Advances in Social Science, Education and Humanities Research, volume 673
2022 3rd International Conference on Language, Art and Cultural Exchange (ICLACE 2022)

Smart Wellness Wearable Devices

Ding Wei[1,*], Chen Lin[1]

[1] Dalian Polytechnic University
[*]Corresponding author. Email: Llinlin19900725@163.com

ABSTRACT
Purpose: With the implementation of the "Healthy China" strategy, it is widely acknowledged that the cognitive thinking about the health of people has been influenced by many complex factors of the complex system, and gradually shifted to the disease recovery index as the measurement standard. Starting from the new growth point of health design in design science, the innovative design of intelligent recreation wearable devices has been adopted to optimize the user's recreation experience from the product and service design dimension on the basis of interdisciplinary design innovation. **Approaches**: Standing on the theoretical basis of functional electrical stimulation technology FES, this paper proposes a design of a smart rehabilitation wearable device that does not restrict the use of scenarios, is more inclusive of patient attributes and is uncomplicated to operate with the function of monitoring muscle vitality parameters and assisting training, on the basis of market research and analysis of the needs of patients with upper limb exoskeletal muscle disorders and smart rehabilitation devices. Additionally, the system utilizes the program embedded in the chip to analyze the training content that matches the individual patient's differentiation and the corresponding current stimulation training and takes the advantage of the neural network analysis method to give the performance evaluation and result in an analysis of this intelligent monitoring and assistive device in practical application. **Results**: After the practice and evaluation of the patient experience and training effect of the product, it demonstrates that the functional electrical stimulation intelligent rehabilitation equipment has a positive effect on the muscle rehabilitation training of the upper limb exoskeletal functional disorder patient group, and also proves that as long as the training intensity and the individual program from time to time are suitable for the corresponding patients, it is possible to achieve the therapeutic effect. **Conclusion:** A healthy social system and a way of life that fits the diverse leisure demands of people that using a smart portable leisure device as a design medium for a humanistic return has been created.

Keywords: *Electrical stimulation for muscle dysfunction, wearable devices, humanistic regression, user needs*

1. INTRODUCTION

On top of population growth and aging, global health concerns continue to grow. Besides, the GBD series of studies released by Lancet presents that China is the country with the largest demand for rehabilitation medical care in the world, and the total number of people in need of rehabilitation in China reaches 460 million, of which the number of patients with musculoskeletal disorders involved in this project is the largest at 320 million. It is worth noting that the lack of resources of traditional external skeletal muscle rehabilitation training physicians makes it difficult to make accurate program design for further rehabilitation training of patients, and consequently, the efficacy and use experience of rehabilitation training equipment products become a concern for patient groups. As a result, the three primary reasons for the complexity of equipment product operation, the absence of patient attribute tolerance, and the constraints of scenario usage have become the fundamental aspects impacting the user experience.

In Human activity recognition (HAR) monitoring sensor data, scholar Nweke HF has addressed the problem of intra-class differences and inter-class similarity from the perspective of upper deep learning feature representation.[1] In reference to this research, scholar Shizhuo Deng solved the spatial dependence between the same axial data concerning triaxial sensors (triaxial acceleration, triaxial gyroscope, etc.) at various locations, which in turn improved the accuracy of the data.[2] The world's first successful case of FES was performed by Dr. Liberson in the United States to correct a foot drop gait in a hemiplegic patient.[4] After a clinical study of Functional Electrical Stimulation in patients, academician Jiaxu Chen found that this therapy was effective in restoring joint function and relieving muscle coordination disorders.[16] Although scholar Peng Liang examined the analysis of active training programs from the standpoint of impedance control, there is still a lack of study on differentiated processing of specific muscle characteristics and the creation of product usage scenarios for hemiplegic patients. [4] Furthermore, in the field of system active interaction design, through technological changes, FES technology has played a huge realistic role in different disease areas. However, traditional rehabilitation training physicians have a large workload and cannot accurately control and record patients' muscle data parameters, and it is difficult to make a more objective evaluation of the indicators of the degree of rehabilitation, and it is difficult to make an accurate program design for patients' further rehabilitation training, which is only inferred by physicians' experience and does not have the characteristics of scientific rigor and data intelligence of the times. In addition, current smart laptops are good for active intelligence design, while feedback intelligence and self-adjustment to adapt to environmental changes are still to be explored. In the existing research on MEMS wearable sensors in the smart wearable market, the combined design of MEMS devices based on magnetometers and inertial sensors has been equipped with the patient's home for out-of-hospital rehabilitation training,[5] notwithstanding, this training method relies on physicians' online assistance and guidance to complete and does not involve research on the closed-loop integrated training of the device system, which naturally cannot meet the demand experience of easy operation.

Based on the above practical reasons, the intelligent recreation wearable device aims to provide innovation in the use of rehabilitation training for functional muscle disorders to further run multiple active feedback systems through the chip embedded in a closed-loop, as well as training content that automatically updates with changes in muscle parameters to match individual differentiated states and stages, to solve the problems of traditional manual rehabilitation training such as cumbersome operation, limitations in use locations, and strict screening conditions that are not highly inclusive of patient attributes, and to improve the practicality of the device.

In this paper, the intelligent rehabilitation wearable device that gives secondary or multiple feedback after receiving user data through the rehabilitation training system designed in combination with user experience requirements well resolves the current development dilemma of intelligent products and sets up an experimental demonstration that the multiple feedback mechanism of individual differentiated training content provided by the sEMG signal data processing system built in this paper can meet the good user experience of patients with multiple scenarios. Meanwhile, in accordance with the characteristics of the motor nervous system, which can be regarded as a highly nonlinear dynamical system, the performance evaluation and result in an analysis of this intelligent monitoring and assistive device in a practical application using the neural network analysis method also provide the theoretical basis for the subsequent research. According to the perspective of combining humanistic design and health interaction service design, it promotes the deep integration of chip embedded control system technology and recreation equipment and deeply approximates the policy idea of personalized health design.

