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Motion Capture Systems Using Optimal Signal Processing Algorithm: A State-of-the-art Literature

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Abstract Motion capture system is a promising research area but the availability of the state-of-the-art literature review on this topic is limited. This research provides a comprehensive literature review for motion capture systems with Kalman filtering algorithms. The summarized state-of-the-art literature review of motion capturing system is being analyzed considering the advantages and the disadvantages of motion capture systems using Kalman filtering algorithm. Afterwards, the human body incorporating noises is represented by system of equations where the system states are unknown. The Kalman filter is adopted to estimate the human body orientations. Simulation results show that the proposed algorithm can be used to track human body orientation accurately.

Keywords Human Body Orientation, Sensors, Kalman Filter, Motion Capture Systems

1. Introduction

In today's world, motion capture has proven to be an extremely useful technique for animating human and human like characters. Motion capture is the process of sampling the position and location information of a subject over time. The subject usually can be a person, an animal or a machine. Basically, the Kalman filter is an optimal estimation algorithm that can track human body segment, temperature, noise system or many kinds of systems. Motion capture system is a promising research area but the availability of the state-of-the-art literature review on this topic is limited. Being driven by this motivation, this paper provides a comprehensive literature review of motion capture using Kalman filter (KF). The main contributions are summarized as follows:

- A comprehensive state-of-the-art motion captures system is being analyzed with advantages and disadvantages of different approaches.
- The human body is represented by system of equations corrupted by noises where the system states are unknown. The Kalman filter is adopted to estimate the human body orientations
- Simulation results show that the proposed algorithm can be used to track human body orientation accurately.

The paper is organized as follows. A comprehensive literature review of motion capture systems using Kalman filter has been discussed in Section 2. Section 3 elaborates signal processing algorithm. Simulation results are described in Section 4. It has been ended up with a conclusion in Section 5.

2. Literature Review

This research provides a comprehensive literature review for motion capture (MoCap) systems using KF algorithm. The KF can estimate the system state when it cannot be measure directly [1-4]. Tables 1-2 show the state-of-the-art literature review for MoCap systems. The KF can play important role in marine integrated navigation system and radar tracking system because it helps to decrease error [5-8]. A very useful technique of wearable sensors can be used to track lower body motion capture by using a cascaded KF based sensor fusion algorithm. It has a great influence on track down joint angles of elbow and shoulder, human motion analysis: deploying sensors for gravity measurement in a body area with wearable inertial sensor. This method can accurately capture dynamic activities without drift [9-15]. For estimating human body orientation, a cascaded two steps KF can be used [16]. For estimation of the spatial orientation of body segments, sensor fusion allows to achieve more robust solutions [17]. In this case, the extended KF can be used for estimating the three-dimensional orientation of a rigid body [18, 19]. Furthermore, the multi view human pose estimation process is described in [20-22]. For determining heart rate, a KF algorithm is used in [23, 24]. It has a significant role not only in the medical science but also in weather forecasting [25]. Object tracking is another widely used term in motion capture systems [26]. IMU and position sensor can be used for fastening tool tracking based on KF scheme [27]. This recursive algorithm can enhance sensor fusion and can be applied to embedded sensor for more robust solution [28, 29]. It has been observed that KF provides accurate and suitable solution for hybrid estimation algorithm and state estimation for large-scale systems [30, 31]. Finally, it can be recognized that motion capture system using KF has great impact on industrial applications [32-37].

Table 1. (Part 1 out of 2): A comprehensive literature review of motion capture systems.

