Vision-based approach for human motion detection and smart appliance control

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ABSTRACT

This study focuses on the use of computer vision technology and motion detection sensors to create an intelligent system that recognizes human presence in monitored spaces. The system uses a relay module for automation and control of household appliances while sensing motion detection, operated by an ESP32 microcontroller. This innovative solution addresses two major issues in home automation: reliable human presence recognition and seamless appliance control. The research merges a camera-based vision system with motion sensors, comparing motion and vision-based identification. The ESP32 microcontroller improves motion detection precision and context awareness by integrating motion sensors and computer vision technologies. The integration of a camera module allows real-time analysis and recognition of human presence, reducing false alarms. The relay module also enables automated control of home appliances, synchronizing and feedbacking operations with sensed human presence. The dynamic adaptation of the system improves user convenience and energy efficiency.

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1. INTRODUCTION

The incorporation of intelligent technologies into our daily lives has grown more common in a time of quick technological breakthroughs and a growing emphasis on automation and convenience [1]. Appliance control systems is able to adjust the real-time occupancy status through feedback, while traditional motion sensors if not placed properly, it prone to false alarms caused by dogs or inanimate objects [2]. This study introduces smart pose, a controller for smart home appliances that relies on visual posture recognition. The Open Pose library is used to extract important points from human joints using a back propagation neural network [3].

In the study, a novel deep learning-based method for creating Internet of Things (IoT)-based intelligent home security and appliance management systems in smart cities is presented. It seeks to deliver the best results even with inadequate information [4]. The idea enunciates a structure that is precise in detecting gestures and which can be used to control devices through manual movements. Most people have seen the usefulness of this technology in daily life [5]. A new method has been developed to locate an immobile subject inside a house by reducing the immobile and mobile obstacles. To this end, it is necessary to combine millimeter-wave frequency-modulated continuous wave (FMCW) radar with EMA algorithm having high-pass filter properties [6]. A new method for detecting static objects indoors with minimal motion and immobility disturbances has been developed. These are done using FMCW millimeter-wave radar and EMA algorithm with high-pass filtering capabilities. This is of great advantage for human life as it helps in the protection of people's assets [7].

This study accentuates the significant strides made towards smart home automation by improving security, comfort, convenience and safety. Technological advancements and the IoT has enhanced remote monitoring and securing of homes as well as better regulation of appliances [8]. Numerous home automation systems have been developed to detect and alert any changes occurring within a house [9]. In this research, a visual servo controller leads a differential drive mobile robot to the direction of a stationary target. A triangle trigonometry kinematic model or a weighted graph is used for this purpose. The study details a robot vision system that decodes original images captured by a camera sensor using optical flow. These processed photos are then used to classify individuals and behaviors.

2. LITERATURE REVIEW

A simple, inexpensive, and user-friendly method that makes use of a standard camera is best to obtain vision based detection [10]. Although this method has been meticulously developed with the goal of accommodating the elderly and those with disabilities, it is nevertheless insensitive to hand form variances [11]. By detecting human presence, our proposed intelligent electrical appliance management system seeks to efficiently operate household equipment. Using this technology, appliances can be turned off when no one is around, potentially saving unnecessary energy [12]. We provide a novel approach to tracking human motion without requiring additional devices.

Wi-Fi RSSI and CSI data collected from widely available IoT devices are utilized in this method. First, a 4D feature vector is extracted from the temporal data spread and used to train a two-stage ensemble machine learning model [13]. To solve the problem of hand gesture-based home appliance control, we present a basic convolutional neural network (CNN) method [14]. This approach uses hand recognition with DetNet to calculate 3D hand skeleton positions. Impressively, it attains a testing dataset accuracy percentage of 99.4%. The findings of our investigation demonstrate how this technology can be utilized to monitor various areas of a home separately [15]. A smart home can transmit data to a home appliance control module via a server. For instance, enabling living areas and remote control and monitoring of the same wireless home are ways through which one can transfer data transparently to a control module for home appliances [16].

A millimeter-wave radar sensor is applied by our technique in this work to identify human movements such as walking, running, crawling and standing [17]. The statistical nature of radar signals in movement shifts detection mode and the changes identified are incorporated into two stages of signal processing used by our method [18]. Then we have to decide what the person is doing with a deep learning-based categorization system. Both processing steps rely on temporal changes in distance that are provided by radar spectrograms [19].

Important devices used in this research are a passive infrared sensor (PIR) based motion detection sensor, an Arduino Mega2560 microcontroller board, an IoT prototype NodeMCU V3 ESP8266 Wi-Fi development board, and a SIM800L GSM module with GPRS capabilities [20]. We provide here a method to characterize the movement of a human being in a space surrounded by. This device provides occupancy tracking across a building while protecting people's privacy by applying localized processing to ascertain people's direction based on information from an infrared array sensor. The system processes data from a cheap infrared array sensor using a state-of-the-art real-time pattern recognition algorithm [21].

