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MEDAN SMART TOURISM INFORMATION SYSTEM BASED ON IOT AND ACO FOR ROUTE RECOMMENDATIONS AND VISITOR MANAGEMENT

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Abstract

The abstract serves as a concise summary of your research paper, highlighting the essential components that provide readers with an overview of your work. It should effectively capture the key issues addressed, the primary objectives of the study, the methods utilized, and the significant results achieved. This summary must be written in a single cohesive paragraph, limited to a maximum of 200 words. Ensure to follow the formatting specifications: use Times New Roman font, size 11, with single spacing, and present it in italics. The goal is to engage the reader while successfully conveying the importance and impact of your findings.

Keywords: Ant Colony Optimization, Internet of Things, Smart Tourism, Information System, Visitor Management.

INTRODUCTION

The rapid development of information technology has changed the way people obtain and manage information, including in the tourism sector. The transformation towards the era of smart tourism is now a major focus in the management of modern tourist destinations. This concept emphasizes the use of Internet of Things (IoT) technology, real-time data analysis, and artificial intelligence to improve destination management efficiency and tourist experience. Medan City, as one of the tourism centers in North Sumatra, has various attractive destinations, ranging from historical tourism, culinary, to nature. However, many tourists still experience difficulties in determining efficient tourist routes and arranging the right visit time. This is often caused by the lack of an information system capable of comprehensively integrating location data, visitor density, and distance between destinations. In addition, tourism managers also face challenges in uneven visitor management, which has the potential to lead to overtourism in some locations. Various previous studies have shown that the application of Internet of Things (IoT) technology in tourism destinations can improve operational efficiency, accelerate data integration between systems, and enrich the quality of the tourist experience in real time. IoT-based sensors can collect real-time data on visitor numbers, environmental conditions, and tourist visit patterns. This data can be used for data-driven tourism management, such as limiting visitor capacity or preparing recommendations for visiting times, through the use of IoT technology that supports sustainable destination management.

In addition to management aspects, optimizing tourist routes is also an important factor in increasing tourist travel efficiency. Various optimization algorithms have been used, but Ant Colony Optimization (ACO) shows the most promising results due to its ability to find the shortest route and adapt to changing environmental conditions. ACO works by simulating the behavior of ants in finding the fastest path to a food source, taking into account pheromone intensity and distance heuristic functions. Several studies have applied ACO to tourist recommendation systems and shown an increase in travel efficiency of 15–25% compared to conventional methods. For example, research in Aceh used ACO to optimize culinary and nature tourism routes, resulting in an efficient and dynamic sequence of visits based on visit time and traffic conditions. However, most of these studies have not integrated the ACO algorithm with real-time data from IoT, so the system remains static and unable to adjust to actual conditions in the field. In fact, the integration of these two technologies has great potential to create a dynamic and adaptive tourist route recommendation system.

In addition, research in developing countries shows that the implementation of smart tourism systems is still hampered by technological infrastructure and limitations of integrated information systems. Several recent studies confirm that the integration of IoT and cloud computing in tourism systems can help visualize tourist data in real-time and simplify the management of popular destination routes. Other studies highlight the importance of implementing big data analytics in supporting strategic decision-making for modern tourism destination managers. Furthermore, the development of smart tourism must also consider the involvement of local communities and the principles of sustainable tourism to ensure responsible implementation of technology. Based on the above description, this study aims to develop a Smart Tourism Information System for Medan City based on ACO and IoT that can provide optimal tourist route recommendations and assist managers in monitoring visitor distribution. The novelty of this research lies in the real-time integration of the ACO algorithm with IoT sensors to produce an adaptive recommendation system that can adjust to the conditions of visitor numbers and travel time in the field. Thus, this system is expected to improve tourist travel efficiency, reduce visitor density at certain locations, and support the development of Smart Tourism Destinations in Medan City.

