Artificial intelligence driven robotic control system for personalized elderly care and foot massage

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ABSTRACT

This research presents an electronic system for providing foot massage to the elderly, along with artificial intelligence (AI) driven voice-controlled conversation bot. The problem under study focuses on the elderly age group suffering from foot related ailments, most commonly foot pain. Also, the risk of depression or anxiety is high for this age group due to social isolation. These problems are addressed by the system under discussion integrated with a voice assistant to converse with the elderly. The AI assisted conversation bot enables the elderly to make customized reminders for their timely medications and provides general updates on essential topics. The system extends to provide the elderly, foot, and calf massage controlled with mobile application. It consists of a low power motor arrangement along with a high computing system. The electronic system was subjected to trials on elderly for verification and validation of the system to assess its ability of providing users with appropriate assistance. The trials were conducted on twenty elderly, aged sixty, and above, living self-sufficiently with foot related ailment. All elderly were subjected to the conversation bot along with the foot and calves' massage, providing subjective feedback on the system's ability to enhance their quality of life. The subjective feedback after quantification have demonstrated the ability of the system in improving their living standards.

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1. INTRODUCTION

The number of elderly staying alone is increasing with an adverse impact on their health and psychological behavior. Recent reports provide an insight regarding elderly population (aged 60 and above), which is currently at 10.5% of India's total population [1]. About 5.7% of the elderly population live alone without the support of any family members [2]. This situation presents a significant problem, the absence of companions and the unavailability of individuals to look after the elderly's health. Prominent reasons for this unavailability might include a lack of family support or situations where the elderly are staying alone. Additionally, hiring a trained career to provide necessary services, such as massage therapy, can be prohibitively expensive. Addressing these challenges is crucial for improving the well-being and life satisfaction of the elderly population. This study aims to tackle these issues by developing innovative solutions that ensure both physical and mental assistance for the elderly, ultimately enhancing their quality of life. The field of elderly care and assistance has witnessed significant advancements in recent years, primarily driven by the integration of cutting-edge technologies like artificial intelligence (AI) and robotics.

The researchers have developed conversational robots for companionship to elderly care with assessing the understanding of elderly and creating a dataset to check prefrontal cortex (PFC) and working memory (WM) [3]. One of the key elements of robotic elderly care is the accuracy with which actions are identified by the robot using data from sensors [4]. By 2050, the elderly will make up around 16% of the global population. To provide better aged care and increase life expectancy, it is essential to monitor older people's physical activity, particularly for fall detection and prevention [5]. For the elderly who are living alone at home, homecare research is particularly important in solving the aging issue. Approaches like camera-based monitoring and wearable based smart devices were tried but did not get the results as expected [6]. The caregivers are now being trained using AI robots which use visual based feedback such as pain level which gives trainees more experience [7]. Robotics and AI together have a bright future in elderly care and assistive technologies.

The proposed system aims to enhance the quality of life by providing digital companionship and massage therapy to the elderly. These objectives are achieved by integrating an electronic system of end effectors with an AI driven conversational assistant. The assistant is designed to generate a stipulated response by analyzing the intent and emotion behind the user’s input. A novel intent recognition system using few-shot learning and a fine-tuned emotion classifier is proposed. The AI assistant decides the response by classifying user input into certain predefined intent classes. Furthermore, emotional analysis of natural language in text is performed to simulate human-like conversations with the elderly. The complex massage system seamlessly collaborates with the AI conversational robot thereby ensuring physical and mental assistance for the elderly. The development of the AI assistant contributes to the existing work in terms of providing companionship to the elderly.

2. LITERATURE REVIEW

Researchers have worked on elderly care to provide an assistive framework for elderly as well as some kind of physical aid. Further, the work done by researchers is discussed along with its outcomes. Smart elderly care robots equipped with AI features provide personalized care, companionship creating personalized datasets to assess PFC and WM to check current understanding of storytelling and memory and difficulty in understanding the story, the model has the accuracy score of 89% [3]. Deep learning approaches, such as convolutional neural networks (CNN) and recurrent neural networks (RNN), have improved the accuracy (92.31%) of activity recognition by capturing spatial and temporal relationships, but they require large amounts of training data and have slow training speeds [4]. The combination of fall detection and human pose estimation using various pipelines such as MovNet, transformer, long short-term memory (LSTM), and AlphaPose. The poorest results were obtained by MovNet 69%, while the greatest results were attained by AlphaPose 89.22% for pose detection and transformer 90% for action categorization [5]. The three phases of the behavior identification algorithm (BIA) are sensor event based grouping (SEG), histogram similarity based grouping (HSG), and behavior based matching (BM). The BIA has the F1-score of around 95% [6]. The introduction of the care training assistant robot revolutionizes caregiver training, offering visual-based feedback in elderly care education environments. This immersive approach allows trainees to acquire and practice essential caregiving skills, elevating the standard of elderly care services with pain levels from 0 to 1.99 which gives the caregiver more exposure for practical applications [7].

