Jurnal Pendidikan Teknologi dan Kejuruan
Vol. 30, No. 1, May 2024, pp. 20-32
https://journal.uny.ac.id/index.php/jptk/issue/view/2602
DOI: https://doi.org/10.21831/jptk.v30i1.59615

Determine majors in vocational high schools based on fuzzy c-means algorithm

Muhammad Bayu Rahmani. AR[1,]*, Putu Sudira[2]
[1,2] Universitas Negeri Yogyakarta, Indonesia
E-mail: muhammadbayu.2019@student.uny.ac.id*
*Corresponding Author

ABSTRACT

The number of prospective students enrolling in vocational high schools is significant each year. Consequently, schools must efficiently manage extensive data, demanding high accuracy to minimize the possibility of human errors in calculations. Additionally, student interests and talents play crucial roles in major selection and influence student learning outcomes. This study aims to investigate the utilization of a decision support system called Fuzzy C-Means to assist schools in managing large datasets to determine majors and group students based on their interests and talents. Fuzzy C-Means was employed to categorize students into several alternative majors, including Catering (CT), Fashion Design (FD), Accounting and Institutional Finance (AIF), Online Business and Marketing (OBM), Multimedia (MM), Office Governance Automation (OGA), and Computer and Network Engineering (CNE). The research adopted a quantitative approach with a pre-experimental research design. Data were collected through interest-aptitude tests and documentation. The participants in this study were 58 students from State Vocational High School Barabai 1. Fuzzy C-Means successfully grouped students into seven clusters. Applying criteria of interests and aptitudes, every student had the opportunity to belong to all existing majors. Fuzzy C-Means was also compared with the K-means algorithm to demonstrate its superiority. The accuracy of Fuzzy C-Means was found to be 89.7%, while K-means achieved an accuracy of 84.5%. This indicates an increase in accuracy by 5.2% when compared to the K-means algorithm. The cluster validity value, assessed using the Partition Coefficient Index, falls within the 'good' category (0.6054). Considering cluster validation and the level of system accuracy, a decision support system utilizing the Fuzzy C-Means algorithm is deemed a feasible alternative for determining school majors.

Keywords: determine majors, fuzzy c-means and k-means, interest and aptitude, vocational high school

Article history

Received:	Revised:	Accepted:	Published:
31 March 2023	*11 May 2023*	*04 January 2024*	*06 May 2024*

Citation (APA Style): AR Rahmani, M. B., Sudira, P. (2024) Determine majors in vocational high schools based on fuzzy c-means algorithm. *Jurnal Pendidikan Teknologi dan Kejuruan*, 30(1), 20-32. https://doi.org/10.21831/jptk.v30i1.59615

INTRODUCTION

Admission of new students to vocational high schools takes place at the beginning of the odd semester. The student selection process is based on criteria established by the school. Each individual characteristic should be considered, as it influences the achievement of learning

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

outcomes (McDermott and Zerr, 2019).Students with a high interest in learning tend to have greater learning achievements compared to those with low interest (Sitanggang et al., 2019).

Interest also affects students' learning difficulties (As'ad et al., 2021). Students not interested in certain lessons are likely to be passive and engage in conversations with classmates during class. On the other hand, students interested in the lesson are more likely to pay attention, experience pleasure and excitement, and have the desire to achieve better results (Setiawan et al., 2020; Permatasari et al., 2019). Interest should be considered alongside aptitudes to help students succeed in their majors. By understanding their aptitudes, students can identify majors that are either easier or more challenging for them to learn. Therefore, students need to carefully choose a major that aligns with their capabilities (Barret, 2009).

According to the Ministry of Education (Kemendikbud, 2018), vocational high schools in Indonesia offer a total of 146 majors. Some examples include Catering (CT), Fashion Design (FD), Accounting and Institutional Finance (AIF), Online Business and Marketing (OBM), Multimedia (MM), Office Governance Automation (OGA), and Computer and Network Engineering (CNE). Given the variety of alternative majors available to students, it is crucial for them to make thoughtful and informed choices.

Moreover, as vocational high schools have a large number of students (Kemendikbud, 2022), these schools commonly require high accuracy to minimize the possibility of human errors in calculations while processing students' data. Considering some of the challenges mentioned above, it is necessary to implement a decision support system using Fuzzy C-Means. In this present study, this system was employed with Matlab software to assist schools in determining majors based on students' interests and aptitudes. Decision support systems can enhance analytical skills and facilitate decision-making alternatives (Supriadi et al, 2021). They enable users to avoid spending excessive time on calculating extensive data (Susanto et al., 2021). Limbong (2020) stated that...

