SPATIAL SENSE USING AI TECHNOLOGY FOR SMART HOMES

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Keywords:

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Introduction:

1. Spatial sensors play a crucial role in capturing and interpreting information about the physical environment. These sensors detect spatial attributes such as position, orientation, distance, and motion, making them essential in fields like navigation, augmented reality, and environmental monitoring. Spatial sensors enable the detection and tracking of objects within a specified environment, facilitating applications such as smart homes, industrial automation, and etc.
2. The evolution of smart home technology has ushered in a new era of intelligent living, where artificial intelligence (AI) plays a pivotal role in enhancing automation, personalization, and safety. Among the most transformative capabilities within this domain is spatial sense-the ability of AI systems to perceive, interpret, and respond to the spatial configuration of domestic environments. Spatial sense goes beyond simple object recognition; it encompasses contextual awareness, environmental mapping, and dynamic interaction with physical spaces. This capability enables smart homes to adapt intelligently to user behavior, environmental changes, and object movement, thereby creating a responsive and user-centric ecosystem.
3. Central to spatial sense is the integration of computer vision, voice interaction, and sensor fusion. AI models trained for object detection serve as the foundation for spatial awareness, allowing systems to identify and localize items within the home. However, rather than relying on broad-spectrum detection across dozens of categories, this research emphasizes selective object detection—focusing specifically on four essential items: bottle, book, key, and bag. These objects are chosen for their relevance to daily routines, potential to trigger meaningful automation. For instance, detecting a key left on a table can prompt a reminder before leaving the house, while identifying a bag near the door may signal readiness for departure. Bottles and books, meanwhile, can be monitored for inventory, hydration tracking, or reading habits.

Objectives:

1. To design and develop spatial sense using AI technology.
2. Develop Voice Command Integration (Gemini API) that enables users to interact with devices
3. To design AI-Powered Object Detection enables to integrate voice command and identify objects within the specified environment.
4. Object detected by trained AI model and testing.

Methodology:

Spatial sense in smart homes with AI begins with identifying the specific needs of the household, such as security, energy efficiency, or elderly care. Data is then acquired through sensors and devices like the Raspberry Pi Camera Module, which captures real-time images and video of the environment. This raw data is pre-processed to remove noise and formatted for analysis, before being fed into lightweight AI frameworks such as TensorFlow Lite or OpenCV. The AI models interpret spatial information by detecting occupancy, gestures, room layouts, and unusual activities, thereby creating spatial intelligence. These insights are integrated into smart home systems to trigger automation routines like adaptive lighting, appliance control, or security alerts. Edge computing on the Raspberry Pi ensures low latency and privacy by processing data locally, supported by a stable USB-C power supply for continuous operation. Over time, the system learns user habits and preferences, refining automation through feedback loops. Finally, the methodology includes evaluation and scalability, testing accuracy and efficiency while expanding the system across multiple rooms to create a fully adaptive, secure, and human-centric smart home environment.

Block Diagram:

