Home Security and Automation with Voice Commands

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With the rapid rise of digitalization in the global economy, home security systems have become increasingly important for personal comfort and property protection. The collaboration between humans, the Internet of Things (IoT), and smart homes can be highly efficient. Interaction considers convenience, efficiency, security, responsiveness, and automation.

Keywords: home automation ; home security system ; Internet of Things

1. Introduction

Crime continues to be a prevalent issue with significant economic, social, and political consequences in countries across the globe [1]. Approximately 83% of the world's population resides in areas characterized by elevated levels of criminal activity [2]. Contemporary home security systems have undergone significant advancements, expanding the system's reach beyond mere residential protection by integrating home automation capabilities. Incorporating these modern features helps improve security measures, provides convenience to consumers in their daily lives, and contributes to endeavors aimed at convenience and energy conservation.

In our rapidly evolving digital age, the Internet of Things (IoT) has emerged as a critical smart application for modern security living [3][4][5][6][7][8][9]. Integrating IoT devices, automation detection, and notification systems with smart home technology offers a comprehensive security solution for everyday activities [8][10][11]. Cost optimization and facilitation are significant benefits provided by IoT-driven transformations for real-time remote-access systems [12] through cellular and Wi-Fi networks [4][6][13]. Integrating mobile access points within an IoT-driven home security system can significantly enhance the system's ability to manage energy resources and maintain robust communication with various sensors and devices. By dynamically adjusting to the optimal positions within a home, these mobile access points ensure that the system's throughput is maximized, resulting in a more responsive and energy-efficient security network [14][15]. The integration of IoT technology and internet connectivity enables users to remotely manage and react to smart home security system functions, including appliance control, security monitoring, intrusion alert, and automation lighting control [4][6][12][16].

Furthermore, incorporating energy monitoring and control is essential in designing and developing smart home security [17][18][19]. Smart home security systems are implemented using a single-board computer (SBC) to reduce energy consumption effectively. Famous microcontrollers, including but not limited to Raspberry Pi, Arduino, and ModeMCU, propel progress in the IoT domains of smart homes and security [7][20][21][22][23][24]. The compatibility of lighting management and intrusion detection exemplifies the revolutionary capacity of IoT technologies. Alarms throughout the property may be automatically illuminated or sounded upon the detection of an intruder by a hub. This interconnectivity improves security, so the responsiveness of IoT systems and user alerts demonstrate how the requirements for home safety are strengthened. Existing studies [25][26][27][28] have established that integrating IoT-enabled PIR (passive infrared sensor) intrusion detection into home automation systems positively influences security by providing comfort, energy, responsiveness, cost savings, remote control, and convenience.

Similarly, customizing smart home security systems to cater to the most stringent user demands poses unique obstacles, particularly concerning hands-free dictation. The use of voice-activated commands has transformed both automation and human-liberated control. Voice recognition technology has surfaced as a potentially effective intelligent security application for enhancing user convenience and natural command methods. Based on the previous research [29], an earlier study proposed IoT-enabled intruder detection via voice and motion to support a smart light. When an intruder was spotted via a PIR sensor, the system could activate the relay to switch the lights on or off. The research results were observed and summarized on user commands via the Blynk button and Google voice assistance in Thai and English during varying delay times of PIR sensors.

2. Emergence of Smart Home Automation System

Smart home automation systems have utilized innovative methods to improve domestic environments' connectivity, efficiency, and adaptability. The ability of users to remotely monitor and control IoT-connected devices through specialized applications provides an exceptional level of flexibility, enabling home management regardless of the user's geographical location [30][31]. Smart home security refers to a range of devices specifically designed to improve the safety and protection of residential areas. These devices include smart cameras, doorbells, locks, sensors, alarms, atmosphere control, and network security measures. Several prior studies have suggested smart home automation systems in diverse domains. Satapathy et al. [32] introduced a novel and economical home automation system utilizing the Arduino framework, which offers straightforward Wi-Fi Internet connectivity. This configuration allows users to access and control their electric devices using smartphones remotely. The essential hardware components consist of an LCD, a relay, an Arduino module, and an ESP8266 in the hardware configuration. Their experimental configuration is meticulously calibrated to optimize the control of diverse domestic devices and proudly exhibits a remarkable efficiency rate of 100 percent. Sharif et al. [33] introduced an innovative home automation model based on the layouts of residential units as part of a simultaneous endeavor. This model offers exceptional versatility in choosing hardware, devices, and communication protocols. The design streamlines essential elements of home automation, particularly the security functionalities. The proposed model provides detailed technical specifications for the hardware and software components of home automation systems. A notable apprehension is that the development process depends exclusively on open-source and readily available software technologies. This strategy enhances the system's flexibility and prepares it for deployment in diverse real-world situations. In their study, Stolojescu-Crisan et al. [34] introduced qToggle, an innovative system that connects sensors, actuators, and various other data sources. The system facilitates smooth communication by harnessing the capabilities and flexibility of an application programming interface (API). The qToggle APIs are commonly executed through sensors and actuators with network connectivity in the upstream direction. Most qToggle devices utilize ESP8266/ESP8285 chips or Raspberry Pi boards. A specialized smartphone application has been created to enhance user accessibility and control by allowing the remote management of a wide range of home appliances and sensors. These three methods demonstrate the ever-changing field of home automation and emphasize the various strategies used to simplify and enhance the control of household environments. These systems enable the development of smart home technology solutions that are more efficient, cost-effective, and flexible, thanks to innovative hardware and software configurations.

