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INTEGRATING AUGMENTED REALITY WITH C4.5 ALGORITHM TO ENHANCE TOURISM EXPERIENCE IN PEKALONGAN

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Abstract— *The tourism industry demands interactive and personalized solutions to enhance the traveler experience. However, providing relevant and customized travel recommendations based on individual preferences remains a challenge. This study integrates Augmented Reality (AR) technology with the C4.5 algorithm to address this issue and improve the tourism experience in Pekalongan Regency. The research method involved collecting data from 500 respondents through an online questionnaire. The collected data underwent preprocessing, including handling missing data, data transformation, and class balancing. The C4.5 algorithm was applied to build a tourism recommendation model, while AR technology presented 3D visualizations of tourist destinations through an interactive application. The research results show that the recommendation model achieved an accuracy rate of 76.92%. The integration of AR provided an interactive experience that enhanced tourist engagement and satisfaction, although limitations were found in AR visualization quality and the completeness of destination information. Further improvements are needed to enhance AR realism, provide more detailed content, and optimize user satisfaction. This study contributes to the development of AR-based tourism technology integrated with the C4.5 algorithm. The findings encourage local tourism innovation and have the potential to enhance the traveler experience in Pekalongan Regency. This model can also be applied to other tourist destinations across Indonesia.*

Keywords*: augmented reality, C4.5 algorithm, machine learning in tourism, personalized tourism experience, tourism recommendation system.*

Intisari— *Industri pariwisata menuntut solusi interaktif dan personalisasi untuk meningkatkan pengalaman wisatawan. Namun, penyediaan rekomendasi perjalanan yang relevan dan disesuaikan dengan preferensi individu masih menjadi tantangan. Penelitian ini mengintegrasikan teknologi Augmented Reality (AR) dengan algoritma C4.5 untuk mengatasi masalah tersebut dan meningkatkan pengalaman pariwisata di Kabupaten Pekalongan. Metode penelitian melibatkan pengumpulan data dari 500 responden melalui kuesioner daring. Data yang dikumpulkan melalui proses pra pemrosesan, termasuk penanganan data yang hilang, transformasi data, dan penyeimbangan kelas. Algoritma C4.5 diterapkan untuk membangun model rekomendasi wisata, sedangkan teknologi AR menyajikan visualisasi 3D destinasi wisata melalui aplikasi interaktif. Hasil penelitian menunjukkan bahwa model rekomendasi mencapai tingkat akurasi sebesar 76,92%. Integrasi AR memberikan pengalaman interaktif yang meningkatkan keterlibatan dan kepuasan wisatawan, meskipun terdapat keterbatasan dalam kualitas visualisasi AR dan kelengkapan informasi destinasi. Peningkatan lebih lanjut diperlukan untuk meningkatkan realisme AR, menyediakan konten yang lebih rinci, dan mengoptimalkan kepuasan pengguna. Penelitian ini berkontribusi pada pengembangan teknologi pariwisata berbasis AR yang terintegrasi dengan algoritma C4.5. Temuan ini mendorong inovasi pariwisata lokal dan berpotensi meningkatkan pengalaman wisatawan di Kabupaten Pekalongan. Model ini juga dapat diterapkan di destinasi wisata lainnya di seluruh Indonesia.*

Kata Kunci*: augmented reality, algoritma C4.5, machine learning dalam pariwisata, pengalaman wisata personal, sistem rekomendasi wisata.*

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INTRODUCTION

Tourism is an important economic sector for Pekalongan Regency due to its abundant natural, historical, and cultural potential that can be developed. Despite this promising potential, tourism is currently not fully optimized due to the lack of adequate information for visiting tourists [1]. This is consistent with the findings of Bretos et al. [2], who stated that many tourist destinations have not maximized digital technology to provide interactive and engaging information for visitors. In the digital age, travelers increasingly desire more personalized and interactive experiences. Augmented Reality (AR) can provide real-time information, enriching the travel experience in a more engaging and immersive manner. According to Han et al. [3], AR can increase the value of the tourist experience, especially in the context of heritage tourism, by providing in-depth information about the history and culture of a place. In addition, Jiang et al. [4] found that AR can enhance the tourist experience at historical sites by delivering information through visually appealing media, making the experience more thorough and memorable. Rizal et al. [5] demonstrated that AR can be effectively used as a learning and promotional medium in a local context, revealing its potential for broader applications in digital tourism. Then Zhang et al., [6] in their work, said that by using AR information that can be accessed in real time, this makes the traveling experience increase. However, most previous studies have focused on using AR as a standalone tool without integrating it with analytical methods, such as classification algorithms. Despite the promising applications, there is still a gap in combining AR with data-driven recommendation systems.

