters, and the restaurant's offerings. On the main page, as shown in Figure 5a, users are greeted with a central hub showcasing the restaurant's branding and navigation options, serving as a gateway to various functionalities. The restaurant menu (Figure 5b) provides a comprehensive overview of available dishes, allowing users to browse categories and view detailed descriptions, prices, and images. Moving to the detail menu (Figure 5c), users can specify quantities and add notes to customize their orders, ensuring their preferences are accurately met. Afterward, My Cart (Figure 6a) acts as a confirmation page, displaying ordered items and total prices for user verification before checking out. Favorites shown in Figure 6b offer tailored suggestions for pregnant women, promoting healthier choices. Finally, the Call Waiters feature (Figure 6c) enhances user experience by enabling direct communication with restaurant staff for assistance.



(a) (b) (c)

Figure 5. User Interface Construction Results including (a) main page, (b) restaurant menu, (c) detail menu



(a) (b) (c)

Figure 6. Next User Interface Construction Results including (a) my Cart, (b) favorites, (c) Call waiters

Cutover

Table 3. User Acceptance Test

Features	Scenario	Expected Result	Score	Average
Manage users	CRUD users	Admin successfully creates, reads, and deletes users.	88	88
Manage menu	CRUD menu	Admin successfully creates, reads, and deletes the menu.	90	90
Features	**Scenario**	**Expected Result**	**Score**	**Average**
Search Menu	Users can search the menu	The Admin and User can view the list of available foods at the restaurant, including options for food items that can be selected successfully. Users can also successfully press a call waitress to ask for help.	81 89 89	86.33
Show recommendation	Users can make a recommendation for a pregnant woman	The system shows a warning if the food chosen is unhealthy for pregnant women. The button sees suggestions works successfully. The button back also works successfully,	88 80 86	84.67
Make order	Users can make an order.	Users can choose a menu, specify the number of portions, and successfully place an order by pressing the order button. Additionally, users can successfully cancel their orders.	84 86 82	84
Make Payment	Users can make payments.	The system displays the bill, and the User can successfully press the pay button. The payment process is carried out without any issues.	89 81 88	86

Testing is conducted in the testing phase once the system has been completed in the programming phase. Testing involves the process of identifying errors and issues within the system and recording the results of those errors. It also entails evaluating the system that has been developed. Testing ensures the system meets the standards, conditions, and specifications defined during the design phase. If errors are identified during testing, necessary corrections are made, and retesting is performed until the system functions properly and efficiently. The testing plan for the Food Recommendation for Pregnant Mothers at the restaurant will utilize the User Acceptance Test. 1 Admin and two users are involved in this testing. They score each application feature with a score of 1 to 100. During the User Acceptance Testing, the acceptance level of features was evaluated using scoring intervals. These intervals classified the scores, ranging from firmly rejected to strongly accepted. Specifically, scores between 0 and 25 were considered firmly rejected, scores between 26 and 50 were classified as abandoned, scores between 51 and 75 were considered accepted, and scores between 76 and 100 were classified as firmly received. In Table 3, the average acceptance level for each feature can be observed. The average acceptance levels for these features range from 84 to 90. The average scores within the 84 to 90 range demonstrate that many features were well-received and successfully implemented. This level of acceptance indicates that the features performed effectively and fulfilled the users' needs. The User Acceptance Testing results suggest that the features have met the desired standards and have been deemed satisfactory by the users involved in the testing process.

CONCLUSION

To help pregnant women make informed choices, an effective method like the KNN algorithm can provide food recommendations based on similarities to known safe and nutritious options. The chosen method for designing and developing this application is Rapid Application Development (RAD). RAD is an object-oriented approach that aims to reduce development time and meet rapidly changing business requirements. The RAD methodology comprises phases such as Requirement Planning, User Design, Construction, and Cutover. During Requirement Planning, stakeholder consultation is conducted to identify user requirements. User Design involves creating, testing, and refining prototypes using UML. The Construction phase involves developing the mobile device application using the Android operating system. User Acceptance Testing is performed for testing. The restaurant system's use case diagram includes functionalities for managing users, menu items, and orders. It allows for user management, menu management, menu search, recommendations for pregnant women, order creation and modification, and payment processing. The User Acceptance Testing results indicate that many features were well-received and successfully implemented, with average acceptance levels ranging from 84 to 90. This demonstrates that the features performed effectively and met the users' needs. Overall, the User Acceptance Testing confirmed that the features met the desired standards and were deemed satisfactory by the testing participants.

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