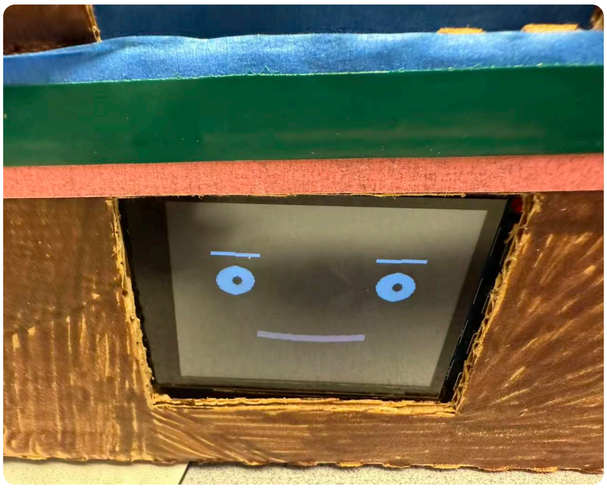
Team 7 ECE5725 Project

Intelligent Companion Robot
A Project By Zhijie(Jack) Zhou and Jinfeng(Jeffery) He

Demonstration Video

Introduction

The goal is to build a small "pet companion robot" to provide emotional support and friendly interaction for users who may be under stress, lonely, or studying for a long time. It chats like a close buddy,responding your voice and touch in real time. It also shows personality with dynamically generated pygame expressions. The robot keeps a friendly smile in IDLE mode and switches to animated mouth-and-eyes “speaking” expressions during conversation. "Buddy" runs fully on a Raspberry Pi 4 with local LLM, STT, TTS, emotion state machine, memory, and display pipelines.



Project Objective:

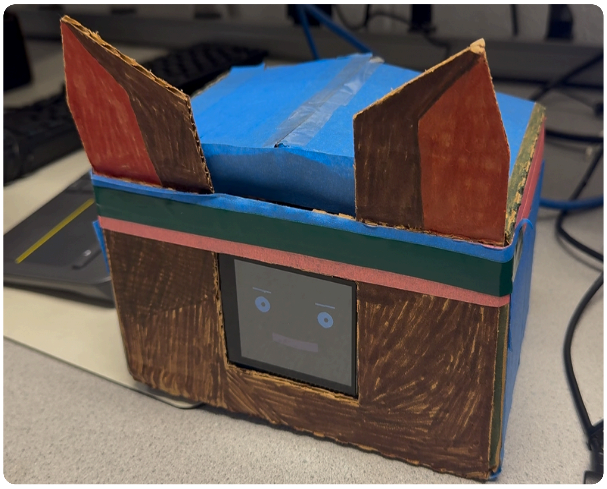
- Robot using Raspberry PI, microphones, speakers, and touch screen to perceive the environment and perform expressive behaviors.
- Responding to voice commands: Using microphone to detect simple voice commands from user
- Responding to touch: Using touch screen to detect user interaction and responding with different expressions
- Showing off personality: Display different emotions when user talk with the robot.
- Run fully local: STT → LLM → TTS on-device, keeping latency low and privacy preserved.

Design

In system architecture, Raspberry Pi 4 runs fully local pipeline: udio I/O → STT (faster-whisper) → LLM (Ollama qwen2.5 0.5b) → TTS (Piper) → emotion engine → pygame display. There are some multimodal interactions like microphone for voice commands, PiTFT touch screen for one tap, two taps, scrolls, and swipe. The robot also has up to 12 different pygame-generated expressions to show different emotions like happy, sad, excited, angry, and sleepy. For example, idle mode keeps smilling and speaking animateds mouth and eyes. More details, in expression rendering, the procedural face shows up through pygame and fallback to sprite frames. We also have per-frame blending and transition controller to avoid pop-in. For reliability and performance, we use WebRTC VAD + adaptive VAD to trim silence and stream STT/LLM/TTS with callbacks. The robot also has GPIO exit and watchdog in display loop. For Memory and History, we use an SQLite-backed conversation log and user memory to maintain context continuity.

Key challenges included iterating LLM choices (llama3.2:3b → tinyllama:latest → llama3.2:1b → qwen2.5:0.5b) to fit latency and RAM on the Pi, switching from Whisper to faster-whisper for STT speed, resolving WM8960 audio card connection issues and package conflicts with PulseAudio, and fine-tuning pipelines and transitions for smoother responsiveness.

Drawings



The basic idea of the appearance to the robot was to create a cat-like figure that is friendly and inviting. To better match the robot's voice personality, we made slight adjustments to the appearance and we also had a background story of "buddy": On a dark and windy night, I was so lonely that I kept staring out of the window in a daze. At the same time, I saw a dark shadow flash by under the moon and come to my window. I live on the 33rd floor. What kind of creature could climb to such a high floor? I had a feeling the person coming meant trouble. Then I saw a pair of brown cat ears appear before my eyes, and it was wrapped in three layers of ninja headscarves on its head! It calls itself "buddy" and came here from the west Coast in order to find its owner. So, "buddy" has been living with me until now and we have become very good friends.

