Advances in Computer Science Research, volume 89
2019 International Conference on Wireless Communication, Network and Multimedia Engineering (WCNME 2019)

A Human Body Motion Capture System Using a Wireless Inertial Sensor

Pengzhan Chen[1,*], Wei Chu[1] and Junchao Wang[1]
[1]East China Jiaotong University, Nanchang, China
[*]Corresponding author

***Abstract*—In this study, a wireless inertial sensor system was designed for application in human motion capture. A human body node displacement and attitude data decoding strategy is proposed based on the gait analysis method, synthesizing the advantages of the complementary filter and Kalman filter methods. A human body motion capture verification platform was set up, and the performance of the wireless inertia sensor network capture system was evaluated. Results show that the designed wireless inertial sensor system can accurately measure joints in the process of human movement in real-time. The proposed attitude algorithm strategy has better accuracy in precise real-time tracking of human motion.**

***Keywords*—motion capture; inertial navigation; complementary filter; wireless sensor network**

I. INTRODUCTION

Human motion capture involves interdisciplinary integration of fields such as electronics, communication, control, computer graphics, ergonomics, and navigation. Human motion capture has vast potential for use in fields such as film and television production [1], robot control [2], interactive games [3], sports training [4], and medical rehabilitation [5]. At present, human body motion capture has become a hot spot in the field of human-computer interaction.

Common optical motion capture systems include Vicon [6] and BTS [7]. With the development of inertial sensor technology and communication technology, real-time tracking of human motion can be achieved by setting up an inertial sensor unit on each joint of the human body.

In this study, a motion capture node composed of an inertial sensor, microprocessor, and high-speed wireless transmission channel is designed. A human body motion capture wireless sensor network platform is set up by decorating a wireless sensor network with multiple sensors in the nodes of each joint. Then, we propose a rotation vector extraction scheme based on space rotation and a gait analysis displacement calculation model based on strapdown inertial navigation. Finally, a type of human body motion capture data verification platform is designed according to the theory of computer graphics. We evaluate the performance of the designed wireless inertial sensor human motion capture system.

II. DESIGN OF HUMAN BODY MOTION CAPTURE SYSTEM PLATFORM

A. Hard Ware Design of the Capture Node

Sensor nodes are placed on each major movement joint in human motion capture. To reduce the computational load of the motion capture system and improve the efficiency and real-time performance of the system, each node should collect inertial sensor data independently and calculate. At the same time, to facilitate the distribution of independent nodes, each node should have a high-speed data transmission channel.

According to the aforementioned specifications, the design in this study uses a TI company CC3200 chip as the core of data processing and transmission and adopts the MPU9250 inertia sensing unit of Invesens to reduce the system volume. The principle of composite inertia nodes is shown in Fig.1.

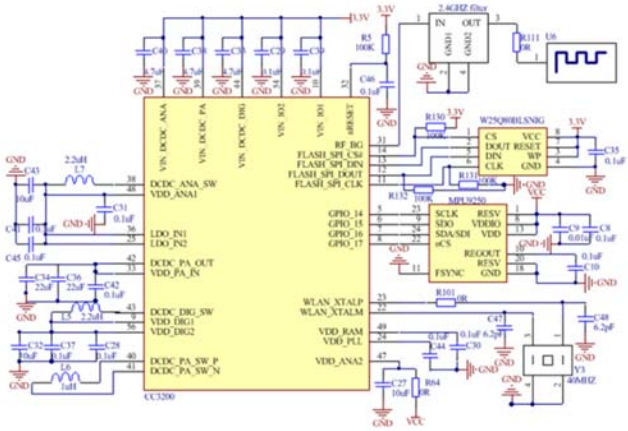

FIGURE I. PRINCIPLE DIAGRAM OF SENSOR NODES

B. Analysis of Data Flow of Motion Capture System

This study uses a PC as a server and each sensor node as the client, there by forming a star topology network. Through address assignment, independent IP addresses are assigned to each sensor node to achieve data interaction between the client and the server. The constructed body feeling network star structure diagram is shown in Fig. 2.

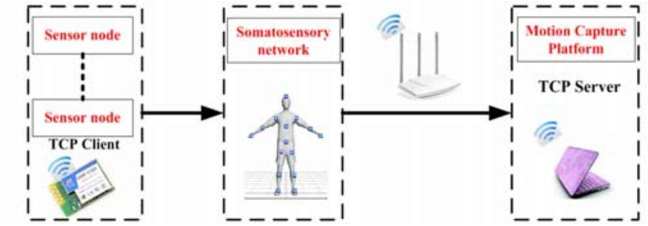

FIGURE II. BODY FEELING NETWORK STAR TOPOLOGY

III. ANGLE MEASUREMENT STRATEGY OF INERTIAL SENSORS

The space angle exact solution based on inertial sensors is an important step in human motion capture. Bachmann [8] proposed the Kalman filter algorithm based on quaternion. Roetenberg et al. [9] proposed a type of compensation for the Kalman filter algorithm. Yun et al. [10] adopted a factor quaternion algorithm to replace QUEST, which reduces computing complexity. However, the aforementioned methods could not completely eliminate data drift.

