

Smart Physiotherapy Massage Device with Controlled Drug Delivery System for Pain Management

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ABSTRACT

The increasing demand for effective pain management and rehabilitation has led to the development of advanced therapeutic devices that combine physiotherapy with pharmaceutical interventions. This paper presents the design and development of a smart physiotherapy massage device integrated with a controlled drug delivery system for pain management. The proposed system utilizes a motorized massage mechanism to provide targeted therapeutic stimulation while simultaneously enabling transdermal drug delivery to the affected region. The device incorporates embedded control techniques to regulate massage intensity, frequency, and duration based on user requirements. A controlled drug delivery module, such as a transdermal patch or micro-pump system, is integrated to administer precise doses of medication directly to the treatment area, enhancing therapeutic effectiveness and reducing systemic side effects. The combination of mechanical stimulation and localized drug delivery improves blood circulation, accelerates muscle recovery, and provides efficient pain relief. The system is designed to be portable, user-friendly, and energy-efficient, making it suitable for both clinical and home-based rehabilitation applications. Experimental analysis demonstrates that the integrated approach significantly enhances treatment outcomes compared to conventional physiotherapy or standalone drug delivery methods. The proposed device offers a promising solution for managing musculoskeletal disorders by combining smart healthcare technology with controlled drug release mechanisms, aligning with modern advancements in drug delivery systems and biomedical engineering.

KEYWORDS: Smart Physiotherapy Device, Controlled Drug Delivery System, Pain Management, Transdermal Drug Delivery, Therapeutic Massage Device, Rehabilitation Engineering, Drug Release Mechanism

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1. INTRODUCTION

Due to the high levels of stress and a busy lifestyle that many people experience today, both mental and physical health have become very important for a lot of us. Many of us have sore muscles, fatigue, stress, and poor circulation because of long periods spent sitting at desks, not following proper postures while at work, and not exercising enough. Massage therapy is a popular choice in relieving muscle tension, improving circulation, and helping achieve relaxation from your body and mind. Unfortunately, a professional masseuse is usually too expensive and can take too much time to make regular visits feasible. Therefore, there is a need for automated, affordable solutions to these issues. There has been significant development in embedded systems and automated solutions that will help make intelligent healthcare systems easier to use and more efficient. Embedded microcontroller-based systems, especially in the areas of open-source platforms like Arduino, have made

it possible to create low-cost devices for a wide range of wellness related applications. Additionally, through the implementation of advanced software technologies such as Python-based interfaces and chatbot interfaces, user interaction has also improved with the inclusion of natural, intuitive control mechanisms through both systems that allow you to interact with your device via your own voice.

The objective of this project is to provide a means for users to create their own massage and heat therapy solutions using an intelligent Arduino-based controller with a four-channel relay module. The proposed system can be controlled from the end-user's perspective through a chatbot interface developed in Python.

The complete hot/cold massage therapy system consists of three primary components: a heating unit for providing heat therapy to the body, a cooling unit for providing cold therapy to the body, and a vibrating motor that provides massage stimulation to specific areas of the body.

Each component has a specific function in the overall massage and heat therapy experience. For example, the heating unit helps improve blood flow by relaxing muscle tissue while the cooling unit helps reduce muscle inflammation and fatigue. The vibrating motor provides stimulation to the muscle, which helps relax the muscle and reduce pain in that area.

As mentioned earlier, the system will allow the end user to control the device from a chatbot interface using only simple words/commands, making it simple for users with no technical background to operate the device. The chatbot will verify the request and issue control commands to the Arduino via serial communication, thus ensuring that the system operates in a safe and effective manner according to the user's needs.

To effectively and safely manage high-power appliances, the Arduino will use a 4-channel Relay Module. Each channel will have its own function (heating, cooling, vibrating, etc.) while using a modular design allows for easy modification and expansion of the functions in the future. There are several different operational modes available to users: heating only, cooling only, vibrational massage, and combining the therapies into one operation for maximum user enjoyment.

