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Optimization of MSMEs promotion strategy using GIS with random forest algorithm and A-star algorithm

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ABSTRACT

Micro, small, and medium enterprises (MSMEs) make a main contribution to improving a country's economy, but it still faces various problems including limited market access, ineffective promotion, and lack of understanding in business profiles. The purpose of this study is to design a geographic information system (GIS) combined with the random forest (RF) algorithm and the A-star algorithm. The RF algorithm functions are to classify MSMEs. Meanwhile, the A-star algorithm is to recommend the shortest route to support accessibility. In addition, it is equipped with a dashboard and MSMEs profile as a reference for stakeholders in making MSMEs development policies and as information to the public in order to expand the reach of promotion in introducing MSMEs and attracting investors, thus optimizing MSMEs promotion strategies. In addition, the evaluation results of the classification model show an accuracy value of 99.6%, indicating that the model is able to predict very well, making it highly recommended for MSME classification.

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1. INTRODUCTION

Micro, small, and medium enterprises (MSMEs) play a very important role in a country's economy because they are able to create jobs, increase income, and support inclusive economic growth. The same applies to Indonesia, where MSMEs are the backbone of the economy, making a significant contribution to the gross domestic product (GDP). Moreover, MSMEs absorb a large portion of the workforce [1]-[3]. Although MSMEs have great potential, they face various challenges in their efforts to survive and grow. Some of the challenges faced by MSMEs include limited access to markets. In addition, there is a lack of effective promotion and a lack of understanding of the target market's profile and characteristics [4], [5].

MSMEs in Pesawaran Regency also face similar problems, including limited market access, as the majority of MSMEs still market their products locally and not many have engaged in online marketing to expand their market reach. In addition, some MSMEs sell their products in bulk to middlemen. This is done for faster financial turnover, albeit with very minimal profit. Some MSMEs actors focus more on production,

making marketing strategies less of a priority. Furthermore, the human resources' ability to utilize digital technology remains low. Packaging has not been a major focus, with many products being packaged modestly, and this extends to the labeling and logos of MSMEs. Meanwhile, packaging is crucial for MSMEs products to be competitive in local, national, and even international markets. Additionally, there is still a lack of understanding regarding MSMEs profiles, which serve as a window to showcase the variety of products and potential available.

The geographic information system (GIS) is a relevant technology to address some of these problems. GIS is a technology for collecting, processing, analyzing, and visualizing spatial data. GIS can be used for mapping and analyzing MSMEs clusters with more accurate and comprehensive results [6]-[8]. Spatial information about MSMEs locations, supporting infrastructure, market accessibility, and environmental factors such as geology, topography, and demographics can be integrated into one integrated platform.

Several studies have been conducted related to GIS for MSMEs, such as the research by Ptak-Chmielewska and Chłoń-Domińczak [9], who used the GIS to understand spatial conditions that support MSMEs growth. The contribution of this research lies in understanding the spatial factors that influence MSMEs development at the local level, as well as supporting decision-making in local economic development. Furthermore, Lehan and Kamarudin [10] used a geospatial approach to develop a business continuity plan (BCP) for small and medium enterprises (SMEs) in Malaysia in the post-pandemic era. The integration of spatial data in the BCP planning process is crucial, including risk mapping, distance and accessibility analysis, and identification of resources and infrastructure. SMEs can identify areas vulnerable to post-pandemic risks, optimize business locations, and formulate effective BCP strategies.

Mu'tamar *et al*. [11] explored marketing using social media during the Coronavirus Disease 2019 (COVID-19) pandemic. The study results showed that the use of various social media platforms such as Instagram, Facebook, and WhatsApp to promote MSMEs products can maintain customer interaction, increase brand awareness, and retain their market share. Kumar *et al.* [12] conducted research on the factors influencing MSMEs to adopt information and communication technology (ICT). This understanding can be utilized by policymakers, including the government, industry, and academia, in designing policies and strategies to support the development of technology in the MSMEs sector.

