Design of an Evaluation System of Limb Motor Function Using Inertial Sensor

Chengqian Wang[1], Liang Lu[2], Peng Zhang[2], Mingxu Sun[1], Tingting Wang[1], and Xuqun Pei[3](✉)

[1] University of Jinan, Nanxinzhuangxi Road 336, Jinan 250022, Shandong, China
[2] Jinan Minzu Hospital, Wenhuaxi Road 125, Shandong 250012 Jinan, China
[3] Jinan Central Hospital, Jiefang Road 105, Jinan 250013, Shandong, China
13370582962@163.com

Abstract. Tailoring the training process according to recovery potentials has gained importance in the process of training. Nowadays, the intelligent hospital is coming into sight, and the traditional rehabilitation assessment has been unable to meet the development of the times. In order to meet the demand, a dynamic assessment of the performance of the recovery process is required. Cloud computing can calculate and store massive data, and its application in the evaluation system of limb motor function using inertial sensor can meet the requirements of hospitals for data security, resource sharing, maintainability and so on. In order to accurately assess rehabilitation for the upper limb, the inertial sensors are used to collect the real-time limb movement data of patients. In the next steps, an evaluation of the patients rehabilitation exercises results is presented, saved and statistically analyzed. The assessment can help achieve more individualized patient care. Therefore, this paper designs an evaluation system of limb motor function using inertial sensor, which effectively improves the efficiency of rehabilitation assessment. The evaluation system increases the real-time action display on the screen to improve the practicability of the evaluation system. At present, the evaluation system is in the development stage, and a lot of data and work are still needed to improve the evaluation system.

Keywords: Rehabilitation assessment · Inertial sensor · Cloud computing

1 Introduction

In the process of rehabilitation assessment, the majority of rehabilitation assessments are carried out manually by rehabilitation physicians, which is highly susceptible to subjective factors that can lead to inaccurate assessment results. Accurate and reliable results of rehabilitation assessment play an important role in the rehabilitation of limb motor dysfunction patients [1]. The dynamic movement evaluation of limb motor dysfunction patients is helpful to provide customized rehabilitation training plan [2]. After rehabilitation training, limb motor dysfunction patients pay more and more attention to accurate rehabilitation assessment results.

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2022
Published by Springer Nature Switzerland AG 2022. All Rights Reserved
M. R. Khosravi et al. (Eds.): CloudComp 2021, LNICST 430, pp. 143–148, 2022.
https://doi.org/10.1007/978-3-030-99191-3_11

In recent years, with the increasing of population aging, the number of limb motor dysfunction patients are also increasing, and the collected rehabilitation assessment data is also increasing. Wearable sensors increasingly being used for human movement analysis [3]. Therefore, a evaluation system of limb motor function using inertial sensor is designed. The evaluation system measures the limb movement information of patients in real time using inertial sensors, and then calculates and stores the results of the rehabilitation assessment. Rehabilitation physicians can use the results of rehabilitation assessment calculated by the evaluation system as a reference for formulating rehabilitation training plans.

2 Design of the Rehabilitation Assessment Module

2.1 General Structure Design

The evaluation system of limb motor function using inertial sensor is a data acquisition and display system combining software and hardware. The hardware of the evaluation system is inertial sensor, and unity3d is used as the data display and processing platform in PC. After a systematic requirement analysis, the general structure of the evaluation system for limb motor dysfunction based on inertial sensor is shown in Fig. 1.

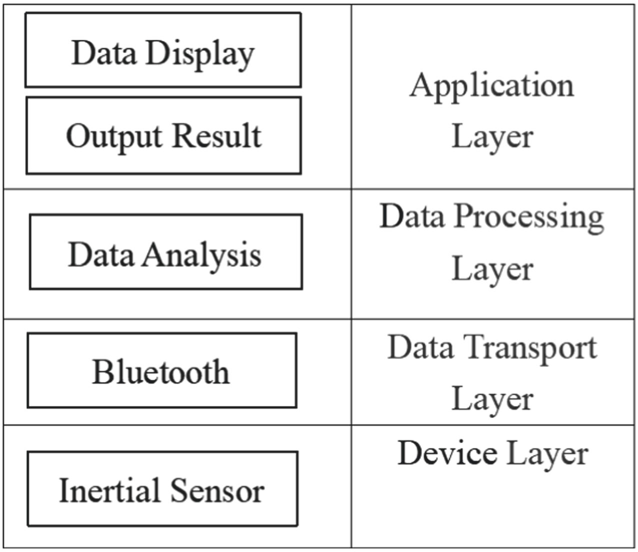


Fig. 1. The general structure of the evaluation system.

