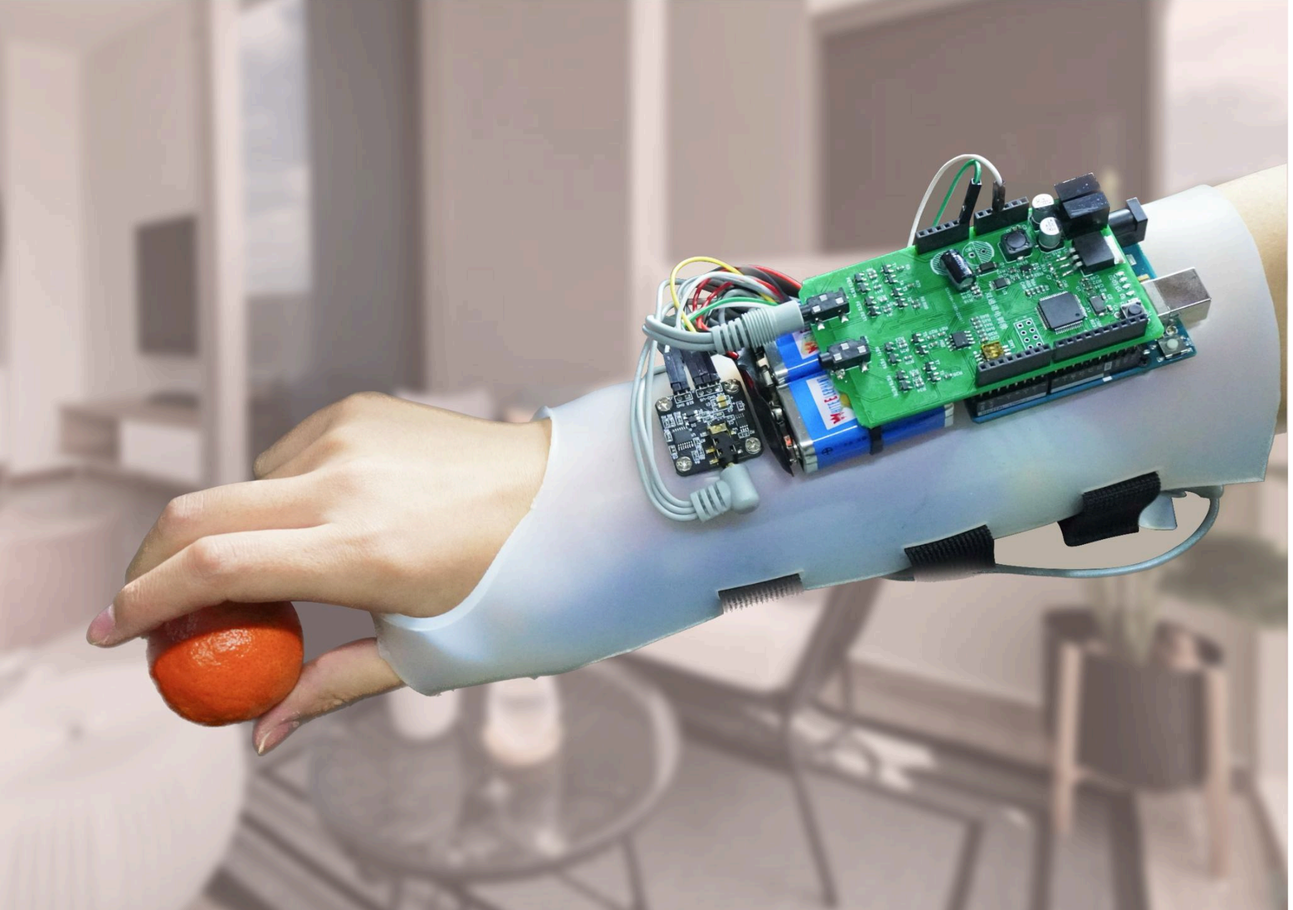


SmartHand

03

An intelligent hemiplegic rehabilitation assistant for stroke survivors.

