Clustering of COVID-19 Provinces in Indonesia Using Fuzzy Means Cluster Methods

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Abstract. COVID-19 is a contagious virus that has global pandemic. Indonesia has the highest infected cases of COVID-19 in South-East Asia. The aim of the research is classified provinces in Indonesia using Fuzzy Mean Cluster (FCM) based on positive cases, recovery cases, and death cases of COVID-19. The result using FCM is three clusters. Fist cluster that marked by red zone is DKI Jakarta, third cluster that marked by orange zone is West Java, Central Java, and East Java, second cluster that marked by yellow zone is other provinces in Indonesia. Validity of FCM using Partition Coefficient Index (PCI) is 95,36%. It means that using three clusters is the most optimal.

Keywords: COVID-19 · Global pandemic · Fuzzy means clusters · Partition coefficient index

1 Introduction

Corona Virus also known as COVID-19 is global pandemic that be contagious respiration system for mid respiratory to severe respiratory infection such as flu or lung infection [1]. The symptoms of COVID-19 are similar with SARS which is fever more than 38 shortness of breath and accompanied by a dry cough [2]. The first time this virus was found in animal market and seafood at Wuhan, China at end of 2019. It spread almost all over the wort in that time, including in Indonesia [3] (Rizal, J.G., 2020). In Indonesia, COVID-19 entered at March, 2nd 2020 that infected by 2 Indonesian citizen [4]. Total population in Indonesia is 270,20 million people with a land area of 1,9 million km^2 [5] (BPS, 2021). Thus, at March, 31st 2021 Indonesia occupies the highest confirmed case in ASEAN infected countries. WHO and PHEOC has recorded COVID-19 case until the end of March of 2021. Total confirmation case of COVID-19 is 1.511.712 cases, recovering 1.348.330 cases, and death 40.858 cases [2]. Based on data the government of Indonesia has formed new policies to prevent and suppress the spread of the Corona Virus, which is *Pembatasan Sosial Berskala Besar* (PSBB) or Large-Scale Social Restrictions.

Cluster analysis is a multivariate analysis to group objects that have similar characters. The similar objects are then grouped into a class consist of several members. One of method in cluster analysis use Fuzzy Clustering algorithm [6]. The advantages of Fuzzy Clustering is the grouping of object in the result being scattered randomly. Data

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has characteristics when it has random distribution. Then, a weighting of the trend of data points is required against a cluster. In this research, use Fuzzy Cluster Means which is the data can be elements of all clusters formed with unequal membership degrees between 0 to 1 [7]. Then, it is clustering technique where the degree of membership determines the existence of each data point in a cluster [6].

The previous research using Fuzzy Clustering is [8] that compare the rate of spread of COVID-19 in high-risk countries, there are three clusters and the results of the grouping show that the spread in Spain and Italy is approximately the same. Then, [9] used K-Means Clustering to group districts/cities in Central Java based on COVID-19 cases and [10] using Fuzzy Cluster Means to group the points of the Special Region of Yogyakarta based on data air quality.

The aim of the research is grouping the spread of COVID-19 in each province of Indonesia using Fuzzy Cluster Means. Then, the government can concern especially in province that has similar characteristics from Fuzzy Cluster result in the future. The expectation Indonesia become the lowest country of COVID-19 case in ASEAN.

2 Method

Fuzzy clustering is a cluster analysis that contains fuzzy sets to classify the level of membership then used as a weighting basis for grouping. Weighting method in Fuzzy develops from partitioning methods. Data have characteristic from other clusters when it has randomly distributed. Then, the weighting of the trend in data points is needed against a cluster. Therefore, the advantage fuzzy clustering is object group in that results are scattered randomly.

One of the most used fuzzy clustering algorithms is The Fuzzy C-Means clustering algorithm. The method has introduced by J.C. Dunn in 1971 then improved by J. C. Bezdek in 1981. The Fuzzy C-Means (FCM) algorithm is determined center of cluster using means for each cluster. The center of cluster condition is inaccurate at the first.

