Application of Fuzzy c-Means Clustering Algorithm in Consumer Psychology

Sun Shufen(✉)

Shanghai Urban Construction Vocational College, No. 2080 Nanting Road, Fengxian District, Shanghai 201415, China
rainheart0528@163.com

Abstract. In order to increase the sales share, mobile phone manufacturers must understand the needs of consumers. The traditional c-means analysis method is sensitive to distance, and the shortcomings of the traditional method can be overcome with the help of fuzzy control theory. In this paper, 200 college students are randomly selected to conduct a questionnaire survey on the six factors affecting the purchase of smart phones, and the data are analyzed by using the improved fuzzy c-means clustering. The results show that the function, appearance and brand of mobile phones have an impact on the purchase of mobile phones. The results are helpful for mobile phone manufacturers to understand users' consumption psychology and improve product competitiveness.

Keywords: Consumer psychology · Mobile phone · Fuzzy clustering · C mean

1 Introduction

As an independent subject, consumer psychology belongs to a branch of general psychology. It refers to the psychological activities that consumers implement, adjust and control their own consumption and purchase behavior according to their own consumption demand and consumption ability under the influence of the overall social economic level and consumption environment. Psychological activity is the reflection process of people's brain to objective things or external stimuli. Consumers' choices, preferences and consumption habits are dominated by psychological activities. This kind of psychological activity can usually be reflected in consumer behavior [1]. Sellers and designers also understand and master consumers' psychological status through observation, analysis and speculation, and meet consumers' psychological needs through a series of promotional activities or changing business methods. On the contrary, sellers and designers can also guide consumers' consumption psychology to a reasonable consumption mode and promote market prosperity in a reasonable and legal way [2].

With the rapid development of China's economy, people's living standards are getting higher and higher, and the use of mobile phones has become very popular. Users have more choices in choosing different brands, systems, styles and functions. However, due to a variety of choices, sales manufacturers are facing unprecedented pressure. How

M. A. Jan and F. Khan (Eds.): BigIoT-EDU 2022, LNICST 465, pp. 261–272, 2023.
https://doi.org/10.1007/978-3-031-23950-2_29

to stand out in the competition and strive for market share is particularly important. To solve these problems, this paper takes the popular touch-screen smart phone in the market as an example to study the user's consumption psychology, understand the user's needs, carry out cluster analysis, and find out the influencing factors of the user's product selection, so as to understand the reasons why they are unwilling to buy, and then make improvement. After improvement, stimulate the user's purchase intention and expand the sales scale of the company's products.

2 Related Work

2.1 Basic Concepts

Consumer psychology is an important branch of psychology. It studies the psychological phenomena and behavior laws of consumers in consumer activities. It is one of the main research fields of business psychology to study the behavior laws of consumers in purchasing and using goods and services.

Consumer psychology holds that any kind of consumer activity is the result of the joint influence of consumer psychology and consumer behavior. Consumer psychology refers to people's subjective thinking as consumers; Consumer behavior is observed from the perspective of market circulation. People's consumer activities are not general mechanical activities. It is a behavioral impulse at a certain time. This behavioral impulse has different changes under the influence of certain consumer environment and psychological factors. Generally speaking, people's consumption psychology can be divided into the following two kinds: first, it is dominated by people's physiological factors and belongs to the instinctive consumption psychology in the natural state; 2. Social consumption psychology caused by socio-economic and consumption environmental factors. These two consumer psychology are interdependent and influence each other [3]. As the basis of human survival and development, instinctive consumption psychology is the natural expression and reflection of people's psychological activities, while social consumption psychology is a psychological activity higher than instinctive consumption psychology on the premise of specific social, political, economic and cultural elements [4].

