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Human body tracking system application in gymnastics rhythmic player technical movement rotating posture analysis

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ABSTRACT

The paper on the basis of analyzing modern computer visual system, it researches on gymnastics rhythmic players' moving postures, in the hope of exploring players' upper body each joint sports features through adjacent frames relations to provide theoretical basis of gymnastics perfect development and scientific guiding. The research in the purpose of human body rotating postures analysis, takes gymnastics rhythmic kind of events free rotation basic motions as research objects, focuses on analyzing stereoscopic vision tracking system designing method, and provides theoretical basis for camera calibration. Then, apply data to make internal parameters calibration on paper provided video camera, and design sports image analysis flow. Finally, it provides static state single frame image mark points analysis methods and adjacent two frames' players' body five mark points space location transformation relations, and sports state and sports process analysis methods, which provides experiment platform and theoretical basis for sports analysis guiding and stereoscopic vision tracking system perfect development.

KEYWORDS

Video camera; Parameter calibration; Coordinate transformation matrix; Mark point; Image analysis; Gymnastics rhythmic; Human body tracking.

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INTRODUCTION

Tan Ai-Di and others (2013) mentioned that with constantly development of Chinese economy, national living standard continuous improvement, people living pressure is also constantly increasing, physiological and psychological health has already become problems that cannot be ignored, numerous scientific researches showed that physical exercising was most effective way and method to alleviate psychological stress[1]. China needed to propel to national fitness process, and in propelling process, it needed to cultivate masses sports enthusiasm, from which sports analysis splendid degree was helpful for cultivating masses sports enthusiasm, in modern sports analyses, regarding mark point analyzing human body moving postures' researches had faster development. The paper takes gymnastics rhythmic player rotation motion as research objects, explores human body sports visual tracking system application value, which provides theoretical basis for Chinese sports analysis scientific development.

For human body moving image analysis researches, lots of scholars have made their efforts, from which Ren Zhi-Jian (2013) targeted specific task identification tracking problems, he designed human body information matching identification system, system extracted its human body contour information and behavior information by image target, utilized improved K-means clustering algorithm and best possibility estimation method to establish human body information matching probability model, and calculated moving individual information matching probability maximum value except for monitoring area[2]; Zhang Yi and others (2014)targeted round target imaging moment occurred deformation and hard to correct detect its contour problem, put forward a kind of random Hough transformation and gradient vector flow active contour model combinative round target moving target detection method, experiment result showed the method effective overcome round target deformation, could rapidly extract target contour, and possessed round moving target real-time detection ability[3].

The paper on the basis of previous researches, analyzes gymnastics rhythmic movement rotating motion, states computer stereoscopic vision tracking system's equipment orientation designing and parameters calibration method principle, studies on human body posture image analysis method, explores human body visual tracking system algorithm, which provides research method for sports analysis.

GYMNASTICS ROTATING MOTION TRACKING SYSTEM ANALYSIS

Zhou Jia-Ying (1997) proposed to handle with sports visual continuous image to get coaches and athletes' urgently need information, was by far a kind of most effective ways and method in sports technical analysis[4]. Current science and technology has been rapidly developed by comparing to 1997, in order to excavate continuous visual image data information to maximum extent, people designed a series of movement tracking systems. We know that gymnasts in movement process, body movement is the main indicator to present movement difficulties, good rotating technique can provide relative stable environment for translation movement and arrive at best movement effects. Content of the paper concerns is gymnastics movement visual tracking human body posture detection problem, starts from modern computer stereoscopic vision system researching, and explores human body posture detection scientific algorithm.

Visual tracking system

In new type research field, human body moving image analysis and human body movement tracking appear the sign of penetrating towards multiple applications, they have relative essential development in following four aspects:

- Intelligent visual surveillance system.
- Virtual reality and man-machine interface.
- Model-based image coding.
- Motion analysis.

In above four aspects, human body motion analysis can combine with medical and sports, and it has good effects on its technical analysis.