3. HUMAN MOTION SMART HOME AUTOMATION SYSTEM

The block diagram of human motion smart home automation in Figure 1 is described as follows. One crucial component of our project is the camera module, which is in charge of recognizing human presence. This module applies modern vision algorithms that take pictures or videos and identify and rate whether there are people in sight. It is the visual input of our project, injecting contextual awareness into our system.

- Motion detector: As a vital component of the system, the motion detector picks up any motion or movement that comes within its vicinity. It can be strategically placed for full coverage. It senses movements and requests the STM32 Blue Pill board to take required action such as triggering an alarm.
- ESP32 microcontroller acts as the central processing unit of this project. It is through the use of logic and algorithms that data from the motion sensor and camera module is analyzed to determine the presence of people. This system has enhanced the capability to differentiate between actual motion and false alarms due to such a complex decision-making process.

– The ESP32 determines the automation of smart things by using relay modules. Relay devices, which act as hands for this project, can control when home appliances get switched on or off. When the ESP32 sensor detects human presence and makes a decision about it, these tasks are then performed by the relay modules which optimize energy utilization and make the user’s life convenient.

The block diagram represents the key parts of our project, which comprises related components and subsystems. By summarizing, it highlights the way in which these components work together to make an intelligent and responsive home automation system. You can enlarge this graphic to incorporate more information or subsystems depending on the difficulty of the task at hand.

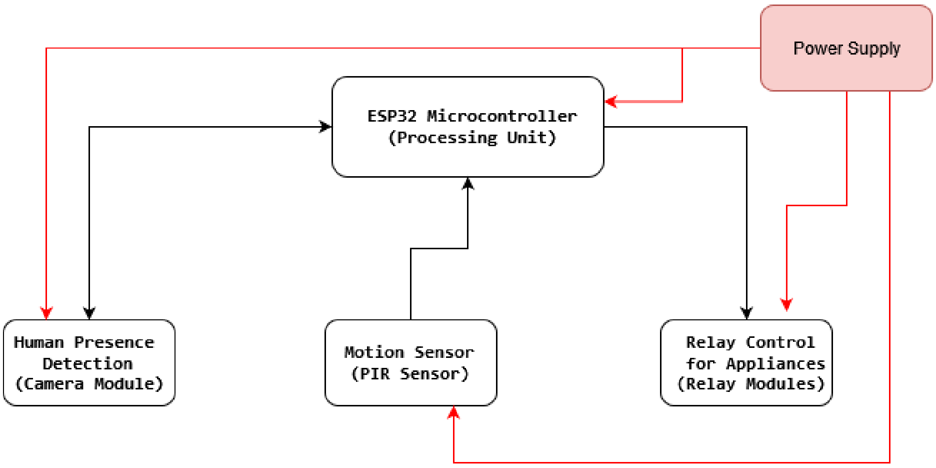

Figure 1. Block Diagram of the human motion smart home automation

4. HARDWARE DEVELOPMENT

The hardware human motion smart home automation is shown in Figure 2.

– The ESP32 board is the brain of the complete system where the external power supply has been attached with the 5 V and ground pin.
– The PIR Motion sensor has been attached to the ESP32 and in any motion detection, it will send the information to the ESP32 board.
– The ground pin of the motion sensor has been connected to the common ground and the voltage pin to the external power. The data pin of the motion sensor has been attached with the 12 no pin of the ESP32 s board.
– The STM32 board is linked with a buzzer for alerting purposes. The power pin is linked to the ESP32 board’s pin 7, and the buzzer’s ground pin is linked to the ground.
– This project is connected to the ESP01 module, which will send all information and alerts to the cloud. Therefore, the ESP01’s voltage pin and ground pin have been linked to the ESP32 board’s 3.3 V and common ground, respectively.
– The ESP01 module’s transmitter pin has been linked to the board’s 19th node, and its Receiver pin has been attached to the board’s 21st node.

