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Human Posture Detection Based on Human Body Communication with Muti-carriers Modulation

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Abstract – Multi-node sensors for human posture detection, by acquiring kinematic parameters of the human body, helps to further study the laws of human motion. It can be used as reference for the quantitative analysis tool for some specific application, such as healthcare, sports training and military affairs, etc. Compared with the traditional optical method, posture detection based on the inertial sensors has smaller limitation of space, lower cost, and easier implementation. In this paper, a human posture detection system was introduced. Utilizing the parameter data obtained by the inertial sensors, three-dimensional angles of the human hand movement could be calculated via quaternion algorithm for data fusion. The angles data transmission among the sensor nodes was successfully realized by the human body communication(HBC) transceivers based on capacitive coupling of multi-carriers OOK modulation at the data rate of 57.6kbps. The bit error rate(BER) was less than 10^{-5}. The human posture could be reconstructed on the PC host. Ultimately, the implementation of the overall result showed the feasibility of the system.

Keywords - Inertial sensors, Human body communication, Multi-carriers OOK modulation, Posture reconstruction

I. INTRODUCTION

In recent years, human action recognition combined with specific applications such as virtual reality, health care, sports training, has caught much attention. Human posture is closely related to some disease characteristics. Detection will be further helpful for some specific condition as a quantitative tool. Physical therapy with quantitative approaches for geriatrics training or Parkinson's patients for example[1]. Due to the improvements of Micro-Electro-Mechanical system (MEMS)[2][3], the size, accuracy, robustness and dynamic response are greatly improved. Compared with the traditional optical method, inertial sensors for posture detection has lower cost, less space requirement, and easier implementation.

However, traditional means of communication among the inertial sensors are often based on Bluetooth, RF, Zigbee or WIFI[4], which have high power consumption and are likely to cause radiation and wireless signal aliasing. To reduce these impacts, the human body communication(HBC) has been introduced. HBC utilizes the human body as signal channel to transmit the data among the nodes. Capacitive coupling method of HBC transmits signals by generating an electric field so that the sensors attached on or implanted in the human body could share the information. Methods of HBC system are divided into two types. The first is the direct transmission of digital square wave signal without modulation[5][6], and the second is a modulation scheme with carrier frequency[7]. While the latter one is more conducive to achieve high data rate[8] and multichannel transmission[9].

In this paper we proposed a novel approach to the human posture detection system design. In order to save the channel resources and reduce the radiation impact, taking the direct measurement of the human body posture into account as well, capacitive coupling method of HBC with multi-carriers on-off keying(OOK) modulation was considered to achieve the two ways transmission of digital signals. The circuit of OOK modem has been proposed, which was capable to transmit the digital signal at the rate of 57.6kbps and the BER was less than 10^{-5}. Besides, multi-carriers modulation method was adopted to realize the two channels parallel transmission in real time.

II. SYSTEM DESIGN

Body posture detection system can detect the precise angle information of human action, and play an important role as a quantitative tool for some specific application. In this paper, a human gesture detection system design was proposed. Three inertial sensors was capitalized on to collect and process information of the posture angle. HBC was responsible for the two ways sensor data transmission among the sensors at the data rate of 57.6kbps. Eventually, the reconstruction operation was implemented on the PC.

