Mining the Body Features to Develop Sizing Systems to Improve Business Logistics and Marketing Using Fuzzy Clustering Data Mining

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Abstract: - Business logistics have played an important role of business operations of procurement, purchasing, inventory, warehousing, distribution, transportation, customer support, financial and human resources. Human body type classifications are also very crucial issue for garment manufacturing. Data mining has been widely used in many fields. But, there is lack of research in the area of establishing of garment-sizing systems for business logistics. This research aims to establish sizing systems of body types from the anthropometric data of females by using a fuzzy clustering-based data mining approach. Certain advantages may be observed when the sizing systems are established, using fuzzy clustering-based data mining procedure. Body types could be accurately classified for garment production according the newly the sizing systems. This approach is found to be effective in processing the anthropometric data, and obtaining regular rules for the development of sizing systems. The results of this study can provide an effective procedure of identifying the clusters of human body type to establish the sizing systems for integrating logistics operations internally with different functions inside the organization and also externally with business partners.

Key-Words: - Data mining; Fuzzy clustering; Sizing systems; Business logistics.

1 Introduction

Business logistics is concerned with the movement, storage and processing of materials and information across the whole of the supply chain, from acquisition of raw materials and components, through manufacturing, to delivery of finished products to end users [5]. Nowadays, business logistics have been receiving very great concern, attention and support from governments as well as enterprises. Whilst it is necessary to understand and able to apply sizing systems for garment manufacturers, it is also important to be able integrate and collaborate logistics operations internally with different functions and departments inside the organization such as marketing, finance and HR etc., and also externally with business partners such as suppliers and customers. This will generate unique values for stakeholders resulting from uplifting customer satisfaction, reducing operations cost, and enhancing competitiveness, through effective cooperation and collaboration of business logistics with other functions in the company.

Mass produced and distributed garments are called ready to wear/RTW. Quality is crucial in the garment manufacturing industry, and standard is the basis for measuring quality. Sizing system is a key standard in garment production. The establishment of standardization is very important to the elevation of product quality in the intensely competitive industry, and standards are set for an index of product quality, with only products that pass being allowed to leave the factory, in order to prevent the enterprise suffering economic losses, or even losing credibility. Clothes standards related to ISO were established by Technical Committee (TC) 133, the scope of this committee was to draft the standardization of a system of size designations resulting from the establishment of one or more clothes sizing systems based on body measurements. All standards related to clothes are listed in Table 1.

Table 1 Sizing systems and designations for clothes of TC 133

Standards	Descriptions
ISO 3635:1981	Size designation of clothes – Definitions and body measurement procedure
ISO 3636:1977	Size designation of clothes – Men's and boys' outerwear garments
ISO 3637:1977	Size designation of clothes – Women's and girls' outerwear garments
ISO 3638:1977	Size designation of clothes – Infants' garments
ISO 4415:1981	Size designation of clothes – Men's and boys' underwear, nightwear and shirts
ISO 4416:1981	Size designation of clothes – Women's and girls' underwear, nightwear, foundation garments and shirts
ISO 4417:1977	Size designation of clothes – Headwear
ISO 4418:1978	Size designation of clothes – Gloves
ISO 5971:1981	Size designation of clothes – Pantyhose
ISO 8559:1989	Garment construction and anthropometric surveys – Body dimensions
ISO/TR 10652:1991	Standard sizing systems for clothes

ISO is a kind of international standard, and although international standards are generally standards of self-voluntary execution, the sizing systems of ISO were not established based on the anthropometric data of the body type of Taiwanese people, and thus these systems naturally cannot be used for designing ready-made garment designs for the domestic market. Thus, establishing sizing systems suitable for the body type of Taiwanese people is evidently very important.

The RTW is a mass produced garment based on a standard proportion size of human body types. RTW uses almost no manual sewing, but uses mass production technology to produce garments. Similar to what the term signifies, the said garments are already completed at the time of sale, allowing them to be worn immediately. In England, RTW is known as off-the-peg, meaning the clothes can be taken directly from the cloth rack and worn, in France, such garments are called prêt-a-porter, and again meaning the garments can be taken straight from the cloth rack [11].

