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Research of badminton forehand smash technology based on biomechanical analysis

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ABSTRACT

For a movement target segmentation complete video result, it can reduce movement target search quantity, and is of great help to effective promoting tracking speed and accuracy. The purpose of video segmentation is to extract movement target out from background in video sequences and used for implementing prospect and background segmentation. The paper researches on background deduction before tennis video human body movement tracking and contour extracting, in the hope of exploring more scientific background deduction algorithm to provide good platform for sports video analysis. In the paper, it firstly introduces Mean Shift algorithm and particle filter method algorithm. It states to algorithm that combines with the two algorithms, and provides LPP background estimation algorithm and particle filter prediction algorithm principle. Use the paper algorithms to compare 3 algorithm, and shows algorithm superiority.

KEYWORDS

Mean shift algorithm; Particle filter algorithm; LPP algorithm; Background deduction; Histogram; Tennis match.

INTRODUCTION

Zhang Xu-Guang (2007)pointed out by far many application systems had appeared in computer vision field, as gait system, speech recognition system and emotion system so on, and meanwhile head posture estimation also was one of hotspots in computer vision field, head posture was people head close-up in a moment, head posture changes could be used for analyzing focused target attention in intelligent environment[1-4]. The paper researches on tennis movement process, net spiking process human body movement video features, explores background deduction algorithm, which provides theoretical basis for video objects' tracking and contour extracting.

For video objects tracking and background deduction, lots of people have made efforts, just their efforts built good basis for sports analysis. Among them, Li Shi-Cheng and others (2014)studied on visual deviation, combined with geometrical analysis results, designed moveable camera shooting fixtures with laser emission setting, overcame video camera position and angle effects on errors[1,5]; Fu Quan and others (2013)summarized movement capture technology, on the basis of analyzing and summarizing existing research achievements, they pointed out movement capture technology development trend[2,6]; Lu Jing and others (2013)used a kind of improved background deduction method to carry on movement target detection, combined with H.246 technologies, and carried out algorithm implementation in embedded video system[3,7].

The paper on the basis of previous research focuses on analyzing two kinds of background deduction methods, analyzes the two algorithms merits, learns from each other, carries out algorithm combinative processing, finally applies the paper algorithms to compare traditional 3 algorithm, it gets tennis athlete head ten kinds of sports movement postures target points detection histogram.

ALGORITHM PRINCIPLE ANALYSIS

Mean Shift algorithm principle analysis

Zhang Xu-Guang (2007)pointed out that Mean Shift was a kind of external features-based tracking algorithm, it could make real-time tracking on nonrigid target[4-8]. Djouadi A and others (1990)pointed out that by Mean Shift iterative operation, it could search potential target that was most similar to target template brightness distribution in current frames, the two brightness distribution similarity degree used Bhattacharyya distance to measure[9-15].

Bhattacharyya distance value calculation accords to potential target brightness and target template brightness estimated value, it can get as formula (1) showed Bhattacharyya distance discrete estimated value in following showed variables definitions:

p : Potential target brightness estimated value

q : Target template brightness estimated value

y : Central position

u : Is a feature vector that represents color of target.

$q(u)$: Target template probability distribution.

$p_u(y)$: Central position potential target feature probability distribution

$$\rho(y) = \rho[\hat{p}(y), \hat{q}_u] = \sum_{u}^{m} \sqrt{\hat{p}_u(y)\hat{q}(u)} \quad \textbf{(1)}$$

m histogram p and q quantization layers,two kinds of distribution difference $d(y)$ has definitions as formula (2) shows:

$$d(y) = \sqrt{1 - \rho[\hat{p}(y), \hat{q}]} \quad \textbf{(2)}$$

In the research, tracking implementation process adopted is Bhattacharyya distance value maximization process,make following assumption of variable can get the process algorithm steps :

$\hat{y}_0$ represents current frame position, assume that it starts target searching from the position.

$\{\hat{p}_u(\hat{y}_0)\}(u = 1 \cdots m)$ represents current frame position potential target color probability.

d represents minimized distance.

ρ represents Bhattacharyya distance.

$\{\omega_i\}(i = 1, \cdots, n_h)$ represents weights.