Various efforts have been made to support MSMEs development, including the research we propose, which integrates the random forest (RF) algorithm and the A-star algorithm into the MSMEs GIS. This is done to optimize MSMEs promotion strategies in achieving sustainable economic growth. The RF algorithm is used for MSMEs classification as the basis for mapping MSMEs spread across Pesawaran Regency using GIS. Additionally, it is equipped with MSMEs profile information as an initial window to attract consumers and investors. Moreover, it provides information on the shortest route to MSMEs locations by utilizing the A-star algorithm, offering a service that facilitates access.

2. METHOD

The method of this study consists of several stages, including a literature study, data collection, data preprocessing, the application of the RF and A-star algorithms, and the implementation of a GIS, as shown in Figure 1. The literature study and data collection stages are conducted to obtain relevant information and supporting data, which are subsequently processed during the data preprocessing stage. The processed data are then analyzed using the RF and A-star algorithms before being integrated into the GIS to support the mapping of MSMEs and the determination of optimal routes.

2.1. Literature review

The literature review involves gathering references from various sources such as journal articles, proceedings, and others. References include discussions on MSMEs, such as promotion strategies and technologies used. Additionally, references related to GIS, the RF algorithm, and the A-star algorithm are collected.

2.2. Data collection

The data in this study includes MSMEs data such as names, product types, assets, turnover, and others. It also includes coordinate point data of MSMEs locations for mapping purposes. Additionally, MSMEs profile data includes business information such as name, type of business, address, phone number, email, and business legality information. Furthermore, photos of logos, business buildings or locations, products, promotional events or activities, and others are collected.

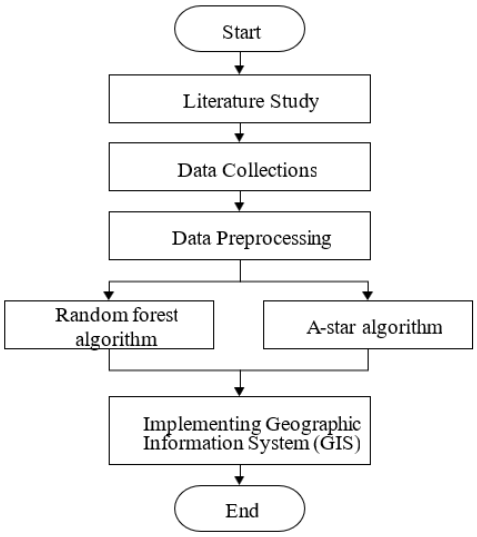

Figure 1. The stages of MSMEs mapping research

2.3. Data preprocessing

The data used in this study is obtained from the Department of Cooperatives, MSMEs, and Manpower of Pesawaran Regency in 2020, which includes 3,084 MSMEs spread across 11 sub-districts. The MSMEs data consists of 16 attributes: name, ID number, home address, business address, phone number, business name, business type, number of employees, product name, business sector, business field, business permits, assets, capital, annual turnover, and business criteria used as class attributes, namely micro, small, and medium. After data cleansing and transformation, the attributes are reduced to 8 such as business name, owner's name, business type, product name, permits held, assets, turnover, and criteria. This refers to the Republic of Indonesia law number 28 of 2008 on MSME. In chapter IV, the criteria for MSMEs are discussed [13].