Garment sizing systems are established based on factors such as consolidated standards of human body size, company measurements, personalized designs, and so on. Sizing system standardization is an important factor in facilitating the vigorous development of the ready-made garment industry. Sizing systems use the body size of a big group people with similar body type, apply the statistical method to calculate the average, and obtain the relative data for each body part. These data represent the size of individual parts. The recent rapid development of mail order business has caused garment companies with involved in direct sales to expend significant effort on formulating sizing systems related to the body. If the sizing system table established by the company conforms to customer body sizes, the rate of returns can be reduced while simultaneously increasing the rate of customer satisfaction with the enterprise and its products [3].

Although numerous countries have established sizing systems based on different body types, the ready-made garment manufacturers have not completely followed nationally recognized ‘fixed’ sizing systems. Manufacturers may target customers with a bust line smaller than their hip line, or maybe with a bust line bigger than their waist line, and may develop their own sizing systems accordingly. Convenience of wearing and design also needs to be considered in establishing sizing systems. Every manufacturer has their standards of wearing and design convenience, and develops a distinct company style accordingly. This phenomenon also explains why consumers may prefer particular garment brands owing to better fit [3]. Therefore, whether it is the national sizing systems or the manufacturer’s revised sizing systems, it will always be an important reference in the garment designing.

In the manufacture and business logistics of RTW garments in Taiwan, the manufacture of RTW garments involves two production marketing methods, namely domestic market RTW and export RTW:

(1) Domestic market RTW: target is the local market, product design aims to meet local tastes, controlling the market pulse, focus is on wide

variety and limited quantities, sales flow is smooth and marketing ability is essential.

(2) Export RTW: production is based on orders received from foreign buyers, production design is according to buyer demand, zero product inventory accurate materials control and effective delivery are required to gain business opportunities.

Both domestic market RTW and export RTW share a common production rule in the manufacturing procedure, primarily, they can be divided into three main stages: (1) garment design stage, (2) pattern design stage, and (3) production manufacturing stage [6]. These three stages are handled and planned by three different departments, as illustrated in Figure 1.

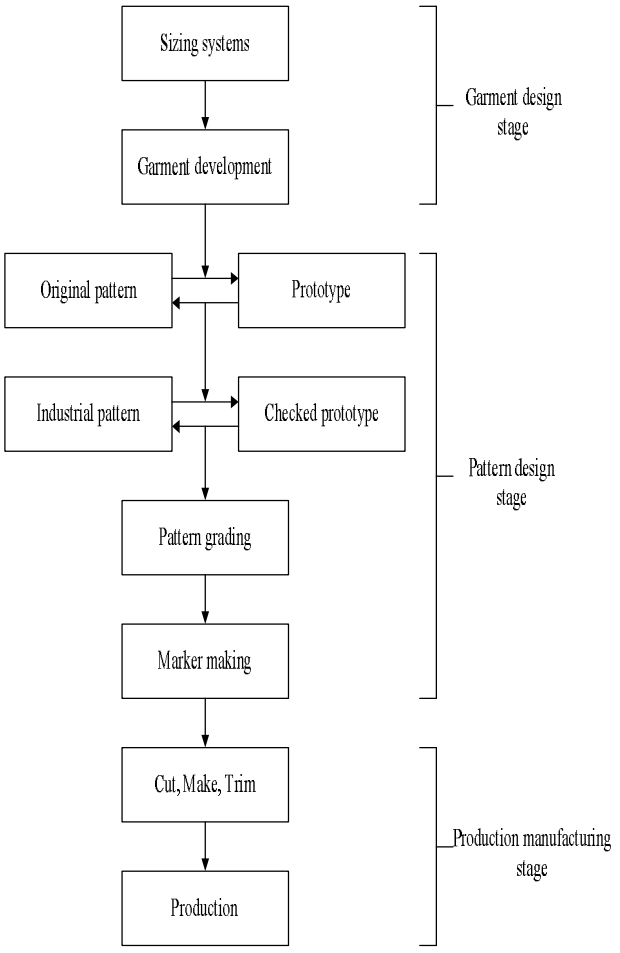

Figure 1 Production procedure of garment.

