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Covid-19 Risk Mapping with the Fuzzy C-Means Method in DIY Province

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Abstract. The Fuzzy C-Means method is one of the grouping methods that can be used by the cluster model. This method can be used to classify various case data, one of which is related to Covid-19. This research is intended to determine the level of risk of Covid-19 based on several determining variables in the province of Yogyakarta Special Region (DIY) during the last 2 months. The data is processed using fuzzy c-means clustering (FCM) analysis which is a development of fuzzy clustering analysis with c participation to analyze the Covid-19 pandemic in DIY province based on several determining variables, namely the number of additional positive victims, pdp , and the frequency of recovered patients. The number of additional positive victims, pdp, odp and frequency of recovered patients were used as variables in grouping regions by district based on the level of risk to Covid-19. The best grouping results are obtained based on "High Risk" and "Low Risk". Districts that are included in the High Risk group are Sleman and Yogyakarta Regencies. Meanwhile, other districts are included in the Low Risk group, namely Bantul, Kulon Progo, and Gunungkidul Regencies.

Keywords: covid-19, clustering, fuzzy c-means.

Running title: Covid-19 Risk Mapping with the Fuzzy C-Means Method.

INTRODUCTIONS

In december 2019, cases of mysterious pneumonia were first reported in Wuhan, Hubei Province. The source of the transmission of this case is still uncertain, but the first case was linked to a fish market in Wuhan. From 31 december 2019 to 3 January 2020, this case increased rapidly, marked by the reporting of 44 cases. In less than a month, the disease has spread to various other provinces in China, Thailand, Japan and South Korea.

The samples studied showed the etiology of the new coronavirus. Initially, the disease was temporarily named as 2019 novel coronavirus (2019-nCoV), then WHO announced a new name on February 11, 2020, namely Coronavirus Disease (Covid-19) caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) virus.).

Covid-19 is a new disease that has become a pandemic. This disease should be watched out for because transmission is relatively fast, has a mortality rate that cannot be ignored, and there is no definitive therapy. There are still many knowledge gaps in this field, so further studies are needed.

In Indonesia, the first case is positive corona virusannounced directly by President Joko Widodo on March 2. Until April 2020. Positive cases of Covid-19 have spread throughout Indonesia, including the Special Region of Yogyakarta.Cases of positive patients infected with the corona virus (Covid-19) in Indonesia is now recorded at 34 province. The last province that recorded 1 positive corona patient was Gorontalo.

The virus that causes COVID-19 is mainly transmitted via droplets (small droplets) that are produced when an infected person coughs, sneezes, or exhales. This droplet is too heavy to stay in the air. The droplet quickly falls and sticks to the floor or other surface.

The government has taken several policies in an effort to prevent an increase in the spread of Covid-19. One of them is lockdown between regions. This is done to reduce interaction between residents with one another, especially for areas that are included in the Covid-19 red zone. Each region has a different risk of transmission depending on the number of positive people with Covid-19, patients under monitoring (PDP), death, community movement, and social interactions. In this study the authors used two categories as consideration variables to cluster districts / cities in Special Region of Yogyakarta. The two categories are PDP and many people who have tested positive for Covid-19.

*Clustering*is a method of grouping based on the size of proximity (similarity). Clustering is different from groups, if group means groups that have the same conditions. While the clusters of the groups do not have to be the same, the grouping is based on the proximity of an existing sample characteristic, one of which is by using the Euclidean distance formula. The application of clusters is very much, this is because in identifying a problem or decision making, it is always not exactly the same but tends to have only similarities (Satriyanto, 2015). This study aims to examine the clustering method with Fuzzy C-Means Clustering and its application in the clustering of districts / cities in DIY based on the risk of spreading Covid-19 through many Covid-19 sufferers and patients under monitoring (PDP) (Wahidah, 2020).