A smart elderly assistance system which uses computer vision algorithms to identify fall condition has been developed. The limitation of the system is the requirement of proper lighting conditions. The author claims accuracy of 98:5%, sensitivity of 97% and the specificity of 100% for the algorithm [8]. A smart robotic arm Emma is designed for medical massage with feedback of force applied through end effectors. It further has a camera for exact placement of finger and palm massage manipulator to conduct feedback control with respect to force [9]. HomeMate is a system which tries to establish ambient assisted living around the elderly. Social robot is another assistive framework that has human robot interaction (HRI) and tries to establish communication with elderly [10]. The author has provided an overview on 12 elderly care systems focused on assistive care that can be provided for exercise and rehabilitation through cognitive based assistance bot (CAs) and personal robot based assistant bot (PRAs). PHAROS is a combination of robotic as well as event planning for elderly monitoring, while they perform physical tasks. Stevie is another assistive robot which engages in social interactions with elderly through gestures and speech [11]. The author discusses smart homes in the context of ‘aging of elderly in place’. A system “CareBot-assisted smart home (CBASH)” is by the author which consists of a sensor-based network, a service processing center and a care responsive Bot. The CareBot is equipped with LIDAR and momentary feedback for navigation and video call functionality along with an AI assisted chat system for interaction with elderly. An improved genetic based algorithm (IGU) consists of various operators (fitness score (450), selection operator, and threshold (1,000)) for task planning. The author confirms that the experiment results show that the CBASH system can perceive complicated tasks and plan for homecare assistance tasks with a quick response in case of emergencies [12]. A robotic massage positioning system which uses prediction modeling of feet acupoints guided by traditional Chinese acupuncture empirical knowledge. A cerebellar model arithmetic computer (CMAC) neural network to further optimize detection of acupoints with reinforcement learning and predictive models resulted in a highly accurate acupoint coordinate system [13]. The psycho-physiological and muscular parameters were studied.

The study concluded that massage stimulation on pressure receptors resulted in improved vagal activity and cortisol levels [14]. The result of the study of assistive and nursing robots concluded that very few technological assistive elderly care solutions were in use due to high costs, legal and safety issues yet to be resolved [15]. Most of the robots were mitigation-based and emergency centric assistants [16]. A detailed report of nursing robots with case studies to analyze the performance of robots in healthcare and nursing environments. It also talks about the social acceptability of robotic healthcare systems within elderly circles. The authors cite a report wherein 51% of European citizens were uncomfortable using care robots [17]. A cost-effective radiation monitoring system is discussed for nuclear sites utilizing wireless sensor networks (WSNs) and ZigBee technology. The system demonstrated 25% reduction in cost compared to available commercial solutions [18]. The literature describes design and implementation of a cost-efficient smart vehicle for environmental parameters analysis in industries, for the well-being of employees [19]. Robots tailored for frail elderly care and their nursing modes are found to be expected to give interpersonal interaction experience to the elderly [20]. An adaptive and aware dialogue system for elderly using virtual assistant is developed and the need for interactive communication for the elderly is emphasized in the work [21]. A compression wave pattern by varying frequency, amplitude and phase generated for massage [22]. Acupoint massage system was developed [23]. Physiological parameters measurement during massage on static and dynamic condition of foot movement was implemented [24].

Comparative study of difference in the skin conductance , as a measure of relaxation was carried out involving a physical therapist and intervention by a robot [25]. It was concluded that the manual massage intervention outperformed robotic massage. The field of assistive technology, elderly healthcare using robotics has seen many advancements in recent years. According to multiple research papers reviewed, some conclusions regarding the research gap could be drawn with respect to the new advancement considered in our system. Many systems as mentioned in the literature survey consisted of features such as - face recognition/elder motion analysis, self-navigation using mapping and localization. Chatting and conversing with elders, remote connectivity through smartphone, physical aid like massaging, physiological and psychological therapy, cognitive training and exercises for elders, determining relation between perception and action, generating an action based on object detection and graph neural network (GNN), human activity and health monitoring. The reviewed papers implement some of the above-mentioned ideas. Many research papers that are reviewed present mobile robots with AI technology, that are able to detect faces, used for increasing cognitive as well as brain agility, finding relationship between perception and action but none of them provides any kind of physical aid to the elderly people. The system proposed in this work integrates conversational AI assistance for elderly as well as an embedded system for foot and calf massage. The system under study provides physical aid in the form of foot and calves massage assisted by a personalized AI assistant which will control the massage system through the mobile application and provide companionship through conversation.

