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Research Article

Apparent Strain Measurement of Ankle Joint in Football Sports Based on Data Mining Algorithm

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It is a very common phenomenon to have ankle injuries during sports. Therefore, the detection of ankle injuries has become a concern theme of scholars. It is of great significance to realize the ankle apparent strain measurement quickly in colleges and universities. In this paper, a data mining algorithm-based approach to measuring the apparent strain of the ankle joint in football sports is proposed. This paper first analyzes and integrates the research results of scholars and then expounds from the two aspects of data mining and ankle apparent strain measurement. The method is introduced in detail, and the principle of apparent strain measurement is explained by the formula. The feasibility and robustness of the research scheme are then demonstrated through specific experimental data. The data showed that there was a difference between the boy group and the girl group in the time of jumping, kicking, and reaching the ground (significant level $P = 0.026$).

1. Introduction

Data mining technology can analyze and learn patterns and rules that are useful to users from a large amount of data. Using these learned patterns and rules, when new sample data is available, possible properties of sample data can be predicted based on existing patterns and rules. Aiming at the noncontact fast dynamic measurement of tissue mechanical properties under the condition of keeping the ankle joint relatively intact, the image processing technology is used to extract the dynamic ankle surface strain information, which is necessary for the comprehensive realization of noncontact dynamic ankle biomechanical properties' rapid measurement. The attempt and development of the ankle joint provide an effective way for the basic research on the biomechanical properties of the ankle joint and provide a powerful theoretical guidance for the clinical and rehabilitation of the ankle joint. However, the first and most critical problem in extracting strain is to extract the motion trajectory of the feature points in the ankle joint measurement area during the ankle flexion movement, that is, by calculating the relative displacement between the feature points to obtain the relative deformation variable and further deduce the strain variable. Therefore, it is necessary to study the extraction method of feature points, that is, how to check and extract the center of mass (coordinates) of feature points, the size (area) of feature points, and the shape of feature points.

After more than ten years of research and practice, data mining technology has absorbed the latest research results of many disciplines and formed a unique research branch. Undoubtedly, the research and application of data mining are very challenging. Like the development process of other new technologies, data mining must also go through the stages of concept proposal, concept acceptance, extensive research and exploration, gradual application, and mass application. From the current situation, most scholars believe that the research of data mining is still in the stage of extensive research and exploration. On the one hand, the concept of data mining has been widely accepted. In theory, a number of challenging and forward-looking questions have been raised, attracting more and more researchers. After the concept of data mining was put forward in the 1980s, its economic value has emerged, and it has been respected by many commercial manufacturers, forming a preliminary market. On the other hand, the development of the current data mining system is by no means as magical as some merchants say in order to promote their products, and there are still many problems to be studied and explored. It is more accurate to describe the current research status of data mining as the gap stage. The so-called stage means that there are still many "chasms" to be overcome before data mining technology can be widely used. Data mining comes from commercial applications, and commercial applications vary greatly depending on the field of application. Therefore, most scholars agree with the view that the commercial success of data mining should not be expected to be a general auxiliary development tool, but a vertical solution that combines data mining concepts with domain-specific business logic.

The innovations of this study are as follows:

(1) Based on the research results of scholars, a data mining algorithm-based approach for measuring the apparent strain of the ankle joint in football sports is proposed, which realizes a fast, efficient, and noncontact apparent strain measurement of the ankle joint

(2) In this paper, by measuring and analyzing the actual situation, the basic knowledge, namely, the optical fiber sensing measurement method, is well verified, and the feasibility of this scheme is proved by data

(3) The article gives two mining methods of data mining, which provides reference for scholars who study related aspects later and also provides the future research direction of data mining

(4) An association rule mining algorithm based on pattern matrix matching is proposed, which does not need to scan the database for many times. Determining whether a k-item set to be generated is a frequent k-item set by direct operation, and outputting the k -item set if it is a frequent k-item set. The algorithm only needs to scan the database once and can mine all the association rules from the database without using the candidate set, which greatly improves the efficiency of the operation

(5) Measuring the deformation and strain of biological tissue through noncontact methods such as pictures and videos obtained by the camera and overcoming the contact errors caused by contact measurement methods such as strain gauges, by analyzing the picture information obtained by several cameras placed in appropriate positions in the video system, the one-dimensional and two-dimensional deformation and strain information of biological tissue with time series are extracted and generated. Fully considering the axial rotation and translation of the motion properties of the ankle joint and quickly determining the flexion angle of the sports ankle joint through video information, it overcomes the theoretical error of the measurement method using the circular motion model with the joint as the center so that it is convenient for the robotic arm to accurately control the flexion degree and flexion range of the ankle joint movement. The video information of the measurement process is actually recorded, which is convenient for information review, experience summarization, and later data mining

2. Related Work

Many scholars at home and abroad have provided a lot of references for research on data mining algorithms, football ankle joints, and apparent strain measurement.

Hong investigated the effects of sling exercises on muscle activity and balance in soccer players with chronic ankle instability [1].

Kizaki et al. aim to survey the ankle structure in commercial soccer players suffering from a stress fracture of the proximal stem of the fifth metatarsal [2].

