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APPLICATION OF COMPUTATIONAL INTELLIGENCE BASED CLUSTERING ALGORITHMS ON EDUCATIONAL DATA

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Abstract: *Contemporary research, especially in the academic community, focuses on the increasingly frequent application of artificial intelligence (AI) in learning and teaching processes, but also on all the benefits and disadvantages that it brings with it. This study was conducted in order to examine the application of computational intelligence (CI) methods on educational data. The main goal of the paper is to group students according to similarity with the aim to analyse each group in details. Data was collected via questionnaire among students enrolled at three universities in three different countries. It represents students' opinion on the use of AI in education. Using k-medoids, self-organized maps (SOM) and fuzzy C means (FCM), two groups of students were identified according to the use of AI in learning process as the most important attribute.*

Keywords: *computational intelligence, education, clustering, FCM, SOM, AI.*

1. INTRODUCTION

Development and everyday presence of AI have revolutionized modern education. The influence of AI on the educational system is often considered two-folded (Hudec et al., 2025). On one hand, there is a strong need to include and/or enhance education in the field of AI due to market demands and trends. On the other hand, there is an ongoing work in creating a solid base for positive perceptions and acceptance of AI technologies. Governments and educational institutions have identified a clear need to rethink and redesign university curricula to better fit the growing presence of AI in every aspect of our lives (Pedro et al., 2019). Still, there is a significant difference in AI perception between regions. The Government AI Readiness Index is commonly used to assess how prepared governments are to implement AI on a global scale (Storozhenko et al., 2023). The level of AI acceptance is often correlated with government efforts and a country's development in information technology (IT). Hence, enhancing AI and IT education is a vital prerequisite for broader and more effective integration. In (Hazaimeh & Al-Ansi, 2024), the authors focus on studying AI acceptance in higher education through human interaction-based factors, including attitudes, competencies, and openness to experience. Their conclusions were based on data from more than hundred participants collected within Arab higher education institutions. The results show that attitude, competency, and openness have a positive and significant relationship with perceived benefits and AI acceptance. Further, in Malaysian and Pakistani higher education institutions, a study (Dahri et al., 2024) underlined that students are concerned about using AI tools to improve their academic performance. Also, previous interaction with AI tools were an important factor in predicting AI acceptance.

Most papers in this area of research rely on traditional methodologies, such as predefined questionnaires with Likert-scale questions, accompanied by statistical analysis and interpretation of results. However, a recent trend is to incorporate soft computing techniques into result analysis, as this more sophisticated approach may enhance insights in the subject area. Particularly, SOM stand out as a useful strategy for analysing survey data (Bedle et al, 2023). Since SOM is in fact unsupervised neural network, it is able to model overcome some of the drawbacks of standard clustering algorithms, e.g. poor modelling of complex non-convex cluster shapes, and sensitivity to initialization.

This research builds on the work presented in (Hudec et al., 2025) which published the initial findings on Icelandic, Slovakian, and Serbian students' perceptions of using AI in education. Herein, we are going one step further, as we aim to cluster survey respondents and analyse their differences regarding background, study area, country, etc. Namely, we aim to use three different clustering techniques to address. First, we used a standard k-means clustering technique, as a benchmark. Furthermore, we applied self-organizing maps as a more sophisticated clustering technique to overcome some of the standard limitations of k-means clustering. Finally, we employed a FCM clustering to detect possible marginal cases that should be carefully addressed and point out the level of membership to a certain cluster. Obtained results show that more sophisticated methods like SOM and FCM performed better on survey data than standard clustering methods.

This paper is organized as follows. Section 2 provides a brief literature review covering the most important aspects and challenges regarding AI in education, as well as the main directions concerning clustering techniques for grouping survey respondents. The questionnaire design and clustering dataset are presented in Section 3. Section 4 is devoted to the methodology, i.e. the clustering techniques used in this study. The results are presented in Section 5, along with a discussion and comparison with previously published work. Finally, Section 6 outlines the main conclusions and suggests directions for future research.

2. LITERATURE REVIEW

In education, technological developments and enhancements have for a long time altered, and even improved, the ways of teaching and studying. Factor in recent emergence of AI as a transformative force in higher education, with a growing body of academic literature exploring its applications in teaching and learning within universities. Integration of AI in this context covers a broad area; from the use of AI among teachers to enhance or facilitate teaching processes, to the use of AI to assist students in learning and solving assignments, to the inclusion of the AI concept within course study materials and lectures. Furthermore, AI can also be utilized for administration purposes at universities.

