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Design of a geographic information system (gis) for the spread of covid-19 disease in medan city

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ABSTRACT

The world is currently facing an outbreak of the corona virus (Covid-19). Covid 19 is a group of highly diverse, enveloped, single-stranded RNA viruses. This disease causes respiratory tract infections in humans with severity ranging from mild to fatal. Examples of mild illnesses such as influenza while for deadly diseases such as MERS and SARS. Medan city is one of the areas that is prone to Covid-19 disease. Where the spread of Covid-19 has reached 16.4% the positive case rate with an assessment of the Covid-19 situation as of February 2022 is at Level 4. So, we need a sytem that can monitor the progress of the case. The purpose of this research is to build a geographic information sytem using the Fuzzy C-Means method and integrate GeoJSON to map the spread of the Covid-19 disease in Medan City. The results of clustering calculations using the Fuzzy C-Means method yield the following results: Cluster 1 which contains the sub-districts of Medan Amplas, Medan Area, Medan Baru, Medan Barat, and Medan Perjuangan is in the green zone. Cluster 2 which contains the sub-districts of Medan Denai, Medan Tembung, Medan Petisah, Medan Kota, and Medan Timur is in the red zone. Cluster 3 which contains the sub-districts of Medan Tuntungan, Medan Selayang, Medan Johor, Medan Sunggal, and Medan Helvetia is in the orange zone. And Cluster 4 which contains the sub-districts of Medan Polonia, Medan Maimun, Medan Deli, Medan Labuhan, Medan Marelan, and Medan Belawan is in the yellow zone.

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1. INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a virus that can infect the respiratory tract and spread from one person to another (Dousari et al., 2020). This virus was first identified in Wuhan City, Hubei Province, China (Covid-19, 2021; Dinisari, 2020). According to data compiled by WHO (World Health Organization), as of 4 July 2020 there were 10.922.324 cases and 523.011 fatalities worldwide. Covid-19 has relatively fast transmission, has a high mortality rate and no definite treatment has been found (Ellyzabeth Sukmawati et al., 2023; Pascarella et al., 2020). On this cases, WHO declared Covid-19 a world pandemic on March 11, 2020 (Organization, 2019; Rantauni & Sukmawati, 2022; Tian et al., 2020).

Based on the monitoring of the National Disaster Management Agency (BNPB) the number of active cases of Covid-19 in Indonesia is increasing. This is evidenced by the number of active cases in 2022 of 549.431 (10.4%) cases. On the same date, the task force for the Acceleration of Handling Covid-19 recorded 60.695 cases and 3.036 fatalities found in Indonesia Medan City is one of the areas with an increase above the national average (Kirana et al., 2020). The rate of spread of Covid-19 has reached 16.4, the rate of positive cases with an assessment of the Covid-19 situation as of February 2022 is at Level 4. Community transmission – Level 4 (TK4) means that the incidence of cases found is very high for the general population (Badan Pusat Statistik, 2020; Meer & Mishra, 2021).

Special attention is needed regarding the Covid-19 disease (Dong et al., 2020; Komite Penanganan COVID-19, 2021). The Medan City Government has provided a Covid-19 information center website as an official source of information on handling Covid-19 which has become a global pandemic. The website can be accessed via the address: https://covid19.pemkomedan.go.id/. The website aims to serve as an appeal to the public regarding the spread of Covid-19 and how to control it . Where the website contains daily reports on handling Covid-19 in Medan City, call centers for Covid-19 posts, ways to reduce the risk of transmission, and steps taken by the community when they are sick. However, the website has not found any grouping of regions with the highest cases of Covid-19 to the lowest cases. So, this study aims to classify the distribution of areas with very high, high, medium, and low risk of infection with Covid-19. This zone grouping really needs the community to remain vigilant, practice social distancing, comply with health protocols in carrying out activities (Rantauni et al., n.d.), as well as a means of educating the public regarding the Covid-19 case (Kirana et al., 2020).

There are several studies that discuss the mapping of Covid-19 cases using geographic information systems. A research Meer & Mishra (2021) building a geographic information system regarding mapping the distribution of Covid-19 cases in Jammu and Kashmir. Where locations such as Srinagar and Jammu with high population and urbanization show a high number of Covid-19 cases in 2020. So, this geographic information system is used to assist medical teams by prioritizing vaccination to the community and management of facilities related to Covid-19 (Abd Majid et al., 2020; Ali, 2020).