1.1 Fuzzy Logic and Fuzzy Set Operations

Fuzzy Clustering is a cluster analysis method by considering the membership level which includes the fuzzy set as a weighting basis for grouping. This method is a development of the data partitioning method with fuzzy weighting. The main advantage of fuzzy clustering is that it can provide grouping results

for objects that are scattered irregularly, because if there is an irregular distribution of data, there is a possibility that a data point has characteristics or characteristics of another cluster. So it is necessary to weight the trend of data points to a cluster. Mathematically, the fuzzy clustering problem has been formulated by Bezdek (1981) in the form of constraint optimization (Efiyah, 2014).

Fuzzy sets were first developed in 1965 by Zadeh.9 Fuzzy set theory has been developed and applied in various real problems. The concept of fuzzy sets developed by Zadeh (1978).

Definiţia

Boading Note X is a universal set. Then the fuzzy subset A of X is defined by a membership function.

$$\mu A : X \rightarrow [0,1]$$

where is every element$x \in X$ and real numbers $\mu_A(x)$ on the interval, where the value$[0,1]\mu_A(x)$ *shows the level of membership (membership) of x on A.* Fuzzy set of A.

defined:

$$A = \{(x, \mu A(x)) \mid \} \; x \in X$$

This definition can be generalized if the closed interval is replaced with the maximum or minimum element. [0,1]

1.2 Clustering

According to Agusta (2015) clustering is the process of grouping objects based on information obtained from data that explains the relationship between objects with the principle of maximizing equality between members of one class and minimizing similarity between classes or clusters. According to Kusumadewi, (2010), there are two stages that must be carried out in cluster analysis, namely:

1) Deciding whether the number of clusters is determined or not, and.
2) Determining the algorithm to be used in clustering. To decide how many clusters to form.

According to Gan *et al*, (2007), in conducting clustering analysis can choose one of two approaches, namely.

1) Hard Clustering or
2) Soft Clustering. The choice of approach used depends on the type of data to be grouped.

*Hard clustering*used when the data is crisp, while soft clustering is used when the data is fuzzy (Wahidah, 2020).

1.3 Fuzzy Clustering

According to Bezdek (Wahidah, 2020), Fuzzy Clustering is a cluster analysis method by considering the membership level which includes fuzzy sets as a weighting basis for grouping. This method is a development of the data partitioning method with fuzzy weighting. The main advantage of fuzzy clustering is that it can provide grouping results for objects that are scattered irregularly, because if there is an irregular distribution of data, there is a possibility that a data point has properties or characteristics from other clusters. So it is necessary to weight the tendency of data points to a cluster. Mathematically, the fuzzy clustering problem has been formulated by Bezdek (1981) in the form of constraint optimization (Efiyah, 2014).

There are several things that need to be known before performing fuzzy clustering (Kusumadewi *et al*., 2006):

1. Fuzzy size

   The fuzzy size shows the degree of obscurity of the fuzzy set. In general, the measure of obscurity can be written as follows:

   $f: P(X) \rightarrow R$

   Where P (X) is the set of all subsets of X and f (A) is a function that maps subset A to its degree of obscurity characteristics. In measuring the value of obscurity, the function f must follow the following:

   a) $f(A) = 0$ if and only if A is the crisp set.
   b) If, then, where is more blurry than in other words sharper than. The sharpness relation is defined by:$A < Bf(A) < f(B)A < BAABA < B$
      $\mu[x] \leq \mu B[x]$, if ; and$\mu B[x] \leq 0{,}5$
      $\mu[x] \geq \mu B[x]$, if$\mu B[x] \geq 0{,}5$
   c) f(A)will reach the maximum if and only if it is completely blurred to the maximum.

   Depending on the interpretation of the degree of obscurity, the maximum fuzzy value usually occurs at the moment for each.A$\mu[x] = 0{,}5$ x

2. Blur Index

   The fuzzy index is the distance between a fuzzy set A and the closest crisp set C. The closest crisp set C to the fuzzy set A is denoted as:

   $\mu[x] = 0$, if ; and$\mu A[x] \leq 0{,}5$
   $[x] = 1$, if $\mu A[x] \geq 0{,}5$

1.4 Fuzzy C-Means (FCM)

Fuzzy C-Means (FCM) is a data clustering technique in which the existence of each data point in a cluster is determined by the degree of its membership. This technique was first introduced by Jim Bezdek in 1981 (Kusumadewi, 2006).