EE Cust is designed to classify Australian rules football (AF) kick types in an application environment using an ankle-mounted IMU. This study highlights the potential of using IMU's applied semiautomatic AF to train a kick detection and type classification system [3].

Green et al. found that running-related injury mechanisms and the presence of severe tendon rupture on MRI were associated with a longer RTP period. Clinical data rather than MRI data best indicate the risk of CMSI recurrence [4].

Jeong and Kim determined the effect of whole body vibration exercise (WBVE) on the lower extremity muscle activity and balance ability of football players with different exercise methods and used it as the basic data for chronic ankle rehabilitation training. The results suggest that WBVE may have a beneficial effect on improving lower extremity muscle activity and balance in soccer players with chronic ankle instability [5].

Ciou et al. proposed a smartphone-based rehabilitation training device for sagging feet that is rapidly popularized and highly portable [6].

The data of these studies are not comprehensive, and the results of the studies are still open to question, so they cannot be recognized by the public and thus cannot be popularized and applied [7].

3. Data Mining Algorithms, Football Ankle Joints, Apparent Strain Measurement

3.1. Data Mining Algorithms. Data mining is the process of extracting hidden, unknown, but potentially useful information and knowledge from a large amount of incomplete, noisy, fuzzy, and random practical application data.

In fact, data mining is sometimes simply understood as "knowledge discovery," and its key steps are as follows:

(1) Data cleaning

(2) Data integration

(3) Data selection

(4) Data transformation

(5) Data mining

(6) Model evaluation

(7) Knowledge representation

Among them, the first four steps can be considered as the data preprocessing stage; the purpose is to prepare for the next data mining. Data mining is an extremely important step, as it undertakes the heavy task of uncovering hidden data patterns for evaluation [8, 9].

The first stage of data mining is based on an independent system, using vector data, and only supports individual algorithms. The second stage is the combination of data mining and database, which can support multiple algorithms at the same time. The third stage of data mining is based on grid computing, and the prediction model is integrated in the data mining process, which can process Web data. The fourth stage is distributed data mining, which is a way of distributing multiple algorithms to execute on multiple nodes. The fifth stage is data mining based on cloud computing, which adopts the mode of distributed parallel processing and service to form a shared resource pool and allocate tasks on demand [10]. Data mining is a complete process (Figure 1).

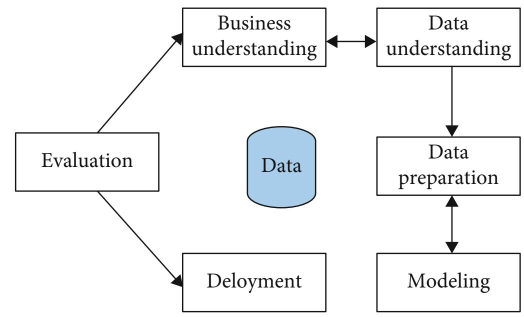

Figure 1: The process of data mining.

(1) Problem description determines business objects: clearly defining business problems and recognizing the purpose of data mining are an important step in data mining. The final structure of the excavation is unpredictable, but the problem to be explored should be predictable. Data mining for the sake of data mining is blind and will not succeed

(2) Data preprocessing: searching all internal and external data information related to business objects and selecting data suitable for data mining applications. Studying the quality of the data in preparation for further analysis. And determining the type of mining operation that will be performed. Transforming the data into an analytical model. This analytical model is built for the mining algorithm

(3) Data mining: mining the obtained transformed data. Apart from perfecting the selection of the appropriate mining algorithm, everything else can be done automatically

(4) Outcome evaluation: interpreting and evaluating the results. Integrating the knowledge gained from the analysis into the organizational structure of the business information system

The methods of data mining are as follows:

(1) Prediction: prediction is to establish a model based on the regularity of existing data and predict the occurrence of future data through the analysis of the model. The typical prediction method is the regression analysis method, which is to obtain a nonlinear or linear regression equation based on the previous data and to set a value for the independent variable to obtain a predicted value of the dependent variable, so as to achieve the purpose of information prediction [11, 12]

(2) Clustering: clustering is a method for computers to recognize things, which can find the categories of things without human assistance. It usually divides the data/records in a dataset into subsets with nonrepetitive elements, that is, clusters. Because the machine discovers the category of things autonomously, the result of clustering is unpredictable. The cluster implementer can summarize the final clusters and find the characteristics of each cluster [13]. A good cluster analysis algorithm is to improve the similarity of objects within the same cluster as much as possible and reduce the similarity between different clusters, and a suitable metric can be selected for the measure of similarity [14, 15]

(3) Classification: first, selecting the training set that has been classified from the data, and using the data mining classification technology on the training set to establish a classification model. Classifying unclassified data, for example, credit card applicants can be classified as low-, medium-, and high-risk levels

(4) Association rules: association analysis is used to explore the association between different data items in data records and generate association rules between data items. In order to discover meaningful association rules, two thresholds need to be given: minimum support and minimum confidence. The former is the minimum support degree that the association rules specified by the user must satisfy, which represents the minimum degree that a set of items needs to satisfy in the statistical sense. The latter is the minimum reliability that the association rules specified by the user must satisfy, and it reflects the minimum reliability of the association rules

This paper briefly introduces the future research directions of data mining:

(1) Website-based mining: with the vigorous development of e-commerce websites, it is easy to build a website, but whether the website can attract customers to browse and reconsume is the key to the success of a website. A website generates a large amount of data every day. How to analyze customers' preferences, purchasing patterns, and purchasing power based on these existing data information, so as to make planned recommendations to customers, which requires data mining technology to achieve. For e-commerce websites, user data can be obtained mainly from three aspects. The first is the personal information registered by the user, the second is the user's purchase record, and the third is the user's website browsing record. Which e-commerce website can dig out more useful customer information, which will better understand customers, retain customers, and enhance their competitiveness [16]

(2) Text-based data mining: due to the numerous application points of text information mining, how to mine text data is also a research hotspot of data mining [17, 18]

(3) Video-based data mining: the research on video data mining at home and abroad is in its infancy, and now it has attracted more and more scholars' attention. The video clips that may be of interest to you can be mined from a bunch of video clips through data mining algorithms. In terms of video surveillance, by comparing the difference between the target object and the video under normal conditions, it is judged whether it is an abnormal event, and an alarm is issued for the abnormal event [19]

The following expounds the model of the data mining method:

(1) The basic model of cluster analysis: the process of cluster analysis mainly includes data processing, design metrics, and result evaluation, and its basic model is shown in Figure 2. The first is data preprocessing, which includes feature extraction from the original dataset and construction of feature vectors. The second is to select a suitable distance function according to a certain similarity measure to obtain the corresponding clustering results. Finally, the clustering results are evaluated and output, and certain knowledge information is obtained [20]

(2) The basic model of association rule mining: the basic model of association rule mining is shown in Figure 3

3.2. Apparent Strain Measurement. Apparent strain testing is actually a technique to achieve measurement data with the aim of being fast, efficient, and noncontact.

The apparent strain measurement method is as follows.

3.2.1. Digital Image Measurement Method. As a practical and effective tool for apparent strain measurement, digital image measurement is widely used in the field of microscale strain measurement. It obtains the speckle digital images before and after deformation of the object surface through a high-speed camera, uses a certain search method to obtain matching subregions before and after deformation, and obtains the displacement field and strain field information through comparison and calculation. The measurement structure is shown in Figure 4. This method has the advantages of noncontact measurement and direct full-field measurement, and the measurement resolution for small displacement changes can reach $1\,\mu$m/pixel. However, the spatial measurement area of this measurement method is regular, and the spatial measurement range is generally only in the order of centimeters. In the surface strain measurement of large-scale structures, it is necessary to move the field of view several times for measurement.

3.2.2. Machine Vision Measurement Method. At present, the technology of using machine vision for strain measurement is relatively mature abroad. Although machine vision has the advantages of fast, nondestructive, and high measurement accuracy, its system cost is high and it has not been widely used. And visual measurement, as a noncontact measurement, requires a certain measurement space, which limits the application of this method in a narrow measurement space.

3.2.3. Strain Gauge Measurement Method. With the advantages of low cost, strong practicability, good performance, and mature technology, strain gauge measurement has become the most commonly used detection method, which is usually measured in the form of strain rosettes or strain gauge array distribution. Strain gauge measurement has high measurement accuracy, the measurement accuracy can reach $1\,\mu\varepsilon$, and the range can reach several thousand micro strains. At present, strain gauges are often used to measure the surface strain of the structure when the blade, wing skin, and bottom structure are shut down for maintenance and inspection.

3.2.4. Grating Sensor Measurement Method. With the advantages of lightweight, corrosion resistance, and long life, optical fiber sensing technology has been widely used, and fiber grating (FBG) sensors have been widely used in structural health monitoring in aerospace, civil construction, and other fields. As a discrete sensor, the FBG sensor is quite mature in single-point and multipoint strain measurement, but the single-point or multipoint strain measurement method can no longer meet the needs of continuous strain measurement. In order to meet the demand of dense measurement points in engineering, the technology of quasidistributed measurement with FBG through high multiplexing technology has been widely concerned and developed.

3.2.5. Optical Fiber Sensing Measurement Method. Although the separation of discrete sensors has reached the order of

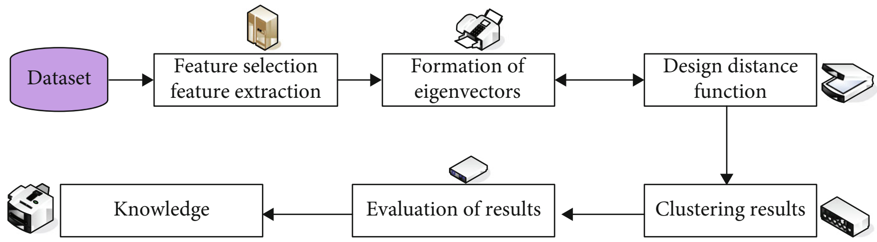

Figure 2: Cluster analysis basic model.

