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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSI*net*

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Application of Motion Estimation in Football Video's Analysis Based on Kalman Filter

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Abstract: Football game video contains huge data and information of the event, in the race study course, the segmentation extraction of the targeted players, football and stadium's flags line and prediction tracking is an important technique of video analysis. In this study, it uses the Kalman filter to study target motion estimation in soccer video analysis, first analyzed the principle of the filter and its mathematical model, sets filter's parameters based on the video analysis object in actual football game and gives the calculation method of prediction estimation, finally carries through experimental simulation for the uniform motion of the players and analyzes the estimation data of player's non uniform motion in the actual video game. The study results show that the error in uniform motion will converges to 0 with the increase of the number of iterations and estimation error for the actual non-uniform motion of the players has no obvious convergence but the Kalman filter has a significant impact on the decreases of motion estimation error for the player.

Key words: Video game, kalman filter, state transition, error analysis

INTRODUCTION

In the field of multimedia image communications and broadcast television field the processing needs of the video signal is very strong. In these real-time systems, the realization of motion estimation and motion compensation has a high demand, that means the algorithms is necessary to be accurate and also a lot easier to achieve. In the video sequences of soccer game, the motion of players and the football and the transfer of the camera angle would make the player's region and the football's region create a shift and produces movement in the image; in order to estimate the motion between two adjacent images, this article does principle studies and achieves data analysis (Zhang, 2013).

The motion estimation for targeted object is a more critical technology in video analysis. With the development of technology and the study of algorithms the technology has been developed rapidly, many people has made efforts on theoretical guidance, including: Zhu Kai-di from Shanghai Institute of computer Engineering and Science University, in the "Motion Estimation Algorithms Based on H.264", analyzed the operation accuracy and efficiency of motion estimation in H.264 video coding algorithm, in order to improve the accuracy and efficiency of the algorithm, using a magnetic head tracker to obtain the camera's motion vectors, synthesis on the motion vectors obtained through the search algorithm of asymmetric cross hexagon, by experiment the improved algorithm can not only maintain the performance of motion estimation but also can

improve the motion estimation accuracy when the scene changes (Zhu, 2011); Xiang You-jun, etc., from school of electronic and Information Engineering in South China University, in the "Fast Motion Estimation Algorithm Based on Moving Direction Prediction", used the highly correlation and the center of gravity offset characteristic of the adjacent block's motion vectors in image sequences, proposed a fast motion estimation algorithm based on the prediction of motion direction, designed four directional templates and then according to the reference motion vector predicted the movement of the image block, depending on the different movement directions selected the corresponding directional template to search and through experimental results the algorithm are superior to the traditional fast motion estimation algorithm in terms of speed and accuracy (Xiang, 2009; Chen, 2009), from Zhejiang Engineering University, in the "a study of motion estimation algorithm optimization in video coding technology", analyzed the main technologies that affected motion estimation search in the video coding technology, put forward fast motion estimation algorithm to early terminate the search for the lack of diamond search algorithm, by simulation experiment improved that under the premise of ensuring the video's and quality performance, the algorithm greatly improved the encoding speed and was suitable for video surveillance, videophone and other video applications (Zhang, 2002; Zheng and Li, 2009) from Digital Technology and instrument Institute of Zhejiang University, "fast global motion estimation based on symmetry elimination and difference of motion vectors" for the problem of high

computation complexity in the global motion estimation, proposed a rapid global motion estimation method for the principles of elimination and difference of motion vector, based on the symmetry offset characteristic between different quadrant motion vectors, first estimated parameters component of the translational motion and used the differential principle of the motion vector, in combination with a confidence judge's strategy, esimated the transformation motion parameters, based on five geometry global motion model and real video sequences, the experimental results showed that in the case that ensure the estimation accuracy the method's average computation time occupied only 50% of remaining methods (Zheng and Li, 2009).

