Journal of Advanced Zoology

ISSN: 0253-7214
*Volume **44** Issue **03 Year 2023** Page **1215:1226***

Application of the K-Means Clustering Algorithm to Determine Student Academic Ability Levels during Covid-19

Bustami[1], Nurdin[2*], Taufiq[3], Fajriana[4], Muhammad Khatami[5]

[1,5]*Department of Informatics, Universitas Malikussaleh, Aceh, Indonesia.*
[2]*Department of Information Technology, Universitas Malikussaleh, Aceh, Indonesia.*
[3]*Department of Electrical Engineering, Universitas Malikussaleh, Aceh, Indonesia.*
[4]*Department of Mathematics Education, Universitas Malikussaleh, Aceh, Indonesia.*

**Corresponding author's E-mail: nurdin@unimal.ac.id*

Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 08 Nov 2023

Abstract

Since the existence of the COVID-19 pandemic in Indonesia, various ways and efforts have been made by the government to prevent the spread of the corona virus. One of them is by implementing an online learning system, so that it causes differences in the learning process that is usually carried out by lecturer face to face with students. Changes in the learning process are expected to be carried out effectively and efficiently. The purpose of this research is to find out how the level of students' academic ability is during online learning in the Informatics Engineering study program at Universitas Malikussaleh and aims to produce a system model that can cluster the level of student academic ability using the K-Means Clustering Algorithm. The variables used in this study are 3 parameters, namely the teaching and learning process, facilities and infrastructure and learning outcomes. The stages carried out in this study were collecting questionnaire data filled out by 200 students. The data obtained would be processed using the K-Means Clustering Algorithm and forming 3 clusters, namely low, medium and high. The clustering results of 200 data obtained 27 students having low academic ability levels (Cluster 1), 87 students having moderate academic ability levels (Cluster 2) and as many as 86 students having high academic ability levels (Cluster 3). The contribution of this research is to help the management of the Informatics Engineering Study Program at Universitas Malikussaleh to find out how the level of student academic ability is during the online learning period during the COVID-19 pandemic, so that evaluation of learning can be carried out online.

Keywords: *K-Means Clustering, COVID-19 Pandemic, Academic Ability, Student.*

1. Introduction

As a result of the COVID-19 pandemic that hit not only Indonesia but also other countries in the world very big impact on various sectors of human life, especially in the economic sector (Fernandes, 2020), environmental sector (Zambrano-Monserrate et al., 2020) and the education sector (Akat & Karatas, 2020), (König et al., 2020). Many universities have closed the face-to-face learning process and are advised to study at home online. In accordance with the Decree of the Ministry of Education and Culture of the Republic of Indonesia Number 1 of 2020 concerning teaching and learning processes that are carried out online is the best choice during the COVID-19 pandemic, so that the teaching and learning process has changed which is usually carried out face to face. With this change, of course learning cannot be carried out optimally and there are many obstacles in the learning process. It is hoped that changes in the teaching and learning process in tertiary institutions can be carried out effectively and efficiently and students are able to adapt to the changes that occur during learning (Handarini & Wulandari, 2020).

Universitas Malikussaleh is a state university that also implements an online learning system. Students also feel changes in the learning system so far and are expected to accept the established online learning system policies. This stipulated policy certainly does not guarantee an increase in students' academic abilities because the level of student abilities is different. Therefore, a system is needed that can

determine the level of student academic ability in online learning so that it can evaluate and improve the constraints in online learning carried out during the COVID-19 pandemic. The system designed in this study is a data mining approach using the K-Means Clustering Algorithm. The K-Means algorithm is a non-hierarchical data grouping method that seeks to partition existing data into two or more groups, so that data with the same characteristics is included in the same group and data with other characteristics is included in another group (Noviana et al., 2019).

The K-Means Algorithm has been widely applied in various case studies, such as the Application of the K-Means Clustering Algorithm for Determining Fire Prone Areas (Khairani & Sutoyo, 2020), Implementation of the K-Means Algorithm for Clustering Feasible Land for Corn Planting in South Lampung Regency (Aldino et al., 2021), Application of the K-Means Method for Clustering Capture Fisheries Products in North Aceh with A Data Mining Approach (Nurdin et al, 2023), Mapping System Model and Clustering of Fishery Products using K-Means Algorithm with Web GIS Approach (Nurdin et al, 2023), and review of the K-Means Clustering algorithm approach on other data models (Shukla, 2014). Besides this K-Means algorithm, there are also many clustering algorithms that are applied in educational data mining (Dutt, 2015), including the naïve Bayes classifier algorithm used for data classification, such as data classification of student scientific work using the naïve Bayes classifier method (Nurdin et al., 2021).

Based on the results of previous related studies, no one has examined the problem of implementing the K-Means clustering algorithm to determine the level of student academic ability during COVID-19. The importance of this research was conducted to determine the level of academic ability of Informatics Engineering students at Universitas Malikussaleh in online learning conducted during the COVID-19 pandemic, which is useful for evaluating learning conducted online so that it becomes even better in the future. The purpose of this study is to find out how the level of student academic ability is during online learning and to produce a system model that can cluster student academic ability levels using the K-Means clustering algorithm. The variables used in this study are 3 parameters, namely the teaching and learning process, facilities and infrastructure and learning outcomes. The output results from this system model obtained 3 clusters of student academic ability levels, namely low, medium and high. Apart from this research, there are other studies that the authors have conducted related to COVID-19 including clustering the distribution of COVID-19 in Aceh Province using the Fuzzy C-Means algorithm (Fitriani, et al., 2022), a comparison of the Naive Bayes and Dempster Shafer methods in expert systems for early diagnosis of COVID -19 (Susanti et al., 2022).