Team Work (3 People)

Personal Improvement

SmartHand is a set of smart medical equipment dedicated to the home life of hand hemiplegic people. It is dedicated to complete the elaborate hand movements with the help of artificial intelligence, and integrate rehabilitation into every moment of life.

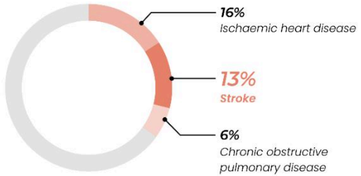
SmartHand consists of two parts: wearable devices and a mobile APP with serious games. Wearable devices continuously monitor hand movement through the camera module, and help patients complete daily activities with the help of EMG biofeedback therapy to promote rehabilitation. Mobile APP collects rehabilitation data, actively participates in and provides two type of serious games, hoping that users can enjoy life and recover. APP and wearable devices jointly help users complete training, which will become a new concept of rehabilitation.

Research	●●●●●
Modeling	●●●●●
Engineering	●●●○○
Coding	●●●●○
Prototyping	●●●●●
UI/UX	●●●●●
Service	●●●●●

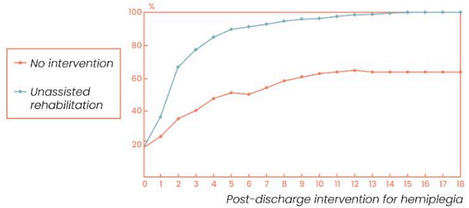
2022.2 - 2022.4

Project Background

Stroke is the 2nd leading causes of death, responsible for approximately 11% of total deaths respectively. ***Up to 60% of stroke survivors suffer from upper extremity impairments.***



Stroke survivors continue to recover at home after inpatient rehabilitation ends. Progression may plateau without constant engagement in treatment.



Post-discharge intervention for hemiplegia

Rehabilitation challenges faced by patients with hemiplegia

The restoration of distal motor function

The functional improvement of upper extremities primarily depends on the hand function. However, in the recovery process from upper extremity hemiplegia, ***the restoration of distal motor function comes later and is more strenuous than the restoration of proximal motor function.***

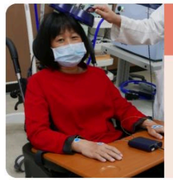
Cognitive dysfunction

Cognitive impairment as evaluated with a comprehensive neuropsychological assessment is prevalent in stroke survivors even with successful clinical recovery. ***Typically multiple domains and complex cognitive abilities are affected.***

A decreased mental state

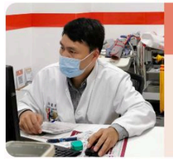
Anxiety is a common psychological problem after stroke. Anxiety disorders or symptoms can also compromise rehabilitation; thus, ***the significance of patients' psychological status after stroke forms an essential element of their treatment process.***

User Research and Interview



Huilan Zhou
Stroke Survivor

I feel:
Training is a heavy burden.
I want to:
Get rid of cumbersome training to return to normal life.



Changming Xu
Chief Physician, Renji Hospital

Patients feel:
Bored and painful in training.
Patients are:
Unwilling to carry out locomotor activities.

Q Do patients after stroke have to undergo rehabilitation? Must be treated in hospital?

