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Guru: AI-Powered Assistive Companion Robot

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Abstract: Guru is AI AI-powered assistive robot for smart living. It integrates emerging technologies like Generative AI, Robotics and Autonomous mobility for a smart assistant. Unlike traditional virtual assistants such as Google Assistant, Alexa and Siri that are limited to screen or static devices, whereas our Guru offers indoor navigation, voice assistant, reminders, surveillance and safety monitoring through emotion-aware conversations. Its innovation lies in combining empathetic AI with robotics in a modular, cost-effective design. The system can operate in indoor environments, recognise wake words without the need for physical contact and ensure user safety with features like fall detection and emergency alerts. For remote user interaction, it is accompanied by a mobile application for setting reminders, location tracking, system updates and user authorisation. It uses modern computing tools such as Raspberry Pi, OpenCV, Arduino, LLMs, STTs, APIs, etc. It can be scaled to use in healthcare, elderly care and rehabilitation. The robot ultimately aims to promote independence, enhance daily living and improve the emotional well-being of its users.

Keywords: Generative AI, Autonomous robot, Assistive technology, Internet of Things, Smart living, Voice assistant, Natural Language Processing, Machine learning, Human Robot Interaction.

I. INTRODUCTION

In today's world of smart automation, everyone wants to rely on technologies to accomplish their daily task, such as housework, navigation, home automation, and task management, something which is more like their personal assistant. Everyone's urge to move towards smart living is increasing, but it comes with a heavy price. Existing technologies is either costly, highly specialised or lack comprehensive support for both functional and emotional needs.

Earlier famous assistive technology, such as a virtual assistant which interacts with users through voice or text to perform tasks, exists only virtually, either through a specific device or a user's mobile phone. Some of the widely used virtual assistants are Google Assistant, Alexa, Siri and ChatGPT. Although it is widely used to perform tasks through commands virtually, but can't perform physical task, cognitive support and highly depends on internet to provide services with zero mobility of its own, unless a user carry them. Whereas assistive robot provides real-world help, useful for any type of users (e.g. child, elderly, disabled), also provide physical and cognitive support. One of the biggest advantages is that Assistive Robot can perform similar task like virtual assistant along with that it provides other services like physical support, mobility, surveillance and companionship too.

In "Assistive Robotic Market Research" Report by Aarti Dhapte shows that global assistive robot martket is expected to grow nearly seven times between 2025 and 2035, estimated to reach over INR 115 lakh crore in market value [1]. This report also shows the need for an assistive robot in the healthcare sector in surgeries, rehabilitation, and elder care. Also, in the manufacturing sector for automation of some tasks improves efficiency and productivity, and also helps to mitigate labour shortages in the industry. The urge to bring Assistive Robot technology is highly demanding. Some of the commercially available robots in the market are Amazon Astro, Robotemi, SoftBank Robot Pepper, and Intuition robotics ElliQ. Indian origin assistive robots such as Aasha, Charlie, Mitra for elderly care, Miko for childcare. Each of these robots has its respective features, different environments (e.g. indoor, home assistant, factories, public places), advantages and limits. The use of assistive robots is focused on human assistance. If there is concern that using this advanced technology means replacing humans, then we need to assure ourselves that no AI robots could replace humans' role in the environment [2].

II. LITERATURE REVIEW

1) ISSN Paper title "*Humanoid Robots for assisting people with disability in activities of daily living*" by Linda Sorensen, Dag Tomas Johannesen, Hege Mari Johnsen have given their review encompasses a study of 44 papers published between 2012 and 2022, focusing on nine distinct humanoid robots. The primary aim of the research was to analyse how these robots support older adults with their Activities of Daily Living (ADL), which include mobility, self-care, and various household tasks. The robots examined included several specifically designed for ADL support, such as Care-O-bot, Doro, Hobbit, PR2, RAMCIP, ROBO, and TIAGO. Other robots with different primary functions, like the social/commercial robot Pepper and the educational/research robot Nao, were also part of the review. The study identified key user needs for practical assistance, including help with cooking, opening doors, fetching and carrying items, garbage disposal, and providing emergency support. For older adults specifically, the most desired tasks were retrieving items, removing clutter, and disposing of garbage, all of which contribute significantly to an improved quality of life. In this paper we find that though humanoid robots have shown significant progress in supporting individuals with disabilities, they are still not fully ready for independent home use. Improving efficiency, safety, and adaptability will be crucial for the next generation of assistive humanoid technologies.[3]

2) IEEE Access paper title "*Low-Cost Assistive Technologies for Disabled People Using Open-Source Hardware and Software: A Systematic Literature Review*" by J. Álvarez Ariza and J. M. Pearce, analysing 809 studies collected from databases such as Web of Science, GitHub, and specialized journals like HardwareX and the Journal of Open Hardware. Their review focused on ATs developed between 2013 and 2022, encompassing various disabilities, including visual, mobility, upper body, prostheses, hearing and speaking, daily living, and participation in society. They identified several key areas where OSHW and OSS have been effectively utilized in AT development such as Sensor Based ATs, Computer Vision-Based ATs, Signal Processing Platforms and Tools (like Arduino, Raspberry Pi). Despite the promising applications, the review highlighted several challenges such as Technical Factors (issues related to hardware limitations and software compatibility), documentation, government policies, user inclusion. Integrating insights from this review into the development of AI-powered assistive companion robots can offer several benefits like cost effectiveness by leveraging OSHW and OSS can significantly reduce development costs, making advanced assistive technologies more accessible, customization, community involvement and scalability. It underscores the potential of open-source approaches in developing low-cost, effective, and accessible assistive technologies. Thus, by addressing the identified challenges and fostering inclusive design practices, we can enhance the development of our AI-powered assistive robot, leading to improved quality of life for individuals who are going to use it.[4]