Besides that, there are several other studies that have been conducted by researchers including, research Lecture Scheduling System Using Welch Powell Graph Coloring Algorithm in Informatics Engineering Departement of Universitas Malikussaleh (Abdullah et al., 2019), Mixed integer linear programming model for integrated fish supply chain planning (Nurdin et al., 2020), Robust optimization approach for agricultural commodity supply chain planning (Nurdin et al., 2021), Data Driven Optimization Approach to Fish Resources Supply Chain Planning in Aceh Province (Nurdin et al., 2019) Optimization and Computing Model of Fish Resource Supply Chain Distribution Network (Nurdin et al., 2021) and Implementation of the BFS algorithm and web scraping techniques for online shop detection in Indonesia (Nurdin, Bustami et al., 2021).

2. Literature Review

There are several previous studies that are related and related to this research conducted by (Nurdin, Nasution, et al., 2022) implementing Fuzzy C-Means to determine the level of student satisfaction in online learning using 500 student respondent data with a maximum 100 iterations, the number of clusters formed is two, namely satisfied and dissatisfied and a minimum error of 0.0001 to get clustering results in the 26th iteration. The results of this study showed that around 61% (303 students) were satisfied with the online learning process that had been carried out and 39% (197 students) were dissatisfied with the online learning process. Research conducted by (Arofah & Marisa, 2018) applied data mining to find out students' interest in mathematics using the K-Means Clustering method, clustering results using the K-Means Algorithm showed that 45 students had a high interest in mathematics, 48 students have moderate interest and 29 students have low interest in mathematics.

Research conducted by (Sianipar et al., 2020) the K-Means algorithm can be used to determine the level of student satisfaction with online learning, based on the level of agreement or disagreement with online learning. Research conducted by (Elizawati & Lesmana, 2017) clustering method with the K-Means Algorithm can be used to group students according to their interests in productive subjects in class XII based on their report card scores when they were in class X. Another study conducted by (Faisal et al., 2022) clustering Information and Communication Technology competencies for SMK students used

the K-Means Clustering Algorithm, this study used 3 clusters namely very competent, competent and less competent clusters with the results of testing 10 students in cluster 1 with predicate very competent, 64 students in cluster 2 with a competent predicate, and 10 students in cluster 3 with a less competent predicate.

Research conducted by (Kane et al., 2016) this study discusses the analysis of student academic performance using the Fuzzy C-Means Clustering method (Aldi & Ade Rahma, 2019). Based on the results of the clustering process of 4255 student academic data, 4 clusters were obtained. The clusters with the best achievement category were cluster 3 with 1753 students, cluster 4 with 1496 students, cluster 2 with 676 students and cluster 1 with 330 students. Research conducted by (Arifin et al., 2021) research results the number of clusters formed there are 3. In the first cluster the category of satisfied with online learning is categorized as "high" with a value of 9.33 while the dissatisfied category is categorized as "low" with a value of 0.67. In the second cluster, the happy category with online learning was classified as "low" with a value of 4.73, while the dissatisfied category was rated as "high" with a value of 5.27 and in the third cluster, those who were satisfied or dissatisfied had no value (0.0). Research conducted by (Aldi & Ade Rahma, 2019) This research uses K-Means and Fuzzy C-Means cluster analysis to group students into three groups based on their learning outcomes. In the first cluster 2.63% got low scores, in the second cluster 23.68% got scores around the average. And in the third cluster 73.68% get high scores.

Research conducted by (Hussain et al., 2018) the academic performance of students was evaluated based on academic data collected from 3 different universities from Assam, India. The number of records is 300 with 24 attributes. The data mining used in this experiment is WEKA 3.8 with the results of the Apriori Algorithm applied to the dataset using WEKA can find some of the best rules. While the results of research on the analysis of student satisfaction with academic services using the Decision Tree Algorithm C4.5 obtained 82 students who were satisfied and the remaining 18 students who were dissatisfied (Aldi & Ade Rahma, 2019). Another study conducted by (Ponto & Nurlaily, 2020) this research discusses the level of student satisfaction with online learning compared to traditional classes for English lessons. The criteria used are teacher expertise, curriculum, facilities, infrastructure, and demographics. The result is that online lectures at UIB are currently not satisfactory and have not reached the standards of students. Data mining techniques used in the context of learning management systems (LMS) can assist in the decision-making process to improve e-learning systems or web-based education (Ajibade et al., 2022).

3. Materials And Methods

Research Stages

The stages in this research are as follows.

1. Literature study

This stage is carried out to obtain literature studies and references from various sources such as journals, books, papers related to the research conducted.

2. Online questionnaire

This stage the author gives an online questionnaire to students of the informatics engineering study program at malikussaleh university to get data from students regarding academic ability.

3. Data processing

This stage is a process carried out to process raw data into data that can be input to the system. This data is obtained from the results of a questionnaire filled out by students of the Universitas Malikussaleh Informatics Engineering study program.

4. System design

The stages carried out in designing this system are designing the database system and designing the interface.

5. System implementation

This implementation is the result of the design stage into the form of an application using the php programming language and mysql database.

6. System testing

This stage testing the system that has been made, which is useful for knowing whether the system is running or as desired. The following are the stages of this research.