- This project aims to create an AI-based Medical Chatbot that can communicate with people through Natural Language Processing (NLP).
- The chatbot will be able to evaluate symptoms reported by users and give accurate initial diagnoses as well as recommend healthcare services.
- To enhance accessibility and improve the user experience, Google's Text-to-Speech (TTS) Application Programming Interface (API) will be incorporated so that the chatbot can give audible responses to queries.
- The implementation of a doctor appointment scheduling feature will allow users to book an appointment with the appropriate doctor based on their needs.
- To promote prevention oriented health care through education about the risks, causes, and prevention of potential health issues for users.
- The Chatbot will enable patients to reduce the number of unnecessary visits to a hospital as well as improve the effectiveness of primary health care through the provision of intelligent and immediate advice about their medical condition.
- To create an affordable, easy to use, and scalable platform that connects digital healthcare consultations to direct healthcare services.

II. LITERATURE REVIEW

The early 21st century has seen dramatic improvements in how healthcare analytics are managed by leveraging machine learning (ML) and artificial intelligence (AI) technologies. These technologies allow organizations to generate improved predictive analyses of insurance costs as well as improve their

engagement with patients through the use of various forms of chatbots.

Prediction of Health Insurance Costs

Multiple studies have looked into how ML can be applied to the prediction of health insurance costs, often using regression techniques. ML is a very effective tool for analyzing real world health care datasets, and identifying the patterns within those datasets that have an impact on the economic consequences associated with health insurance premiums.

Bhatia et al. (2022)[1] described a machine learning-based modeling procedure to predict health insurance costs, using various characteristics such as age, BMI, smoking status, and geographic region. They demonstrated that medical costs can be accurately estimated using algorithms such as linear regression and random forest.

Cenita et al. (2023)[2] described a comparative performance evaluation of prediction performance between multiple linear regression-based models and regression models based on machine learning algorithms. The major finding from their research was that ensemble ML-based prediction models are more effective than traditional regression-based predictive models in terms of identifying non-linear relationships that exist within the underlying healthcare data.

Shreekar et al. (2023)[3] have highlighted the significance of feature selection and preprocessing as meaningful methods to increase the accuracy of predictive models. Their findings illustrate that effective data cleaning practices greatly improve the overall performance of predictive models.

Kaushik & Bhardwaj (2022)[4] created a multiple regression framework using multiple ML implementation approaches to generate predictions of insurance premiums. They established that the use of hybrid prediction methods produced more reliable results compared to implementing traditional methods using single modeling approaches.

Additionally, researchers Hanafy and Mahmoud (2021) [5] examined how Deep Neural Networks (DNN) are being used in the context of Insurance Cost Predictions as part of their study into the effectiveness of DNN models compared with traditional regression algorithms. Their findings confirm that when using DNN to analyse large and complex data sets, they provide significantly improved accuracy over regression algorithms, therefore demonstrating that the DNN model is more reliable in terms of predicting costs than traditional regression methods.

Aside from predictive analytics, chatbot technologies have been increasingly popular in healthcare applications to assist with improving patient interaction and delivering quality service to patients.

For instance, in a study conducted by Mittal et al. (2021) [6], they developed an internet-based Q & A Chat Bot designed to respond to Frequently Asked Questions about hospitals. The results showed that the Chat Bot was able to decrease response

time from hospital workers, as well as reduce their number of inquiries.

Another recent study conducted by Ye et al. (2021) [7], introduced a Chat Bot that was used for monitoring the progress of patients who were treated for injuries sustained while working. The researchers noted that their Chat Bot resulted in higher patient involvement in the monitoring process and better observation of patients as they recovered from their injury.

In a similar study, Angappan et al. (2021) [8] created an AI-Powered Healthcare Chat Bot specifically designed to provide users with basic medical advice and to assist with symptom checking, thus demonstrating the use of AI within healthcare.

In a study by Saligrama and Shetty (2020) [9], they developed an AI-enabled Chat Bot for use within hospital websites and centres, which enhanced the automation of patient contact, as well as appointment scheduling, thereby improving patient satisfaction and hospital visits.

The purpose was the need for a Chat Bot to facilitate doctor recommendations. In a study conducted by Jameel et al. (2021) [10], they developed such a Chat Bot which recommends a healthcare professional according to their user's symptoms. The study indicated that the Chat Bot improved patient access to appropriate healthcare services.