3) IEEE Access paper title "*A Human Decision-Making Behaviour Model for Human-Robot Interaction in Multi-Robot Systems*" by Jie Huang, Wenhua Wu, Zhenyi Zhang and Yutao Chen proposes a comprehensive model that characterizes human decision-making behaviors in the context of HRI. The model integrates cognitive processes, emotional states, and environmental factors to predict human actions and intentions. By incorporating these elements, the model aims to enhance the adaptability and responsiveness of robots in dynamic environments. We find this paper is a solid contribution modelling human decision behaviour in human–multi-robot contexts, but its limitations centre around scale, environment realism, heterogeneity of agents, real-time integration, human behaviour complexity, and transferability to new tasks/domains.[5]

4) IEEE Robotics and automation paper title "*Conversation-Based Medication Management System for Older Adults Using a Companion Robot and Cloud*" by Zhidong Su, Fei Liang, Ha Manh Do, Alex Bishop, Barbara Carlson, and Weihua Sheng, presents a conversation-based medication management system (CMMS). Its medication reminder service as Many older adults commonly forget to take prescribed medication, which can have an adverse effect on health. It also addresses the limitations of traditional reminder apps, which are complex and visually unfriendly for seniors. The CMMS uses a companion robot and the cloud to create medication reminders and check medication adherence. It integrates automatic speech recognition, natural language understanding dialog management, and text-to-speech technologies to support intuitive, conversational interaction. Also, caregivers and family members can monitor older person remotely via a cloud-connected Telegram chatbot. But there are some limitations in their current evaluation like the robot was evaluated in the lab environment only while real home environments are noisy. Therefore, the interaction would be much messier and people might not hear a reminder. We find some takeaways from paper is that voice-based interaction for elder user as speech is most natural communication method for person limited digital literacy or vision. So, reminder creation and modification via voice command improves accessibility and user satisfaction.[6]

5) ACM paper title "*VoicePilot: Harnessing LLMs as Speech Interfaces for Physically Assistive Robots*" explores how Large Language Models (LLMs) can be integrated as speech-based control interfaces for physically assistive robots. Unlike conventional control frameworks that primarily depend on pre-coded commands and rigid APIs, this approach emphasizes natural speech interaction, personalization, and safety. It focuses on improving natural interaction between users and robots through spoken language understanding and execution. But there is certain key limitation to this technology such as it requires continuous internet connectivity and external APIs, LLMs are not deterministic which means the same input can produce slightly different outputs, this limits accuracy in real-world assistive scenarios where context understanding is essential.[7]

6) IEEE Access paper title "*Real-Time Implementation of Face Recognition and Emotion Recognition in a Humanoid Robot Using a Convolutional Neural Network*" by Suci Dwijayanti, Muhammad Iqbal, Bhakti Yudho Suprapto proposed a system which have ability to recognise both face as well as emotion in humanoid robots. They use of CNN architectures (AlexNet & VGG16) and a modified AlexNet for training face and emotion recognition models and integrates it with real-time system, built using

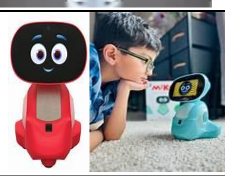
Raspberry Pi, Arduino, Webcam, Servo motor, Dot Matrix. They got 100% accuracy in face recognition. But while studying their research paper we find certain limitation and gaps in it. Some of them are they have lower emotion accuracy than face recognition due to poor illumination, limited emotion variations in training data, camera angle and distance issues, their VGG16 model has a longer training time due to deeper network layers and servo movement sometimes affected real-time tracking stability.[8]