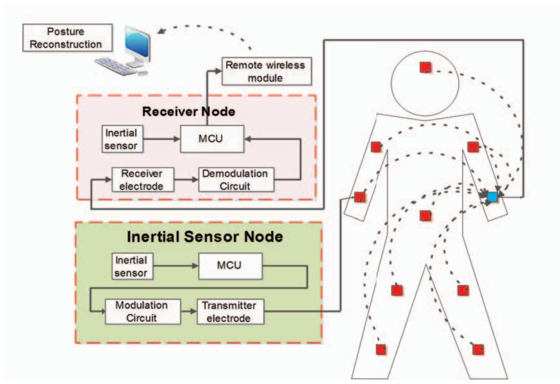

Fig.1 Diagram of the proposed human posture detection system

The structure of the system can be showed in Fig. 1, it comprises of: (1) Inertial sensor nodes, (2)HBC device, (3)Reconstruction of body posture. To begin with, the inertial sensor node, which consists of accelerometer, gyroscope and magnetometer, will detect the kinematics data of the body. Fig.1 shows the structure of the sensor. In this paper, we had three sensors put on the up arm, lower arm and hand respectively to get the kinetic information of the three parts. Then algorithm of data fusion will figure out the three-dimensional angles of three parts in the free space. The capacitive coupling HBC was used for wireless transmission. Only the signal electrodes of TX and RX are attached to the body while the ground (GND) electrodes are left floating. The TX establishes the quasi-static electric field, while the RX detects the electric potential at the remote end in this application[10], therefore, the information could be shared between TX and RX, which performs less attenuation than the galvanic coupling. As shown in the Fig.2. In this mechanism, the node 1 got the upper arm posture data and then transmitted it with carrier 1 modulation. The node 2 received the data via the HBC receiver 1 and transmitted the data of node 2 and node 1with carrier 2 frequency modulation. Finally, the node 3 received former two channel signal via HBC receiver 2, and then the received signals together with the data of node 3 would be used to reconstruct the posture on the PC. Therefore a tree structure was formed to detect the arm and hand posture. The transceivers position setup on the human body is as Fig.5.

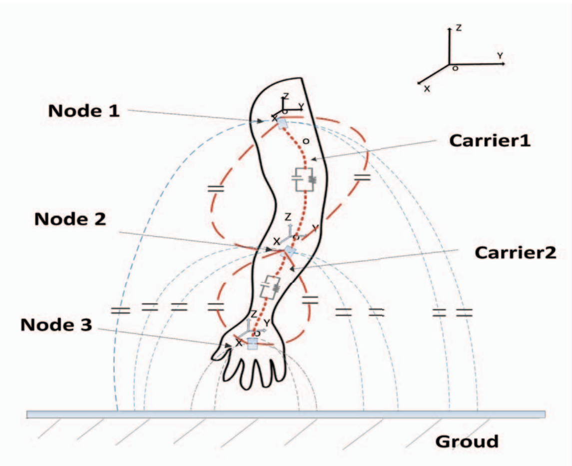

Fig.2 The HBC mechanism

III. METHOD

A. Calculation of Angles

In this system, inertial sensor module MPU6050, was adopted considering its convenience in wearable property. With sensor attached, the arm movement for example can be regarded as the coordinate change of the sensor model. Therefore the three-dimensional angles of arm is equivalent to the module's, which could be expressed by quternion as shown in (1). Equation (2) is the carrier's transformation matrix. With the data obtained by the accelerometer, gyroscope and magnetometer, the transformation matrix could be corrected using error vector products. Then the quaternion is refreshed by the numerical integration method, and the RungeKutta method is described as (3). Finally, due to the transformation of quaternion being equivalent to the Euler's, the Roll, Pitch and Yaw angles can be calculated eventually, following the (4)-(6).

$$Q = q_0 + q_1 i_0 + q_2 j_0 + q_3 k_0 = \cos\frac{\theta}{2} + (li_0 + mj_0 + nk_0)\sin\frac{\theta}{2}, \tag{1}$$

$$C_b^R(q) = \begin{bmatrix} 1-2(q_2^2+q_3^2) & 2(q_1q_2-q_0q_3) & 2(q_1q_3+q_0q_2) \\ 2(q_1q_2+q_0q_3) & 1-2(q_1^2+q_3^2) & 2(q_2q_3-q_0q_1) \\ 2(q_1q_3-q_0q_2) & 2(q_2q_3+q_0q_1) & 1-2(q_1^2+q_2^2) \end{bmatrix}, \tag{2}$$

$$\begin{bmatrix} \dot{q}_0 \\ \dot{q}_1 \\ \dot{q}_2 \\ \dot{q}_3 \end{bmatrix} = \frac{1}{2} \begin{bmatrix} 0 & -g_x & -g_y & -g_z \\ g_x & 0 & g_z & -g_y \\ g_y & -g_z & 0 & g_x \\ g_z & g_y & -g_x & 0 \end{bmatrix} \begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{bmatrix}, \tag{3}$$

$$Yaw = \arctan\frac{\sin\varphi}{\cos\varphi} = \arctan\left[\frac{2q_1q_2+2q_0q_3}{1-2(q_2^2+q_3^2)}\right], \tag{4}$$

$$Pitch = \arcsin(2q_1q_3 - 2q_0q_2), \tag{5}$$

$$Roll = -\arctan\left[\frac{2q_2q_3+2q_0q_1}{1-2(q_1^2+q_2^2)}\right], \tag{6}$$