Step 1. According to $\hat{y}_0$ initialize current frame target position, apply distribution probability $\hat{p}_u(\hat{y}_0)$ to proceed with as formula (1)showed Bhattacharyya distance.

Step 2. According to formula (3),define $\{\omega_i\}(i = 1, \cdots, n_h)$.

$$\omega_i = \sum_{u=1}^{m} \delta[b(x_i) - u] \sqrt{\hat{q}_u / \hat{p}_u(\hat{y}_0)} \quad \textbf{(3)}$$

Step 3. According to formula (4),calculate target new position $\hat{y}_1$,and then according to formula (1),it gets updated target position Bhattacharyya distance.

$$\hat{y}_1 = \sum_{i=1}^{n_h} x_i \omega_i g\left(\left\|(\hat{y}_0 - x_i)/h\right\|\right)^2 / \sum_{i=1}^{n_h} x_i g\left(\left\|(\hat{y}_0 - x_i)/h\right\|\right)^2 \quad \textbf{(4)}$$

Step 4. If it exists as formula (5) showed relations,then $\hat{y}_1 \leftarrow \frac{1}{2}(\hat{y}_0 + \hat{y}_1)$.

$$\rho[\hat{p}(\hat{y}_1), \hat{q}] < \rho[\hat{p}(\hat{y}_0), \hat{q}] \quad \textbf{(5)}$$

Step 5. If it exists updated position and current position difference is extremely small, end searching process, otherwise endow updated position as current position, and return to STEP1 to do new round searching.

Particle filter algorithm principle analysis

Particle filter algorithm is a kind of Bayes estimation-based Monte Carlo method,its basic thought is describing one weight random sample probability distribution, the sample is called " particle". On the basis of observed samples, update random sample position and weight; let it to be used for estimating approximate practical probability distribution. The algorithm not only can be better implemented in computer, but also can be better applied in case that observed information happens to abnormal status. In general, a dynamic system is as formula (6) features:

$$\begin{cases} x_{k+1} = f_k(x_k, w_k) \\ z_k = h_k(x_k, v_k) \end{cases} \quad \textbf{(6)}$$

In formula (6), x_k represents k moment system state; f_k represents system transformation function; w_k represents system noises,it conforms to zero-mean Gaussian distribution ; z_k represents k moment system observed value; h_k represents system observation function; v_k represents observed noises; it conforms to zero-mean Gaussian distribution.

Filter is on the condition of known observed value sequence $z_{1:k}$, it calculating probability of occurring x_k, its mathematical expression is as formula (7) shows:

$$p(x_k|z_{1:k}) \quad \textbf{(7)}$$

Formula (7)can calculate according to Bayes formula, its calculation result is as formula (8)shows:

$$p(x_k|z_{1:k}) = \frac{p(z_k|x_k)p(x_k|z_{1:k-1})}{p(z_k|x_{1:k-1})} \quad \textbf{(8)}$$

The purpose of prediction is predicting x_{k+1} value on the basis of solved $z_{1:k}$, its mathematical expression and computational method is as formula (9)shows:

$$p(x_{k+1}|z_{1:k}) = \int p(x_{k+1}|x_k)p(x_k|z_{1:k})dx_k \quad \textbf{(9)}$$

In formula (9), $p(x_k|z_{1:k})$ can be calculated by formula (8), and then by Bayes theory, let x_k estimated value and actual value error to be minimum, at that time corresponding value $\bar{x}_k$, computational method is as formula (10)shows:

$$\bar{x}_k = \int x_k d(p(x_k|z_{1:k})) \quad \textbf{(10)}$$

Because $p(x_k|z_{1:k})$ generally cannot be explained, approximate $p(x_k|z_{1:k})$ as kalman filter form, considering $p(x_k|z_{1:k})$ probability distribution generally is the case of non-analysis, therefore it needs to utilize Monte Carlo random sampling method of approximately processing with $p(x_k|z_{1:k})$ by a group of particle set with weights,by Monte Carlo method, it is known that $p(x_k|z_{1:k})$ approach way is as formula (11) shows:

$$p(x_k|z_{1:k}) = E(I_{\{xk\}}(x)|z_{1:k}) \quad \textbf{(11)}$$

In formula (11), when $x = x_k$, $I_{\{xk\}}(x)$ value is 1, otherwise is 0; $E\left(I_{\{xk\}}(x)|z_{1:k}\right)$ can approximate with its sample average value,as formula (12)shows:

$$E\left(I_{\{xk\}}(x)|z_{1:k}\right) \approx \frac{1}{N}\sum_{i=1}^{N} I_{\{xk\}}\left(x^j\right) = \frac{1}{N}\sum_{i=1}^{N}\delta\left(x - x_k^i\right) \tag{12}$$