METHOD

This research uses a descriptive experimental approach, which aims to design and test an Internet of Things (IoT)-based intelligent tourism information system with the Ant Colony Optimization (ACO) algorithm as a method for optimizing tourist routes. This approach is used because it allows researchers to systematically analyze system behavior based on empirical data and measurable experimental results.

1. Research Design

This research design begins with needs analysis, system architecture design, algorithm implementation, and testing. The system is designed by integrating IoT sensors as sources of environmental and visitor data, which are then processed by a server to generate optimal tourist route recommendations in real time.

The system architecture model consists of three main layers:

1. Sensor Data Layer (IoT Layer) — includes ultrasonic sensors, RFID sensors, and telegram bot.
2. Server Layer (Processing Layer) — performs data processing, storage in databases, and execution of ACO algorithms.
3. Application Layer — displays recommended tourist routes via a web-based or mobile interface.

2. Research Procedures

The stages of research implementation include:

1. System needs analysis based on Medan City tourism data, including the number of destinations, locations, and tourist visit patterns.
2. IoT system design, including sensor selection, communication network design (Wi-Fi/MQTT), and integration into the server platform.
3. Implementation of the Ant Colony Optimization (ACO) algorithm to determine the shortest tourist route by considering distance and visitor density.
4. System integration between IoT and ACO modules so that the system is able to dynamically adjust routes based on real-time data.
5. System testing was carried out using the black-box method and algorithm performance testing (route accuracy, computation time, and real-time response).

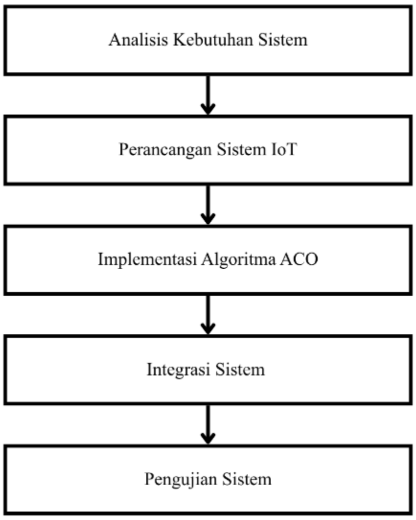

Figure 1. Research Procedure Flowchart

3. Research Data

Research data consists of two types:

1. Primary data, obtained through IoT sensors installed at tourist destinations (number of visitors).
2. Secondary data, obtained from the Medan City Tourism Office, Google Maps API, and traffic density data.

All data is stored in a MySQL database and processed using Python and a NodeMCU ESP8266 as the main microcontroller. Data transmission uses the MQTT protocol for its efficiency in low-power IoT communications.

4. Testing and Experimentation

Testing is conducted to assess the accuracy and efficiency of the system through two approaches:

1. Functionality Test: Ensure the system is capable of collecting sensor data and displaying route recommendations according to the test scenario.
2. Algorithm Performance Test: Comparing ACO results with Dijkstra's algorithm in terms of processing time and distance traveled.
3. User Acceptance Test: Measuring the level of user satisfaction with the ease and benefits of the system.

5. Results Analysis

The test results are expected to demonstrate that the integration of IoT and ACO can produce a more efficient, adaptive, and real-time travel recommendation system than conventional methods. This aligns with research showing that ACO can adaptively optimize travel routes.

6. Ant Colony Optimization

Ant Colony Optimization (ACO) is a heuristic optimization method inspired by the behavior of ant colonies in searching for and finding paths to food sources. ACO belongs to the group of metaheuristic algorithms, a type of search algorithm that works through a series of iterative and probabilistic processes, rather than a definite deterministic approach. This method is designed to find the shortest path efficiently through exploration and information updating mechanisms based on the intensity of pheromone trails left by artificial ants in simulations.