2.4. RF algorithm

RF is a flexible and easy-to-use algorithm. It can be used to solve various problems, making this algorithm popular [14], [15]. The RF algorithm works by designing multiple decision trees during the training process. Each tree is designed using a random subset of the training data, and better results are obtained by combining them [16]. The RF algorithm has better performance compared to algorithms with single decision trees [17]-[19]. In designing a decision tree, it uses the classification and regression tree (CART) method [20]-[22], Meanwhile, this study uses the (1) to find the impurity value.

$$Gini(D) = 1 - \sum_{i=1}^{m} p_i^2 \quad (1)$$

It stated that p_i shows the probability value of a node value D in a class. Meanwhile, m is the class label. The next step is to calculate the weight of the impurity of each partition obtained, the Gini index value uses the (2).

$$Gini_A(D) = \frac{|D_1|}{|D|} Gini(D_1) + \frac{|2|}{|D|} Gini(D_2) \quad (2)$$

For impurity reduction caused by binary splitting on attributes with discrete or continuous values, A is used in (3).

$$\Delta Gini(A) = Gini(D) - Gini_A(D) \quad (3)$$

The RF is an ensemble method of decision trees that uses the Bootstrap aggregating (Bagging) technique. It involves creating bootstrapped datasets to reduce variance in noisy data and aggregating results by voting for the most frequent outcome. Bootstrapped datasets are used to train each decision tree model in parallel. Subsequently, the varied results from each decision tree model are aggregated by voting, and the most frequent result becomes the final value.

2.5. A-star algorithm

This study uses the A-star algorithm to determine the shortest route from the starting point to the destination point in the form of a graph. It is specifically from the starting point to the target MSME location. The A-star algorithm is an effective tool that enhances efficiency in various situations requiring sequential planning in automation systems [23]. The A-star algorithm is a systematic and efficient method for determining the optimal path in a parameter space [24]. Additionally, the A-star algorithm enhances the efficiency and effectiveness of path planning by considering various objectives or criteria [25]. The use of the A-star algorithm is to determine the best route connecting multiple tourist destinations based on established criteria [26]. In this study, geospatial data will be used to determine the best route connecting MSMEs locations, allowing customers, tourists, and potential investors to visit more MSMEs in a shorter time with an optimized route. The A-star algorithm uses a heuristic approach to estimate the cost from a particular point to the destination in (4).

$$f(n) = g(n) + h(n) \quad (4)$$

The function $f(n)$ is used to determine the order of nodes to be checked, where the main focus is on the node with the lowest $f(n)$ value first. Meanwhile, $g(n)$ shows the actual cost from the starting node to node n, and $h(n)$ shows the cost from node n to the destination (heuristic function).

2.6. Implementing GIS

The mapping of MSMEs is carried out using a GIS to be equipped with the A-star algorithm to recommend the most optimal route for visiting multiple MSMEs. Additionally, MSMEs will be classified according to their categories using the RF classification algorithm. The combination of GIS, random forest, and A-star allows for optimal utilization of geographic data and better data-driven decision-making, so it is enhancing service to users and opening up business development opportunities by attracting investors.

3. RESULTS AND DISCUSSION

This study designs a GIS to map MSMEs in Pesawaran Regency using the RF and A-star algorithms. The RF algorithm is used to classify MSMEs into categories such as micro, small, and medium. Additionally, it displays MSME profiles including logo photos, business location photos, and product photos. This GIS is also equipped with the A-star algorithm to provide recommendations for the shortest route to MSMEs, thereby optimizing time and enhancing service to customers and potential investors.

3.1. The implementation of RF algorithm

At this stage, MSMEs are classified into three classes micro, small, and medium using the RF algorithm. Based on the preprocessed data, the original 3,084 records are reduced to 2,844 in Table 1. Then, this MSMEs data is processed using the RF algorithm to predict the classification of MSMEs into micro, small, and medium categories. The model evaluation results show an accuracy of 99.6%, so it is making it a reference for determining MSME classes in the future. The evaluation results are presented in Table 2.

