Research Article
A Wushu Referee’s Decision Support System Using Error Recognition Theory

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1. Introduction

At present, it is moving forward from the era of industrialization to the era of digitization and informatization. Relevant experts believe that digitization and informatization will have an important impact on human development. After the twenty-first century, information has become an important factor of production and the main foundation of the information society. Governments, entrepreneurs, and scientists are all pursuing an ideal information resource base. The advance of Wushu must also keep up with the pace of the information age, so that Wushu can adapt to the new era and give full play to the function and value of Wushu in the new era. In the process of the Wushu competition, the referee needs to evaluate the athletes’ Wushu wrong actions according to the competition rules, to clarify the results of the Wushu competition. However, there is no unified and quantifiable decision support scoring system and other related software in Wushu referees.

In the process of Wushu competition, referees mainly rely on their own subjective experience to judge the wrong actions of Wushu athletes, which can not objectively and accurately reflect the competitive ability of different Wushu athletes. The decision-making results will cause disputes between coaches and athletes. The referee’s fairness and scientificity in the decision-making of Wushu competition can not meet the needs of the development of Wushu, which will have an impact on the process of Chinese Wushu moving towards the world. Therefore, the research on Wushu referees is an objective and standard decision-making system, which must support the development of Wushu referees.

With the help of electronic referees, the difficulty of referees' recognition can be reduced. It can also help reduce man-made errors and influence the process of competition judgment. It can further make the referee’s work fairer and more scientific. The electronic referee’s mechanism can be realized with the help of recognition and scoring of Wushu
Athletes’ wrong actions. Hence, this research is proposed to make an in-depth study on the Wushu referee decision support system using the theory and method of error recognition.

The key innovations of this paper are as follows:

(1) This paper expounds on the overall structure of the Wushu decision support system, uses the error matrix logic equation to solve the recognition state and target, introduces nrej3d technology to collect the characteristics of Wushu error actions, and uses the sports space to complete the matching and recognition of Wushu actions.

(2) Experiments show that the proposed method is superior to other methods in the recognition accuracy and effective measurement of Wushu wrong movements and can promote the long-term development of Wushu.

The rest of this paper is organized as follows. The background studies on decision making abilities of Wushu referees are presented in Section 2, which is followed by a decision support system for Wushu referees in Section 3. Next, in Section 4, the design of a decision support system for Wushu judges based on error recognition theory and method is proposed. In Section 3, the experimental results are provided, which lead us to the conclusion of our paper in Section 5.

2. Related Work

Several advanced nations have paid more consideration to the data construction and knowledge discovery of referees’ decision-making in the context of decision support for Wushu referees, while China has gradually improved the informatization construction of referees’ decision-making and put forward relevant research methods. LV m is to assist the referee to give correct scores for martial arts actions and design a martial arts auxiliary decision support system based on big data and action recognition algorithm. Firstly, the database of decision score comparison criteria is constructed by using extended data action. In addition, the overall architecture of the decision support system is given, and then the module of 3D data acquisition is given. The feature fusion of Fourier filtering is used to classify the fused data into martial arts action data of support vector machine, to realize the design of martial arts wrong action recognition module. The test results show that this method has a relatively accurate recognition effect and provides strong support for referees’ decision-making and scoring, but this method has poor practicability because of its complexity in the process [1].

In order to improve the effective guidance of martial arts action, Tian proposed a referee decision support system of martial arts wrong action visual image recognition method based on feature extraction, combined with frame segment scanning technology to sample martial arts action data images, adopt the segmentation method of edge features to process the expression of action visual features, and construct the analysis model of edge features of martial arts wrong action visual images. Combined with the identification method of fuzziness, the fuzziness of the visual image of Wushu action is processed to suppress the signal-to-noise ratio of the visual output of Wushu action, and the feature analysis and feature extraction model of Wushu wrong action data is constructed. According to the results of the visual feature extraction of Wushu’s wrong action, the recognition of the visual image of Wushu’s wrong action is completed, to complete the research of the referee decision support system. The simulation results show that this method can be used to identify the wrong actions and facilitate the referee to score the wrong actions of Wushu. This method has good feature recognition ability, but this method does not improve the accuracy of referee recognition [2].

