RESEARCH ARTICLE

RSP Science Hub

International Research Journal on Advanced Science Hub
2582-4376
www.rspsciencehub.com
Vol. 07, Issue 12 December

Check for updates

http://dx.doi.org/10.47392/IRJASH.2025.123

AI Pet Robot for Mental Health Care and Personal Assistance

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Article history

Received: 24 September 2025
Accepted: 25 October 2025
Published:26 December 2025

Keywords:

AI Pet Robot, Mental, Health Assistance, Emotion Recognition, Natural Language Processing (NLP), Human–Robot Interaction (HRI)

Abstract

The increasing prevalence of mental health concerns and the growing demand for personalized assistance have motivated the development of intelligent robotic companions. This project, "AI Pet Robot for Mental Health and Personal Assistance", presents a cost-effective, autonomous robotic platform capable of recognizing human emotions, understanding speech, and responding interactively to support user well-being. The system integrates a Jetson nano-based hardware setup comprising a camera, microphone, display screen for facial expressions, and Bluetooth connectivity, enabling real-time interaction. Using advanced algorithms in natural language processing (NLP) and facial emotion recognition, the robot interprets user inputs, detects emotional states, and generates contextually appropriate responses. The architecture synergizes hardware control, AI-driven decision-making, and personalized feedback to create an engaging and responsive user experience. Experimental evaluation demonstrates the robot's potential in mental health monitoring, companionship, and adaptive interaction. This project highlights the promise of combining artificial intelligence and robotics in developing accessible, interactive, and supportive personal assistants.

1. Introduction

In recent years, human-robot interaction has gained significant attention as robotics moves beyond industrial automation into healthcare and assistive technologies. Mental health issues, such as anxiety and loneliness, are rising globally, creating a need for accessible emotional support systems. Traditional therapy is often expensive or inaccessible, leading to a gap that socially assistive robotics can fill. The AI Pet Robot proposed in this work is designed to bridge this gap by providing a reliable, always-available companion. It leverages the power of the Jetson Nano Developer Kit, which enables high-performance edge AI computing for real-time vision and audio processing. The robot is equipped with multimodal interaction capabilities, allowing it to perceive the user's emotional state through facial cues and voice tone, responding with empathetic dialogue and animated facial expressions on its screen. Additionally, the system includes autonomous mobility and IoT connectivity, transforming it into a holistic personal assistant capable of both emotional support and smart home management.

Figure 1 Hardware Components and Assembly Kit of the AI Pet Robot System

2. Literature Survey

- The development of socially assistive robotics requires a multidisciplinary approach, integrating human-robot interaction (HRI) design, sensor-based autonomy, and advanced decision-making algorithms. This section reviews existing literature relevant to the design of the proposed AI Pet Robot, focusing on emotional expression, interactive system architectures, and autonomous coordination.
- **Human-Robot Interaction and Emotional Expression** Effective communication in social robots relies heavily on non-verbal cues such as facial expressions and gestures. A study on HRI design for older people emphasized the importance of optimizing these cues to enhance emotional engagement. By utilizing user-robot integrated scenarios, researchers identified six key emotional states essential for interaction: Loving, Joyful, Upbeat, Hopeful, Concerned, and Grateful. The study utilized the Facial Action Coding System (FACS) to analyze human expressions and map them onto robot faces, highlighting that geometric shapes for eyes and mouths are most effective for clear emotional communication. Additionally, motion capture technology was employed to design fluid upper-body gestures, validated through the Laban Effort Framework to ensure natural movement dynamics. These findings provide a critical framework for developing the display-based facial animation system in our proposed project.
- **Interactive Robotic Systems and Home Assistance** The integration of multiple sensors and AI for home assistance is exemplified by "BLU" (Beloved Until), an interactive pet robot designed for security and entertainment. Unlike traditional biomorphic robots like Robosapien or Cozmo, BLU integrates a comprehensive sensor suite—including light, passive infrared (PIR), and sonar sensors—to monitor environmental conditions and detect objects. The system utilizes a multi-protocol communication framework, enabling interaction via voice commands, infrared remotes, and Bluetooth-connected mobile applications. Crucially, BLU features an autonomous decision-making algorithm that processes sensor data to execute mechanical actions, such as obstacle avoidance using sonar data to calculate optimal navigation paths. This architecture supports the feasibility of combining personal assistance with autonomous mobility in a low-cost platform.
- **Autonomous Navigation and Decision Making** While social interaction is key, the ability to navigate dynamic environments is vital for a pet robot. Research into autonomous mobile robots (AMRs) in smart factories offers valuable insights into decentralized decision-making. A study on Quantum Multiagent Reinforcement Learning (QMARL) proposed a framework for coordinating robots in non-stationary environments using Variational Quantum Circuits (VQCs). This approach utilizes Centralized Training and Decentralized Execution (CTDE), allowing robots to learn from shared experiences while executing tasks independently. Although applied to industrial material transport and defect detection, the principles of maximizing