Among the anthropometry data, the body dimension is actually the most important variables for garment design [14]. In addition to the genetic heredity, there are also some other variables like ages, sexes, races, eras and occupations correlative to body dimension [18].

Some researches indicated that the body dimension comes with the proportional relationships of body dimensions. Among them, the variable receiving most attention is exactly the body height and body weight. The body height comes with the high correlation to the vertical dimension such as body height, eye height, and shoulder height, etc. The body weight is highly correlative to horizontal dimension also, such as body weight, chest/bust girth, and waist girth, etc. Thus, whenever we just capture the major body dimensions, it is available for us to profile the body type easily [29]. The frequent adoption is to treat body height as the basic value to deduce various correlations between dimensions and body height; the correlation is also demonstrated with graphics to allow the users to capture the human body types more comprehensively. About the research related to body dimension proportion, Mououdi (1997) used to conduct the static bodily measurement among 105 male students and 74 female students with the ages ranging from 20 to 30 with the body dimension proportional results shown in Figure 2 and Figure 3 [26].

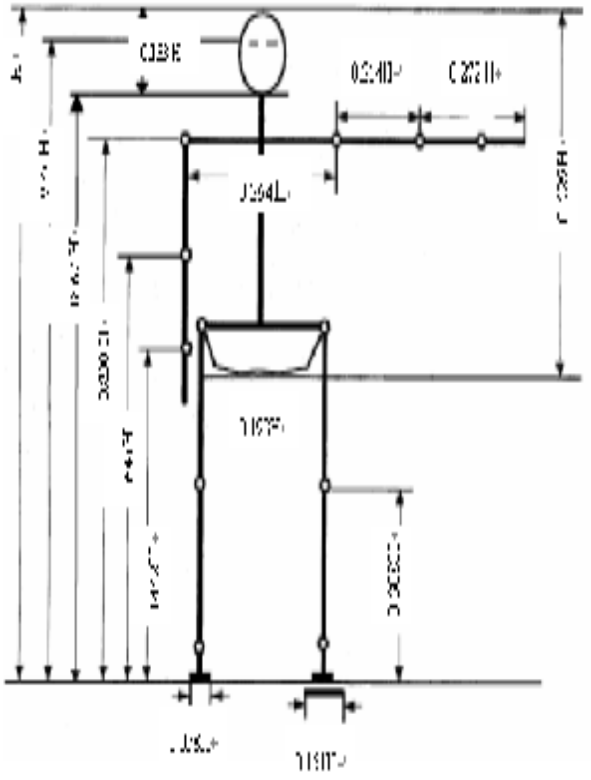

Figure 2 The Iran female body dimension proportion with the ages from 20 to 30.