In this study, based on the previous studies, for the movement of target players and football in football game video it uses Kalman filter to conduct motion estimation; This method can not only be applied in soccer video analysis but also be applied in soccer video simulation and analyzes the estimation accuracy by the experimental data.

MOTION ESTIMATION OF KALMAN FILTER

In the application of motion vision, the Kalman filter has been widely used; the method is to conduct linear minimum variance estimation error for the state sequence of a dynamic system, that can the dynamical and observed equations to describe the system, capable of taking any point as starting observation point. In the computing process it uses recursive filtering method to calculate, the motion estimation based on Kalman filter has small amount of calculation, easy to realize by the computer and other advantages. The following studies the prediction principle of the method theory and parameter setting in the application of soccer video analysis (Tan, 2013).

Forecast principle of Kalman filter: Kalman filter is generally used to estimate the state variable $x \in \mathcal{R}^n$ of the discrete-time process, the discrete time process can be represented by the discrete stochastic differential equation in Eq. 1:

$$x_k = Ax_{k-1} + Bux_{k-1} + w_{k-1} \quad (1)$$

Suppose $z \in \mathcal{R}^m$ is the observed variable and the resulting measurement equation is shown in Eq. 2 below:

$$Z_k = Hx_k + v_k \quad (2)$$

The random signal w_k in Eq. 1 and the random signal v_k in Eq. 2, respectively mean the process excitation noise and measurement noise. In the prediction it is seen as independent and normally distributed white noise, as shown in the Eq. 3 below:

$$P(w) \sim N(0, Q), p(v) \sim N(0, R) \quad (3)$$

In Eq. 3 Q, R , respectively represent the covariance matrix of process excitation noise and observation noise. If the control equations u_{k-1} or process excitation noise W_{k-1} is 0, then the nHn gain matrix A of differential Eq. 1 linearly maps the state at the previous time $k-1$ to the current time state k .

Definition $\hat{x}_k^- \in \mathcal{R}^n$ represents a priori state estimation of the k th step when the state before the k th step is known; definition $\hat{x}_k \in \mathcal{R}^n$ represents a posteriori state estimation of the k th step when the measured variable z_k is known, then the priori error estimation e_k^- and posteriori estimation error e_k are in the Eq. 4:

$$e_k^- = x_k - \hat{x}_k^-, e_k = x_k - \hat{x}_k \quad (4)$$

The covariance of priori estimation error and a posteriori error is in the Eq. 5 below:

$$P_k^- = E[e_k^- e_k^{-T}], P_k = E[e_k e_k^T] \quad (5)$$

The linear combination of priori estimation $\hat{x}_k^- \in \mathcal{R}^n$ and the difference between the weighted measured variable Z_k and the prediction $\hat{x}_k \in \mathcal{R}^n$ forms a posteriori state $H\hat{x}_k^-$, as shown in the Eq. 6:

$$\hat{x}_k = \hat{x}_k^- + K(z_k - H\hat{x}_k^-) \quad (6)$$

In Eq. 6 $(z_k - H\hat{x}_k^-)$ means the difference between the measured variable and their prediction, called the residual of the measurement process; this value reflects the inconsistency degree between the predicted value and the actual value, when the residual is zero, which means that the two fit entirely; K -means the residual gain of the $n \times m$ order matrix and its role is to make the posteriori estimation error's covariance in Eq. 5 minimum.

The $n \times m$ order matrix K is calculated as in Eq. 7:

$$K_k = P_k^- H^T (H P_k^- H^T + R)^{-1} = \frac{P_k^- H^T}{H P_k^- H^T + R} \quad (7)$$

By the Eq. 7 shows that the residual gain increases with the decrease of the observed noise covariance R ,