A research (Prasetyo et al., 2020) design and build of the Covid-19 pandemic geographic information system application in East Nusa Tenggara. The output of this research is a web-based geographic information system that can display data in the form of a map of the East Nusa Tenggara Province area and can store data on the Covid-19 disease outbreak and countermeasures by integrating general database operations in the form of queries with unique analytical data visualization capabilities mapping.

A research (Rezaei et al., 2020) application of geographic information system in monitoring and detecting the Covid-19 outbreak. The output of this research is in the form of a web-based GIS that provides useful information for the community, including the location of detected patients, high-risk locations, and infected areas in South Korea. Apart from that, it also provides information on available health facilities (clinic screens for Covid-19 tests, and drugstore to find masks and hand sanitizers).

A research (Mardalius, 2020) geographical information system mapping spread of Covid-19 with the CodeIgniter Framework. The output of this research is in the form of a GIS mapping the spread of Covid-19 which can be accessed quickly, easily, and provides information on mapping the spread of Covid-19 covering Indonesia (Mardalius, 2020; Martindale, 2018; Pillai, 2020). The map in the system is able to display information in each Province in the form of recovered cases, death cases, and confirmed cases (Esri, 2019).

Based on the background described above and previous related research, no one has discussed and conducted research on the clustering of the spread of COVID-19 in the Medan City area using the Fuzzy C-Means Algorithm. Fuzzy C-Means Clustering is considered more accurate because each data is reallocated to each cluster during the iteration process by utilizing fuzzy set theory (Afzal et al., 2021; Kumar & Kumar, 2022), where each data has the possibility to be able to join each cluster based on its membership degree.

2. RESEARCH METHOD

The research method used in this study includes three main parts, namely data collection methods, analytical methods, and system design methods (W. Abdillah, 2018b, 2018a). The research method can be seen in Figure 1.

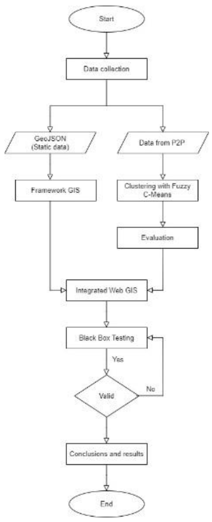

Figure 1. Research Flowchart

2.1 Data Collection and Variable Type

Data collection is done by collecting data or information needed in making geographic information systems. Data collection was obtained from static data (GeoJSON) through the website (http://nominatim.openstreetmap.org/). As for Covid-19 data with variables (recovered case data, death case data, and positive case data) obtained from the Medan City Health Office website (https://covid19.pemkomedan.go.id/) as well as from the Health Office. With the variables used for clustering are as follows:

a. Confirmed number, namely the number of people who are confirmed positive for Covid-19 after a lab test is carried out even though they are asymptomatic.
b. The number of recovered patients is the number of patients who have been hospitalized and have recovered.
c. The number of deaths namely the number of people who died from Covid-19.

2.2 Fuzzy C- Means (FCM) Algorithm

Fuzzy C-Means Algorithm (FCM) is a data collection technique where the existence of each data point in a cluster depends on the degree of membership. FCM is a supervised grouping algorithm because in the FCM algorithm the number of clusters to be formed needs to be known in advance. The basic concept of the FCM algorithm is to determine the center of the group which will mark the average position of each cluster. In the initial conditions, the cluster center is still less accurate. The following flowchart of the FCM Algorithm can be seen in Figure 2.

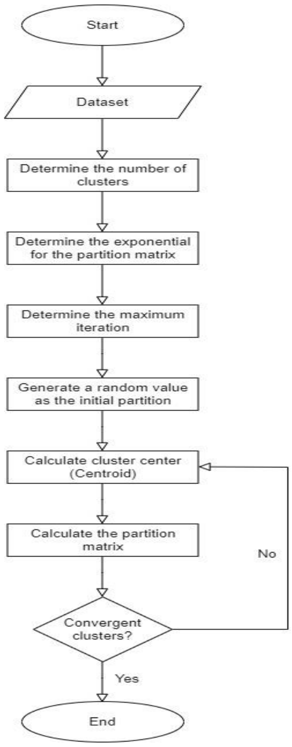

Figure 2. Fuzzy C – Means Algorithm Flowchart

2.3 Evaluation of Clustering

2.3.1 Silhouette Coefficient (SC)

Silhouette Coefficient (SC) is used to study and understand the separation distance generated by clusters. This analysis is used to measure how far a cluster is separated from other clusters. Subjective criteria for measuring whether grouping based on SC is good or not is presented in the following table:

Table 1. Silhouette Coefficient Value Interpretation

Silhouette Coefficient Value	Structure
0.7 < Silhouette Coefficient < = 1	Strong Structure
0.5 < Silhouette Coefficient < = 0.7	Medium Structure
0.25 < Silhouette Coefficient < = 0.5	Weak Structure
Silhouette Coefficient < = 0.25	Unstructured

3. RESULTS AND DISCUSSIONS

3.1 Dataset and Variable

Based on data obtained from the Medan City Health Service website (https://covid19.pemkomedan.go.id/) as well as from the Health Office, clustering or zone grouping will be carried out based on the level of cases in the Medan City area. This study used datasets from 21 sub-districts in Medan City, namely Medan Tuntungan, Medan Denai, Medan Baru, Medan Helvetia, Medan Perjuangan, Medan Selayang, Medan Tembung, Medan Polonia, Medan Barat, Medan Deli, Medan Johor, Medan Kota, Medan Maimun, Medan Petisah, Medan Labuhan, Medan Amplas, Medan Area, Medan Sunggal, Medan Timur, and Medan Marelan. Where the variables that will be used for the clustering process are the number of positive cases, the number of recovered patients, and the number of deaths. Where the 3 variables are initialized in Table 2 as follows:

Table 2. Variable Clustering

No	Variable Name	Initials
1	Recovered	X_1
2	Die	X_2
3	Confirmed	X_3

The initials of the variable names listed in Table 2 above will be used in manual calculations using the Fuzzy C-Means algorithm. As for the Covid-19 case dataset that will be used in the calculation process, it was obtained from the Medan City Health Office starting from January 1 2019 – June 16 2022 as many as 72,958 cumulative recoveries, 15 active Covid-19 case data and 1,019 cumulative deaths.

3.2 Elbow Method

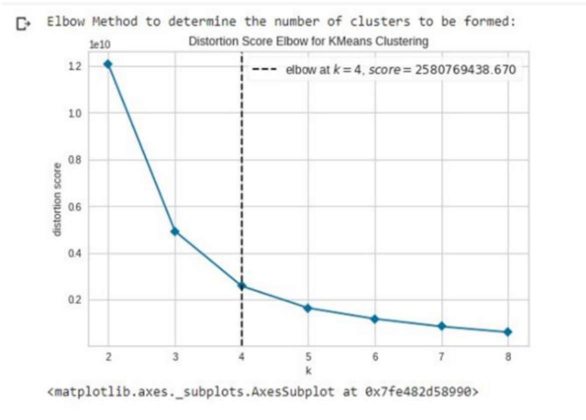

Figure 3. Elbow Method

In Figure 3, a *K* value of 4 is obtained. In the elbow method, the cluster value adjusted as the optimal cluster is the point that forms the elbow. And the optimal value is found in 4 clusters because after 4 clusters it is followed by a relatively constant value. Thus, the data will be divided into 4 clusters which will be used to determine areas based on the transmission rate of Covid-19.

3.3 Calculation Result with Fuzzy C-Means Algorithm

After carrying out manual calculations using the stages of the Fuzzy C-Means Algorithm, the final results of calculating the clustering of the spread of COVID-19 in Medan City for each data with a calculation process of up to 28 iterations can be seen in Table 3.

Table 3. Clustering Results

No	Degree of Membership in the *th* cluster				Selected cluster	cluster
	1	2	3	4		
1	27926.34424	101036.0907	186871.5016	9115.145127	186871.5016	3
2	3591.449707	7584.934094	181915.103	1729.532932	181915.103	3
3	0	0	934.4663558	0	934.4663558	3
4	9845.871355	131.8152128	6.734745706	39.34246979	9845.871355	1
5	0.89707152	703.3496399	0	0	703.3496399	2
6	1399.259059	26257.4068	185.9623674	122.6427204	26257.4068	2
7	584.884621	18301.54159	91.78698101	45.43539421	18301.54159	2
8	55798.05981	37566.23345	1685.9419	2581.949676	55789.05981	1
9	36366.12823	1136.963321	134.477326	920.2553665	36366.12823	1
10	7.883796067	5.405355948	0	4195.76127	4195.76127	4
11	176.8615491	45.60062593	16.20951373	18455.31167	18455.31167	4
12	28851.18576	105575.1592	184074.2273	9045.67909	184074.2273	3
13	7.668594669	3.415524833	5521.202816	0	5521.202816	3
14	42201.22337	1507.487565	212.7376659	1305.564149	42201.22337	1
15	36110.07088	56840.66082	1908.124568	2255.435955	56840.66082	2
16	9405.471285	107769.0432	8372.254851	1973.813654	107769.0432	2
17	4427.727945	26.25353114	6.912216872	2.352972303	4427.727945	1
18	9055.872543	2601.4562	713.247597	93950.85394	93950.85394	4
19	126.4666836	57.48197238	18.50965752	19281.84881	19281.84881	4
20	2259.351458	659.0302023	137.8966392	55357.59343	55357.59343	4
21	63998.20828	32960.01073	13315.65597	478954.8376	478954.8376	4