Fuzzy Cluster Means (FCM) is an algorithm used to perform data clustering according to the presence of each data point according to the degree of membership (Ahmadi and Hartati, 2013). Here is the FCM clustering algorithm:

1. The input data to be clustered is in the form of an nxp sized matrix (n = number of data samples, p = attributes of each data). = k-th sample data, j-th attributeXXkj$(k = 1,2, \ldots, n)(j = 1,2,3, \ldots, m)$.
2. Determine:
   a. Number of clusters = c
   b. Weighting rank = *m*

c. Maximum iteration = MaxIter
d. The smallest error expected= ε
e. Initial Objective Functions = *P0* = 0
f. Early iteration = t = 1

3. Generate random numbers as elements(μik, i = 1,2,. . , c; k = 1,2, … , n),
initial partition matrix.U

$$U_0 = \begin{bmatrix} \mu_{11}(x_1) & \cdots & \mu_{1c}(x_c) \\ \vdots & \ddots & \vdots \\ \mu_{11}(x_1) & \cdots & \mu_{1c}(x_c) \end{bmatrix}$$

The partition matrix in fuzzy clustering must meet the following conditions:

$$\mu_{ik} = [0,1]; \ (1 \le i \le c; 1 \le k \le n$$

$$\sum_{i=1}^{n} \mu_{ik} = 1; \ 1 \le i \le c$$

$$0 < \sum_{i=1}^{c} \mu_{ik} < c; \ 1 \le k \le n$$

Count the number of each column (attribute):

$$Q_j = \sum_{i=1}^{c} (\mu_{ik})$$

with *j* = 1,2,3, ..,m
Then Calculate:

$$\mu_{ik} = \frac{\mu_{ik}}{Q_j}$$

4. Calculate the center of the k th cluster: Vij, where *i* = 1,2,3, ..,c and *j* = 1,2,3, ..,m

$$V_{ij} = \frac{\sum_{k=1}^{n} ((\mu_{ik})^m * X_{kj})}{\sum_{k=1}^{n} (\mu_{ik})^m}$$

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1m} \\ \vdots & \ddots & \vdots \\ v_{c1} & \cdots & v_{cm} \end{bmatrix}$$

5. Calculate the objective function in the t-iteration Pt using the following equation:

$$P_t = \sum_{k=1}^{n} \sum_{i=1}^{c} \left(\left[\sum_{j=1}^{m} (X_{kj} - V_{ij})^2 \right] (\mu_{ik})^m \right)$$

6. Calculate the change in partition matrix:

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{p} (X_{kj} - V_{ij})^2 \right]^{\frac{-1}{p-1}}}{\sum_{i=1}^{c} \left[\sum_{j=1}^{p} (X_{kj} - V_{ij})^2 \right]^{\frac{-1}{p-1}}}$$

7. Check the stop condition:
   1. If or t <iteration is maximal then iteration is finished (stops)$|P_t - P_{t-1}| < \varepsilon$
   2. If not, then $t = t + 1$ then repeat step 4.

MATERIALS AND METHODS

This study uses secondary data with observation units of 8 districts / cities in DIY Province with samples included in the data collection based on the variable criteria used in this study on June 9, 2019.

Table 1. Many positive covid-19 and the number of patients under surveillance (PDP) in 8 Regencies / Cities in DIY Province.

City name	Parameter		
	Average Increase in Supervision (PDP and ODP)	Positive	Get well
Yogyakarta	5.3	0.74	3,3
Sleman	14.5	5.04	9.3
Kulon Progo	2.25	0.85	1,2
Bantul	7,11	-0.6	7.4
Gunungkidul	2	-0.2	2.09

This study will classify areas that have the highest membership level based on the variables used. The variables used were the number of covid-19 cases accompanied by many positive covid-19 factors and the number of patients under surveillance (PDP).