7) Robotica paper title "*Voice-enabled human-robot interaction: adaptive self-learning systems for enhanced collaboration*" by Indra Kishor, Udit Mamodiya, Sumit Saini and Badre Bossoufi, their paper discusses the development of an adaptive human robot interaction system that integrates voice recognition, emotional intelligence, and self-learning mechanisms to enhance collaboration in dynamic environments. It aims to overcome challenges in dynamic and noisy environments while achieving real time and scalable performance. Traditional systems struggle with accents and background noise. Proposed system combines voice input acquisition, emotional context detection, and adaptive decision-making It achieved 95% accuracy in voice recognition and a 96% task success rate in noisy environments. But we find its self-learning capabilities are limited, requiring manual updates and retraining for new users or environments. Also, their model combines deep learning for speech and emotion recognition with reinforcement learning for behaviour adaptation. This hybrid design demands significant processing power and memory, making it difficult to deploy on low-cost. Although advanced architectures are used, the model's accuracy drops under noisy, multi-speaker, or accented conditions.[9]
8) MDPI paper title "*Voice Interaction Recognition Design in Real-Life Scenario Mobile Robot Applications*" by Shih-An Li, Yu-Ying Liu, Yun-Chien Chen, Hsuan Ming Feng, Pi-Kang Shen and Yu-Che Wu, this paper presents a voice interactive robot system designed for executing service tasks in real-life scenarios using advanced speech recognition technologies. The system operates without a microphone, allowing users to control the robot through commands. the voice commands are then recognized by a well-trained deep neural network model of automatic speech recognition. This section details the architecture and functionality of the speaker separation and ASR components of the robot system. We find that though the model performs well in structured indoor environments but its accuracy decreases in highly dynamic and outdoor settings where background noise, echo are more intense. Also, the ASR model struggles with accented, slurred, or spontaneous speech, which affects recognition accuracy for diverse users and the model includes a speaker separation module, it is effective only under moderate noise levels.[10]
9) IEEE Access paper title "*Socially-Aware Navigation of Omnidirectional Mobile Robot with Extended Social Force Model in Multi-Human Environment*" by Chun-Tang Yang, Tianshi Zhang, Li-Pu Chen and Li-Chen Fu, this paper state that earlier research on socially-aware navigation focused on human comfort, natural motion, and sociability. However, these methods were often static, individual-based, and limited to non-holonomic robots. This paper addresses these gaps with a dynamic grouping model and an Extended Social Force Model (ESFM) for omnidirectional robots. Experiments in indoor and corridor environments with multiple humans demonstrated the effectiveness of the approach. The ESFM based robot achieved smoother, safer, and more efficient navigation compared to traditional models. It also handled group interactions and social spaces more effectively. But this also show some limitation such as its performance under crowded, unstructured, or dynamic environments (e.g., malls, airports) remains untested, it also may fail in cases of unexpected human motion or social interactions that deviate from force-based assumptions and thus, raises questions about the scalability and adaptability of the model outside lab conditions.[11]
10) IEEE Sensors Journal paper title "*Human Fall Detection Based on Posture Estimation and Infrared Thermography*" by Huichen Fu and Junwei Gao presents a human falls detection using infrared cameras and body posture estimation. It focuses on helping robots or systems detect falls even in the dark and without recording visible images, which protects privacy. It applies a pose estimation model based on YOLO that detects key body points like head, shoulders, knees, etc. The system checks the person's body position and movement if the person suddenly becomes horizontal marked as a fall. It works well in dark or low light environments. The paper integrates a classification function into YOLOv7POSE / YOLO pose family. Which is modern deep learning algorithm it is fast and effective. But we find that their pose models are usually trained on normal RGB images, so they not work perfectly on thermal images unless retrained and their datasets are small and often collected in labs, dataset may not cover all real-life situations and also it detects the fall moment, but not how long the person stays down like long-lie detection missing. It may also need hardware optimization to run smoothly on small embedded devices.[12]
11) IJIRT paper title "*AI Voice Assistant using Raspberry Pi 4*" by Abja VS, Akhil Santhosh, Niyas Mohammed, Mohammed Anaz, Ms. Divya VB proposed a system that demonstrates an efficient design for an AI-powered voice assistant using Raspberry Pi 4 and the LLaMA 3 language model. It combines speech recognition, text processing, and speech synthesis to enable smooth and

interactive communication between humans and machines. The use of open-source tools and Python-based libraries such as Tkinter, PyAudio, and gTTS makes the system cost effective and easy to implement. Its modular structure also allows further development, such as facial recognition, emotion analysis, or offline functioning. Overall, the study highlights the practicality of combining edge computing with AI to build a responsive, real-time voice assistant that can be applied in educational, domestic, or assistive environments. But we find that although the system performs well in controlled environments, a few limitations were observed during testing of it such as the accuracy of speech recognition decreases in noisy surroundings, which affects consistent performance. The processing speed and response time depend on Wi Fi stability and backend model load, leading to slight delays during heavy usage. Additionally, the Raspberry Pi's limited processing power prevents it from handling large AI models entirely on device, requiring external hardware for high end tasks.[13]

Apart from literature review on research paper we have done some research on currently commercially available assistive robot. Their name, company, uses and technical limitation, which we briefly shown in Table 1.

TABLE 1
LIST OF EXISTING ASSISTIVE ROBOT

S. No	Name & Location	Product image	Key Specs / Deployment	Technical Limitations
1	"Aasha"- Budget home-care robot for elderly by Safira Robotics. (Bengaluru) [14]		Tele-medicine support, fall detection, medication reminders, regional language voice interface. Already sold around 500 units.	Limited physical assistance (no full-manipulator arms). Navigation in cluttered home environments likely basic. Battery charging infrastructure in rural homes may be weak.
2	"Mitra" by Invento Robotics. (Bengaluru) [15]		Humanoid robot for interaction, customer service & healthcare screening.	High-cost hardware, designed for interaction rather than daily physical assistance in home for disabled persons and has mobility or manipulation limits.
3	"Miko" -Companion robot for children by Emotix. (Mumbai) [16]		Designed for children: interaction, learning, social play.	Designed originally for children not disability/assistive care; physical assistance modules lacking; home environment adaptation and language/regional support may be limited.
4	"Amazon Astro"- smart home assistant by Amazon (USA) [17]		Designed for smart home assistant, integrates Alexa, with wheeled base bot, indoor navigation, give telepresence, smart-home control and its availability is region-dependent.	Limited physical assistance (no arms/handling), navigation struggles in cluttered homes, privacy concerns (cameras/mic), highly expensive, subscription features & service discontinuations changed capabilities historically
5	"Pepper" by SoftBank Robotics (Europe) [18]		Social companion, engagement in retail/education/elder care settings Well-studied HRI (speech, body language, tablet UI), easy to program for dialogic tasks and engagement.	Older onboard compute limits running modern heavy AI locally (cloud needed), limited manipulation capability (not for physical assistance), navigation and durability issues in very busy public spaces.
6	"ElliQ" by Intuition Robotics (Israel) [19]		Proactive conversational prompts, reminders (meds, routines), caregiver alerts/summary, simple UX for seniors; designed with research in HRI for older adults.	No mobility or physical assistance, relies on cloud services and subscriptions for advanced caregiver features, limited sensing (no cameras used for intrusive monitoring by design, can miss incidents requiring vision/motion detection unless complemented by other sensors
7	"OhmniCare" or Ohmni Telepresence by OhmniLabs (USA) [20]		Wheeled indoor base, adjustable screen height/tilt to approximate eye-level, far-field mic & speaker, compute for video stream and remote control, sold to healthcare & consumers.	No physical manipulation, depends on good network bandwidth for video, telepresence only (no autonomous caregiving actions), models and support changed