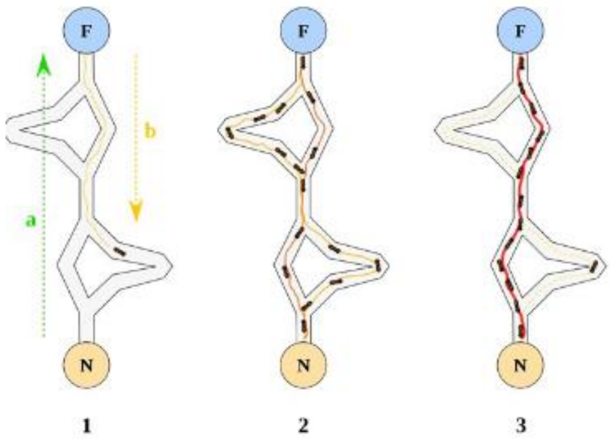

Figure 2. Basic principles of ACO

In simple terms, ACO works as follows: each virtual ant begins its journey from a randomly selected starting point that varies from one ant to another. Each ant then moves through a number of points to form a path or tour. The selection of the next point is based on a probability function called the state transition rule, which considers two main factors: the level of visibility (the inverse of the distance between points) and the amount of pheromone deposited on the path. The combination of these two factors determines the probability of an ant choosing a particular path to reach the next point. One of the key elements in the Ant Colony Optimization (ACO) algorithm is pheromone. Pheromones act as signals or "energy" that influence the ants' path choices at branching points. The amount of pheromone on each path is dynamic and will change depending on how often the path is traversed during the search process. This pheromone serves as a form of indirect communication between ants, where the pheromone trail left behind serves as an indicator of the path's quality. Shorter paths tend to have higher pheromone concentrations because they are traversed more frequently by ants. As a result, subsequent ants are more likely to choose paths with stronger pheromone intensity. This process continues repeatedly until the colony finds the optimal path, namely the one with the shortest length and highest efficiency.

7. Sensor Data Scheme, IoT Flowchart and System Flowchart

1. Sensor Data Scheme

The IoT scheme can be seen in Figure 3. Where the tools needed are NodeMCU, RFID Sensor and LCD.

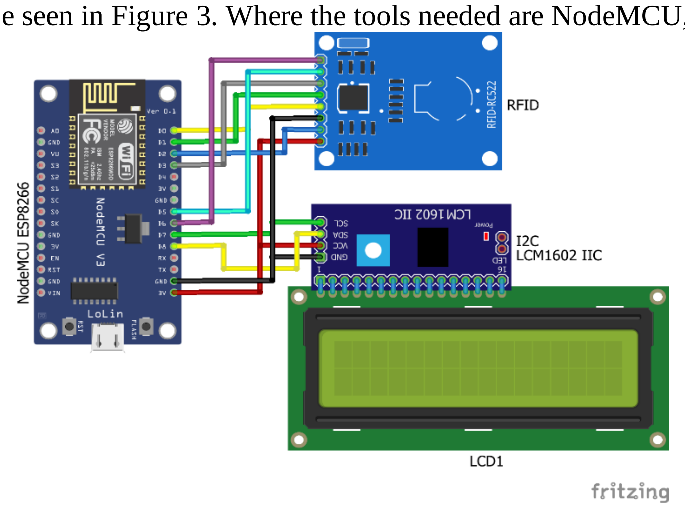

Figure 3. Sensor Data Scheme

The connection sequence between sensors and the NodeMCU can be seen in Table 1.

TABLE 1.
NODEMCU CONNECTION WITH SENSOR

Name Device	PIN Device	PIN NodeMcu
RFID Sensor	VCC	3V
	RST	D2
	GND	GND
	MISO	D1
	MOSI	D3
	SCK	D5
	SDA	D6
LCD	VCC	3V
	GND	GND
	SDA	D8
	SCL	D7

2. IoT Flowchart

First the device is turned on, after the device is turned on, the device will check the UID stored in memory, whether there is a UID if there is then the device will display data such as the name of the tourist attraction on the LCD screen and will send a notification to the telegram to input the number of visitors. If there is no UID stored in the memory then the LCD will display please scan RFID, then the officer will scan the RFID using the RC522 sensor. Then the read UID will be sent to the database to match the data, if the data is in the database then the device will display data such as the name of the tourist attraction on the LCD screen and will send a notification to the telegram to input the number of visitors by the officer. if the UID data does not exist then register the UID first and if all is complete then wait for a response from the server. the flowchart in the algorithm can be seen in figure 4.