The research on consumer psychology can be traced back to psychology. As a very classic theoretical model, Maslow's hierarchy of needs theory is not only an important theory to explain personality, but also an important theory to explain motivation. It reflects the common law of human behavior and psychological activities to a certain extent. Psychologist Maslow divides human needs into five different levels: physiological needs, security needs, social needs, respect needs and self realization needs. (as shown in Fig. 1) the demand hierarchy theory is a theoretical system based on people's needs, exploring people's incentive mechanism and studying people's behavior. Its basic view is that people's needs continue to develop from low level to high level [5]. The demand hierarchy of most people in a country is directly related to the country's scientific and Technological Development and people's cultural quality. Generally speaking, people's needs will develop to a higher level after meeting one level [6].

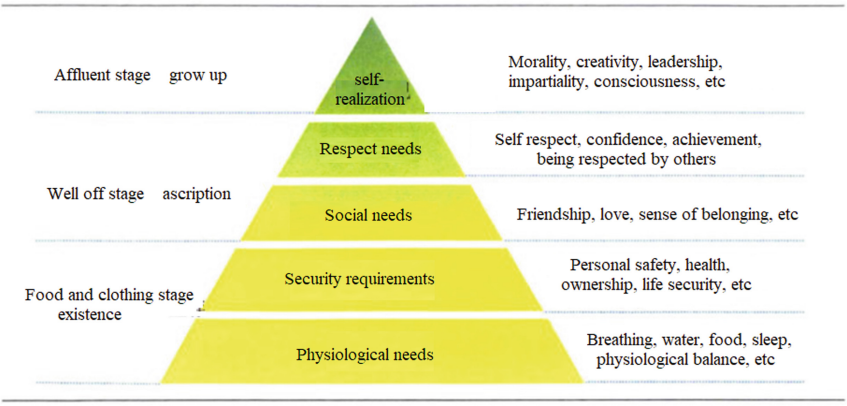

Fig. 1. Maslow's demand theory

2.2 Modern Consumer Demand Analysis

(1) Characteristics of consumer demand

Consumer needs mainly refers to a kind of psychological activity, which will strongly promote consumers to achieve their goals and meet their needs. It is the most common internal reason to promote consumers to carry out various consumption behaviors, It is a psychological tendency before consumption behavior "Need is the motivation and starting point of the purchase process. Without people's needs, all goods will lose their significance of existence. However, in the actual process, the performance of consumers' needs is very complex. It is affected by both consumers' own characteristics and various external factors [7]. Therefore, it is necessary to analyze the characteristics of consumers' needs before analyzing consumer demand OK, I understand. Its main features are as follows:

① Consumers need to show diversity

Due to the different income level, education level, occupation, personality, age, nationality and living habits of each consumer, they will naturally have a variety of hobbies and interests, so consumers' demand for goods and services is also very different. This difference is reflected in the diversity of consumer demand.

② Consumers need to be developmental

With the development of society, the psychological needs of consumers will continue to be intensified and promoted. One need will be met, and another demand will be generated. When the needs of the old generation are met, the new generation will have higher needs, and move forward again and again. The unlimited development of consumers' needs for goods interacts with the development of science and technology, which has become an important driving force for the development of human society. The development trend of consumption needs always develops from low-level to high-level, and from simple to complex.

③ Consumers need to be full of characteristics of the times

Although the needs of each consumer are different and changeable, in a certain period of time and within a certain social scope, due to the influence of social factors and environment at that time, people often show a common love for one or some commodities, which has the characteristics of that era.

④ Consumers need scalability

Scalability refers to the characteristics that consumers' needs are affected by many factors, satisfied or realized, or suppressed or weakened. It is different due to the variety and level of goods or services. Generally speaking, the demand for durable consumer goods is more flexible, and the demand for daily necessities is less flexible.

⑤ Consumers need to be differentiable

The emergence, development and change of consumers' psychological needs are closely related to the real life environment. The development of production technology, the development and change of commodities, the renewal of consumption concept, the change of social fashion, the change of working environment, the edification of culture and art, and the induction of packaging and advertising may change the needs of consumers.

