TESTUDO: A Robotics Kit Evolving into an AI-Driven Companion

Kaan Tabağ[1], Mehmet Bener[1], Emre Dayangaç[1], Pelin Başyurt[1], Irmak Üreten[1], and Sedat Yalçın

[1] Hisar School IdeaLab Fablab, Istanbul, Turkey

Abstract
Despite Artificial Intelligence (AI)-driven STEM kits being widely available, K-12 students often struggle to access them at reasonable prices. Given the crucial role of hands-on projects in early engineering education, we developed TESTUDO, an affordable, open-source, AI-integrated robotic companion[1]. It is inspired by a tortoise in design and powered by an AI-integrated low-cost microcontroller. It offers a customizable learning experience, making adaptive educational kits accessible to students from all backgrounds. After students build their device, it uses a custom-trained AI model to learn from user interactions, adapting its behavior over time to create a more engaging and personalized experience. Students can then modify and personalize their version of TESTUDO to fit their needs while continuously improving in the iteration process. This modification system relies on open-source programs, designs, and electronic frameworks. The AI model adjusts the tortoise's development path to align with individual strengths by analyzing user data collected from verbal interactions. This adaptive system enables a dynamic progression, guiding users through tasks based on their performance and engagement levels.

Keywords and Phrases: Robotics, Artificial Intelligence (AI), Education, STEM Kit

1. Introduction

1.1 Manufacturing
FDM 3D printers are used to produce TESTUDO, a low-cost manufacturing system for designs that can be iterated and must be produced quickly. While one kit takes 2 hours and 7 minutes of printing time, it is possible to iterate continuously through our CAD software to shorten the 3D printing period. Filament usage may be reduced by finding the best infill density and pattern, inner and outer wall thickness, and support structure that is almost unused in 3D printed components of TESTUDO. We chose Polylactic Acid (PLA) as the filament type to ensure a stable and reliable shell while keeping the print affordable and easy to maintain. PLA is also well-suited for commercial 3D printers, making printing efficient. After production, magnets are used to assemble printed parts, and internal components are supported by snap-fit connections to ensure that TESTUDO remains easy to assemble while maintaining durability.

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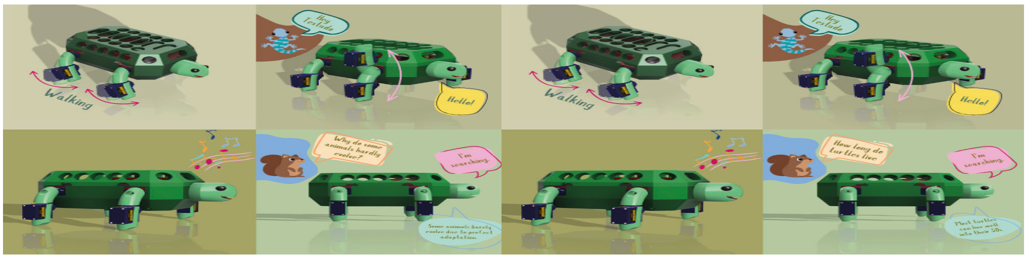

Figure 1: Photo of Testudo walking, talking, music-playing and web-searching.

1.2 Electronics

TESTUDO integrates various electronic components for processing, communication, and movement. The primary processing unit of the system is a Raspberry Pi 4 Model B, which mainly handles the computational operations and enables communication with the embedded Artificial Intelligence model. A ReSpeaker 2-Mic Pi Hat with a 4-ohm speaker is used for audio processing and input-output operations. TESTUDO also employs an Adafruit 16-Channel PWM Servo Driver to precisely control the 4 servos on the tortoise. Three AAA batteries are used to power 4 SG90 micro servos, and a power bank is used to power the Raspberry Pi 4. The estimated total cost of the TESTUDO kit is 4650 TL or 122 USD currently.

1.3 Software

The software of TESTUDO mainly consists of speech processing, the Wizard Vicuna model customized with prompt engineering, user data extraction, and movement scripts. This system combines multiple AI techniques; Natural Language Processing, Prompt Engineering, Large Language Models, Pattern Recognition, Context Management, and Emotional Intelligence. The speech processing is initiated when the word "Testudo" is detected, where a continuous recognition procedure is used on a real-time speech-to-text algorithm, which is the Google Speech API. This algorithm captures and transcribes speech. Once the user stops their speech, the text is inputted into the Large Language Model, which is based on a server running LMStudio in our IdeaLab. Each input from the user is put through the user data extraction scripts, which store data about the user that it can find in a JSON file on the Raspberry Pi. The Raspberry Pi gives the user input as well as the user's data stored from the JSON file to the model. The model gives a response to the Raspberry Pi, which is then read out loud using TTS. The model on LMStudio is provided with a system prompt containing very detailed instructions on how the chatbot should respond to the user as TESTUDO, containing information about the project and the context. Additionally, voice commands such as "Go forward" will trigger the movement scripts.