III. PROPOSED SYSTEM

A. System Aim and Objectives

This project is aim to design and develop a multi-functional, AI-powered autonomous robot that serve as a companion as well as personal assistant for individuals who needed a companion and special assistance. It acts as an AI-powered assistive companion robot for smart living that integrates generative AI, autonomous mobility, and emotion-aware interaction to support people in their daily lives by providing functional assistance, safety monitoring, and emotional companionship, thereby promoting independence and well-being for people. Following are the key objectives of our system:

1) To provide Generative AI based conversation we integrating an AI chatbot for natural, empathetic, and emotion-aware dialogue.
2) To provide autonomous mobility we equipping the robot with motors, wheels, and navigation algorithms for safe indoor movement.
3) To provide practical support like reminders, home automation control and communication we integrating with generative AI, autonomous mobility and emotion-aware interaction to support people in their daily lives

Thus, providing functional assistance, safety monitoring and emotional companionship, thereby promoting independence, smart living and well-being of people.

B. System Scope

The “Guru” - AI Assistive Robot is designed to act as a personal companion and helper for individuals who needed personal assistance and want to rely on technology for emotional support and companionship. This software will provide voice-based communication, emotional support, autonomous navigation, and smart reminder. It will support natural language processing to understand user commands and deliver responses via speech or actions. The system will manage daily routines by setting up reminders like taking medication, attending appointments etc. In emergencies, such as a fall or medical distress, the robot will automatically trigger emergency alerts to caregivers or family members through notifications or call.

It will also offer entertainment and emotional support by engaging in casual conversation, playing music, reading news, and even performing basic wellness check-ins to reduce feelings of loneliness.

C. Hardware Interface

In our AI Assistive robot – “Guru”, we are using various hardware component, which has distinguished features and has a definite purpose in this system. This hardware component is the physical body of our assistive robot. Following is the list of hardware component with their type, purpose and function as shown in Table 2.

TABLE 2
LIST OF HARDWARE COMPONENT

Component Type	Purpose / Function
Microprocessor: Raspberry Pi 4B or Raspberry Pi 5	Main processing unit for AI, ML, and GenAI tasks which is shown by Guru
Microcontroller: Arduino UNO or Arduino NANO	Use for controls sensors, motors, and low-level hardware operations
Storage: 32GB SD Card	Use for fast model loading, logging, database storage, and local datasets
Camera: Standard or HD Camera	For vision-based tasks, object & fall detection
Microphone: Built-in or External	To captures user’s voice commands as an input
Speakers: Mini Bluetooth	To provides voice feedback and responses as an output
Ultrasonic or Infrared Sensors	For obstacle detection and distance measurement

Motion Sensors: PIR Sensor /Accelerometer	For activity monitoring and movement detection of robot system
Display: LED / OLED Screen	For display information, alerts, or system status to users
Mobility: 4 DC Motors with 4 Wheels or Tracks	To enables movement and navigation of robot
Battery: Rechargeable Lithium-ion Battery / 5.1V Power Bank	Use to power the overall robot system to run module and perform task
Motor Driver: L298N	To controls motor speed and direction of robot
Connectivity: Components Jumper Wires, Breadboard	To establish circuit connections and prototyping of internal hardware component of robot
Chassis / Body Case: Metal / Plastic Frame	To provide structural support for mounting all components and upper body of robot.

D. Communication Interface

Guru relies on wired and wireless communication protocols to exchange data between software modules, sensors, and external devices.

1) *Internal Communication:*
   - Serial Communication (UART) between Raspberry Pi and Arduino.
   - I2C/SPI interfaces for sensors and actuators.
2) *External Communication:*
   - Wi-Fi / Internet Connectivity: For cloud-based speech processing, updates, and data sync.
   - Bluetooth: For connection with mobile app or wearable devices.
   - Re Protocol: For lightweight IoT data transmission and remote alerts.
   - Emergency Communication: SMS or email alerts via connected network module in emergencies.

E. Software Interface

In this AI assistive companion robot system, software interface provides an interactive platform that bridges communication between the user and the robot. This software component will serve as the logical unit of our system. The software specification of this proposed system is as follow:

1) *Operating System:* To operate and connect with Raspberry Pi we are going to use Raspberry Pi OS (Lite) which is lightweight, efficient and provide robust connectivity. It comes with pre-installed tools such as GPIO tools and it is python friendly. Using this OS is mandatory, as the main brain of the proposed system is Raspberry pi.
2) *Backend:* The Backend will act as System's core where the main AI computation, data handling and communication with frontend will occur. The system is going to use Python as backend programming language. Python will be used to build system logic and to simplifies the integration of AI models. Python also has in-built libraries such as pandas, NumPy, Sklearn, Scikit learn, etc. The backend integration was implemented using Flask, ensuring communication between the AI modules and the web-based monitoring interface. To create a backend server, python has FastAPI and Flask as web framework. This framework allows quick deployment of REST APIs, easy for debugging and provide scalability for future extension. This required minimal setup and run easily on local or embedded system.
3) *AI & ML Framework:* The AI/ML framework is responsible for enabling intelligent features like object detection, gesture recognition, or face tracking in the system. AI/ML libraries and tools which system is going to used are OpenCV for image preprocessing, pretrained TensorFlow Lite (TFLite), MediaPipe for vision task, other python libraries which support machine learning model. OpenCV supports image filtering, contour detection, thresholding, and real-time video analysis. MediaPipe provides ready-to-use pipelines for vision and multimodal AI tasks such as prebuilt pipelines for pose detection, hand tracking, and face mesh. TensorFlow Lite models run deep learning inference efficiently on Raspberry Pi, Arduino, low-power embedded, or mobile devices. Further detail explanation of AI & ML framework is done in next section of paper.