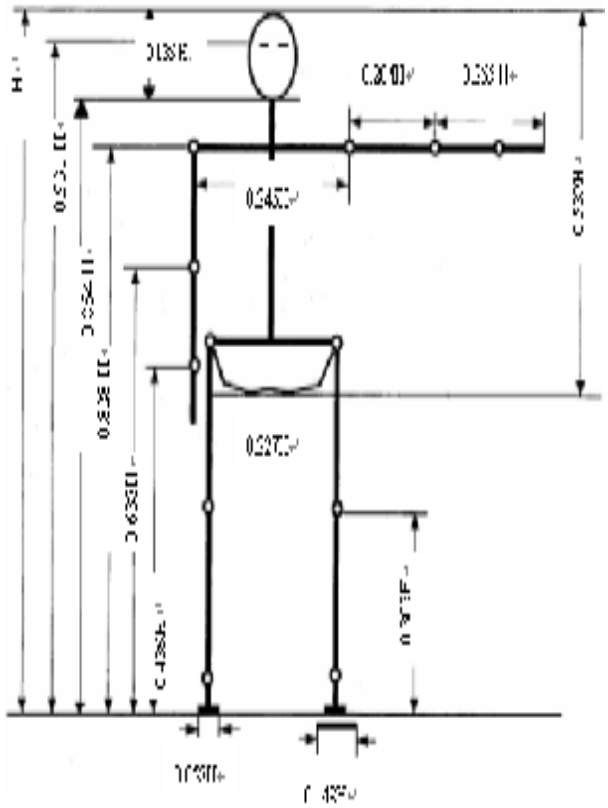

Figure 3 The Iran male body dimension proportion with the ages from 20 to 30.

Human body type classifications are very crucial issue, play an even important role for physiology, medical treatment, sports talent and garment manufacturing. Taking the sizing systems used in the garment manufacturing industry as an example, garment manufacturers have never developed standard sizing systems according classified body type, finally resulting in heavy stock burden. Human body types could be accurately classified, garment manufacturers can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning according standard sizing systems for business logistics and marketing [3, 14].

Standard sizing systems can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning [3, 17]. Due to differences in the body types of people in different countries, each country must have its own standard sizing systems for manufacturers and consumers to follow. Under traditional production procedures, Taiwan has not yet developed its own sizing systems. Most garments are manufactured using revised overseas sizing data; as a result, garment sizes differ from factory to factory, with no consistent standards. Apart from the fact that most overseas sizing data do not correspond to Taiwanese body types, domestic manufacturers have been inconsistent in their size classifications, so consumers must choose suitable garments by trial and error, resulting in enormous inconvenience, not to mention wasted time and money. Thus, the development of standard sizing systems for garment manufacturers and consumers is long overdue.

Body type classifications have different goals. The earliest exploration body types were most focused on physiology, medical treatment and sports talent. Until 1950, body type data was only applicable to garment sizing systems [23]. In the late 18th century, garment-sizing systems originated from the rough proportional distribution developed by tailors. After accumulating a large number of original patterns, tailors developed these patterns into several styles, which could be used to make garments for people with similar body types. The important approaches, developing the sizing systems of today, are briefly discussed below. Emanuel et al. (1959) concentrated on applying different body types to garment-sizing classifications, and worked out a set of procedures to formulate standard sizes for all body types. According to these procedures, people of all body types were first classified, according to body weight, into four grades, within the same range of weight and then subdivided into two categories in terms of body height. As a result, people were divided into eight categories, each category comprising those of similar height and weight. Based upon the number of people in each category, estimates could be made of the number and proportion of people of each body type [8].

In other studies, Tryfos (1986) proposed an integer programming approach to classify sizes, so as to maximize expected sales [31]; McCulloch, et al. (1998) proposed a non-linear optimization technique, in order to derive a set of sizes [24]; Laing et al. (1999) used multivariate analysis to establish size charts for the protective clothing used by New Zealand firemen [22]; and Gupta and Gangadhar (2004) applied a statistical model to develop size charts for young Indian females [13].

Human body types can be distinguished by taking various approaches. When classifying garment sizes, instead of targeting every consumer, manufacturers simply produce garments in several sizes. Although a greater number of sizes offers consumers a greater number of choices, this can cause difficulties for manufacturers, as far as production and stock are concerned. As far as possible, the garment sizing systems should have the fewest number of sizes and cover the greatest

number of people. Therefore, it would be helpful to formulate sizing systems, which have the fewest number of sizes to fit the largest number of body types, for the majority of consumers [3, 21].

Human body types can be classified by taking various methods. Taking body type classifications for sizing systems development as an example, many approaches utilize approximate range of the anthropometric difference to determine body types for developing sizing systems, but these body types could not be accurately classified. Moreover, few studies have applied the fuzzy clustering approach to body typing.