Method	Advantage	Disadvantage
Object tracking based on Kalman filter [26].	• Can track down moving object accurately. • Errors are very small.	• Covariance being assumed.
Pperformance analysis of hybrid estimation aalgorithms [30].	• Understanding is easy. • Estimation algorithm is more accurate.	• Algorithms are scenario dependent.
Evaluation and comparison for large-scale systems [31].	• Providing suitable solution. • Three types of Kalman filters.	• The accuracy of the systems will need to improve.
Enhanced sensor fusion based on Kalman filter [28].	• Has the ability to overcome the sensitivity of the system. • High robustness to the uncertainties.	• The process is expensive.
Probabilistic now-casting of object-oriented tracked convective storms [25].	• Noise parameters use physical quantities. • Help one to choose a reasonable parameterization for the filter.	• The system cannot stable for different situations.
Rapid tool tracking system using IMU and position sensor [27].	• Can estimate orientation and position correctly. • Reduce orientation error.	• Quaternion system might not give correct value. • Very lengthy process.
Marine integrated navigation system [5].	• Helps to decrease error on marine navigation system.	• The process and measurement covariance matrices are unknown.
Aircraft turbofan engine health estimation [6].	• Effective method for turbofan engine health estimation.	• Requires larger computational effort.
3-D radar tracking estimation [7].	• Nonlinear process and measurements can be solved effectively.	• Covariance being assumed.

Table 2. A comprehensive literature review of motion capture systems.

Method	Advantage	Disadvantage
Navigation system on ultra-tightly coupled SINS/GPS [8].	• Can avoid the impact of abnormal error. • Tracking stability is significant.	• Failed to detect initial errors.
Discrete KF based sensor fusion for robust accessibility interfaces [34].	• Accessibility interfaces over small screens. • More robust solution.	• Less susceptible to outer surface. • Less susceptible to its environment.
Overview about industrial applications of KF [32].	• Summarized the research efforts made over the past two decades.	• Authors stated that KF implementation in real time is very complex.
Fault identification in a fluid catalytic cracking unit [35].	• True estimation obtains easily. • More accurate state values.	• Complicated chemical process.
Optical motion captures data solving [36].	• The burden of hand processing is reduced	• Not automatic process. • Sometimes shows error even if there is nothing.
Embedded sensors being applied by KF [29].	• Applicable for real-time systems. • Great capabilities to cope up with complex application.	• Limited availability of processing power. • Filter equation finds it difficult to fit with low power requirements.

For the improvement of orientation estimation, indentifying covariance matrices [21].	• Can indentify covariance values. • Reduce the period of the process.	• Noise covariance method cannot properly estimate the noises.
Determining orientation using inertial or magnetic sensors [13].	• Lie derivatives can apply to test the observability.	• Large estimation errors.
Miniature orientation sensor for wearable human motion systems [15].	• Estimation accuracy is significant improved. • Applicable for real life condition.	• Failed to give explanation about noise affected sensors.
Motion captures systems for lower body and trajectory tracking [9].	• Accuracy of 3D localization rise remarkable. • Accurately track joint angles.	• The process is more complex and cannot apply in real time.
Estimation of vertical trajectory tracking with integrated inertial and pressure sensor [16].	• Avoids unnecessary states estimation.	• This process used complicated two-step cascaded KF.

3. KF Algorithm

The orientation of the human body is represented by [18], [37]:

$$s_{k+1} = \Phi s_k + w_k \,, \tag{1}$$

here, $s = [a \ \Delta a]'$ is the state vector at time k, a is the orientation of the human body, Δa is the difference between actual and measured signal, Φ is the state transition matrix and w_k is the white noise [33].

The measurement can be modeled as:

$$z_k = H s_k + \upsilon_k \tag{2}$$

here, z_k is the actual measurement. Connection between the state vector and the measurement vector is H. υ_k is the associated measurement error [9]. Φ and H are given by [37]:

$$\Phi = \begin{bmatrix} 1 & -\delta t \\ 0 & 1 \end{bmatrix}, H = \begin{bmatrix} 1 & 0 \end{bmatrix}. \tag{3}$$

Here, δt is the step size and H is the sensing matrix. Based on the process and measurement, optimal KF is adopted to estimate the system states [25]. The whole process is described in Fig. 1. It has two steps: prediction and correction.