In this research, classification algorithms, such as C4.5, are used to classify traveler preference data based on demographic information, interests, and travel history. According to research by Suherman et al. [7], C4.5 has proven effective in predicting preferences based on various factors. The data generated from this classification process can then be integrated into the AR system, enabling tailored tourist destination recommendations for each tourist. Additionally, combining AR technology with data-driven recommendation systems can optimize the way tourists interact with information during their trips. For example, Zhang et al. [6] explored the impact of location-based AR on tourists' behavior and their intention to visit specific destinations, showing that AR influences tourists' decisions by providing more relevant, real-time information. Dewi and Ikbal [8] also noted that high-quality AR design can strengthen the promotion of local tourist destinations, although the visual quality and content still need to be improved to meet user expectations. The novelty of this research lies in its integration of AR with the C4.5 classification algorithm to provide personalized tourism recommendations. While previous studies have explored AR or classification algorithms individually, this research combines both to enhance the tourism experience in a way that has not been fully addressed in existing literature. As noted by Kalloori et al. [9], AR-based recommendation systems in the tourism sector are still relatively rare, emphasizing the need for further exploration of data-driven recommendation systems to provide more customized and engaging tourism experiences. Moreover, Rane et al. [10] highlighted the importance of advanced technologies such as AR and AI in fostering sustainable and interactive tourism development, which is crucial for promoting local tourist destinations. The following Table 1 presents a review of previous literature to highlight the novelty and originality of this study.

Table 1. previous study

Author	Previous study	This study
[2]–[6], [11]	using only AR without integration with classification algorithms	this research will integrate both
[7], [9], [10], [12], [13]	using the classification algorithm without AR	this research will integrate both

Source: (Research Results, 2024)

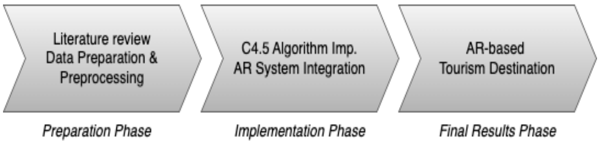
The main objectives of this research are to integrate Augmented Reality (AR) technology with the C4.5 algorithm to improve the tourist experience in Pekalongan Regency, create a recommendation system that provides personalized tourist destination suggestions based on traveler demographics, interests, and travel history, and to evaluate the effectiveness of AR combined with classification algorithms in promoting local tourist destinations. This research aims to address the existing gap in digital tourism by combining AR with machine learning algorithms, offering a novel and data-driven approach to enhancing the tourism experience and promoting local destinations in Pekalongan Regency.

MATERIALS AND METHODS

Research flow

Figure 1 outlines the research process, which includes a literature review, data preparation, preprocessing, the implementation of the C4.5

algorithm, and the deployment of AR-based applications for tourist destinations.



Source: (Research Results, 2024)
Figure 1. Research flow

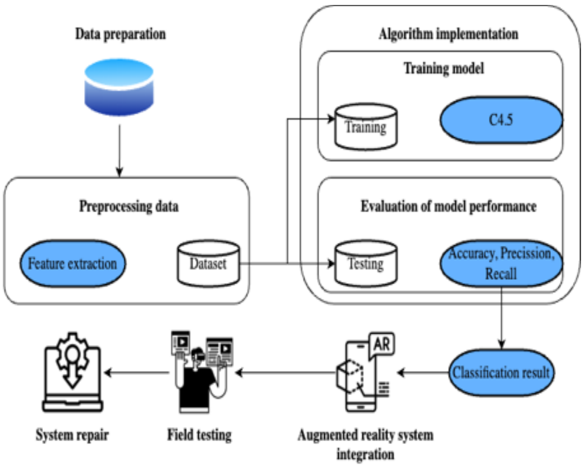
Review of Related Literature

This research builds upon previous studies on tourism management and technology applications, particularly in enhancing tourist experiences. While many existing studies emphasize the role of Augmented Reality (AR) in enriching tourism experiences through immersive and interactive features [2], [3], [11], they often treat AR as a standalone tool rather than integrating it with data-driven personalization systems. AR has been widely used to provide historical or cultural narratives through visual devices, making travel experiences more engaging and informative [4], [8].

