Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

15th June 2025. Vol. 4. No. 3; e-ISSN: 2808-4519

Geographic Information System for Shortest Route Search of Inseminator Locations Using A* Algorithm

Rini Sabdo Ningsih[1], Sucipto[2], Barry Caesar Octariadi [3*]

[1,2,3] *Fakultas Teknik, Universitas Muhammadiyah Pontianak*
1812200586@unmuhpnk.ac.id[1], sucipto@ummuhpnk.ac.id[2], barry.ceasaro@unmuhpnk.ac.id[3]*

Abstract

This research develops a web-based Geographic Information System (GIS) to help farmers in Ketapang Regency locate the nearest inseminator efficiently using the A* algorithm. Livestock plays a crucial role in food security, and artificial insemination (IB) enhances cattle quality and quantity. However, farmers face challenges in finding inseminator locations quickly. The system is implemented using the Laravel framework for the backend and Google Maps API for visualization. It also evaluates the A* algorithm's effectiveness in determining optimal routes by comparing it with the Google Maps API route feature. The expected outcome is a more efficient insemination process, supporting modern and productive livestock development in Ketapang Regency.

Keywords: *Geographic Information System, Inseminator, A* Algorithm, Route Search, Google Maps API*

1. Introduction

Livestock farming contributes to fulfilling animal protein needs, improving nutrition, and strengthening food security. According to the Central Bureau of Statistics of West Kalimantan (2019–2021), cattle are the most commonly raised livestock in Ketapang, reaching 34,226–33,216 heads. Cattle are popular in Indonesia as a source of high-economic-value meat, rich in protein and iron, which are essential for human health[1].

Artificial insemination (AI) in livestock is the process of deliberately introducing sperm into the reproductive tract of a female animal ready for fertilization, assisted by an inseminator to increase the chances of pregnancy. AI is a reproductive technology promoted by the government to enhance livestock productivity and improve farmers' welfare[2]. The success of cattle insemination depends on the timing after estrus, requiring farmers to find the shortest route to the nearest inseminator. Therefore, a geographic information system (GIS) is needed to help locate inseminators efficiently.

A GIS is a computer-based system used to collect, examine, integrate, and analyze geographical data. It consists of three main components: system, information, and geography, emphasizing the geographical aspect of data processing[3]. Route searching is crucial in daily life to find the best path based on the shortest travel time, road conditions, or minimal congestion. The A* algorithm is an optimal and complete route-finding algorithm, ensuring the best path and reaching the intended destination[4].

This research aims to develop a web-based GIS for cattle farmers in Ketapang to locate inseminators using the shortest route with the A* algorithm. The system will utilize Ketapang's geographical data to optimize route searches. The Head of the Livestock and Animal Health Office of Ketapang, Khoirul Syahri, S.Pt, stated that some farmers are unaware of the inseminators in their area, leading to missed insemination opportunities for estrous cattle.This study is expected to accelerate inseminator location searches, enhance cattle quality and quantity, and serve as a reference for researchers and practitioners interested in developing GIS using the A* algorithm.

2. Theoretical basis

This chapter discusses the scientific theories that underlie the problems studied, which consist of general theories and specific theories.

2.1. Previous Research

The purpose of comparing previous studies is to avoid similarities with this research. Therefore, previous research findings are added, as shown in Table 1

Table 1: Comparison with Previous Research

No	Researcher	Year	Title	Results
1.	Hendri Yusriadi, Harun Mukhtar, Soni	2022	Implementation of Algorithm A in Shortest Route Search for the Post Office Search System in Pekanbaru	This study aims to determine the shortest route to the post office using the A* algorithm by processing post office location points. The system records a total distance of 2,739 km per month, requiring 182.6 liters of fuel at a cost of Rp. 1,396,890 per month, saving 17.69% monthly [5].
2	Alzena Dona Sabilla, Ahmad Taufiq	2022	Implementation of A Algorithm in WebGIS for Shortest Route Search	Metode This study uses the A* algorithm, which calculates paths through nodes using heuristics. Google Maps data is converted into a grid format before processing. The research generates alternative shortest routes, while Google Maps' road accuracy affects the displayed results [6]..
3.	Ungkawa Uung, Mu'minin, Dwiki Faizal	2022	Perbandingan Algoritma Floyd Warshall dan A* (A-Star) dalam Penentuan Rute Terpendek Menuju Unit Gawat Darurat	Algoritma A* dan Floyd-Warshall bekerja dengan mekanisme berbeda. Hasil keduanya dibandingkan dan dianalisis berdasarkan jarak, baik dari sistem maupun perhitungan manual Google Maps. Validasi menunjukkan akurasi A* 99,56% dan Floyd-Warshall 99,44% [7].