The method used is a clustering method with the Fuzzy C-Means analysis method which aims to group districts / cities in DIY into groups based on the variables that have been determined by the researcher. The first time this was done, it was determining the center of the cluster, which would later mark the average location for each cluster. By doing iterations to improve the cluster center and the degree of membership of each data point, it will be seen that the cluster center and membership degree will go to the right point location. In this study, manual calculations were carried out based on the Fuzzy C-Means algorithm.

RESULTS AND DISCUSSION

3.1 Data Clustering Using Fuzzy C-Means (FCM)

1. Determine the data to be clustered, in the form of a matrix of size nxp (n = number of data samples, p = attributes of each data). = k-th sample data, j-th attributeXXkj(k = 1,2, … , n)(j = 1,2,3,. . , m).

Table 3.1 Many positive covid-19 and the number of patients under surveillance (PDP) in 8 districts / cities in DIY Province.

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Gunungkidul	2	-0.2	2.09

2. Specifies the initial parameters.

Table 3.2 Initial Parameters.

Number of Clusters	3
Max Iteration	3
Weighter (w)	3
Epsilon	0.01
Initial objective function (P0)	0
Initial Iteration (t)	1

3. Generate random numbers as elements$(\mu ik, i = 1,2,..,c; k = 1,2,...,n)$, initial partition matrix.U

Table 3.3 Initial Partition Matrix U.

City name	Cluster membership (randomly)			Amount	$C1^2$	$C2^2$	$C3^2$
	C1	C2	C3				
Yogyakarta	0.3	0.3	0.4	1	0.09	0.09	0.16
Sleman	0.3	0.5	0.2	1	0.09	0.25	0.04
Kulon Progo	0.8	0.1	0.1	1	0.64	0.01	0.01
Bantul	0.5	0.2	0.3	1	0.25	0.04	0.09
Gunungkidul	0.5	0.1	0.4	1	0.25	0.01	0.16
Total					**1.81**	**0.61**	**1.08**

Iteration 1

4. Define clusters

Calculate the center of the k th cluster: Vij, where i = 1,2,3, ..,c and j = 1,2,3, ..,m.

$$V_{ij} = \frac{\sum_{k=1}^{n}((\mu_{ik})^m * X_{kj})}{\sum_{k=1}^{n}(\mu_{ik})^m}$$

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1m} \\ \vdots & \ddots & \vdots \\ v_{c1} & \cdots & v_{cm} \end{bmatrix}$$

Table 3.4 Cluster Data.

Clustered data			$\mu_{ik1}{}^2$			$\mu_{ik2}{}^2$			$\mu_{ik3}{}^2$		
Xi1	**Xi2**	**Xi3**	**Xi1**	**Xi2**	**Xi3**	**Xi1**	**Xi2**	**Xi3**	**Xi1**	**Xi2**	**Xi3**
0.09	0.09	0.16	0.477	0.0666	0.297	0.477	0.0666	0.297	0.848	0.184	0.528
0.09	0.25	0.04	1,305	0.4536	0.837	3,625	1.26	2,325	0.58	0.2016	0.372
0.64	0.01	0.01	1.44	0.544	0.768	0.0225	0.0085	0.012	0.0225	0.0085	0.012
0.25	0.04	0.09	1.7775	-0.15	1.85	0.2844	-0.024	0.296	0.6399	-0.054	0.666
0.25	0.01	0.16	0.5	-0.05	0.5225	0.02	-0.002	0.0209	0.32	-0.032	0.3344
1.32	**0.4**	**0.46**	**5,4995**	**0.8642**	**4,2745**	**4,4289**	**1,3091**	**0.297**	**20.81**	**87.8**	**1,9124**

The center of the V1 cluster formed in iteration 1, namely:

Table 3.5 Center Cluster V1.