Wang proposed a decision support system for Wushu wrong action referees based on image recognition. The morphological gradient is used to eliminate the noise background and obtain the contour edge of the human body. The contour edge of the martial arts wrong action image is extracted and accumulated in the same image. The feature vector of martial arts wrong action in the image is attained by using the calculation technique of the accumulated edge image. The similarity of the joint change sequence of wrong actions can be identified by using the combination of enhanced dynamic events and the time series change characteristics of martial arts wrong actions. The classifier to input the characteristic data of image martial arts actions can be used into the referee decision support system to realize the process of recognizing martial Arts wrong actions based on images and help the referee make accurate decisions. The experimental results show that this method can decompose Wushu movements and help referees improve decision-making efficiency, but this method has the problem of poor recognition accuracy [3]. Since Wushu athletes are prone to wrong movements in the process of training and competition, using the traditional recognition method to judge Wushu movements will produce some errors.

With the gradual development and application of machine vision technology, the application of vision technology to the decision support system of Wushu referees to identify Wushu wrong movements is helpful in improving the recognition and scoring of referees. Therefore, the detailed introduction of computer vision technology and the digital analysis of Wushu wrong action images have strong application performance, as well as the comprehensive analysis of the extraction of Wushu Athletes’ action features. In the literature, the Bayesian algorithm is used to efficiently identify Wushu’s wrong actions to obtain the detection model of three-dimensional vision. Through the detection model of three-dimensional vision, the experimental research is carried out on the decision support system of Wushu referees based on machine vision. The results show that, compared with the traditional detection methods, this method can be applied to martial arts action recognition and has high feasibility, but the overall process is too complex, resulting in low accuracy of this method and poor fairness of the game [4].
### 3. Decision Support System for Wushu Referees

The decision support system for Wushu referees is layered architecture composed of three different layers. The main layer included the presentation layer, the application layer, and the data layer. The layered architecture is preferred to decompose the complexity of the system into various phases and layers. The system architecture explanation is provided in the upcoming section.

#### 3.1. Overall System Architecture

The decision support system for Wushu referees is mainly used for Wushu referees at different levels. It must meet the learning requirements of Wushu referees at different levels, and design different stages. It not only needs to include the learning stage, but also can carry out training and simulated examination. In addition, the system software includes video production, which improves the decision support system according to the relevant rules of the Wushu competition and athletes’ Wushu movements. The referee decision support system can be divided into different levels, such as learning mode and examination mode. Due to the many processes involved, it is necessary to communicate with users during software design, and the scalability of the decision support system must be comprehensively considered [5, 6].

The overall outline of the Wushu referee decision support system is depicted in Figure 1 according to the early demand analysis of the Wushu referee decision support system. In Figure 1, most Wushu referees’ decision support system users are Wushu referees of different levels. The learning and training of referees specifically include teaching materials and related system software and hardware equipment in Wushu movement rules. System software mainly refers to the relevant design of referee learning in Wushu action rules, including material software, examination software, and learning software. The hardware system is a simulator for identification and scoring. When the system hardware is connected to the computer, it can operate for the system user [7, 8]. Most educational CDs are released by the government and made according to the teaching-related materials, but the CDS cannot be played separately and can only be used with the cooperation of the corresponding learning system and examination system.

The education system is a complete system, which is divided into three parts by function, specifically the learning system of Wushu wrong action rules, the production system of Wushu wrong action teaching materials, and the action examination system. The databases corresponding to the above systems are multimedia database, learning operation database, and user information database [9, 10]. The three databases can operate independently or cooperatively, thus forming a relatively perfect and widely used training mode. The detailed structure can be shown in Figure 2.