(2) Emotional consumption needs

According to Maslow's hierarchy theory of human needs, according to its importance, human needs are divided into five kinds: physiological needs, security needs, belonging and love needs, self-esteem needs and self realization needs. They are interrelated and gradually arranged into a hierarchy from low to high. Then, on the basis of Maslow's hierarchy of needs theory, aldev, a professor at Yale University, further classified human needs into three categories: survival needs (physiological and security needs), relationship needs (social and respect needs), and personal growth needs (self-esteem and self realization needs). From these two sets of theories, we show that human needs are a process from low-level material needs to high-level spiritual needs. Only when all the needs are met in succession will there be the need for self realization at the highest level.

Western marketing theory divides consumer demand development into two stages:

The first stage is the era of quantitative consumption, which is due to the limitations and lack of social productivity, socio-economic conditions and material resources. In the early stage of entering the commodity economy, people's demand for consumer goods only stayed on the necessities of life. In this consumption period, social consumer goods only meet people's most basic survival needs and are in a low consumption state of survivability [8]. The quality of goods in this period is often ignored.

The second stage is the era of qualitative consumption. During this - period, people's income level and self-awareness have improved, and the corresponding consumption demand has also changed. Consumption should not only meet the needs of survival, but also meet the needs of life and self affirmation. Therefore, people gradually began to pay attention to the quality of consumption, not only at the material level, but also in the direction of high quality, diversification and differentiation. This stage belongs to the era of perceptual consumption. When people enter the information society, their pace of life is accelerating day by day. Consumers' demand for goods is more expressed as emotional satisfaction and desire, and pay attention to spiritual pleasure, personality

realization and other demand tendencies. Therefore, we find that the transformation of consumer demand is consistent with the essence of human needs, which also rises from material needs to emotional needs.

2.3 Analysis of Consumers' Purchase Motivation

(1) Analysis on the characteristics of consumers' purchase motivation
In psychology, motivation refers to the psychological motivation that triggers and maintains individual behavior and leads to certain goals. Consumer motivation is generated on the basis of consumer needs. It is the direct cause and driving force to trigger consumer consumption behavior. Consumer motivation behaviorizes consumer needs. Usually, consumers choose and consume specific commodity types according to their own motivation [9]. The generation of consumers' purchase motivation is the result of the interaction of a series of complex factors and presents many characteristics. The analysis of modern consumers' purchase motivation needs to be based on the grasp of consumers' purchase motivation. The characteristics of its consumer motivation are:

① Conflict: because consumers will be exposed to a wide variety of goods in the selection process before purchase, it will produce two or more motives, which will cause psychological contradictions. Its concrete manifestation is that several contradictory consumption motives struggle with each other, and the result of the struggle will determine how to buy goods and what kind of goods to buy. In real life, the situation of motivation contradiction is very complex, including double tendency conflict, double avoidance conflict, avoidance conflict, multiple conflict and so on.
② Fuzziness: when consumers buy goods, they often have many different purchase motives. Some of these motives are clearly recognized by consumers, while others are potential consciousness that consumers do not feel. Whether they are aware or not, they are intertwined and jointly affect consumers' purchase behavior.
③ Induceability: in the process of selecting goods, consumers' original motivation may be transferred due to external stimulation and inducement. In other words, in the purchase process, consumption will be stimulated by various commodities and affected by the shopping environment, and its original motivation status can be changed.

(2) Emotional purchase motivation is the dominant motivation of modern consumption
Because purchase motivation is the direct driving force of consumption behavior. No one's actions happen for no reason, and any activities they engage in are caused by certain motives. Similarly, most of consumers' purchase behavior is the result of the joint action of multiple motives. Among them, the strongest and most stable motivation of consumers is the dominant motivation of purchase. Under the same other factors, the purchase behavior is consistent with the dominant motivation. Consumers' purchase motivation is complex, changeable and multi-level. In the research of consumer psychology, purchase motivation is divided into physiological purchase motivation and psychological purchase motivation.

