

# Requirement Analysis

## 1. Project background and objectives

The goal of this project is to design and implement a lower limb rehabilitation data management system, which aims to help patients carry out personalized rehabilitation training through the acquisition, processing, storage, analysis and display of lower limb joint movement data, and to provide effective monitoring and analysis tools for medical personnel. The core functions of the system include data acquisition, data transmission, real-time data processing, rehabilitation status analysis, and personalized training recommendation. At the same time, the system supports medical personnel to remotely view patient data, conduct data comparison and analysis and timely intervention.

## 2. functional requirement

### 2.1 Patient data uploaded to server

#### Data sources:

Angle sensors are installed in the joints of the patient's lower limbs to capture the angular changes of the joints in real time.

The sensor has a sampling frequency of 100Hz and collects 100 angular data points per second.

#### Data transfer process:

1. Sensor Data Acquisition: Records changes in the angle of the joint every second to ensure that the accuracy of the acquisition meets the needs of rehabilitation.

2. BLE Transmission: The sensor pairs with a mobile device (e.g., smartphone) via the Bluetooth Low Energy (BLE) protocol to establish a connection and transmit data. Once the BLE connection is complete, the sensor sends the data to the device in real time.

3. Data caching: The mobile application continuously listens to the BLE signal in the background, automatically receives the sensor data and caches it into the device memory to ensure that the data is not lost.

4. Data collation: The data collation process includes timestamp synchronization (to ensure that the data are consistent over time) and unit conversion (to harmonize data units as required).

5. Data uploading: Once the data is organized, the mobile device uploads the data to a cloud server via the Internet to ensure remote access and storage.

#### Data storage:

Local database (SQLite): caches the last 7 days of data on the device. If the device is disconnected from the network, the data will not be lost and the user can synchronize the data after the network connection is restored.

Server database (cloud storage): Cloud storage of data for long-term preservation, medical staff can access patient data at any time for remote monitoring and analysis.

## 2.2 Server-side data noise reduction processing

### Raw data denoising:

Kalman filtering algorithm: Kalman filtering is used to filter the raw data of the sensor, remove environmental noise and electromagnetic interference, and smooth the angle change data.

Abnormal data rejection: A reasonable range of joint angles is set, and data outside the range (e.g. knee angles between  $0^{\circ}$  and  $140^{\circ}$ ) are flagged as invalid and rejected from the analysis.

Data Compensation: When BLE transmission is interrupted or data is lost, linear interpolation is used to repair the data and fill in the gaps to maintain the continuity and integrity of the data.

### Performance Requirements:

Data processing time: the processing time of each data packet should be less than 50 milliseconds to ensure the real-time response capability of the system.

Data error after noise reduction: The data error after denoising should be less than  $\pm 0.01$  degree to ensure the accuracy of the data.

Data Integrity: Redundant storage technology is used to ensure the integrity of data storage and prevent data loss.

## 2.3 Data analysis and presentation

### Functional Requirements:

#### 1. Calculation of motion state parameters:

Range of Angle Change: Calculates the maximum and minimum angles of movement of a joint to assess the range of motion of the joint.

Speed of movement: the speed of joint movement is evaluated by calculating the rate of change of angle.

Acceleration: the smoothness of the motion is assessed by calculating the second order derivative of the angle to obtain the acceleration of the joint motion.

#### 2. Comparison of rehabilitation status:

Real-time Data vs. Rehabilitation Target Values: Real-time tracking of a patient's movement data and comparison to set rehabilitation goals (e.g., joint angle range).

Real-time data vs. past 7-day averages: Compare current exercise data with averages from the past 7 days to see how the patient's recovery is progressing.

#### 3. Data visualization and presentation:

Line graphs: show the patient's movement trends and visualize the patient's recovery over time.

Bar Chart: Shows the current exercise data compared to the rehabilitation target value, helping patients and doctors to clearly see the gap.

Radar chart: Display multi-dimensional comparisons of movement parameters, such as angular range, movement speed and acceleration, etc., to help doctors comprehensively assess the patient's rehabilitation status.

**Performance Requirements:**

Visualization update frequency: Data visualization should have an update frequency of 10Hz or more to ensure smooth system interaction.

Data Error: The error of the displayed data should be controlled within  $\pm 0.5$  degrees to ensure accurate analysis of rehabilitation trends.

## **2.4 Adaptation of rehabilitation programs**

**Functional Requirements:**

1. Rehabilitation assessment mechanisms:

If the patient's current range of motion is achieved, the system will indicate "good recovery".

If the patient does not meet the preset rehabilitation goals, the system will recommend a new training program to help the patient recover better.

2. Training effect score: The system calculates the degree of improvement of the patient based on the exercise data of the past 7 days and scores the training effect.

3. Personalized program recommendation: Combined with the AI model to predict the training effect, dynamically adjust the training intensity and program according to the patient's specific situation.

**Performance Requirements:**

Training program update cycle: update the training program every 3 days to avoid too frequent adjustments affecting the patient's recovery process.

AI Prediction Accuracy: AI models should have a prediction accuracy of 90% or more to avoid incorrect recommendations for rehabilitation programs.

## **2.5 Server-side storage of raw data**

**Functional Requirements:**

1. Short-term storage: the local database should store the last seven days of data, making it easy for patients to view and review the effects of their recent rehabilitation.

2. Long-term storage: The cloud database should save the patient's historical data for a period of one year to support the medical staff in comparing and analyzing the historical data.

**Performance Requirements:**

Individual Patient Data Storage: Data storage for each patient should be controlled within 10MB/month to ensure scalability of cloud storage.

Data backup: To prevent data loss, all patient data should be backed up daily.

## **2.6 Medical staff view and compare data**

**Functional Requirements:****1. Real-time data comparison:**

Doctors can compare a patient's real-time data with rehabilitation goals, standard health data, and average values of patients at the same stage of life to help them quickly assess the patient's recovery.

**2. Anomaly alerts:**

If the patient's oxygen saturation falls below 90% or the angle of joint mobility decreases abnormally, the system automatically sends an alert to notify the physician, facilitating timely intervention.

**Performance Requirements:**

Doctors querying patient data: The response time for querying patient data should be less than or equal to 2 seconds to ensure that medical staff can access the data quickly.

Abnormal Alert Push: The push delay for abnormal alerts should be less than or equal to 1 second to ensure that medical personnel can respond and intervene in a timely manner.

**2.7 Management of patient information by medical staff****Functional Requirements:**

1. Add new patient: The doctor can enter the patient's basic information (e.g. name, age, medical history) and bind the corresponding rehabilitation equipment.

2. Switching Patient Views: Doctors can quickly switch between different patient views to see their respective recovery data.

3. Deletion of invalid patients: The system should automatically archive or delete information on patients who have not used the system for six months.

**Performance Requirements:**

Patient data query response time: the response time for querying patient data should be less than or equal to 2 seconds.

Database support scalability: The system should support data management for at least 1000 patients and have good scalability.

**3. Performance requirements**

BLE connection establishment time:

the connection time should be less than 2 seconds to ensure that the sensor and the mobile device can be paired quickly and avoid long waiting time.

Data uploading delay:

The delay of uploading data should be less than 200 milliseconds to ensure timely data

transmission to the server.

Data processing time:

The processing time of each data packet should be less than 50 milliseconds to ensure the real-time processing capability of the system.

Storage capacity:

Data storage for each patient should be controlled within 10MB/month to ensure that the system's storage space is not overloaded.