3.4 Implementation of Evaluation Clustering
3.4.1 Silhouette Coefficient (SC)

The calculation to determine the Silhouette Coefficient value in this study is by using Python by finding the average Silhouette Index in each cluster (Dudek, 2020; Hidayati, Zubair, Hidayat Pratama, et al., 2021). And the results obtained are as follows:

Table 4. Silhouette Coefficient Value

Silhouette Index of each Cluster	
Cluster 1	0.41079
Cluster 2	0.52599
Cluster 3	0.54644
Cluster 4	0.52466

Silhouette Coefficient	0.50197

Based on table 4 above, it can be seen that the *Silhouette Coefficient* value obtained is 0.5019 which is in the range 0.5 < *Silhouette Coefficient* < = 0.7 indicating that the clustering data is moderately structured.

3.5 Implementation of System Interface

3.5.1 User Interface Page

User Interface (UI) design is designed using several design aspects ranging from layout, logo images, and appropriate color selection which aims to make WebGIS look eye-catching for stakeholders. In this study WebGis was built using Leaflet JavaScript (Cheng & Bhaskar, Karambelkar Yihui, 2021). This library is designed for building web-based map applications and supports most mobile operating systems and desktop platforms (Rahmayuda et al., 2021; Tutorialspoint, 2019). In addition, LeafletJS with a lightweight JavaScript framework is able to display, organize, and layer GeoJSON files so that they can be used directly for embedding interactive maps in websites and applications (M. Z. Abdillah et al., 2021; Dorman, 2020; Shaikh et al., 2022). LeafletJS has several advantages such as: it can work efficiently on all major desktop and mobile platforms, it can be extended with many plugins, it has a beautiful, easy-to-use and well-documented API, and its source code is simple and easy to read. LeafletJS can be accessed at the URL: https://leafletjs.com/.