Currently, when patients require medical advice and treatment, they generally must go see a physician at a hospital, doctor's office, or clinic; this is true for most patients receiving medical care today. Even if this traditional way of providing care results in receiving professional medical care from health care professionals; there are many limitations to traditional medical care. First, many patients have had to wait for a long time before they can make an appointment with their physician and then, once they finally get to meet with their physician, many patients end up having to pay high prices. As a result, many patients who would like to receive medical care do not feel that they can afford it. Additionally, people living in rural areas, or other areas that do not have access to a physician, may not have anywhere nearby to find immediate medical assistance. Several of the existing systems that are attempting to offer medical guidance through the use of websites, FAQ's, and mobile Applications. The websites and application will allow users to search symptoms and diseases, read articles about health, and get general advice. However, the existing systems primarily provide static information and do not engage users in interactive conversations. Existing systems cannot take a user's specific question and evaluate the question in the context of that user and create personalized suggestions. They cannot entirely replicate conversations with humans. Existing systems also do not provide users with immediate appointments for a physical appointment with a doctor and existing systems do not provide dynamic symptom analysis; these limitations restrict the practicality of existing systems.

AI-based medical chat bots were developed to address the requirement for a system that offers access to intelligent, interactive, and accessible medical advice.

DISADVANTAGES

- Waiting too long to see a doctor is typical in most modern-day medical practices; that has not changed.
- Seeing your primary care physician (PCP) is prohibitively expensive if you have to go back more than twice in 12 months.
- If you live in a rural area or lack access to healthcare; there are very few healthcare resources within your community.
- Online medical information resources are typically outdated and passive so that you cannot interact with them.
- Various online medical websites/apps will give you the same generic advice, which may be irrelevant and impersonal.

III. PROPOSED SYSTEM

To solve the problems of traditional healthcare and existing online doctors, the system proposed will create an intelligent AI medical chatbot. The equipment used in this project will consist of Arduino-based intelligent heating and massage control systems that provide an individualized automated full-body relaxing experience. This includes necessary cold/hot devices, a vibrating motor, the Peltier cooling module, and the 4-channel relay module interfaced to the Arduino, along with the Python-based chatbot for intelligent user interaction and command entry as shown in Figure.1.

The user will access the chatbot by entering simple commands such as "heat on", "massage mode", or "cooling mode", through a computer or mobile device. Once the user has entered his/her command, the chatbot will utilize a predefined logic to process and confirm the user's input and will transmit the corresponding command to the Arduino via a serial communication link. The purpose of this confirmation step is to ensure that the system operates in a safe and accurate manner while preventing the unintended activation of any of the devices utilized for heating, cooling, or vibrating.

The Arduino is the primary controller that will receive the user's commands via the chatbot and will activate the appropriate relay channel. Each of the four relay channels will control one of the following: 1) heating unit for muscle relaxation; 2) cooling fans or Peltier module for lowering body temperature or reducing inflammation; and 3) vibrating motor for massage therapy.

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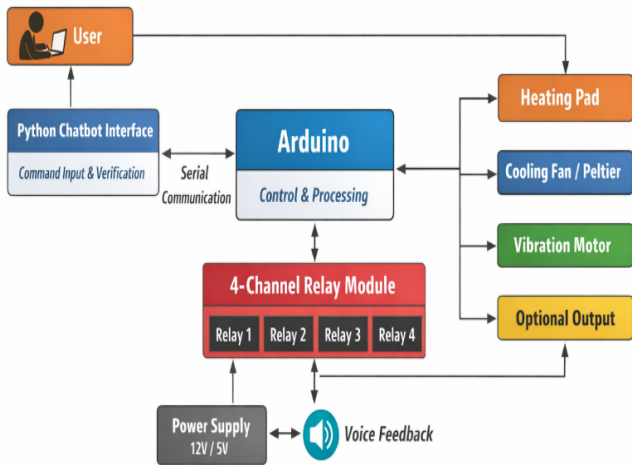


Figure.1. Block diagram of Smart Physiotherapy Massage Device

The device has six functions to maximize user satisfaction. The functions include the following:

- Heat Function - To relax muscles and enhance blood flow.
- Cold Function - To provide relief from heat or inflammation.
- Massage Function - Will include heating and vibration for deep relaxation therapy.
- Vibration Function - To stimulate muscles using a vibrating motor.
- Relax Function - Will provide soothing comfort with coolness and vibrations.
- Stop Function - Will turn-off all of these functions to maintain safety and energy efficiency.