3. METHOD

The system consists of an AI-based conversational bot (robot) and a control system for foot sole and calf massage. The entire system is connected to a mobile application via Bluetooth for user interaction using voice and text commands. The system comprises four major components: a platform for foot which consists of vibration motors at specific acupoints based on the foot reflexology, two medical cuffs are fixed with the air pump for the calf massage, which inflates and deflates to generate the massage, both the systems are connected with a fast-computing system which is controlled by a mobile application through Bluetooth as represented in Figure 1. This system is composed of two main subsystems: conversation robot with foot sole and calf massaging system along with a mobile application for controlling the intensity of the massage. The Raspberry-Pi acts as the central processing unit for the system.

3.1. Development of conversation robot

The development of the AI assistant is a pivotal element of this research article. The AI is designed to provide companionship and assistance with medication management through reminders. AI learns from user interactions, adapting its responses and services over time. The AI translates the user's health objectives, expressed through natural language input, into specific vibration patterns and intensities for the massage. The conversational bot performs mainly three tasks - emotion recognition and response, processing natural language input for massage control and setting medication reminders for the elderly. This research work proposes a custom-built intent recognition system that is able to distinguish natural language input into the above designated intents.

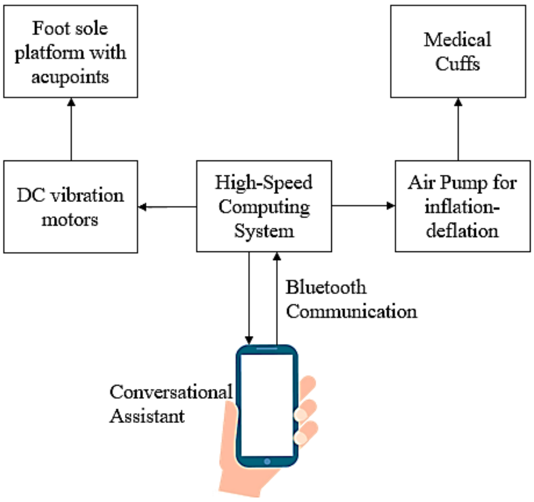

Figure 1. AI assistant driven massage control system

3.1.1. Custom intent recognition system using few shots learning

A diverse dataset is curated with multiple examples necessary for few shot learning with examples of different phrasings, emotions, and contextual details along with their labeled intent. This data undergoes the standard 80:20 train test split. The conversational robot is triggered by receiving a natural language input from the user, typically in the form of a conversational query or command. Input received through voice is converted into text using speech to text libraries like pyaudio. The input text is tokenized into words or sub words, and contextualized embeddings are extracted using the pre-trained GPT-3 model. These embeddings capture the semantic meaning and context of each word within the sentence. The algorithm utilizes few-shot learning, providing the GPT-3 model with prompts that include examples of each intent. Sample input for few shot learning:

- Intent 1: ("Converse with elderly"): "Converse with an elderly person about their day."
- Intent 2: ("Manipulate massage control"): "Adjust the robotic massage control system to a gentle intensity."
- Intent 3: ("Set medication reminders"): "Create a medication reminder for a daily dosage of [Medication Name]."

The GPT model is trained on these few-shot examples to adapt to the specific intent recognition task. The model while training and fine-tuning adjusts its weights to better recognize patterns associated with each intent. The classified intent is then mapped to pre-defined functions or tasks.

3.1.2. Emotion recognition

The algorithm for emotion classification is initiated when the intent classifier recognizes that the user wants to have a conversation. In this study, we employed a bidirectional encoder representations from transformers (BERT)-based emotion classification model for fine-tuning on the "dair-ai/emotion" dataset. The dataset is split into 80% training, 10% validation and 10% testing. It consists of 6 output classes that are (0: sadness, 1: joy, 2: love, 3: fear, 4: anger, 5: surprise) that represent six basic emotions. The dataset was loaded using the hugging face datasets library, and tokenization was performed using the BERT tokenizer. To ensure compatibility with the model, the maximum sequence length was determined based on the training dataset. The dataset was then preprocessed to include padding and truncation with a specified maximum length. The base model "BERT-base-uncased" was fine-tuned on the training data for 5 epochs. For a sample user input of "I miss the times when their laughter echoed through these walls. Now, it's just silence, and I can't help but feel a bit forgotten.” The fine-tuned BERT model performs emotion classification by generating probability distributions in the 6 output classes or emotions. The confidence scores provided by the fine-tuned BERT model are displayed in Table 1.