Then, the degree of membership in each data and the cluster center is repaired at each point continuously until the cluster center moves towards the appropriate location. The process is repeated to minimization the objective function which is described by the distance from the data point to the cluster center. Objective functions are weighted by the degree of data point membership [11]. The objection function that used

$$J_w(U, V) = \sum_{k=1}^{N} \sum_{i=1}^{c} (u_{ik})^w d_{ik}^2 \tag{1}$$

where,

$J_w(U, V)$: objection function to U and V

c: number of clusters in x.

w: rank (weighted), $w \in [1, \infty)$

Then, x is data to be clustered that formed $n \times m$. Where, n is number of sample and m is criteria for each data [11].

x_{ij}: *i-th* sample($i = 1, 2, 3, \ldots, n$), *j-th* attribute ($j = 1, 2, 3, \ldots, m$)

$$x_{ij} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \tag{2}$$

$\boldsymbol{u}$: initial partition matrix

$$\boldsymbol{u} = \begin{bmatrix} u_{11}(x_1) & u_{12}(x_1) & \cdots u_{1c}(x_n) \\ u_{21}(x_1) & u_{22}(x_2) & \cdots u_{2c}(x_n) \\ \vdots & \vdots & \vdots \\ u_{n1}(x_1) & u_{n2}(x_2) & \cdots \quad u_{nc}(x_n) \end{bmatrix} \tag{3}$$

$\boldsymbol{v}$: cluster center matrix

$$v_{kj} = \begin{bmatrix} v_{11} & \cdots & v_{1m} \\ \vdots & \ddots & \vdots \\ v_{c1} & \cdots & v_{cm} \end{bmatrix} \tag{4}$$

u_{ik}: elements of $\boldsymbol{u}$ partition matrix. Then, *k-th* data membership function which is ($k = 1, 2, 3, \ldots, c$) in *j*-th cluster ($j = 1, 2, 3, \ldots, m$)

d_{ik}: distance function in each center of cluster

$$d_{ik} = d(x_i - v_k) = \left[\sum_{j=1}^{m} \left(x_{ij} - v_{kj}\right)^2\right] \tag{5}$$

Where,

x_i: *i-th* data with ($i = 1, 2, 3, \ldots, n$)

v_k: *k*-th center value of matrix with ($k = 1, 2, 3, \ldots, c$)

m: number of variable (criteria)

v_{kj}: center of *k*-th cluster in *j*-th variable.

FCM is part of Hard K-Means method. Therefore, the data can be element of the cluster with degree of membership that unequal membership degrees between 0 to 1. The degree of membership on it is a determinant of the level of existence of data in cluster [7].

2.1 Fuzzy Cluster Means Algorithms

The FCM algorithms are [7].

1. Input data that clustering, x, that formed matrix $n \times m$ and x_{ij}
2. Determining
   a. Number of clustering: c
   b. Rank: w
   c. Maximum iteration: *MaxIter*
   d. The smallest error expectation: ε

e. Initial objective function: $p_0 = 0$
f. Early iteration: $t = 1$

3. Generating random number $u_{ik}, i = 1, 2, 3, \ldots, n; k = 1, 2, 3, \ldots, c$; as early matrix elements of U
   a. Computing number of columns

$$Q_i = \sum_{k=1}^{c} u_{ik} \tag{6}$$

   Where, $j = 1, 2, 3, \ldots, n$
   b. Then computing random number u_{jk}

$$u_{jk} = \frac{u_{ik}}{Q_i} \tag{7}$$

4. Computing center of cluster k-th, v_{kj}

$$v_{kj} = \frac{\sum_{i=1}^{n} \left({u_{ik}}^{w} \times x_{ij} \right)}{\sum_{i-1}^{n} {u_{ik}}^{w}} \tag{8}$$

5. Determining objection function in *t-th* iteration, p_t

$$p_t = \sum_{i=1}^{n} \sum_{k=1}^{c} \left(\left(\sum_{j=1}^{m} \left(x_{ij} - v_{kj} \right)^2 \right) {u_{ik}}^{w} \right) \tag{9}$$