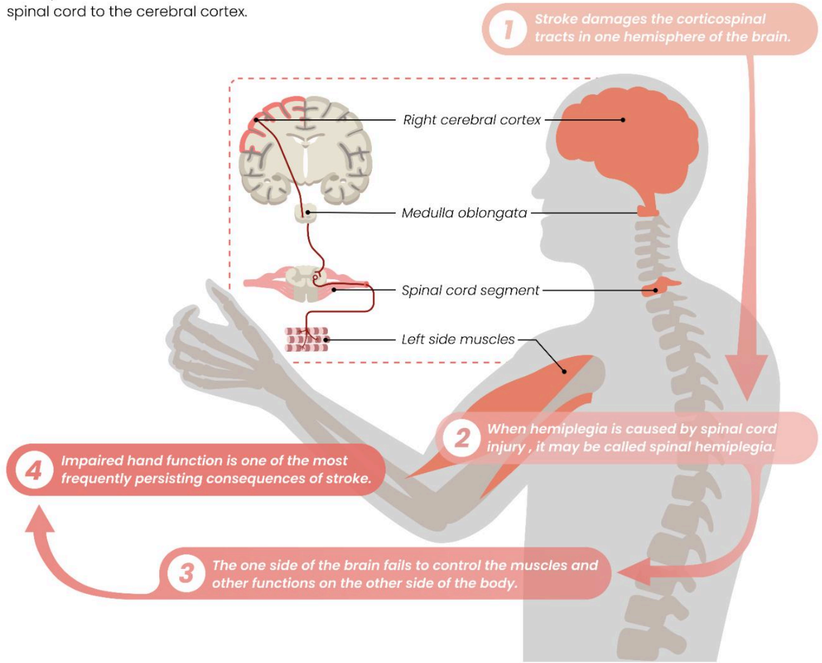
The post-stroke functional symptoms ***will not gradually recover voluntarily. It's impossible to stay in the hospital for a long time*** for rehabilitation after a stroke, so it's necessary to return home for rehabilitation.

Q Whether patients after stroke can fully recover to normal through rehabilitation training?

There is no way to fully restore the functional impairment after a stroke. Hard work in rehabilitation training can improve it, but ***it will get worse if patient don't work hard.***

Introduction of Hemiplegic Pathology

Hemiplegia is the paralysis of the muscles on one side of the body. The most common cause is stroke, which damages the corticospinal tracts in one hemisphere of the brain which extend from the lower spinal cord to the cerebral cortex.



Insight

Camera-based Systems

*This method can be accurate but **involve privacy issues.** Also, **the environment cannot be too cluttered,** to avoid skeleton merging.*

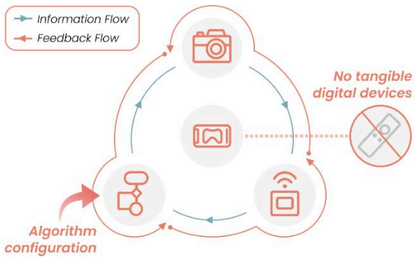
Tangible-interaction-objects-based System

*These systems can **reduce a learning times.** However, they are generally **limited to a single training mode and have poor scalability.***

Wearable-sensor-based System

*EMG sensors have been widely utilized for rehabilitation systems. However, **classification accuracy for stroke patients is typically much lower** than that of healthy individuals.*

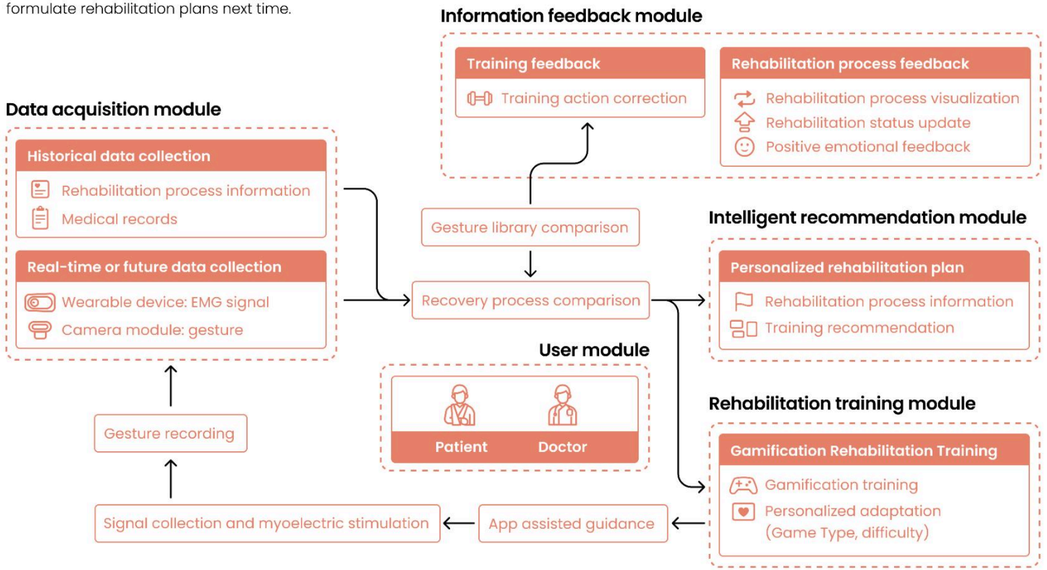
We hypothesized that the proposed sensing and algorithm configuration could detect stroke patient hand gestures during the cognitive and motor tasks required in the serious games.