In formula (12), x_k^i represents x_k the i sampling value, generally adopt important sampling method to approach $p\left(x_k|z_{1:k}\right)$,under important sampling $E\left(I_{\{xk\}}(x)|z_{1:k}\right)$ can use formula (13) to express:

$$E\left(I_{\{xk\}}(x)|z_{1:k}\right) \approx \frac{1}{N}\sum_{i=1}^{N} w_k^i\delta\left(x - x_k^i\right) \propto \sum_{i=1}^{N} w_k^i\delta\left(x - x_k^i\right) \tag{13}$$

Set important function to be $q\left(x_k|z_{1:k}\right)$, then it has formula (14),

$$w_k^i \propto \frac{p\left(x_k^i|z_{1:k}\right)}{q\left(x_k^i|z_{1:k}\right)} \tag{14}$$

By formula (14),it is clear when targeted one concrete x_k, every time sampling and when $x = x_k$, w_k^j is a fixed value;from the significance of probability theory, it refers to randomly collect sample for N times from x, when $x = x_k$, corresponding $\delta\left(x - x_k^j\right)$ is equal to 1, now correspond to a weight w_k^j.

ALGORITHM IMPLEMENTATION

Algorithm overall thought

Chen Shu-Ming and others (2011)pointed out that during tracking process, in case current target is similar to background or multiple targets happen to shelter that generate short multiple peak values, Mean Shift algorithm will be restrained into non-real target, and particle filter algorithm can also well track in case of non-linear, non Gaussian system state and multiple targets sheltering, but it exists particle shortage and lacking of diversity problems, when particle selection is too many, tracking instantaneity cannot be ensured, while selection is less the tracking result is not correct[6]. Therefore the paper adopts two algorithms combinative way to carry on background deduction and contour extraction on tracked target, firstly applies Mean Shift to fast track target, and then uses particle filter method to screen tracking target.

When movement prospect moves at a specified speed, it can predict movement prospect regional coordinate in current frame according to previous frame movement prospect region coordinate and prospect horizontal and vertical movement speeds. According to system equation and observed equation, apply particle filter can get N pieces of prospect region predicted value, now it can calculate dropping into the N pieces of regions' pixel points as prospect probability, and then it can get prospect probability. In case that sampling number is m that is defined,known that one event occurrence probability P,in sampled N pieces of samples, one event occurrence probability is lower than P,and in other $N-M$ pieces of samples, the event occurrence probability is relative larger, if segmentation algorithm can utilize the event prior probability to make self-adaption segmentation, then the algorithm robustness will correspondingly increase, in the paper described algorithm is strengthening image

segmentation robustness from above two perspectives. Among them, when image each point (i, j) is background, its pixel value distribution conforms to Gaussian distribution, when is prospect, its each point pixel value distribution also conforms to Gaussian distribution. Algorithm overall flow chart is as Figure 1 shows.