However, these implementations typically lack adaptive mechanisms that adjust recommendations based on user preferences. A key limitation of previous research is the absence of an intelligent recommendation system that combines AR with classification algorithms. Studies such as Zhang et al. [6] focused on AR as a location-based information tool but did not incorporate user preferences into the experience. In contrast, this study integrates AR with the C4.5 classification algorithm, which has been proven effective in categorizing users based on various attributes, such as travel interests and demographic factors [7], [12]. Unlike prior studies that rely solely on AR content delivery, this research introduces a data-driven approach to dynamically adjust recommendations, enhancing personalization and user engagement. The methodological differences are also notable. Many previous studies rely on static datasets or pre-defined content delivery models, which do not adapt to individual user profiles.

This research, however, utilizes a three-stage process: (1) data collection through digital forms to collect user preferences, (2) classification using the C4.5 algorithm to group users based on their travel interests, and (3) integration of the classification results into an AR-based system to provide real-time customized recommendations. Details of the AR system implementation can be seen in (figure 5) in the results and discussion section. Compared to prior research, this approach not only improves personalization but also enhances decision-making accuracy through intelligent classification mechanisms [7], [13]. Another key differentiation is the validation approach. While past studies typically focus on AR usability or general engagement metrics, this research evaluates system effectiveness based on classification accuracy, user satisfaction, and interactive experience quality. For example, unlike studies that only assess AR's ability to provide visual enhancements [6], this study incorporates user feedback to measure how well the system adapts to individual preferences and enhances travel experiences [10].

By bridging the gap between AR and intelligent recommendation systems, this research goes beyond conventional implementations. Unlike previous studies that treat AR as a passive information provider, this research leverages the C4.5 algorithm to actively tailor experiences based on data-driven insights. This aligns with findings from Rane et al. [10], who emphasized the need for AI and AR integration in creating more sustainable and interactive tourism solutions. Ultimately, this study contributes to a more sophisticated and user-centric approach to smart tourism. For the integration stage of AR and classification, as shown in the following figure 2.



Source: (Research Results, 2024)
Figure 2. stage of AR and classification
The detailed stages will be explained in the next section.

Data Preparation and Preprocessing

1. Data preparation

The researchers conducted the data collection process with a modern and effective approach, namely through the online distribution of questionnaires. To achieve broad participation, the questionnaire was distributed digitally through the Google Forms platform, which can be easily accessed by local communities through the link https://forms.gle/AYPzjpuJRYs6TTy77.

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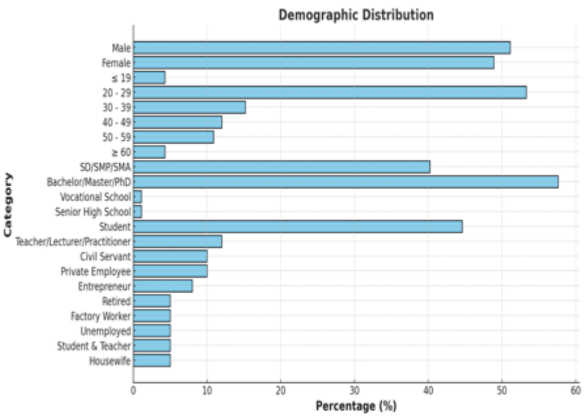
The questionnaire was comprehensively designed to collect a range of demographic data and travel preferences crucial to the research. Some of the key attributes to focus on include information on gender, age, education level, employment type, and interest in the destination. With this information, researchers hope to build an in-depth profile of the characteristics of the local community and their preferences for tourism in the area. The data collected will play an important role in the next stage of analysis. Through this approach, the researcher not only obtained accurate and relevant data but also involved the local community directly in the research process, giving them the opportunity to contribute to the improvement of their local tourism sector. Hopefully, the results of this questionnaire will provide valuable insights and serve as a strong foundation for the next stage of the research. detailed data can be seen in figure 3 below.



Source: (Research Results, 2024)
Figure 3. demographic distribution

2. Data preprocessing

The data used for this study came from 500 people who answered a questionnaire survey. To ensure that the data to be used in further analysis and modeling processes is ready and of optimal quality, several stages of feature extraction were performed on this data. In this process, several important steps were carefully taken to address various issues that may arise with the raw data. The data preprocessing process will be discussed in the next section.