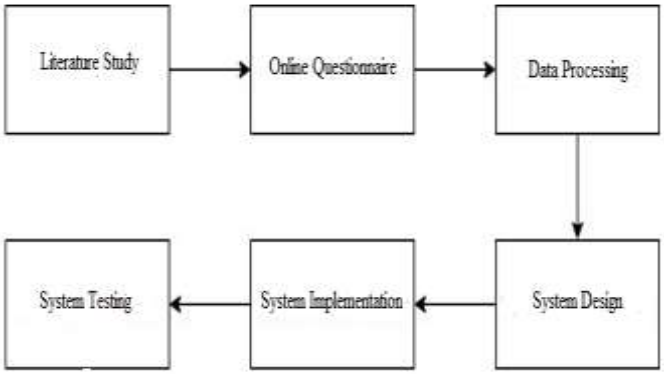

Figure 1. Research stages

K-Means Clustering Algorithm

The K-Means algorithm is used to determine the number of clusters (Escorcia Guzman, 2021), formed through the use of a specific condition known as criterion, which is involved in the optimal, the splitting method utilizes a condition called as criterion, which is involved in the optimal division of the dataset set by appropriate optimization problems (Borlea et al., 2021). K-means provides a more comprehensive view of applicant characteristics and needs; using K-means clustering, it is possible to identify the key characteristics of each potential data cluster (Abdullah et al., 2022). Data that has a representative value similarity in one group and data that has a difference in another group so that it allows grouping different data that has a small level of variation. The main principle of this technique is to construct K centroid mass partitions from a set of data, Using the Euclidean Distance formula, calculate the distance between each input data point and each centroid (Sulistiyawati & Supriyanto, 2021).

$$D_{(x,y)} = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots + (x_n - y_n)^2} \quad (1)$$

Where, $D_{(x,y)}$ represents *Euclidean Distance*, X_1 represents first data training, Y_1 first data testing, X_2 represents second data training, Y_2 represents second data testing, X_n represents *n* data training, and Y_n represents *n* data testing.

The process stages in implementing the K-Means Clustering algorithm are as follows (Kane et al., 2016):

1. Determine the value of k as the number of clusters to be formed;
2. Initialize k cluster centers in a random way from the dataset;
3. Calculating the distance of each input data to each centroid using the Euclidean Distance formula;
4. Classify each data based on the closest distance to the centroid;
5. Update the centroid value, the new centroid value is obtained from the cluster average;
6. Repeat from step 2 to 5, until nothing changes in the members of each cluster.

The application of the K-Mean Clustering Algorithm in this study is to determine the level of academic ability of students during the COVID-19 pandemic by dividing the data into three clusters, namely low (cluster 1), medium (cluster 2) and high (cluster 3). The system scheme of the K-Means Clustering Algorithm can be seen in Figure 2 below:

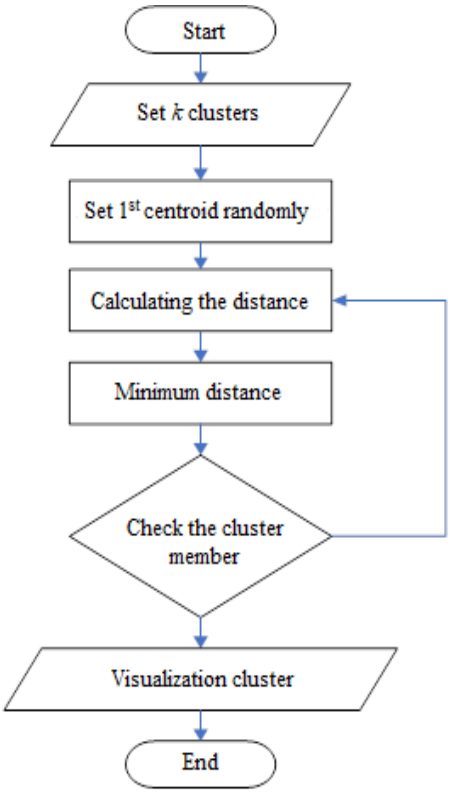

Figure 2. Data clustering flowchart using K-Means Algorithm

Data Collection and Variable Type

In this study, the authors collected data by distributing questionnaires to students using google form which was carried out in the odd semester of the 2021/2022 Academic Year at the Department of Informatics Engineering, Universitas Malikussaleh. The data used is the data from the questionnaire of 200 students from the class of 2018, 2019 and 2020 using 3 variables and 16 Question Categories as in Table 1.

Table 1: Value of Optimal Decision Variable

Variable 1 (V1): Learning Process	
Categories	**Questions**
A1	Online lectures can be accessed easily
A2	Implementation of online lectures on time and according to schedule
A3	Online lectures increase theoretical understanding and skills
A4	The material presented online is in accordance with the Lecture Contract
A5	Easy to send tasks
A6	The exam material is in accordance with the lecture material
A7	Fulfills a minimum of 14 meetings
A8	Your general level of understanding of the course presented online
Variable 2 (V2): Facilities and Infrastructure	
Categories	**Questions**
A9	Materials on online learning are well available
A10	Students have devices/equipment that support them during online lectures
A11	Selection of varied online platforms
A12	Lecturers provide opportunities for students to ask questions and discuss
A13	Lecturer gives information if the lecture is canceled
A14	Lecturers give grades in accordance with the assessment procedures in the syllabus and lecture contract.
A15	Lecturers are able to explain the relevance of the topics taught to other topic areas
Variable 2 (V3): Learning Outcomes	
Categories	**Questions**
A16	How much is the Semester IP earned

3. Results and Discussion

Calculation Results Using K-Means Clustering Algorithm

Dataset This study uses data from questionnaires filled out by Universitas Malikussaleh Informatics engineering students as many as 200 students from the class of 2018, 2019 and 2020. The following are the calculation steps carried out using the K-Means Clustering Algorithm.