B. Human body communication of OOK multi-carriers modulation

In order to transmit multiple signals, we use a multi-carrier OOK modulation method based on frequency division multiplexing principle. As shown in the Fig.3, the total bandwidth of the human body channel was divided into many sub-bands(or subchannels) to transmit multiple signals with different carrier frequency modulation, while the receiver end would separate the channels, so that multi-channel parallel transmission of signals without interference could be possible. The energy of electromagnetic wave is mainly in the form of electric field when its frequency is below 10MHz in the capacitive coupling of HBC, which performs less radiation and better transmission characteristics[11]. In this system, we use 6MHz, 9MHz as carriers frequency. The narrow band pass filters with center frequency of the carriers separate the two channel signals and removed the unwanted noise.

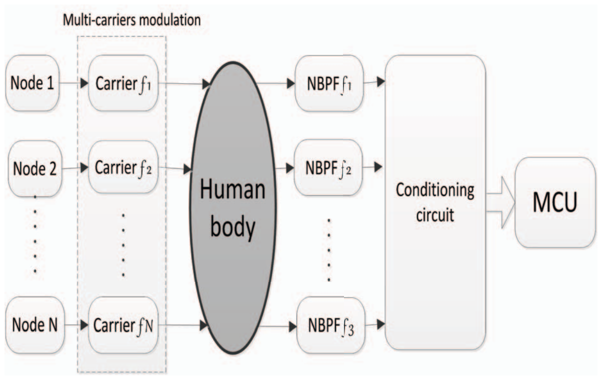

Fig.3 Multi-carriers modulation of HBC

HBC on-off keying modulation scheme is shown in Fig.4. The HBC transceiver realizes the OOK modulation by sinusoidal oscillator circuit and analog switch. We produce the frequency of 9 MHz or 6MHz 3V amplitude sine wave. The digital signal is input to the TXIN. When the TXIN is '1', frequency sine wave is output, and when the TXIN is '0', no signal is output. Thus the OOK modulation is realized. In the receiver, signals suffered attenuation and distortion. Chebyshev passive band pass filter has been employed because of its fast attenuation of the transition band to remove the unwanted signals. The center frequency of the filter is carrier frequency. Then the envelop detector together with the comparator could demodulate the signal and control the electrical level in the range of TTL level, making sure the MCU of the receiver could get the digital signal via the serial port directly.

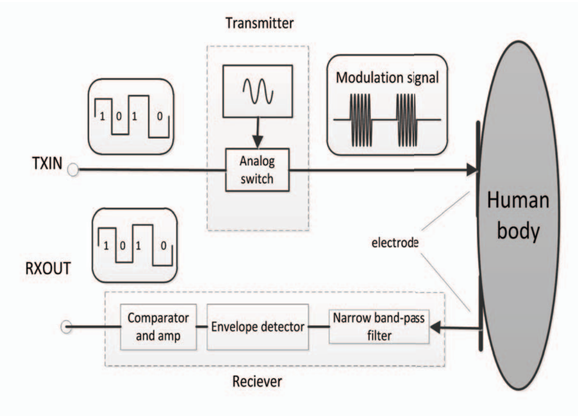

Fig.4 The OOK modulation scheme

IV. Result and Discussions

A. Experiment of HBC

In the measurement experiment, all of the circuits board were powered by battery in order to separate the transmitter node and the receiver node; the Textronix2024 oscilloscope was used in the experiment, which is self-powered by its own battery inside, could keep apart two passageways in the round as well. A 24-years old male's left arm was used as experimental subject. The medical electrode's size was 4cm×4cm.