We convert the Euler angle to quaternions q0, q1, q2, and q3. Then, we introduce a complementary filter to conduct the fusion calculation of posture and to obtain a stable attitude quaternion. The Euler angle of the movement can be derived through transformation of the quaternion and Euler angle formula. To further improve the anti-interference performance, a Kalman filter is conducted to the attitude quaternion through a decoding strategy. The decoding strategy is shown in Fig. 3.

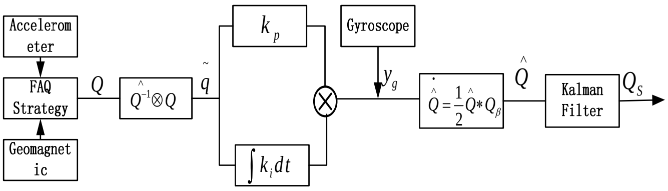

FIGURE III. ANGLE SOLVING STRATEGY

The optimal estimate angle can be obtained after applying the Kalman filter. Fig. 4 is a set of the quaternion of movement angle calculated by this algorithm.

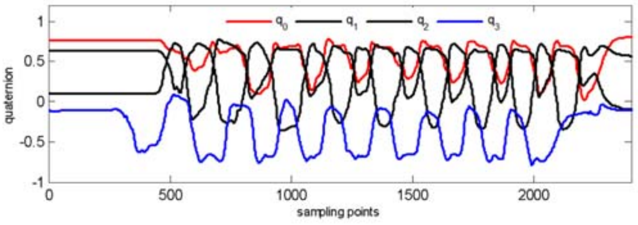

FIGURE IV. QUATERNION OF MOVEMENT ANGLE

IV. SENSOR DISPLACEMENT STRATEGY

Based on reference [11-12], this study fully considers the 3D features of the walking process. A kind of initial azimuth reset method at the ZUPT moment is proposed. The human walking process can be divided into several steps. In each step, the ZPUT can be used as a starting point for the navigation cycle. The displacement solution strategy for walking is shown in Fig. 5.

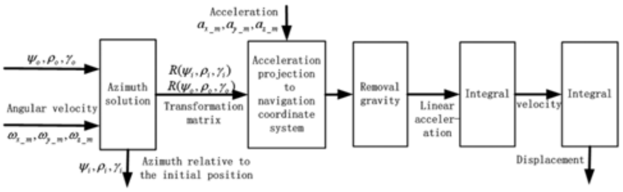

FIGURE V. DISPLACEMENT CALCULATION PROCESS

At time *T1*, the transformation matrix from $Ox^by^bz^b$ to $Ox^ly^lz^l$ is $R(\Psi_0, \rho_0, \gamma_0)$. At this time, we assume that the initial azimuth is $(\Psi_0, \rho_0, \gamma_0)$. In the process of walking, we set the carrier system of three-axis angular velocity measured by the inertial components as $\omega_{x\_m}, \omega_{y\_m}, \omega_{z\_m}$; acceleration as $a_{x\_m}, a_{y\_m}, a_{z\_m}$; sampling period as δt; and *m* as sampling time. Suppose that *m* time is the transformation matrix of the location of the coordinate system $Ox^by^bz^b$ to the corresponding position of T1 time is $R(\Psi_m, \rho_m, \gamma_m)$. The velocity and displacement at *m* moment when vector coordinate axis is in the coordinate system $Ox^ly^lz^l$ can be represented by the following formula:

$$\begin{bmatrix} v^l_{x\_m} \\ v^l_{y\_m} \\ v^l_{z\_m} \end{bmatrix} = \begin{bmatrix} v_{x\_0} \\ v_{y\_0} \\ v_{z\_0} \end{bmatrix} + \begin{bmatrix} \sum_{j=1}^{m} a^l_{x\_m}\delta t \\ \sum_{j=1}^{m} a^l_{y\_m}\delta t \\ \sum_{j=1}^{m} a^l_{z\_m}\delta t \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} s^l_{x\_m} \\ s^l_{y\_m} \\ s^l_{z\_m} \end{bmatrix} = \begin{bmatrix} s_{x\_0} \\ s_{y\_0} \\ s_{z\_0} \end{bmatrix} + \begin{bmatrix} \sum_{j=1}^{m} v^l_{x\_m}\delta t \\ \sum_{j=1}^{m} v^l_{y\_m}\delta t \\ \sum_{j=1}^{m} v^l_{z\_m}\delta t \end{bmatrix} \tag{2}$$

In the walking process, the initial azimuth angleΨ_0, ρ_0, γ_0 can be calculated by the calculation strategy in Section3.3. Taking *T1* and *T2* as a navigation cycle and combining it with the above equation allows us to calculate the speed and displacement of every step and every moment.