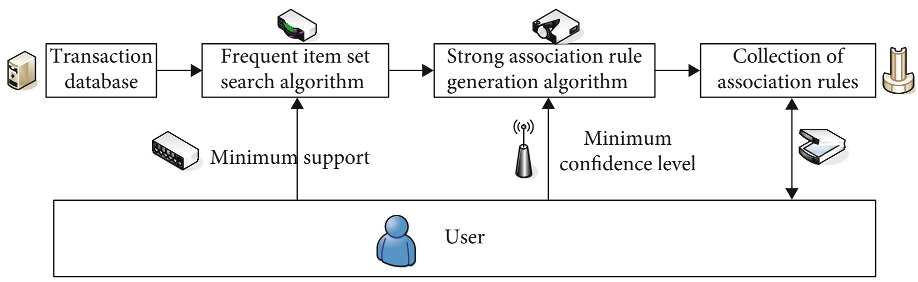

Figure 3: Basic model of association rule mining.

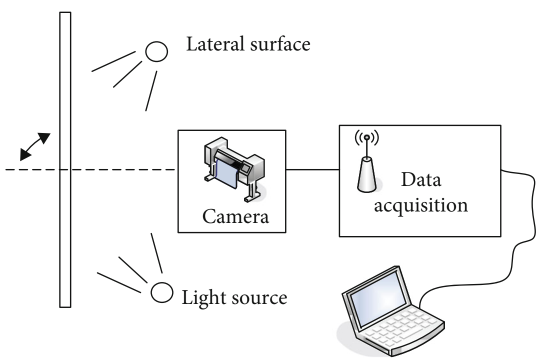

Figure 4: Schematic diagram of the typical structure of digital image measurement method.

centimeters, they still do not have the ability to measure continuously. Once the sensor placement is determined, it cannot provide precise measurements of the strain field at any location or over a small area. In another branch of optical fiber sensing, distributed sensing technology with optical fiber itself as the sensor has received high attention in the past two decades.

Compared with traditional optical strain measurement methods such as FBG, the optical fiber transmits and senses signals at the same time, and each position or section of the optical fiber can be used as a sensor without manual marking, which is a true distributed measurement technology.

In OTDR, short pulse light is injected into the sensing fiber, and the position of backscattering can be located by the time delay of the reflected signal. Restricted by pulse width and signal-to-noise ratio, the spatial resolution of OTDR sensors is only a few tens of centimeters. Therefore, strain sensing based on optical time-domain reflectometry is mainly used in long-distance sensing of several kilometers.

The principle of optical fiber distributed strain measurement is shown in Figure 5. Distributed strain measurement enables sensing and signal transmission through a single fiber. The fiber is divided into continuous overlapping local fiber segments, and each local fiber segment can be used as a strain sensing unit.

The optical frequency domain reflection beat frequency process is shown in Figure 6.

When the light source is linearly tuned, instantaneous optical frequency

$$\lambda(t) = \lambda_0 + \zeta_\lambda t. \tag{1}$$

Then, the local oscillator light emitted by the light source

$$\varepsilon_r(t) = \phi_r \cos\left[2\pi\left(\lambda_0 t + \frac{1}{2}\zeta_\lambda t^2\right)\right]. \tag{2}$$

In the formula, φ_r is the local oscillator light amplitude. Time delay difference

$$\kappa_a = \frac{2\eta a}{c}. \tag{3}$$

Then, the measured optical

$$\varepsilon_s(t) = \phi_s \cos\left\{2\pi\left[\left(\lambda_0(t-\kappa_a) + \frac{1}{2}\zeta_\lambda(t-\kappa_a)^2\right)\right]\right\}. \tag{4}$$

In the formula, φ_s represents the measured light amplitude.

The local oscillator light and the measurement light interfere, and the photocurrent in the detector can be

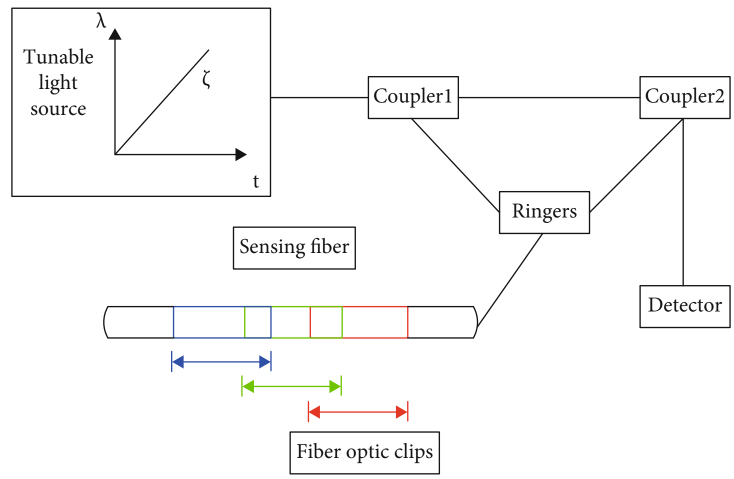

FIGURE 5: Schematic diagram of fiber optic distributed strain measurement.