6. Generating changed of partition matrix, u_{ik}

$$u_{ik} = \frac{\left(\sum_{j=1}^{m} \left(x_{ij} - v_{kj} \right)^2 \right)^{\frac{-1}{w-1}}}{\sum_{k=1}^{c} \left(\sum_{j=1}^{m} \left(x_{ij} - v_{kj} \right)^2 \right)^{\frac{-1}{w-1}}} \tag{10}$$

7. Verifying stop condition

   If $|P_t - P_{t-1}| < \varepsilon$ or $t > MaxIter$ then stop; or $t = t + 1$, repeat 4-th step

2.2 Category Determination Based on Center of Cluster Value

In each element of data has a trend in one cluster that seeing from rank of member of each clustered. Then, the results are seen in center of cluster by matrix v_{kj}. Based on those, obtained information about clustered by determining category on each variable. In this study, center of cluster, v_{kj}, ordered center of cluster in each variable that used categorical label from the lowest to the largest [1]. The categorical define characteristic of data which is low, medium, high, and others [12] depending on number of clusters.

2.2.1 Cluster Validity

Validity in cluster use to accuracy formed or goodness of cluster. One of cluster validity use *Partition Coefficient Index* (PCI). Coefficient index proposed by Bezdek in 1974 [11]. It is first validity of FCM to measure number of overlapping between cluster that has geometric information.

$$PCI = \frac{1}{N} \sum_{i=1}^{c} \sum_{k=1}^{N} u_{ik}^2 \tag{11}$$

Then,

N: research object

c: number of clustering

Coefficient index partition has range $\frac{1}{c} \leq PCI \leq 1$. When, approached 1 has optimum clustered or has the best performance clustered for those data set [10].

2.3 COVID-19

COVID-19 or Corona Virus Diseases is one of virus that caused respiration in human or animal. It is a contagious disease respiration infection such as influenza to Middle East Respiration (MERS) and Severe Acute Respiratory Syndrome (SARS). The first known case of COVID-19 discovered in Wuhan, China in December 2019 then spreads worldwide, leading to an ongoing pandemic. Symptoms of COVID-19 are similar to SARS. Common symptoms of it are fever more than 38 °C, shortness breath and accompanied by a dry cough. People who have severe medical condition such as diabetes, heartache, asthma, high blood pressure and others have more risked susceptible and fatal than healthy people [2].

COVID-19 transmission cause through droplets that occur when someone coughs, sneezes, or talks. Someone who infected accidentally spread the droplets then people must keep the distance minimum one meter or using mask. However, COVID-19 prevented by washing hands using soap and running water, or cleaning them with alcohol. WHO assesses the risk of transmission from people who lack of symptoms has low probability infected others. Some people that infected by COVID-19 have mild symptoms such as coughing in early stage. The experts are still investigating the disease [2].

2.4 Data Source

Data that use in this research is COVID-19 transmission in Indonesia 2021 from Ministry of Health of Indonesia (Kemenkes). Data is number of cases COVID-19 from 34 province in Indonesia. Number of cases in this research mean number of COVID-19 patient in each case where has three cases in data specifically positive case (x_1), recovery case (x_2), death case (x_3) by COVID-19.

The definition regarding COVID-19 by Kemenkes is [13].

- The number of positive COVID-19 (x_1): Number of people who infected by COVID-19 then the laboratory result was positive
- Recovery case (x_2): Number of people who healed after infected by COVID-19 then the laboratory result was changed from positive to negative
- Death case (x_3): Number of people who death by COVID-19 then the result of laboratory was positive