Table 1. MSMEs data and classification

Sub-district	Micro	Small	Medium
Tataan	298	23	0
Kedondong	524	8	0
Marga Punduh	371	26	8
Negeri Katon	126	0	0
Padang Cermin	117	16	1
Puduh Pidada	242	16	13
Tegineneng	388	50	0
Teluk Pandan	74	48	0
Way Ratai	124	32	0
Way Hiu	114	0	0
Way Lima	222	3	0
Total	2600	222	22

Table 2. The RF classification model evaluation

Model	Area under the curve (AUC)	Classification accuracy (CA)	F1	Precision	Recall
RF	0.996	0.995	0.995	0.995	0.995

3.2. The implementation of A-star algorithm

The GIS of MSMEs will feature a dashboard displaying the total number of MSMEs. It is categorized by micro, small, and medium classifications. Additionally, it will provide information on business types such as handicrafts, fashion, and culinary. This dashboard will serve as a reference for the Department of Cooperatives, MSMEs, and Manpower of Pesawaran Regency for analyzing and making decisions related to MSMEs distribution by category, so it is allowing policies to be more focused and specific to the categories or types of businesses present. Furthermore, the information on business types will reveal market trends and developments, and open opportunities for collaboration among MSMEs. The MSMEs dashboard can be seen in Figure 2.

The GIS of MSMEs is also equipped with MSMEs profiles to be providing detailed business information including logo photos, photos of business locations, product photos, photos of events or promotional activities, and addresses with coordinates. The GIS with MSMEs profiles can be used as a reference for stakeholders in policy-making regarding commercial area development by understanding the distribution and potential of MSMEs in specific areas. It can also guide infrastructure planning that supports MSMEs, such as road access or public facilities that enhance access to business locations. This design of the GIS with MSMEs profiles will improve information accessibility in a centralized platform. It is also facilitating navigation to MSMEs locations, so it is impacted by saving the time, efficient, and effortless in finding MSMEs. MSMEs profiles can be seen in Figure 3, MSMEs mapping in Figure 4, and the implementation of the A-star algorithm for the shortest route in Figure 5.