Testing

In the video, we tested the robot with several scenarios including voice command recognition, touch interaction, and emotional response. For example, if we use our finger to tap the screen once, the robot will say "Hi there!" If we tap the screen twice, the robot will respond "I love this!" If we press the screen with a long time, the robot will say "That feels nice." If we drap the screen, the robot will say "Hehe, that tickles!" If we scroll on the screen, the robot will say "Round and Round!" In the speak mode, the robot will first show a smile face and when we speak, a blue box will appear at the edge of the robot. This means the robot is listening. After we finish speaking, the robot will process our voice command and respond accordingly For instance, when we say "I feel sad today", the robot will show a sad face and say "oh no, can't image what makes you feel".

Result

Performance on the Raspberry Pi 4 shows fully local operation with average end-to-end latency around 28 s (p95 ~38 s) and perceived “first audio” near 5.5 s; STT and small Ollama LLMs are the main contributors, while RAM stays modest (~560 MB main, ~150 MB Ollama). Further gains will come from smaller STT/LLM models, tighter VAD, and shorter responses to reduce TTS time.

Future Work

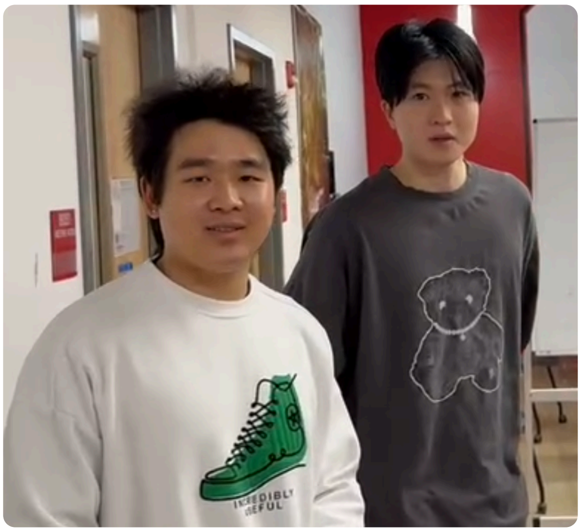
Next steps focus on adding a camera-driven computer vision layer to track people and maintain eye contact, plus an optional advanced mode that can offload heavier LLM/TTS workloads to cloud APIs for better performance and roomier long-term memory, while keeping the local Pi-first path as the default.

Conclusion

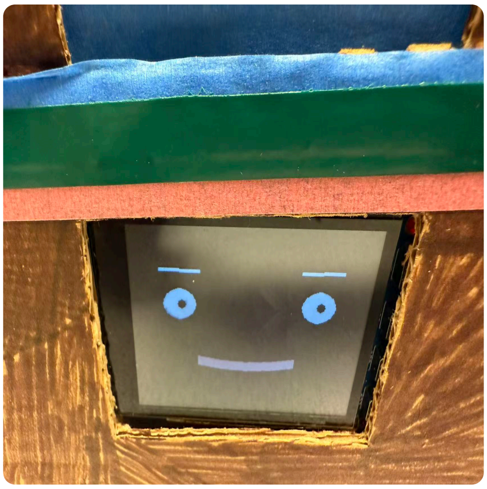
Companion Bot delivers responsive, fully local interactions on the Raspberry Pi, blending speech, touch, and expressive visuals into a cohesive experience. The modular pipeline and configuration make it a practical platform for future sensing and personality upgrades.

What worked well: we strictly followed the implementation plan and kept the system modularized, which simplified integration and tuning. What did not work as well: keeping up with weekly progress reports—these slipped and should be tracked more diligently next time.

Work Distribution



Project group picture



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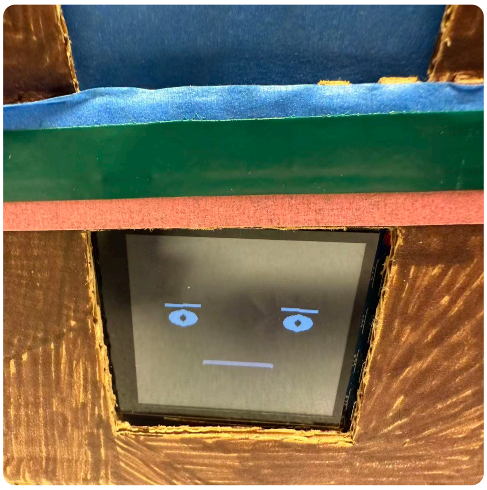
Designed the overall software architecture (Just being himself).



Zhijie(Jack) Zhou

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Tested the overall system.

Make the cardboard appearance

Code the early pygame prototype

Parts List

- Raspberry Pi 4 (core compute)
- piTFT display (touch + framebuffer)
- Mini microphone (USB/I2S) — $5
- Speaker with wm8960 soundcard — ~$20
- 256GB USB drive — ~$20
- Mini Breadboard

Total: ~$45

References

Lab2_Spring2025_v3.pdf (https://canvas.cornell.edu/courses/79187/files/13726568?module_item_id=3382921)
Raspberry Pi Pinout (https://pinout.xyz/pinout/pin12_gpio18/)
Running Large Language Models on Raspberry Pi (https://www.hackster.io/mjrobot/running-large-language-models-on-raspberry-pi-at-the-edge-63bb11?utm_source=perplexity)

Code Appendix

> Full source is available at https://github.com/GGCav/companion_bot (https://github.com/GGCav/companion_bot).