Table 1. Confidence scores

Emotion	Sadness (0)	Joy (1)	Love (2)	Fear (3)	Anger (4)	Surprise (5)
Confidence score	0.984	0.002	0.004	0.005	0.003	0.002

3.1.3. Response generation

The emotion with the highest confidence score was employed to generate an emotionally aware response from the conversational bot. The OpenAI GPT-3 model was deployed for response generation. The recognized emotion, obtained from the fine-tuned BERT model, served as a prompt for the GPT-3 model. The GPT-3 API was utilized to generate contextually relevant responses. Parameters such as max_tokens and temperature were adjusted to control response length and creativity. The integration of the emotion recognition and response generation models provides a comprehensive system for understanding user input and generating appropriate and contextually relevant responses. The response generated based on the previous example would be – “I'm sorry to hear that you're feeling this way. It's natural to miss the joyous moments and the laughter that once filled the space around you. Remember that emotions, including nostalgia and a sense of being forgotten, are valid. If you need someone to talk to or share your feelings with, I'm here for you.”

3.1.4. Manipulation of robotic massage control system

Upon classifying the user's intent as "Manipulate massage control," the algorithm commences with user input processing, employing regular expressions (regex) to identify massage-related instructions, encompassing aspects like intensity, areas, or feedback. Extracted information is then harnessed to dynamically adjust the parameters of the robotic massage control system. For instance, the algorithm responds to user preferences by increasing or decreasing intensity, directs the massage system to focus on specific areas of the body, and accommodates alterations in massage modes or patterns. This approach ensures a responsive and tailored experience, allowing the elderly care chatbot to intuitively interpret user instructions and execute precise adjustments to the massage system. The user_input "increase the intensity and focus on the tibial foot area" is processed with given (1):

$$m = '\backslash b(\ i|\ a|\ f)\backslash b' \quad (1)$$

where $\backslash b$ is a word boundary to ensure whole words are matched, m is massage parameter, i is intensity, a is area, and f is feedback. (intensity|areas|feedback) is a group that matches any of the specified words (intensity, areas, or feedback).

The regex would identify "intensity" and "areas" as massage-related instructions, and the extracted information would be "intensity, areas". This information can then be utilized to adjust the parameters of the robotic massage control system accordingly. Medication reminder: upon identifying the user's intent as "Set medication reminders," the algorithm employs regex to meticulously extract pertinent medication-related details, such as medication names, dosages, and frequencies, from the user's input. The user_input = "Set a reminder for Azithrol at 9 AM every day" undergoes parameter extraction using (2):

$$r = '\backslash b(med|d|freq)\backslash b' \quad (2)$$

where, r is reminder parameter, med is medication, d is dosage, and $freq$ is frequency.

The regex in (2) will extract medicine name, time and frequency. The extracted information is utilized by the algorithm to dynamically adjust the parameters for setting up a medication reminder. Subsequently, the system utilizes Bluetooth communication to transmit the medication reminder information to a connected mobile application. The implementation involves establishing a Bluetooth connection and sending relevant data to the mobile app, thus ensuring seamless integration between the elderly care chatbot and the mobile platform. The algorithm concludes by generating a confirmation response to notify the user of the successful setup of the medication reminder. The summary of the end to end execution of user input by the AI assistant can be described in Figure 2. This process flow is crucial for the efficient functioning of the control system and ensures that a correct decision is made for each user input. This algorithm runs in a loop wherein each user inputs the request met with a corresponding output. The end nodes of the process as given in the flow diagram in Figure 2, represent the corresponding outputs for every type of user input.

