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Design and experimental analysis of gesture analysis system of basketball players for human kinematics

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Abstract. Body motion is a complex process and the study of body motion has a far-reaching influence on many research fields. In the basketball game, we can use the body movement measurement to scientifically plan the training of basketball players. In the automatic control system of robot, the human kinematics measurement provides a theoretical basis and verification platform for motion control such as bionic robot. In clinical medicine, the human motion measurement provides reliable data for the diagnosis and monitoring of medical staff. Gait is a branch of the human movement. Human gait is a long-term formation of a regular movement, and the gait movement contains a lot of sports information. In this paper, we use low-cost inertial sensors, including accelerometers and gyroscopes, to measure human gait data, and through these data to analyze the gait of human body. It is necessary to establish a gait database by collecting the experimental data of many people, so as to lay the foundations for future gait recognition work.

Key words. Gait movement, inertial sensor, gait database.

1. Introduction

Human kinematics is a popular science. As the human body movement is a highly-automated process, each person will have different movement patterns in different environment, that is, the human body movement has a certain random, so many studies are hoping to find the pattern of motion from human kinematics. In human kinematics, human gait is a relatively regular branch. From the birth of a human being to the learning of bipedal walking, the gait of a human being has formed a basic pattern that can be observed and measured, and further analyzed. There is no doubt that the theory of human gait movement can provide guidance for many scholarships and practices. For example, the gait pattern can be used in biped robot gait control strategy, so that the robot can be closer to people walking habits movement, to achieve a high degree of intelligent bionic movement [1].

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In addition, the measurement of human gait can be applied to clinical medicine. Doctors can use the patient's gait data to determine whether the patient needs treatment, or to provide strong data support for treatment [2]. Gait analysis emerged in the European renaissance. In the early days, in order to understand and record the gait information, most people use the method of observation and hand drawing to understand the human gait. A variety of computer equipment are used to collect and deal with human gait information. These methods include video image processing, pressure sensor signal processing and inertial sensor signal fusion processing [3]. These methods provide a theoretical and practical basis for the development of clinical medicine, intelligent robot control and other disciplines.

In this paper, we use low-cost inertial sensors, including accelerometers and gyroscopes, to measure human gait data, and through these data to analyze the gait of human body. It is necessary to establish a gait database by collecting the experimental data of many people, so as to lay the foundations for future gait recognition work [4].

2. 2. Algorithm flow design of gait analysis

After the node's hardware is filtered, the raw data of the inertial sensor is stored in the computer. The host computer program separates the two-node data into left and right node data, and each time the data packets are marked with time, so that the data can be further analyzed to calculate the gait parameters. Figure 1 is a flow chart of data analysis [5].

The data of the two nodes also contain information about the movement of the feet. Through the acceleration and angular velocity data fusion, we can get a single foot of the walking cycle. The original data of the acceleration and angular velocity are the data at the inertial boundary system, so we must project it into the navigation coordinate system and then obtain some spatial parameters such as step size by further integration [6].

In order to automatically identify the number of steps, we use the sliding window method to find the peak, so as to get the number of steps. The specific method is as follows. In the collected N data points, starting from the Mth one, if the ith point to meet the following relationship

$$\theta(k_1) \leq \theta(i) < \theta(k_2) \tag{1}$$

where k_1 and k_2 are the serial numbers of the sampling point, and its range is $k_1 :\ i - N \sim i - 1$, $k_2 :\ i + 1 \sim i + N$, $i :\ M \sim N - M$, M being the size of the sliding window.