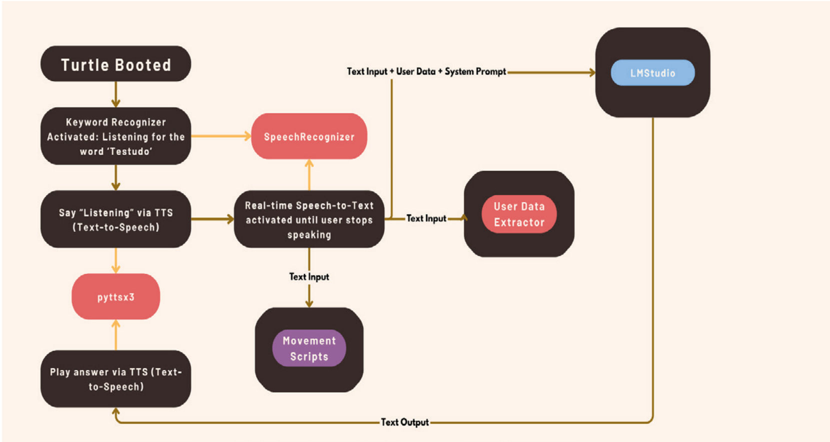

Figure 2: Programming Architecture.

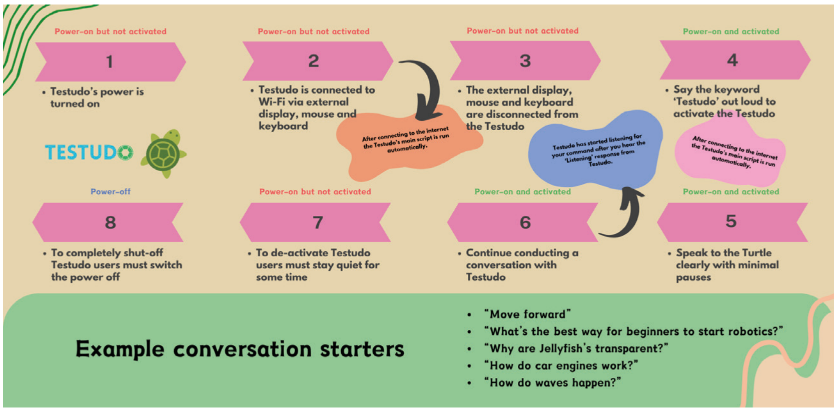

Figure 3: User Workflow Diagram.

2. Kit Design

2.1 Kit Explanation

TESTUDO meets the students in multiple pieces; these include all the components needed to build a TESTUDO, such as the Raspberry Pi 4 or 3D printed components. While assembling TESTUDO, high-level K-12 students who have experience in software learn how to integrate AI into the Raspberry Pi in many different ways, while lower-level K-12 students focus on core concepts of the software of TESTUDO. Some examples of learning outcomes include using a connection over the internet to connect to the server that has the Large Language Model loaded, integrating real-time speech-to-text and text-to-speech using Python libraries, extracting and using user data, and engineering both a system prompt and a user prompt that enables TESTUDO to communicate with humans. Additionally, TESTUDO enables students to learn how microcontrollers interface with various peripherals through the Pulse-Width Modulation (PWM) protocol. They will be familiarized with various types of electronic connections, fundamental voltage, and amperage controls through regulators. The process of assembling the kit will teach students how to transform ideas into functional projects through CAD design, 3D printing, and manufacturing. It will also enhance their problem-solving skills, foster creativity, and develop a systematic approach to engineering design [2]. Students are expected to build TESTUDO using an interactive assembly animation. Only high K-12 students aspire to work with CAD design, 3D printing, and programming AI, so our customizable kit-building experience enables students to learn based on their needs. Users without programming or CAD experience will have a different learning experience compared to those who have experience in programming or CAD. This creates a student-centered, discovery learning process where students use what they already know to acquire more knowledge, aligning with constructionist principles. In addition, the total assembly of the kit for a K-12 science class would take approximately 4 to 8 2-hour lectures, depending on the level of the K-12 students in the class and the experience of the students in areas like CAD or programming. Furthermore, the building of TESTUDO can be a good addition to the country's education plan for science or computer science classes to learn several topics. As a future step, we plan to test TESTUDO outside the lab in a K-12 learning environment.

2.2 Continuous Learning and Personalization

Unlike traditional STEM kits that follow a fixed assembly process and become obsolete once completed, TESTUDO provides learning opportunities after the initial build, gradually introducing more advanced guides for further developing the tortoise in all areas of the building process. The building process can adapt according to the information gathered from the user data extraction of the tortoise to fully personalize future steps based on the user's strengths and challenges. Additionally, with progress and personal achievements, TESTUDO creates an emotional bond that encourages users to further their learning [3][4].

3. Conclusion

Although AI-driven STEM kits are common on the market, TESTUDO aims to make them accessible for K-12 students by offering an affordable, open-source, AI-integrated quadruped robotic companion powered by a Raspberry Pi 4. Students build, personalize, and iterate on their tortoise, gaining hands-on experience on STEM and improving on programming, designing, and electronics skills. With an AI model and a user data extraction system, TESTUDO continuously adapts and learns, creating a personalized experience. This experience enhances interactivity by adjusting the tortoise's development based on verbal user interactions, providing dynamic learning for K-12 students.

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