2.2. Geographic Information Systems

A Geographic Information System (GIS) integrates geographic data with software and hardware to collect, store, manage, analyze, and visualize location-based information, functioning as a computer system that processes geographic data through data acquisition, validation, integration, storage, updating, management, exchange, manipulation, retrieval, display, and analysis [8]. Designed to store, input, retrieve, process, and analyze geospatial data, GIS supports decision-making in land use planning, environmental management, transportation, urban facilities, natural resources, and public services [9], making it a computerized system that aids decision-making by providing methodologies and technologies for spatial analysis, while continuously evolving and developing significantly.

2.3. Shortest Route

The shortest route is the minimum path needed to reach a destination from a starting point, determined using an unweighted graph without numerical values or weights. Shortest path problems include a pair shortest path, all pairs shortest path, single source shortest path, and intermediate shortest path. Several algorithms for finding the shortest route in a Geographic Information System include A* (star), greedy, Dijkstra's, ant colony, Floyd-Warshall, graph method, Bellman-Ford, and tabu search.

2.4. A-star Alggortihm

The A* algorithm, also called the A letter algorithm, uses open and closed lists like Best First Search (BFS) and evaluates three conditions for each successor: already in open, already in closed, or new. It applies BFS to find the least-cost path from the initial node to the goal node, using a heuristic function f(x) (distance + cost) to determine the search order in the tree [9].

2.5. Implementation of A-Star Algorithm without library assistance

In this implementation, the A-Star algorithm is developed using PHP and Laravel without third-party libraries. The main steps include defining nodes—locations on the map with attributes like name, latitude, and longitude—and edges, which represent connections between nodes with information such as start point, endpoint, and distance. The data structures prepared are the Open Set (nodes to be evaluated), Closed Set (nodes already evaluated), Came From (to track the shortest path found), gScore (the shortest cost from the start point to the current node), and fScore (the total estimated cost from the start point to the destination). The A-Star search algorithm begins by adding the starting node to the Open Set, then repeatedly selects the node with the lowest fScore for evaluation. If the current node is the destination, the optimal path is found and reconstructed. All neighboring nodes are evaluated, and gScore and fScore are updated if a more optimal path is discovered. Evaluated nodes are moved to the Closed Set, and this process repeats until the destination node is found or the Open Set is empty. For heuristic calculation, the Haversine Formula estimates the distance between two points based on geographic coordinates; this heuristic value is used in fScore calculations to expedite pathfinding.

2.6. Inseminator

An inseminator is an officer responsible for performing artificial insemination by inserting semen into the reproductive tract of a female animal in heat. The Ministry of Agriculture has established inseminators as the main pillar of the Upsus Siwab program, which is an effort to increase the domestic cattle population.

2.7. JSON

JavaScript Object Notation is a lightweight data interchange format that is easy for humans to read and write and for computers to parse and generate. It is based on JavaScript (ECMA-262 3rd Edition - December 1999) and is independent of any programming language, following a syntax common in C-family languages like C, C++, C#, Java, JavaScript, Perl, and Python, making it ideal for data exchange [10]. JSON structures are universal and supported by modern programming languages, allowing easy data exchange. Its structure consists of (1) objects, which are unordered name/value pairs enclosed in {} and separated by ,, (2) arrays, which are

ordered values enclosed in [] and separated by ,, (3) values, which can be strings, numbers, true, false, null, objects, or arrays, (4) strings, which are Unicode characters in double quotes with backslash escapes \, similar to C or Java, and (5) numbers, which resemble those in C or Java but do not support octal or hexadecimal formats.