System Design

The SmartHand application will work with wearable devices to help users complete training. During training, the application will give action guidance.

At the same time, the camera module records hand movement data and transmits it back to the background in time. So that the algorithm can recommend more targeted daily activities and formulate rehabilitation plans next time.



Current Rehabilitation

Stage	1-3 months	3-6 months	6 months - 5 years or longer
	Soft paralysis period	Cramping period	Recovey period
	No voluntary movement of the hand, muscle atrophy.	The condition is stable, the best period of rehabilitation.	The condition is stable, the best period of rehabilitation.
Action	**Acute phase: Patients are manic**	Patients **tend to give up**	Upper limb functions **recover much slower**
Feeling	Depressed and fatigue Feel life meaningless	**Acute phase: Patients are manic**	· **Losing confidence** in training · Recording daily small progress can maintain a **positive attitude**
Point	**As time goes on, the speed of rehabilitation slows down and it is more difficult to persist.**		

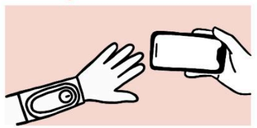
Sequence of rehabilitation: Leg → Arm → Hand

Storyboard

Daily time

Help users to complete hand movements through electrical stimulation.

Training time



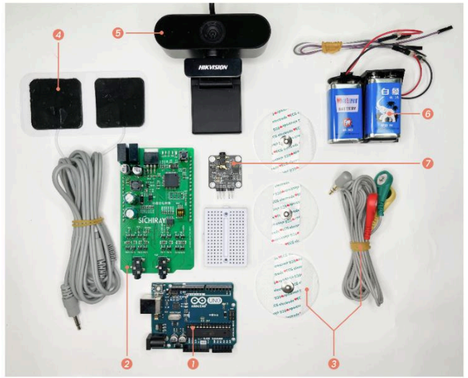
Provide users interesting games, guide them to complete their training. Users would qualitatively be more enthusiastic about training.

After

Give users feedback about their recovery process. Regularly communicate with the doctor to update the rehabilitation plan.

Hardware

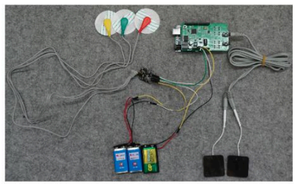
EMG detection and electrical stimulation ***are controlled through Arduino-based electrical stimulation module.*** The camera module is used to record gestures.