A. Handling missing value

At this stage, it will be checked whether there are empty or missing values. The presence of missing data can cause serious problems in the analysis, so the researcher decided to fill these missing values by using the mode value of each attribute. The mode value was chosen because it represents the most frequently occurring category in the data, so it can minimize information distortion [14]. The steps in handling missing value data are presented in the following program code.

```
# Checking for missing data
missing_data = df.isnull().sum()
print(missing_data)
# Fill the missing value with the mode value
df['age'].fillna(df['age'].mode()[0],inplace=True)
df['gender'].fillna(df['gender'].mode()[0],inplace=True)
df['education'].fillna(df['education'].mode()[0], inplace=True)
df['occupation'].fillna(df['occupation'].mode()[0], inplace=True)
```

B. Class Balancing

At this stage, duplicate data will be checked and handled. Duplicate data can cause bias in the model and over-analysis, so it is important to identify and remove duplicate data so that only unique and valid data is used in this study [15]. The steps in handling duplicate data are as in the following code.

```
# Checking for data duplication
duplicates = df.duplicated().sum()
print(f'Length of DataFrame before removing duplicates: {df.shape[0]}')
df = df.drop_duplicates()
print(f'Length of DataFrame after removing duplicates: {df.shape[0]}')
```

C. Class cleaning

At this stage, the data will be checked to ensure that the value is correct. The values in the type_gender column are validated to ensure that they match the predefined categories of “Male” or “Female”. Values that do not fit into these categories will be identified as invalid data, and appropriate steps will be used to deal with them [16]. The following are the steps in dealing with data validity.

```
# Checking for invalid values for the type_gender column
valid_type_gender = ['Male', 'Female']
df = df[df['male'].isin(valid_male)]
```

D. Class transformation

At this stage, data transformation will be carried out including: Category Conversion to Numeric, Changing Attributes to Dummy Variables and Oversampling Technique. Transformation of the category_tourism column into numeric form

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using the LabelEncoder method. This method converts each category in the column into a number, which is very useful for modeling purposes, where machine learning algorithms generally require data in numeric format [17]. Attributes such as age, education, occupation, and sex are then converted into dummy variables (one-hot encoded). This process generates binary columns (0 and 1) for each category, which allows the model to handle categorical data more effectively and without the assumption of order in the categories. Handles the problem of unbalanced classes that may exist in the data. When the class distribution in the data is unbalanced, the model tends to be biased towards the majority class, which may reduce the prediction accuracy for the minority class. To overcome this, oversampling is done with the resampling method, which aims to equalize the number of samples from each class, so that the resulting model becomes more balanced and accurate in prediction. The following code handles data conversion.

```
# Convert category data to numeric data
le = LabelEncoder()
df['category_travel'] =
le.fit_transform(df['category_travel'])
# One-hot encoding for age, education, and
occupation columns
df = pd.get_dummies(df, columns=['age',
'education', 'occupation', 'sex'],
drop_first=False)
# Handle unbalanced classes (if needed)
X = df.drop(columns=['category_travel'])
y = df['category_travel']
X_resampled, y_resampled = resample(X, y,
random_state=42)
```

Implementation of the C4.5 Algorithm

Decision Tree is a machine learning algorithm that recursively divides data into subsets based on the most significant attribute in each node [12]. Each internal node represents a decision based on a particular feature, and each leaf node represents the final decision or result. Some previous studies have also applied Decision Tree for vehicle crashes topic classification case studies [13] and division of regional zones to determine the status of COVID-19 [18]. The C4.5 algorithm was selected in this study because it is suitable for a relatively small dataset, approximately 500 data points. This algorithm has good computational efficiency and does not require complex preprocessing steps, such as normalization or data transformation. Additionally, C4.5 can handle both numerical and categorical attributes directly and effectively manage missing values. Another advantage is its pruning mechanism, which reduces the risk of overfitting and improves model generalization. The classification results in the form of a decision tree are also easier to interpret compared to other black-box models, such as Random Forest or Neural Networks. Previous studies have demonstrated the effectiveness of this algorithm in various fields, including autonomous vehicle crash classification [13], predicting tourist visit potential [19], and comparisons with other models such as Support Vector Machines [12], [20].