" ... the characteristic of an effective decision support system is its ease of use and allows the user flexibility to choose or develop new approaches in discussing the problems faced".

Fuzzy C-Means belong to the soft clustering classification. Soft clustering has an advantage in data membership restriction compared to hard clustering (Gustafson and Kessel, 1978). Fuzzy C-Means allows data to be part of several clusters (Rahmayanti et al., 2023). It differs from other algorithm concepts; data is not fully a member of a cluster, but it can be a member of several clusters simultaneously. It will be assigned as a member of a cluster based on the highest degree value, ranging from 0 to 1 (Anggoro et al., 2022).

The first step in performing Fuzzy C-Means calculations is to determine some initial parameters such as the number of clusters (c), Weighting Exponent (m), and the smallest error (e). Fuzzy C-Means divides the data set (X) into cluster groups (c) by minimizing the objective function (P)

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

(Al-Dabagh., 2021). It has been widely used in various areas, such as finance (Guha and Veeranjaneyulu, 2019), electricity (Senen et al., 2023), medical diagnosis (Kim et al., 2021), wireless sensor networks (Hassan et al., 2020; Moussaoui et al., 2021), 3D modeling (Hamza et al., 2020), and isolation forest (Karczmarek et al., 2021). Additionally, Fuzzy C-Means was chosen because it demonstrates a good level of accuracy and a low error rate in calculations (Murugan et al., 2020).

Previous studies show that a decision support system using the Fuzzy C-Means algorithm could be employed in selecting majors in vocational high schools with three majors (Az-Zahra et al., 2018). Other studies also demonstrate that the Fuzzy C-Means algorithm is feasible for use in vocational high schools with four majors (Basorudin, 2015). Therefore, this study aims to examine decision support systems using Fuzzy C-Means for grouping more than 3–4 majors in vocational high school to determine whether the system is still feasible to implement. Fuzzy C-Means will also be compared with the K-Means algorithm to prove that Fuzzy C-Means is the best solution to determine majors in this study. The cluster validation used is the partition coefficient index. The purpose of this research is to implement a decision support system using Fuzzy C-Means to group students in State Vocational High School Barabai 1 based on the scores of interest and aptitude tests.

METHOD

This study employed a quantitative approach with a pre-experimental research design. The design allowed us to focus on one group and provide intervention during the experiment. Unlike the experimental group, it did not include a control group (Creswell., 2020).

The experiment in this study aimed to test the validity of the cluster and the accuracy of the Fuzzy C-Means algorithm in selecting seven majors based on students' interests and aptitudes. Data were obtained from the research location, namely State Vocational High School Barabai 1, with 58 students participating in the study. Data collection involved interest tests, aptitude tests, and documentation. The interest test consisted of four subtests, while the aptitude test comprised nine subtests (Kemendikbud, 2016). Documentation in this study was used to obtain average scores, which were then employed to assess students' accuracy in selecting majors. The cluster validity used in this study was the Partition Coefficient Index. Additionally, this study will apply the k-means algorithm with the same data and analysis techniques for comparison with the fuzzy c-means algorithm.

The accuracy of the fuzzy c-means and k-means systems used for selecting majors will be compared to the no-system (manual) selection method currently implemented in the school. Subsequently, fuzzy c-means and k-means accuracy will be compared to determine which algorithm is suitable for implementation in schools.

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

RESULTS AND DISCUSSION

The hierarchical structure of this study comprises objectives, criteria, and alternatives. The ultimate goal of this hierarchy is to establish a decision-support system for selecting majors. The criteria in this hierarchy include the interests and aptitudes of students, while the alternatives consist of Catering (CT), Fashion Design (FD), Accounting and Institutional Finance (AIF), Online Business and Marketing (OBM), Multimedia (MM), Office Governance Automation (OGA), and Computer and Network Engineering (CNE). The hierarchical structure of the major selection process is presented in Figure 1 below.