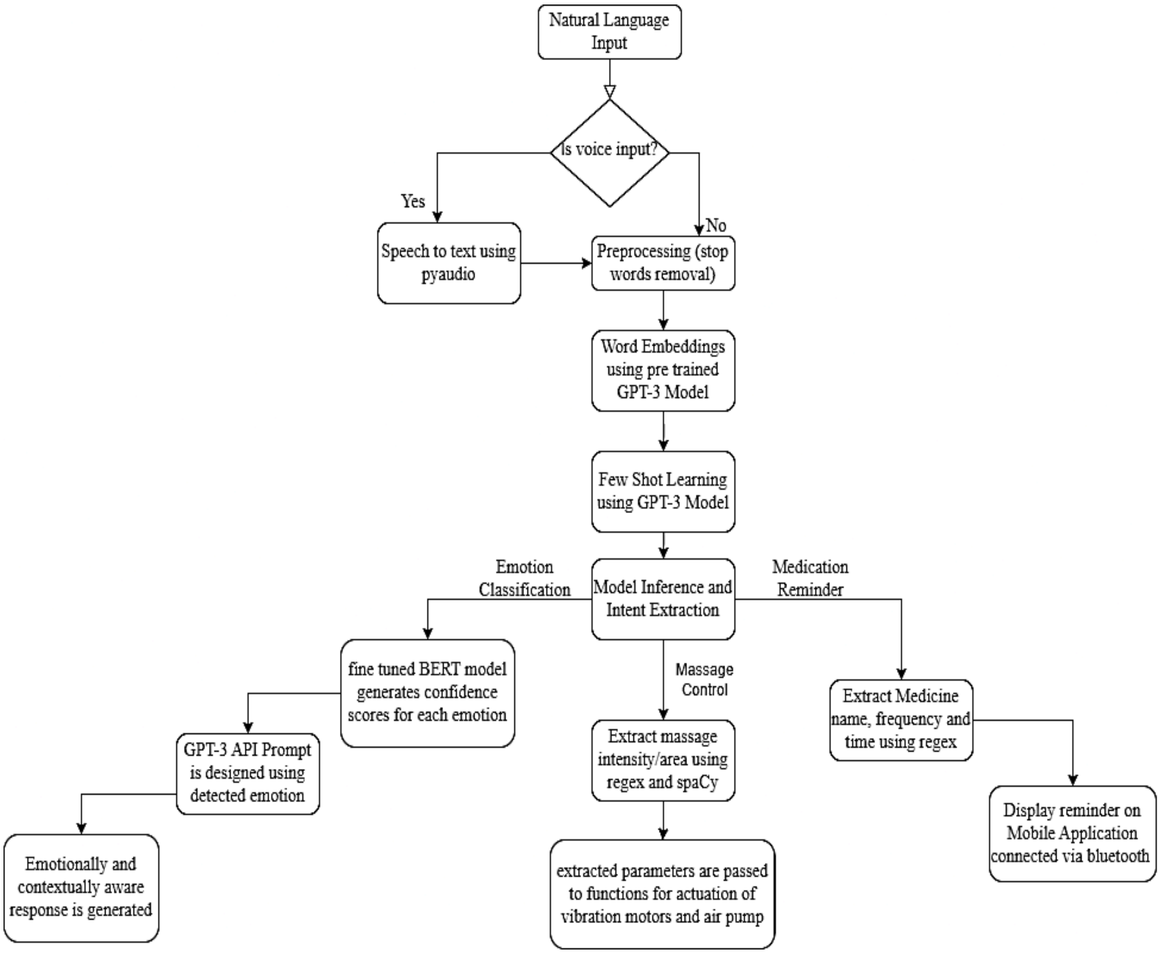

Figure 2. AI assistant: intent recognition and action execution

3.2. Design of foot and calf massager

3.2.1. Calf massage

The system consists of a pneumatic network for connecting air pumps with two medical cuffs. It is powered using a lithium polymer battery pack with Raspberry Pi acting as its processing unit. The algorithm executed on the processing unit decides the duty cycle for inflation and deflation of the medical cuffs based on the inputs provided by the app.

3.2.2. Foot sole massage

The system has acupuncture points allocated at 7 different positions on the foot sole according to the foot reflexology as shown in Table 2. The different acupuncture points base is connected with a series of DC motors attached, which are responsible for enhancing the functionality of particular organs. The foot sole is divided into primarily three sections- lateral plantar, median plantar and tibial plantar as shown in Figure 3. The placement of vibration motors is provided in Table 2 and is performed using foot reflexology technique. It gives information about the placement of vibration motors and the organs acupoints that are being targeted by the vibration motors. The motors are situated with five (vib1 to vib5) in the median plantar area, one in the tibial plantar area (vib6), and one in the lateral plantar area (vib7). The default duration of foot sole massage is 3 minutes. The user can alter the pulse width modulation (PWM) of each of the three foot-sole sections separately by providing voice feedback. The maximum and minimum RPMs of the vibration motors mounted on the foot massage platform are 13,500 and 8,500, respectively.

Table 2. Vibration motor placements respective to acupoints

Vib1	Vib2	Vib3	Vib4	Vib5	Vib6	Vib7
Heart	Lungs	Liver	Pituitary	Stomach	Small intestine	Arm

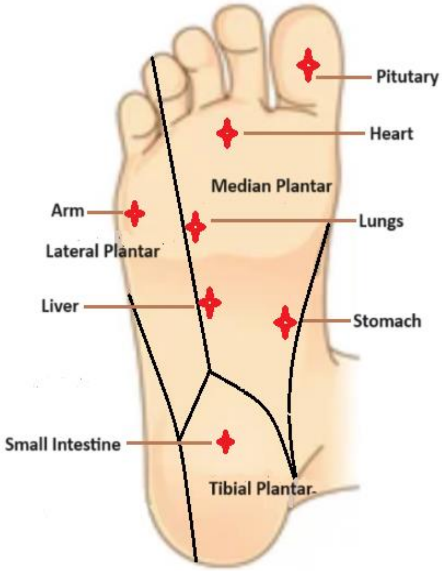

Figure 3. Representation of divided foot sole along with sensor positioning

Few of the most common health challenges are related to the heart, lungs, liver, pituitary, stomach, small intestine and arms. The vibration motors are placed on the acupoints related to the above-mentioned areas based on the foot reflexology, these points are associated with different body organs and functions. A predefined mapping of acupoints on the feet as shown in Figure 3 is employed. The location of these acupoints is correlated with the positioning of the vibrational motors on the massage subsystem.

$$Force\ applied = f(x, y, z) \quad (3)$$

Where: x is user's health objective, y is acupoint position and z is motor capability.