#### 3.1.1. Wushu Rule Input System

Wushu action rules input system refers to the combination of data and video, so that the saved audio resources can be effectively utilized and widely used in Wushu competitions. The rule-making system must have the following functions: first, the Wushu competition rules data collection function. Rule-related data collection is an important way to decide support system. Rule collection will input the prescribed format and data into the referee decision support system. The second is organic synthesis: rule entry belongs to the production platform of organic synthesis. Information processing, motion recognition, and scoring system applications are carried out on the platform. Users of decision support systems use and process data in related formats. Third, the storage and utilization integration: the data input to the decision support system of martial arts judges can be applied to the martial arts competition again, so that the overall rule system can be updated step by step [11, 12].

#### 3.1.2. Decision Scoring System

The decision scoring system is a decision management system integrated with martial arts competition scoring and real-time evaluation based on advanced data and information technology. The whole system is suitable for different grades and levels. It handles the test itself and can also expand the test with the help of other materials. The detailed structure is shown in Figure 3. The martial arts referee combines with the competition and uses the corresponding equipment to identify and score the live and video recordings. Judges can make decisions on the matches that are completed within a specified time frame, the decision system will automatically evaluate the results, and the corresponding managers can check the exam participants’ specific conditions with the help of the playback function of the decision support system. The main process of module application is to start and then enter the name of the sport, as well as the number and category of the competition, prompt, hardware decision-making equipment prompt decision-making to start, then the referee scored, the result evaluation of the category competition, and finally decide whether to complete the examination [13, 14].

#### 3.2. Database Design

The user registration is carried out in the form of a database design. The database design of the decision support system for martial arts judges mainly depends on the specific requirements, follows the characteristics of the database design, takes the design theory of the database as the main basis, and designs the global logical
results of the database and the local logical structure of the users. The database structure contains the following data tables, which are counted in Tables 1 and 2. The data tables include the user table and the rule import table. Table 1 represents the user registration examples along with the corresponding values.

4. Design of Decision Support System for Wushu Judges Based on Error Recognition Theory and Method

The proposed decision support system is designed for the Wushu Judges using the error recognition theory and technique. A detailed discussion of the error recognition theory is provided in Section 4.1.

4.1. Error Recognition Theory and Method. According to the error matrix equation research, combined with the error logic theory, the error logic matrix equation mostly uses the error logic matrix equation $X \subseteq B$, and all kinds of equations are represented in Table 3.

The wrong action state of Wushu can be described according to the error logic and the specific object state in the real world can be expressed as $A_z$, and $A_z = z(t)$ can be expressed as the following formula:

$$ (U, S(t), p(\psi_1, \psi_2, \ldots, \psi_n), T(t), L(t)). $$

(1)

As per formula (1), $U$ represents the universe, $S(t)$ represents the described martial arts wrong action, $p(\psi_1, \psi_2, \ldots, \psi_n)$ represents the current space, $T(t)$ represents the described martial arts characteristics, and $L(t)$ represents the described quantity value. The elements in the martial arts wrong action state matrix are expressed by the variables of wrong logic. It can be seen that the matrix of martial arts wrong action state can be either a real number or a set [15, 16]. The required matrix is shown as the following formula:

$$ A_z = \begin{bmatrix}
U_{10} & S_{10}(t) & p_{10}(\psi_1, \psi_2, \ldots, \psi_n) & T_{10}(t) & L_{10}(t) \\
U_{11} & S_{11}(t) & p_{11}(\psi_1, \psi_2, \ldots, \psi_n) & T_{11}(t) & L_{11}(t) \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
U_{1n} & S_{1n}(t) & p_{1n}(\psi_1, \psi_2, \ldots, \psi_n) & T_{1n}(t) & L_{1n}(t)
\end{bmatrix}. $$

(2)

Formula (2) is called $m \times 5$ martial arts action state matrix. According to the above definition, the characteristics
and quantities of Wushu action state in the universe and space-time state are described.