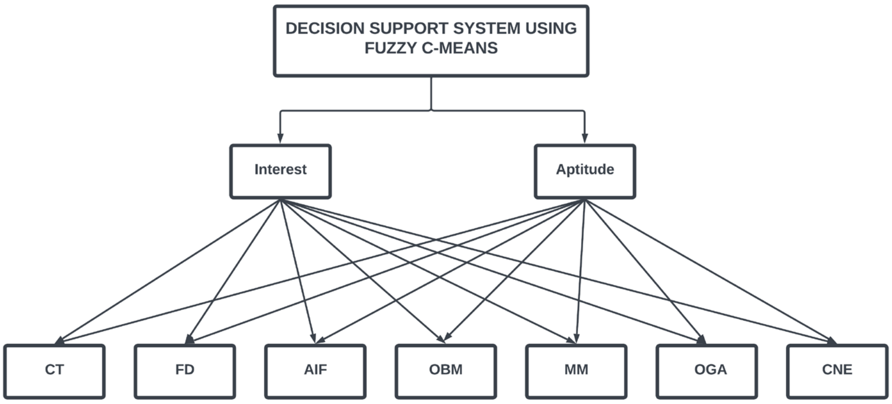

Figure 1. Hierarchical Structure of Major Selection with Decision Support System

After obtaining the data on students' interests and aptitude, data normality was checked before calculating the Fuzzy C-Means. In the next step, several initial parameters in the Matlab software for Fuzzy C-Means calculations were set: the number of clusters (c) to 7, rank weight (m) to 2, the maximum number of improvements (ξ) to 10^{-5}, the maximum number of iterations (MaxIt) to 200, and initial objective function (P_0) to 0. In this study, the calculation stopped at the 51st iteration. The objective function values obtained at the 50th and 51st iterations were 1367.51535 and 1367.51536, respectively. Therefore, the objective function at the 51st iteration is 0.00001, according to the parameters set at the beginning of the calculation.

1. **Cluster center in the last iteration for fuzzy c-means**

In the last iteration (51), the cluster center (V_{kj}) generated (by Matlab Software) is:

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

$$\begin{pmatrix} 18.2526 & 18.0809 & 10.2480 & 28.0813 & 19.5116 & 13.3492 & 18.4547 \\ 23.8146 & 16.3047 & 21.0565 & 20.3166 & 20.7364 & 17.5546 & 21.9204 \\ 16.5598 & 17.3919 & 20.0918 & 16.8659 & 16.4415 & 15.0086 & 16.3760 \\ 22.9145 & 19.6472 & 17.7422 & 28.3554 & 33.9516 & 17.0015 & 30.6054 \\ 19.1322 & 17.8674 & 12.9339 & 22.6754 & 22.7443 & 15.1957 & 26.8510 \\ 20.8666 & 27.1714 & 19.5497 & 20.1791 & 21.1922 & 15.8794 & 21.7530 \\ 14.9757 & 14.7773 & 9.8391 & 14.8876 & 15.6256 & 23.7856 & 14.4361 \end{pmatrix}$$

Figure 2. Cluster Center in The Last Iteration for fuzzy c-means

For example, if the highest scores on student interest tests and aptitude tests are used as the basis for determining majors:

a) In the first cluster (first row), the highest score is in the 4th column (Online Business and Marketing). The first cluster is identified as the group of Online Business and Marketing major.
b) In the second cluster (second row), the highest score is in the first column (Catering Management). The second cluster is identified as the group of Catering major.
c) In the third cluster (third row), the highest score is in the third column (Accounting and Financial Institutions). The third cluster is identified as the group of Accounting and Institutional Finance major.
d) In the fourth cluster (fourth row), the highest score is in the fifth column (Multimedia). The fourth cluster is identified as the group of Multimedia major.
e) in the fifth cluster (fifth row), the highest score is in the seventh column (Computer and Network Engineering). Therefore, so the fifth cluster is identified as a group of Computer and Network Engineering major.
f) In the fifth cluster (fifth row), the highest score is in the seventh column (Computer and Network Engineering). The fifth cluster is identified as the group of Computer and Network Engineering major.
g) In the seventh cluster (seventh row), the highest value is in the sixth column (Office Governance Automation). Therefore, the seventh cluster is identified as the group of Office Governance Automation major.

After calculations in the last iteration (51), clusters can be identified as groups in certain majors with the highest membership values based on test scores. Cluster identification is presented in Table 1.