The (3) describes the application of force as a function of users' health objective, acupoint position and motor capability connected.

$$t = Vcuff/Q \quad (4)$$

where: t is the time in minutes, $Vcuff$ is the capacity of each medical cuff bag in milliliters (200 ml) (two of such cuffs used), and Q is the flow rate of the air pump in milliliters per minute (12,500 ml/min, as 1 liter=1,000 milliliters).

$$t = 200 * 2/12{,}500$$

$$t = 0.032\ min \sim 1.90\ seconds$$

By the calculations given in (4), both the cuffs get inflated in 1.9 seconds considering the 100% duty cycle of the air pump motor. Furthermore, the motor has the capability to exert a minimum of 200 mmHg and a maximum of 325 mmHg pressure on each of the connected medical cuffs. The default duration of calf massage is 3 cycles of 5 seconds each, considering the instance when massage is requested through mobile application. After completion of massage, the user may request for another cycle of massage if necessary. The user can alter the intensity of inflation and deflation calf cuffs through mobile application. The intensity levels are classified into three states: low, medium, and high. When the user clicks the increase/decrease intensity button, the status of the massage changes in relation to its present state. The algorithm provides control and response generation for the massage device via a mobile application and voice input. It handles commands for initiating foot sole massage, adjusting the intensity of calves' massage, and responding to user prompts as mentioned in Algorithm 1. The system implements an AI assistant for elderly care, leveraging conversation capability for user interactions. It also controls a massage subsystem via PWM adjustments based on foot reflexology principles through a mobile app. Conversation enhances the well-being of elderly users through personalized care and companionship.

Algorithm 1. Algorithm for massage control and response generation

```
Input: Mobile application string(X1) and voice input(X2)
Output: Run foot sole massage(Y1), adjust intensity of calves massage(Y2)
and provide response(Y3)
Initialize:
 Device Bluetooth connection
Loop:
UserInput = X2
CharacterInput=X1
if X1 is "Running foot sole massage" then
     Invoke Y1
else if CharacterInput is "Running calves massage" then
     Invoke Y2(5)
     if IncreaseButtonPressed() then
      Invoke Y2(5+1)
     end if
     else if DecreaseButtonPressed() then
      Invoke Y2(5-1)
     end if
end if
else if X1 is "Stop button pressed" then
      StopMassage()
end if
if Prompt(X2) then
     Emotion= ExtractEmotion(X2)
     Invoke Y3(Emotion)
end if
Return
```

4. RESULTS AND DISCUSSION

The setup under study consists of two separate systems, which are voice assistant and massage system. The voice assistant takes the input from elderly and processes the input, generating a response based on the requirements. The foot and calves massage system can also operate through a mobile application, which enables the user to control the massaging intensity. The whole setup is provided to the users for testing, some of the responses given by the conversation robot are mentioned below. Eg. user input “Give medication information related to Azithromycin tablet”, the response to the above input is given as “Azithromycin is a macrolide antibiotic used to treat bacterial infections. It comes in tablet form, with common side effects including nausea and diarrhea”. Next input given as “make a reminder at 10 pm today to take blood pressure medicine” its response “Reminder is set for 10 pm today to take blood pressure medicine”. Such types of responses are converted to numerical data of how well the AI responded to the given query, plotted in Figure 4. The standard deviation of the response score is at 1.62 whereas mean of the feedback data points is 7.70. The emotion classification model was fine-tuned on the foundational BERT-base-uncase model and trained on the Dair-ai dataset. The validation dataset was used to perform hyperparameter tuning through various trial and error experiments. After multiple iterations and tests the below training arguments were found to be the most suitable to achieve high accuracy as mentioned in Table 3.

Table 3. Hyperparameter values

Hyperparameters	Values
Learning rate	$2x10^{-5}$
Training batch size	64
Evaluation batch size	64
Random seed	42
Optimizer	AdamW with betas=(0.9, 0.999) and epsilon=1e-08
LR scheduler type	Linear
Number of epochs	5

The model was trained on these optimal hyperparameters and evaluated on the test dataset. The model after 5 epochs of training achieved an impressive validation accuracy of 93%. The validation loss was 0.1416 at the end of 5 epochs. The model was evaluated on multiple performance metrics such as F1 score, recall and precision. The effectiveness of the model to correctly predict each of the output classes was measured using these performance metrics and a classification report was generated as shown in Table 4. The proposed research article successfully developed an AI driven robotic control system for foot sole and calves' massage along with conversational bot to provide elderly care and companionship. The prototype was tested on a sample size of 20 elderly people having ages within the range of 60-85 years and a review of the massager and the conversational relevance was obtained.