4) *Voice interface:* The voice interface allows the system to understand and respond to user commands using speech. The tools which we are going to use are Vosk which converts spoken words into text (STT), while pyttsx3 converts text responses into voice (TTS). This will build the Wake-word logic of AI robot system. The Vosk is lightweight and offline STT tool which support Multilanguage. Similarly, Pyttsx3 works without internet and provide customizable voice. Using the integration of these two tools ensures fully offline conversation as well as privacy and reliability. It is easy to integrate with another module. It provides fast response time with no cloud delay, thus enhancing interactivity and accessibility for users.
5) *Database:* The database of the system stores important data such as user details, sensor readings, AI outputs, or system logs. We are going to use SQLite, which is a lightweight, file-based database that requires no server setup and no need of database administration. Using it need simple setup and can easily integrate with python. It is ideal for offline device with low memory footprint and fast access.
6) *Communication:* The Communication layer of the proposed system ensures, data exchange between components such as to connect AI backend with Robot and Mobile App. This will be done using Flask REST API which handles data transmission using HTTP methods like GET and POST, while Blynk provides an IoT platform for alerts and real-time monitoring. Using REST API, Blynk and HTTP requests makes simple, cost-effective and standardised communication protocol. This work with both mobile and web client. And enable remote control and monitoring.
7) *Frontend (Mobile Application):* The frontend will be the user interface allows interaction with the AI-powered system. It will be a mobile application or webpage(optional), which will be created with minimal coding using Blynk. The Blynk is one of the Python libraries used for IoT integration, enabling the project to send or receive data between devices and a mobile application. Blynk provides real-time dashboard control, supports notifications, sensor monitoring, and cloud connectivity. It can integrate with Flask or local APIs. Thus, provide free and easy mobile control interface.

IV. METHODOLOGY

A. AI and Machine learning Models

The proposed GURU system employs a combination of Artificial Intelligence (AI) and Machine Learning (ML) models to enable adaptive interaction, emotional intelligence, and autonomous decision-making. These models collectively empower the robot to interpret speech, recognize emotions, understand context, and navigate its surroundings intelligently. The AI and ML framework is organized into five core components: Natural Language Processing, Emotion Recognition, Computer Vision and Navigation, Activity Recognition, and Reinforcement Learning.

1) Natural Language Processing Model

To enable human-like communication, the GURU robot integrates Natural Language Processing (NLP) and Generative AI techniques that facilitate understanding and generating spoken language. The NLP pipeline includes speech recognition, text interpretation, intent detection, response generation, and speech synthesis. User speech input is transcribed through APIs such as OpenAI Whisper or Google Speech Recognition. The resulting text is then analyzed using transformer-based architectures like BERT or GPT derivatives to extract semantic meaning and user intent. This allows the robot to comprehend not just the literal message but also the emotional tone and contextual relevance.

Once the intent is recognized, the robot generates appropriate and context-sensitive responses through dialogue-generation models similar to ChatGPT frameworks. The generated text is converted into natural speech using Vosk or Google Text-to-Speech (TTS). The integration of NLP ensures seamless communication and supports multilingual interaction, enabling the robot to assist users in regional languages as well.

This approach allows GURU to maintain fluent, empathetic, and context-aware dialogue, ensuring that the communication feels natural and emotionally engaging for the user.

2) Emotion Recognition Model

The Emotion Recognition model is designed to identify and respond to the emotional states of the user in real time. The system employs a hybrid architecture combining Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) to analyze facial expressions, speech patterns, and tone.

The CNN component processes visual data obtained from the robot’s camera, detecting facial landmarks and micro-expressions that reveal emotions such as joy, sadness, anger, or fatigue. The RNN, particularly Long Short-Term Memory (LSTM) networks, processes temporal audio data to capture variations in voice pitch, energy, and rhythm. These variations are crucial in recognizing subtle emotional cues from speech.

By combining both visual and auditory analysis, the GURU robot gains a comprehensive understanding of the user's mood. This enables it to adapt its tone of voice, facial display (through LEDs or screen-based expressions), and conversational content. For instance, if sadness is detected, the robot may respond with comforting words or calming behavior. This emotional adaptability strengthens the robot's companionship and psychological support role.

3) Computer Vision and Navigation Model

The GURU robot's mobility and environmental awareness are supported by its Computer Vision and Navigation Model. This system uses deep learning-based object detection algorithms such as YOLO, SSD, or MobileNet to recognize and track surrounding objects, obstacles, and pathways.

Using real-time image streams from onboard cameras, the CNN-based vision module identifies obstacles and interprets environmental layouts. The data is then processed using simultaneous localization and mapping (SLAM) techniques to generate a navigational map of the surroundings.

In addition to perception, a Reinforcement Learning-based control layer governs movement and navigation decisions. The robot continuously receives sensor feedback about its distance, speed, and proximity to objects, allowing it to optimize routes and avoid collisions. Over time, the model learns efficient paths and develops situational awareness that supports autonomous and safe mobility. This model ensures that the GURU robot can independently move through various environments, interact safely with users, and perform tasks such as object delivery or location-based assistance.