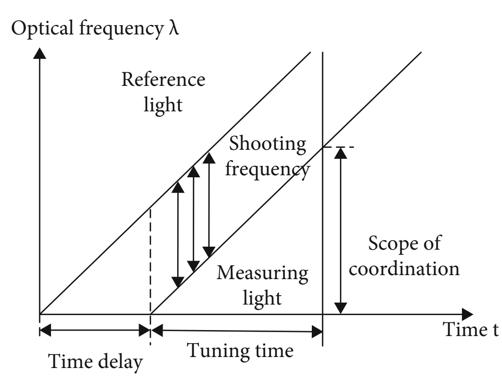

FIGURE 6: Optical frequency domain reflection beat frequency process.

expressed as

$$I = \phi_r{}^2 \cos^2[\pi(2\lambda_0 + \zeta_\lambda t)t] + \phi_s \cos^2\{\pi[2\lambda_0(t-\kappa_a) + \zeta_\lambda(t-\kappa_a)^2]\}. \quad (5)$$

In Formula (5), the first two terms are DC terms, which can be directly filtered out by filtering. The third term is the sum-frequency term of the interference, which is not responded by the detector. The fourth term is the difference frequency term, which carries the position information of the reflection point. The photocurrent output after this term is responded by the detector is

$$I(t, a) = \phi_r \phi_s \cos\left\{2\pi\left[\lambda_0\kappa_a + \zeta_\lambda\kappa_a t + \frac{1}{2}\zeta_\lambda\kappa_a{}^2\right]\right\}. \quad (6)$$

The beat frequency is

$$\omega_b = \zeta_\lambda\kappa_a = \frac{2\eta a\zeta_\lambda}{c}, \qquad a = \frac{c\omega_b}{2\eta\zeta_\lambda}. \quad (7)$$

Beat frequency signal

$$I(t) = \sum_{i=1}^{N} I(t, a), \qquad I(t) = \cos\left\{2\pi\phi_i\left[\lambda_0 + \frac{2\eta a_i}{c}\zeta_\lambda t + \frac{1}{2}\zeta_\lambda\left(\frac{2\eta a_i}{c}\right)^2\right]\right\}, \quad (8)$$

where φ_i is the amplitude of the ith scattered signal.
Differentiating both sides of Formula (3), getting

$$\mu_a = \frac{c\mu_\kappa}{2\eta}, \quad (9)$$

where μ_a is the spatial resolution and μ_κ is the group delay resolution.

The Fourier transform transforms the beat signal from the optical frequency domain to the distance domain. The group delay resolution is related to the optical frequency tuning range as follows:

$$\mu_\kappa = \frac{1}{\Delta\rho}. \quad (10)$$

Substituting Formula (10) into Formula (9), the spatial resolution can be expressed as

$$\mu_a = \frac{c}{2\eta\Delta\rho}, \quad (11)$$

$$\Delta\rho = \frac{c\Lambda\sigma}{\sigma_0{}^2}. \quad (12)$$

In the formula, σ_0 is the center wavelength, and $\Lambda\sigma$ is the wavelength tuning range.
Substitute Formula (12) into Formula (11) to get

$$\mu_a = \frac{\sigma_0{}^2}{2\eta\Lambda\sigma}. \quad (13)$$

The effect of external fields (such as temperature field and strain field) will also cause the shift of Rayleigh spectrum, and the magnitude of the shift is proportional to the axial strain of the fiber:

$$\Delta\sigma = k_e e. \tag{14}$$

In the formula, k_e is the proportionality coefficient, and e is the relative change of the fiber length.

Letting ${\gamma_{\alpha,\beta}}^{\text{ref}}$ and ${\gamma_{\alpha,\beta}}^{\text{meas}}$ be the Rayleigh reference spectrum and measurement spectrum of the local fiber segment, then the cross-correlation spectrum is

$$Q\left({\gamma_{\alpha,\beta}}^{\text{ref}}, {\gamma_{\alpha,\beta}}^{\text{meas}}\right) = {\gamma_{\alpha,\beta}}^{\text{ref}} \otimes {\gamma_{\alpha,\beta}}^{\text{meas}}. \tag{15}$$

The complex amplitude of backscattered light described by the change in dielectric constant with distance

$$H(-\infty,\nu) = \frac{\varepsilon_0}{2i}\int_{-\infty}^{+\infty} \frac{\Delta m_*(a)}{m_*} \exp\,(i2\nu a)da. \tag{16}$$

In the formula, $H(-\infty,\nu)$ is the complex amplitude of back Rayleigh scattering. ε_0 is the amplitude of the local oscillator. ν is the wave number. m_* is the core dielectric constant. $\Delta m_*(a)$ is the change of the dielectric constant with the position of the core.

The beat frequency signal carries the amplitude and phase of Rayleigh scattering, and the spectrum of the beat frequency signal is the distribution of the reflectivity of the scattering points in the fiber along the fiber axis:

$$I(a) \cong \sum_{i=1}^{N} \phi_i \pi\mu(a + a_i) \exp\left\{2\pi\left[\lambda_0 + \frac{2\eta a_i}{c}\zeta_\lambda t + \frac{1}{2}\zeta_\lambda\left(\frac{2\eta a_i}{c}\right)^2\right]\right\}. \tag{17}$$

For a localized segment in an optical fiber, the Rayleigh spectrum

$$\gamma(t) \cong \sum_{\alpha}^{\beta} \phi_i \cos\left\{2\pi\left[\lambda_0 + \frac{2\eta a_i}{c}\zeta_\lambda t + \frac{1}{2}\zeta_\lambda\left(\frac{2\eta a_i}{c}\right)^2\right]\right\}. \tag{18}$$

In the formula, a_α and a_β are the starting and ending positions of the local fiber segments.