3. Research Methods

The research flow applied in this study is as follows:

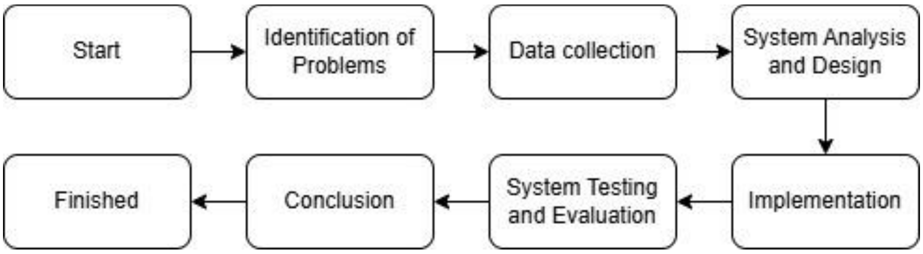

Fig. 1: Research Flow Chart

3.1. Identification of Problems

Data collection involves defining the background, problem formulation, research objectives, and benefits. This study focuses on finding the shortest route in Ketapang using the A* algorithm and evaluating its accuracy in locating inseminators based on secondary data from the Department of Agriculture, Livestock, and Plantations, which will be developed into a website.

3.2. Data Collection

ad Developing a website for finding the shortest route to inseminators using the A* algorithm requires supporting data. This research involved direct observation by visiting the Department of Agriculture, Livestock, and Plantations in Ketapang and interviewing the head of livestock and animal health, Khoirul Syahri, S.Pt. The interview provided a report on artificial insemination service officers' locations. Afterward, researchers analyzed relevant literature from books, journals, magazines, and online sources to support data analysis.

3.3. System Analysis and Design

Ada The system analysis and design using the A* algorithm begins with collecting road data from Google Maps, forming graph nodes and edges based on spatial points and distances. Inseminator locations are mapped using longitude and latitude, serving as references for heuristic calculations. A grid illustrates data connections, with distances labeled in kilometers. The A* algorithm calculates h(n) using the Euclidean method, then derives f(n) from g(n) and h(n). The system is modeled using use case diagrams, activity diagrams, class diagrams, and UI designs.

3.4. Implementation

System analysis and design with the A* algorithm involve collecting road data from Google Maps, mapping inseminator locations, and forming graph nodes. A grid visualizes connections with distances in kilometers. The A* algorithm calculates h(n) using the Euclidean method and derives f(n) from g(n) and h(n). The system is modeled with use case, activity, class diagrams, and UI designs.

3.5. System Testing and System Evaluation

System testing ensures accuracy, performance, and functionality, including shortest route searches, using black-box testing. Performance analysis measures processing time, while user evaluation gathers feedback on usability and satisfaction. After MAPE evaluation, testing data assesses the data mining model’s performance. If the model meets the objectives, it proceeds to deployment

4. Result and Discussion

4.1. System Implementation

The fastest route search system for Inseminator has been implemented using the Laravel framework as the backend and Google Maps API for map visualization. This system is designed to assist the Inseminator in determining the best path by utilizing the A Star (A) algorithm.

4.2. Inseminator Location Data

In this study, collected data is divided into two categories: road and intersection points and the locations of Inseminator officers. The Inseminator location data consists of points representing the officers' locations in Ketapang Regency, as detailed in the following table.

Table 2: Inseminator Location Data Table

No	Nama Pegawai
1	Drh. Eko Susanto
2	Ismanto, S.PKP
-	-
13	Drh. Matias Re Mete Tenggo