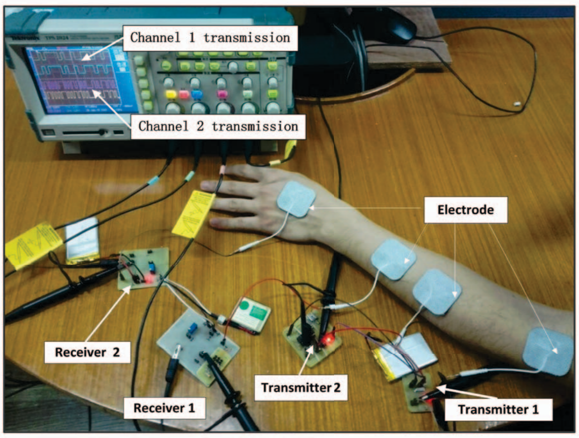

Fig.5 HBC devices experiment

Fig.5 shows the measurement setup and the wave result. The electrodes of transceivers were attached on the human arm and hand back as described in session II. The data was modulated and transmitted though the human body to the receiver board. The test signal was NRZ type generated by a STM32 serial port with a rate of 57.6kbps. The measured output waveform of recovered data could be seen clearly on the screen of the oscilloscope, showing that the data receivers recovered the modulation signals and separated the two channel signals successfully. The Fig.6 shows the output of the modulation signal and the received signal of transceiver 1 whose carrier frequency is 6MHz. After analysis, the bit error bit was less than 10^{-5} when the data rate was 56.7kbps, indicating the HBC system could work successfully.

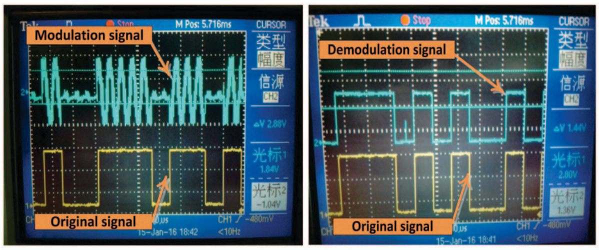

Fig.6 Modulation and demodulation wave form compared with original signal

B. Reconstruction of the posture of human arm and hand

As shown in Fig.7, three inertial sensors are respectively put in the upper, lower arm and the hand back to obtain the attitude angles of the three parts. As a result, the three dimensional angles could be acquired by the computer. The result of reconstruction could be seen in Fig.7, there are three cylinders regarded as the human arm and hand, the red part is the upper arm, and the yellow one is the lower arm, while the purple one is the hand. The result showed that the system based on the inertial sensor was able to measure and reconstruct the human posture.

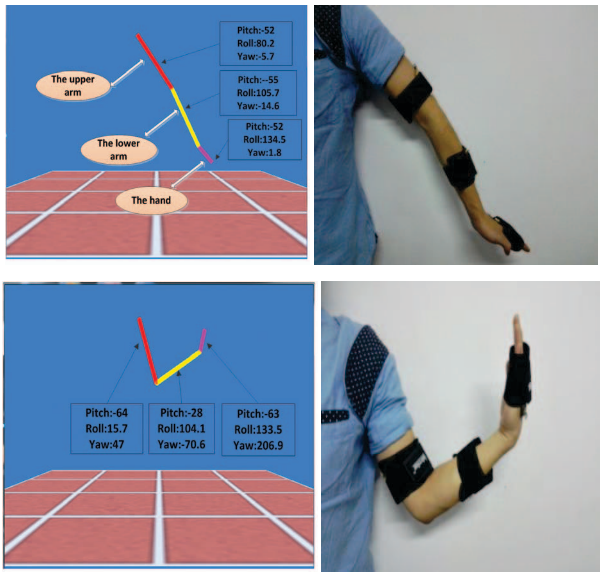

Fig. 7 The reconstruction of human posture

V. CONCLUSION

In this paper, a human posture detection system based on inertial sensors and human body communication was proposed and implemented. Using algorithm of quaternion to calculate the three-dimensional angles of the human arm and hand, the posture information could be obtained. The human body was selected as propagation medium for two channel data transmission. Capacitive coupling method of HBC was considered, besides, the frequency of 6MHz and 9MHz were chosen as multi-carriers frequency in HBC devices of OOK modulation. The transceivers were implemented and the BER was less than 10^{-5} when the data rate was 57.6kbps as system designed. The arm and hand posture could be reconstructed on computer so that the results are visible and quantitative for some specific application.

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