V. EXPERIMENTATION

Based on the dynamics of the human body, a 3D tracking model was built on the basis of the topological structure of human motion. First, we produced a bone model through 3dmax. Then, we loaded the bone file under the OpenGL graphics library environment of the Visual Studio. A diagram of the system is shown in Fig. 6. The motion capture interface was constructed based on Fig.10 through certain matrix calculations. The calculation process of movement characteristic parameters is shown in Fig. 7.

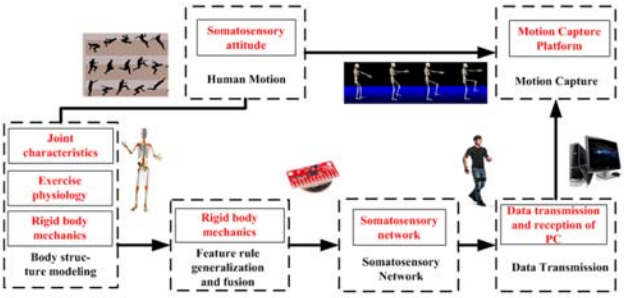

FIGURE VI. SYSTEM STRUCTURE OF MOTION CAPTURE

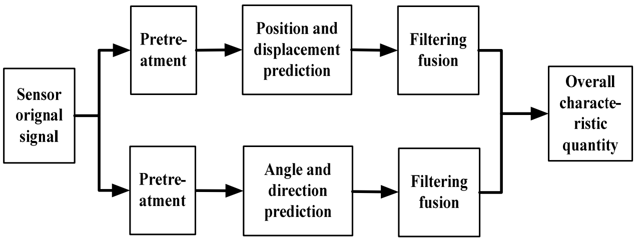

FIGURE VII. CALCULATION PROCESS OF CHARACTERISTIC PARAMETERS

In this study, a total of 344 reduction data frames were obtained through real-time BVH motion capture data exported by the motion capture platform. Action restore was conducted on the data frame to verify its accuracy. The reduction results are shown in Fig. 8.

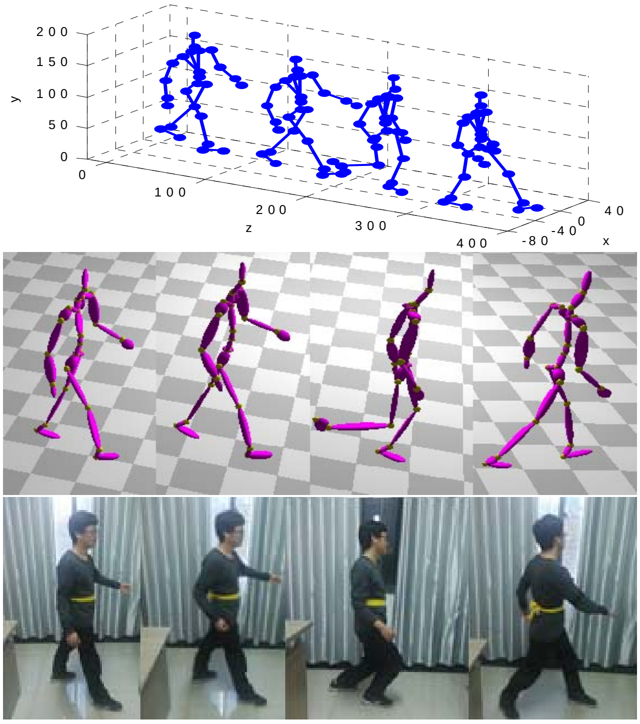

FIGURE VIII. BVH MOTION CAPTURE DATA REDUCTION EFFECT OF WALKING PROCESS

Similarly, a total of 713 frames and 2980 frames, respectively, from walking to sitting were obtained through real-time BVH motion capture data exported by the motion capture platform. The precision of the system was verified through MATLAB and Visual Studio motion capture verification platform *t*. Fig. 9 respectively show real images of sitting movements.