On the other hand, data mining has been successfully applied in many fields. The application domain is quite broad and plausible in marketing [32], production [30], human resource management [25], sequence decisions [16], software design [15] and health insurance [4]. However, research on identifying body type classifications using fuzzy clustering-based data mining is lacking. Accordingly, this study attempts to classify body types using the fuzzy clustering-based data mining procedure to identify the clusters for body type classifications. By applying fuzzy clustering-based data mining procedure, body types can be classified from an anthropometric database for establishing the sizing systems for garment production and business logistics.

2 Fuzzy clustering-based data mining

Within the growing improvement of information technology and the trend of business knowledge management, how to convert information into valuable information and knowledge will be the critical lesson for quick decision making of the business leader from modern business management. During the routine commercial management, execution of operational application will create large amount of data and the useful application for the data infused into the decision making procedures will bring with considerable value adding efficiency. For the modern business, the data will be viewed as important assets. Yet, the data must be available for practical application; namely, the conversion of large amounts of data into the useful information will just create the real value of data. The data mining can be referred to as a new technique for business improvement and scientific decision making process to assure of quality and efficiency. The software of data mining is mainly functioned to excavate the most contributable and valuable informational treasures from a great deal of information collected for a long time [9].

Data mining has been extensively used as a major step of knowledge discovery in databases (KDD). Fayyad and Stolorz (1997) defined KDD as the nontrivial process of identifying valid, novel, potentially useful and ultimately understandable patterns in data [10]. Berry and Linoff (2000) defined data mining as the analysis of a huge amount of data by automatic or semi-automatic means to identify significant relationships and rules [1]. Thus, there are also some other people refer to this process as “Data Anthropology”, “Data Pattern Analysis”, and “Function Dependency Analysis”, etc [27].

About the technology of data mining, each scholar proposed different definitions and classification methods. This study is aimed to classify the techniques of data mining into below 6 types as shown Table 2 [7, 27].

Table 2 The technique type of data mining

Type	Description
Classification	According to the attributes of experimental subjects, it is defined by classification to create the type models.
Clustering	Sort up the heterogonous matrix with the interval to cluster the elements with much more similarities.
Association	From all the objects, determine which objects shall be collected together.
Sequence pattern	Locate the correlation orders frequently seen.
Estimation	Based on the attributes of currently continuous value correlation, locate the unknown values of a certain attribute.
Prediction	Based on the historic observed values of the subject attribute, forecast the future value of the said attribute.

To summarize foresaid mention, it is available to find below features of data mining [7]:

(1) The database desired to be analyzed is inclusive of a great deal of data.

(2) The process of data mining is created in an automatic or semiautomatic manner.

(3) The information excavation must be meaningful or usable.

(4) The formats of new information are composed of correlation.

The data mining can increase the business wisdom and sharpen the business competence. According to the research made by Fayyad et al. (1996), they proposed some proceeding steps for reference.

(1) Realize the data and the proceeding tasks;

(2) The acquisition of relevant knowledge and techniques;

(3) Integration and data checking;

(4) Clean erroneous and incongruent data;

(5) Model and hypothesis development;

(6) Actual data mining tasks;

(7) Test and verify the excavated data (Testing and verification);

(8) Interpretation and use.

Seeing from 8 operational steps, the data mining is involved with numerous projections and preparations with 80% of effort spent for the preparation stages. The data mining is only one of the steps of KDD and to reach this step is still required for many tasks for achievement [10].

Berry and Linoff (1997) suggest the reasons for the widely accepted usage of data mining [1]:

(1) A large scale database has existed: Because the data mining is under great demand of data for operation support of model establishing and testing, it has been quite convenient for telecommunication business, monetary business, or the vendors of POS systems to reach a great deal of data.

(2) Data Pool: Establishing data pool is available for information inquiry, together with the retrieve and integration of relevant information. But, not all the relevant information can be directly applied and it is definitely required for extracting operations the same the management of warehouse. Thus, the data pool is currently viewed as the vital task for data mining.