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

Table 1. Identification of Clusters in The Last Iteration for fuzzy c-means

No	Cluster	Majors
1	Cluster 1	OBM
2	Cluster 2	CT
3	Cluster 3	AIF
4	Cluster 4	MM
5	Cluster 5	CNE
6	Cluster 6	FD
7	Cluster 7	OGA

In the last k-means iteration (7), cluster identification is presented in Table 2.

Table 2. Identification of Clusters in The Last Iteration for fuzzy c-means

No	Cluster	Majors
1	Cluster 1	OGA
2	Cluster 2	CNE
3	Cluster 3	MM
4	Cluster 4	OBM
5	Cluster 5	FD
6	Cluster 6	CT
7	Cluster 7	AIF

2. The membership degree partition matrix (μ) of the last iteration for fuzzy c-means

From the last iteration of the μ partition matrix, there is a tendency for the data to fall into certain major groups. The highest degree of membership among all clusters makes students members of certain clusters. The total degree value allowed in all clusters is 1. FCM has advantages over k-means in terms of providing information about the class to which a point belongs through a probability. This allows for a more accurate classification of each data point. Some of the membership degree data for each student in each cluster are presented in Table 3 below.

Table 3. Some of The Membership Degree Data for Each Data Point in Each Cluster in fuzzy c-means

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

Student	Degree of Membership (μ) at Last Iteration							Data trends enter the cluster
	(μ1)	(μ2)	(μ3)	(μ4)	(μ5)	(μ6)	(μ7)	
1	0.0406	0.0389	0.0719	0.0159	0.0347	0.0311	0.7670	7
21	0.6581	0.0505	0.0631	0.0296	0.0879	0.0510	0.0598	1
31	0.1070	0.0801	0.0702	0.0545	0.5540	0.0790	0.0551	5
32	0.0788	0.0867	0.0704	0.0461	0.0973	0.5805	0.402	6
37	0.0391	0.6766	0.1177	0.0207	0.0552	0.0575	0.331	2
38	0.0294	0.7473	0.0590	0.0300	0.0506	0.0606	0.232	2
45	0.0490	0.1107	0.0809	0.0393	0.0686	0.6193	0.0323	6
51	0.0853	0.2252	0.3213	0.0522	0.1058	0.1069	0.1034	3
53	0.1219	0.1765	0.1130	0.1462	0.2440	0.1039	0.0945	5

From the last iteration in k-means, the data becomes a full member of the cluster. Some of determination cluster membership is presented in Table 4.

Table 4. Some determination of cluster membership in k-means

Student	CT (cluster 6)	FD (cluster 5)	AIF (cluster 7)	OBM (cluster 4)	MM (cluster 3)	OGA (cluster 1)	CNE (cluster 2)	Data trends enter the cluster
1	13	13	10	13	14	25	11	1
21	16	18	7	29	16	13	17	4
31	16	18	10	19	23	14	27	2
32	20	28	16	22	23	18	20	5
37	24	15	21	19	18	17	20	6
38	25	16	24	20	22	19	22	6
45	23	29	23	20	18	16	23	5
51	14	13	26	20	17	20	20	6
53	17	13	15	20	31	19	22	6

3. Accuracy of a decision support system using the fuzzy C-means and K-means algorithm

The determination of majors using the system was compared to the manual determination method that has been implemented in the school. The accuracy of the results is determined based on the following criteria:

a) If the manual determination is the same as the determination by Fuzzy C-Means/Kmeans, and the average test score obtained is greater than or equal to (>=) the minimum completeness criteria/standard (>= 75), the determination using Fuzzy C-Means/Kmeans is declared accurate.
b) If the manual determination is the same as the determination by Fuzzy C-Means/Kmeans, and the average test score obtained is smaller than (<) the minimum

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

completeness criteria, the determination using the Fuzzy C-Means/Kmeans algorithm is declared inaccurate.

c) If the manual determination is not the same as the determination by Fuzzy C-Means/Kmeans, and the average test score obtained is greater than or equal to (>=) the minimum completeness criteria, the determination using Fuzzy C-Means/Kmeans is declared inaccurate.

d) If the manual determination is not the same as the determination by Fuzzy C-Means/Kmeans, and the average test score obtained is smaller than (<) the minimum completeness criteria, the determination using Fuzzy C-Means/Kmeans is declared accurate.

The accuracy of the data and the results produced by the Fuzzy C-Means and K-Means algorithms is presented in Table 5-6.