① Physiological purchase motivation refers to the needs of consumers to maintain and continue life organisms
Students' purchase motivation. Physiological factors are the root of consumers' physiological purchase motivation. In order to continue their life, consumers must seek food, clothing and safety, be able to organize families and reproduce, as well as enhance their physique and intelligence. All these needs must be met through various commodities. The motivation to buy these commodities is based on physiological needs. With the development of society, modern people's physiological needs have been greatly met and began to pursue emotional satisfaction. Correspondingly, in the modern society, there are fewer and fewer Purchase Motives driven by purely physiological needs, Physiological purchase motivation is often mixed with other non physiological purchase motivation. The degree of mixing is generally closely related to the consumption level. The higher the consumption level, the higher the degree of mixing.
② Psychological purchase motivation refers to the purchase motivation caused by the change of consumers' psychological activities. People's psychological activities are divided into perceptual psychological activities and rational psychological activities. Consumers' psychological purchase motivation is also divided into perceptual purchase motivation and rational purchase motivation. Emotional purchase motivation can be divided into emotional motivation and emotional motivation due to the different degree of emotional stability. Emotional motivation is people's purchase motivation with impulse, improvisation and instability; The purchase motivation with relatively stable morality, taste and aesthetics is emotional motivation. Like people's psychological activities, emotional motivation and emotional motivation also have an interactive relationship. Emotional motivation opportunities are affected by emotional motivation, but more depend on people's rational consumption concept and consumption demand. Rational consumption motivation comes from the analysis and comparison of product quality, price, purpose, style and variety on the basis of consumption demand. Consumers with rational consumption motivation have certain requirements and standards for the price, service and practicability of goods [10]. This standard is based on the rational cognition of goods. Compared with emotional purchase motivation, rational purchase opportunity is more objective, practical and detailed. The price of the product will affect the type of consumers' purchase motivation. For example, the consumption of one yuan candy is easy to trigger emotional purchase motivation, and the consumption of 10000 yuan computer is more likely to trigger rational purchase motivation. Due to the different income of consumers, the purchase of the same commodity will also be different.

Generally speaking, with the continuous improvement of living standards and demand levels, compared with consumers' psychological needs and physiological needs, their psychological needs play a more important role in purchase motivation and purchase behavior. Psychological consumption motivation has gradually become the leading motivation of modern consumption, as shown in Fig. 2. The demand concept of consumers is not only to obtain more material products and products themselves, but also to consider the symbol of goods. In short, consumers

pay more attention to the satisfaction of personality, spiritual pleasure, comfort and superiority through consumption [11]. Therefore, in store design, we should pay attention to the psychological feelings of consumers.