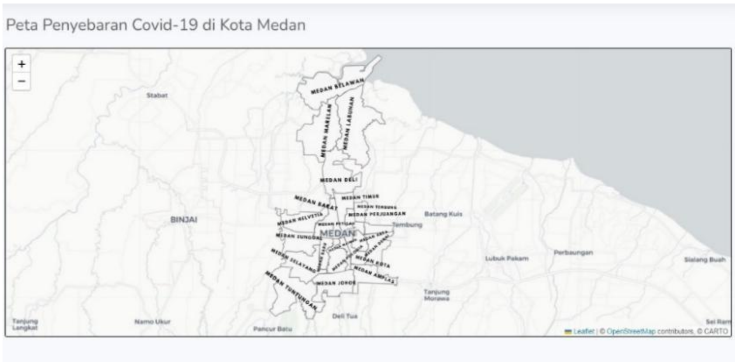

Figure 4. Medan City Map Before Display with Fuzzy Cluster

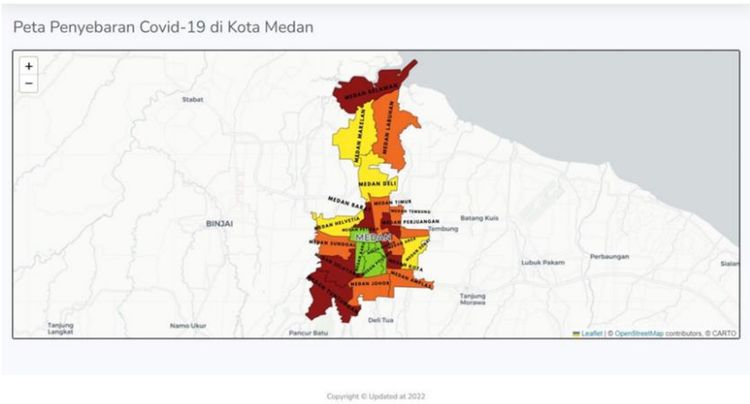

Figure 5. Medan City Map After Display with Fuzzy Cluster

3.5.2 Information Graphic Page of the Number of Active Cases of Covid-19

Figure 6. Graph of The Number of Active Cases

In figure 6 above, it can be seen that in Medan Timur District there were 5 positive cases of Covid-19, in Medan Kota District there were 3 positive cases of Covid-19, in Medan Selayang, Medan Tembung, Medan Area, Medan Sunggal, Medan Helvetia, Medan Petisah Districts, and Medan Marelan there was 1 positive case of Covid-19, and in the Districts of Medan Tuntungan, Medan Johor, Medan Amplas, Medan Denai, Medan Marelan, Medan Polonia, Medan Maimun, Medan Barat, Medan Perjuangan, Medan Deli, Medan Labuhan, and Medan Belawan did not find any positive cases of Covid-19.

3.5.3 Information Graphic Page of the Number of Covid-19 Death Cases

Figure 7. Graph of The Number of Cases of Death

In Figure 7 it can be seen that in Medan Tuntungan District there were 47 cases of death, in Medan Selayang District there were 29 cases of death, in Medan Johor District there were 37 cases of death, in Medan Amplas District there were 30 cases of death, in Medan Denai District there were 40 cases of death, in Medan Tembung District there were 37 cases of death, Medan Kota District had 39 cases of death, Medan Area District had 34 cases of death, Medan Baru District had 38 cases of death, Medan Polonia District had 47 cases of death, Medan Maimun District had 45 cases of death, Medan Sunggal District had 51 cases of death, Medan Helvetia District had 59 cases of death, Medan Barat District had 40 cases of death, Medan Petisah District had 45 cases of death, Medan Timur District had 70 cases of death, Medan Perjuangan District had 38 cases of death, Medan Deli District had 76 cases of death, Medan Labuhan District had 83 cases of death, Medan Marelan District had 84 cases of death, and Medan Belawan District had 50 cases of death.

3.5.4 Information Graphic Page of the Number of Covid-19 Recovered Cases

Figure 8. Graph of The Number of Recovered Cases

In Figure 8 it can be seen that in Medan Tuntungan District there were 4988 recovered cases, Medan Selayang District had 6199 recovered cases, Medan Johor District had 5771 recovered cases, Medan Amplas District had 3146 recovered cases, Medan Denai District had 3992 recovered cases, Medan Tembung District there were 3793 recovered cases, Medan Kota District had 3825 recovered cases, Medan Area District had 3460 recovered cases, Medan Baru District had 2842 recovered cases, Medan Polonia District had 1641 recovered cases, Medan Maimun District had 1715 recovered cases, Medan Sunggal District had 4975 cases recovered, Medan Helvetia District had 5814 recovered cases, Medan Barat District had 2824 recovered cases, Medan Petisah District had 3557 recovered cases, Medan Timur District had 4355 recovered cases, Medan Perjuangan District had 3112 recovered cases, Medan Deli District had 1926 recovered cases, Medan Labuhan District had 1439 recovered cases, Medan Marelan District had 1827 recovered cases, and Medan Belawan District had 724 recovered cases.

4. CONCLUSION

Based on the results of the trials that have been carried out, it can be concluded that in the form of a Geographic Information System that was built capable of displaying a visualization of the mapping of Covid-19 cases in Medan City based on the color of the zone of the Covid-19 virus infection area. From the results of Fuzzy C-Means Clustering calculations, the results are Cluster 1 which contains the Districts of Medan Amplas, Medan Area, Medan Baru, Medan Barat, and Medan Perjuangan, which are in the green zone. Cluster 2 which contains the districts of Medan Denai, Medan Tembung, Medan Petisah, Medan Kota, and Medan Timur is in the red zone. Cluster 3 which contains the districts of Medan Tuntungan, Medan Selayang, Medan Johor, Medan Sunggal and Medan Helvetia is in the orange zone. And Cluster 4 which contains the districts of Medan Polonia, Medan Maimun, Medan Deli, Medan Labuhan, Medan Marelan and Medan Belawan are in the yellow zone. The test results using the Silhouette Coefficient get a value of 0.52 which indicates that the data clustering is moderately structured.

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