1. Input data of questionnaire results

The first step is to input the data from the questionnaire that will be clustered. There are 3 types of variables used, namely V1= learning process, V2= facilities and infrastructure and V3= learning outcomes can be seen in Table 2.

Table 2: Questionnaire Result Data

No.	Name	Student ID	Class	V1	V2	V3
1.	X1	180170094	2018	2,75	3,25	3,5
2.	X2	180170092	2018	3,25	3,125	3,8
3.	X3	180170110	2018	4	4	3,82
4.	X4	190170075	2019	2,875	3,625	3,91
5.	X5	200170239	2020	4,375	4	3,53
..	……	……...	…….	….	…..	….
200.	X200	190170101	2019	3,875	3,75	3,60

The values of V1 and V2 are obtained by calculating the average value of each variable, while V3 contains only one question, based on the answers of the respondents through the questionnaires that have been distributed, with equation 3:

$$\text{Score average} = \frac{Total\ score}{Number\ of\ items} \quad (2)$$

Where, X1 on the variable V1 (learning process) = $\frac{3+3+2+3+1+3+4+3}{8} = \frac{22}{8}$ = 2,75.

variable V2 (facilities and infrastructure) = $\frac{4+3+4+3+3+2+3+4}{8} = \frac{26}{8}$ = 3,25 and variable V3 (learning outcomes) = 3,5 and so on for respondents 2 to 200.

2. Determining the Dataset

This dataset is used for data processing in Table 3.

Table 3: Determining the Dataset

No.	Name	V1	V2	V3
1.	X1	2,75	3,25	3,5
2.	X2	3,25	3,125	3,8
3.	X3	4	4	3,82
4.	X4	2,875	3,625	3,91
5.	X5	4,375	4	3,53
..	……	….	…..	….
200.	X200	3,87	3,75	3,60

3. Determine the initial centroid

This initial centroid is randomly selected from the data from the questionnaire results that have been filled in by students in Table 4.

Table 4: Initial Centroid

No.	Name	V1	V2	V3
2.	X1	3,25	3,125	3,8
12.	X2	3,125	3,25	3,87
16.	X3	4	4,25	3,64

4. Use of K-Means Clustering Algorithm

The input parameters used are the datasets in table 3, with an initial centroid of 3 data, with the steps performed as follows:

a. Determination of clusters.

There are 3 clusters used, namely: C1=low, C2=medium and C3=high.

b. Determination of the initial cluster centroid, can be seen in Table 4.

c. The calculation uses the Euclidean distance equation.

To determine the distance of each data to each centroid using the Euclidean distance equation. 1st data with centroid-1. The calculation of the distance of the 1st data in each cluster is as follows.

$$d(x_1 - c_1) = \sqrt{(PP_{c1} - PP)^2 + (SP_{c1} - SP)^2 + (HP_{c1} - HP)^2}$$

$$= \sqrt{(2{,}75 - 3{,}25)^2} + (3{,}25 - 3{,}125)^2 + (3{,}5 - 3{,}8)^2$$

$$= \sqrt{0{,}765 + 0{,}015 + 0{,}09}$$

$$= 0{,}596$$

$$d(x_2 - c_2) = \sqrt{(PP_{c2} - PP)^2 + (SP_{c2} - SP)^2 + (HP_{c2} - HP)^2}$$

$$= \sqrt{(2{,}75 - 3{,}125)^2} + (3{,}25 - 3{,}25)^2 + (3{,}5 - 3{,}87)^2$$

$$= \sqrt{0{,}140 + 0 + 0{,}136}$$

$$= 0{,}526$$

$$d(x_3 - c_3) = \sqrt{(PP_{c3} - PP)^2 + (SP_{c3} - SP)^2 + (HP_{c3} - HP)^2}$$

$$= \sqrt{(2{,}75 - 4)^2} + (3{,}25 - 4{,}25)^2 + (3{,}5 - 3{,}64)^2$$

$$= \sqrt{1{,}562 + 1 + 0{,}019}$$

$$= \sqrt{2{,}5816}$$

$$= 1{,}606$$

The same calculation will be done as above for all student data.

d. Allocate each data based on its proximity to the centroid (smallest distance).

After the calculation is done, the closest distance and cluster group for each student's academic ability level data can be seen in Table 5.

Table 5: Closest Distances and Cluster Groups

No.	Name	C1	C2	C3
1.	X1	0,5963	0,5268	1,6068
2.	X2	0	0,1901	1,3615
3.	X3	1,1526	1,1535	0,3080
4.	X4	0,5269	0,4524	0,9242
5.	X5	1,4505	1,4968	0,4639
..	……	….	…..	….
200.	X6	0,9062	0,9409	0,5169

After each data is calculated for each cluster, the next step is to group the data according to its cluster. The cluster group of a data is taken from the shortest distance of the data to a cluster. Clustering is done on 200 data and the clustering results can be seen in Table 6.