In the transformation process of recognition state and target state, the error logic matrix equation $A \lor X_{qa} \subseteq B_a$ is used to represent it. Assuming that $A_s$ is the recognition state matrix of Wushu action, $B_a$ represents the target state matrix of Wushu action, and $X_{qa}$ represents the solution matrix, the transformation result of displacement transformation is obtained [17, 18].

4.2. Decomposition and Recognition of Wushu Movements. The Wushu action pattern recognition framework is shown in Figure 4 combined with the above error recognition theory. When the nrej3d technology is introduced into Figure 4 and the NReJ3D technology is used to express the action characteristics, the characteristics of martial arts wrong actions must be analyzed to convert the human body into a moving variable of rigid connection orientation. Describe the motion translation, scaling, and multidimensional changes [19, 20].

Assuming that the martial arts wrong action is at time $t$, NReJ3D technology is used to describe that the node data is $i$. In the coordinate $(x_i(t), y_i(t), z_i(t))$, the transformed area of the human body is taken as the center to describe the changes of node of the dynamic data. It describes that when the node meets the $h$ condition, the change difference of the $i (i \neq h)$ data of the dynamic data node is regarded as a part of the dynamic characteristics. It is expressed as the following formula:

$$P_i = p - p_h, i \neq h. \quad (3)$$

In formula (3), $P_i$ represents the dynamic node change of martial arts wrong action, $p_h$ represents the data node of the original position, and the directional vector data is obtained by making difference. The action characteristics of Wushu at time $t$ are expressed as the following formula:

$$f_t = \{P_i | i = 1, 2, \cdots, 20; i \neq h\}. \quad (4)$$

In formula (4), $f_t$ represents the data of the total node of martial arts movement change, normalizes $f_t$, and represents the detailed dynamic characteristics as the following formula:

$$f'_t = \frac{p_{ix}}{\sum_{i=1}^{x} p_{ix}} + \frac{p_{iy}}{\sum_{i=1}^{y} p_{iy}} + \frac{p_{iz}}{\sum_{i=1}^{z} p_{iz}}. \quad (5)$$

<table>
<thead>
<tr>
<th>Equation</th>
<th>A class</th>
<th>The second</th>
<th>Operator meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$AX \subseteq B$</td>
<td>$XA \subseteq B$</td>
<td>General matrix multiplication</td>
</tr>
<tr>
<td>2</td>
<td>$A \cdot X \subseteq B$</td>
<td>$X \cdot A \subseteq B$</td>
<td>optimal</td>
</tr>
<tr>
<td>3</td>
<td>$A \Delta X \subseteq B$</td>
<td>$X \Delta A \subseteq B$</td>
<td>bad</td>
</tr>
<tr>
<td>4</td>
<td>$A \lor X \subseteq B$</td>
<td>$X \lor A \subseteq B$</td>
<td>or</td>
</tr>
<tr>
<td>5</td>
<td>$A \land X \subseteq B$</td>
<td>$X \land A \subseteq B$</td>
<td>with</td>
</tr>
</tbody>
</table>

Table 1: User registration examples.

<table>
<thead>
<tr>
<th>The field type</th>
<th>Field code</th>
<th>Fields that</th>
</tr>
</thead>
<tbody>
<tr>
<td>bigint</td>
<td>11</td>
<td>Increment, primary key</td>
</tr>
<tr>
<td>varchar</td>
<td>110</td>
<td>The login password</td>
</tr>
<tr>
<td>varchar</td>
<td>20</td>
<td>The name</td>
</tr>
<tr>
<td>varchar</td>
<td>20</td>
<td>Id number</td>
</tr>
<tr>
<td>varchar</td>
<td>20</td>
<td>Place the unit</td>
</tr>
<tr>
<td>varchar</td>
<td>10</td>
<td>Contact phone number</td>
</tr>
<tr>
<td>varchar</td>
<td>20</td>
<td>E-mail address</td>
</tr>
</tbody>
</table>

| The field code | Type: 0 video producer, 1 judge, 3 administrators |

Table 2: Rule import table.