2. RESEARCH CONTENT AND METHODOLOGY

2.1. The Significance of the Research

(1) Background in the field of study

The Chinese government has come to recognize that the significance of design disciplines in navigating scientific and technical innovation and industrial growth cannot be overlooked in order to effectively handle the political, economic, social, and cultural ramifications of globalization. At the same time, the national perception and demand for health have been upgraded from the traditional evidence-based medical model to a standard combined with the narrative medical model system. As early as 2015, among the top five non-fatal diseases, there are two statistics on health care services, namely exoskeletal muscle dysfunction and low back pain, and the number of people involved in this disease in China reached 460 million. Nevertheless, there are many pain points of product and service design in the market first, hence, it is of theoretical and practical significance to bring into play the disciplinary attributes of design and use interdisciplinary design thinking to solve the multifaceted needs of user experience in the context of health design.

(2) Disciplinary perspective

The analysis of the user pain points and research of the significance of recreation experience from the interdisciplinary theoretical perspective, and a study of the use of functional electrical stimulation technology in the field of recreation service industry and the current situation of user experience in the service system has been done, which requires the creation of the ideas of Liu Guanzhong and Zhang Daoyi in the research method, research paradigm and scientific theory of design. Subsequently, we will focus on combining the empirical research method, service design, interaction design, and other natural disciplinary methodologies to shift the paradigm of design from a theoretical discipline to a rigorously applied discipline and propose design solutions with practical value. In addition, we will concentrate on combining functional electrical stimulation technology, product, environment, and service design under the perspective of the sustainable design concept for the design of intelligent recreational wearable devices is a pioneering attempt of collaborative innovation between art and science resources under the concept of interdisciplinary design thinking, and provides a reference for humanistic design practice in the field of intelligent wearable design.

(3) Reality perspective

In accordance with the design concept of humanistic regression, we can solve the existing problems of product design in the field of recreation services, fully consider the humanistic expression of functional design, subdivide the needs of recreation service users in different scenarios, set the product business goals corresponding to the needs of the community as a guide, balance the dynamic relationship between products and health services, explore the methods of humanistic design innovation of intelligent recreation products, and enhance the added value of products. Existing smart recreation wearable devices include difficult operation, poor tolerance for user qualities, limited usage scenarios, dependency on therapist experience, and homogenous training material, all of which are design aspects that must be taken into account when transforming into user demands. Through the systematic design of services of a type of product, we can drive the dynamic development of related industries and construct a healthy social system and lifestyle with a humanist design.

2.2. Innovation: Research Ideas and Methods

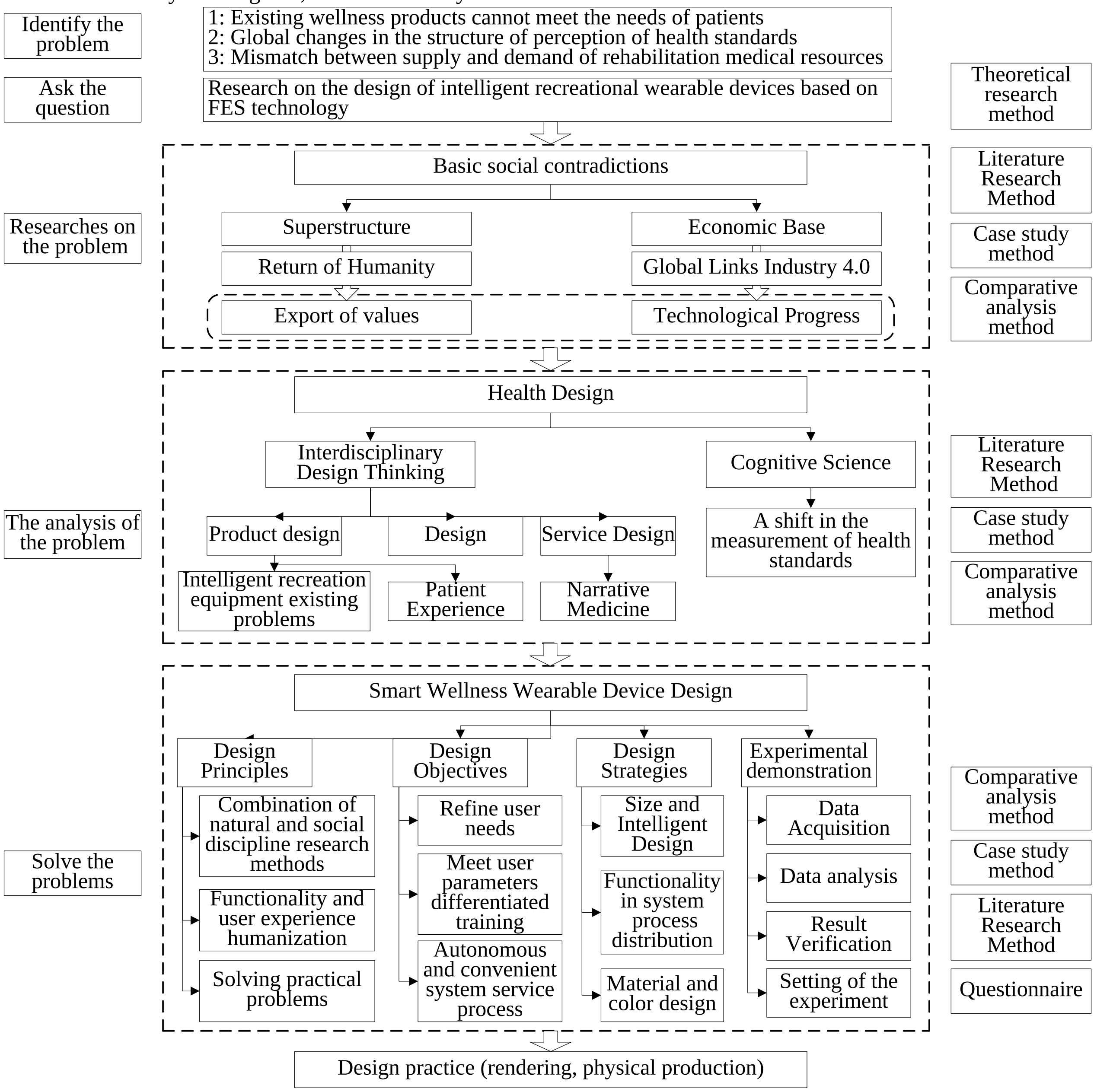

Figure 1 Research technology route of intelligent recreational wearable devices based on FES technologh.