Table 5. Data of Major Determination Using Fuzzy C-Means Algorithm

Student	Major		Student Grade Point Average	Result
	Manuals	C-means		
1	OGA	OGA	77.4	Accurate
21	OBM	OBM	74.9	Not accurate
31	CNE	CNE	78.43	Accurate
32	CNE	FD	74.87	Accurate
37	CT	CT	80.95	Accurate
38	CT	CT	79.25	Accurate
45	FD	FD	74.85	Not accurate
51	AIF	AIF	80.12	Accurate
53	MM	CNE	80.6	Not Accurate

Table 6. Data of Major Determination Using K-Means Algorithm

Student	Major		Student Grade Point Average	Result
	Manuals	K-means		
1	OGA	OGA	77.4	Accurate
21	OBM	OBM	74.9	Not accurate
31	CNE	CNE	78.43	Accurate
32	CNE	FD	74.87	Accurate
37	CT	CT	80.95	Accurate
38	CT	CT	79.25	Accurate
45	FD	FD	74.85	Not accurate
51	AIF	CT	80.12	Not accurate
53	MM	CT	80.6	Not accurate

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

Table 7 shows the results on a dataset with 7 clusters. Fuzzy C-Means performed 51 iterations, whereas K-Means performed 7 iterations. The accuracy of Fuzzy C-Means was 89.7%, and the accuracy of K-Means was 84.5%.

Table 7. Comparison of results between fuzzy c-means and k-means

Iteration Fuzzy C-means	**Iteration K-means**	**Accuracy Fuzzy C-means**	**Accucary K-means**
51	7	89.7%	84.5%

4. Cluster validity for fuzzy c-means

The cluster validity used in this study is the Partition Coefficient Index (PCI). PCI is a valid measure of overlap in clusters. The range of this validity value is 0–1. If the validity value is close to 1, the quality of the cluster is getting better. The PCI value obtained in this study is 0.6054.

The determination of majors plays an important role in students' lives at school. When the choice has been made, various consequences await in the future. Some fail, and some succeed and live prosperously in the future. For this reason, the determination of majors in schools must be done precisely and accurately. In this study, a decision support system is proposed using the Fuzzy C-Means algorithm. Fuzzy C-Means can produce smooth results because the data do not only belong to one cluster but to other clusters with different membership levels. The data tend to be a member of a particular cluster with the largest membership value among the others. The system is run using Matlab software, a leading tool in the field of mathematics, offering various algorithms in its toolbox, making it easier for scientists to achieve their goals.

Aiming to make it easier for students to determine majors, a decision support system using the Fuzzy C-Means algorithm can divide students into seven clusters based on their interests and aptitudes. With the criteria of interest and aptitude, every student has the opportunity to belong to all existing majors. Separation among all majors is determined by the number of degrees of closeness to the centroid on each interest and aptitude test score. The higher the interest and aptitude test scores in a particular major, the higher the chance of becoming a member of that cluster. There were 8 students in cluster 1 (OBM), 6 students in cluster 2 (CT), 7 students in cluster 3 (AIF), 5 students in cluster 4 (MM), 6 students in cluster 5 (CNE), 10 students in cluster 6 (FD), and 16 students in cluster 7 (OGA).

The results of determining majors using the Fuzzy C-Means algorithm for first-year students (grade X) show that 52 (89.7%) out of 58 students selected their majors correctly, while determining majors using the K-Means algorithm shows that 49 (84.5%) out of 58 students chose the major correctly. When comparing the accuracy of the two algorithms for determining majors,

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

there is a difference of 5.2% (89.7% - 84.5%). Based on the results with datasets and data analysis techniques, Fuzzy C-Means is more accurate than K-Means, indicating that the Fuzzy C-Means algorithm is better.

After the Fuzzy C-Means calculation process is complete, cluster validity was tested using the Partition Coefficient Index (PCI). With a larger number of clusters than in previous studies, the PCI validity value obtained is still in the good category. The PCI validity value will decrease to close to 1, or it is not feasible with an increase in the number of clusters given (Rajkumar et al., 2019; (Afzal et al., 2021). The validity value of PCI with seven clusters in this study is 0.6054, meaning that the cluster has a good status.