Table 4. Classification performance

Class	Precision	Recall	F1 Score
0	0.96	0.97	0.97
1	0.96	0.94	0.95
2	0.80	0.87	0.83
3	0.93	0.91	0.92
4	0.88	0.92	0.90
5	0.82	0.71	0.76

The reviews of the elderly who used the system, including the foot sole massage and calves' massage are provided in Figures 4 and 5 respectively. These reviews show the system's performance in real life scenarios. The standard deviation in feedback analysis as given in Figure 5 for foot sole massage stands at 1.98 whereas for conventional foot massage is 2.32. Further the mean feedback rating in foot sole massage data is 7.10 and in conventional massage data is 5.95 indicating higher rating to the proposed system. The comparison of the system with the conventional human massage is plotted in Figure 6. The plot portrays that the presented system has better performance as per the rating given by participants.

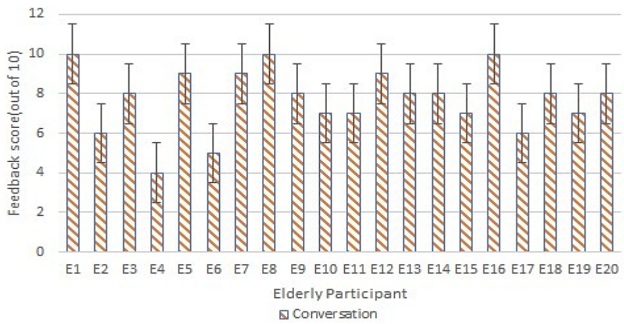

Figure 4. Elderly feedback on AI response system (rating out of 10)

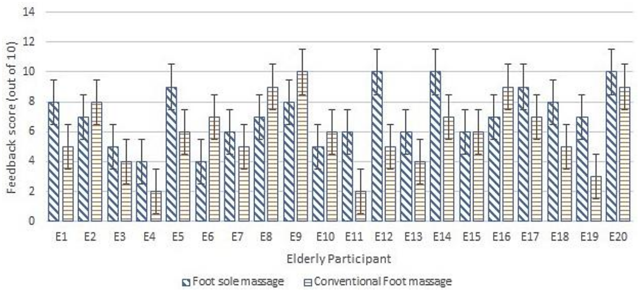

Figure 5. Elderly feedback on foot massage system (rating out of 10)

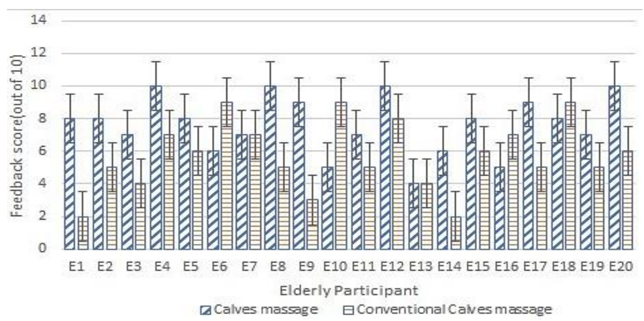

Figure 6. Elderly feedback on calf massage system (rating out of 10)

The subjective feedback for our system in comparison with conventional leg massage alternatives available in the market are plotted in Figures 5 and 6 respectively. The standard deviation for calves' massage and conventional massage are 1.78 and 2.12 respectively. Further, the mean of the data points for calves' massage and conventional massage are 7.60 and 5.70 respectively. The trials were conducted on 20 individuals (aged 60 and above). The statistical inference from the plots demonstrates 70% were satisfied with foot massage and 75% appreciated the calves' massage over the conventional massage (provided by humans). The parameters that are taken into consideration for the massage system are: torque applied by motor on feet, the pressure imparted by cuff on calves and comparison with conventional massage. The parameter for conversation robot is the relevance of response provided by the system. The evaluation matrix for massage feedback is represented in Table 5. The matrix depicts the feedback evaluation score provided by each elderly person for foot sole and calf massage. The matrix also includes a post-modification experience assessment (PMEA) index, which depicts feedback from the elderly on how the massage system responded to user input. The index consists of foot sole massage feedback weighted at 60% and calves massage feedback weighted at 40%. The conversational relevance of the chatbot is evaluated by calculating semantic similarity between the generated response and a ground truth response. A total of 30 pairs of generated responses and ground truth responses are collected across all 6 emotion classes. The ground truth responses are manually curated for each user input. The sentences undergo preprocessing - tokenization, lowercasing, punctuation removal, and stop words elimination to ensure standardized representations conducive to subsequent analysis. The pre-processed tokens are transformed into dense vector representations using global vectors (GloVe) for word representation GloVe word vectors, capturing the semantic nuances inherent in the language. GloVe word vector representations are renowned for their effectiveness in capturing semantic relationships between words based on their co-occurrence statistics in large text corpora. The calculated similarity score S is denoted by (5):

$$S(i,j) \in [-1,1] \quad (5)$$

where: i, j denotes the generated response and ground truth response respectively.