<table>
<thead>
<tr>
<th>The field name</th>
<th>The field type</th>
<th>Field code</th>
<th>Fields that</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>int</td>
<td>11</td>
<td>Rules of the import</td>
</tr>
<tr>
<td>learn</td>
<td>varchar</td>
<td>2</td>
<td>Score calculation</td>
</tr>
<tr>
<td>jihua</td>
<td>varchar</td>
<td>2</td>
<td>Degree of completion</td>
</tr>
<tr>
<td>complete</td>
<td>varchar</td>
<td>2</td>
<td>time</td>
</tr>
<tr>
<td>dateime</td>
<td>varchar</td>
<td>0</td>
<td>Modified 0: Not modified. 1 Modified</td>
</tr>
<tr>
<td>block</td>
<td>varchar</td>
<td>10</td>
<td>Modified 0: Not modified. 1 Modified</td>
</tr>
</tbody>
</table>

Table 3: Classification of inclusion type error logical matrix equations.
The above process completes the detailed description and recognition of Wushu wrong actions. Combined with the above process, the basic recognition of martial arts wrong actions is completed, and the Hausdorff comparison method is used for effective measurement (assuming that the recognition matching action points and martial arts wrong action pattern matching process are in the mean state), that is expressed as the following formula:

$$\text{Fit}(A_X, A_Y) = \frac{1}{N_A} \sum_{i=1}^{N_A} \min \| A_X(i), A_Y(J) \|. \quad (6)$$

In formula (6), $A_X$ represents motion space action data, $A_Y$ represents motion space recognition action data, $A_Y(J)$ represents martial arts wrong action data in motion space, and $A_Y$ carries out matching recognition on the $J$ action data node. When realizing martial arts action data matching and pattern matching, vector $P$ is introduced to represent the similarity of martial arts wrong action data matching. And select $C = N_X/N_Y$ as the benchmark to measure the matching. Carry out node matching on the sports models decomposed by different martial arts, expressed as the following formula:

$$d(i) = \sum_{j=1}^{C} \min \| A_x(i) - A_y(j) \|. \quad (7)$$

Through the calculation, the martial arts wrong action nodes $d(i)$ must be sorted according to the ascending order to obtain the martial arts wrong action node data $d_{\text{sort}}(i)$, cut and select num = round$(N_{xy} \times p)$, round represents the action data after processing, and $N_{xy}$ represents that the sequence points of the overall martial arts wrong action matching data are the data point set of similarity matching pattern, which can be obtained by association recognition. The association is expressed as the following formula:

$$\text{Sim} = \frac{1}{\text{num}} \sum_{i=1}^{\text{num}} d_{\text{sort}}(t). \quad (8)$$

The degree of pattern matching of the data set of martial arts decomposition movement is expressed as the following formula:

$$\text{Dist}(A_X, A_Y) = \text{Fit}(A_X, A_Y) + \text{Sim}(A_X, A_Y). \quad (9)$$

Through the above matching calculation, the design and research of Wushu referee decision support system based on error recognition theory and method are completed.

### 5. Analysis of Experimental Results

Simulation experiments are carried out to confirm the efficiency of the proposed Wushu referee decision support system using error recognition theory. Table 4 represents the experimental data.

<table>
<thead>
<tr>
<th>Experimental environment</th>
<th>The experimental data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host configuration</td>
<td>Pentium</td>
</tr>
<tr>
<td>CPU</td>
<td>2.79 GHz</td>
</tr>
<tr>
<td>Memory</td>
<td>8 GB</td>
</tr>
<tr>
<td>The simulation environment</td>
<td>Matlab7.0</td>
</tr>
</tbody>
</table>

Table 4: Experimental data.