4.3. Implementation Results

a) Dashboard Page Results

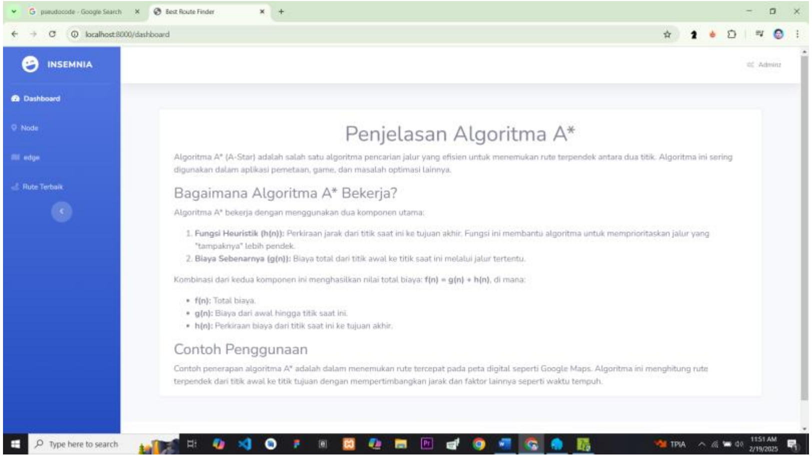

Fig. 2: Dashboard page screenshot

b) Best Route Results

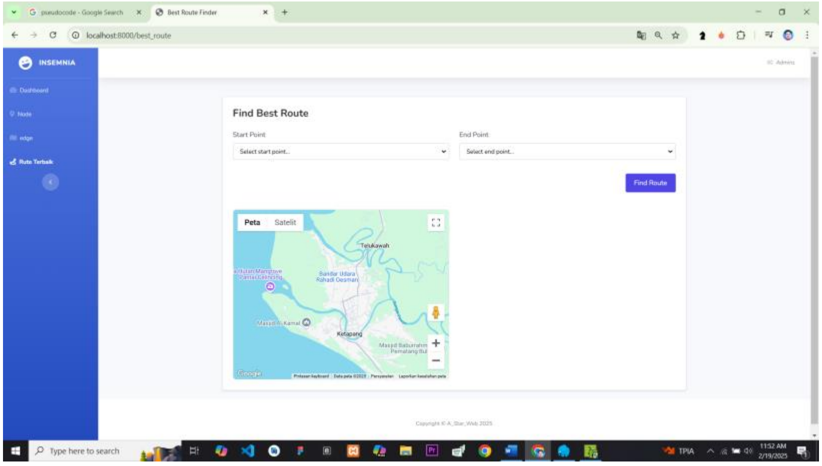

Fig. 3: Best Route Page Screenshot

c) Home Page Results

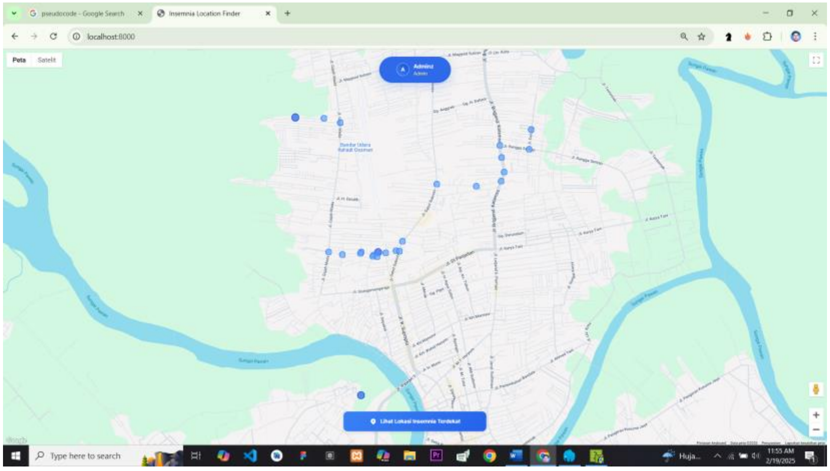

Fig. 4: Home Page Screenshot(index)

4.4. Implementation of the A Star Algorithm

This program utilizes Google Maps API for route and map visualization and Laravel, a PHP framework following the Model-View-Controller (MVC) architecture, with its folder structure based on MVC and models including Edge, Node, and User. The controllers are: AuthController for user authentication, DashboardController for the main dashboard menu, NodeController for CRUD operations on Nodes, EdgeController for managing Node connections, IndexController for the homepage display, UserController for managing user data (farmers and admins) with CRUD operations, and BestRouteController for finding the best route using the A* algorithm through the findRoute() method. The findRoute() method takes start_node and end_node as parameters, received from user requests and processed by RouteService as outlined in the BestRouteService pseudocode.

4.5. Analysis of the Effectiveness of the A Star Algorithm

The analysis compares multiple destination points from the same starting point, measuring the total distance for each travel scenario.

Table 3: Comparison Table

No	Algoritma A Star	*Google Maps*	Jarak Algoritma A Star	Jarak *Google Maps*
1	drh. Eko Sutanto, Ismanto, S.PKP	drh. Eko Sutanto, Ismanto, S.PKP	3.12 km	3.1 km
2	drh. Eko Sutanto Suyadi, S.PKP	drh. Eko Sutanto Suyadi, S.PKP	5.78 km	7.7 km
3	drh. Eko Sutanto, dedi sukari	drh. Eko Sutanto, dedi sukari	7.81 km	8.0 km
4	drh. Eko Sutanto abd. Kani saragih	drh. Eko Sutanto abd. Kani saragih	12.19 km	12.1 km
5	drh. Eko Sutanto, irawan	drh. Eko Sutanto, irawan	12.81 km	38.6 km

The comparison between the A* algorithm and Google Maps API shows that both produce the same route order, proving A*'s effectiveness in shortest path searches. In most cases, A* provides shorter distances, though Google Maps may consider additional factors like road conditions and traffic. Despite one extreme case with a significant distance difference (12.81 km vs. 38.6 km), A* remains an effective alternative for route optimization in GIS-based systems. Further analysis is needed to account for external factors affecting real-world route selection.

