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Biomechanical model-based sprint athlete articulation point identification method research

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ABSTRACT

Video human sports analysis is an important research direction in computer research field, main content is getting human movement information from single or multiple video camera shooting video sequence, and further carry on three-dimensional reconstruction, with modern human movement capturing and behaviors understanding's research development, it has higher and higher requests on the research[1]. The paper grasps sports movement process human articulation point automatic recognition scientific algorithm as key points to make discussion, in the hope of building basis for more authentic and scientific three-dimensional reconstruction. The paper implements flow research by human articulation point automatic recognition software, and states image processing latter period human body model principle of model that reconstructs according to proportion. Apply video camera measuring apparatus and scientific measuring method, provides basis for effective and scientific data collection. Research result defines human body 15 links and 21 articulation points, and provides each articulation point defining mathematical model, establishes special status discriminant model, provides visible lateral articulation point entering into human contour line, invisible lateral articulation point sheltering and hand definite impacts on hip joint processing methods.

KEYWORDS

Articulation point recognition; Recognition algorithm; Human model; Artificial intelligence; Automatic recognition.

INTRODUCTION

Sports scientific advancement relies on modern science and technological development, and gets profit from science and technological development, especially after electronic measurement technology and computer image processing technology developing. The paper takes running's athletes as research objects, for its contour extraction algorithm and articulation point extraction algorithm, it makes analysis, and in the hope of exploring more effective human movement articulation point automatic recognition system, and provides basis for Chinese sports development.

For human movement analysis and its articulation joint extraction researches, lots of scholars have successively made efforts, and promoted sports technical development to a certain degree, domestic some scholars provided some opinions and conclusions, from which Zhu Yi-Wen (2013) proposed a kind of character skeleton length proportion features characters modeling method, by researching human each part skeleton length proportion features, made parameterization on skeleton model, and finally established hierarchical skeleton model that met movement capturing data[2]; Wang Dan-Dan and others (2013) made analysis of moving body, analyzed articulation point extraction and articulation point tracking method, finally applied three-dimensional coordinate forms to calculate feature points positions, and introduced current human movement analysis research status[3]; Li Rui-Feng and others (2014) summarized human motion recognition problem into symbolic motion information that got by computer testing motion data, and then extracted and understood motion features to implement motion behaviors classification process, on this basis, it carried on reviewing analysis of involved techniques from movement objective detection, motion features extraction and motion features understanding three aspects, made classification on correlation methods, and discussed correlation difficulties and research orientations[4].

The paper based on former researches' running process human each articulation point extraction system; it makes analysis, in the hope of letting sports analysis to be more scientific and effective by the paper researches.

ATHLETES HUMAN MODEL'S EACH ARTICULATION POINT DEFINING AND SOFTWARE RECOGNITION PROCESS

For indicators than can monitor and these indicators feedback information, adjust athletes training contents is basis of current scientific training, that is to say, is a kind of sports training model that adapts to social and science and technological development. In current sports training, in general, it adopts movement videos analysis method to extract monitoring indicators, and mines training process shortcomings from monitoring indicators changing features, in the hope of providing basis for more scientific and reasonable sports training improvements, but applying movement video analysis method has relative complex implementation process, and it will appear certain deviations in operational implementation, which can let numerous scholars to continue to pursue on movement identification and indicators data mining simplified implementation that can monitor. In order to explore more simple movement recognition algorithm, the paper takes running process athletes as research objects, researches on human model's articulation point extraction and recognition process, in the hope of making contributions to simplified movement recognition.

To sum up, the paper research target is designing simplified human movement recognition system, and simplified human recognition system designing starting point is applying model method to monitor movement articulation point movement features. Therefore, the chapter divides two sections to make statement and illustration on athletes each articulation point software recognition flow and athlete human model's each articulation point defining, in the hope of providing basis for simplified human movement recognition system algorithm designing.