4. Measurement of Apparent Strain of Ankle Joint in Football Sports

This study took a football team player as the basic research object and screened out 10 athletes, 5 male and 5 female athletes. The basic information of the athletes is shown in Table 1.

The sagittal peak torque and its appearance time are shown in Table 2.

The angular features of the ankle socket in the sagittal plane of the athlete are shown in Figure 7.

Table 1: Basic information of a soccer team player.

Number	Age	Height (cm)	Weight (kg)
1	30	190	86
2	27	176	73
3	22	189	96
4	21	185	72
5	21	170	65
6	20	173	67
7	19	170	64
8	19	190	79
9	18	185	75
10	17	180	72

From Figure 7, it can be seen that the individual variability of the jumping and swinging legs of men and women is more obvious. Among them, T1 is the moment when the take-off foot touches the ground, T2 is the moment when the take-off kicks off the ground, T3 is the moment when the take-off kick extends off the ground, T4 is the moment when both feet land on the ground, and T5 is the maximum buffer moment for landing.

The peak torque and appearance time of frontal face are shown in Table 3.

The angular feature of the anterior surface of the anterior ankle is shown in Figure 8.

It can be seen from Figure 8 that there was no significant difference in the ankle joint angle between the boys group and the girls group at five time points.

The peak moment on the horizontal plane and its occurrence time are shown in Tables 4 and 5.

The angular profile of the horizontal plane of the ankle is shown in Figure 9.

It can be seen from Figure 9 that the ankle joint of the take-off leg in the horizontal plane has the maximum external rotation at the moment of the maximum kick-off and gradually adducts the ankle joint in the horizontal direction of the action. From the ankle joint of the swing leg, it can be seen that the ankle joint is always in different degrees of external rotation during the whole movement (from the step on the force platform to the landing buffer), but the degree of external rotation gradually decreases during the landing process.

The data algorithm performance is shown in Figure 10(a). The running time under the data mining process is shown in Figure 10(b).

It can be seen from Figure 10(a) that the data mining algorithm can meet the needs of mining in experimental research. Figure 10(b) shows that the running time does not increase much with the increase of the number of nodes, and it has certain stability for the nodes.

5. Discussion

With the successful application of association rule mining technology, more and more units and individuals rely on association rule mining technology to discover knowledge,

Table 2: Sagittal peak moments and appearance time.

Sagittal plane	Male group		Female group	
	Jumping legs	Swinging jumping legs	Jumping legs	Swinging jumping legs
First wave peak force distance	1.25	1.36	1.78	0.59
One time	1.15	0.28	1.35	0.86
Second wave peak force distance	0.75	0.84	1.46	1.98
Two times	1.52	0.26	0.28	1.24

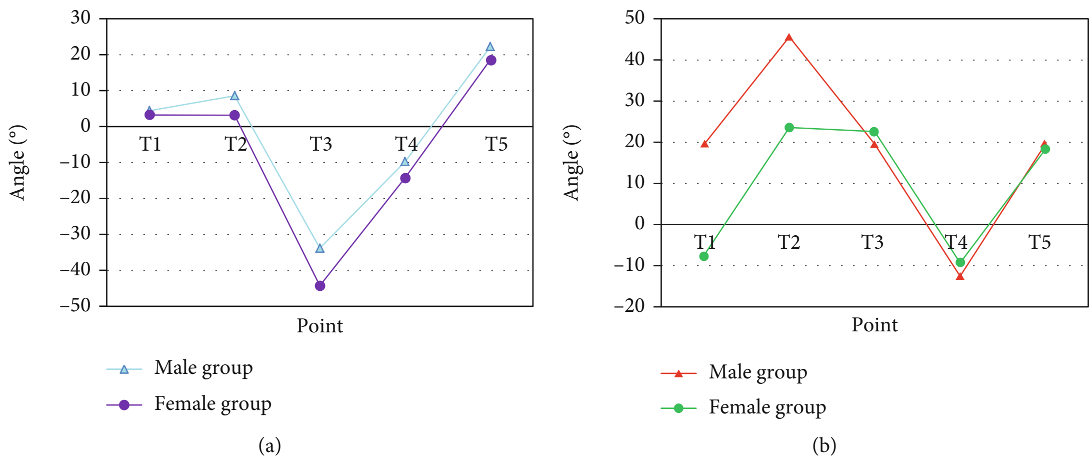

Figure 7: Ankle joint sagittal plane angle characteristics.

Table 3: Frontal plane peak moment and appearance time.

