Sports 3D Simulation Technology and Its Application in Minority Sports Popularization

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Abstract. Though motion posture correction technology based on the computer vision technology has been developed to decrease the loss from sports injury, there still exists some weakness. The joint movement of the same athlete varies in different sports program. Under high movement speed, the angle changes of joints are relevant to the motion effects, but it is difficult to measure the subtle changes with constraint models or methods. The traditional identification methods include the Factorization method and skeletal model method, both of which use the stable constraints model to analyze the motion parameters, so they cannot analyze motion parameters in the small-scale areas or effectively measure the subtle movement of the athlete motion posture parameters. To address these issues, this paper presents a new method to measure the 3D motion posture of the athletes. Through the simulation experiments, it has been proved that this method is able to measure the 3D motion parameters of athletes accurately and has a high application value.

1. Introduction

In recent years, it is quite often to see the athlete injury and sickness caused by improper motion postures during the sports process. With the constantly improvement of sports science and technology, not only the motion characteristics of athletes can be analyzed in an efficient way but also the skill of athletes can be improved and also unnecessary injuries can be avoided to the maximum extent. The analysis of human motion posture parameters mainly includes the theory of exercise physiology; computer image processing and etc. [15]. The human body is made up of numerous tissues and organs, including 206 pieces of bones, and more than 600 muscles [16]. These bones, as well as muscles can create different behavior information and then realize the regulation of human behavior. The comprehensive analysis of the behavior information generated from bones and muscles can be helpful to make the accurate judgment to the human body's motion posture parameters. Nowadays, the typical approaches for human motion posture parameter analysis are the body parameter identification method based on the main frame image; the body motion analysis method based on the modeling of body motion characteristics and the body behavior analysis method based on the algorithm of the skeleton model characteristics[17]. The effective analysis of Athletes' motion parameters can improve their athletic skills and minimize the injuries. So searching for the effective method to accurately analyze the movement parameters of athletes and maximally avoid injury problem become the focus within the sports science field [18].

2. Proposed model

To measure the athlete motion parameters, the movement of athlete in 2D space should firstly be measured using the graph sensing devices and converted to 3D images, then the 3D image data are analyzed using the related algorithm to get the motion parameters in different spatial coordinates.
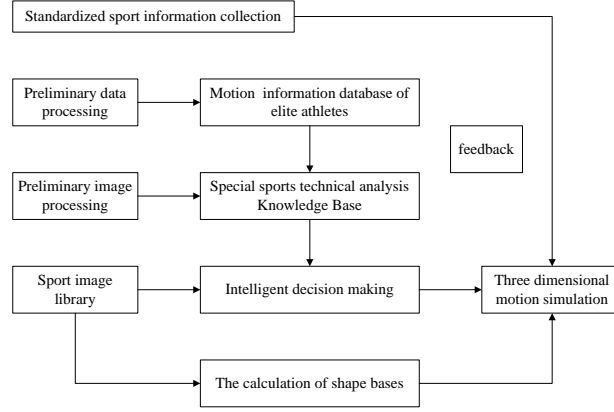
Figure 1. Principles of computational simulation of athletic motion

Through the analysis of the joint depth parameter during movements, it can be concluded that the motion skeleton models used mostly by traditional methods can be shown in Fig. 1. This model contains 8 joints and 7 body parts. The upper body part is tree-shaped structure and the joint at the chest is the kernel node for the whole model. The lines in the figure are to describe the bones of human body and their lengths are proportional to the length of the real bones. The rectangle is to describe the appearance of the human body and the related histogram can describe the textures of the body.

The coordinate system for constructing the human body motion skeleton models is shown in the right part of Fig. 1. The positive direction of z-axis is compatible to the direction of the left-hand coordinate system and the origin of the coordinate system is equivalent to the kernel part of all the joints. According to the multi-rigid motion principle, the human body can be considered as a concatenated tree-like procedure for joint-conversions, therefore the procedure of converting the kernel joint to the root joint can be considered as the procedure of converting the local coordinate system to the global coordinate system and both the global coordinate system and the local kernel joint coordinate system of the human motion share the same direction and origin. When describing the skeleton status during the human movement using the perspective imaging model, the relationship between the point (x, y, z) and its corresponding 2D projection point (w, e) is shown in (2). The z is linear-proportional to p, so their relationship can be acquired using the simple remarking, therefore the depth distance between the two joints in the 3D space can be acquired using the coordinates of the two joints and the bone-length-no-alter constraint.