A review of published research over a ten year period between 2015 and 2024 studying teachers‘ use of AI technology in their teaching and professional development, a considerable gap was found between studies examining the application of AI technology in teaching (65%) versus AI‘s role in enhancing teacher professional development (35%) (Tan et al., 2024). The majority including studies on applications such as conversational AI, AI-driven learning and assessment systems, immersive technologies, visual and auditory computing, and teaching and learning analytics, against aspects of teachers' integration AI technologies into their teaching practices. This highlights the need for future research focusing more on the potential of AI in teacher professional development and how AI technologies address the development needs of teachers integrating AI technologies into their teaching practices (Tan et al., 2024).

Most research on AI in education is within computer science and STEM fields. Out of 40 research studies involving AI and reviewed by Zhang and Aslan (2021), 25 were in the fields of engineering, computer science, information technology, mathematics and science.

Among AI technologies commonly used to facilitate education are intelligent tutoring systems (ITS) where a trainee interacts with a software to acquire knowledge with a real time assessment, adjusting tutoring level accordingly (Alfaro et al., 2020; Crompton & Burke, 2023), learning management systems (LMS) used to manage learning and teaching interventions, including identifying drop-out risks to provide necessary support for students (Rosário and Dias, 2022), and content creation and curation of teaching materials to personalize students' learning experience and improving their engagement with learning resources (Zawacki-Richter et al., 2019; Chen et al., 2020).

Then there is the notion of the future role of human teachers versus AI-based teaching. Over a ten year period, Cope and al. (2020) researched how the nature of machine intelligence could enhance education. Although they determined that AI would not take over the role of a human teacher because it profoundly differs from human intelligence, they identified how AI can empower educators with better ways to teaching.

In a Swedish study of a machine learning-based teaching aid in mathematics, authors counter the notion that human actors will always be needed along with technology-enhanced learning and that teachers‘ tasks cannot be automated (Sperling et al., 2022). In his book, Neil Selwyn (2019) even argued whether robots could possibly replace teachers in the classroom and in response to increasing shortage of teachers around the world, some have proposed that AI could replace some of the functions historically performed by human power (Edwards & Cheok, 2018; Selwyn, 2019). One could argue that would not only hold true, but also, be a method of increased productivity in more complex aspects of research and teaching where AI could relieve teachers of the most automated aspects of their functions, providing them with more time to focus on expanding their knowledge of expertise.

3. DATA

A questionnaire was sent to enrolled students at three universities. The questions were designed to capture student's knowledge, usage and perceptions towards the use of AI in education. As data was collected in native languages of three different countries, questions were translated to best represent the same meaning across all participants.

Each questionnaire was divided into three themes. First theme was focused on perception and knowledge of AI with questions such as Do you think AI can improve education? and Which AI technology do you know? The second theme focused on benefits of using AI in education where participants were asked to rate and evaluate the benefits of AI in various areas within their university. The last theme was focused on preference towards AI in studying and teaching with participants indicating how intensively they prefer to use AI in various aspects of their learning processes and in which fields of education AI should or should not be used.

For the research presented in this paper, a dataset collected through a survey of students from Serbia, Slovakia, and Iceland was used (Hudec et al., 2025). The survey was completed by 49 students studying Information Systems and Technologies and 16 students studying Management at the University of Belgrade, Faculty of Organizational Sciences; 62 students studying Business Informatics at the University of Economics in Bratislava, Slovakia; and 54 business students from Bifröst University in Iceland. Since four students from Iceland did not fully complete the survey, their responses were excluded from further analysis. As a result, the final dataset consists of 177 instances described by 30 attributes, including responses related to the AI tools used in the learning process, their impact on various aspects of education and universities, and students' concerns or fears about AI. As the questions were answered using a Likert scale, the responses were transformed into values ranging from 1 to 5. An analysis of the dataset confirmed that there are no missing values or outliers that could affect the stability of the clustering model.

4. METHODOLOGY

Clustering is a method for grouping observations based on their similarities and it is significant for many areas, such as predicting students' performance (Mohamed et al., 2022), influence of different factors on student learning (Moubayed et al., 2020), predicting students' risk of dropout (Pecuchova & Drlik, 2024), etc. According to literature (Ferraro & Giordani, 2020), clustering can be divided into two main subgroups: hard clustering and soft clustering.