Table 6: Cluster Grouping Iteration 1

No.	Name	C1	C2	C3	Clusters
1.	X1	0,5963	0,5268	1,6068	C2
2.	X2	0	0,1901	1,3615	C1
3.	X3	1,1526	1,1535	0,3080	C3
4.	X4	0,5269	0,4524	0,9242	C2
5.	X5	1,4505	1,4968	0,4639	C3
..	……	….	…..	….	….

200.	X6	0,9062	0,9409	0,5169	C3

e. Determining the new centroid

After determining the cluster based on the smallest distance, the next step is to calculate the new centroid value obtained from the formula below:

$$\text{New centroid} = \frac{amount\ of\ data\ in\ cluster\ i}{many\ data\ in\ cluster\ i} \quad (3)$$

The new centroid values can be seen in Table 7.

Table 7: New Centroid Iteration 1

Centroid	V1	V2	V3
C1	3,1562	2,9034	3,6636
C2	2,8152	3,3623	3,6155
C3	3,9870	4,1422	3,6540

f. Comparing the new centroid with the previous centroid.

After the new centroid value is obtained, the next step is to compare with the previous centroid value. If the value is the same then the iteration process is stopped. But on the contrary, if the centroid value is different the iteration process must be repeated from step 3 to step 6. The results in the ninth iteration calculation show that the centroid values are all the same and the calculation is complete.

Table 8: Cluster Grouping Iteration 9

No.	Name	C1	C2	C3	Cluster
1.	X1	0,9307	0,5173	1,5476	C2
2.	X2	1,2355	0,3006	1,2652	C2
3.	X3	2,3438	1,0032	0,1821	C3
4.	X4	1,6350	0,3510	0,8362	C2
5.	X5	2,6493	1,3264	0,4334	C3
..	…….	….	…..	….	….
200.	X200	2,0922	0,7631	0,4205	C3

The results of the new centroid calculation can be seen in Table 9.

Table 9: New Centroid Iteration 9

Centroid	V1	V2	V3
C1	2,1296	2,5509	3,6792
C2	3,1997	3,3951	3,7003
C3	4,0014	4,1380	3,7011

In the 9th iteration the calculation is complete, because the results of the 8th and 9th iteration cluster calculations get the same results, where the cluster results of each data remain the same and there is no change. Clustering results from 200 student data using the K-Means Clustering Algorithm obtained in cluster C1 students who have a Low academic ability level are 27 students, cluster C2 students who have a Medium academic ability level are 87 students and cluster C3 students who have a High academic ability level are 86 students. The following is a graph of the clustering results of the academic ability levels of students during the COVID-19 pandemic at the Universitas Malikussaleh Informatics Engineering Department in Figure 3.

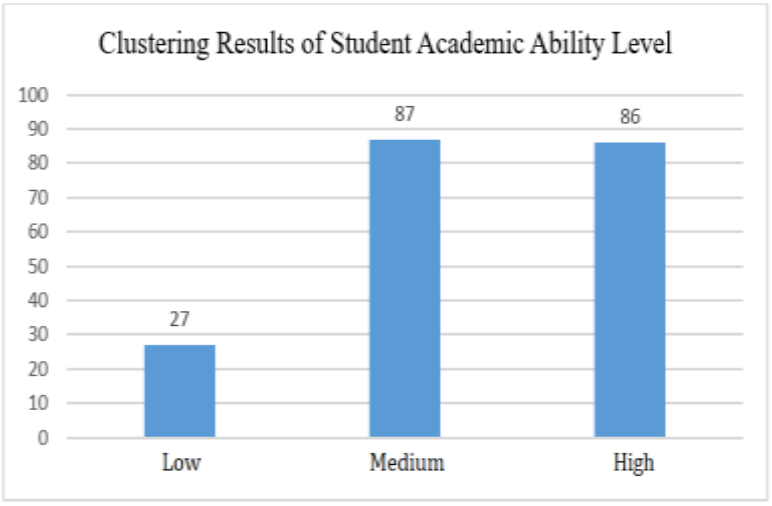

Figure 3. Clustering Result Graph

Class of 2018 students are 38 people, where 5 people belong to cluster C1 (low), 20 people belong to cluster C2 (medium) and 25 people belong to cluster C3 (high). Class of 2019 as many as 58 students, where 4 people belong to cluster C1 (low), 21 people belong to cluster C2 (medium) and 33 people belong to cluster C3 (high). While the Class of 2020 is 104 students, where 18 people belong to cluster C1 (low), 47 people belong to cluster C2 (medium) and 39 people belong to cluster C3 (high). The following is a graph of the level of academic ability of students based on class from 2018-2020 in Figure 4.