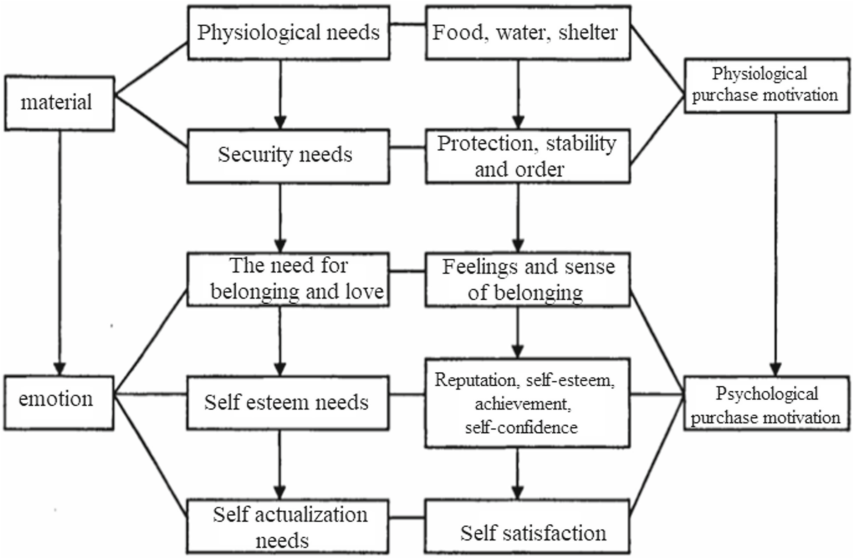

Fig. 2. Conversion between consumer needs and purchase motivation

3 Classification Algorithm

3.1 Overview of Fuzzy Clustering Algorithm

Traditional cluster analysis is a kind of hard partition, which strictly divides each object to be identified into a certain class, and only belongs to this class, with the nature of "either or". However, in real life, due to the complexity of things, the boundary between clustering objects is often not very clear, especially in humanities, such as social science, economic management, regional planning, pedagogy, etc. this ambiguity is more prominent in some disciplines here. Since the first mock exam of fuzzy set theory was established by Professor Chad in 1965, because of his success in dealing with the uncertainty and fuzziness of a wide range of problems, he has been more and more popular in dealing with the complexity and complexity of systems, and to some extent, to make up for the deficiency of classical mathematics and mathematical mathematics. L.A. Zadeh has been increasingly popular [12].

The first mock exam provides a powerful tool for analyzing soft partition, and brings new vitality to the classical clustering analysis. In 1973, dunnl first proposed the first fuzzy C-means (FCM) clustering algorithm, which is an extension of the hard c-means

(HCM) clustering algorithm proposed by ball and Hall. Because fuzzy clustering obtains the uncertainty degree of the sample belonging to each category, that is, it establishes the uncertainty description of the sample for the category, which can more objectively reflect the real world and describe the unclear objects, so as to make the actual clustering results more reasonable [13]. Especially when the classical cluster analysis meets the obstacle of coincidence, fuzzy cluster analysis shows its unique skills and quickly becomes the mainstream of cluster analysis.

The data object in cluster analysis is called sample, which is represented by several indicators or parameters that can reflect the characteristics of the object itself. Cluster analysis is to adopt scientific methods to distinguish all objects into several categories according to the similarity between samples, such as similarity in nature and characteristics [14]. Fuzzy c-means clustering (FCM) algorithm is the most common algorithm in fuzzy clustering algorithm. The steps of FCM algorithm are as follows:

(1) Initialization: given the number of clusters C and $0 \leq C \leq n$, set the iteration stop threshold ε, Set iteration counter $B = 0$;
(2) Initialize the fuzzy clustering center V (0);
(3) Calculate the partition membership matrix U (0);
(4) Update the fuzzy clustering center to V *, if $| V (b) - V (B + 1) | \leq \varepsilon$, End the iteration, otherwise return to step (2).

FCM algorithm obtains the membership degree of each sample point to the class center by optimizing the fuzzy objective function, so as to determine the ownership of the sample points. Its iterative process uses a so-called mountain climbing technology to find the optimal solution.

3.2 Fuzzy c-Means Algorithm

The traditional dynamic clustering method divides m samples into C categories respectively, so that the mean value of each sample and its category is the minimum sum of squares of error, i.e.

$$(t) \leq ce^{at} + \int_0^t e^{a(t-\tau)} mi(\tau) y\tau \tag{1}$$

Minimum, where m is the sample mean of class I, $y \in \tau$ Is all samples divided into class I. The method to minimize the result is the C-means method. In the C-means algorithm, there are many methods to calculate the discrimination between samples, such as calculating the similarity between two samples or the distance between samples. In this paper, the hard partition is changed into fuzzy partition, that is, fuzzy c-means method.

The iterative method is the fuzzy c-means algorithm. The specific steps of the algorithm are as follows:

① Set the number of clusters C and parameter B;
② Initialize each cluster center m;
③ Repeatedly calculate the membership function and update various clustering centers until the membership value of each sample is stable.

When the algorithm converges, each membership value is obtained, and finally the fuzzy clustering division is completed.