3 Results and Discussions

3.1 Descriptive Statistics

Figure 1 is COVID-19 transmission data by date March, 31st 2021. It shows that patient who has positive COVID-19 scattered in 34 provinces with varying numbers. Based on data, Indonesia is the highest cases in ASEAN that increased day by day which is 5.937 positive cases, 2635 recovered cases, then 104 death cases by COVID-19 [13]. The lowest province case is Maluku Utara (North Maluku) which is 4.328 cases. While, the highest positive case is the capital city of Indonesia, DKI Jakarta, which is 38.2055 cases. Then, it has the highest recovered cases 36.8935 cases. The highest province death case is Jawa Timur (East Java) which is 9.922 cases and the lowest death cases is Kalimantan Barat (West Kalimantan) which is 33 cases. Enhancement COVID-19 in Indonesia cases have volatile cases from March, 2nd 2020 to March, 31st 2021. The condition gained government attention to handle COVID-19 especially in areas that have high daily condition. Figure 2 is development graphic of positive COVID-19 cases in Indonesia [14].

Figure 2 shows that COVID-19 in Indonesia has volatile then increased. However, in March 2021 the cases decreased from last month. It because the result of implementation

Fig. 1. Distribution Positive Case of COVID-19 in Indonesia

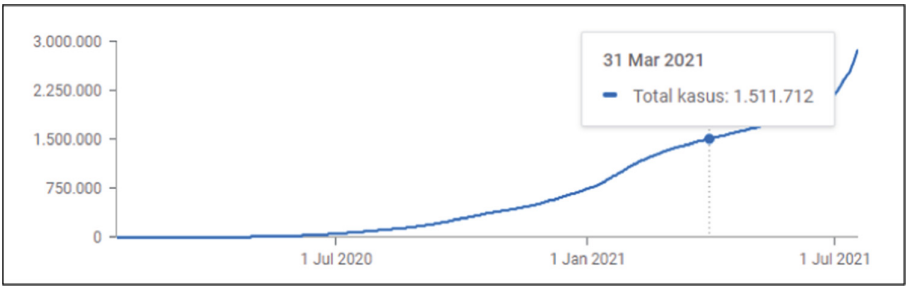

Fig. 2. Development Graphic of Positive COVID-19 Cases in Indonesia

government of Indonesia which is Enforcement of Restrictions on Community Activities (PPKM) at February 23rd to March 8th 2021 then to be extend at March 22nd 2021. The new cases at March 31st 2021 was 5.937 cases then total cases COVID-19 in Indonesia by 31 March 31st 2021 was 1.511.712 cases. The cases spread into various regions in 34 provinces.

3.2 FCM Analysis

Based on FCM algorithms are

- Determine three input variables as x_1 (positive cases), x_2 (recovery cases), x_3 (death cases). Then input data into cluster $n \times m$ (n: number of sample data which is 34 provinces and m: attribute in each data which is 3). x_{ij} is sample data i-th ($i = 1, 2, 3, \ldots,$ n) then j-th attribute ($j = 1, 2, 3, \ldots, m$)
- Define
  - Number of clustering : 3
  - Rank : 2
  - Maximum iteration : 100
  - The smallest error expectation: 10^{-5}
  - Initial objective function : 0
  - Early iteration : 1
- Generating random number u_{ik}, $i = 1, 2, 3, \ldots, n$ and $k = 1, 2, 3, \ldots, c$, as early matrix elements of U (Table 1).
- Computing partition matrix change

  Change of partition matrix of u using Eq. (10).

$$u_{ik} = \frac{\left[\sum_{j=1}^{m} (X_{ij} - v_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m} (x_{ij} - v_{kj})^2\right]^{\frac{-1}{w-1}}} \text{ dengan } i = 1, 2, \ldots, n \text{ dan } k = 1, 2, \ldots, c$$

  Then, produced new matrix partition of u_1. Table 2 shows new matrix partition in first iteration of u_1.

- Verifying stop condition

$|P_1 - P_0| = |189854115419,014 - 0|$ then, it has $189854115419,014 > 10^{-5}$ and iteration $1 <$ MaxIter (100) later iteration continues to second iteration. In second iteration, redefined three clusters center of v_{kj} (the algorithms such as in first algorithm) to $|P_t - P_{t-1}| < \varepsilon$ or $t >$ MaxIter.