(1) Research Routes

The technical line of research in this paper is divided into six parts: problem identification, problem formulation, problem research, problem analysis, problem-solving, and design and implementation.

(2) Research Methods

The research methodologies for this article are mainly as follows.

① Literature research method: collect the current situation and theoretical basis of research on smart wearable devices, functional electrical stimulation technology, health design, and humanistic design at home and abroad, and understand the current situation and development trend of research on functional electrical stimulation technology in the field of recreation services through the process of sorting out relevant theories, to lay a solid theoretical foundation for the research.

② Empirical research approach.

③ Interdisciplinary method: This design proposal uses the theory, method, and results of interdisciplinary design, and synergizes and innovates the disciplinary resources of evidence-based medicine, narrative medicine, mechanical engineering, human electrochemistry, information science and engineering, and human ergonomics, and systematically studies the topic of intelligent recreation wearable devices from the new growth point of health design in design science.

④ Comparative analysis method: Through the method of analyzing and comparing smart wearable products, functional electrical stimulation products, and recreation service products in the market, we analyzed the advantages and disadvantages of each type of product, to provide realistic guidance for the development of smart recreation devices.

⑤ Experimental testing method: The micro-current signal data generated during human epidermal movement is collected by muscle electrical sensors and analyzed and transformed to form training parameters matching individual differentiation; through model verification of the effectiveness of rehabilitation training content with non-linear characteristics, and finally realizing the functional design of the product.

2.3. A Literature Review of the Current State of Research on Related Theoretical Principles of Construction

2.3.1. Research Related to Functional Electrical Stimulation FES Technology

Functional electrical stimulation therapy is a non-invasive transcutaneous myoelectric therapy in which, when the muscle epidermis is stimulated with a certain intensity (up to a threshold), there is a large inward flow of sodium ions in the cell membrane and a rapid change from a negative potential to a positive potential in the membrane, which causes an electrical potential difference between the excited and unexcited areas, creating a local currency. The aim is to excite the muscle groups to perform actions similar to normal voluntary movements, thus restoring the body functions capable of producing these actions[15]. Depending on the purpose of the application, neuromuscular electrical stimulation may be divided into functional electrical stimulation, FES, and therapeutic electrical stimulation, TES[15]. Among them, functional electrical stimulation is compensation for voluntary motor function, such as the use of point stimulation for foot drop; therapeutic electrical stimulation is aimed at enhancing muscle strength or restoring motor function, such as the electrical stimulation used in stroke motor function rehabilitation.

Functional Electrical Stimulation, in which an electric current stimulates the muscles, causes them to "passively contract" while performing simple training movements, creating a "confrontation" between the passive contraction and the active movement of the muscles. After a sufficiently long time, the cells will form memory and gradually partially, or completely rejuvenate the muscle. The current control circuit is the key part of the stimulator, the first operational amplifier constitutes a positive side adder, the in-phase input is connected to the digital-simulator output (DAC output), the inverted input is connected to the reference voltage, and the adjustable resistor R2 is adjusted to obtain the appropriate reference voltage to obtain the over-zero square wave signal. This functional electrical stimulation treatment helps patients improve their muscle vigor and performance. In order to better address bottlenecks and design limitations of existing portable products, the project integrates the self-developed data processing and analysis program into the system chip in an innovative way.

2.3.2. Myoelectric Signal Operation and Amplification Principle

The master controller chip must complement the signal processing and all computing operations of the complete hardware system as the heart of the onboard control system. The system uses STM32F103C8T6 as the main control chip, whose core is Cortex-M3, 48KB SRAM can read and write at the CPU's speed and 256KB flash memory and provides ADC, SPI, USB, and other interfaces, which are rich in physical resources and can meet the design requirements of the system. The EMG sensor system for monitoring muscle movement parameters firstly parses the received data stream, displays the parsed voltage changes on the HMI, and draws a graph based on the collected muscle movement data. Subsequently, the operational amplification module of this system will calculate the corresponding bioelectric stimulation currents for differentiating individual muscle vitality by the following formula.

The formula is:

$$(\text{Human body voltage from 0-5V}) \quad voltage = \frac{sensorvalue * 5 \leftarrow \text{Voltage multiple}}{1023(\text{Resolution of ADC})}$$

$$Sensorvalue : The\ voltage\ detected\ by\ the\ sensor$$

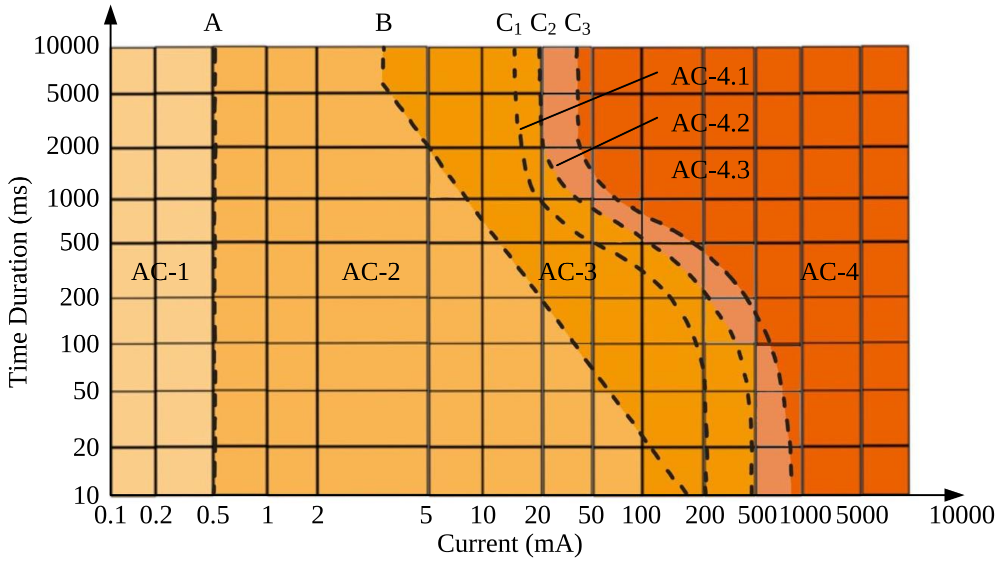

Figure 2 Variation of alternating current and human response over time[22].