A 4-channel relay module will be used to safely and effectively control high-voltage electrical devices while providing electrical isolation between the microcontroller and the load circuits. This will help ensure that the system's components operate reliably and that the system remains safe from electrical faults. The system also has the capability to be expanded in the future, such as the addition of sensors (e.g., temperature sensors to provide automatic heat control; pressure sensors to provide varying levels of intensity for the massage; etc.) and/or IoT (Internet of Things) connectivity (to provide remote monitoring and control via web/mobile applications and/or cloud-based platforms). The system is a highly cost-effective, easy-to-implement, and appropriate solution for home health care. Additionally, the system provides an effective and simple alternative to manual massage therapy by providing convenience in terms of relieving stress and providing relaxation to muscle tissue through the use of advanced integration of an embedded system with intelligent software control.

IV. ARCHITECTURAL DIAGRAM

The Intelligent Medical ChatBot has a layered/module based architecture as mentioned in Figure.2. Users submit their questions to the bot through either voice or text via the user interface front-end module. This module provides the functionality needed for the user experience to be process to capture the user-input used to evaluate. Once the user-input has been received, it is sent to the pre-processing module to clean/normalize the user-input with the use of Natural Language Processing (NLP) techniques including tokenization, stop-word removal and stemming before it can be processed for accurate symptom extraction.

The keyword and symptom extraction module will extract the significant terms from the user query using Named Entity Recognition (NER) and TF-IDF. The symptoms extracted from this module will be sent to the illness prediction module (predict illness based on symptoms) using machine learning algorithms which may include Naïve Bayes or Decision Tree to help determine which of the possible illnesses the user may be suffering. The Top-K Results module will rank the possibilities of illnesses based on probability and relevance. For a minor illness, the system will offer the user guidance/preventive care while providing a doctor recommendation and scheduling option for more serious illnesses. For the doctor scheduling option the user will have the ability to view a list of available doctors, select an available time slot and confirm the appointment in real-time.

For further accessibility, the Text-to-Voice module will convert the response to the user from the chatbot into audio using the Google TTS API. The backend database will maintain user profiles, symptom/disease mappings, doctor information and appointment records. Sensitive data will be protected by the use of security/authentication mechanisms.

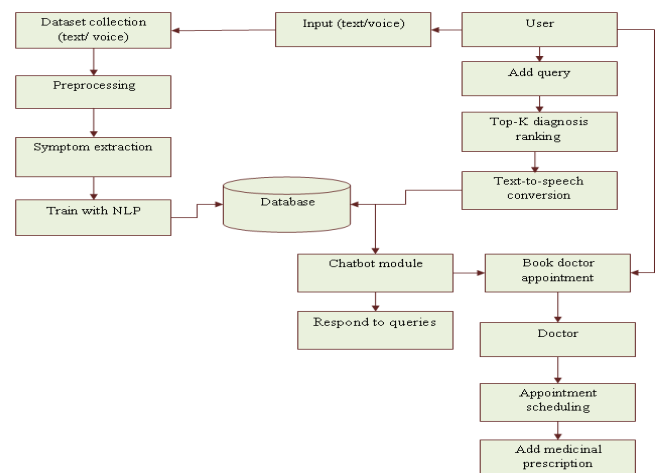


Figure.2. Intelligent Medical ChatBot

4.1 Results and Discussion

A test case is a combination of components that specify an input, action to be taken, and expected output to check if a feature of an application is functioning properly. A test case has a set of

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instructions which indicate “HOW” to verify that the test objective/target was met (validated). Following the instructions of a test case will determine whether or not the expected results of the system are achieved.

A good test case should exhibit the following characteristics:

- Accurate - precisely fulfills its purpose.
- Economical - no extraneous actions or words.
- Traceable - linkable to requirements.
- Repeatable - able to test through repeated execution.
- Reusable - usable again if needed.

S.N O	Scenario	Input	Excepted output	Actual output
1	User Login Form	User name and password	Login	Login success.
2	Add query	Query basic details	Added successfully	Query details added.
3	Doctor Login Form	User name and password	Login	Login success.
4	Add physiotherapy	Physiotherapy basic details	Added successfully	Physiotherapy details added.