The study use MATLAB to help computing center of clusters, rank of cluster or matrix u, then objection function. The result is number of clusters group 3, 4, and 5. The center of clusters has generated one center of cluster. At the beginning center of cluster is inconstant then improving continuously towards in right location. The process has discontinued when the objection function constant. The number of iterations in this study are 36 times for three group of clusters, 34 times for four group of clusters and 27 times for five group of clusters. Category COVID-19 is based on the value of cluster

center [12], to simplify interpretation, then the sequenced of each variable has some labels.

Table 3 show center of cluster that has constant in each iteration in the group of clusters with some labels. Then, matrix u is a partition matrix that has last generated membership level value. The level membership value use to determine location of the cluster. Subsequently, the result of group clusters provinces in Indonesia using 3 cluster, 4 cluster and 5 cluster respectively.

3.3 Cluster Validity

Cluster validity use for goodness of the result of grouping. The study applies Partition Coefficient Index (PCI) as evaluating of membership value in cluster. Parameter validity of cluster that use PCI describes value of proximity. It has 0 to 1 when the value approached 1 is satisfactory, and vice versa. Table 4 is result PCI in this study.

Based on PCI value COVID-19 spreading in Indonesia by March, 31st 2021 has obtained using 3 cluster. It has optimal cluster than the others. Then, in this case use 3 cluster for grouping COVID-19 spread in Indonesia.

The risk map zone draws pandemic situation by region that created using public health indicators. Based on National Disaster Management Agency (BNPB) [15] in

Table 1. Early Matrix Element of *U* Partition

Number	Early Matrix Partition			Number	Early Matrix Partition		
1	0,538	0,44	0,022	18	0,548	0,432	0,02
2	0,523	0,46	0,017	19	0,543	0,442	0,015
3	0,509	0,48	0,011	20	0,526	0,471	0,003
4	0,51	0,478	0,012	21	0,543	0,445	0,012
5	0,548	0,444	0,008	22	0,527	0,457	0,016
6	0,519	0,456	0,025	23	0,513	0,475	0,012
7	0,513	0,472	0,015	24	0,537	0,455	0,008
8	0,509	0,463	0,028	25	0,542	0,44	0,018
9	0,522	0,469	0,009	26	0,518	0,468	0,014
10	0,507	0,48	0,013	27	0,505	0,487	0,008
11	0,505	0,487	0,008	28	0,511	0,479	0,01
12	0,526	0,467	0,007	29	0,508	0,478	0,014
13	0,558	0,418	0,024	30	0,506	0,483	0,011
14	0,542	0,445	0,013	31	0,514	0,478	0,008
15	0,504	0,46	0,036	32	0,533	0,452	0,015
16	0,546	0,443	0,011	33	0,651	0,342	0,007
17	0,51	0,475	0,015	34	0,514	0,478	0,008

Source: Data Processing in MATLAB

Table 2. New Matrix Partition in First Iteration

Number	New Partition in First Iteration (u_1)		
1	0,395	0,349	0,256
2	0,45	0,351	0,199
3	0,493	0,346	0,161
4	0,536	0,335	0,129
5	0,39	0,348	0,262
6	0,412	0,351	0,237
7	0,389	0,348	0,263
8	0,404	0,35	0,246
9	0,395	0,349	0,256
10	0,395	0,349	0,256
11	0,327	0,331	0,342
12	0,322	0,329	0,349
13	0,313	0,324	0,363
14	0,492	0,344	0,164
15	0,309	0,323	0,368
16	0,55	0,326	0,124
17	0,691	0,256	0,053
18	0,394	0,349	0,257
19	0,399	0,35	0,251
20	0,39	0,348	0,262
21	0,41	0,35	0,24
22	0,453	0,35	0,197
23	0,207	0,258	0,535
24	0,397	0,35	0,253
25	0,405	0,35	0,245
26	0,398	0,35	0,252
27	0,189	0,243	0,568
28	0,397	0,349	0,254
29	0,389	0,348	0,263
30	0,389	0,348	0,263
31	0,392	0,349	0,259
32	0,387	0,348	0,265
33	0,407	0,35	0,243
34	0,393	0,349	0,258