Three-dimensional dynamic simulation and mathematical models are established as following steps:

For two-dimensional human motion images, the occlusion parameters representing different body parts are set as χ_{ij}, among which i and j are serial numbers of human body parts that are mutually occluded. The data set of collected two-dimensional human motion images is $\{a_1, a_2, \cdots, a_n\}$, and different body parts are sorted to form a new data set $\{b_1, b_2, \cdots, b_n\}$. For the ith two-dimensional human motion image, the key point of jth body part is referred as T_{ij}, and the motion time is expressed as $T = \{t_1, t_2, \cdots, t_k\}$. Lastly, three-dimensional shape bases of human motion activities could be established using the following formula:

$$\varphi_i = \frac{a_i \times b_i \times \sqrt{i + k^2 - 1}}{\left|2 \times \chi_i \times T_i\right|} - \sum_{i=1}(a_i + b_i) \tag{1}$$

$$\begin{pmatrix} w \\ e \end{pmatrix} = \frac{1}{p}\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{2}$$

The movement complexity of the athletes depends on the sports programs and the subtle changes of the athletes' joints and the motion effects are especially tightly related under fast moving speed. However, these subtle changes cannot be measured quantitatively using the stable constraints methods. The traditional 3D motion image analysis methods analyze athlete's motion status using the stable constraints models, so they cannot effectively analyze the dynamic small-area parameters, therefore losing the accuracy when measuring the subtle variable parameters of the joints during their movements.

During human motion activities, three-dimensional dynamic simulation of human motion is the core question of computer vision research. Three dimensional dynamic simulation based on traditional computational algorithms unavoidably has calculation inaccuracy, mainly due to severe visual occlusion of different body parts spatially that causes the overlapping and missing of key points. Therefore, an improved three-dimensional dynamic simulation of human motion image factorization algorithm is proposed.

The optical flow recovery of motion image characteristics plays an irreplaceable role in computational visual field. With an assumption that the motion of human body is observed through human eyes, the motion of human body can be displayed as ordered image sequences. Because these image sequences flow through our eyes, they are also called the optical flows. By using optical flow recovery method, the motion images of human motion could be recovered, and major steps of this method include:

During the setup of human motion process, the brightness of point (y, z) at time u_1 is described as $J(y, z, u_1)$，and the brightness of point (y', z') at time u_2 is described as $J(y', z', u_2)$. With the assumption that the time interval is very short, the brightness of pixels would not change, and the following formula could be obtained：

$$J(y', z', u_2) = J(y, z, u_1) \tag{3}$$

$I(y', z', u_2)$ at position (y, z) is further expanded and the following formula is applied:

$$I(y', z', u_2) = I(y + \Delta y, z + \Delta z, u_1 + \Delta u) \quad = J(y, z, u_1) + \frac{\partial J}{\partial y}\Delta y + + \frac{\partial J}{\partial z}\Delta z + + \frac{\partial J}{\partial u}\Delta u + h.o.t \tag{4}$$

A new formula could then be obtained through a consolidation of above formulas:

$$\frac{\partial J}{\partial y}\Delta y + \frac{\partial J}{\partial z}\Delta z + + \frac{\partial J}{\partial u}\Delta u = 0 \tag{5}$$

When time interval is next to 0，the following formula could be obtained:

$$\frac{\partial J}{\partial y}\frac{dy}{du} + \frac{\partial J}{\partial z}\frac{dz}{du} + \frac{\partial J}{\partial u} = 0 \tag{6}$$

among which $W = (\frac{dy}{du}, \frac{dz}{du})$ represents the velocity of point (y, z) in human motion images，

$\nabla J = (\frac{\partial J}{\partial y}, \frac{\partial J}{\partial z})$ represents the grey scale of this point in human motion images, and J_u represents the

ratio of image grey scale and the time interval of collected images. Therefore, the optical flow recovery of motion image could be realized using above mentioned methods.

3. Experiments and Result

During three-dimensional dynamic simulation processes of human motion, three - dimensional simulation model is established based on two-dimensional images of human body. Suppose that occlusion events occur in different parts of the body during motion activities, key points would then be missing or repeated, resulting in inaccurate calculation of shape bases and a reduction of three-dimensional simulation authenticity of human motion. Therefore, a modified three-dimensional dynamic simulation of human motion image algorithm with factorization specifically improved is proposed. The collected human motion images are recovered to establish three-dimensional dynamic simulation model, and to realize three-dimensional dynamic simulation of human motion image sequences.