ARDUINO

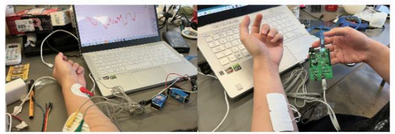
1. *Arduino UNO Board*
2. *Electrical stimulation module*
3. *Electrode slice*
4. *Electrode slice*
5. *Camera*
6. *Power unit*
7. *EMG sensor*

Assembly and Functional Principles



EMG signals detection

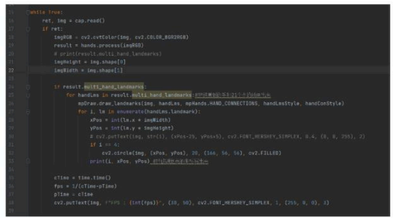
The EMG sensor ***detects the myoelectric signal,*** and outputs EMS to ***promote the muscle contraction.***



EMG signals detection *Apply electrical stimulation*

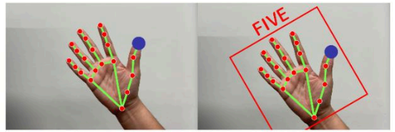
Software and Coding

We use the Python-based MediaPipe to ***recognize gestures and compare them with standard gestures in the gesture library.*** It is converted into data by an algorithm, and the data is transmitted to the host.



MediaPipe

Coding



Mark hand coordinates *Gesture classification*

Test

Work Flow of Gesture Recognition

Template matching requires ***the establishment of a basic gesture library*** to compare the accuracy of patient hand movements.

Gesture Library

The FMA is an effective and detailed evaluation tool for assessing motor function after stroke. 11 upper extremity fine movements are selected from the FMA and are suitable for motor function rehabilitation. The movements include hand, wrist and forearm movements.

Mass flexion (MF)

Mass extension (ME)

Hook like grasp (HG)

Thumb adduction (TA)

Opposition (O)

Cylinder grip (CG)

Spherical grip (SG)

No motion (NM)

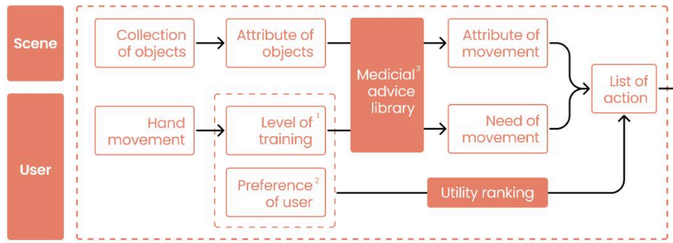
Wrist volar flexion (WF)

Wrist dorsiflexion (WD)

Forearm pronation (FP)

Forearm supination (FS)

Movements Generation Algorithm Framework



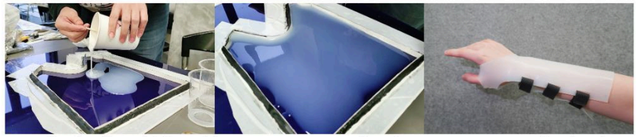
The data generated by the activity **enters the next round of recommendation cycle**

This algorithm recommends appropriate hand activities for patients, and gives a suitable recovery plan based on the gesture library and medical advice library. ***Serious games will be considered as possible solutions.***

[1] Level of training — *Assessed in the number of hand movements obtained by the vision module*
[2] Preference of user — *Calculation of clicks from user training records and activity recommendation lists*
[3] Medicial advice library — *Define the action requirements such as muscle training and action intensity corresponding to the training level*

Prototyping and Test

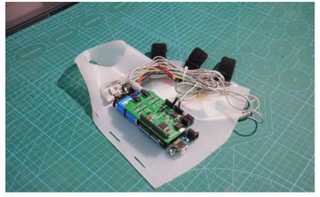
Silicone Casting and Component Assembling



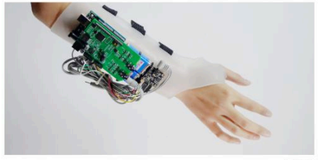
Pour the silicone into the mold *Stereotypes* *Punch and wear*