(3) The overall functionalities of computer to process a great deal of database capably: The data mining algorithm is especially required for overall functionalities of computer to perform parallel algorithm capability.

(4) Violent competitive stress: Under violently competitive business climate, the enterprises holding a great deal of resource of customer data and market channels, will be more willing to perform the tasks related to data mining and knowledge discovery in database.

The data mining is executed in various manners such as statistics, decision trees, artificial neural networks, and genetic algorithms, etc. Within the whole process of data mining, it is always repeated with below four procedures [2].

(1) Identifying the program: Firstly clearly define and frame the questioning scope and research target such as how the customer's special demand being well known by business.

(2) Analyzing the data: Use the data mining tools to analyze a great deal of information to locate the currently usable data.

(3) Taking action: According to the usable information reached, create the adequate action projects for decision making.

(4) Measuring the outcome: Evaluate the mining efficiency according to the satisfaction degree and effectively use the results for next cycle of improvement.

One of the most important data mining techniques is cluster analysis, which is an exploratory data analysis tool for solving classification problems. Its object is to sort cases into clusters, so that the degree of association is strong between members of the same cluster and weak between members of different clusters. The cluster analysis includes both hierarchical and non-hierarchical methods [12]. In fuzzy clustering, data elements can belong to more than one cluster, and associated with each element is a set of membership levels. These indicate the strength of the association between that data element and a particular cluster. Fuzzy clustering is a process of assigning these membership levels, and then using them to assign data elements to one or more clusters.

The operation steps of fuzzy clustering [20]:

(a) Build the characteristic index matrix for fuzzy

clustering analysis;

(b) Data standardization: The dimensions and magnitude orders of m characteristic indexes may vary, so data standardization must be performed for each index value to eliminate the influence caused by variable units and different magnitude orders of the characteristic indexes;

(c) Build the fuzzy similar matrix: When data of $u_{ij}(i=1,2,\cdots,n;\ j=1,2,\cdots m)$ has all been standardized, the degree of similarity between sample $u_i=(u_{i1},u_{i2},\cdots,u_{im})$ and $u_j=(u_{j1},u_{j2},\cdots,u_{jm})$ can be determined through the method of multivariate analysis as: $r_{ij}=R(u_i,u_j)\in[0,1], i,\ j,=1,2,\cdots,n$ and therefore the fuzzy similar matrix $R=(r_{ij})_{n\times n}$ among the samples can be built;

(d) Build the fuzzy equivalent matrix: The fuzzy similar matrix among samples, as built through above steps, may not be necessarily of transitivity, and should be reformed to get a fuzzy equivalent matrix. The specific reform is to build the transitive closure of similarity by obtaining the square of R, that's $R \mathbf{o} R=R^2$, then $R^2 \mathbf{o} R^2=R^4$, $R^8, R^{16},\cdots$, so on and so forth, until we come to $R^{2k}=R^k$, and R^k is the fuzzy equivalent matrix with which we can proceed with fuzzy clustering analysis.

A fuzzy clustering-based data mining procedure was proposed, in order to mine the patterns of anthropometric data for the significant rules of human body types for establishing the sizing systems for garment production and business logistics.

3 The Data Mining Procedure

The data mining procedure involves a series of activities, from defining the goal to evaluating the results. The previous steps can be served as the baseline reference for the next step.

3.1 Defining the goal

Owing to outdated and incomplete the classification of human body type, an anthropometric database was created for Taiwanese adult females. The ages of these samples are from 20 to 30 years old. According to the definition of the ISO 8559 [19], the anthropometric database based on 52 anthropometric variables measured in each of 104 females. The goal of this study was to explore and analyze an amount of data, by employing fuzzy clustering-based data mining procedure, so as to identify significant rules within body dimensions. Based on these rules, the body types classification of Taiwanese adult females may be classified.