With full consideration of safety issues, the parameters of transcutaneous stimulation microcurrent training in this system are set above the primary perception threshold of human macroscopic shocks and below the secondary let go threshold range of 10-20 mA [18], equivalent to the AC-2 area on the form, which not only avoids damage to human organs but also achieves the effect of promoting muscle movement to stimulate neurons to assist in rehabilitation training exercises.

2.3.3. Electromyography Sensor System Data Collection and Calculation

The actual development of the muscle electrical sensor in the main control chip used ADI chip AD8221 as EMG signal for adjustable amplification, while the measurement will be filtered, rectified electrical activity of the muscle signal output 0-Vs volts, the output size depends on the amount of activity of the selected muscle. It is useful to detect muscle activity by means of an Arduino controller. The detector module detects the surface electromyography (sEMG) signal of the human body, which in turn responds to the activity of human muscles and nerves. Besides, a filtering and amplifying circuit are integrated to amplify the weak human surface electromyographic signal in the range of ±1.5mV by 1000 times, and the noise (especially industrial frequency interference) is effectively suppressed using differential input and analog filtering circuit. The output signal is in analog form, with 1.5V as the reference voltage and a 0 to 3.0V range of output. The waveform of the output signal can significantly indicate the condition of the subcutaneous muscles at the observed location, which is convenient for doing analysis and research of EMG signals, for instance, using Arduino as a controller to monitor muscle activity, such as whether the muscles are tight, how strong they are, and whether they are fatigued. This active detecting sensor is simple to use and allows for the gathering of high-quality signals. Whether adopted in static or dynamic applications, it only needs a critical simple preparation. The product uses dry electrodes and does not need a conductive gel to get a good signal quality, therefore it has a long service life and is easy to use.

2.3.4. Radio Communication Module Design

The wireless communication module is responsible for establishing the data transmission bridge between the surveillance system and the onboard control system and completing the data communication work between them. The system adopts the NRF24L01 wireless communication module to complete the wireless data sending and receiving work, and the module is small in size, fast transmission rate, good communication effect, with high-cost performance. When the receiver receives valid data, it automatically sends a response signal to the transmitter, guaranteeing the accuracy and integrity of the entire process.

2.3.5. A Diagnosis and Treatment System Combining Two Evidence-Based and Narrative Medicine Models to Construct a Recreational Services System

Evidence-based medicine originates from the traditional natural science and empirical research, based on the scientific basis of standardized disease surveillance index data and randomized controlled trials to conduct probability testing of treatment effects. Narrative medicine is a good complement to the missing humanistic part of the evidence-based model, which is to understand patients deeply and empathize with them to achieve patient satisfaction in a highly complex environment. Narrative medicine and design disciplines, combining art and science, share common goals, theories, and methodologies. Therefore, in today's complex system development, the construction of recreation and health service systems also needs the cross-combination of two different treatment models for different perspectives as a research paradigm, and the design thinking of interdisciplinary resources of design to meet the new health of patients after the upgrade of user cognition. The new health standard after enhanced patient cognition is met with reflection on the interdisciplinary design of design resources.

2.4. Smart Wearable Devices in Health Service Industry Market Research

2.4.1. Product Classification (Analysis)

The existing smart wearable products in the market are divided into two categories, one of which is the use of bioelectric stimulation or low-frequency pulse to stimulate muscles to achieve muscle massage and relaxation, the common shortcomings of these products exist in the training content fixed, cannot match the individual differences of patients. Although the device includes a range of modes for patients and users to choose from, it is more difficult for users to choose a healthy and appropriate state training model for their muscle characteristics. Another type of product is the use of physical massage to relieve muscle fatigue and soreness, the common problem of these products is the inconvenience of operation, while the device has limitations for the use of scenarios.

Table 1. Functional parameters of similar intelligent recreational wearable devices

Brands	Product Images	Technologies	Functions	Pros	Cons
Lega mini cervical spine massage patch with the charge		TENS low-frequency pulse technology	Soothing muscle, massage relaxation	1. Compact and portable shape 2. with 6 modes to choose	1. The adhesive place needs to be replaced regularly with new conductive stickers. 2. Training massage content fixed
Feiyidu top acupuncture point massager		Ems Microcurrent Technology	Acupressure	1. Provide massage for acupuncture points 2. Suction cup type adsorption on the skin	1. The user is not able to control the professional acupuncture points.
VEINOPLUS French imports of low-frequency neuromuscular stimulator		Bioelectric stimulation	Pain, varicose veins	Promotes venous blood flow	1. The machine needs to be connected to the power supply when operating 2. Operation is not convenient 3. Electrode paste needs to be changed regularly
Beyeasy cervical spine massage instrument		Physical massage	Relieve shoulder and neck pain	Mimic manual massage	The inconvenient operation requires both hands to continuously pull the device tightly against the neck

2.5. Summary of Research Methods

Currently, scholar Liu Jiapeng has adopted a comprehensive analysis method that crosses the two disciplines of rehabilitation medicine and neurobiology, adopting the theory of brain plasticity for simultaneous stimulation of multiple channels to produce movement by active neural modulation of clusters around the muscles to treat functional disorders of the external skeletal muscles after stroke surgery. This idea was proposed to provide a diversified mode of thinking for the study of such problems, however, the drawbacks of this solution are the same inclusiveness of the patient's attributes, the need for the patient to be able to stand safely, and the complexity of the system operation to accomplish the synergistic contraction of multiple muscle groups.[17] Based on the humanistic perspective of health service, this solution shows the solution of this kind of intelligent recreation wearable devices from both software and hardware aspects compared with the previous solutions in terms of low tolerance of user attributes, complicated operation, and reliance on physician's experience. Although the previous Kalman filter principal recreation equipment can calculate the user's movement trajectory to achieve the effect of physician monitoring in the hospital, this equipment is extremely dependent on the physician and the equipment is used under harsh conditions. The software part of the program parameter measurement and analysis: (1) system initialization data setting: when the patient purchases the device, there will be an X-ray for the user's muscle length and force arm length of individual parameter measurement, after analysis as the reference value of the system analysis model; (2) system internal data analysis module, through Hill-type musculoskeletal model and sEMG electrical signal data and exoskeletal muscle activation degree (2) the system internal data analysis module, through the Hill-type musculoskeletal model and the relationship between the sEMG electrical signal data and the degree of activation of the exoskeletal muscle two parts of the model, respectively calculate the force moment and exoskeletal muscle vitality difference value, so as to jointly analyze the real-time update training content in line with individual patient differentiation. The hardware component of the device is small: all programs in the system are integrated into the chip. Compared with the remote monitoring device designed by the Kalman filter algorithm of Huaxi Hospital, this solution not only realizes the micro-compact integrated control technology, so that the patient can carry out recreational training alone without being monitored by a doctor, but also realizes the training content through one patient muscle parameter and two models formed by the data analysis compared with the former The module forms training data that match the individual patient's differentiation and has no limitations for the use scenarios.