Welding *Assembling*

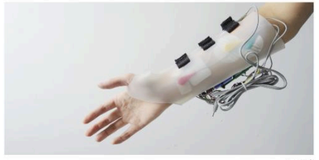
Inside



Outside

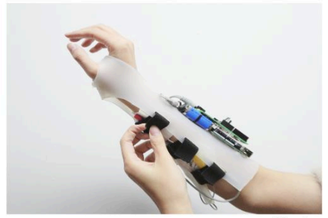


Front



Back

Functional Model Test



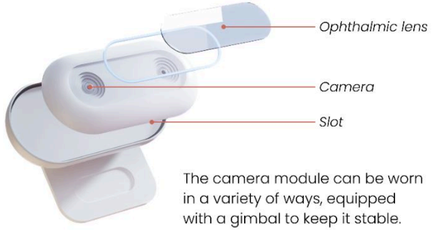
Wearing

Grasp Movement Recognition Test

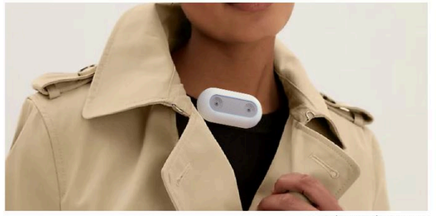
Function test

Product Design

Camera Module



The camera module can be worn in a variety of ways, equipped with a gimbal to keep it stable.



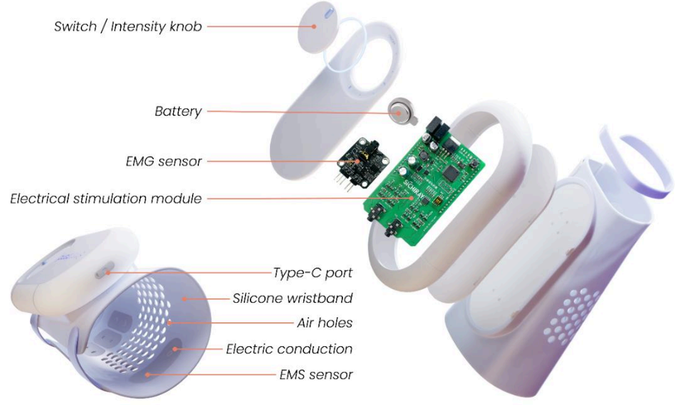
Wearing performance

Wearable Module

A switch on the top of the device can be rotated to control the intensity of electrical stimulation.

The soft wrist strap wraps the arm to prevent slipping, and the magnetic buckle adjusts the tightness. ***The integrated electrodes containing hydrogel patches on the inside of the wristband conduct bidirectional current conduction.***

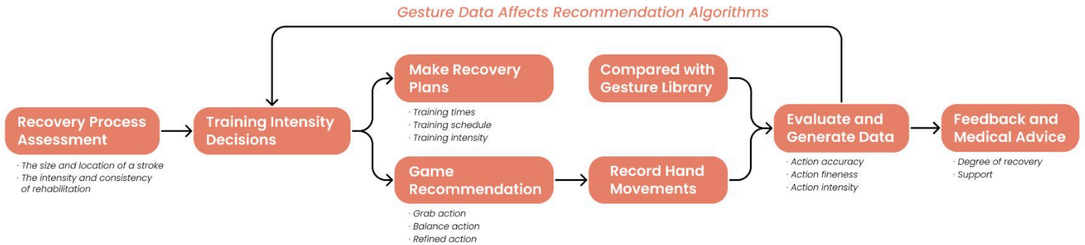
Wearing performance



Interaction

How SmartHand helps people recover from hemiplegia?

SmartHand supports daily supplementary training through App. The algorithm builds a dynamic healing process for the user based on the data. ***App can give training recommendations and guidance, record and analyze data, and develop personalized training plans.***



Architecture Diagram

The App assists patients in rehabilitation in the form of games. In addition to the game section, the App can view the rehabilitation progress and achievement wall to get the latest training plan and medical advice.

Interaction Prototype

Rehabitation tasks

User Profile

Serious Games

Two serious games were developed based on movement estimation. The games provide visual and audio feedback to the patients.