Table 5. Massage evaluation matrix

Elderly ID	Foot sole evaluation	Calves massage evaluation	PMEA index
E1	8	8	8
E2	7	8	7.2
E3	5	7	5.8
E4	4	10	6.4
E5	9	8	8.6
E6	4	6	4.8
E7	6	7	6.2
E8	7	10	8.6
E9	8	9	8.6
E10	5	5	5
E11	6	7	6.4
E12	10	10	10
E13	6	4	5.6
E14	10	6	8.4
E15	6	8	6.8
E16	7	5	6.2
E17	9		8.6
E18	8	8	8
E19	7	7	7.2
E20	10	10	10

Values closer to 1 (refer to Table 6) indicate perfect similarity between two vectors implying that the generated response is ideal and is identical in content and meaning with respect to the ground truth response. Scores ranging from 0 to -1 indicate complete dissimilarity implying the generated response is completely out of context or is wrong. The mean similarity score of each sentence pair for each emotion class is calculated separately as shown in Table 6. A mean similarity score across all emotion classes is calculated to be 0.79. Results from the experiments reveal several key insights. The foot massage task demonstrated good performance, with acceptable feedback from the user. Conversation and updates are effective methods to engage in meaningful conversation with providing relevant information. The similarity scores in Table 6 imply that the conversational bot is highly effective in generating responses and building meaningful conversations that depict joy, anger or fear while being less relevant where emotions like fear or surprise come into play.

Table 6. Similarity scores between generated responses and ground truth responses for each emotion class

Emotion	Sadness (0)	Joy (1)	Love (2)	Fear (3)	Anger (4)	Surprise (5)
$S_{emotion}$	0.84	0.89	0.78	0.73	0.84	0.68

The mobile application's first page asks for the user to connect with the system using Bluetooth, a scan button is provided which shows all the visible Bluetooth devices available. When the mobile app is successfully connected with the system a new window opens which has options to start and stop the foot and calf massage. The calf massage section contains two more buttons to increase or decrease the intensity of the calf massage as shown in Figure 7. The system is enabled with a switch for turning the system on/off. It contains a Rpi mic, which takes the user input and a speaker which delivers the output of the conversation response to the user is shown in Figure 8. However, it is essential to acknowledge some limitations. The elderly population's varying responses to the system may affect results in Foot sole and calf massage. The currently available products in the market for foot and sole massage are significantly expensive, because of which many people are unable to afford it. Furthermore, the products in the market mainly focus on either foot massage or calf massage, very few focus on both. The proposed system is cost effective as well as easy to use and it provides not only companionship but also foot and calf massage to the elderly.

Figure 7. Mobile app GUI

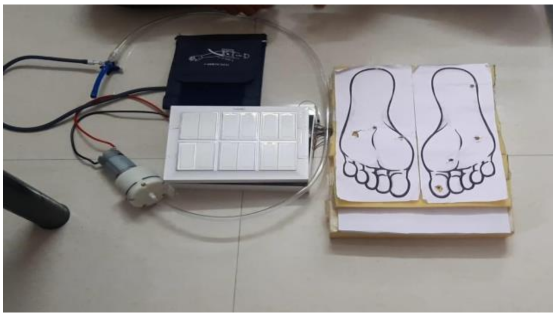

Figure 8. Foot massager system

5. CONCLUSION

The elderly subjects evaluated the system in real and controlled environments. The proposed research developed an AI Assistant that provides companionship by inducing fruitful conversations, manipulating massage control systems and also setting precise medication reminders thereby enhancing the overall user experience and quality of life. The solution stands out in three distinct ways. Firstly, it boasts the ability to dynamically adapt to individual user preferences, making each massage session personalized to some extent. Secondly, its real-time responsiveness ensures an uninterrupted experience for the users as mentioned in the results section. Thirdly, it provides a user-friendly mobile app to control the foot sole massage and calves massage, with additional features such as controlling the intensity of calves' massage. The advantages offered by our system are significant. Users can enjoy a substantial reduction in manual intervention, leading to a hassle-free experience. Moreover, there's potential for improved therapy outcomes, making it an invaluable tool for elderly individuals seeking relaxation and wellness.

It is important to acknowledge a couple of limitations. The effectiveness of our system is contingent on the quality and diversity of personalized settings for therapeutic goals. In future scope, improvements could focus on interfacing AI with mobile applications, implementing different modes for massaging and improving the conversation response. The features to be extended in future work include multiple calf massage arrangements with an improved pneumatic system. The system currently has limited voice input-based conversation, to be improved with added functionality of voice assistance.

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