Hard clustering algorithms are partitive, i.e. divide the dataset into groups. Therefore, k-means clustering algorithm classify the data points based on features into k number of group by minimizing the sum of squares of distances between data and the corresponding cluster centroid (Madhulatha, 2011). The k-means clustering algorithm is sensitive to outliers, because a mean is easily influenced by extreme values. Hence, *k*-medoids clustering, as a variant of k-means, is more resistant to noise and extreme values (Lund & Ma, 2021). A medoid is defined as a cluster element that minimizes the total distance to all other points within the same cluster, thus ensuring greater interpretability of the results (Madhulatha, 2011).

SOM are the most popular artificial neural network for clustering because they use the same procedure for a competitive layer, determine a final neuron, and then weight vectors for the neighbours of the final neuron within a certain radius (Hagan et al., 2014). The primary goal is to represent a multidimensional input space in two dimensions. Unlike other types of neural networks, SOM preserves the topological relationships among input data, enabling meaningful grouping based on spatial proximity. One of the key advantages of SOM is that it does not require prior assumptions about the nature of the data.

In soft clustering, therefore also in the FCM, each observation belongs to each cluster, although the membership functions are different. Level belonging to the cluster depends on the proximity of the observation to the centroid (Bezdek et al., 1984). The purpose of this type of clustering is the minimization of the objective function to prove the similarity between observations in a cluster and reduce the similarity between observations compared to other clusters (Bezdek et al., 1984). The advantages of fuzzy clustering are in the fact that it provides more detailed data information as well as membership function values that are suitable for analysis, and it is adaptable to numerical optimization (Hashemi et al., 2023).

Clustering was performed first using the *k*-medoids method as benchmark, and then according to literature, more sophisticated methods such as SOM and FCM were used. Since all methods require a defined number of clusters, the elbow method, as well as silhouette score, Calinski-Harabasz index and Davies-Bouldin index were applied for determining the optimal number of clusters. By applying these methods, it was decided that the instances can be optimally clustered into two clusters.

5. RESULTS AND DISCUSSION

Experiments were conducted with different parameters for *k*-medoids, SOM and FCM. By measuring the silhouette coefficient for each listed model, the highest coefficient was measured for the model of FCM. However, when applying the FCM, four students whose cluster membership functions were extremely close to the value 0.5 were discovered. Hence, it is difficult to assign these students to a specific cluster, and additional analysis and attention should be paid to them. Table 1 show given metrics, while Figures 1 to 3 represent the cluster distribution for each of the algorithms.