	Find the Zombie			Happy Salesman		
Group 1	MF	O	WD	TA	SG	FP
Group 2	ME	CG	WF	CG	FP	FS
Group 3	TA	SG	FP	HG	O	FS
Group 4	HG	NM	FS			

Patients select the correct target in the serious game and perform the corresponding movement. The game ***"Find the Zombie"*** was designed for both motor and cognitive function training. The game ***"Happy Salesman"*** was designed to train motor function and improve performance in ADLs.

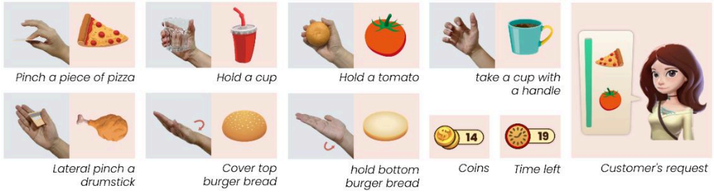
Game 1: Find the Zombie

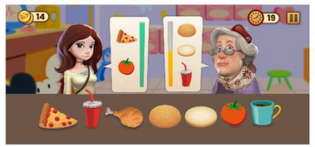
Complete the movement to flip the card

Zombie card

In this game, three cards appeared with a Zombie and two Plants on the front. Then, all cards were flipped over and randomly swapped positions. ***The patient was required to find which card is the one with the Zombie and perform the corresponding hand movement shown below that card.***

Game 2: Happy Salesman



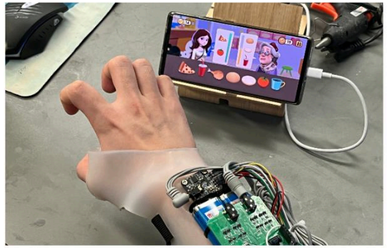


Pass the right food to the customers

Level score

Daily use scene

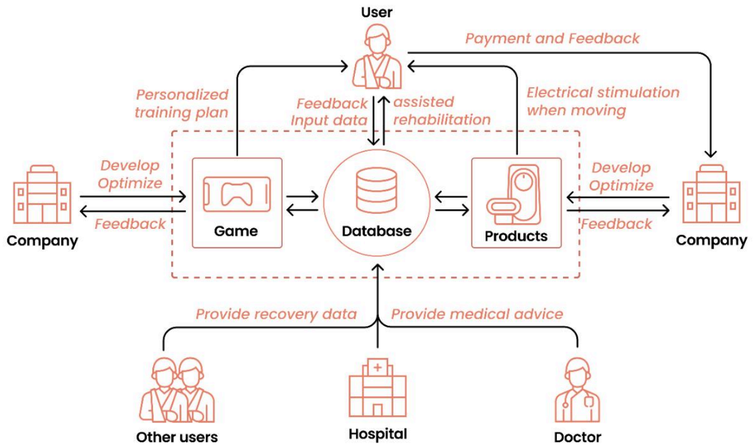
The user owns a store that sells 7 types of food. Customers keep coming to the store to buy 1-3 types of food. ***Users need to pass the right food to the customers by performing the correct corresponding movement.*** The coins represents the number of objects that participants successfully "sold" to customers.



Game testing

Service System Mapping

SmartHand is equipped with a database developed by professional companies. User recovery data and professional medical advice can be uploaded to the database for users and hospitals. ***SmartHand has the function of continuous learning, calls the database in real time and dynamically adjusts rehabilitation plan.***



Telemedicine to support recovery

Telemedicine can effectively solve the problem of shortage of medical resources. For long-term recovering patients, in-person medical care is often unnecessary. ***Telemedicine improves efficiency and saves costs.***

Data transfer and sharing between users

Build a user-centric database which data comes from doctors and users. ***The continuous learning of the algorithm is realized. Integrating usage information from others will improve the effect of rehabilitation.***

Service Blueprint