4) Activity Recognition and Personalization Model

The Activity Recognition and Personalization Model focuses on understanding the daily routines, habits, and behavioral patterns of the user. The system leverages Decision Tree and Random Forest algorithms to analyze recorded interaction data and identify relationships between activities, time, and emotional states. By learning from these patterns, the robot can predict user needs such as reminding medication schedules, suggesting rest periods, or recommending leisure activities. For example, if the user consistently engages in physical therapy exercises at a specific time, the robot can initiate reminders or motivational prompts automatically.

Additionally, this model contributes to personalization by adapting the robot's responses and recommendations over time. Continuous feedback from the user is utilized to refine predictions, ensuring that the robot evolves with the user's lifestyle. This adaptive learning allows GURU to act as a supportive companion rather than just a functional device.

5) Reinforcement Learning Model (Optional)

Reinforcement Learning (RL) forms the foundation for GURU's adaptive decision-making and learning from real-world experiences. The RL model operates through a feedback-based mechanism where the robot performs actions, observes outcomes, and receives rewards or penalties based on the success of its decisions. This iterative process allows the robot to develop optimized behavior for navigation, interaction timing, and energy efficiency. Over time, the RL agent improves its policies for performing tasks like approaching users safely, maintaining conversational flow, or avoiding unnecessary movements.

The integration of reinforcement learning ensures that the robot becomes more autonomous and self-reliant with each interaction. It minimizes the need for constant human intervention and enhances both task performance and long-term adaptability in dynamic environments

B. Autonomous Mobility and Navigation

The autonomous mobility and navigation system forms a vital component of the GURU Assistive Companion Robot, enabling it to move independently and assist users effectively in both structured and dynamic environments. The system is designed to ensure safe navigation, obstacle avoidance, and efficient route planning using a combination of sensors, control algorithms, and localization techniques. It enhances the robot's capacity to deliver assistance without requiring constant human intervention.

1) Sensor Integration and Environment Perception

The mobility framework begins with multi-sensor data acquisition. The robot is equipped with ultrasonic/infrared or LiDAR sensors to perceive its surroundings in real time. These sensors measure distances, detect obstacles, and capture spatial layouts of the environment. The collected data is continuously processed to generate a dynamic environmental map, ensuring the robot maintains awareness of objects, walls, and pathways. The fusion of sensor data enhances accuracy in detection and positioning, even under varying lighting or noise conditions. This multi-sensor approach enables robust obstacle detection and improves navigation stability across different indoor surfaces or confined spaces.

2) Localization and Mapping

Accurate localization and mapping are essential for the autonomous movement of the GURU robot. The system employs Simultaneous Localization and Mapping (SLAM) to create and update maps of unknown environments while tracking its own position in real time. By combining LiDAR or ultrasonic sensors and odometry data, the SLAM algorithm helps the robot recognize previously visited areas and avoid redundant movement.

This mapping process allows GURU to navigate efficiently in complex environments such as homes, hospitals, or care centers. The adaptive capability of SLAM ensures that the robot can operate even when the layout of the environment changes over time.

3) Path Planning and Obstacle Avoidance

Once the environment is mapped, the robot uses path planning algorithms to determine the safest and most efficient route to its destination. Algorithms are implemented to calculate the optimal path while minimizing travel time and avoiding collisions.

During movement, the robot continuously monitors its surroundings using real-time sensor feedback such as ultrasonic sensor. If an obstacle is detected, the system immediately re-evaluates its path and adjusts direction dynamically. This real-time replanning ensures smooth and uninterrupted navigation, allowing the robot to respond effectively to sudden environmental changes.

4) Motion Control and Safety

The motion control subsystem ensures stable and precise navigation. It operates through a closed-loop feedback mechanism that adjusts motor speeds and directions based on sensor inputs and encoder readings. This mechanism guarantees accurate turning, smooth acceleration, and controlled braking, even in confined or crowded spaces.

To enhance safety, the system includes adaptive speed regulation and emergency stop protocols. When an obstacle or human presence is detected within a predefined proximity, the robot automatically reduces speed or halts movement. This ensures user safety and prevents collisions during operation.

5) Adaptive Learning for Navigation Efficiency

The navigation system incorporates Reinforcement Learning (RL) principles to improve efficiency over time. Through continuous interaction with its environment, the robot learns to optimize routes, reduce redundant movements, and improve obstacle avoidance strategies. The RL-based feedback mechanism allows GURU to adapt to new environments, making it increasingly reliable and intelligent with repeated use.

C. Human Robot Interaction (HRI)

The Human Robot Interaction (HRI) module is designed to create an intuitive and emotionally responsive interface between the GURU robot and users, particularly individuals with disabilities. This system focuses on enabling smooth communication, emotional support, and adaptive behavior, ensuring that users experience a sense of companionship and assistance in their daily lives.

1) Multimodal Communication Interface

The robot integrates voice, facial expression, and gesture-based communication to establish a natural mode of interaction. Speech recognition and synthesis systems allow the robot to understand spoken commands and respond with human-like clarity. Additionally, the use of computer vision enables the robot to interpret facial expressions and gestures, enhancing non-verbal communication.

2) Emotion Recognition and Response Adaptation

Using advanced emotion recognition algorithms, the robot can detect the user’s emotional state through facial cues, tone of voice, and linguistic patterns. Based on the detected emotion, the system adapts its responses for instance, offering encouragement, comfort, or information as needed. This adaptive capability makes the interaction empathetic and supportive.

3) Voice-Based Command System

The voice interaction feature allows users to control the robot and access various functions hands-free. The system uses natural language processing (NLP) to interpret user intent accurately. This is especially beneficial for users with limited mobility, providing convenience and accessibility.

4) Conversational AI and Dialogue Management

The GURU robot employs conversational AI models to sustain meaningful dialogue. The dialogue management system ensures continuity and context retention in conversations, allowing users to engage in longer and more natural interactions. The integration of generative AI enhances the robot's capability to provide personalized and context-aware responses.