RESULTS AND DISCUSSION

This research produces a web prototype that integrates tourism recommendation features, a tourism map, and an Augmented Reality (AR) interface. These features aim to help tourists find destinations that best match their preferences[21]. In the development of the system, this research includes the application of the C4.5 algorithm to provide personalized tourism recommendations, as well as field evaluation to test the effectiveness of the system. Although similar in concept, RandomForestClassifier is not the same as C4.5; it is an ensemble method. The data used in this research has undergone a resampling process to ensure a more balanced class distribution [19]. Code below illustrates the resampling process performed on the training data to ensure a more balanced class distribution. This technique aims to reduce bias toward the majority class, so that the model can provide more fair and accurate predictions for all tourism categories.

```
# Split the data into training and testing sets
X_train, X_test, y_train, y_test =
train_test_split(X_resampled, y_resampled,
test_size=0.2, random_state=42)
# Train the model using C4.5 with more cautious
settings
clf = RandomForestClassifier(n_estimators=100,
max_depth=10, random_state=42) clf.fit(X_train,
y_train)
```

As a comparison, other algorithms such as Random Forest and SVM (Support Vector Machine) can be used to assess whether there is a significant difference in performance regarding accuracy and efficiency in tourism destination recommendations. Several studies have compared the C4.5 algorithm with Random Forest and SVM in recommendation applications [20]. Research findings show that Random Forest often delivers better performance in

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terms of accuracy and precision compared to C4.5 and SVM, especially when handling larger and more complex data. However, SVM can provide more optimal results with high-dimensional datasets and when parameters are properly tuned. After the training process is complete, the next step is to evaluate the model. Evaluation is conducted using accuracy metrics, as well as a classification report that includes precision, recall, and F1-score metrics. Code below illustrates the model evaluation process, which is performed using various performance metrics, including accuracy, precision, recall, and F1-score.

```
# Evaluate the model on the test data
y_pred = clf.predict(X_resampled)
accuracy = accuracy_score(y_resampled, y_pred)
print(f'Accuracy: {accuracy * 100:.2f}%')
print(classification_report(y_resampled, y_pred))
```

The study by Suherman et al. [7], which used 544 student data points with 7 attributes, achieved an accuracy of 93%. Meanwhile, Charbuty et al. [12] analyzed various algorithms using 16 global data points and obtained the highest accuracy of 99.93%, outperforming KNN, RF, and SVM. In comparison, our model, built with 500 data points and 5 attributes, achieved an accuracy rate of 76.92%, indicating room for further improvement, particularly in optimizing resampling techniques and feature selection. Figure 4 below shows the accuracy results of the model that was tested on the test data.

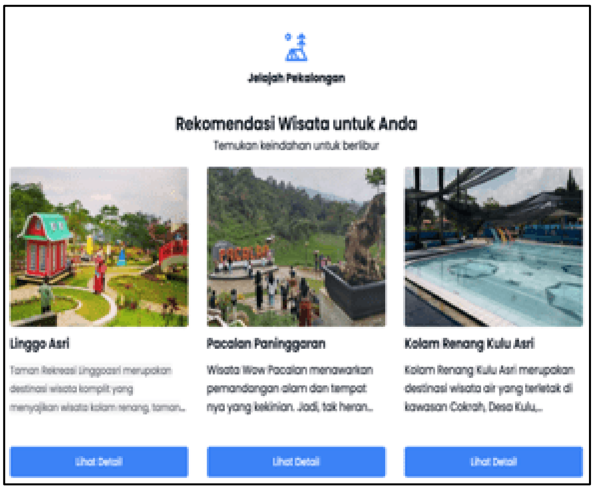
```
id                  0
gender              0
age                 1
work                0
education           0
tourism_category    0
dtype: int64
DataFrame length before removing duplicates: 61
DataFrame length after removing duplicates: 61
Accuracy on test data: 76.92%
              precision    recall  f1-score   support

           0       0.50      0.67      0.57         3
           1       1.00      0.67      0.80         3
           2       0.80      0.80      0.80         5
           3       1.00      1.00      1.00         2

    accuracy                           0.77        13
   macro avg       0.82      0.78      0.79        13
weighted avg       0.81      0.77      0.78        13
```