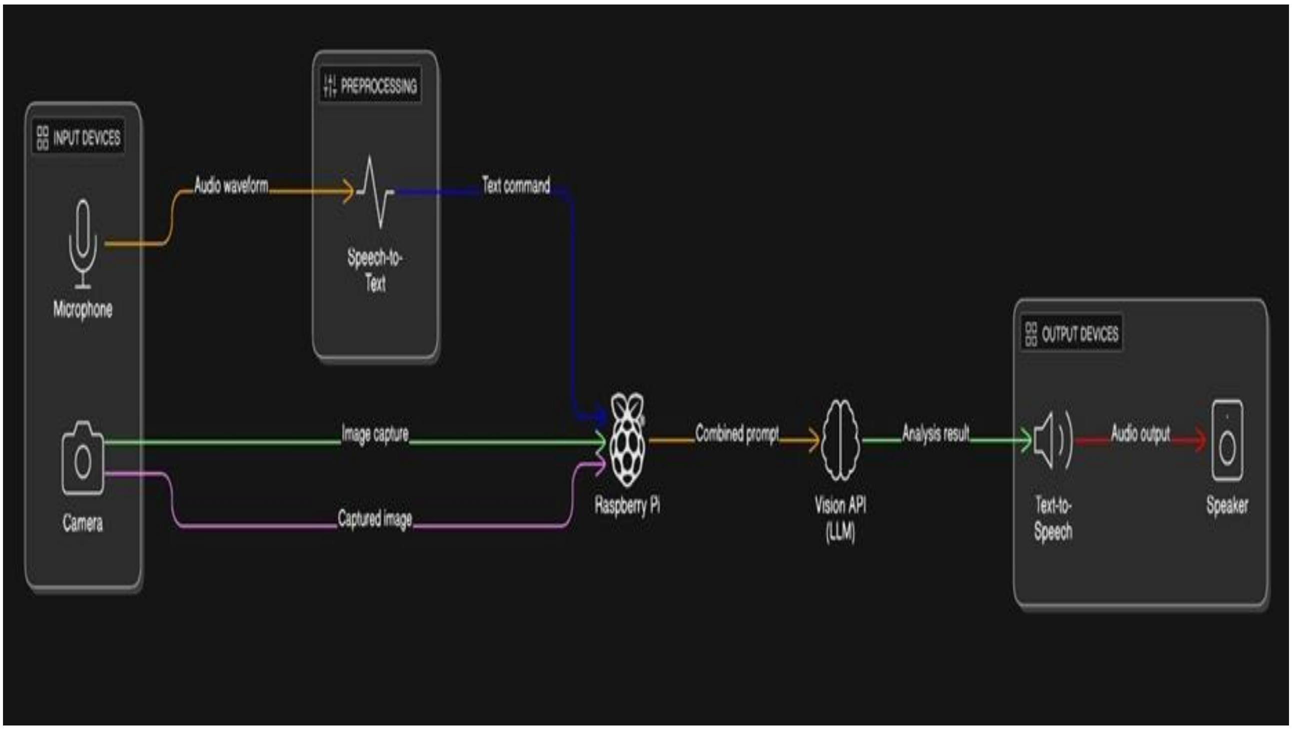

Figure 1: Block diagram of spatial sense using AI technology for smart homes

Flow Chart:

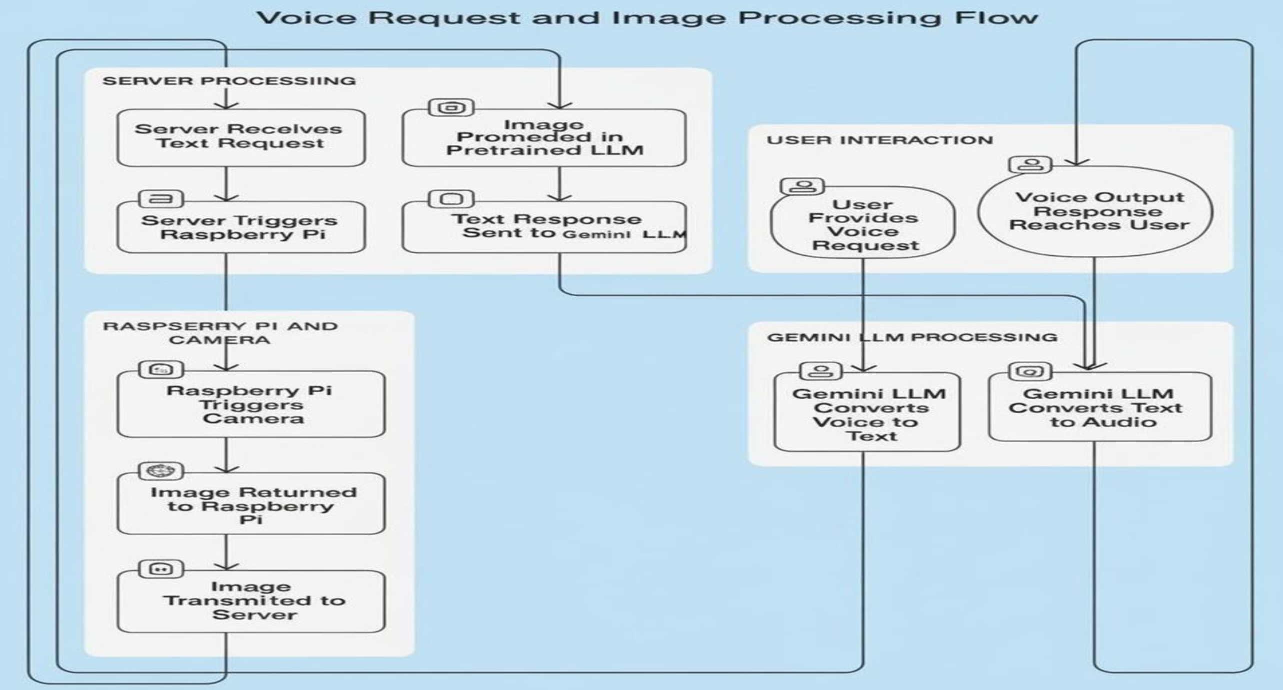

Figure 2: Flow chart of spatial sense using AI technology for smart homes

Result:

Table 1: Experimental Results of Trained Object Detection System

Sl.no	Object's	No of trials	No of times detected	Efficiency
01	Bag	5	5	100%
02	Ganesha idol	5	5	100%
03	Bulb	5	5	100%
04	Mobile charger	5	5	100%
05	Key	5	5	100%

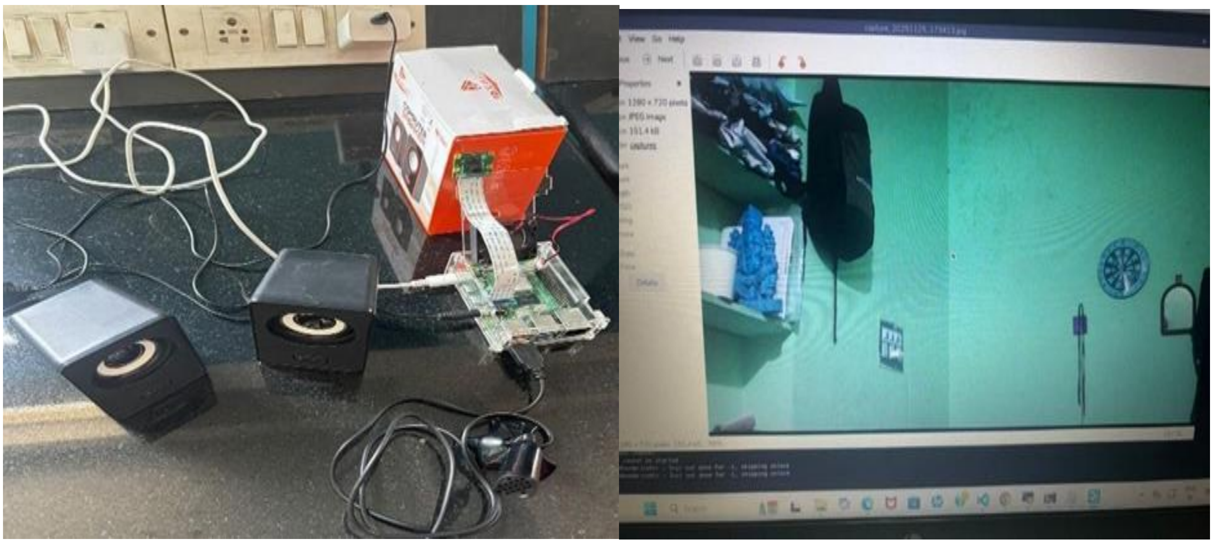

Figure 4: Hardware setup and detecting the objects

Sl.no	Object's	No of trials	No of times detected	Efficiency
01	Book	5	2	40%
02	ID card	5	3	60%
03	Food packet	5	1	20%
04	Cosmetic items	5	2	40%
05	Earphones	5	1	20%

Table 2: Experimental Results of Untrained Object Detection System

Conclusion:

In Conclusion, the project has successfully demonstrated an integrated spatial sensor system using Raspberry Pi, Alexa voice module, camera module, and microphone audio input. Experimental results indicate solid foundational performance in voice recognition, visual spatial sensing, and acoustic signal processing under controlled indoor conditions. Challenges related to sensor sensitivity, environmental effects, and processing latency provide clear directions for future optimization and hardware enhancements. The multimodal data fusion approach validates the feasibility of creating interactive spatial sensing systems capable of real-time environmental interaction and user command responsiveness. Recommendations for ongoing research include focusing on noise resilience in voice modules, expanding sensor modalities for comprehensive spatial awareness, and leveraging edge AI processing to reduce latency.

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Future Scope:

The future scope of this project includes:

1. Improving spatial accuracy using advanced sensors like 3D Camera.
2. Enhanced usability through natural language commands and real-time feedback.
3. Adding advanced processing capabilities such as edge AI inference for object recognition, expanding sensor arrays for 3D spatial mapping, and improving privacy features with edge-based voice recognition.