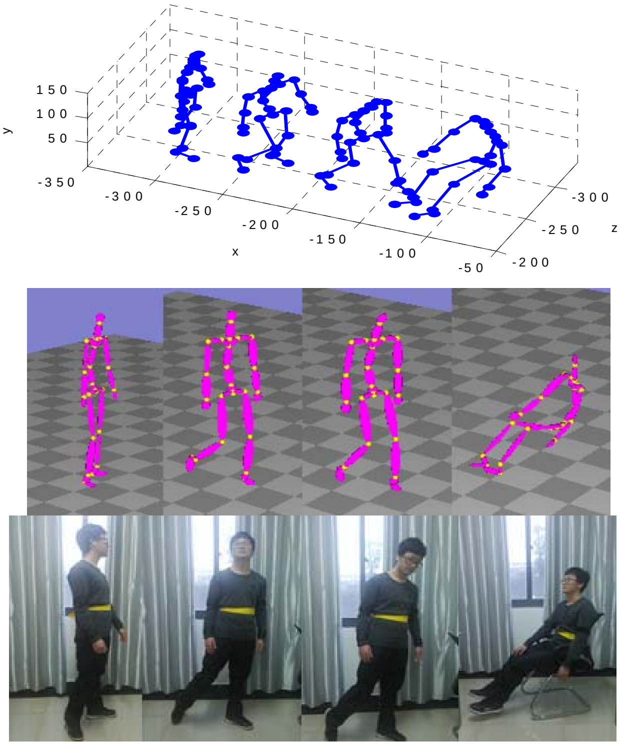

FIGURE IX. BVH MOTION CAPTURE DATA REDUCTION EFFECT OF SITTING

The aforementioned movement reduction effect shows that the BVH file action reduction effect generated by the designed motion capture system can perform the reduction of real motion at a basic level. Thus, the algorithm designed in this paper has a certain reference value, and the performance of the system can be guaranteed.

VI. CONCLUSION

Results of the evaluation analysis of inertia of the wireless sensing human motion capture system show that the human motion capture system based on inertial sensors can accurately capture the human body movement process in real time. This study used the network-distributed sensing model to arrange sensor location flexibly and to distribute the attitude algorithm task during motion capture to the motion capture platform and sensor node in a balanced manner. This specification improves the accuracy of real-time motion capture and provides a new method and perspective on the inertia of human body movement.

REFERENCES

[1] TAN W., LI W., ZHENG Y., et al.: ‘A physical game based on wireless sensor networks’, International Journal of Distributed Sensor Networks, 2009, 5(1), pp. 68

[2] WEI H., ZHAO J.: ‘Real-time control of 7R manipulator based on motion capture’, Journal of Mechanical Engineering, 2013, 23(49), pp. 68-73.

[3] WANG Z., QIU Sen, CAO Z., et al.: ‘Quantitative assessment of dual gait analysis based on inertial sensors with body sensor net-works’, Sensor Review, 2013, 33(1), pp. 48-56.

[4] WALLACE E S, HUBBEL J E, ROGERS M J.: ‘Driver shaft length influences on posture and swing tempo in skilled golfers’, The Engineering of Sport, 2004, 1(5), pp. 216-223.

[5] WANG Z, ZHAO C, QIU S.: ‘A system of human vital signs monitoring and activity recognition based on body sensor network’, Sensor Review, 2014, 34(1), pp. 42-50.

[6] M. Senesh, A. Wolf: ‘Motion estimation using point cluster method and Kalman filter’, J. Biomech. Eng., 2009,5(5), pp. 051008:1-051008:7.

[7] H. Karnath, J. Ruter, A. Mandler, and M. Himmelbac: ‘The anatomy of object recognition-Visual form agnosia caused by medial occipitotemporal stroke’, J. Neurosci.,2009,5(18), pp. 5854–5862.

[8] Bachmann E R.: ‘Inertial and magnetic tracking of limb segment orientation for inserting humans into synthetic environments’, Monterey, California: Naval Postgraduate School, 2000.

[9] Roetenberg D, Luinge H J, Baten C T Mt et al.: ‘Compensation of magnetic disturbances improves inertial and magnetic sensing of human body segment orientation’, IEEE Trans on Neural Systems and Rehabilitation Engineering, 2005, 13(3), pp. 395-405

[10] Yun Xiaoping, Bachmann E R, McGhee R B.: ‘A simplified quaternion-based algorithm for orientation estimation from earth gravity and magnetic field measurements’, IEEE Trans on Instrumentation and Measurement, 2008, 57(3), pp. 638-650.

[11] Alvarez D., Gonzalez R C, Lopez A, et al.: ‘Comparison of step length estimators from wearable accelerometer devices’, 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, USA, 2006, pp. 5964-5967.

[12] Li Q, Young M, Naing V., et al.: ‘Walking speed estimation using a shank-mounted inertial measurement unit’, Journal of Biomechanics, 2010, 43(8), pp. 1640-1643.