Frontal plane	Male group		Female group	
	Jumping legs	Swinging jumping legs	Jumping legs	Swinging jumping legs
First wave peak force distance	1.48	0.57	1.39	2.14
One time	1.54	0.25	1.27	1.04
Second wave peak force distance (N·m)	0.12	0.28	1.54	1.05
Two times	2.31	1.28	2.14	0.49

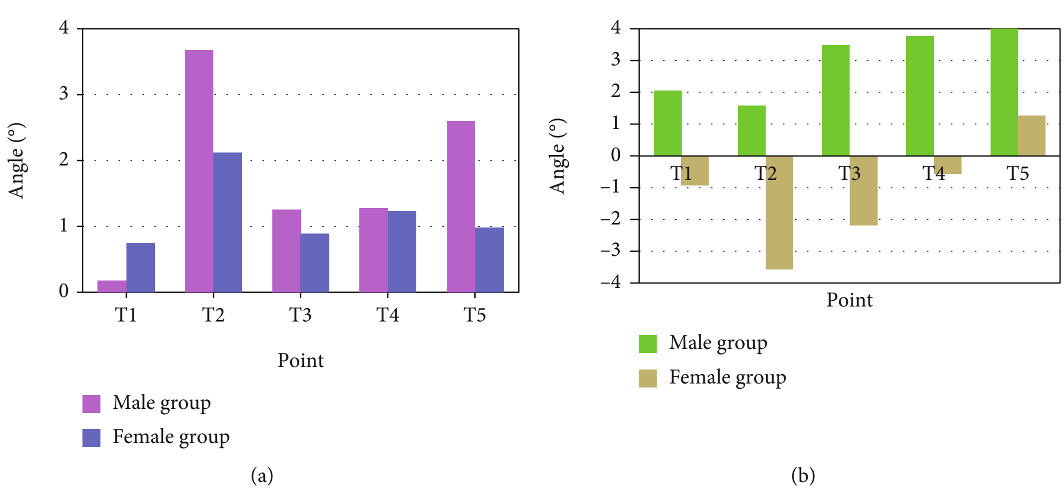

Figure 8: Angular characteristics of the frontal plane of the ankle joint.

Table 4: Horizontal peak moment and emergence time.

Horizontal plane	Male group		Female group	
	Jumping legs	Swinging jumping legs	Jumping legs	Swinging jumping legs
First wave peak force distance	1.15	0.25	0.14	0.79
One time	1.05	1.58	0.26	0.27
Second wave peak force distance (N·m)	0.75	1.25	1.39	1.46
Two times	0.75	1.58	1.25	1.78

Table 5: Horizontal peak moment and emergence time.

Horizontal plane	Male group		Female group	
	Jumping legs	Swinging jumping legs	Jumping legs	Swinging jumping legs
First wave peak force distance	1.25	0.58	1.26	1.52
One time	0.85	1.28	1.36	0.45
Second wave peak force distance (N·m)	0.58	0.46	1.25	0.58
Two times	0.58	1.26	0.58	1.36

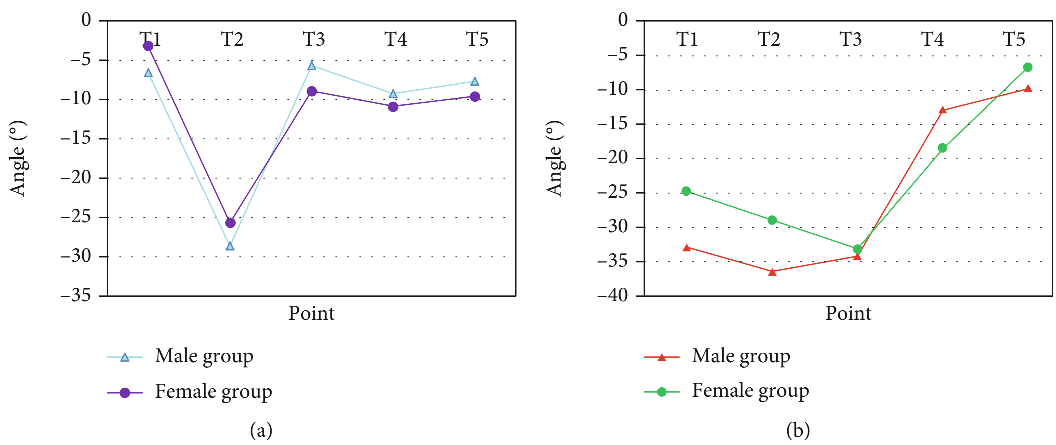

Figure 9: Ankle joint horizontal plane angle characteristics.

and at the same time, they have increased research efforts on association rule technology. At present, association rule mining has a wide range of application requirements in commercial fields such as market planning, advertising planning, classification design, and website mining. Research and improvement of association rule models and algorithms can better serve decision support.

For the goal of dynamic noncontact measurement of flexion, three sets of schemes are designed. Option 1 directly uses camera equipment to photograph the ankle joint during ankle flexion movement, then extracts the boundaries of the ankle joint femur and tibia from the image, and conducts measurement through the boundary points. The fitting technique is used to obtain the central axis of the medullary cavity (ideal symmetry central axis) of the two bones, respectively. Option 2 directly uses the camera equipment to photograph the ankle joint during ankle flexion movement, then extracts the image of the ankle joint as a whole and refines the ankle joint, and finally obtains the ideal symmetrical central axis of the medullary cavity of the two bones. Option 3 designs and installs a pointer pointing along the central axis of the medullary cavity on the two bones of the ankle joint, and basically, the pointer is relatively stationary with the long bone during the movement. In this way, the pointer is used to indicate the angle formed by the two long bones in motion, that is, after the image is acquired, the image of the pointer is extracted and then refined. Although the first two options are relatively straightforward, the boundaries of the femoral and tibial segments of the ankle joint are not axisymmetric in all directions, especially the extracted boundaries. In the field of research on the mechanical properties of ankle soft tissue, a noncontact dynamic and fast measurement method is needed, and the application of measurement technology based on machine vision to the study of object deformation will be a brand-new development trend.