3.2 Data preparation

Before mining the data, the data had to be processed, with all missing data being separated out [28]. As a result, of the 104 samples of adult females, 15, which had missing data, were deleted; this left a total of 89 valid samples.

Not all of the 52 anthropometric variables were suitable for use in identifying significant rules within body dimensions; therefore, in coordination with the judgment of domain experts, this study identified 11 variables.

3.3 Data mining by fuzzy clustering

Data mining was undertaken through data preparation, using the fuzzy clustering to mine the patterns of anthropometric data for identifying significant rules within body dimensions.

This study discovered that three clusters are appropriate for clustered result by the fuzzy clustering. To gain a better insight into the differences between the three clusters resulting from the cluster analysis, the Analysis of variance (ANOVA) was then conducted. In order to verify the anthropometric variables of all body types, and to determine whether notable differences existed among them. As the results that the three clusters did not bear significant differences in the height anthropometric variables. The girth anthropometric variables have significant differences.

Therefore, this study defined the body type, formed by cluster 3, with large girth anthropometric variables, as type L; the body type, formed by cluster 2, with medium girth anthropometric variables, were defined as type M; and the body type, formed by cluster 1, with small girth anthropometric variables, were defined as type S. This definition of the three body types, used in this study, is shown in Table 3. No significant differences among the three body types in the height anthropometric variables.

Table 3 Definitions of three body types

Clusters	3	2	1
Numbers	8	72	9
Girth variables	Large	Medium	Small
Height variables	—	—	—
Body types	L	M	S

3.4 Application of results

Having classified the females into three body types, the new classified body types were identified using fuzzy clustering-based data mining procedure. Body types could be accurately classified for garment manufacturing according the newly classification rules. The sizing systems for female's garment are shown in Table 4.

Table 4 The sizing systems for female garments
Dimensions in cm

	S	M	L
Body height	159	160	158
Bust girth	75	81	89
Waist girth	63	68	72
Hip girth	88	91	94
Wrist girth	14	15	15
Back waist length	37	37	35
Back width	28	29	30
Bust width	29	30	31
Neck point to waist, front	40	41	41
Neck point to waist, back	40	41	39
Arm length	53	54	52
Percentage (%)	9	81	10

Taking the sizing systems used in the garment manufacturing industry as an example, garment manufacturers can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning according the newly classified body types. Furthermore, the sizing systems thus developed provide the percentage of females, and the distribution of body types, enabling manufacturers to access reference points and facilitating garment production for specific markets, and supplying effective manufacturing information, improving the movement, storage and processing of materials and information across the whole of the supply chain. The standard sizing systems can then be developed to integrate and collaborate logistics operations internally with different functions and departments inside the organization such as marketing, finance and HR etc., and also externally with business partners such as suppliers and customers.

The data mining procedure emphasizes the dataset information by repeating interaction activities. Since people's body types and dimensions can change rapidly, the anthropometric database must be updated continually; therefore, the fuzzy clustering-based data mining approach, proposed in this study, will continually update the anthropometric database and continually develop the latest sizing systems. These revised sizing systems will exactly represent female body types and dimensions, allowing manufacturers access to the latest sizing systems, thus facilitating garment production and business logistics.

4 Conclusion

Business logistics have played an important roles of planning, design, and support of business operations of procurement, purchasing, inventory, warehousing, distribution, transportation, customer support, financial and human resources.

Human body type classifications also play an even important role for physiology, medical treatment, sports talent and garment manufacturing. On the other hand, the application domain of data mining has been quite broad. However, little research has been done in the area of identifying the significant rules of human body types, using the fuzzy clustering-based data mining approach. This study applied fuzzy clustering-based data mining procedure to identify the clusters of female body types. Body types could be accurately classified. Garment manufacturers can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning according the newly sizing systems.

The results of this study can provide an effective manufacturing information for garment production and business logistics. This will generate unique values for stakeholders resulting from uplifting customer satisfaction, reducing operations cost, and enhancing competitiveness, through effective cooperation and collaboration of business logistics and marketing.

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