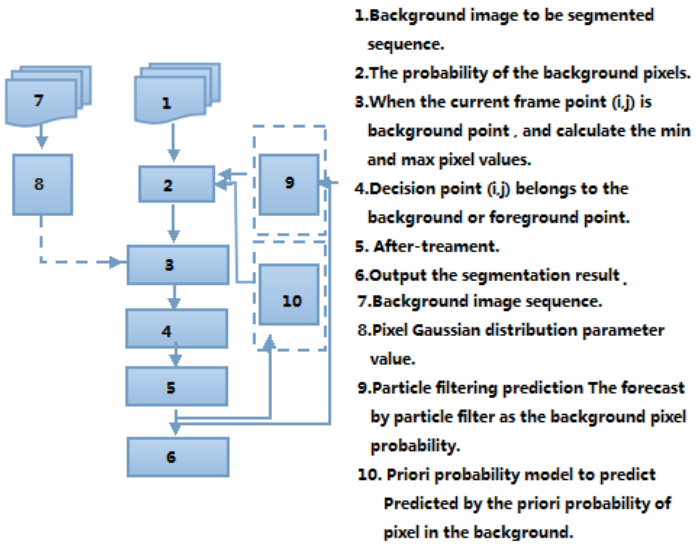

Figure 1 : Algorithm overall flow chart

Background estimation algorithm

Background estimation algorithm adopts LPP algorithm, the algorithm is Laplace Beltrami algorithm feature function one linear estimation, its target is maintaining data close relations, if assume that in high dimension sample set $X = \{x_1, x_2, \cdots, x_N\}$,it has N pieces of data sample points, and every sample point x_i belongs to D dimension Euclid space R^D ,LPP projection is to map high dimension space samples into low dimension space.

LPP algorithm implementation steps are as following shows:

Step 1. To provided high dimension sample set X ,apply formula (15) to calculate mutual distance d_{ij} :

$$d_{ij} = \begin{cases} \left\| (x_i - x_j)^2 \right\| & x_i \rightarrow\leftarrow x_j \\ \infty & x_i \leftrightarrow x_j \end{cases} \tag{15}$$

Step 2. According to high-order samples domain relations to establish overall adjacent map, select as formula (16) showed any two high-order data points' similarity S_{ij} :

$$S_{ij} = \begin{cases} \exp\left(\dfrac{-d_{ij}}{\sigma^2}\right) & d_{ij} \neq \infty \\ 0 & d_{ij} = \infty \end{cases} \tag{16}$$

Step 3. Apply formula (17) to calculate projection matrix U :

$$\min \sum_{i,j=1}^{N} \left\| y_i - y_j \right\|^2 S_{ij} \to Y(D-S)Y^T \xrightarrow{L=D-S} YLY^T \to U \tag{17}$$

Particle filter prediction

Particle filter prediction divides into five parts that are respectively particle initialization, prospect region prediction and probability calculation of pixel point belongs to background, particle weights calculation, important adoption and postprocessing.

Particle initialization is according to observation equations, use initial particle set to approximate X_n distribution, from which observation equation is as formula (18)shows:

$$Y_n = X_n + V_n \tag{18}$$

In formula (18), V_n represents observation noise,it conforms to standard normalization distribution. Particle initialization process :use first frame segmentation result prospect region coordinates to compose of N pieces of 8 dimensions state vector, which is also N pieces of particles, state vector is as formula (19)shows:

$$(x_0, y_0, u_0, v_0, x_1, y_1, u_1, v_1) \tag{19}$$

In formula (19), (x_0, y_0) represents target region top left corner coordinate value, (x_1, y_1) represents target region bottom right corner coordinate value, (u_0, v_0) represents target region top left corner horizontal movement speed and vertical movement speed, (u_1, v_1) represents target region bottom right corner horizontal speed and vertical speed. Initially, $(u_0, v_0) = (0,0)$, $(u_1, v_1) = (0,0)$;and then, let state vector to add with normal random noise, it gets N pieces of new state vectors;finally, enclose every new state vector with a weight $\frac{1}{N}$;So that it can get particle filter initial particle set.

Utilize initial particle set or the particle set got by sampling to predict new frame prospect region, as formula (20) shows system equations:

$$\begin{cases} x_0^{n+1} = x_0^n + u_0^{n+1} + w_n, y_0^{n+1} = y_0^n + v_0^{n+1} + w_n \\ u_0^{n+1} = u_0^n, v_0^{n+1} = v_0^n \\ x_1^{n+1} = x_1^n + u_1^{n+1} + w_n, y_1^{n+1} = y_1^n + v_1^{n+1} + w_n \\ u_1^{n+1} = u_1^n, v_1^{n+1} = v_1^n \end{cases} \tag{20}$$

By formula (20),it can get next frame's prospect region N pieces of predicted values. Prediction result accuracy is according to formula (21) showed particle weight computational method:

$$\frac{P\left(Y_n \middle| X_n^*(i)\right)}{\sum_{j=1}^{N} P\left(Y_n \middle| X_n^*(j)\right)} \quad \textbf{(21)}$$

According to formula (21)calculation, it gets particle weight, and then carry out normalization processing, it can calculate each particle accumulative weight, each particle accumulative weight can classify[0,1] space into N pieces of regions,and then make even sampling in the space and generate N pieces of random numbers, finally copy the random number affiliated one region corresponding particle into one particle in new particle set, therefore it can fulfill new particle set adoption, and in important sampling process, particle that weight is bigger, its corresponding space region will get bigger, copied as new particle probability will also be bigger.