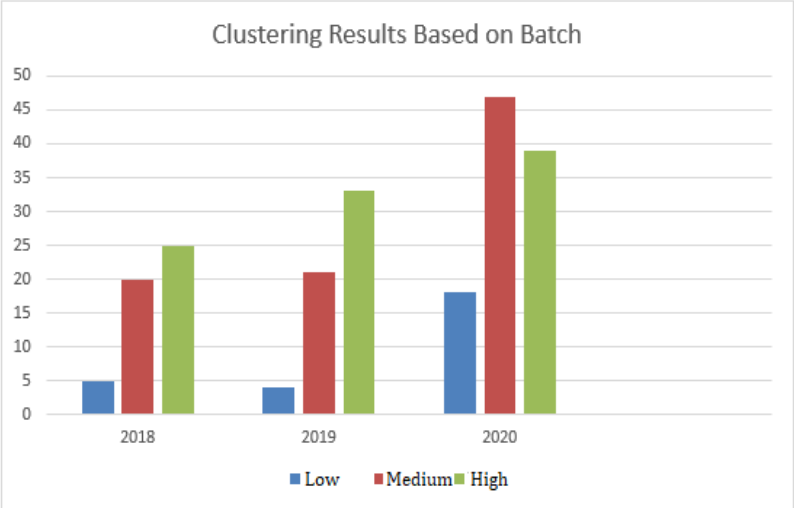

Figure 4. Graph of Clustering Results Based on Class

Implementation of System Interface

The following is the interface of the dashboard page. On the output page of this system displays a graph of the results of the calculation of the clusterization of the academic ability level of students using the K-Means clustering algorithm can be seen in Figure 5.

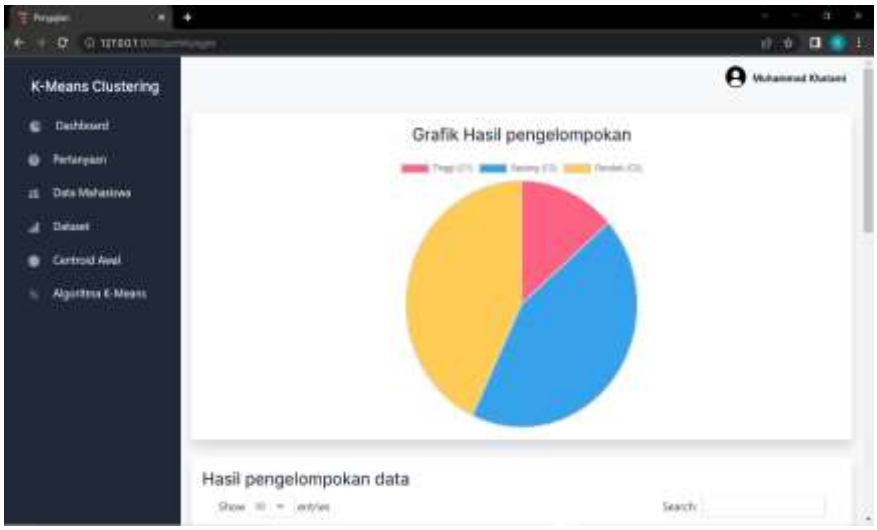

Figure 5. Graph of Clustering Results of Student Academic Ability Levels

The following is a display image of the clustering results of the student's academic ability level according to the cluster. This page also contains the clustering results of all datasets and variables processed using the K-Means Algorithm in Figure 6.

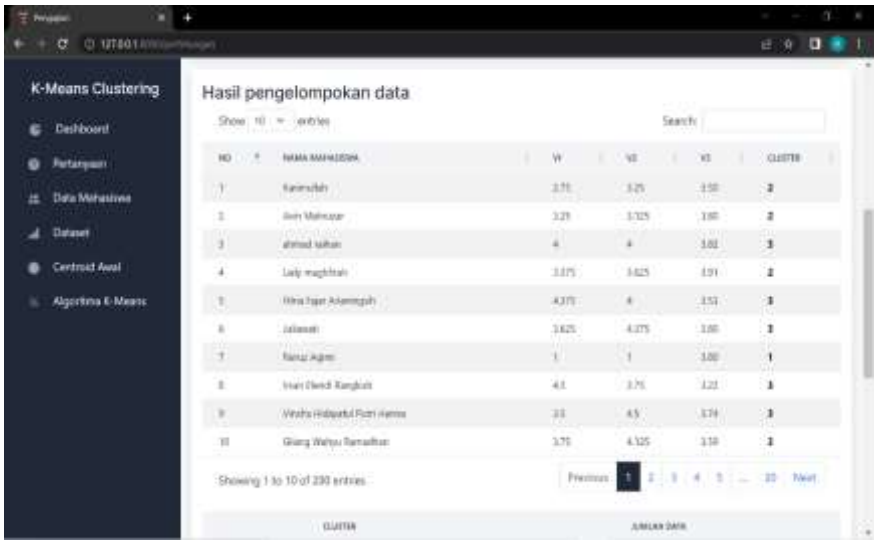

Figure 6. Display Page of Student Data Clustering Results

4. Conclusion

Based on the results of this study, the K-Means Clustering Algorithm can perform a clustering process to determine the level of academic ability of students during the COVID-19 pandemic. This study uses 200 student respondent data with manual calculations and application systems until the 9th iteration. From 200 student data grouped into 3 clusters, of which in cluster C1 there are 27 students with low academic ability levels, cluster C2 there are 87 students with moderate academic ability levels and cluster C3 there are 86 students with high academic ability levels. This research produces a system that is able to cluster the level of academic ability of students using the K-Means Clustering Algorithm, so that it can help managers of the Universitas Malikussaleh, Informatics Engineering Department to evaluate and improve the online learning process.

Further research is recommended to use other clustering methods as a comparison to find out which method is better. This application system is still web-based can be developed again into an android-based system to make it easier to use.

References:

Abdullah, D., Nurdin, N., Yaton, M., et al. (2019). Lecture Scheduling System Using Welch Powell Graph Coloring Algorithm in Informatics Engineering Departement of Universitas Malikussaleh. IOP Conf. Series: Journal of Physics: Conf. Series, 1363, 012074.