The method of obtaining the motion trajectory of feature points through correlation is very suitable for rapid judgment with a small number of feature points. If it is used in the regional detailed study of mechanical properties of ankle

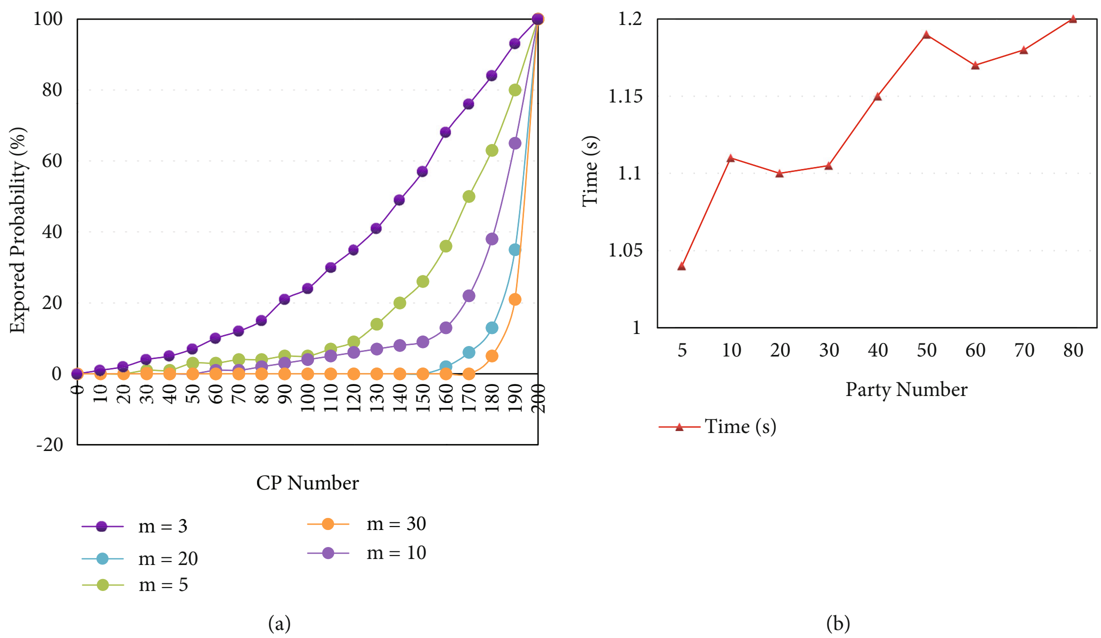

Figure 10: Algorithm performance test results.

joint tissue, the number of feature points will be very large, the amount of computation will be very large, and the hardware requirements are also high. Therefore, in order to lower the technical threshold and obtain as much feature point information as possible, the research area of the ankle joint is marked by artificial means, that is, the artificial feature point lattice is manufactured. These lattices can be regular-shaped small pieces of paper, fluorescent markers, colored strokes, etc., as long as they can stand out from the background of the study area and move with the movement of the study area, and the markers can be ignored relative to the size of the study area its own size.

6. Conclusion

Firstly, the basic knowledge of imaging equipment technology and image processing technology is roughly sorted out, and then, aiming at the significance of noncontact measurement of flexion angle in ankle flexion movement, a rapid noncontact measurement system of flexion angle based on image technology is designed. Furthermore, using the method of artificial marking, a feature point motion trajectory extraction system based on image technology is designed, and the corresponding calculation method of body surface deformation and strain is proposed. After comparing the performance parameters of the imaging technology, the hardware platform of the imaging system is determined. Through the understanding of image processing technology, as well as the research significance and technical path of the subject, a method for measuring buckling angle, extracting feature point trajectory, and calculating related strain based on image technology is proposed. In terms of flexion angle measurement, on the one hand, noncontact measurement of flexion angle is adopted to overcome the theoretical error of the model loading and measurement of the flexion ankle circumference model. At the same time, the loading of the ankle joint by the loading system is more comprehensive and more in line with the physiological conditions to simulate the flexion movement of the ankle joint in vivo, and better feedback and more accurate physiological parameters are obtained in terms of exercise intensity and amplitude. On the other hand, in clinical and rehabilitation engineering, ankle joint loading system can be applied, that is, the ankle joint needs controlled movement after operation. It is necessary to control the speed, strength, amplitude, time length, etc. of the loading system in the process of ankle flexion movement, and accurate flexion angle measurement is an indispensable task. In this project, a noncontact dynamic and fast measurement method of apparent strain of ankle flexion movement with high reliability, strong operability, easy popularization, and data mining has been realized while keeping the ankle joint relatively intact. The basic research of the ankle joint provides an effective way, thus providing a new theoretical guidance for the clinical and rehabilitation of the ankle joint. Association rules will generate a large number of redundant rules in the process of data mining. It is necessary to cut redundant rules to improve the quality of the generated rules. Correcting use of constraints can focus the mining task and ensure the accuracy of mining. How to combine constraints with the mining techniques of positive and negative association rules discussed in this paper requires further research and considering how to efficiently organize and classify the excavated rules.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there is no conflict of interest with any financial organizations regarding the material reported in this manuscript.

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