In which the non-linear relationship between exoskeletal muscle activation and pretreated transcutaneous electric signal data is formulated as follows:

$$a(t) = \frac{e^{Au(t)} - 1}{e^{A} - 1} \quad (1)$$

The general numerical expression formula of the Hill-type muscle model is:

$$F^m(t) = F_A^m(t) + F_P^m(t) \quad (2)$$

3. EXPERIMENT AND ANALYSIS (EXPERIMENTAL DATA)

To verify the effectiveness of the training program and service system that matches the individual patient's muscle parameters proposed in this program, this paper compares the changes in muscle parameters in the training state without the patient's participation in the training content, the focus of this paper is not to test the training effect of existing products in the market than the effect of the training content provided in this paper, but through the horizontal holding effect of this product can provide users more independent of product design restrictions on the use of The service of the scenario. Therefore, the selected data is a comparison of the patient’s muscle adjustments when using this product and when not participating in training.

3.1. Experimental Settings

3.1.1. The criteria for the experimental selection of subjects' conditions were:

(1) non-infectious functional muscle damage; (2) partial or partial functional muscle damage with loss or partial loss of arm movement; (3) age between 35 and 45 years; (4) musculoskeletal disorders without other causative factors affecting arm muscle movement function; and (5) consent signed by the patient's legal guardian according to the experimental content. A two-group comparison experiment was conducted.

The device was worn on the patient's arm brachioradialis and triceps position corresponding to the electrode piece on the back of the device (if the position deviated the system would automatically beep to assist the patient to wear it at the exact point by himself).

The pulse rate is set at 2 Hz and the pulse width is set at 200 ms. Each cycle consists of a 2-second rise time, a 5-second work time, a 2-second fall time, and a 10-second rest time. The power was raised to the maximum tolerance level of the person between 12 and 18 mA for 20 minutes a day, 5 days a week, for 8 weeks.

Table 2. Program of muscular stimulation bioelectric

Parts receiving training	Program number	Stimulation time	Stimulation intensity	Interval time	Total number of times
Small arms	010	2-5s	10-20mA	10-25s	15*2
Large arms	1012	2-5s	10-20mA	10-15s	20*2
Hip	1020	2-5s	10-20mA	10-25s	15*2

3.1.2. Overall System Design

The optimal allocation of hardware and software resources is also an important part of the system for the integration of user requirements can be implemented on the ground. First, according to the design concept of monitoring and assisting muscle movement embedded in the main control board Atmega32u4 chip control program, the data collected by the EMG sensor through the corresponding algorithm, calculate the degree of different muscle injuries affecting muscle movement adequately, or the specific parts of the patient who partially lost muscle movement function need to assist the current force parameters.

Secondly, the amplification module in the EMG sensor can amplify several times the microcurrent monitored by the muscle epidermis, which is a bioelectric phenomenon that persists in both the active and resting state of the body cells, and the essence of which is that microelectronic stimulation uses the generated low-frequency pulses instead of bioelectric signals to stimulate the neurons and thus affect the human body tissues and organs. Clinical studies have confirmed that less than 1000 Hz with 15 mA is considered a low-frequency current in medicine and falls within the safe range of low-frequency electrical pulse myoelectric stimulation therapy with a positive feedback effect[16]. Once again, the integration of three knowledge systems lies at the heart of the design of wearable smart devices to monitor and support muscle movement: bioelectrochemistry, computer science, and ergonomics, to monitor the effects of patients' past rehabilitation training; the smart sportswear designed by the brand Athos to monitor muscle movement for professional athletes; training does not take into account the daily personalized needs of ordinary users, despite providing detailed monitoring data The smart sportswear designed by the brand Athos for professional athletes' training provides detailed monitoring data but does not take into account the daily individual needs of ordinary users. This system device fully transforms differentiated user needs into design elements under the perspective of humanistic regression, and uses science and technology to analyze and provide corresponding needs with different feedback program contents to help patients with muscle injury or hemiplegia and patients with physical dysfunction to recover and maintain physical training to improve the quality of life and happiness.

The general scheme of intelligent portable recreational devices is separated into three parts: integrated control system, supervision, and auxiliary system. It is based on the progressive control principle. The onboard control system complements the collection of sensor synthesis and computation data, as well as the transmission of new signals to the micro-current output system.

3.2. Experiment Results and Analysis

3.2.1. Experiment Results

The supervisory system is a myoelectric sensor system responsible for collecting data from the patient's muscle stimulation training process (Figure 7) and transmitting the data to the microcontroller embedded in the control system for computation. The microcurrent stimulation training part of the system receives the signal of the calculation result from the microcontroller and outputs the corresponding current conduction to the affected muscles of the patient according to the instruction, to match the function of individual differentiation to assist the muscle movement. The graphic proves that muscles that are being trained are activated.