Tennis match application result analysis

Make image segmentation on five sections videos, respectively carry out 3σ method as well as Mean Shift algorithm and particle filter algorithm combinative algorithm to segment, contrasts from pixel points total amount, number of background points being segmented into prospect points by mistake, number of prospect points being segmented into background points by mistake, ratio that background points being segmented into prospect points by mistake and ratio that prospect points being segmented into background points by mistake these five aspects,as TABLE 1 shows.

TABLE 1 : Experiment result contrast table

Classification	Algorithm selection	Pixel points number	Points of segmented prospect points by mistake	Points of segmented background points by mistake	Ratio of segmented prospect by mistake	Ratio of segmented background by mistake
Video1	Method1	207360000	2818020	38672640	1.359%	18.650%
	Method2	207360000	2954880	19838130	1.425%	9.567%
Video 2	Method1	207360000	9053330	52047360	4.366%	25.100%
	Method2	207360000	9092730	16914360	4.385%	8.157%
Video 3	Method1	207360000	2596140	44893440	1.252%	21.650%
	Method2	207360000	2193860	15336340	1.058%	7.396%
Video 4	Method1	207360000	2421960	37698040	1.168%	18.180%
	Method2	207360000	2411590	22415610	1.163%	10.810%
Video 5	Method1	207360000	4053880	38900730	1.955%	18.760%
	Method2	207360000	4281980	21233660	2.065%	10.240%

Note:Method 1 is 3σ method,method 2 is Mean Shift algorithm and particle filter algorithm combination-based algorithm

By TABLE 1, it is clear that particle filter and prior probability model-based algorithm is overall superior to 3σ method.

For tennis match, net spiking hitting instant human face motion process carries out background deduction processing, extracted athlete head ten kinds of postures histogram is as Figure 2 shows.

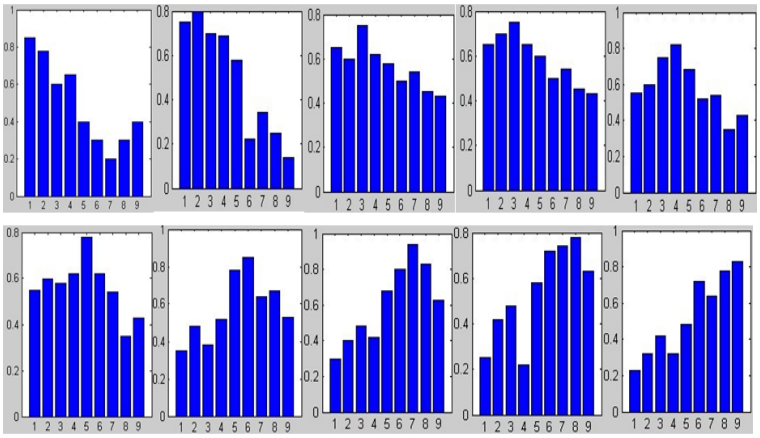

Figure 2 : Athlete head ten kinds of postures histogram result

CONCLUSION

The paper firstly states Mean Shift algorithm and particle filter algorithm mathematical model and algorithm principle, which provides theoretical basis for tennis match human body movement tracking and contour extraction. The writer combines with two algorithms merits, designs algorithm thought that first applies Mean Shift to rapidly track target and then uses particle filter method to screen track target, and provides when move at specific speed, background deduction algorithm overall flow. In order to rapidly implement video background deduction work and arrive at more rapidly extract objects contours, it provides background estimation algorithm and particle filter prediction implementation principle, which provides theoretical basis for improving algorithm implementation speed. For tennis net spiking hitting instant athlete head changing features, it carries on background deduction processing, and gets head instantaneous ten frames histogram, and makes comparison of the paper algorithms with 3σ algorithm, comparison result shows that Mean Shift algorithm and particle filter algorithm combinative algorithm is superior to 3σ algorithm.

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