precision and minimizing delays through reinforcement learning are directly applicable to the autonomous navigation modules of domestic robots. The study demonstrated that advanced learning models could significantly outperform classical approaches in processing efficiency and adaptability.

- **Summary** The reviewed literature highlights the necessity of three core components for a successful companion robot: (1) an expressive interface based on validated emotional models, (2) a robust sensor-fusion architecture for environmental awareness, and (3) intelligent algorithms for autonomous navigation and decision-making. The proposed AI Pet Robot builds upon these studies by integrating Jetson Nano-based edge AI to process these tasks simultaneously in real-time.

3. Problem Statement

Despite advancements in AI, most personal robot companions are either prohibitively expensive or lack genuine interactive capabilities. There is a lack of low-cost, autonomous systems that can effectively monitor mental health while performing useful household tasks. Furthermore, running deep learning models for emotion recognition and NLP simultaneously on embedded devices presents optimization challenges regarding latency and power consumption.

4. Objectives

The primary objectives of this project are:

- **Emotion Recognition:** To develop deep learning models (CNN) that identify user emotions (Happy, Sad, Angry, Neutral) from facial images in real-time.
- **Natural Language Interaction:** To implement an NLP-based chat system that converts speech to text, processes the intent, and responds via synthesized speech.
- **Expressive Feedback:** To utilize a display screen to render animated facial expressions that sync with the robot's emotional state and verbal response.
- **Autonomous Mobility:** To enable the robot to navigate indoor environments autonomously using ROS, avoiding obstacles and following the user.
- **IoT Integration:** To incorporate smart home control features, allowing the robot to operate lights and appliances based on voice commands.

5. System Architecture

The system architecture consists of three core layers: Perception, Reasoning, and Action.

- **Perception Layer:** Inputs are gathered via a high-definition camera (for facial detection) and a USB microphone array (for voice commands) connected to the Jetson Nano.
- **Reasoning Layer:** The Jetson Nano processes these inputs. It runs a CNN model for emotion classification and an NLP engine for dialogue generation. It acts as the central brain, utilizing its 128-core Maxwell GPU for parallel processing.
- **Action Layer:** Outputs include audio responses via speakers, facial animations on the LCD screen, and movement via DC motors controlled by a motor driver. IoT commands are sent via Wi-Fi to smart home devices.

6. Methodology

6.1. Hardware Setup

The core processing unit is the JETSON-NANO-DEV-KIT (4GB version). It includes a Quad-core ARM Cortex-A57 CPU and a 128-core NVIDIA Maxwell GPU, capable of 472 GFLOPS, making it ideal for AI applications.

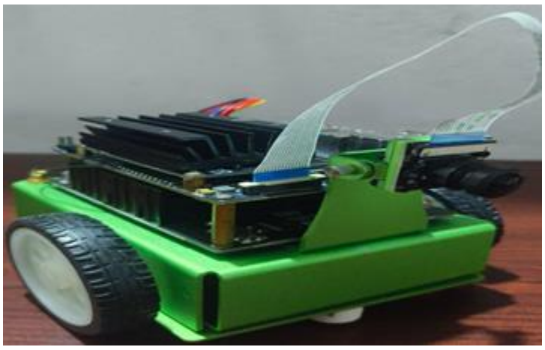

Figure 2 Assembled AI Pet Robot Prototype with Embedded Jetson Nano Platform

- **Storage:** A 16GB eMMC or external MicroSD card is used for the operating system and datasets.
- **Connectivity:** The device supports Gigabit Ethernet and M.2 Key E for Wi-Fi modules.