Abdullah, D., Susilo, S., Ahmar, A. S., Rusli, R., & Hidayat, R. (2022). The application of K-means clustering for province clustering in Indonesia of the risk of the COVID-19 pandemic based on COVID-19 data. Qual. Quant, 56(3), 1283–1291. https://doi.org/10.1007/s11135-021-01176-w

Ajibade, S. S. M., Dayupay, J., Ngo-Hoang, D. L., & Oyebode, O. J. (2022). Utilization of Ensemble Techniques for Prediction of the Academic Performance of Students. Journal of Optoelectronics Laser. 15(6), 48–54.

Akat, M., & Karatas, K. (2020). Psychological Effects of COVID-19 Pandemic on Society and Its Reflections on Education. Journal of Turkish Studies, Volume 15 (Volume 15 Issue 4), 1–13. https://doi.org/10.7827/turkishstudies.44336

Aldi, F., & Ade Rahma, A. (2019). University Student Satisfaction Analysis on Academic Services by Using Decision Tree C4.5 Algorithm (Case Study : Universitas Putra Indonesia "yPTK" Padang). Journal of Physics: Conference Series, 1339(1). https://doi.org/10.1088/1742-6596/1339/1/012051

Aldino, A. A., Darwis, D., Prastowo, A. T., & Sujana, C. (2021). Implementation of K-Means Algorithm for Clustering Corn Planting Feasibility Area in South Lampung Regency. Journal of Physics: Conference Series, 1751(1). https://doi.org/10.1088/1742-6596/1751/1/012038

Arifin, T. S. J., Natassa, N., Khoirunnisa, D., & Hendrowati, R. (2021). The Level of Student Satisfaction with the Online Learning Process During a Pandemic Using the K-means Algorithm. Inform : Scientific Journal of Information and Communication Technology, 6(2), 123–126.

Arofah, S. N., & Marisa, F. (2018). Penerapan Data Mining untuk Mengetahui Minat Siswa pada Pelajaran Matematika menggunakan Metode K-Means Clustering. JOINTECS (Journal of Information Technology and Computer Science), 3(2), 85–90. https://doi.org/10.31328/jointecs.v3i2.787

Borlea, I. D., Precup, R. E., & Borlea, A. B. (2021). Improvement of K-means Cluster Quality by Post Processing Resulted Clusters. Procedia Comput. Sci, 199, 63–70. https://doi.org/10.1016/j.procs.2022.01.009.

Bustami, Hutomi, M., Elveny, M., & Syah, R. (2021). Implementation of the BFS algorithm and web scraping techniques for online shop detection in Indonesia. Journal of Theoretical and Applied Information Technology, 99(12), 2878-2889.

Dutt, A. (2015). Clustering Algorithms Applied in Educational Data Mining. International Journal of Information and Electronics Engineering, 5(2), 112–116. https://doi.org/10.7763/ijiee.2015.v5.513

Elizawati, N., & Lesmana, L. S. (2017). Analisis Nilai Rapor Siswa Kelas X Jurusan Multimedia Terhadap Minat pada Pelajaran Produktif Di Kelas XII untuk Menentukan Kompetensi Siswa dengan Metode Clustering Algoritma K-Means (Studi Kasus Di SMKN 4 Padang). Jurnal Komputer Terapan, 3(2), 133–148.

Escorcia Guzman, J. H., Zuluaga-Ortiz, R. A., Barrios-Miranda, D. A., & Delahoz-Dominguez, E. J. (2021). Information and Communication Technologies (ICT) in the processes of distribution and use of knowledge in Higher Education Institutions (HEIs). Procedia Comput. Sci, 198, 644–649, https://doi.org/10.1016/j.procs.2021.12.300

Faisal, M., Nurdin, N., Fajriana, F., & Fitri, Z. (2022). Information and Communication Technology Competencies Clustering For Students For Vocational High School Students Using K-Means Clustering Algorithm. International Journal of Engineering, Science and Information Technology, 2(3), 111–120. https://doi.org/10.52088/ijesty.v2i3.318

Fernandes, N. (2020). Economic effects of coronavirus outbreak (COVID-19) on the world economy Nuno Fernandes Full Professor of Finance IESE Business School Spain. SSRN Electronic Journal, ISSN 1556-5068, Elsevier BV, 0–29

Fitriani, S., & Yunizar, Z. (2022). Clustering the Distribution of COVID-19 in Aceh Province Using the Fuzzy C-Means Algorithm. JTAM (Jurnal Teori Dan Aplikasi Matematika, 6(3), 665–677.

Handarini, O. I., & Wulandari, S. S. (2020). Pembelajaran Daring Sebagai Upaya Study From Home (SFH). Jurnal Pendidikan Administrasi Perkantoran (JPAP), 8(3), 465–503.