Athlete each articulation point software recognition flow

The paper adopts windows operating system platform, and runs sprint human articulation point automatic recognition software system in the platform. Human articulation point automatic recognition

software system is composed Figure 1 showed video converted chattering free digital image, input image, human articulation point automatic recognition, manual modifying specific points, output data, exit and help seven main modules.

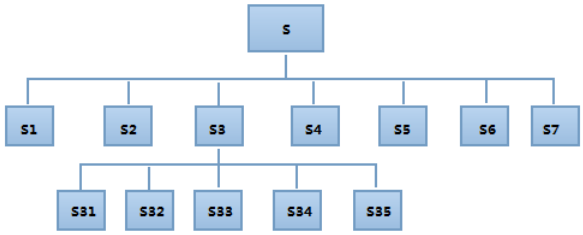

Figure 1 : Software system structure schematic diagram

In Figure 1, each symbol definition is as TABLE 1 shows.

TABLE 1 : Figure 1 symbol description table

No.	Description	No.	Description
S	Sprint intermediate human articulation point automatic recognition software system	S6	Exit
		S7	Help
S1	Convert videos into chattering free digital image sequence	S31	Extract moving body contour line
S2	Input image sequence	S32	Defining movement time phase
S3	Human articulation point automatic recognition	S33	Define proportion length
S4	Manual modifying specific points	S34	Human each articulation point automatic recognition
S5	Output data	S35	Search and process with specific point

When apply the system software to do human articulation point automatic recognition, after inputting images, the system can automatic enter into human articulation point automatic recognition phase without any manual operating, software will recognize every image human articulation point, recognition process is firstly extracting human contour, and then according to human model, extracting skeleton bar chart on contour, finally targeted at skeleton connection points, which is extracting data of human articulation points changing status, applying menu's data output and printing basic data report into data extracted data, and getting each articulation point corresponding coordinate, recognition effect graph is as Figure 2 shows.

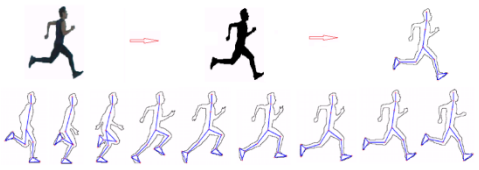

Figure 2 : Human articulation point recognition process and recognition efficiency graph

Athlete human model's each articulation point defining

In software image post processing procedures, it should restore human initial size according to certain proportion, in order to research objects human articulation point tracking, it needs to firstly define human tracking pint, human tracking point and skeleton located postures measurement status is as Figure 3 shows.

In order to achieve the purpose of simplifying calculation amount and recognition effectiveness, it should carry on tracking during movement process targeted at feature points nearby regions. Sprint athlete movement has complex, his body each link doesn't make constant movement in movement process, traditional predicting next moment sports status only relies on previous moment sports status cannot correctly proceed, in addition, in recognition process, it will appear status that visible lateral

articulation point enters into human contour line and invisible lateral articulation point sheltered, hand definite impacts on hip joints as well as other specialties, let recognition process to lead to interruption, therefore the paper firstly utilizes obtained human contour line highest point A lowest point B to define moving body basic positioning and get basic proportional length L_{HI}, and then according to this, define human external contour points C D E F G H, and finally according to already obtained feature points, combines with sprinting rules to define human each articulation point regional tracking, for each articulation point specialties and each time phase specialties, for different time phases each articulation point, adopts different tracking region center and radius, and makes adaptive adjustment according to motions coherences.

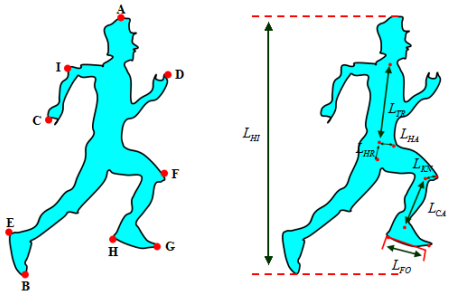

Figure 3 : Runner human contour region tracking and proportional length defining

Sprint is a periodic movement event, for the convenience purpose, it can regard the event as being composed of double steps one by one, and every double step is composed of two single steps, for every single step, it can be divided into supporting time phase, soaring one time phase and soaring two time phases totally three time phases, three time phases separation are foot landing instant, foot out of ground instant, lowest point changing from one foot to another foot instant as well as foot re-landing instant.