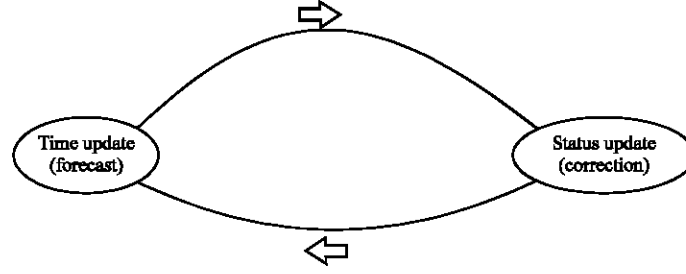


Fig. 1: Cycle update graph of Kalman filter

while the priori estimated error covariance PG_k decreases with the decrease of the residual gain and when R tends to zero there is the relationship in the Eq. 8:

$$\lim_{R_k \rightarrow 0} K_k = H^{-1}, \lim_{R_k \rightarrow 0} K_k = 0 \quad (8)$$

Kalman filter uses the feedback control method to estimate the process state, by estimating the state of the process at a time obtain the feedback by the way of measurement; So the Kalman filter is divided into two parts, the cycle refreshing of the Kalman filter is in Fig. 1 below.

The time update equation of Kalman filter is in the Eq. 9 below:

$$\begin{cases} \hat{x}_k^- = A\hat{x}_{k-1}^- + Bu_{k-1} \\ P_{k-1}^- = AP_{k-1}A^T + Q \end{cases} \quad (9)$$

The state update equation of Kalman filter is in the Eq. 10 below:

$$\begin{cases} K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \\ \hat{x}_k = \hat{x}_{k-1}^- + K_k (z_k - H\hat{x}_{k-1}^-) \\ P_k = (I - K_k H) P_k^- \end{cases} \quad (10)$$

Parameter settings of Kalman filter in the application: In the video sequences of soccer game, the players and the football's movement and the camera angle's change, resulting in the movement of players' region and football's region in the image; this study aims to deal the state update situation of the target between the two adjacent images, as the time interval is very small, the movement of the football and player during this period can be seen as uniform motion. So the speed can reflect the target's movement trends, use the motion parameter of football and players to locate the target's position and speed at a certain time.

Define the system state x_k of Kalman filter as a four-dimensional vector as in the Eq. 11:

$$x_k = (xs_{k0} \ ys_{k0} \ xv_{k0} \ yv_{k0})^T \quad (11)$$

In Eq. 11, xs_{k0} , ys_{k0} , xv_{k0} , yv_{k0} respectively represent the position and speed of target in the X axis and the Y axis direction, because in the image observation we can only observe the target's position, so the definition of the observation state vector z_k is $(xw_{k0} \ yw_{k0})^T$.

State transition matrix A is defined as Eq. 12 below:

$$A_{k,k-1} = \begin{pmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (12)$$

In Eq. 12 Δt means the moment $(t_k - t_{k-1})$.

Through the relationship between the system state and the observed state the observation matrix H_k can be derived as in Eq. 13:

$$H_k = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \quad (13)$$

Suppose the w_k and v_k are and mutually independent noise vector with zero mean, so covariance matrix is shown by Eq. 14 below:

$$Q_k = \begin{pmatrix} 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{pmatrix}, R_k = \begin{pmatrix} 1.0 & 0.0 \\ 0.0 & 1.0 \end{pmatrix} \quad (14)$$

By the Eq. 9 and 10, P_{k-1} will gradually converge accompanied by the number of update cycles, the initial time can theoretically take any value within the range, the value P_0 in this article is as Eq. 15 below:

$$P_0 = \begin{pmatrix} 2.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 2.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 2.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 2.0 \end{pmatrix} \quad (15)$$

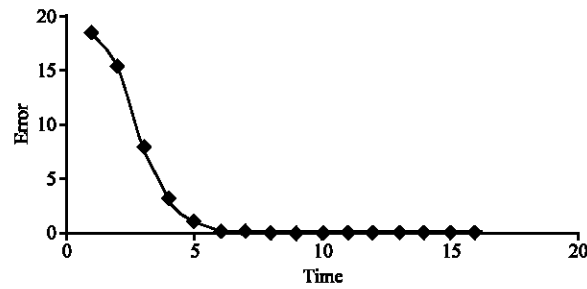


Fig. 2 : Error trends

Calculation step:

- Step 1:** Initialize the filter, that is using the target's position and velocity obtained in the target detection process to assign initial value to the vector x_0 , when the velocity is unknown, it is set to zero
- Step 2:** Before processing each subsequent frame image, calculate the time interval of previous frame, set it as Δt and substitute it into Eq. 12, predict the current state motion $\hat{x}_k$ and then detect a certain area that takes the center as the midpoint (XS_k, yS_k) of $\hat{x}_k$, seek the target pattern's best match and get points (xw_k, yw_k)
- Step 3:** Bring $Z_k = (xw_k, yw_k)$ into the Eq. 10, update the state of Kalman filter, then cycle

EMPIRICAL ANALYSIS

Motion estimation data analysis of uniform motion simulation experiment: For the uniform motion of the starting position (10, 15), the initial velocity (-7, 12) and velocity (10, 5) we carry through simulated motion estimation experiments, the predicted results are shown in Table 1.

From Table 1 the error continues to increase over time and the trend is shown in Fig.2:

Motion estimation data analysis of non-uniform motion's actual video game: In the video sequence analysis, the motion of players and the football is not uniform motion, the movement has unknown; by the use of the Kalman filter estimation results of a player's motion with the initial position (79, 245) and the initial velocity (10, 10) in the soccer video is shown in Table 2.

Table 2 shows the error is not monotonous under the target's non-uniform motion estimation but with the increase of the simulation number the error convergence phenomenon will not appear.

Table 1: Prediction result data of uniform motion simulation experiment

Time	Target coordinates	Predicted coordinates	Error
1	20, 20	3.000, 27.000000	18.384800
2	30, 25	15.8333, 30.83330	15.320600
3	40, 30	32.1743, 33.00000	7.871900
4	50, 35	47.0976, 36.19510	3.138860
5	60, 40	59.0677, 40.38390	1.008250
6	70, 45	69.5059, 450.7990	0.209904
7	80, 50	80.0189, 49.9922	0.052832
8	90, 55	90.0489, 54.97990	0.036043
9	100, 60	100.0170, 64.99310	0.018036
10	110, 65	110.0170, 64.99310	0.007169
11	120, 70	120.0070, 69.99730	0.002207
12	130, 75	130.0020, 74.99990	0
13	140, 80	140.0000, 79.99990	0
14	150, 85	150.0000, 180.0000	0
15	160, 90	160.0000, 90.00000	0
16	170, 95	170.00000, 95.0000	0

Table 2: Motion estimation data of non-uniform motion's actual video game

Time	Target coordinates	Predicted coordinates	Error
1	88, 63	89.225	8.06226
2	101, 276	97.83333, 274.333	3.57849
3	113, 290	111.5714, 289, 143	1.66599
4	123, 303	124.498, 303.65900	1.36596
5	136, 316	134.367, 316.64000	1.75420
6	153, 324	147.504, 329, 3.680	7.68248
7	162, 329	166.135, 335.94400	8.08205
8	175, 321	175.105, 338.29400	17.29460
9	183, 302	187.343, 324.83900	23.24790
10	194, 282	194.265, 297.18700	15.18890
11	203, 264	204.427, 269.34130	5.59815
12	121, 249	213.031, 247.38700	1.91426
13	225, 231	221.526, 231.81600	3.56896
14	231, 219	235.189, 213.90400	6.59662
15	243, 208	240.786, 203.00200	5.46624
16	255, 196	252.58, 194.129000	3.05893

CONCLUSIONS

In this study, it uses the Kalman filter method to implement the motion estimation algorithm in the football game video; For uniform motion simulation experiments, the prediction error has the characteristics that converge to 0 with the increase of the iteration numbers, indicating that the algorithm can be well applied in soccer video simulation; for the motion estimation in the actual game video of non-uniform motion, the application of this algorithm has certain error; although the error does not converge with the increase of iteration numbers but the relative error in most cases is smaller and has some help from the video analysis.

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