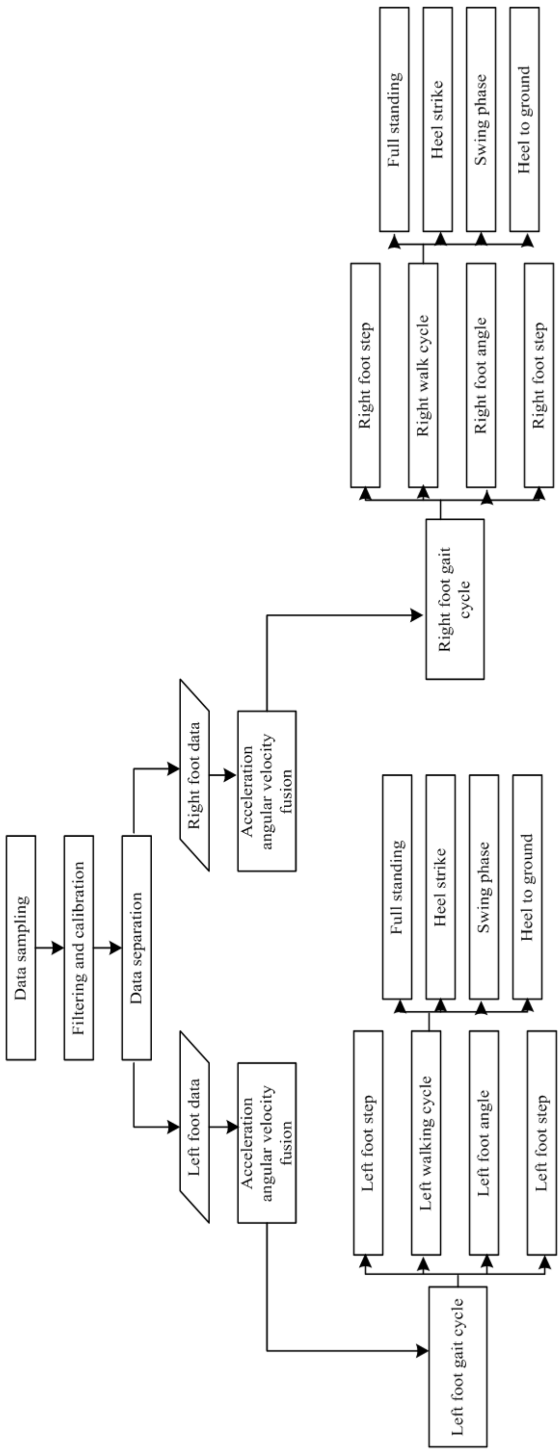

Fig. 1. Flow chart of data analysis

3. Walking cycle

3.1. Introduction of the walk cycle

The human walking process is a regular pattern. For regular movements, it can study its periodicity, and a walking cycle is divided into standing and oscillating phases. The stance phase is the time period when the foot is in contact with the ground. On the contrary, the time period when the foot leaves the ground and moves forward is called the swing phase.

The standing phase and the oscillating phase can be preliminarily divided into gait cycles, which can be done using the pressure sensor to complete the division of these two phases. Because of the use of inertial sensors, the complete process of motion can be captured, so the station can be further divided into heel off, heel strike, and foot flat.

In this way, our walking time can be divided into four stages as shown in Fig. 2, which are full standing, heel to ground, swing phase, and the heel strike. Heel off the ground is the experimental man still, or the heel first left the ground in the next step, but at the same time, the toes are also connected with the ground. The swing phase, as described earlier, is the foot that leaves the ground. Then, followed by the heel hit the ground, when the swing phase is completed, the foot to fall back to the ground, the heel first contact with the ground, and then flat the feet. Finally, when the foot is completely stationary, the other foot will move, and then the foot cycle of a single foot will end.

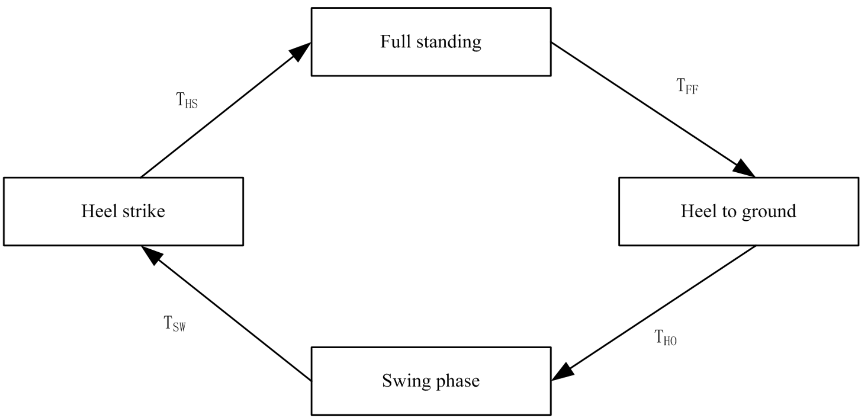

Fig. 2. Single foot walking phase

3.2. Motion decomposition of vector plane

Figure 3 shows the motion process in the vector plane, where $X - O - Y$ is the navigation coordinate system and $x - o - y$ is the inertial sensor coordinate system. Since the gait parameters are mostly in the vector plane, it is necessary to do a specific analysis of the motion within the vector plane.