Single step three time phases' four time features separation's definition in corresponding images magnitudes are as following shows:

Out of ground instant corresponding magnitude: human contour lowest point vertical displacement occurs obvious change, the change already goes beyond error fluctuation range instant corresponding magnitude

Landing instant corresponding magnitude: In case that human contour lowest point's vertical displacement changes from variation to static, one fluctuation range time corresponding magnitude.

Lowest point transforms from left foot to right foot corresponding magnitude: human contour lowest point horizontal displacement occurs obvious changes; the change surpasses set range instant corresponding magnitude.

Human contour line lowest point vertical direction and horizontal direction coordinates values change status with magnitudes numbers increasing is as TABLE 2 shows, vertical direction coordinate is using Y to express, horizontal direction coordinate is using X to express.

Data distribution features are as Figure 4 show.

In Figure 4, corresponding magnitude expressive definitions are as following show :

- n1 represents the first time landing instant corresponding magnitude.
- n2 represents first time leaving instant corresponding magnitude.
- n3 represents the first time lowest point left foot to right foot transformation corresponding magnitude.
- n4 represents the second time landing instant corresponding magnitude.
- n5 represents the second time lowest point left foot to right foot transformation corresponding magnitude.

Sprint athlete human articulation point automatic recognition mathematical modelling

TABLE 2 : Contour lowest point coordinates values change data table

Magnitude	X coordinate	Y coordinate	Magnitude	X coordinate	Y coordinate
1	148.98	251.92	16	390.74	258.85
2	172.34	257.79	17	400.78	264.49
3	179.25	261.21	18	415.30	264.86
4	169.52	263.06	19	430.50	264.92
5	200.31	264.81	20	430.46	266.24
6	200.36	262.13	21	430.23	264.68
7	200.38	261.22	22	430.07	266.72
8	200.25	264.07	23	430.50	264.87
9	200.92	261.70	24	430.52	266.42
10	200.70	264.47	25	430.64	264.15
11	200.89	261.75	26	430.14	264.24
12	200.62	264.94	27	440.37	247.11
13	203.82	250.59	28	580.88	247.86
14	330.20	247.22	29	600.65	254.39
15	360.53	254.11	30	610.84	257.80

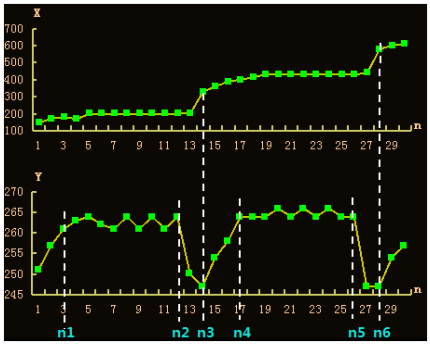

Figure 4 : Contour lowest point coordinate value change trend with magnitudes

Research objects and measurement method

Research objects: The paper takes second grade 10 sprint athletes as research objects, clothes is dark skintight outfits and dark shoes and stockings without attaching any mark points in body, background color is light fixed wall.

Measurement method:Apply two-dimensional fixed video camera measurement principle, video camera shooting frequency is 50HZ installation position is as Figure 5 shows.

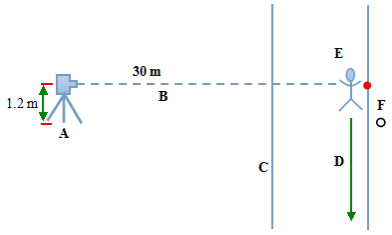

Figure 5 : Two-dimensional fixed shooting schematic diagram

Figure 5 each symbol description is as following show:
A represents video camera
B represents principal optic axis
C represents track

D represents movement direction
E represents sprint athlete
F represents origin

Video camera placed position lets principal optic axis to be vertical to track, video camera nose and athletes distance is 30m, video camera height is 1.2m, range of video camera field of view is 10m,research objects 10 athletes run successively and every athlete sprint for six times,his average speed is controlled around 7m/s.