Table 5 shows the comparison between the decision support system of Wushu referees based on error recognition theory and method proposed in this paper and the evaluation time of referees by the methods proposed in literature [3] and literature [4].

<table>
<thead>
<tr>
<th>Different methods for</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In this paper, methods</td>
<td>5.3</td>
</tr>
<tr>
<td>Literature [3]</td>
<td>7.6</td>
</tr>
<tr>
<td>Literature [4]</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 5: Comparison of judges’ judging time under different methods.

It can be seen from the data in Table 5 that the Wushu referee decision support system based on the error recognition theory and method proposed in this paper has the fastest speed for the judgment of Wushu wrong actions, while the time of the judgment of the referee of the decision support system proposed in literature [3, 4] is significantly slower than that of the method proposed in this paper, which reduces the efficiency of the judgment of the referee decision support system. Because this experiment is mainly error recognition, the accuracy of martial arts error action recognition, recognition recall, and the efficiency of automatic recognition are tested. The recognition accuracy is mainly used to represent the recognition quantity of martial arts wrong actions, which is expressed by the following formula:

$$Q = \frac{\theta_1}{\theta_2} \times 100\% . \quad (10)$$

In formula (10), $\theta_1$ stands for the correctly identified wrong martial arts movements, and $\theta_2$ stands for recognizable martial arts wrong movements. The recall rate of the recognition result represents the number of martial arts wrong actions obtained by the recognition method, which is expressed by the following formula:

$$L = \frac{\theta_1}{\theta_2} \times 100\% . \quad (11)$$

In formula (11), $\theta_2$ represents the martial arts wrong action to be recognized.

The effective measure of automatic recognition represents the efficiency of automatic recognition. The effect of error recognition method is determined according to this index, which is expressed by the following formula:

$$S' = \frac{2 \times L \times Q}{L + Q} \times 100\% . \quad (12)$$

Select the Wushu referee decision support system based on error recognition theory and method proposed in this paper, compare and analyze with the methods proposed in literature [3] and literature [4], and compare the recognition accuracy, recognition recall, and the effectiveness of
automatic recognition of the three methods. The comparison results are shown in Figures 5–7.

Through the analysis of Figure 5, it can be seen that this index reflects the effects of three methods in the experiment. The decision support system of the method proposed in this paper has high recognition accuracy and can recognize most martial arts wrong actions. Compared with other methods, the methods proposed in literature [3] and literature [4] only identify a small number of martial arts wrong actions and cannot analyze and identify martial arts wrong actions with high precision. The method proposed in this paper is helpful for referees to identify and score quickly.

After the recognition accuracy of the decision support system is verified, the recall rate of the recognition results is studied and analyzed. It can be seen from Figure 6 that there are corresponding differences in the recall rate of martial arts wrong action recognition of the three methods. The recall rate of the recognition results of the method proposed in this paper is relatively good, which can recognize all kinds of martial arts wrong actions, while the recall rate of the recognition results of the other two methods is low and cannot recognize all martial arts wrong actions. Combined with the above analysis results, to obtain the final experimental results, the recognition effective measure of Wushu referee decision support system under different methods is studied, which is shown in Figure 7.

6. Conclusions

This paper puts forward the overall structure design of Wushu referees’ decision support system based on error identification theory and method from the perspective of decision support system function. It starts from the development needs of Wushu projects, in order to better promote the socialized promotion of competitions, ensure the fairness, transparency, and fairness of Wushu competitions, and cultivate the business promotion platform of referees. It lays a foundation for the design and use of the overall system database. The practical application performance of the system is relatively high, which provides technical support for promoting the long-term development of Wushu.

Data Availability

The confidential data are available upon request from the corresponding author.

Conflicts of Interest

No conflicts of interest exist for the publication of this paper.

References