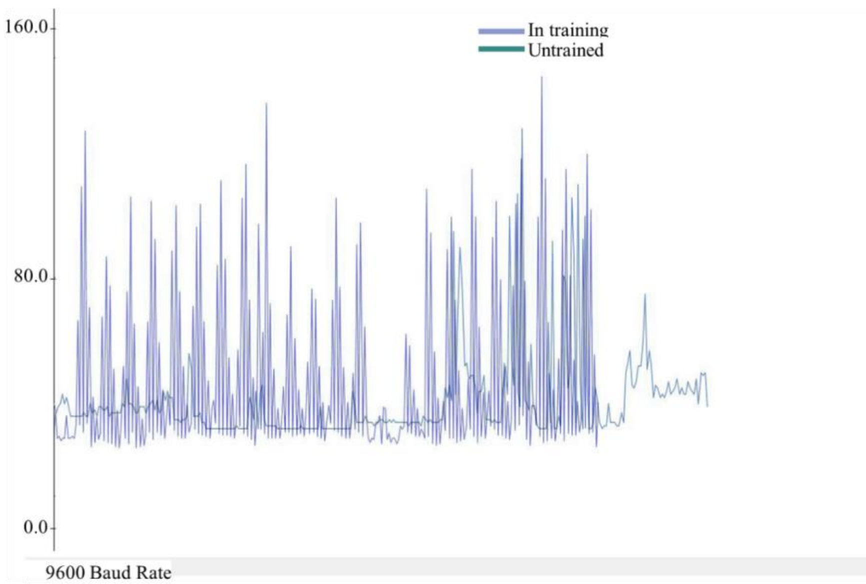

Figure 3 Comparison of muscle vitality during workout and resting status as monitored by the system.

The monitoring system is the first part of the system, and it is in charge of monitoring the current difference in the process of muscle movement to generate EMG data, which can be used as a reference to judge the patient's muscle vitality as well as project the reference data of current stimulation rehabilitation training. Besides, the monitoring function of the system will continue to exist in every training process of the patient to ensure that with the change in the training process the patient's muscle vitality condition improves in time to adjust the iterative upgrade of the training parameters independently.

3.2.2. Performance Evaluation and Results Analysis in Practical Applications

The performance evaluation and result analysis of this smart recreation wearable device in practical application are given using the neural network analysis method applicable to the verification of this feature and also provides the theoretical basis for the subsequent research, based on the feature that the motor neural system can be regarded as a highly nonlinear dynamical system.

The inverse problem in the mechanic's system is the inverse system identification problem. The system input must be known when solving the production of the system. Identification consists of establishing a model equivalent to a measurement system from a given set of model classes on the basis of input and output data. That is, based on known input and output data, a system model is selected and an optimization method is used to make the system model an approximation of the real system. Figure 4 shows how to identify the reverse model of the system.

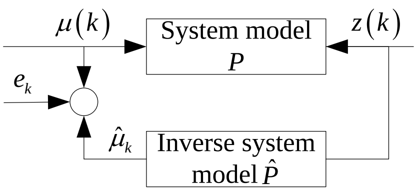

Figure 4 Identification of the inverse model of the system

Definition $e(k)=\hat{\mu}(k)-\mu(k)=\hat{P}-1\left[z(k)\right]-\mu$

The inverse identification of the model is to find PΛ-1 so that e(k) is minimized under some error criterion. Neural network-based system identification can better solve this problem[3]. The BP Network is a common network template for reverse system identification. A neural network is a large-scale complicated system made up of many neurons coupled inside a certain structure to execute various cognitive processing activities. The network consists of an input node layer, an output node layer, and the connecting weights of the nodes between the layers. Figure 3 At layer j, the input values of the nodes are

$$net_j=\sum\omega_{ji}o_i\varphi \tag{3}$$

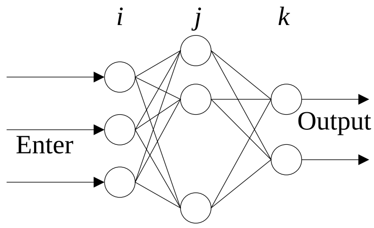

Figure 5 BP neural network map

where: o_i is the output of the ith node in the previous layer, and w_{ji} wji is the connection weight between the i-th node in the previous layer and the j-th node in the current layer. The output value of the node is o_j=f(net_j), where: f is the excitation function of the node, and the Sigmoid function is usually chosen

$$f(x)=\frac{1}{1+e^{-(x-\theta)}} \tag{4}$$

Where ϑ is the threshold value of the neuron. Information flows from the input layer to the output layer, and given the input information, an output result is obtained.

It has been theoretically proven that there exists a three-layer network capable of implementing mappings of arbitrary continuous functions with arbitrary accuracy. The mapping is implemented through the formation of the network, and the learning process of the training is as follows.

(1) Weight and threshold initialization, randomly assigning initial values to all weights and thresholds of neurons;

(2) Given an input x and a target output y/\;

(3) Calculate the actual output y;

(4) Correction weights: Starting from the output layer, the error signal is propagated backward to minimize the error by correcting each weight to:

$$E=\frac{1}{2}\sum_{k=1}^{N}\left(y_k-\hat{y}_k\right)^2 \tag{5}$$

Weighting correction: wji=wji+Δwji=wji+ηδpjypi

where η is the learning factor and the subscript p denotes the pth sample. and there are

If j is an output node, then δpy/\=(y/\pj-ypj)fj(netpj)

If j is a hidden node, then

$$\delta_{pj}=f_j'\left(net_{pj}\right)\sum_k\left(\delta_{pk}\omega_{kj}\right) \tag{6}$$

If the inertia term is added Δwji(n+1)=ηδjyi+ αΔwji(n)

Where: n+1 denotes the n+1th iteration, and α denotes a scaling factor.

(5) The learning is stopped when the error accuracy is reached, otherwise it returns to (2).

Neural network-based system identification is to train the network based on the input and output samples of the system so that the neural network model approximates the input-output relationship of the actual system. For reverse system identification, it is to take the system input as the network output and the corresponding system output as the network input. As long as the system is reversible, a network may be taught to develop an inverse model of it, hence validating the training content delivered to patients in this approach.

3.2.3. Discussion

After fitting the prediction curve of the GM-BP neural network model established in this paper to the actual value (patient's training data for 30 consecutive days as the input value) is significantly higher than that of the traditional GM(1, N) model, it also proves that the treatment effect can be achieved as long as the training intensity and the hourly individual scheme are suitable for the corresponding patients. More importantly, this also effectively solves the problem of complex screening conditions for users and the cumbersome operation of the device, because the training contents in this program are all under the system's active multiple feedback mechanism, without the need for user self-adjustment.