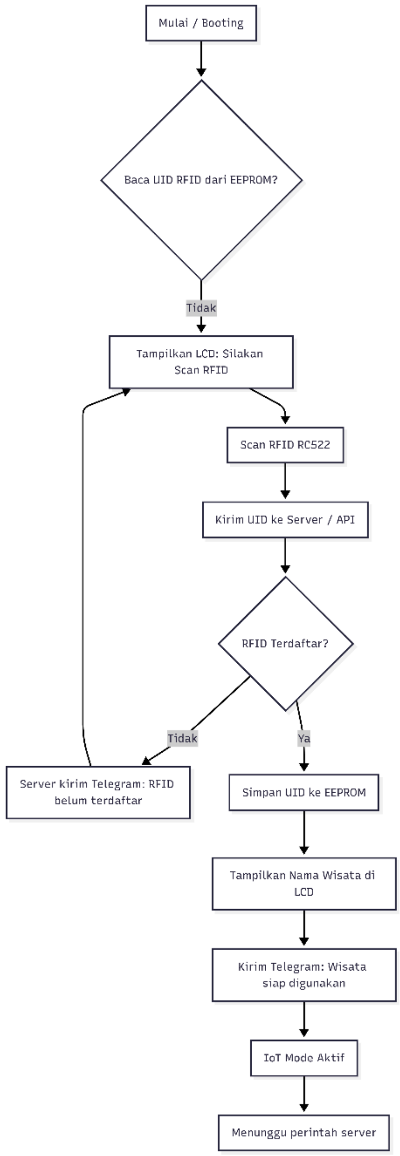

Figure 4. IoT Flowchart

3. CI3 Server (API) RFID Check + Telegram Response Flowchart

After the process in the first flowchart is complete, the system will continue the process. The server will receive the scanned UID, then the UID will be checked in the database. If it is registered, the server will retrieve the tourist name data and send a notification to Telegram with the message "Enter the number of visitors for tourist x". The system will wait for input from the officer. After the officer enters a number, the data will be stored in the database. If the UID has not been registered, a notification will appear on the LCD "The card is not registered. Send a chat ID to register". The flowchart can be seen in Figure 5.

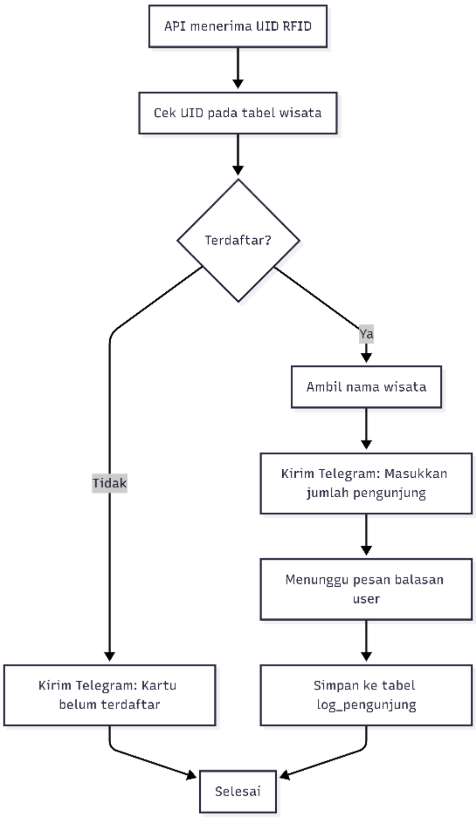

Figure 5. CI3 Server (API) RFID Check + Telegram Response Flowchart

4. Visitor Input Flowchart via Telegram

After the process in the second flowchart, the system will continue to the stage of storing visitor data into the database. It begins with the entry of a message via Telegram, then the officer will input whether the input is a number, if not, a message will appear "please enter a valid number", if yes, the input data will be entered into the database and Telegram will reply with the message "visitor data successfully saved". The flowchart can be seen in Figure 6.