Device Layer. The device layer is located at the bottom of the evaluation system and is the foundation of the whole system. The hardware device used in the device layer is inertial sensor, which is used to measure the limb movement information of patients during rehabilitation assessment. Quaternion is used to describe the attitude information of the inertial sensor in reference coordinate system.

Data Transport Layer. The data transport layer is located in the upper layer of the device layer. The main function of the transport layer is to transmit the data collected by the device layer to the computer through Bluetooth.

Data Processing Layer. The data processing layer is located in the upper layer of the data transport layer. The data processing layer receives the data transmitted by the data transport layer. After the received data is processed by the data processing layer, more accurate rehabilitation assessment data can be obtained. Finally, the results of the rehabilitation assessment were calculated.

Application Layer. The application layer is at the top of the whole system. The application layer includes two modules for the data display and the output result. The application layer receives the rehabilitation assessment data and results processed by the data processing layer. The evaluation system drives the human model for real-time movement simulation based on rehabilitation assessment data and presents The results of rehabilitation evaluation in the form of line chart.

2.2 Realization of Upper Limb Real Time Motion Simulation

Human joint motion data is an important parameter for rehabilitation assessment [4]. So the inertial sensor is used to measure the motion data of the joint. The real-time motion simulation of upper limb involves many degrees of freedom of joints, so it is the most important part of human motion analysis. The upper limb consists of the shoulder joint, the elbow joint and the wrist joint. The shoulder joint has three degrees of freedom. The elbow has one degree of freedom. The wrist has two degrees of freedom.

Wearing of Sensor. Before the rehabilitation data is measured, the inertial sensor should be worn in the corresponding position, and ensure that each inertial sensor is on the same horizontal plane. The wearing of inertial sensor is shown in Fig. 2. The inertial sensors are attached to the body with straps.

As shown in Fig. 3. The positions of shoulder joint, elbow joint and wrist joint are A_1, A_2 and A_3 in the global coordinate system. The four-dimensional vectors of upper arm is $\overrightarrow{A_1A_2}(0, 0, 0, -len_{A_1A_2})$. The four-dimensional vectors of fore arm is $\overrightarrow{A_2A_3}(0, 0, 0, -len_{A_2A_3})$.

Measurement of Shoulder Range of Motion. The range of motion of shoulder joint was measured by adduction, abduction, flexion, extension, internal pronation and external pronation. To define $\overrightarrow{A_1A_2}^*$ as a vector of $\overrightarrow{A_1A_2}$. The subscript u indicates that the motion data of the upper arm is calculated. The x_u indicates the motion data of the upper arm in the x-axis direction. The y_u indicates the motion data of the upper arm in the y-axis direction. The z_u indicates the motion data of the upper arm in the z-axis direction. The $q_{u(t)}$ represents the upper arm motion data measured at moment t and expressed as a quaternion. Using the following (1):

$$\overrightarrow{A_1A_2}^* \ (0, x_u, y_u, z_u) = q_{u(t)} \otimes \overrightarrow{A_1A_2} \otimes q_{u(t)}^{-1} \quad (1)$$

Fig. 2. The wearing of the inertial sensor.

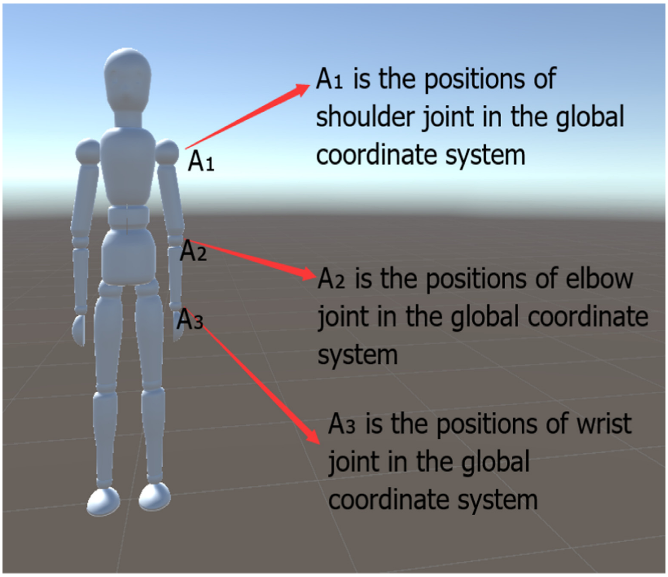


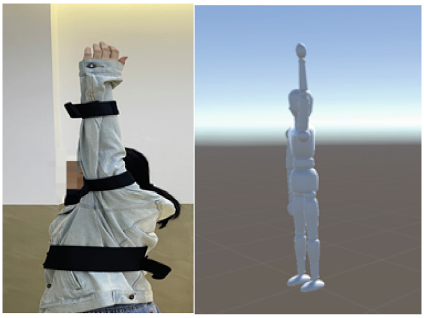
Fig. 3. The character model.