The paper is going to study on sports analysis, when visual tracking system studies on sports, it needs to make reasonable designing on sensor location and image processing technology, in order to monitor gymnasts human body rotating postures with mark points from different orientations, the research system adopts multiple pairs of binocular cameras systems cooperative ways, in the hope of building basis for human body movement postures data collecting, in Figure 1, it shows three groups of binocular structural video camera equipments, equipment orientation designed included angle are all 120^{O}, and input them into computer through USB data transmission and save, which provides data references for next step analysis.

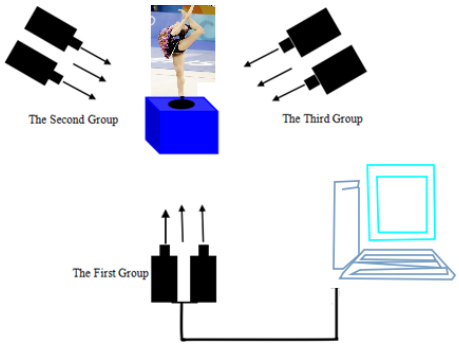

Figure 1 : Gymnastics kind of movement rotating postures visual tracking system compositions

In Figure 1 blue cube represent platform, The First Group~The Third Group represents CCD that is binocular video camera system.

Apply Figure 1 detection equipment location designing method can make stereoscopic motion tracking on player from different orientations, which provides comprehensive data for overall moving image data analysis, from which video camera is selected the Model No. as SONY DCS753.

System parameter setting

If system selected SONY DCS753 every group first video camera directly faced world coordinate system origin is O, while for the second video camera position, it should reduce some distances from a video camera along video camera coordinate axis X axis positive direction, the translation distance is using d to express, in the research the translation distance is 100mm, then it can utilize linear video camera model to calibrate it, let (M_i, N_i) to express image coordinate, let (X_i, Y_i, Z_i) to express space point coordinate, explore two coordinate systems approximate linear transformation relations in the hope of arriving at video camera calibrated effects, which can utilize DLT algorithm to integrate it in a matrix formula A in case not distinguishing video camera internal and external parameters, the formula is as formula (1) shows:

$$\begin{bmatrix} M_i \\ N_i \\ 1 \end{bmatrix} = A \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \quad (1)$$

In calibration process, each coordinate system corresponding relations is as Figure 2 left picture shows, coordinate corresponding relations should select needed control points according to practical movement process region, in the paper it collects 10 data points to make calibration, applies least square method to calculate, image resolution ratio is 680×480, in calibration experiment, collected 10control points data and image analysis obtained computer image coordinate and actual world coordinate

corresponding relation is as TABLE 1shows, gridding round feature marker is as Figure 2 right picture shows, from which (M, N) represents corresponding point value in computer image line and column, X, Y, Z represents actual world coordinate axis, its minimum unit is millimeter.

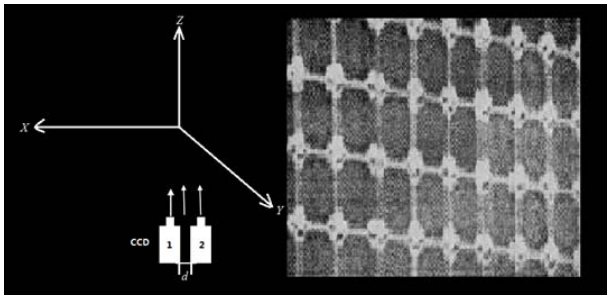

Figure 2 : Video camera calibration process coordinate system relations and gridding control points schematic

TABLE 1 : Video camera calibration sample data

No.	M	N	X	Y	Z	No.	M	N	X	Y	Z
1	38	239	175	129	580	6	456	68	276	-167	800
2	24	62	184	148	740	7	425	36	-240	-183	840
3	40	284	174	128	540	8	107	193	122	21	640
4	48	92	167	110	720	9	87	269	139	56	560
5	628	256	-455	-85	580	10	50	241	166	110	580