Traditional functional electrical stimulation treatment requires long-term analysis of clinical trial results to determine the treatment effect, while the neural network solution method does not require the establishment of an inverse identification algorithm model of the biomechanical system. It is due to the fact that the neural network itself is a model that fits the input-output relationship of the system through the adjustment of the weights within the network without any direct relationship with the complexity of the system, the inverse problem-solving process can be performed using the neural network as long as the muscle electrical biostimulation therapy is confirmed to be the correct channel to solve the problem and the input-output relationship is established. The deeper meaning is that the neural network is continuously learnable and can achieve more detailed and flexible program data output by continuously increasing the sample data, which makes the treatment program tend to be highly adaptive and effective visualization based on the expanding patient population involved in the treatment scope.

3.3. Design Practice - Overall Solution Design

The traditional myoelectric rehabilitation training can only treat conscious patients with defects, this product because of the attached monitoring function, which can be the user muscle vitality and healthy muscle vitality difference, (as demonstrated in Figure 6-8) to carry out independent analysis and conversion, the formation of individual differences in the microcurrent stimulation parameters. This is an acceptable solution to the disadvantage of strict clinical screening conditions for patients who can participate in muscle rehabilitation training, and it also makes it easier to apply sufficient auxiliary force control when the system detects that the patient is having difficulty completing the movement and assists the patient in completing the intelligent muscle rehabilitation training. In other words, it provides a secondary or multiple active feedback mechanism for the patient's service.

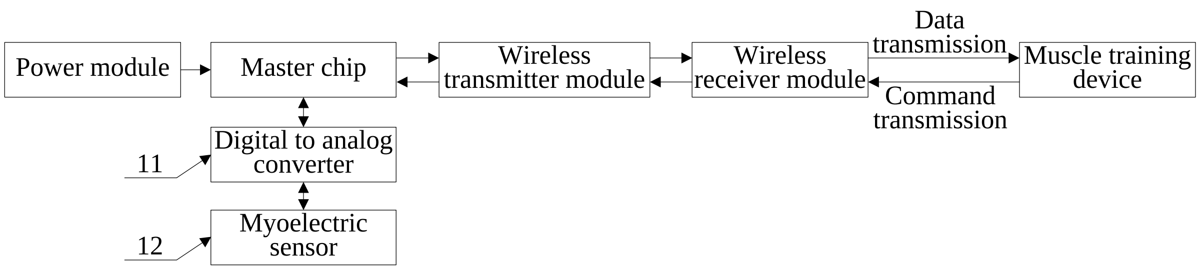

Figure 6 Overall system solution structure design diagram.

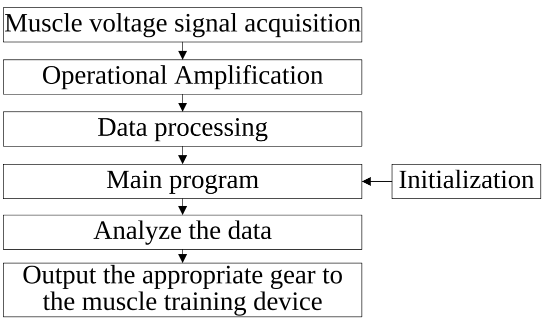

Figure 7 Overall system structure block diagram.

In the microcontroller there are task modules, combined with Figure 8, data acquisition module, control module, system initialization after power on the power terminal (port) will pull high, representing the successful power on the microcontroller, all the input and output port according to the program settings initialization, digital / analog port according to the program settings into the working state, data acquisition module (EMG sensor) began to collect muscle electrical signals, through the serial port The data acquisition module (EMG sensor) starts to collect muscle electrical signals and transmits the data to the main CPU through the serial port protocol; the

CPU analyzes the data according to the Hill-type musculoskeletal model and the relationship formula between sEMG electrical signal data and exoskeletal muscle activation; the main CPU sends commands to the control module through digital/analog signals according to the analyzed data, and the smart wearable device terminal carries out exoskeletal muscle training assistance according to the received commands.

Through the above closed-loop process, the system not only solves the problem of screening conditions for patients to participate in training through parameter analysis but also is an intelligent recreational wearable device that can automatically iterate and upgrade training contents to match the changing muscle vitality parameters of different users without the need of physician's monitoring compared with previous studies.

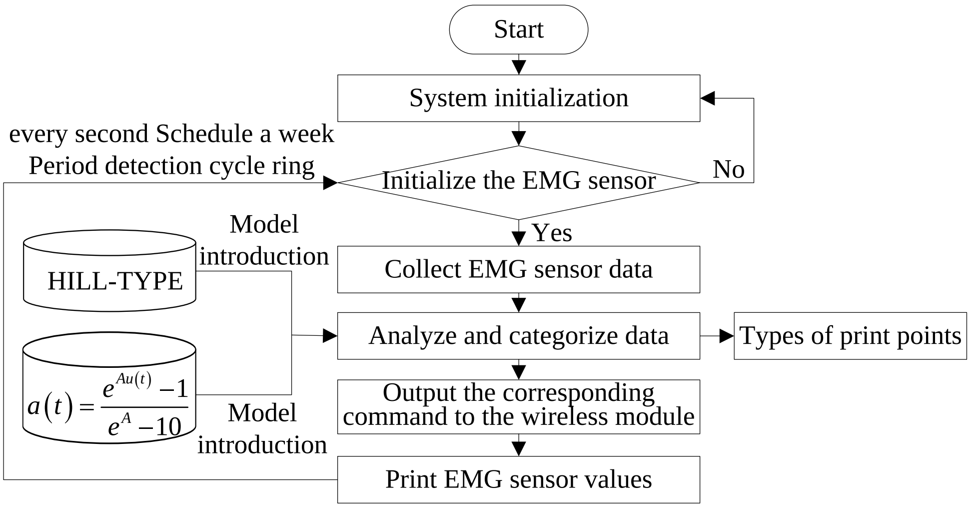

Figure 8 System software workflow diagram

In addition, the product uses a breathable knitted spandex fabric mixed with mesh fabric as the main material of the device to ensure maximum comfort for the user when wearing it. However, the size and height of this product, as indicated in the figure, are quite tiny, making it convenient for customers to use on a range of circumstances such as work and leisure. It is worth mentioning that the middle of the product is removable meta-accessories, such as the cleaning equipment fabric part, you can always independently disassemble the meta-accessories part for a certain degree of cleaning.

Figure 9 Product schematic (in progress).

Figure 10 Product schematic (in progress).

Figure 11 Product 3D modeling display.