The Fuzzy C-Means method makes it easier for schools to group new students because determining majors using the manual method requires high accuracy and the possibility of human error in calculations. Additionally, interest tests and aptitude tests can be used as criteria in determining majors for schools since the tests will provide an overview of which majors are easier and which may be more difficult for each student. Paying attention to their interests and aptitudes, students can consider majors that are easier to deal with than others.

Based on cluster validation and the system's accuracy level, the decision support system using the Fuzzy C-Means algorithm is deemed feasible to provide guidance for determining majors in vocational high schools. This system simplifies the process for schools to handle the large number of new students who enroll each year and assists students in selecting majors from the available alternatives.

CONCLUSION

This research demonstrates that a decision support system using Fuzzy C-Means is superior to the k-means algorithm and can effectively determine majors in vocational high schools that offer up to seven majors. However, this study was conducted at one vocational school. Further research should apply this system in vocational schools with more majors and compare it with other algorithms.

REFERENCES

Afzal, Asif, et al. "Clustering of COVID-19 Data for Knowledge Discovery Using c-Means and Fuzzy c-Means." *Results in Physics*, vol. 29, 2021. https://doi.org/10.1016/j.rinp.2021.104639.

Al-Dabagh, Mustafa Zuhaer Nayef. "Automated Tumor Segmentation in MR Brain Image Using Fuzzy C-Means Clustering and Seeded Region Methodology." *IAES International Journal of Artificial Intelligence*, vol. 10, no. 2, 2021. https://doi.org/10.11591/ijai.v10.i2.pp284-290.

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

Anggoro, Faisal, et al. “Revisiting Cluster Vulnerabilities towards Information and Communication Technologies in the Eastern Island of Indonesia Using Fuzzy C Means.” *Sustainability (Switzerland)*, vol. 14, no. 6, 2022. https://doi.org/10.3390/su14063428.

As’ad, Salahudin, et al. “The Affecting Factors Difficulty InLearning:Case in Vocational School Students.” *The International Journal of Social Sciences World*, vol. 3, no. 1, 2021. https://www.growingscholar.org/journal/index.php/TIJOSSW/article/view/105.

Az-Zahra, Rifqi Rahmatika, et al. “Clustering Majors for New Students at Vocational High School Muhammadiyah 3 Yogyakarta Using Fuzzy C-Means.” *Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control*, vol. 3, no. 3, 2018. https://doi.org/10.22219/kinetik.v3i4.642.

Barret, Jim. *Aptitude, Personality And Motivation Test*. 3rd ed., London : Kogan Page, 2009.

Basorudin. “Penerapan Algoritma Fuzzy Clustering Untuk Penentuan Jurusan Sekolah Menengah Kejuruan (SMK Negeri 1 Rambah).” *Riau Journal Of Computer Science*, vol. 1, no. 1, 2015. https://e-journal.upp.ac.id/index.php/RJOCS/article/view/1265.

Creswell., John W. *Research Design: Qualitative, Quantitative, And Mixed Methods Approaches*. California : SAGE Publications Inc, 2020.

Guha, Arup, and N. Veeranjaneyulu. “Prediction of Bankruptcy Using Big Data Analytic Based on Fuzzy C-Means Algorithm.” *IAES International Journal of Artificial Intelligence*, vol. 8, no. 2, 2019. https://doi.org/10.11591/ijai.v8.i2.pp168-174.

Gustafson, Donald E., and William C. Kessel. “Fuzzy Clustering With a Fuzzy Covariance Matrix.” *Proceedings of the IEEE Conference on Decision and Control*, no. December, 1978. https://doi.org/10.1109/cdc.1978.268028.

Hamza, Najlaa Abd, et al. “3D Model Retrieval Using Mesh SIFT Descriptor and Fuzzy C-Means Clustering.” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 19, no. 3, 2020. https://doi.org/10.11591/ijeecs.v19.i3.pp1452-1460.

Hassan, Ali Abdul hussian, et al. “Evaluate the Performance of K-Means and the Fuzzy C-Means Algorithms to Formation Balanced Clusters in Wireless Sensor Networks.” *International Journal of Electrical and Computer Engineering*, vol. 10, no. 2, 2020. https://doi.org/10.11591/ijece.v10i2.pp1515-1523.

Karczmarek, Paweł, et al. “Fuzzy C-Means-Based Isolation Forest.” *Applied Soft Computing*, vol. 106, 2021,

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

https://doi.org/https://doi.org/10.1016/j.asoc.2021.107354.