3.3 Improved Fuzzy c-Means Clustering Algorithm

Assuming that M is a fuzzy relation on universe u, if M can satisfy the conditions: m (a, b) = 1 and m (a, b) = m (B, a), then we call m a fuzzy similarity relation on u, and m (a, b) represents the similarity between elements a and B in U. When u includes many elements, i.e. u = {U1, U2,…, UN}, the fuzzy similarity relationship of M can be expressed as fuzzy matrix M = [mij] m × N, mij is the membership function. In the established fuzzy matrix, the elements on the diagonal are the similarity between themselves, so the value is 1 and meets mij = Mji. The matrix satisfying such conditions is called fuzzy similarity matrix.

For example, let one person give it to five strangers (μ1, μ2, μ3, μ4, μ5) The similarity degree between is scored, and the scoring results are as follows:

$$||\Delta x_{k+1}(t)|| \le k_f \int_0^t ||\Delta x_{k+1}(t)||d\tau + m_1 \int_0^t ||\Delta u_k(\tau)||d\tau + m_2||x_d(t)|| + m_3||x_{k-1}(t)|| \tag{2}$$

In the formula, the elements on the diagonal represent their similarity with themselves, so the value is 1. The larger the value of the element in the matrix, the higher the degree of similarity between two people. The smaller the value, the lower the degree of similarity.

4 Specific Case Analysis Based on Fuzzy Clustering

The factors affecting consumers' purchase psychology and behavior include internal conditions and external conditions. The internal conditions include consumers' psychological activity process, consumers' personality psychological characteristics, consumers' psychological activities in the purchase process and psychological factors affecting consumers' behavior; The external conditions include the influence of social environment on consumption psychology, the influence of consumer groups on consumption psychology, the influence of consumption situation on consumption psychology, the influence of commodity factors on consumption psychology, the influence of shopping environment on consumption psychology, and the influence of marketing communication on consumption psychology. Under the influence of these two conditions, in the general purchase process, people's psychological activities mostly go through three stages: cognitive process, emotional process and will process:

① Cognitive process: from the perspective of consumer psychology, consumers' overall first feeling initially obtained from factors such as commodity, store image design and internal design is the cognitive process, which is the premise of purchase behavior;
② Emotional process: on this basis, different customer groups will have unique experiences or attitudes towards the items sold by the store, forming an emotional process;
③ Will process: the behavior that consumers decide whether to consume is the will process.

Based on the open-ended questionnaire, a questionnaire on purchasing smart phones was compiled, and a random sampling survey was conducted on 200 students in normal college. Subjects were asked to understand the mobile phone functions that affect their purchase intention (μ 1), speed (μ 2), appearance (μ3), screen size (μ 4), price (μ 5), mobile phone brand (μ 6) And other 6 attributes, using the 10 level scoring method, the weight of 1–10 in turn indicates that they don't care very much - they care very much and other 10 different degrees, which are scored by the subjects. Fuzzy clustering method is used for classification, as shown in Fig. 3.

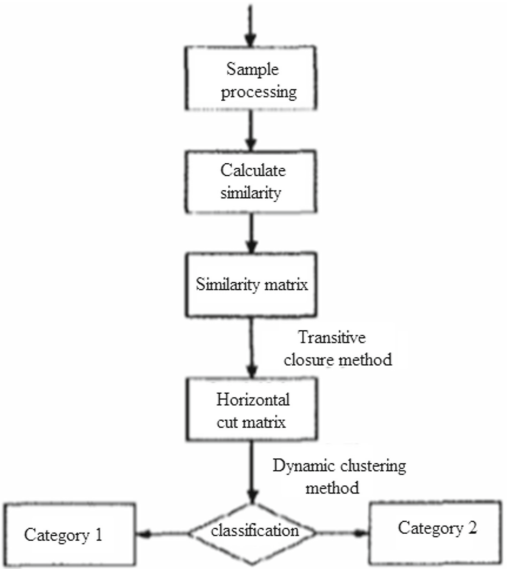

Fig. 3. Flow chart of cluster analysis

The mutual information method is used to calculate the chance that any two attributes affect the purchase intention at the same time, and the similarity is obtained.