5) Feedback and Learning Mechanism

To continuously improve user experience, the HRI module includes a feedback loop that records interaction patterns and preferences. This data is processed to refine the robot's responses and emotional intelligence over time. The learning mechanism ensures that GURU becomes more attuned to individual user needs, strengthening the bond between human and robot.

In summary, the Human Robot Interaction module transforms GURU into a socially intelligent companion capable of understanding, responding to, and learning from human behaviour. This not only enhances accessibility but also promotes emotional well-being among users who rely on robotic assistance for daily tasks.

V. SYSTEM INTEGRATION AND WORKFLOW

A. System Integration

The integration of various subsystems in the GURU robot ensures coordinated operation and data flow across all functional modules. Each module interacts through a centralised control unit, maintaining consistent communication and real-time response. The major components integrated are shown in Fig. 1.

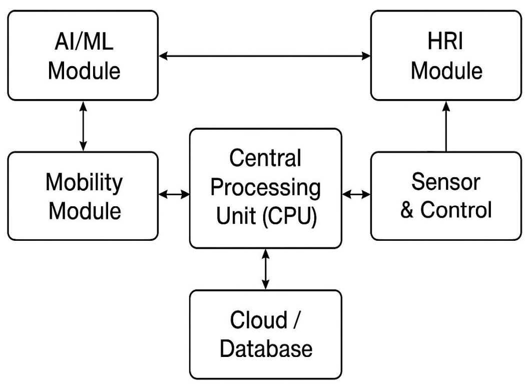


Fig. 1 Guru System Integration diagram

We have already covered the description of each module in the methodology section. Although the following points cover a brief overview of all modules:

1) *Central Processing Unit (CPU):* Acts as the core of the system, managing and synchronising all connected modules. It handles task scheduling, command execution, and inter-module communication.
2) *AI/ML Module:* Processes the input data collected from sensors and converts it into actionable decisions. It enables perception, learning, and intelligent behaviour through deep learning and natural language understanding.
3) *Human–Robot Interaction (HRI) Module:* Facilitates communication between the robot and the user through voice commands, gestures, and emotional cues. It ensures natural and context-aware interactions.
4) *Mobility Module:* Responsible for the robot's physical movements and navigation. It receives motion commands from the CPU and uses real-time feedback from sensors to avoid obstacles and reach destinations.
5) *Sensor and Control Systems:* Provide environmental awareness by capturing data from ultrasonic, infrared, and visual sensors. The feedback loop ensures safe and adaptive movement.
6) *Cloud and Database Integration:* Manages data storage, remote monitoring, and software updates. It allows continuous improvement of AI models and system diagnostics through cloud connectivity.

Together, these modules operate in a unified framework where the CPU acts as a communication bridge, ensuring that all subsystems function harmoniously and that the robot performs real-time decision-making and assistance tasks efficiently.

B. System Workflow

The workflow of the GURU system explains the sequence of processes through which the robot interacts with users, interprets commands, and performs actions effectively. It ensures continuous communication and adaptive learning through feedback mechanisms. The major steps involved in the workflow are as follows:

1) *Voice or Command Input:* The process begins when the user provides a verbal command or voice input. This input acts as the primary mode of interaction between the user and the robot.
2) *Speech Recognition:* The spoken command is processed by the speech recognition module, which converts the audio signal into text form. This allows the system to interpret the user's speech accurately.
3) *Natural Language Processing (NLP):* The converted text is then passed to the NLP unit. This module analyses the syntax and semantics of the text to understand the user's intent and context behind the command.
4) *Emotion Recognition:* Alongside language understanding, the system also performs emotion recognition. It detects the user's tone, pitch, and expressions to gauge emotional states such as happiness, sadness, or stress, helping the robot to respond empathetically.
5) *AI Decision System:* Based on the interpreted command and identified emotion, the AI decision module determines the most suitable response or action. It integrates contextual understanding and prior learning to make accurate decisions.
6) *Navigation and Control:* Once the decision is made, the navigation and control system plans the robot's movement or response strategy, whether it involves mobility, gestures, or positioning adjustments.
7) *Motor and Sensor Execution:* The planned actions are executed through motors and sensors. This stage converts digital decisions into physical or verbal responses, ensuring proper task execution.
8) *Sensor Feedback and Monitoring:* Sensors continuously collect environmental and positional data during task execution. This feedback is sent to the AI decision system to improve accuracy and adapt future responses.
9) *Response or Voice Output:* Finally, the robot provides the output to the user in the form of a verbal response or a physical action. This closes the interaction loop, allowing real-time and adaptive communication.

Following is the visual representation of the workflow of the Guru Robot system, as shown in Fig. 2.

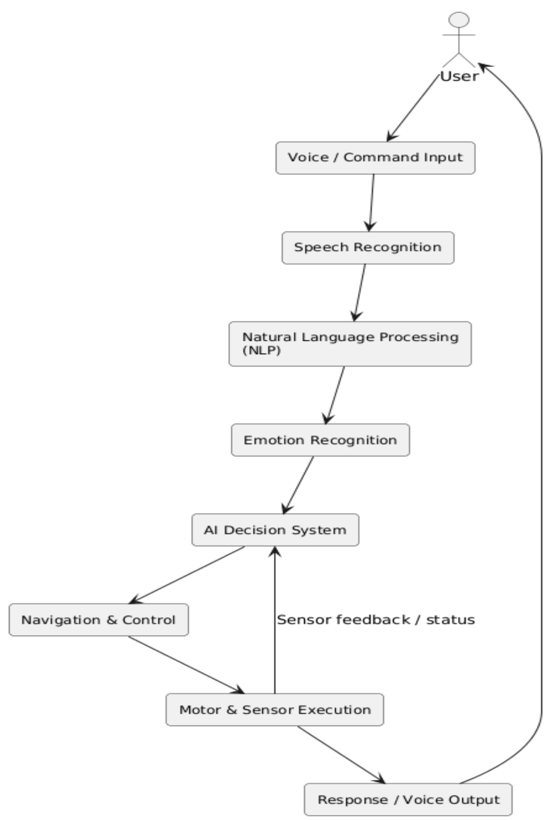


Fig. 2 Workflow of Guru System

Overall, this structured workflow ensures that GURU operates seamlessly by combining perception, understanding, decision-making, and action. It highlights the integration of intelligent modules to create a responsive and emotionally aware assistive system for people.