By formula (1)and TABLE 1 ten groups of data, it can get equation set that is composed of twenty equations containing eleven unknown quantities, then solve them by applying least square method and can get transformation matrix A_{ij}, subscript i represents group number of video camera, subscript j represents left and right video cameras' mark number, group numbers are 1、2and 3, mark numbers are 1and 2. Result is as formula (2) shows:

$$\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \\ A_{31} & A_{32} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \\ E & F \end{bmatrix}$$

$$A = \begin{bmatrix} -0.912428 & -0.246993 & -0.009146 & 233.800533 \\ 0.033754 & -0.302293 & -1.024453 & 856.082664 \\ 0.000062 & -0.000681 & 0.000050 & 1.000000 \end{bmatrix}$$

$$B = \begin{bmatrix} -0.912524 & -0.246893 & -0.009246 & 325.043333 \\ 0.033768 & -0.302284 & -1.024442 & 852.707244 \\ 0.000061 & -0.000679 & 0.000050 & 1.000000 \end{bmatrix}$$

$$C = \begin{bmatrix} 0.670116 & -0.666689 & -0.009146 & 233.801000 \\ 0.244916 & 0.180378 & -1.024450 & 856.083000 \\ 0.000559 & 0.000394 & 0.000050 & 1.000000 \end{bmatrix}$$

$$D = \begin{bmatrix} 0.242312 & 0.913682 & -0.009146 & 233.802000 \\ -0.278670 & 0.121915 & -1.024450 & 856.083000 \\ -0.000621 & 0.000287 & 0.000050 & 1.000000 \end{bmatrix}$$

$$E = \begin{bmatrix} 0.670003 & -0.667732 & -0.009469 & 166.789000 \\ 0.245061 & 0.180592 & -1.024630 & 930.591000 \\ 0.000591 & 0.000294 & 0.000480 & 1.000000 \end{bmatrix}$$

$$F = \begin{bmatrix} 0.241420 & 0.913593 & -0.009233 & 209.570000 \\ -0.278546 & 0.121809 & -1.024560 & 883.950000 \\ -0.000627 & 0.000186 & 0.000041 & 1.000000 \end{bmatrix} \quad \textbf{(2)}$$

Athlete body mark points setting ways

As Figure 3 shows the gymnasts back attached small white balls marks, use the marks to distinguish from backgrounds, use white marked movement to reflect athlete motion features.

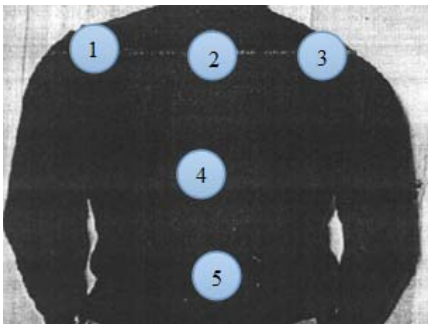

Figure 3 : Small white balls mark points' position distribution

In Figure 3, point 1 and point 3 locate in shoulders of athlete body, the two points position detection purpose is to judge shoulders positions lean degree, point 2 、point 4 and point 5respectively locate in athlete spine three parts from the top down, the three points positions detection purpose is to track human body spine direction crook degree, by 1-5 mark points mutual cooperation, then it can get human body posture information under rotating movement state.

Human body during rotation process, each mark point will change with body changes, three groups of video cameras composed image pickup system can well all-around track mark points, and can implement human body rotating state collecting and monitoring. In one moment of human body rotating, it should consider that only one or two video cameras can completely observe athlete body attached five mark points positions, therefore utilize detectable mark points video camera collected images.

Video camera collected video can be stored as computer files in the format of AVI, if extract one frame BMP image from AVI file, then it can use DirectX's IMediaDet interface implementation, ImediaDet interface's IMediaDet:GetBitmapBits method is obtaining appointed time BMP format image from media file, its interface form definition is as following shows :

```
HRESULT GetBitmapBits (
Double StreamTime,
Long*pBufferSize,
Char*pBuffer,
LongWith,
Long Height
)
```

Interface parameters are respectively used to set image time in file, receive buffer zone position, receive image information file buffer zone position and image height width, under the setting, it can get one frame BMP image under required time.