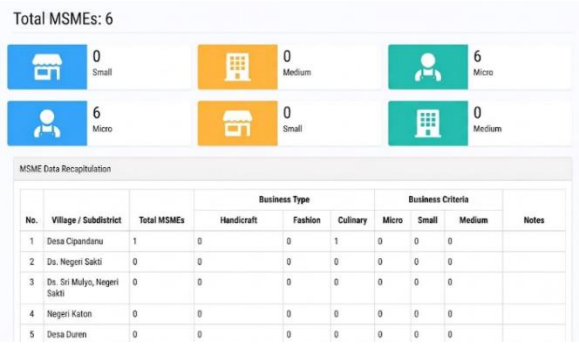

Figure 2. MSMEs dashboard

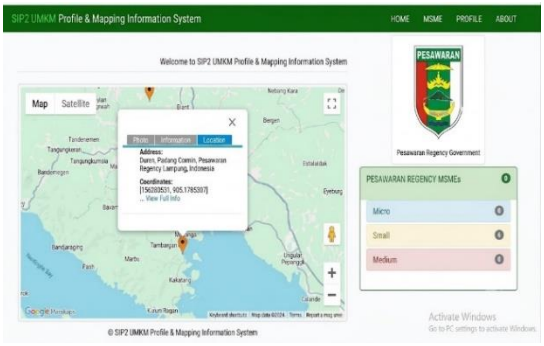

Figure 3. MSMEs profile

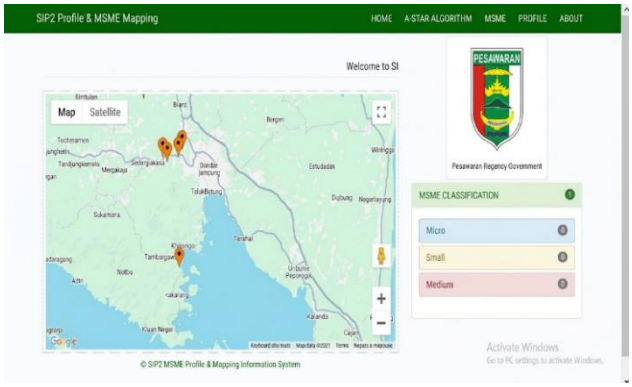

Figure 4. The mapping of MSMEs

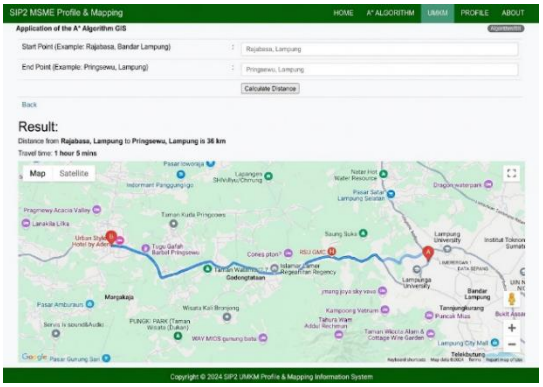

Figure 5. Implementation of A-star algorithm for shortest route

3.3. Discussion

The integration of GIS with RF and A-star can enhance promotional effectiveness by displaying location points, MSME category information, MSME profiles, and shortest-distance recommendations for easier access. This application helps solve MSMEs' problems related to limited market access, inefficient promotion, and profile visibility. With a dashboard displaying MSME profiles and various product types, it

serves as a limitless online marketing platform. The distribution of MSME locations within an area and shortest-distance recommendations assist stakeholders in regional development policy-making and make it easier for investors and consumers to reach MSME locations. Classifying MSMEs by category simplifies targeted policy-making for MSME development strategies according to each category. As in Table 3, the proposed approach differs from previous studies by integrating GIS, random forest, and A-star into a single MSME promotional framework. While previous studies mainly addressed local economic development, MSME business continuity planning, product promotion through social media, and ICT-based MSME policy development, this study combines spatial visualization, MSME classification, profile information, and shortest-distance recommendations. Therefore, the proposed approach extends previous research by providing both promotional and location-based decision-support functions for optimizing MSME promotional and development strategies. GIS, random forest, and A-star offer an effective package for optimizing MSME promotional strategies and represent an innovative approach that supports technology-based MSME growth.

Table 3. Comparison with previous research

Researcher	The approach used	Results
Ptak-Chmielewska and Chłoń-Domińczak [9]	GIS	Supporting decision making in local economic development.
Lehan and Kamarudin [10]	Geospasial	For the preparation of MSMEs BCP.
Mu'tamar *et al.* [11]	Use of various social media platforms such as Instagram, Facebook, and WhatsApp to promote MSME products	Promoting MSME products.
Kumar *et al.* [12]	Factors that influence MSMEs using ICT.	To design policies and strategies that can support technology development in the MSMEs sector.
Sulyono *et al.* (this study)	GIS, random forest, A-star	Displaying location points, MSMEs category information, MSMEs profiles, and shortest distance recommendations to facilitate access using the A-star algorithm. In addition, using the RF algorithm for MSMEs classification with model evaluation results showing an accuracy of 99.6%. This research is able to optimize MSMEs promotion and development strategies.

4. CONCLUSION

The GIS of MSMEs, combined with the RF and A-star algorithms, can optimize promotion strategies. This GIS can display MSMEs mapping according to micro, small, and medium category. It states based on the classification results from the RF algorithm with an accuracy of 99.6%. Additionally, it features a dashboard to serve as a reference for stakeholders in making more specific policies for MSMEs development. Furthermore, it provides information to the public about MSMEs profiles and opens up broader opportunities in introducing the existing MSMEs and serving as a window for potential investors to understand the MSMEs market structure and emerging business types. The A-star algorithm enhances accessibility, saving the time, efficient, and effortless in locating MSMEs, thus improving service to customers and potential investors.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data supporting the findings of this study are available from the Department of Cooperatives and SMEs of Pesawaran Regency.

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BIOGRAPHIES OF AUTHORS

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