Kemendikbud. *Data Pokok Pendidikan*. 2022. https://dapo.kemdikbud.go.id/pd.

Kemendikbud. *Pengembangan Minat Dan Bakat Siswa SMK*. Jakarta : 2016. [E-Book] Avalaible :Repositori Kemendikbud.

Kemendikbud. *Perditjen Dikdasmen No. 06 Tahun 2018 No. 06 Spektrum Keahlian SMK/MAK*. Jakarta : 2018.

Kim, Kwang Baek, et al. "Intelligent Automatic Segmentation of Wrist Ganglion Cysts Using Dbscan and Fuzzy C-Means." *Diagnostics*, vol. 11, no. 12, 2021. https://doi.org/10.3390/diagnostics11122329.

Limbong, Tonni, et al. *Sistem Pendukung Keputusan: Metode & Implementasi*. Medan : Yayasan Kita Menulis, 2020. https://books.google.co.id/books?id=t5PYDwAAQBAJ&printsec=copyright&hl=id#v=onepage&q&f=false.

McDermott, Kathleen B., and Christopher L. Zerr. "Individual Differences in Learning Efficiency." *Current Directions in Psychological Science*, vol. 28, no. 6, Oct. 2019, https://doi.org/10.1177/0963721419869005.

Moussaoui, Djilali, et al. "Clustered Chain Founded on Ant Colony Optimization Energy Efficient Routing Scheme for Under-Water Wireless Sensor Networks." *International Journal of Electrical and Computer Engineering*, vol. 11, no. 6, 2021. https://doi.org/10.11591/ijece.v11i6.pp5197-5205.

Murugan, A., et al. "A Time Efficient and Accurate Retrieval of Range Aggregate Queries Using Fuzzy Clustering Means (FCM) Approach." *International Journal of Electrical and Computer Engineering*, vol. 10, no. 1, 2020. https://doi.org/10.11591/ijece.v10i1.pp415-420.

Permatasari, Berti Dyah, et al. "The Influence of Problem Based Learning towards Social Science Learning Outcomes Viewed from Learning Interest." *International Journal of Evaluation and Research in Education*, vol. 8, no. 1, 2019. https://doi.org/10.11591/ijere.v8i1.15594.

Rahmayanti, Nabillah, et al. "Caregiver Segmentation Using The Integration of The Modified Burden Dimensions and Fuzzy C-Means." *Procedia Computer Science*, vol. 219, Elsevier B.V., 2023, https://doi.org/10.1016/j.procs.2023.01.402.

Rajkumar, K. Varada, et al. "Fuzzy Clustering and Fuzzy C-Means Partition Cluster Analysis and Validation Studies on a Subset of CiteScore Dataset." *International Journal of Electrical and Computer Engineering*, vol. 9, no. 4, 2019. https://doi.org/10.11591/ijece.v9i4.pp2760-2770.

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735

Senen, Adri, et al. "Fuzzy C-Means Clustering Based on Micro-Spatial Analysis for Electricity Load Profile Characterization." *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 30, no. 1, 2023. https://doi.org/10.11591/ijeecs.v30.i1.pp33-45.

Setiawan, Johan, et al. "Understanding Indonesian History, Interest in Learning History and National Insight with Nationalism Attitude." *International Journal of Evaluation and Research in Education*, vol. 9, no. 2, 2020. https://doi.org/10.11591/ijere.v9i2.20474.

Sitanggang, Nathanael, et al. "The Effect of Using Real-Object Media on the Students' Interest in Cost Estimation Learning." *Jurnal Pendidikan Teknologi Dan Kejuruan*, vol. 25, no. 1, 2019. https://doi.org/10.21831/jptk.v25i1.22190.

Supriadi, Didi, et al. "The Moderation Effect of Information Systems on Vocational High School Principal Decision-Making Model." *Cakrawala Pendidikan*, vol. 40, no. 1, 2021. https://doi.org/10.21831/cp.v40i1.31268.

Susanto, Aris, et al. "Decision Support System on Quality Assessment of the Prospective Civil Servant's Education and Training Using Fuzzy Method." *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 24, no. 1, 2021. https://doi.org/10.11591/ijeecs.v24.i1.pp519-529.

Copyright © 2024, author, e-ISSN 2477-2410, p-ISSN 0854-4735