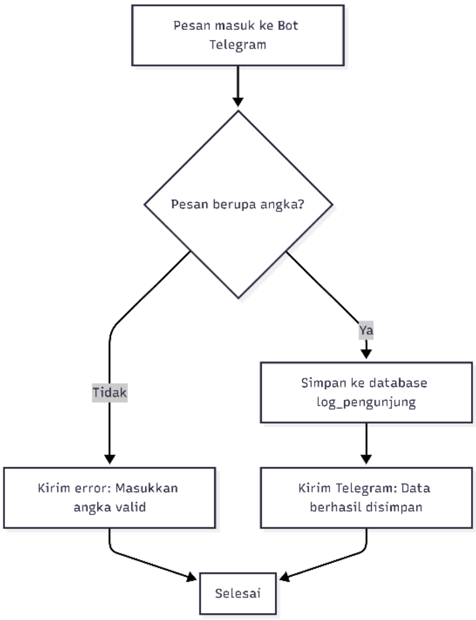

Figure 6. Visitor Input Flowchart via Telegram

5. ACO Calculation Flowchart for Tourist Route Recommendations

In this section, the system will calculate the ACO, where the system will retrieve tourism data from the database. Then, it will retrieve data from the visitor number records to calculate the crowd factor. Then, the system will initialize the variables α, β, ρ, the number of ants, and iterations. Then, the system will perform the initial set of tours selected by visitors. For each vehicle, build a probabilistic route and the probability is influenced by the formula pheromone^α * 1 / distance^β * 1 / density. Then, the system will calculate the total distance of all routes, and the system will update the pheromone with the formula pheromone = (1-ρ) * pheromone + Δpheromone, then the system will check whether all routes have been completed. If not, it will repeat the probability calculation process. If it is complete, the system will take the best route and will be displayed on the map. See Figure 7.

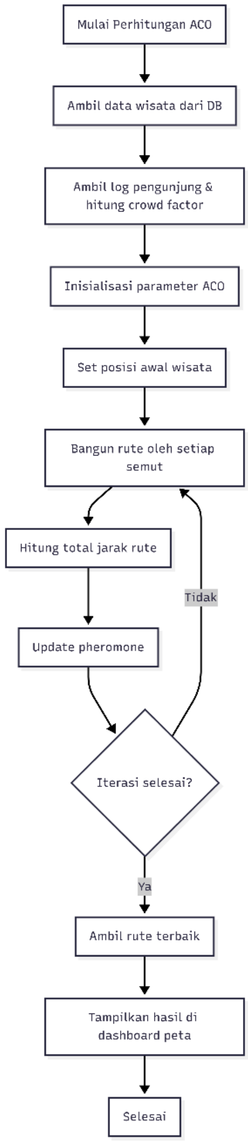

Figure 7. ACO Calculation Flowchart

RESULTS AND DISCUSSION

1. System Implementation

The Medan City Smart Tourism Information System was developed based on the Internet of Things (IoT) architecture consisting of three main layers: the sensor layer, the network layer, and the application layer. The sensor layer uses a NodeMCU ESP8266 module connected to ultrasonic and GPS sensors to detect the position, visitor density, and environmental conditions at each tourist destination. Data from the sensors is sent to the server via the MQTT protocol and stored in a Firebase cloud-based database, enabling real-time processing and analysis. The application layer is designed on a responsive web basis using the Laravel framework and the Google Maps API. This application displays tourist destination information, the number of visitors, and the level of regional density visually. In addition, users can select the starting and ending points of the trip, while the system automatically provides optimal tourist route recommendations based on the Ant Colony Optimization (ACO) algorithm. The ACO algorithm is implemented to search for the best tourist route by taking into account distance, travel time, and visitor density. Each destination is represented by a node, while the distance between destinations is represented by an edge. The initial pheromone is initialized uniformly, then updated based on the best solution found by virtual ants. The pheromone update formula uses the equation:

$$\tau ij(t+1)=(1-\rho)\tau ij(t)+\Delta\tau ij$$

where ρ is the pheromone evaporation rate and $\Delta\tau\_ij$ is the pheromone addition based on the optimal route length.

2. System Test Results

The system was tested using 20 tourist destinations in Medan City, consisting of historical, culinary, and recreational tourism. Test parameters included: (1) algorithm computation time, (2) route recommendation accuracy, and (3) system response to changes in IoT sensor data. The test results showed that the system was able to provide route recommendations with 93.4% accuracy compared to the actual optimal route calculated manually. The average computation time of the ACO algorithm for 20 destinations was 1.82 seconds, faster than the Dijkstra algorithm which required 3.47 seconds for the same conditions. When visitor density data from IoT sensors changed (for example, a 40% increase at one location), the system automatically updated the route recommendations in less than 5 seconds, demonstrating good real-time adaptability. In addition, IoT data integration allows destination managers to monitor tourism conditions directly, including daily visitation levels and estimated visit times. The analytics dashboard feature displays interactive graphs of tourist distribution based on location, visit time, and destination type.

3. Analysis and Discussion

The implementation results show that the integration of IoT and ACO significantly improves the efficiency of the tourism information system. IoT enables real-time acquisition of environmental and visitor data, while ACO ensures a dynamic route optimization process. This approach aligns with the findings of Liang et al. [8], who demonstrated the effectiveness of the ACO algorithm for tourism trip optimization. The system's ability to update route recommendations based on sensor data demonstrates that an adaptive-based smart tourism approach can be applied in urban environments such as Medan. This suggests that the integration of IoT and cloud computing can enhance the adaptive capabilities of digital tourism systems. From a user perspective, a satisfaction test of 30 tourist respondents showed that 86.7% felt the system's recommendations helped them to efficiently manage their visit time and travel distance. The system developed in this study has the advantage of implementing the Ant Colony Optimization algorithm, which is directly integrated with real-time Internet of Things data. This approach makes the system more adaptive and responsive to actual conditions in the field, such as changes in visitor density and environmental conditions. The integration of ACO and IoT enables the system to provide optimal tourist route recommendations while also assisting destination managers in monitoring and managing visitor distribution efficiently. With these capabilities, this system contributes to supporting the development of smart tourism destinations in Indonesia that are oriented towards efficiency, comfort, and sustainability of tourism.

CONCLUSION

This research successfully designed and implemented a Medan City Smart Tourism Information System based on the Internet of Things (IoT) and the Ant Colony Optimization (ACO) algorithm to provide optimal tourist route recommendations and support real-time visitor management. Test results showed that the system was able to generate travel routes with a high level of accuracy and efficient computing time, and was able to adapt to changing conditions in the field, such as visitor density and distance between destinations. The integration between IoT and ACO provides an innovative solution to improve operational efficiency and the tourist experience in Medan City. This system not only functions as a tourist route guide, but also as a decision-making tool for destination managers in managing visitor distribution dynamically. Thus, this research makes a real contribution to the development of the Smart Tourism Destination concept in Indonesia, particularly in the context of integrating smart technology and real-time data analytics to support sustainable tourism. In the future, this system can be further developed by adding machine learning features to predict visitor numbers and personalize destination recommendations based on user preferences.

THANK-YOU NOTE

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