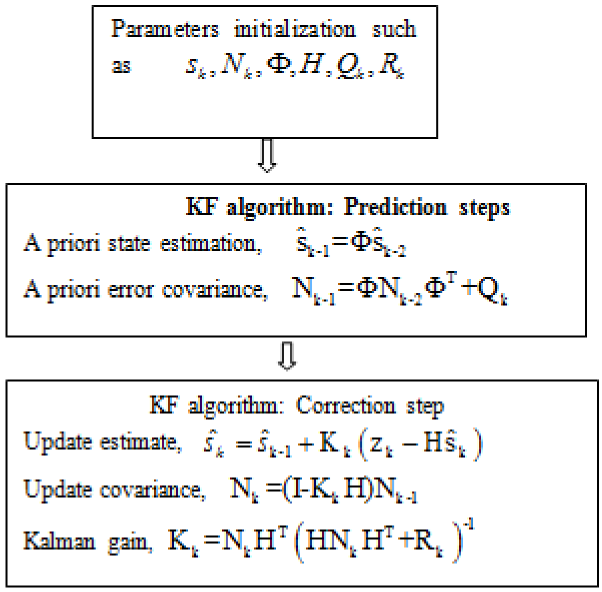

Figure.1. Flowchart of KF algorithm [37].

4. Simulation Results and Discussions

The process and noise covariance are assumed to be 0.005**I** and 0.05**I**. Matlab is used for simulation. The simulation result is shown in Fig. 2 when step size is 0.001 sec. It is observed that the proposed algorithm can accurately track the orientation of the human body.

When the step size is 0.01 sec, the simulation is illustrated in Fig. 3. It can be seen that, the proposed algorithm can properly track the orientation of the human body.

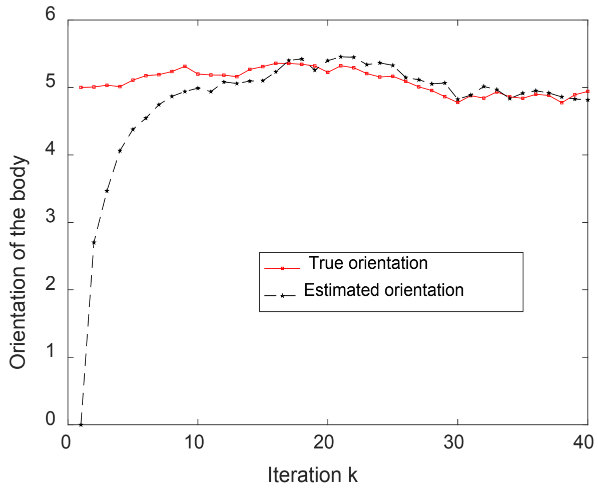

Figure 2. Orientation of the human body with step size=0.001.

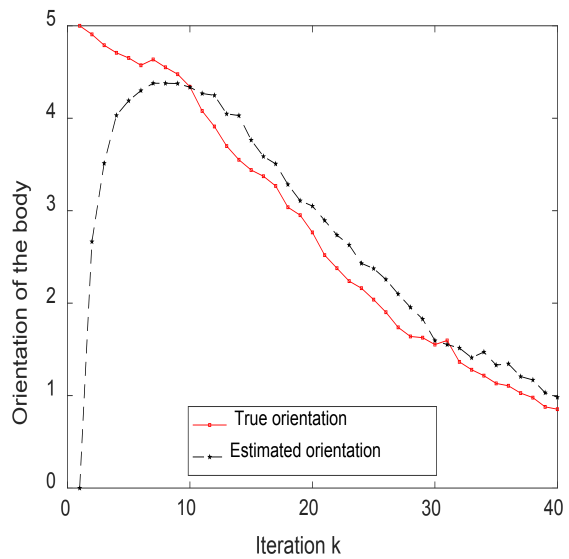

Figure 3. Orientation of the human body with step size= 0.01.

5. Conclusions

A comprehensive literature review has been provided on motion capture systems using optimal signal processing algorithm. Simulation result shows that the proposed algorithm can properly track the orientation of the human body. Hopefully, this work is valuable for beginners who want to know the relative advantages and disadvantages of motion computer systems and applied methods.

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