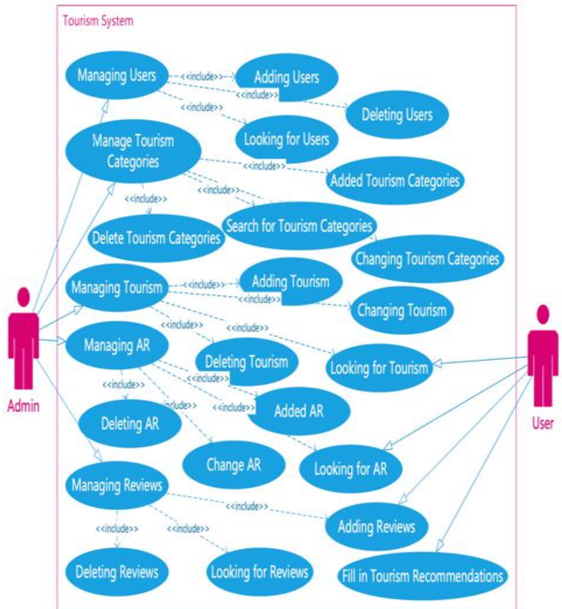
Source: (Research Results, 2024)
Figure 4. Accuracy results

With an accuracy rate of 76.92%, this model demonstrates a good ability to provide tourism recommendations that align with tourists' preferences. This model is capable of capturing more complex patterns in the data and reducing the risk of overfitting by combining multiple decision trees. However, there is still room to improve the performance further by optimizing the application of resampling techniques on the data to enhance performance in possibly imbalanced classes. The C4.5 algorithm is then applied to the tourism system at https://jelajahpekalongan.com. Figure 5 below shows the results of tourism recommendations



Source: (Research Results, 2024)
Figure 5. Tourism Recommendations

The system is designed to recommend tourism categories according to the data inputted by the user. The implementation is tested in a real context to ensure that the algorithm works well and provides a better travel experience in Pekalongan. Furthermore, to understand the workflow of this system, we developed a use case diagram that illustrates the interaction between the admin and users in the system. For more details, see Figure 6 use case diagram below.

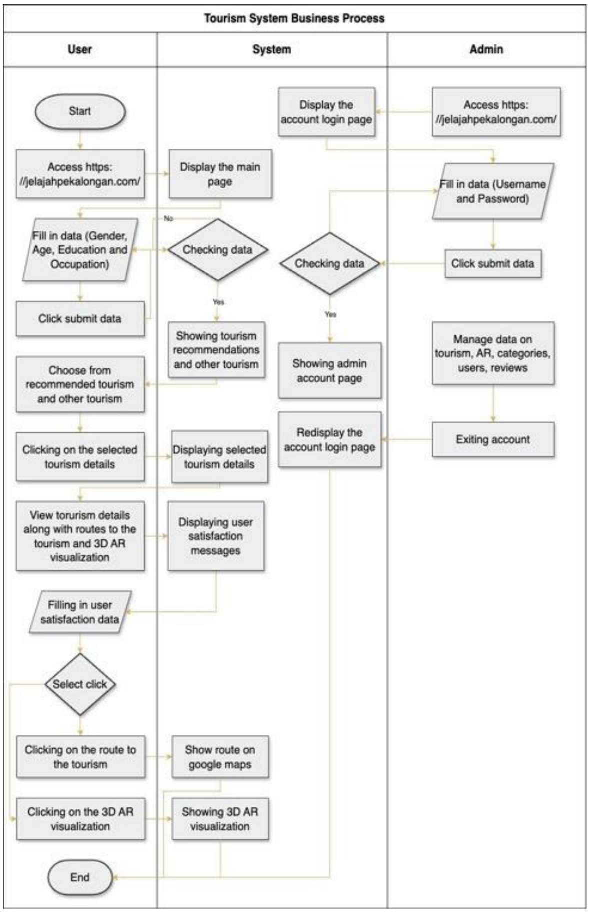


Source: (Research Results, 2024)
Figure 6. Use Case Diagram

Figure 6 above helps explain how the two roles contribute to the overall operation of the system [22].

Tourist System Business Process

To further understand how the travel system works, we present the business process of the travel system that outlines the system's workflow in detail. Figure 7 below shows how the system we developed works.



Source: (Research Results, 2024)
Figure 7. System Workflow

This business process describes how input data from users is processed through the algorithm, how tourism predictions and recommendations are generated, and how the system provides final results to users. Through these stages, it is expected that the implementation of the C4.5 algorithm in the tourism system can run smoothly, provide accurate results, and improve user experience in exploring tourist destinations in Pekalongan.