The real-time position of the upper arm in the global coordinate system is calculated as following (2):

$$P_u = (x_u, y_u, z_u) \tag{2}$$

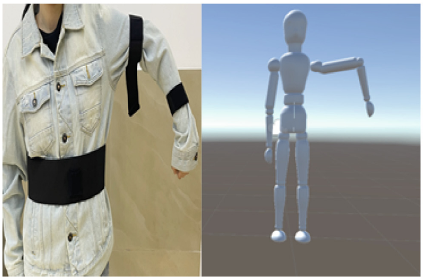
The P_u indicates the position of the upper arm in the global coordinate system.

The real-time motion simulation of shoulder joint range of motion is shown in Fig. 4.

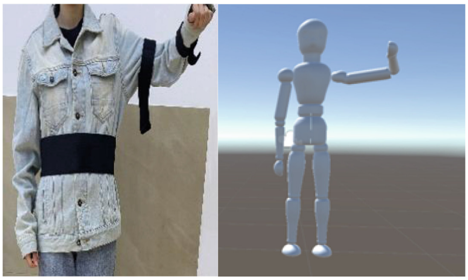


a. The flexion of the shoulder joint.

b. The extension of the shoulder joint.



c. The internal pronation of the shoulder joint.



d. The external pronation of the shoulder joint.

Fig. 4. The real-time motion simulation of shoulder joint range of motion measurement.

Measurement of Elbow Range of Motion. The range of motion of the elbow joint is measured by flexion and extension. To define $\overrightarrow{A_2A_3}^*$ as a vector of $\overrightarrow{A_2A_3}$. The subscript u indicates that the motion data of the fore arm is calculated. The x_f indicates the motion data of the fore arm in the x-axis direction. The y_f indicates the motion data of the fore arm in the y-axis direction. The z_f indicates the motion data of the fore arm in the z-axis direction. The $q_{f(t)}$ represents the fore arm motion data measured at moment t and expressed as a quaternion. Using the following (3).

$$\overrightarrow{A_2A_3}^*(0, x_f, y_f, z_f) = q_{f(t)} \otimes \overrightarrow{A_2A_3} \otimes q_{f(t)}^{-1} \tag{3}$$

The real-time position of the forearm in the global coordinate system is calculated as following (4):

$$P_f = (x_f, y_f, z_f) \tag{4}$$

The P_f indicates the position of the fore arm in the global coordinate system.

The real-time motion simulation of elbow joint activity measurement is shown in Fig. 5.

a. The flexion of the elbow joint. **b**. The extension of the elbow joint.

Fig. 5. The real-time motion simulation of elbow joint range of motion measurement.

3 Discussion

In this paper, a evaluation system that uses inertial sensors to measure rehabilitation assessment data and output rehabilitation assessment results is presented. The evaluation system still needs a lot of comparative experiments to improve the accuracy of the rehabilitation assessment results output by the evaluation system. A large amount of data was generated during the rehabilitation assessment. Cloud computing can effectively handle the huge amounts of data generated in healthcare [5]. In the future, it is expected that the evaluation system will be deployed on cloud computing platforms, making it possible to benefit more users.

4 Conclusion

The effective management of rehabilitation assess process is helpful to improve the work efficiency of rehabilitation physicians. In the boring process of rehabilitation, the character model of real-time simulation on the screen also improves the rehabilitation enthusiasm of patients. The evaluation system of limb motor function using inertial sensor can provide rehabilitation assessment for limb motor dysfunction patients and save these rehabilitation data. Rehabilitation physicians can log in to the evaluation system at any time to view the rehabilitation data, which reflects the good application effect of the evaluation system.

References

1. Zhang, M., Sun, J., Wang, Q., Liu, D.: Walking rehabilitation evaluation based on gait analysis. J. Biosci. Med. **8**(6), 215–223 (2020)
2. Meziani, Y., Morère, Y., Hadj-Abdelkader, A., Benmansour, M., Bourhis, G.: Towards adaptive and finer rehabilitation assessment: a learning framework for kinematic evaluation of upper limb rehabilitation on an Armeo Spring exoskeleton. Control Eng. Pract. **111**, 104804 (2021)
3. Chander, H., et al.: Wearable stretch sensors for human movement monitoring and fall detection in ergonomics. Int. J. Environ. Res. Public Health **17**(10), 3554 (2020)
4. Xiong, B., et al.: Determining the online measurable input variables in human joint moment intelligent prediction based on the hill muscle model. Sensors **20**(4), 1185 (2020)
5. Rajabion, L., Shaltooki, A.A., Taghikhah, M., Ghasemi, A., Badfar, A.: Healthcare big data processing mechanisms: the role of cloud computing. Int. J. Inf. Manage. **49**, 271–289 (2019)