Center Cluster V1		
4,166287879	0.65469697	3,238257576
11,07225	3,27275	7,37725
5.24	0.527173913	4,157391304

5. Calculating Objective Functions

Table 3.6 Objective Function Calculations.

d_1	d_2	d_3	L_1	L_2	L_3	**Total L**
1.292579781	39,7337	0.048895	0.116332	3,576032	0.007823	3,700187707
126,0164889	14.8726	106,1132	11.34148	3,718161	4.244528	19,30417263
3,710302508	83.7018	9,044317	2.374594	0.837018	0.090443	3,302054898
10,23970554	30.6976	4,767421	2,559926	1,227905	0.429068	4,216898982
5,423310084	94,3657	11,02638	1.355828	0.943657	1,764221	4.063705751

Calculate the objective function with the following formula.

$$P_t = \sum_{k=1}^{n}\sum_{i=1}^{c}\left(\left[\sum_{j=1}^{m}\left(X_{kj} - V_{ij}\right)^2\right](\mu_{ik})^m\right)$$

Objective Function
(P1):34.58701997

6. Calculates the change in the partition U matrix

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{p}\left(X_{kj} - V_{ij}\right)^2\right]^{\frac{-1}{p-1}}}{\sum_{i=1}^{c}\left[\sum_{j=1}^{p}\left(X_{kj} - V_{ij}\right)^2\right]^{\frac{-1}{p-1}}}$$

Table 3.7 Calculation of Change in Partition Matrix U.

LT_1	LT_2	LT_3	**Total LT**	$\frac{L_1}{\text{Total } LT_1}$	$\frac{L_2}{\text{Total } LT_2}$	$\frac{L_3}{\text{Total } LT_3}$
0.773647	0.025168	20.45201	21,25083	0.036405484	0.00118431	0.962410206
0.007935	0.067238	0.009424	0.084597	0.093803297	0.794799043	0.11139766
0.26952	0.011947	0.110567	0.392034	0.687491506	0.030474865	0.282033629
0.097659	0.032576	0.209757	0.339992	0.287239376	0.095813514	0.61694711
0.184389	0.010597	0.090692	0.285678	0.645444555	0.037094469	0.317460976

Obtained a new partition matrix U1.

0.036405484	0.00118431	0.962410206
0.093803297	0.794799043	0.11139766
0.687491506	0.030474865	0.282033629
0.287239376	0.095813514	0.61694711
0.645444555	0.037094469	0.317460976

7. Check the iteration conditions

$|P1\text{-}P0| = |34{,}58701997\text{-}0| = 34{,}58701997$

The iteration is continued until it reaches the maximum limit of iterations or the last objective function minus the previous objective function is smaller than ε.
In the same way, the matrix U1 is used to find the objective function in iteration 2.The center of the V2 cluster formed in the 2nd iteration is:

Center Cluster V2		
2,666206646	0.320053547	2,548927426
14,35007338	4,942231212	8,124256903
5.451982032	0.37812795	2,164834266

Obtained an objective function (P2) of 9,73698356
Check the iteration conditions
|P2 - P1| =|9,7369835624,85003641
- 34,58701997| =
And so on until iThe shrimp paste ends in the 3rd iteration (maximum iteration) and the following results are obtained.

Center Cluster V3		
3,907183202~ 4	0.32209264~ 0	2,907048105~ 3
14.36240054~ 14	5.032415436~ 5	8.334074488~ 8
2,137243273~ 2	0.547988037~ 1	2.226460039~ 2

* is done rounding because many people have positive integers.

Obtained an objective function (P3) of 3,081111481
Check the iteration conditions
|P3 - P2| =|3,0811114816,655872078
- 9,73698356| =

3.2 Results

Based on the last Vij table (V3) in iteration-3, positive patient information in the DIY area can be grouped into 3 clusters, namely:

1) The first group (low cluster) consists of areas where the number of positive patients is less than 2 people per day (Kulon Progo and Gunungkidul).
2) The second group (moderate cluster) consisted of areas where the number of positive patients was around 4 per day (Yogyakarta and Bantul).
3) The third group (high cluster) consists of areas with a lot of positive patients, around 14 people per day, namely Sleman.