Authenticity factors could be calculated using the following formula when different algorithms are applied：

$$imag\_err = T_{ij} - W_{ij} = \left[quater(R) \right] \times \left[quater(Q_i) \times W_{ij}^{'} + T_i \right] - W_{ij} = \begin{bmatrix} u_{1j} - u_{1j}^{'} \\ v_{1j} - v_{1j}^{'} \\ ... \\ u_{Fj} - u_{Fj}^{'} \\ v_{Fj} - v_{Fj}^{'} \end{bmatrix}$$

Imag_err represents the error between reverse projection of point i and measured matrix, and corresponding authenticity factors could be calculated under different shielding environment and with different algorithms：

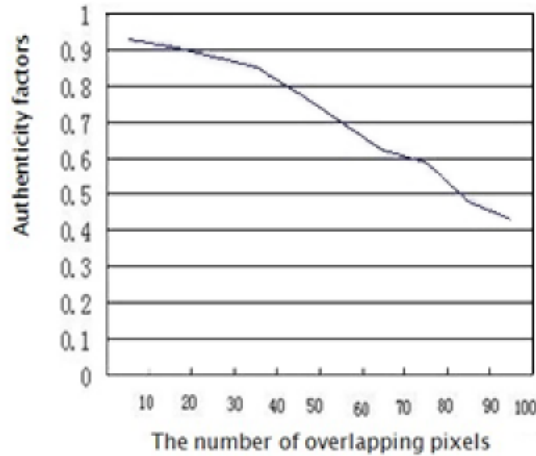The authenticity trend is shown in Figure 2:

Figure II. The simulation results using projection linear approximation algorithm

When two-dimensional image sequence algorithm is applied to the three-dimensional dynamic simulation of human motion process, the corresponding authenticity trend is shown in Figure 3:
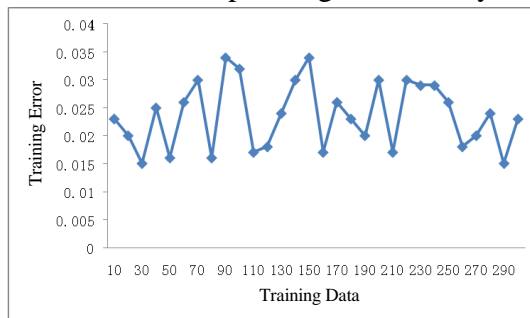

Figure III.   The results of this paper's algorithm

From Fig. 3, it can be concluded that the predicted data characteristics of the motion posture using the algorithm proposed in this paper matches more closely with the characteristics from the database. To further testify the improvement of the algorithm in this paper, 6 motion parameter behavior samples are selected randomly from the sample database and then their motion posture parameters are measured using both the traditional algorithm and the one in this paper. Bones from two main parts of the athlete body are chosen, with θ_1, θ_2 illustrating the deflecting angle and s_1, s_2 illustrating the contraction degree of the muscles.

4. Conclusion

This paper proposed a new three-dimensional dynamic simulation technique of human motion activities based on the factorization algorithm. By using optical flow recovery method, the collected motion images of human motion were recovered. Also, a modified three-dimensional dynamic simulation of human motion image algorithm with factorization specifically improved was established to realize three-dimensional dynamic simulation processes. The experimental results showed that this algorithm greatly improved the authenticity of three-dimensional dynamic simulation of human motion image sequences. The simulation experiments show this method can measure the 3D motion parameter with high accuracy and improve the precision of parameter measurement, therefore performing more suitable protection to athletes from injuries.

5. Reference

[1] M. Biba, F. Esposito, S. Ferilli, N. D. Mauro, and T. Basile, "Unsupervised discretization using kernel density estimation," The Twentieth International Joint Conference on Artificial Intelligence (IJCAI), pp. 696–701, 2007.

[2] G. Schmidberger and E. Frank, "Unsupervised discretization using tree-based density estimation," The European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML PKDD), pp. 240–251, 2005.

[3] F. J. Ruiz, C. Angulo, and N. Agell, "IDD: a supervised interval distance-based method for discretization," IEEE Transactions on Knowledge and Data Engineering, vol. 20, no. 9, pp. 1230–1238, 2008.

[4] Y. Geng, J. Chen, K. Pahlavan, Motion detection using RF signals for the first responder in emergency operations: A PHASER project, 2013 IEEE 24nd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), London,Britain Sep. 2013

[5] Y. Geng, J. He, K. Pahlavan, Modeling the Effect of Human Body on TOA Based Indoor Human Tracking[J], International Journal of Wireless Information Networks 20(4), 306-317