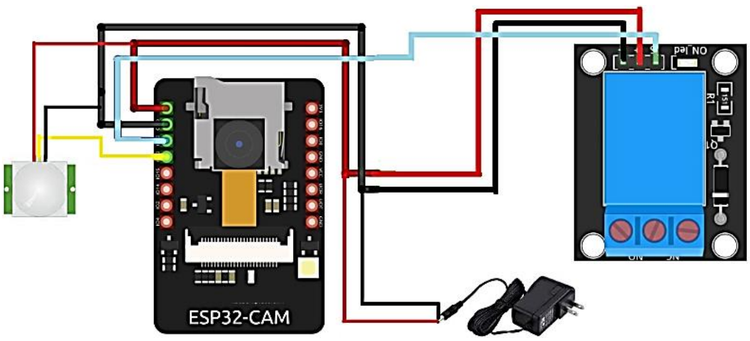

Figure 2. Connection diagram of motion smart home automation

5. IMPLEMENTATION OF THE SYSTEM

The project prepares the environment for operation during the initialization phase. Initializing the ESP32 microcontroller and all attached parts, such as the camera module, motion sensor, and relay modules, is required for this. If necessary, communication interfaces like Wi-Fi are configured. Additionally, variables and flags are established to track the status of the system and crucial variables [22]. The project continuously takes pictures or video frames from the camera module. Figure 3 shows the hardware setup for the innovative proposed solution. The live pictures act as the system's visual input for making decisions. Computer vision algorithms are employed in each frame in order to examine the image for any signs of a human presence. This action lays the groundwork for precise detection.

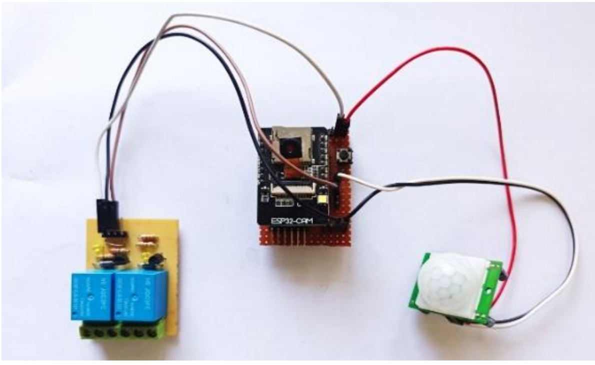

Figure 3. Hardware setup for the system implemented

The motion sensor, which acts as the system's eyes, feeds data to the project. Any movement within the motion sensor's defined field of view will trigger its sensitivity. The project signals the possibility of a potential human presence by recording the event and its timestamp after motion is detected. The system moves on to the human presence analysis stage. Here, the system delves more deeply into the information the camera module has recorded [23].

To verify the presence of a person, powerful computer vision algorithms are used to examine the image. The system logs the event and timestamp if human presence can be positively identified. It then turns on the pertinent relay module in charge of managing the connected smart appliances. Appliance control is managed by a timer, enabling automated deactivation after a given period of time or when no further motion is detected. Updated system state flags show the current occupancy [24]. The system keeps track of the occupancy status while maintaining constant motion and human presence monitoring. Figure 4 shows real time detection of the facial with motion sensor comparison for the house automation. The system reacts if no motion is detected for a predetermined amount of time and human presence is no longer verified. To save energy, it turns off any relay modules that were previously turned on [25].

Figure 4. Real time facial detection for the proposed system

To reflect the absence of occupancy, system state flags are updated once more. An alternate user interface, such as a mobile app or web interface, can be implemented for improved user interaction and convenience. This interface enables system monitoring and remote control [26]. Features like feedback, notifications about detected human presence, and appliance management are all part of the project's effort to improve user experience. It also has error-handling protocols to deal with different problems such as malfunctioning hardware, problems with connectivity, and unexpected behavior of the system [27].

To improve the system's dependability and reliability, protocols are put in place that include alerts for system failures and recovery mechanisms. When necessary, a termination procedure is established to guarantee appropriate system shutdown [28]. This procedure puts an end to the system's activities and easily deactivates every part, leaving the system safe and secure. The system then repeats the monitoring and control phases incessantly. This continuous procedure guarantees that the system will continue to function over time, producing a resource-efficient and responsive home automation system [29].

6. CONCLUSION

The study demonstrated computer vision technology integration with motion sensors and smart appliances to improve contemporary living areas. By enhancing the accuracy of human presence recognition using a camera module and advanced image analysis techniques, the project enables a context-aware home automation system that intelligently responds to occupants and manages smart appliances through relay modules. The system is user-friendly, energy-efficient, and versatile, reducing energy waste by using real-time occupancy status to turn on or off electric appliances. This aligns with sustainability and eases goals in modern habitation design. The research emphasizes the use of visual-based techniques in home automation, particularly the Internet of Things and networked smart devices. The project represents a significant step towards smart home automation, enhancing residential living and adding to discussions about IoT, computer vision, and environmentally friendly technology. The goal is to create a world where homes intuitively recognize and accommodate owners' preferences, creating a more secure, cozy, and energy-efficient living space.

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