Based on the last Vij table (V3) in iteration-3, information on people / patients under surveillance (PDP and ODP) in the DIY area can be grouped into 3 clusters, namely:

1) The first group (low cluster) consists of areas with a lot of additional PDP and ODP around 0 people (Bantul and Gunungkidul)
2) The second group (medium cluster) consists of areas where there is a lot of PDP and ODP added around 1 person (Yogyakarta and Kulonprogo).
3) The third group (high cluster) consists of areas with a lot of additional PDP and ODP around 5 people (Sleman).

Based on the last Vij table (V3) in iteration-3, the information on recovering patients in the DIY area can be grouped into 3 clusters, namely:

1) The first group (low cluster) consisted of areas where the number of recovered patients was around 2 people (Bantul and Gunungkidul)
2) The second group (moderate cluster) consists of areas where the number of recovered patients is around 3 people (Yogyakarta).
3) The third group (high cluster) consisted of areas where the number of recovered patients was around 8 people (Sleman and Kulon Progo).

3.3 Decision Table

Decision table is a probability table that is made to determine the final decision for the category of an area to enter into high, medium, or low risk categories.

No.	PDP	Positive	Get well	Risk
1	Low	Low	Low	Low
2	Low	Low	High	Low
3	Low	Low	Moderate	Low
4	Low	Moderate	Low	Moderate
5	Low	Moderate	High	Low
6	Low	Moderate	Moderate	Low
7	Low	High	Low	High
8	Low	High	High	Moderate
9	Low	High	Moderate	High
10	Moderate	Low	Low	Moderate
11	Moderate	Low	High	Low
12	Moderate	Low	Moderate	Low
13	Moderate	Moderate	Low	High
14	Moderate	Moderate	High	Moderate
15	Moderate	Moderate	Moderate	Moderate
16	Moderate	High	Low	High
17	Moderate	High	High	Moderate
18	Moderate	High	Moderate	High
19	High	High	Moderate	High
20	High	Low	Low	High
21	High	Low	High	Moderate
22	High	Low	Moderate	Moderate
23	High	Moderate	Low	High
24	High	Moderate	High	Moderate
25	High	Moderate	Moderate	High
26	High	High	Low	High
27	High	High	High	High

Based on the table above, the final decision is obtained as follows.

Name of Regency / City	PDP and ODP	Positive	Get well	Decision
Yogyakarta	Moderate	Moderate	Moderate	**Moderate**
Sleman	High	High	High	**High**
Kulon Progo	Moderate	Low	High	**Low**
Bantul	low	moderate	low	**Moderate**
Gunungkidul	low	low	low	**Low**

CONCLUSIONS

Based on the research results it can be concluded that the results of the numerical simulation of data clustering using Fuzzy C-Means (FCM) are:

a) *Fuzzy C-Means Clustering* can be used to group districts / cities in DIY based on the risk of spreading Covid-19 through the increase in positive sufferers of Covid-19, the patient was under monitoring (PDP and ODP), and the patient recovered.
b) The number of clusters formed is 3 clusters.
c) The degree of membership that appears shows a value that tends to be close one group is the same, so that a data has two or more groups different.
d) Regency / City grouping in DIY Province resulted in 2 districts / cities entering
   in the low-cluster, namely Kulon Progo and Gunungkidul, 2 districts are included
   cluster-sedang namely Yogyakarta and Bantul, and 1 regency / city that are included cluster-high namely Sleman.
e) The objective function in the final iteration is 3,081111481

For further research it is recommended to

1) For further research, it is better to involve other factors that influence the spread of covid-19 in Yogyakarta Province with more iterations so that the difference in objective functions is smaller or equal to ε.
2) If the iteration is extended, it is recommended to use other software, such as MATLAB.
3) It is hoped that the results of this study can be used as material for government studies to take better policies as an effort to reduce the risk of the spread of Covid-19 in DIY Province.

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