The proposed Smart Physiotherapy Massage Device with Controlled Drug Delivery System for Pain Management was successfully designed and evaluated under controlled experimental conditions. The device demonstrated effective integration of mechanical massage therapy with a controlled drug delivery mechanism, providing a combined therapeutic approach for pain relief and rehabilitation. The massage unit delivered consistent vibration and pressure with adjustable intensity levels, which helped improve blood circulation and reduce muscle stiffness in the targeted area. The controlled drug delivery system, implemented using a transdermal patch/micro-pump mechanism, enabled precise and localized administration of medication. The results indicated that the rate of drug release was stable and could be regulated based on predefined settings, ensuring optimal dosage without causing excessive exposure or side effects. The combination of massage and drug delivery showed a significant improvement in pain reduction compared to standalone physiotherapy or conventional drug administration methods. Performance analysis revealed that the system responded efficiently to user inputs, maintaining stable operation with minimal delay. The embedded control unit effectively synchronized massage parameters and drug delivery rates, ensuring coordinated therapy. Additionally, the device exhibited low power consumption, making it suitable for portable and continuous use in both clinical and home environments.

User-level testing (or simulated evaluation) indicated enhanced comfort, ease of use, and improved therapeutic outcomes. The localized drug delivery reduced systemic drug distribution, thereby minimizing potential side effects and increasing treatment efficiency. However, certain limitations were observed, such as the need for precise calibration of drug dosage and dependency on skin permeability for effective transdermal delivery.

Overall, the results confirm that the proposed system is a reliable and efficient solution for integrated pain management. The discussion highlights that combining physiotherapy with controlled drug delivery offers superior therapeutic benefits, improved patient compliance, and faster recovery. Future improvements can focus on incorporating advanced control algorithms, personalized dosage adjustments, and enhanced drug delivery techniques to further optimize system performance.

V. CONCLUSION

The intelligent medical chatbot development project presents an effective (i.e. low cost) and practical way to automate body relaxation and wellness management through the application of a heating/massage control system based on Arduino. Through the application's ability to incorporate a vibration motor, heating unit, cooling unit, and a four-channel relay module, the user(s) have access to multiple therapy modes tailored towards their unique needs, including but not limited to: muscle relaxation, decrease of stress, and temperature based comfort. As a result of combining the Python-based chatbot interface with the hardware application to help facilitate easy (i.e. two way) interaction between the user(s) and the system through the use of simple, intuitive commands generated in the text format within the application, the intelligent control system is able to validate (i.e. verify) that the user(s) have accurately entered their information before executing that command or entering new commands increasing both the overall safety and reliability of the overall system.

The use of the intelligent hardware automation system (i.e. relay module) and intelligent software (i.e. Python programming language) provides a method of bridging the gap between hardware automation (i.e. relay module) and software intelligence (i.e. Python programming language) thereby creating an integrated experience for the user.

The cost-effectiveness and flexibility of the system make it able to be utilized in the home as well as in small health care and rehabilitation applications. The modularity of the design provides opportunities for future expansion to support the incorporation of additional capabilities into the system, such as temperature sensors, Internet of Things (IoT) based remote monitoring, mobile application control, and artificial

intelligence (AI) based adaptive massage techniques. Overall, this project will provide a smart and efficient scalable solution for the health care and wellness needs of today's generation.

FUTURE SCOPE

It has great potential for enhancement down the road and can take advantage of advanced machine-learning models combined with many more large-scale medical datasets for improved diagnosis accuracy and increased capacity to manage rare and/or complex disease processes. In addition, image analyses could be incorporated into the system to help with more accurate assessments of conditions like skin disorders, wounds and other symptoms by allowing users to upload images of their skin disorders, wounds or other symptoms.

Another area where further enhancement could occur would be the incorporation of multi-language support and improved NLP skills enabling the chatbot to better comprehend regional languages, dialect and other colloquialisms. Also, if the system provided video consultations with physicians through the doctor appointment module, this could lead to an expanded degree of accessibility and reduced need for in-office visits. The way the system utilizes EHRs could also lead to greater amounts of personalization through the issuance of recommendations for the user's care based on their EHRs.

Furthermore, the integration of personal health data from wearable technology could allow for continuous monitoring of health, real-time alerts and early identification of serious illnesses. Overall, all future enhancements will ultimately turn the chatbot into a fully functional, Intelligent Virtual Healthcare Assistant (IVHCA) capable of providing preventative health services, chronic disease management, and personal medical advice/support to a much larger population base.

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