Human articulation joint defining and its mathematical model

According to Hanavan mathematical model, it is clear that human can be expressed as mathematical model that is composed of 15 links by spherical hinge connections, the model classifies human into 15 links as following shows:

1) Head –start from top of head to the seventh cervical vertebra, one piece.
2) Upper trunk—Start from the seventh cervical vertebra to inferior margin of breastbone, one piece.
3) Lower trunk—Start from inferior margin of breastbone to greater trochanter, one piece.
4) Upper arm—Start from shoulder joint center to elbow joint center, two pieces.
5) Forearm—Start from elbow joint center to wrist joint center, two pieces.
6) Hand—Start from wrist joint center to metatarsophalangeal joints center, two pieces.
7) Thigh—Start from hip joint center to knee joint center, two pieces.
8) Shank—Start from knee joint center to ankle joint, two pieces.
9) Foot—Start from calcaneal tuber to toe, two pieces.

To sum up, 15 pieces of links, totally define 21 articulation points as following shows:

Top of head
The seventh cervical vertebra
Inferior margin of breastbone
Right shoulder joint
Right elbow joint
Right wrist joint
Right metatarsophalangeal joint
Right hip joint
Right knee joint
Right ankle joint
Right calcaneal tuber
Right toe
Left shoulder joint
Left elbow joint
Left wrist joint
Left metatarsophalangeal joint
Left hip joint
Left knee joint
Left ankle joint
Left calcaneal tuber
Left toe

In the time that before and after athlete pedaling backward and leaving instant and landing leg will land soon, knee joint angle is larger, knee joint nearby contour line inflection point features are not obvious, it cannot apply inflection point midpoint to define knee joint, therefore take ankle joint $A(X_A, Y_A)$ as the center of a circle,and take shank length L_{CA} as radius to draw round, intersection points with knee joint nearby contour line are B, C the two intersection points center is supposed to be knee joint point, as Figure 6 shows.

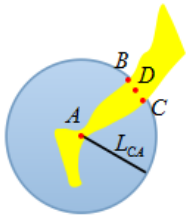

Figure 6 : Knee joint point

As Figure 7 showed knee joint point D coordinate solution way is as formula (1) shows:

$$\begin{cases} \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2} = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2} = L_{CA} \\ X_D = \frac{1}{2}(X_B + X_C), Y_D = \frac{1}{2}(Y_B + Y_C) \end{cases} \quad \textbf{(1)}$$

Similarly, apply link length method, it can solve hip joint coordinate, top head coordinate and inferior margin of breastbone coordinate.

Apply shortest distance midpoint method to define the seventh cervical vertebra point, firstly it needs to define two contours lines shortest distance two points $A(X_A, Y_A)$ and $B(X_B, Y_B)$, and take $C(X_C, Y_C)$ as the seventh cervical vertebra point, as Figure 7 shows.

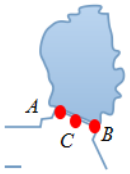

Figure 7 : The seventh cervical vertebra point

Simultaneous formula (2), it can get the seventh cervical vertebra point coordinate $C(X_C, Y_C)$.

$$\left[X_C = \frac{1}{2}(X_A + X_B), Y_C = \frac{1}{2}(Y_A + Y_B) \right] \quad \textbf{(2)}$$

Apply link length method to define knee joint point, the method application evidence is in sprinting process, moving body each link vertical axis is always vertical to video camera principal optic axis, therefore in image each link length is supposed to remain unchanged, apply fixed link length to define articulation point coordinate.

Apply vertical link tangent line midpoint method, it can solve shoulder joint coordinate, it needs to firstly define upper arm two ends contour line's feature points $A(X_A, Y_A)$ and $B(X_B, Y_B)$, in line segment AB distance A point as $\frac{1}{5}AB$ area, take point $F(X_F, Y_F)$ to make vertical line segment AB vertical line, the straight line and contour line intersect in $C(X_C, Y_C)$ and $D(X_D, Y_D)$, take two intersection points midpoint E as shoulder joint point, as Figure 8 shows.