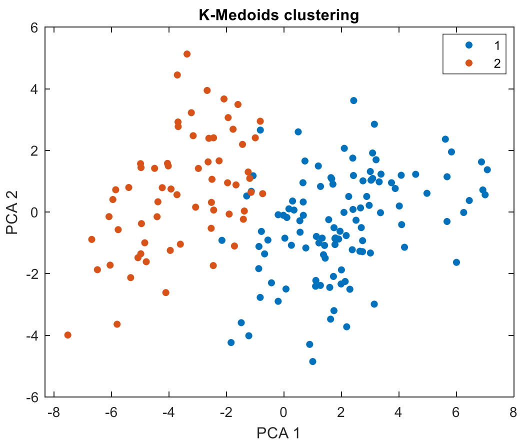

Figure 1: Result of *k*-medoids clustering

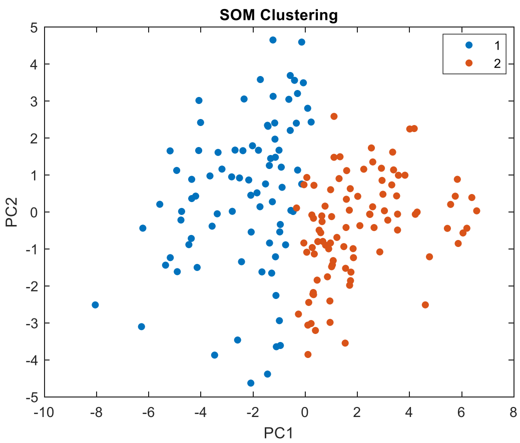

Figure 2: Result of SOM clustering

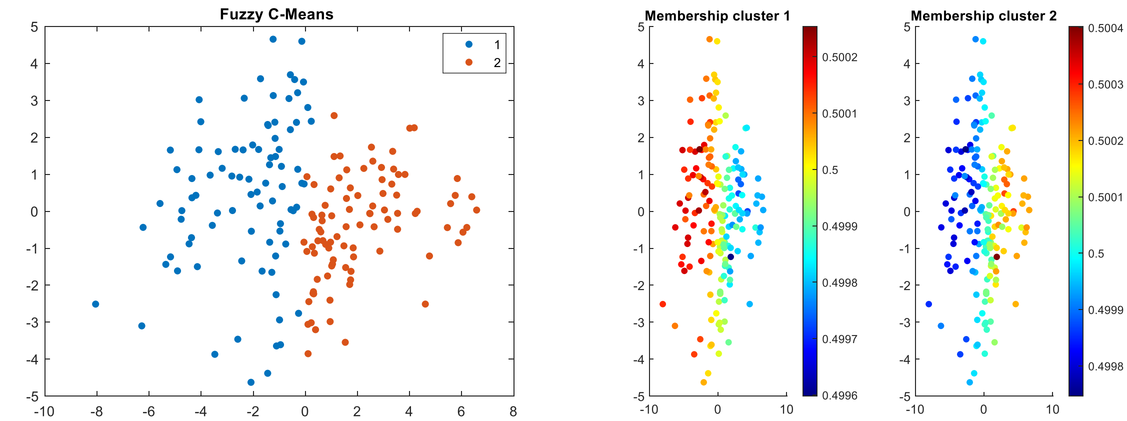

Figure 3: Result of FCM clustering

Table 1: Metrics of applied clustering algorithms

Metrics		*k*-medoids	SOM	FCM
Number of instances	Cluster 1	69	84	82
	Cluster 2	108	93	91
	'Gray area'	-	-	4
Silhouette coefficient		0.5332	0.5742	**0.5752**

Results of clustering provide significant insight into students' preferences and behavior patterns which can have a direct impact on study program curriculums and strategies for inclusion of AI into education. Based on the application of SOM and FCM algorithm with two clusters, the following groups were identified:

1. ***Analog minds*** – Students who do not use AI tools in learning process and who believe that AI negatively affects skills, especially social interactions. Also, these students are strictly against the use of AI when translating a foreign language into English and processes automation (for example applying to the university, registration for courses, dealing with financial matters, asking Erasmus mobility, etc.). The only exception where students use AI is for application for project development and assistance with literature reviews and summarization. Interestingly, this cluster is mostly made up

of students studying computer science or similar study programs, but they explicitly point out that they are afraid of the negative impact of AI. If you are a student from Serbia, you probably belong to this cluster.

2. ***AI-powered learners*** – These students represent visionaries who believe that AI can improve processes at universities. They believe that AI has a positive impact on education, but also that it can improve it in the future. Technology-augmented students see benefits of AI in many areas at university, especially in searching for information concerning study, as well as available literature and resources for seminar essays and final thesis. They also support the use of AI learning tools, except automatic analysis of online discussion boards, in order to provide feedback to students on their participation in LMS. These students are not afraid of negative impact of artificial intelligence, and in fact, strongly support its inclusion in study programs of computer science, general business and business informatics. These are mostly Slovak students.

Students in the gray area of the FCM method have characteristics of both clusters and use AI to a moderate extent in the learning process. These students are enrolled in computer science study programs and mostly use AI when searching for information related to their studies.

6. CONCLUSION

The main goal of this study was to answer the questions of how to group students using CI methods. The paper evaluates the application of CI methods, *k*-medoids, SOM and FCM in order to cluster students from three European countries. Students were grouped according to the answers they gave in the questionnaire. Two groups were obtained according to the use of AI tools in the learning process. It was concluded that the first group includes students who do not use AI and are afraid with its negative effects, while the second group includes students who consider AI to have a positive impact on education in general. Additionally, the FCM has been shown to perform well when it comes to survey data.

The improvement of the research is reflected in the expansion of the dataset to students from other countries, which would provide a broader picture, but also to observe the problem from the teacher's point of view. Moreover, further continuation of the research can go in the direction of applying other fuzzy clustering methods.

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