VI. CONCLUSIONS

The project represents a significant step toward using technology to enhance the quality of life for individuals who require daily assistance, such as the elderly, people with disabilities, or those living alone. By integrating features like voice command recognition, voice interaction, fall detection, smart reminders, emotional support, and emergency assistance, GURU addresses not only physical needs but also emotional and social well-being.

Using Raspberry Pi, Arduino, and cloud communication, the robot efficiently bridges hardware and software integration while maintaining user-friendliness and real-time responsiveness. The project emphasises not only technical innovation but also social impact, enhancing independence and improving the quality of life for users who require assistance.

This system contributes meaningfully to society by promoting independence and safety among vulnerable populations, reducing the burden on caregivers, and enabling users to live with dignity and confidence within their own homes. The robot’s intelligent interaction and adaptive behaviour make it a supportive companion capable of understanding and responding to human needs in real time.

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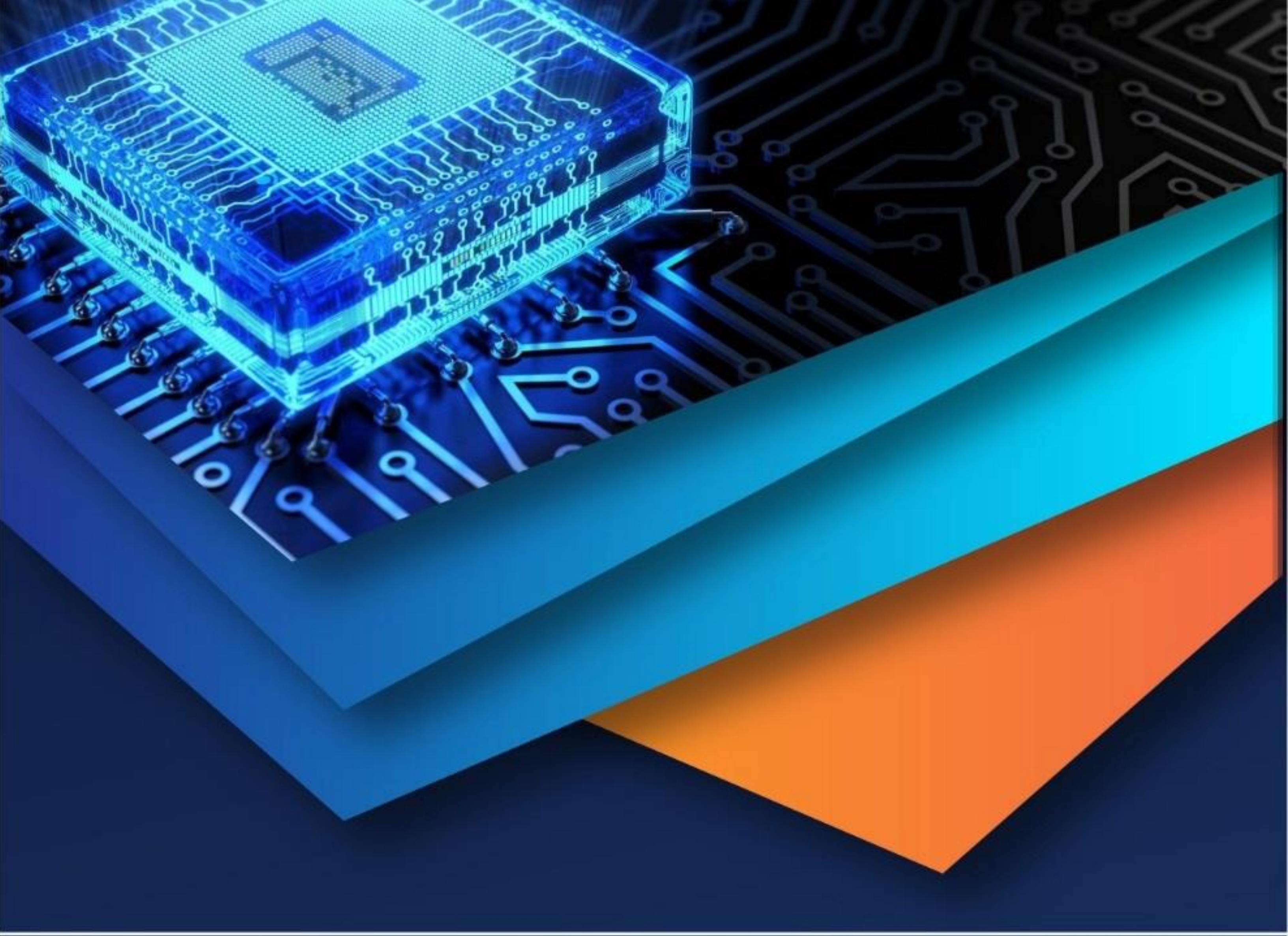

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