5. Conclusion

The implementation of a GIS-based system using the A* algorithm in Laravel effectively determines the shortest route for inseminators, producing results that are largely comparable to those generated by Google Maps API, though without considering real-time traffic conditions. In several cases, the A* algorithm was able to generate shorter routes than Google Maps, demonstrating its effectiveness in static shortest-path calculations. However, Google Maps remains superior in terms of accuracy due to its ability to incorporate live road conditions and traffic data. The A* algorithm was successfully integrated into the Laravel framework, enabling automated route processing based on predefined road network data. Additionally, Google Maps API was utilized for interactive route visualization, allowing users to view and analyze routes more intuitively. The system also efficiently manages location and road network data through a structured database, ensuring optimal performance in route calculations.

6. Advice

To improve route accuracy, the A* algorithm can be optimized by refining heuristic parameters and incorporating more intersection data, while integrating real-time traffic sources like Google Maps Traffic API would enhance effectiveness by providing more accurate route estimations. A hybrid model combining A* for local route searches and Google Maps API for broader routes with live traffic data could further improve performance, supported by database optimizations such as indexing and caching to enable faster calculations and efficient request handling. Additionally, enhancing user experience through improved map visuals, estimated travel time, voice navigation, and key route information would make the system more user-friendly, ultimately helping inseminators find the fastest routes more efficiently and increasing productivity in serving farmers.

References

[1] K. S. F. S. Sutopo, “studi komparasi pemeliharaan usaha penggemukan sapi potong di kecamatan gunung pati kota semarang.” .
[2] T. Herawati, A. Anggraeni, L. Praharani, dan D. Utami, “Inseminasi Buatanad Pa Sapi Perah Inseminator Role in the Success of Artificial,” hal. 81–88, 2012.
[3] E. Prahasta, “Sistem Informasi Geografis: Tutorial ArcView,” Inform. Bandung, 2002.
[4] M. H. Fadhlurrahman, B. Dirgantara, dan A. Mulyana, “Impementasi dan Analisis Penggunaan ALgoritma A Star dengan Prioritas pada Pemilihan Rute Lintas Kendaraan Roda Dua,” Sist. Komputer, Univ. Telkom, 2014.
[5] H. Mukhtar dan Y. Hendri, “IMPLEMENTASI ALGORITMA A STAR DALAM PENCARIAN RUTE TERPENDEK (SHORTEST PATH PROBLEM) PADA SISTEM PENCARIAN KANTOR POS DI KOTA PEKANBARU,” J. Softw. Eng. Inf. Syst., hal. 111–119, 2022.
[6] . A. D. Sabilla dan A. Taufiq, “PENERAPAN ALGORITMA A* PADA WEBGIS PENCARIAN RUTE TERPENDEK,” J. Inf. Syst. Comput., vol. 2, no. 2, hal. 32–35, 2022.
[7] U. Ungkawa, D. F. Mu’minin, dan D. Rosmala, “PERBANDINGAN ALGORITMA FLOYD WARSHALL DAN A STAR DALAM PENENTUAN RUTE TERPENDEK MENUJU UNIT GAWAT DARURAT,” 2022.
[8] T. Bernhardsen, Geographic information systems: an introduction. John Wiley & Sons, 2002.
[9] I. B. G. W. A. Dalem, “Penerapan algoritma A*(Star) menggunakan graph untuk menghitung jarak terpendek,” J. Resist. (Rekayasa Sist. Komputer), vol. 1, no. 1, hal. 41–47, 2018.
[10] T. Syahputra, J. Halim, dan K. Perangin-angin, “Penerapan Data Mining Dalam Memprediksi Tingkat Kelulusan Uji Kompetensi (UKOM) Bidan Pada STIKes Senior Medan Dengan Menggunakan Metode Regresi Linier Berganda,” Sains dan Komput., vol. 17, no. 1, hal. 1–7, 2018.