Hussain, S., Dahan, N. A., Ba-Alwib, F. M., & Ribata, N. (2018). Educational data mining and analysis of students' academic performance using WEKA. Indonesian Journal of Electrical Engineering and Computer Science, 9(2), 447–459. https://doi.org/10.11591/ijeecs.v9.i2.pp447-459

Kane, S. N., Mishra, A., & Dutta, A. K. (2016). Preface: International Conference on Recent Trends in Physics (ICRTP 2016). J. Phys. Conf. Ser, 755(1). https://doi.org/10.1088/1742-6596/755/1/011001

Khairani, N. A., & Sutoyo, E. (2020). Application of K-Means Clustering Algorithm for Determination of Fire-Prone Areas Utilizing Hotspots in West Kalimantan Province. International Journal of Advances in Data and Information Systems, 1(1), 9–16. https://doi.org/10.25008/ijadis.v1i1.13

König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: teacher education and teacher competence effects among early career teachers in Germany. European Journal of Teacher Education, 43(4), 608–622. https://doi.org/10.1080/02619768.2020.1809650

Nasution, U. M. P., Aidilof, H. A., & Bustami. (2022). Online Implementation of Fuzzy C-Means to Determine Student Satisfaction Levels. SISTEMASI: Jurnal Sistem Informasi 11(1), 121–136. http://sistemasi.ftik.unisi.ac.id

Noviana, T., Jasmir, J., & Novianto, Y. (2019). Penerapan Data Mining Menentukan Kelompok Prioritas Penerima Bantuan Beras Rastra Dengan Clustering K-Means. Program Studi Teknik Informatika, Stikom Dinamika Bangsa, 159–174.

Nurdin, Bustami, & Maryana. (2021). Robust Optimization Approach for Agricultural Commodity Supply Chain Planningg. Journal of Theoretical and Applied Information Technology, 99(2), 304–315.

Nurdin, Bustami, Meiyanti, R., Fahada, A., & Marleni. (2023). Application of the K-Means Method for Clustering Capture Fisheries Products in North Aceh with A Data Mining Approach. Journal of Advanced Zoology, 44(4), 39–49. https://doi.org/10.17762/jaz.v44i4.1358

Nurdin, Taufiq, Fajriana, & Ulhaq, M. Z. (2023). Mapping System Model and Clustering of Fishery Products using K-Means Algorithm with Web GIS Approach. Int J Intell Syst Appl Eng, 11(3), 738–749.

Nurdin, Zarlis, M., Tulus., & Efendi, S. (2021). Optimization and Computing Model of Fish Resource Supply Chain Distribution Network. IOP Conf. Series: Journal of Physics: Conf. Series, 1898, 012022.

Nurdin, Zarlis, M., Tulus., & Efendi, S. (2019). Data Driven Optimization Approach to Fish Resources Supply Chain Planning in Aceh Province. IOP Conf. Series: Journal of Physics: Conf. Series 1255 012081.

Nurdin, Zarlis, M., Tulus., & Efendi, S. (2020). Mixed Integer Linear Programming Model for Integrated Fish Supply Chain Planning. Journal of Theoretical and Applied Information Technology, 98(12), 2017-2028.

Ponto, G., & Nurlaily, N. (2020). Students' Satisfaction Level Towards Online Learning Compared To Traditional Classroom For English Subject. Jet Adi Buana, 5(02), 131–138. https://doi.org/10.36456/jet.v5.n02.2020.2540

Rosadi, R., Akamal, Sudrajat, R., Kharismawan, B., & Hambali, Y. A. (2017). Student academic performance analysis using fuzzy C-means clustering. *IOP Conf. Ser.: Mater. Sci.* https://doi.org/10.1088/1757-899X/166/1/012036

Sari, I. P., & Batubara, I. H. (2021). Cluster Analysis Using K-Means Algorithm and Fuzzy C- Means Clustering for Grouping Students Abilities in Online Learning Process. J. Comput. Sci. Inf. Technol. Telecommun. Eng, 2(1), 139–144. https://dx.doi.org/10.30596/jcositte.v2i1.6504

Shan, Y., & Zhi, Z. (2016). A novel fuzzy SVM based on fuzzy c-means for credit scoring. 2016 2nd IEEE International Conference on Computer and Communications, ICCC 2016 - Proceedings, 1349–1353. https://doi.org/10.1109/CompComm.2016.7924924

Shukla, S. (2014). A Review ON K-means DATA Clustering APPROACH. International Journal of Information & Computation Technology, 4(17), 1847–1860. http://www.irphouse.com

Sianipar, K. D. R., Siahaan, S. W., Siregar, M., R.H Zer, F. I., & Hartama, D. (2020). Penerapan Algoritma K-Means Dalam Menentukan Tingkat Kepuasan Pembelajaran Online Pada Masa Pandemi Covid-19. Jurnal Teknologi Informasi, 4(1), 101–105. https://doi.org/10.36294/jurti.v4i1.1258

Suhendri, M., Afrilia, Y., & Rizal, R. (2021). Klasifikasi Karya Ilmiah (Tugas Akhir) Mahasiswa Menggunakan Metode Naive Bayes Classifier (NBC). Sistemasi, 10(2), 268. https://doi.org/10.32520/stmsi.v10i2.1193

Sulistiyawati, A., & Supriyanto, E. (2021). Implementasi Algoritma K-means Clustering dalam Penetuan Siswa Kelas Unggulan. J. Tekno Kompak, 15(2), 25-36. https://doi.org/10.33365/jtk.v15i2.1162

Susanti, E., Aidilof, H. A., & Priyanto, D. (2022). Comparison of Naive Bayes and Dempster Shafer Methods in Expert System for Early Diagnosis of COVID-19. MATRIK Jurnal: Manajemen, Teknik Informatika dan rekayasa komputer, 22(1), 217–230. https://doi.org/10.30812/matrik.v22i1.2280

Zambrano-Monserrate, M. A., Ruano, M. A., & Sanchez-Alcalde, L. (2020). Indirect effects of COVID-19 on the environment. Science of the Total Environment, 728, 138813. https://doi.org/10.1016/j.scitotenv.2020.138813