MOTION IMAGE ANALYSIS

One moment human body posture image analysis

Video is composed of lots of static state images, video in one moment is equal to one frame still-frame, and experiment simulates a group of images under first group of cameras. The paper applies Gaussian smoothing filter to carry out binary processing with images, image filtering refers to restrain target image noise on the condition that try to keep image details features as much as possible, is an indispensible operation in image preprocessing, and Gaussian smoothing filter is linear smoothing filter that selects weights according to Gaussian function shape, its function expression is as formula (3) shows, its core presentation layout is as Figure 5 shows.

$$g[i,j] = \exp\left(-\frac{i^2 - j^2}{2\sigma^2}\right) \quad (3)$$

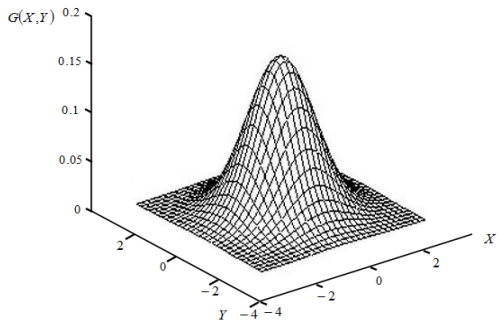

Figure 4 : Gaussian smoothing filter core presentation layout

In Figure 6, it shows image after left CCD going through Gaussian smoothing filtering, image after right CCD going through Gaussian smoothing filtering, left CCD binaryzation threshold 200 image and right CCD binaryzation threshold 200 image.

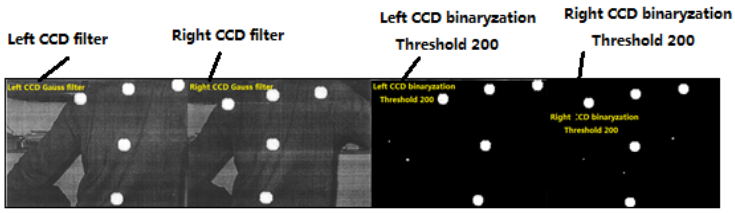

Figure 5 : Picture effect after still-frame image processing

As Figure 6 shows, small white ball mark points following human body movement process, when it changes relative to video camera, its size will change accordingly, but due to spherical features, imaging round features in image will not change, but round radius features will change, due to athlete rotation process, gravity center leaning is not so great, athletes body attached small balls always change in specific range in vertical direction, so in experiment three intervals are respectively as (1, 150), (150, 300)and (300, 480), minimum interval unit is pixel, after dividing image into three slices, the top segmentation region mark points may occur to overlapping phenomenon, which observed angle gets smaller, small balls mark points overlapping probabilities would be larger, but system designed overlap ratio highest status is the case that video camera optical axis and human body shoulders area small balls connecting line form into 30 degree angle, as Figure 7 shows.

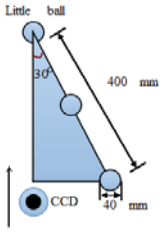

Figure 6 : Small white mark points highest overlap ratio status analysis

In Figure 7, value upward arrow pointed direction is observed direction. In experiment process, shoulders distance is nearly 400 millimeters, small white ball mark point diameter is 40 millimeter, therefore in case as Figure 6 showed 30 degree only mark point radius is above 60 millimeters, based on above analysis, it is clear if establish three pairs of binocular video cameras observation system at 120° angle, always there is a group would not happen mark point sheltering, therefore it is clear that the three complete mark points can completely observe and handle with human body attached five mark points.

Human body posture image experiment data analysis flow

Generated flow of left CCD and right CCD images mark points data by programming processing is as Figure 8 shows; it gets Figure 3 showed mark points data as TABLE 2 shows.

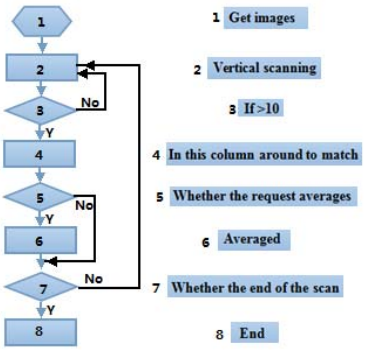

Figure 7 : Image mark points data processing flow

TABLE 2 : Binocular image experiment data

CCD	Image coordinate axis	Mark point1	Mark point2	Mark point3	Mark point4	Mark point5
Left CCD	u	152	324	500	322	304
	v	92	60	42	252	454
Right CCD	u	261	431	605	417	389
	v	90	54	40	256	450