- **Peripherals:** A CSI camera is connected via the MIPI CSI-2 connector, and a display is connected via HDMI/DP.

6.2. System Environment & Software Installation

The system runs on Ubuntu 18.04, installed via the NVIDIA SDK Manager.

- **OS Flashing:** The Jetson OS is flashed onto the eMMC/SD card using the SDK Manager or by creating a bootable USB drive using Rufus. The Jetson Nano is placed in Force Recovery Mode by shorting the FC REC and GND pins during power-on.
- **SDK Installation:** NVIDIA JetPack SDK (version 4.6) is installed, providing crucial libraries like CUDA, cuDNN, and TensorRT for hardware acceleration.
- **CUDA:** Used for parallel computing tasks.
- **TensorRT:** Optimizes deep learning inference for image classification.
- **Computer Vision:** OpenCV and VPI libraries are installed for image processing.
- **Python Environment:** Python 3.6 is used as the primary programming language. Libraries such as TensorFlow (v2.5.0), PyTorch (v1.9.0), and Torchvision are installed to support the AI models.

6.3. Feature Implementation

- **Emotion Detection:** A pre-trained CNN model is optimized using TensorRT. The camera captures video frames, faces are detected using Haar cascades, and the model classifies the emotion.
- **Voice & NLP:** The system uses speech_recognition libraries to capture audio. The input is processed by a local NLP model (or API) to generate a text response, which is converted to audio using a Text-to-Speech (TTS) engine.
- **Smart Home Control:** The robot serves as a local MQTT broker. Voice commands like "Turn on the lights" are parsed, and corresponding signals are sent to ESP32-based smart switches over the local Wi-Fi network.

[Insert Figure 2: Flowchart showing Input -> Face/Voice Detection -> Emotion Analysis -> Response Generation -> Action]

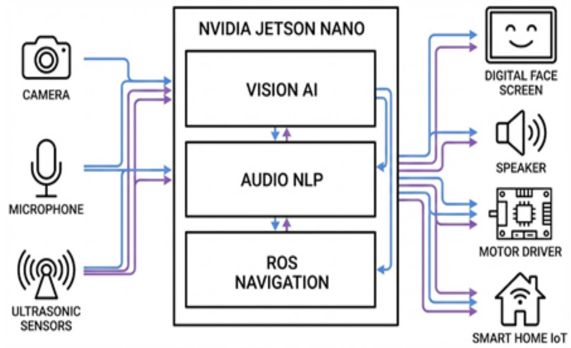

Figure 3 System Architecture of the AI Pet Robot Integrating Vision, Audio NLP, and ROS-Based Control

7. Results and Discussion

The developed AI Pet Robot successfully demonstrated the integration of vision, voice, and mobility.

- **Performance:** The Jetson Nano's GPU acceleration allowed the emotion recognition model to run at approximately 15-20 FPS, providing seamless real-time interaction.
- **Interaction:** The robot accurately identified "Happy," "Sad," and "Angry" expressions and adjusted its digital face and voice tone accordingly.
- **Mobility:** The ROS-based navigation allowed the robot to traverse rooms without collision.
- **IoT Control:** Voice commands for smart home devices were executed with a latency of under 2 seconds.

8. Future Scope

Future enhancements include:

- **Cloud Integration:** Integrating cloud-based Large Language Models (LLMs) for more complex and varied conversations.
- **Health Monitoring:** Adding sensors to monitor the user's vital signs (e.g., heart rate via non-contact vision techniques).
- **Advanced Mobility:** Implementing SLAM (Simultaneous Localization and Mapping) for complex environment mapping.

Conclusion

This project successfully designed and implemented an AI Pet Robot for mental health assistance. By leveraging the Jetson Nano’s capabilities, the system provides a multimodal interface combining emotion recognition, NLP, and IoT control. The robot serves as a cost-effective, empathetic companion that not only alleviates loneliness but also assists in daily living tasks, demonstrating the profound potential of AI in personal healthcare.

Acknowledgements

We thank our guide, Dr. G Gayatri Tanuja, and the Department of AIML at Bangalore Technological Institute for their support.