4. CONCLUSION

In the context of upgrading the health cognitive structure of the whole population, it is necessary to analyze the user pain points and research the significance of the recreation experience from the theoretical perspective of cross-discipline and build a healthy social system and lifestyle that meets the diversified recreation needs of users. In addition, the intelligent recreation wearable device solves the realistic problems of individual user differentiation and ease of device operation and fits the theme of the times of hardware-software synergy and system-level optimization technology of artificial intelligence chip development, and this kind of intelligent recreation wearable device well demonstrates the pioneering attempt of synergistic innovation of art and science resources under the interdisciplinary design thinking approach of design, and the performance evaluation and results in analysis in practical application given in the analysis of the paper also provide a basis for the subsequent research. The performance evaluation and analysis of the results of the practical application given in the analysis in this paper also provide the theoretical basis for the subsequent research.

However, the project still has flaws, which may be addressed in the future by doing the following: Although the main control board is embedded with as good a smart and convenient program as possible, all calculation processes are done automatically in the closed-loop inside the microcontroller, and there is no visual data information for the user to view, so if you want to observe the data, you need to disconnect the closed-loop of the system to connect to the computer to view the data. For this reason, in the next research, we can develop a cell phone app that can be downloaded by customers, so that patients can have a visual experience while enjoying the tactile sensation during the training process.

REFERENCES

[1] H.F. Nweke, Y.W. Teh, M.A. Al-Garadi, U.R. Alo, Deep learning algorithms for human activity recognition using mobile and wearable sensor networks: State of the art and research challenges, Expert Systems with Applications 105 (2018) 233–261. DOI: https://doi.org/10.1016/j.eswa.2018.03.056

[2] S.Z. Deng, B.T. Wang, C.G. Yang, G.R. Wang, Human Activity Recognition with CNN Multi-position Wearable Sensor, Northeastern University, Journal of Software 30(3) (2019) 718–737. DOI: https://doi.org/10.13328/j.cnki.jos.005685

[3] F. Liu, J.L. Han, J. Qi, et al., Research and application progress of smart wearable devices, Chinese Journal of Analytical Chemistry 49(2) (2021) 159-171. DOI: https://doi.org/10.19756/j.issn.0253-3820.201410

[4] D. Silver, A. Huang, C.J. Maddison, et al., Mastering the game of Go with deep neural networks and tree search, Nature 529(7587) (2016) 484–489. DOI: https://doi.org/10.1038/nature16961

[5] L. Peng, Z.G. Hou, W.Q. Wang, Synchronous active interactive control and realization of rehabilitation robot, Chinese Journal of Automation, 41(11) (2015) 1837–1846. DOI: https://doi.org/10.16383/j.aas.2015.c150270

[6] L. Dong, Y. Qu, Design and application of motion capture algorithm for wearable sensors in telerehabilitation, China Medical Devices 36(11) (2021) 32–35. DOI: https://doi.org/10.3969/j.issn.1674-1633.2021.11.007

[7] W.T. Liberson, H.J. Holmquest, D. Scot, M. Dow, Functional electrotherapy: stimulation of the peroneal nerve synchronized with the swing phase of the gait of hemiplegic patients, Archives of Physical Medicine and Rehabilitation 42 (1961) 101–105.

[8] Y.X. Zhong, W.J. Zhou, J.Y. Liu, Clinical study of Athos intelligent sportswear combined with MOTOmed intelligent exercise system in the treatment of upper extremity motor dysfunction after stroke, Chongqing Medicine 47(14) (2018) 1896–1899. DOI: https://doi.org/10.3969/j.issn.1671-8348.2018.14.014

[9] S.M. Wu, An artificial intelligence method for evaluating human arm muscle strength and muscle fatigue based on electromyography (EMG) signals, PhD., Huazhong University of Science and Technology, 2013.

[10] J.H. Liu, Evaluation of muscle function state based on nonlinear dynamic analysis of sEMG signal, PhD., Zhejiang University, 2006.

[11] S. Niu, Development of a wireless microcurrent neurostimulation system based on SimpliciTI, MA., Shanghai Jiao Tong University, 2009.

[12] W. Li, R. Zhang, Y.L. Luo, et al., Efficacy of gait-induced functional electrical stimulation in improving lower extremity motor function in children with spastic diplegic cerebral palsy, Chinese Journal of Rehabilitation Medicine 28(12) (2013) 1126–1130. DOI: https://doi.org/10.3969/j.issn.1001-1242.2013.12.010

[13] L.J. Chen, D.H. Chang, Wireless data communication based on nRF2401, Chinese Journal of Electron Devices 29(1) (2006) 248–250. DOI: https://doi.org/10.3969/j.issn.1005-9490.2006.01.070

[14] D.H. Sun, Q. Hu, H. Xu, Neural network analysis method for mechanical inverse problems, Computational Structural Mechanics and its Applications (13) (1996) 59–63.

[15] R. Xu, Neuromuscular electrical stimulation rehabilitation and gait analysis key technologies for motor dysfunction, PhD., Tianjin University, 2017.

[16] Y. Fan, Q. Cheng, Analysis of the therapeutic effect of low-frequency pulse current on the human body, Journal of Henan University of Science and Technology 41(5) (2013) 45–47. DOI: https://doi.org/10.3969/j.issn.1008-7516.2013.05.011

[17] J.X. Chen, Z.M. Xie, Y.J. Jiang, et al., Effects of electrical muscle stimulation training on the surface electromyography of the vastus medialis muscle in patients with knee extension retardation, Chinese Practical Medicine 16(22) (2021) 96–98. DOI: https://doi.org/10.14163/j.cnki.11-5547/r.2021.22.034

[18] J.P. Liu, W.N. Wang, S.J. Liang, et al., Effects of multichannel functional electrical stimulation treadmill training on walking function in stroke patients, Chinese Journal of Rehabilitation Medicine 36(2) (2021) 182–185. DOI: https://doi.org/10.3969/j.issn.1001-1242.2021.02.010

[22] K. Michinari, T. Takumi, N. Hiromi, M. Takashi, R. Jun, Design guideline for developing safe systems that apply electricity to the human body, ACM Transactions on Computer-Human Interaction 25(3) (2018) 1–36. https://doi.org/10.1145/3184743