Source: Data Processing in MATLAB

Indonesia has four colors to identify regional risk which is red, orange, yellow, and green. The explanation of thus colors are

- Green Zone
  - Zero case confirmed area or some infected cases that arrived from the other countries
- Yellow Zone
  - Area that has several local transmissions, without any form of community transmission
- Orange Zone
  - Area that adjacent to red zone, or small spreading clusters

Table 3. Center of Clusters in 36 Times, 34 Times, and 27 Times Iterations

Group of clusters	Last times iteration	Clustering	Positive cases	Recovery cases	Death cases
3	36 times	Cluster 1	3,7452	3,6057	0,0616
		Cluster 2	0,1809	0,1585	0,0046
		Cluster 3	1,7078	1,435	0,0736
4	34 times	Cluster 1	0,1057	0,0895	0,0028
		Cluster 2	3,7641	3,6265	0,062
		Cluster 3	0,4034	0,3653	0,0094
		Cluster 4	1,7273	1,4425	0,0749
5	27 times	Cluster 1	1,5377	1,2684	0,0857
		Cluster 2	0,3913	0,3536	0,0092
		Cluster 3	3,8204	3,6892	0,0634
		Cluster 4	0,104	0,0881	0,0028
		Cluster 5	2,5019	2,2199	0,0316

Source: Data Processing in MATLAB

Table 4. Cluster Validity

Number of Clusters	PCI value
3	0,953628
4	0,887807
5	0,908188

Source: Data Processing in MATLAB

- Red Zone
  - Area that has the highest number of confirmed cases

Regarding on FCM result and optimal PCI value has 3 cluster that is positive cases, recovery cases, and death cases. Then, the cluster is visualized in Fig. 3 and Fig. 4 for red zone.

- Cluster 1 (Red Zone): Cluster with positive cases are relatively high, recoveries are relatively high, and deaths cases are relatively moderate by COVID-19. The cluster area is capital city of Indonesia, DKI Jakarta, with the highest population density which is 15.900 jiwa/km^2.
- Cluster 2 (Yellow Zone): cluster with positive cases are relatively low, recovering cases are relatively low, and death cases are relatively low by COVID-19. Clusters are dominated by sparsely populated areas with a population density of $<$1000

Fig. 3. Results for Grouping 3 Clusters (Optimal PCI). Source: Data Processing

Fig. 4. Red Zone in Cluster 1 using FCM. Source: Data Processin

people/km^2 which is Aceh, North Sumatera, West Sumatera, Riau, Jambi, South Sumatera, Bengkulu, Lampung, Bangka Belitung, Riau Islands, DI Yogyakarta, Banten, Bali, West Nusa Tenggara, East Nusa Tenggara, West Kalimantan, Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, North Sulawesi, Central Sulawesi, South Sulawesi, Southeast Sulawesi, Gorontalo, West Sulawesi, Maluku, North Maluku, Papua and West Papua.

- Cluster 3 (Orange Zone): Clusters with positive cases are relatively moderate, recovery cases are relatively moderate, and death cases are relatively high. The cluster

which is dominated by densely populated areas with a percentage of Indonesia's population of 56.10% is located on the island of Java which is West Java, Central Java, and East Java

The result section may also be divided by subheadings covering the key findings of the study, discussing the potential shortcomings and limitations on their interpretations; discussing their integration into the current understanding of the problem and how this advances the current views; speculate on the future direction of the research and freely postulate theories that could be tested in the future.

4 Conclusion

The conclusion based on FCM and optimal PCI value has three clusters by COVID-19 in provinces of Indonesia. The result of the research should be considered for government to monitor in the future variants of COVID-19 especially in Red Zone and Orange Zone. Since, they produce government policies regarding of this pandemic. However, Bed Occupancy Rate (BOR) or hospitals and bed capacities in Indonesia are not evenly distributed throughout Indonesia [16].

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