AR System Integration

To implement the AR system for enhancing the tourist experience, the hardware requirements include 8GB RAM, an i7 processor, and a 500GB HDD. The software tools used are Microsoft Visio for system design, VSCode for application development, and Python for testing algorithms. Researchers integrated the AR system through the website https://www.meshy.ai, a platform chosen for its ease in creating and managing 3D objects that can be directly inserted into the AR-based system. Figure 8 shows the stages of AR implementation.

Source: (Research Results, 2024)
Figure 8. stages of AR implementation

Figure 8 above illustrates the steps for implementing an Augmented Reality (AR) system using the Meshy.ai platform. The process begins by accessing the website https://www.meshy.ai/, where users can create 3D models by providing a description in the form of a prompt. One of the destinations created is Bukit Pawuluhan in Pekalongan, a beautiful hill with breathtaking natural scenery. The researcher generated a 3D model of this hill using a prompt that describes a green grassy hill, several trees, and a gazebo at the top. The text "Bukit Pawuluhan" was added at the base of the hill to enhance its authenticity. Once the prompt is completed, the user clicks the "Generate" button to create the 3D model. The result is an interactive 3D visualization of Bukit Pawuluhan, which can be used in the AR system to enrich the virtual tourism experience.

AR-based Destinations

Augmented reality (AR)-based tourism systems allow users to explore destinations

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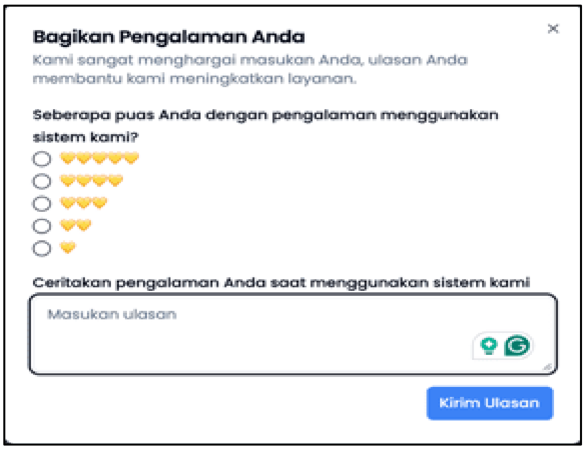
virtually with interactive 3D displays. For example, users can explore Pawuluhan Hill with a 3D model that can be rotated and enlarged, giving the sensation of being at the location. Users can also see the view from the gazebo at the top of the hill in the following Figure 9.

Source: (Research Results, 2024)
Figure 9. AR-based Destinations

In the field trial, researchers integrated a notification feature in the tourism system that allows users to provide real-time ratings and reviews. This feature serves to strengthen user interaction with the AR-based tourism platform being developed, with the aim of improving user engagement and experience directly. Figure 10 shows the form used to rate the application.



Source: (Research Results, 2024)
Figure 10. User Ratings and Reviews Feature

To ensure that the system meets user expectations, User Acceptance Testing (UAT) was conducted using statistical analysis and sentiment evaluation. Among the 20 users who tested the system, the average rating was 4.7, with a median rating of 5, indicating that most users were satisfied. Thirteen users gave a rating of 5, while seven users rated it 4, resulting in a 100% satisfaction rate. Sentiment analysis of user reviews revealed that most opinions were positive, particularly regarding the accuracy of travel recommendations and the interactive experience with Augmented Reality (AR). However, some users suggested improving the visual details of AR and adding more information, such as facilities, operating hours, and travel tips. Additionally, Jamil Hussain et al. [23] stated that systems with an average rating above 4 generally meet user expectations. In the context of UAT, Gordon et al. [24] emphasized that testing with end users in real-world conditions is crucial to ensuring system acceptance before full implementation. Furthermore, Mayur Wankhade et al. [25] explained that sentiment analysis provides deep insights into system aspects that require improvement. Based on these results, it can be concluded that the system has been well accepted by users. However, enhancements in AR visualization and additional destination-related information are still needed to further optimize the travel experience and provide a more comprehensive service.

CONCLUSION

This study successfully developed a tourism recommendation system that integrates AR and the C4.5 algorithm, achieving 76,92% accuracy. User satisfaction was high, supported by interactive 3D experiences. Limitations include AR detail and content breadth, suggesting future enhancements in realism and integration of deep learning models. The system shows promise for scalability across tourism and beyond, pending further feasibility studies.

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