As TABLE 2 showed experiment data corresponds to first group video camera lens observed data, and then according to respective imaging transformation matrix, it can get as formula (3) and formula (4) showed image coordinate and world coordinate relations :

$$\begin{bmatrix} u_L \\ v_L \\ 1 \end{bmatrix} = \begin{bmatrix} -0.912428 & -0.246993 & -0.009146 & 233.800533 \\ 0.033754 & -0.302293 & -1.024453 & 852.707244 \\ 0.000062 & -0.000681 & 0.000050 & 0.993924 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \quad \textbf{(3)}$$

$$\begin{bmatrix} \mathbf{u_R} \\ \mathbf{v_R} \\ \mathbf{1} \end{bmatrix} = \begin{bmatrix} \mathbf{-0.912326} & \mathbf{-0.247002} & \mathbf{-0.009136} & \mathbf{352.043333} \\ \mathbf{0.048897} & \mathbf{-0.491062} & \mathbf{-1.003670} & \mathbf{830.758247} \\ \mathbf{0.000048} & \mathbf{-0.000672} & \mathbf{0.000053} & \mathbf{1.000000} \end{bmatrix} \begin{bmatrix} \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \\ \mathbf{1} \end{bmatrix} \quad \textbf{(4)}$$

By formula (3) and formula (4) as well as TABLE 2 data, it can get as TABLE 3 showed world coordinate value its unit is millimeter.

TABLE 3 : Mark point world coordinate computation result table

World coordinate axis	Mark point1	Mark point2	Mark point3	Mark point4	Mark point5
X	152	324	500	322	304
Y	92	60	42	252	454
Z	261	431	605	417	389

By TABLE 3, it is clear that five mark points space distribution status is as Figure 8 shows.

By Figure 8, it is clear that athlete body's spine and shoulders crook degree, his left shoulder is lower than right shoulder, and body upper part leans towards body left side.

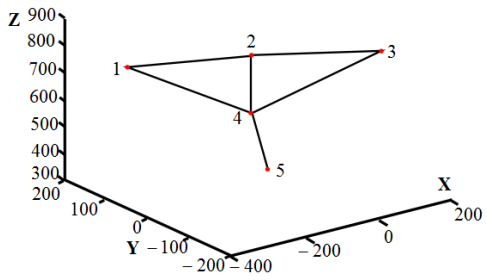

Figure 8 : Athlete five mark points space schematic in a moment

Movement rotating posture changing analysis

If to analyze athlete basic motion and postures changing status, then it only needs to analyze adjacent frames mark points transformation status, as Figure 9 showed two frames' image five mark points unknown status in adjacent moments.

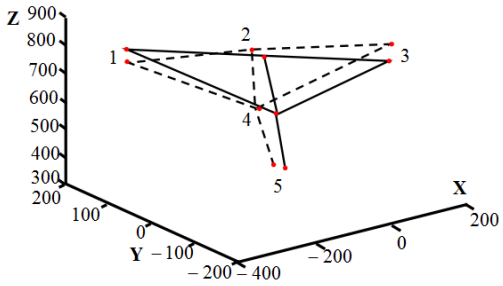

Figure 9 : Two frames mark points' space position schematic in adjacent moments

In Figure 9, dotted line part represents previous moment athlete body five mark points space coordinate orientations composed image, and solid line part is post moment, from previous moment to post moment the two frames mark points' changing status, it is clear about human body rotating direction is rotating round the clock from the top down, according to two frames images time difference and athletes' rotating angles, it can calculate athletes' rotation angular speed, combine with adjacent frames' mutual relations, it can get athlete upper body posture changing relative conclusion during rotating process, it can play correcting roles in athlete mistake when do training aiding.

CONCLUSION

In the paper, it introduces human body posture tracking system compositions; video camera internal system parameters calibration and athlete back mark points setting method. It focuses on analyzing still-frame image mark points' space position accurate defining method, and solves athlete mark points' state distribution status in one moment by the method. It analyzes adjacent frames' image mark points' space position distribution relations, and explores rotating process reflected kinematics parameters by two frames' relations.

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