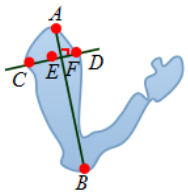

Figure 8 : Shoulder joint point

As Figure 8 shows, simultaneous equation set formula (3), it can get point E coordinate:

$$\begin{cases} X_F = X_A + \frac{1}{5}(X_B - X_A), Y_F = Y_A + \frac{1}{5}(Y_B - Y_A) \\ \frac{|Y_C - Y_F|}{|X_F - X_C|} = \frac{|X_B - X_A|}{|Y_B - Y_A|} = \frac{|Y_D - Y_F|}{|X_F - X_D|} \\ X_E = \frac{1}{2}(X_C + X_D), Y_E = \frac{1}{2}(Y_C + Y_D) \end{cases} \quad (3)$$

Similarly apply vertical link tangent line midpoint method; it can solve wrist joint and ankle joint coordinate.

Special case discriminant and processing model

Human movement has complex,in sprint process, it often appears visible lateral articulation point entering into human contour line, invisible lateral articulation joint sheltering and hand definite impacts on hip joint as well as other special status, in order to process with special cases, firstly it needs to judge when will appear special cases, according to one articulation point top three frames displacement to define athlete the articulation point movement tendency, define current frame unique range, if the articulation point appears special cases, displacement will appear huge fluctuation, let displacement to surpass calculation defined displacement range, n time displacement range center position calculation is as formula (4)shows:

$$\begin{cases} X_n = V_{n-1}(x) \cdot T + \frac{1}{2} a_{n-1}(x) T^2 \\ Y_n = V_{n-1}(y) \cdot T + \frac{1}{2} a_{n-1}(y) Y^2 \end{cases} \quad (4)$$

By formula (1) relationship, it is clear that speed parameter gets bigger, searching region will get bigger, on the contrary, speed parameter gets smaller, then searching region will get smaller, acceleration parameter absolute value is not equal then searching region increases, when acceleration parameter is equal to zero, searching region size is unchanged.

When visible lateral swinging leg forward swinging process gets through supporting leg, swinging leg knee joint, toe point and calcaneal tuber successively enter into supporting leg contour line, now these links are sheltered by supporting leg, define sheltered articulation point evidence is articulation point center surely will locate in link vertical axis and link length is unchanged.

Invisible lateral toe point, calcaneal tuber point and knee joint point defining method and visible lateral articulation point entering into human contour problem processing method is the same; sheltering lateral hip joint always shelters and sprint left and right limbs movement has symmetry, then it can apply visible lateral hip joint to calculate sheltering lateral hip joint coordinate; arms each link vertical axis in sprint process is not vertical to video camera principal optic axis, let image arm each link length to be constantly transformed, so it cannot apply leg sheltering processing method, due to sprint intermediate left and right limbs movement symmetry can apply visible lateral articulation joint to calculate sheltering lateral corresponding articulation joint coordinate.

Due to hand position gets closer to hip joint, hand may enter into definite hip joint tracking region, now intersection points will have three or four pieces, so compare adjacent line segments length, take maximum length key points as hip joint required coordinate point; when hand and trunk overlap, it can extract original image, set distinguished skin color and clothes color gray threshold value to use for judging trunk region and arms region.

CONCLUSION

The paper firstly analyzes human articulation point automatic recognition software implementation flow, and states image post processing human model's model principle that reconstructs

according to proportions. It studies on video camera measurement apparatus and scientific measurement method, which provides basis for effective and scientific data collection. It defines human body 15 links and 21 articulation points, and provides each articulation point defined mathematical model. It analyzes image overlapping and other specific cases, establishes special cases discriminant model, provides visible lateral articulation point entering into human contour line, invisible lateral articulation point sheltering and hand definite impacts on hip joint processing method.

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