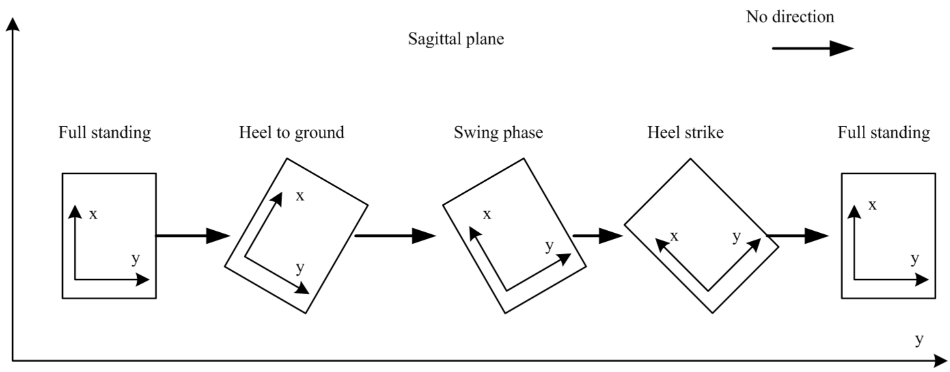

Fig. 3. Motion decomposition of vector plane

When the experimenter stats the experiment, or at the end of the step, it is in the complete standing stage, and this stage of the angle and acceleration are static output; When the gait movement begins, we enter the heel off the ground. With the movement of the experimenter, the sensor that tied to the ankle also rotates and moves. At this time, the gyroscope will produce a negative angular velocity, and when the negative angle reaches the maximum, the heel off the ground stage is end. The gyroscope will measure a positive angular velocity change, and then turn off the negative angle until it reaches the maximum angle, the swing phase is end. In the very short time of the heel to offset the adjustment angle, complete a gait cycle, return to the gait of the initial state, and prepare the beginning of the next cycle.

3.3. Sliding variance algorithm

For a sample value, if we want to know its fluctuation throughout the sample, variance is a good choice. We can use the sliding variance to evaluate the fluctuation of the sampling sequence in the experiment. The specific method of sliding variance is as follows:

First, using formula (2) we calculate the moving average:

$$E_i(j) = \frac{1}{M}\sum_{j=0}^{M} a(j+i)\,. \tag{2}$$

Here, M is the size of the sliding window, $a(j+i)$ is the data size of the $j+i$th sample point and $E_i(j)$ represents the moving average of the jth point in the window M.

4. Discussion of the results

Through the study of the gait mode, we accurately divide the walking cycle into four stance phases, which are heel strike, swing phase, heel off and foot flat. As shown in the follows, Table 1 is the average of the single-step gait time information of the four experimenters. In the table, we give the form of (mean ± standard deviation). In the table, HO refers to the heel off the ground, SW refers to the swing phase, the HS finger abraded. Their units are seconds (s), and the table gives the data of the left foot and right foot.

Table 1. The average of the single-step gait phase (mean standard deviation

Param.		Experimenter 1	Experimenter 2	Experimenter 3	Experimenter 4
HO(s)	Left	0.296±0.024	0.295±0.058	0.357±0.043	0.278±0.026
	Right	0.284±0.038	0.273±0.026	0.336±0.032	0.273±0.036
SW(s)	Left	0.437±0.024	0.425±0.024	0.387±0.058	0.382±0.059
	Right	0.437±0.026	0.426±0.016	0.406±0.053	0.418±0.043
HS(s)	Left	0.257±0.024	0.218±0.037	0.146±0.017	0.197±0.024
	Right	0.354±0.047	0.203±0.037	0.154±0.017	0.183±0.17

From the above table, we can get that, when normal people walking, the time to complete a walk cycle is about 1.2 seconds. In a walk cycle, the time of the heel off the ground is about 0.3 seconds, the time of the swing phase is about 0.4 seconds, the time of the heel strike is relatively short for about 0.2 seconds, and the time of full standing is about 0.3 seconds. Everyone's walk has a certain difference, and the average of the walking cycle can reflect a general law of the pedestrian.

Figure 4 shows the percentage of the gait cycle of the right footers. For example, the heel to ground of the right foot accounts for 24 % of the entire walking cycle. The swing phase of the right foot accounts for 36 % of the total walking cycle. The heel strike of the right foot accounts for 14 % of the total walking cycle. The full standing of the right foot accounts for 26 % of the whole walking cycle. In this way, we can see that the right feet is balanced in a normal walking process, so the comparison results of the stance phases are also relatively symmetrical.

5. Conclusion

In this paper, we use the inertial measurement device to collect the acceleration and angular velocity signals in the walking process of the human body, and make a detailed analysis of the human gait movement. Through the error model to eliminate the static error, we correct the sensitivity of the sensor, so as to get a more accurate sensor data. We use the two inertial sensor nodes that are tied to the ankle of the experimenter to collect the inertia signals of the human gait movement. Through the study of the gait mode, we accurately divide the walking cycle into four stance phases, which are heel strike, swing phase, heel off and foot flat. The results show that the percentage of the gait cycle of the left and right swing phase is relatively large, and the percentage of the gait cycle of the left and right heel strike is relatively small.

Fig. 4. Pie chart with the percentages of the walking cycle

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