Then take different thresholds λ Classify the samples, such as:

① λ = At 0.85{μ 1, μ 3} The classification shows that the appearance and function of mobile phones play a major role in consumers' purchase psychology.

② $\lambda =$ At $0.82\{\mu\ 1, \mu\ 3, \mu\ 6\}$ It belongs to the first category, and the rest belong to the first category, indicating that the function, appearance and brand of mobile phones play a major role in consumers' purchase psychology Through many experiments, choosing a reasonable threshold plays a very important role in analyzing the factors affecting consumers' purchase determination.

5 Conclusion

Maslow put forward the "five levels theory of human needs", he said: "generally, only after meeting the low-level needs, the high-level needs will gradually appear." Nowadays, with the improvement of living standards, people's requirements for their quality of life are gradually transitioning from simple life products to products that provide spiritual needs. When shopping, many consumers do not buy in a simple sense or just to meet their own living needs. They will also buy their own satisfactory products and services in combination with their own actual situation and consumption habits. This study classifies the samples through the improved fuzzy c-means theory, obtains the ideal classification effect, reflects the influence of some factors on consumers' purchase psychology, and provides a reference for enterprises in the production of products.

References

1. Wu, W., Yin, B.: Personalized recommendation algorithm based on consumer psychology of local group purchase e-commerce users. J. Intelli. Fuzzy Sys. **37**(5), 5973–5981 (2019)
2. Kühbauch, G.W.: A new algorithm for automatic Rumex obtusifolius detection in digital images using colour and texture features and the influence of image resolution. Precision Agriculture (2007)
3. Canellidis, V., Giannatsis, J., Dedoussis, V.: Genetic-algorithm-based multi-objective optimization of the build orientation in stereolithography. Int. J. Adv. Manuf. Technol. **50**(1–4), 419 (2010)
4. Luo, L., et al.: Curve fitting using a genetic algorithm for the X-ray fluorescence measurement of lead in bone. J. Radioanal. Nucl. Chem. **269**(2), 325–329 (2006)
5. Fischer, B., Modersitzki, J.: A Super Fast Registration Algorithm. Springer, Berlin Heidelberg (2001)
6. Millán, S., et al.: An Algorithm to Calculate the Expected Value of an Ongoing User Session. Springer Berlin Heidelberg (2005)
7. Kong, Y.T., et al.: Cricothyrotomy training increases adherence to the ASA difficult airway algorithm in a simulated crisis: a randomized controlled trial. Canadian Journal of Anesthesia/Journal canadien d'anesthésie (2015)
8. Pandian, P.P., et al.: Secondary population implementation in multi-objective evolutionary algorithm for scheduling of FMS. Int. J. Adv. Manuf. Technol. **57**(9–12), 1143 (2011)
9. Cinaroglu, S.: Comparison of Fuzzy C-Means and K-Means Clustering Performance: An Application on Household Budget Survey Data (2021)
10. Singh, S., Srivastava, S.: Kernel fuzzy C- means clustering with teaching learning based optimization algorithm (TLBO-KFCM). J. Intelli. Fuzzy Sys. **1**, 1–9 (2021)
11. Kuo, R.J., Lin, J.Y., Nguyen, T.: An application of sine cosine algorithm-based fuzzy possibilistic c-ordered means algorithm to cluster analysis. Soft. Comput. **25**(11), 1–16 (2021)

12. López-Oriona, N., et al.: Quantile-based fuzzy C-means clustering of multivariate time series: Robust techniques (2021)
13. Tokat, S., et al.: Fuzzy C-means clustering-based key performance indicator design for warehouse loading operations. J. King Saud Univ. Comp. Info. Sci. (2021)
14. Saxena, S., Kumari, N., Pattnaik, S.: Brain Tumour Segmentation in FLAIR MRI using sliding window texture feature extraction followed by fuzzy C-Means clustering. Int. J. Healthc. Info. Sys. Info. (IJHISI), 16 (2021)