The smart home automation system has been researched to enhance home management and convenience in various aspects, including responsiveness, accuracy, and voice command integration [35][36]. The instantaneous execution of commands and adjustments is essential for ensuring security features and energy management. Precision is the primary objective of accuracy, aiming to carry out tasks with minimal errors to foster user confidence. A previous study includes regulating temperatures, controlling lights, and managing intruders. The implementation of voice command technology can be customized to enhance user-friendliness via the control system [19][37]. The system provides unmatched convenience and accessibility, enabling users to control various aspects through voice commands. The voice command functionality can be practical, particularly for individuals with mobility limitations or visual impairments [29]. Smart home automation systems benefit from quick responsiveness, precise accuracy, and easy-to-use voice command capabilities, improving efficiency, comfort, and accessibility [35]. Dbritto et al. [38] and Zaro et al. [39] examined the utilization of Wi-Fi and mobile applications for the purpose of control and monitoring. Zaro et al. [39] also highlighted explicitly the use of Arduino technology to achieve cost-effectiveness.

Communication technologies, such as 3G, 4G, and 5G, play a pivotal role in the efficient functioning of smart home automation systems [29][40][41]. These cellular connections are important and essential for facilitating effective communication between diverse devices and systems. They ensure universal compatibility across different network generations and maintain the functionality of smart home devices in various network environments. The evolution of cellular networks from 3G to the more advanced 4G and 5G networks signifies a significant leap in enhancing the effectiveness of smart home automation systems. However, it is important to note that while these technologies can significantly enhance the functionality of smart home systems, they may make the systems more complex and expensive to install and use. Many smart home systems are designed to be user-friendly and cost-effective, making them a practical choice for homeowners. The interconnected nature of smart home devices heavily depends on data speed and capacity for real-time data transmission and processing. The advent of 5G technology significantly reduces latency, which is vital for smart home applications that require immediate responses, such as security systems. It also boosts smart home automation systems' reliability, efficiency, and responsiveness [35][41][42][43].

3. PIR (Motion) Sensors for Intruder Detection and Security

Afreen et al. [44] introduced an innovative smart surveillance system designed for security areas using an IoT framework and a gravity microwave sensor. The Arduino UNO is utilized to control the operations of this setup. The system rapidly transmits a real-time alert message when a sensor, utilizing microwaves within its designated coverage area, detects object movement. The system uses a GSM module to establish a call connection to a cloud service. While a gravity microwave sensor remains unaffected by environmental factors such as temperature fluctuations, it necessitates precise placement to achieve optimal accuracy in larger areas. On the other hand, a PIR sensor is particularly adept at detecting motion in specific regions, making it ideal for intrusion detection purposes. Combining a Raspberry Pi with a PIR sensor creates an intrusion detection and alarm system. This system can include a siren for immediate alerts and the ability to send email notifications to the administrator in the specified area. The PIR sensor is commonly and exceptionally well suited to motion detection, given the characteristics of its infrared waves. In order to precisely detect human and animal motions, electronic security systems frequently implement PIR sensors; however, despite their relatively low cost, false positive alarms may still happen on IoT-enabled PIR systems due to sudden environmental fluctuations, such as altitude, height, light, temperature, and angle [20].

In addition, positioning and calibration accuracy are crucial to achieve optimal performance. Implementing PIR sensor technology is routine in intrusion detection and action movement systems [45][46]. When combined with additional security protocols, the sensors provide enhanced protection for residential properties, commercial establishments, and places of business [47]. Nevertheless, implementing these technologies poses difficulties when attempting to reduce false alarms and ensure precise detection. Design and development are essential during the design and installation of a system to meticulously evaluate environmental factors, such as temperature fluctuations, as they can affect the functionality of sensors. PIR sensors are also commonly utilized for reliable and economical intrusion detection [45]. Difficulties arise due to the environment's delicate characteristics and the requirement for accurate calibration. In order to maximize the potential of PIR sensor technology for enhancing security and automation systems, this study seeks to assess its practical capabilities.

4. Voice Recognition in Smart Home Security

Currently, the automated smart home system adapted to voice command recognition is an essential technological element along with smart home security systems, providing a convenient and secure method to manage different home devices [48][49][50]. Gunawan et al. [51] and Wang [52] emphasized the significance of precise speech recognition in these systems. In addition, Gunawan [51] showcased the efficacy of the cloud speech technique by employing the Google Voice Kit to enhance processing speed and accuracy. Abidi et al. [49] and Chenxuan [50] highlighted the potential of voice control in augmenting home security, specifically in improving user experience and accessibility. Abidi et al. [49] emphasized the utilization of vocal commands for the management of household devices. Chenxuan [50] investigated a tailored speech recognition system designed specifically for elderly individuals.

Furthermore, the mobile version of Google Translate is a potent instrument that surpasses linguistic obstacles through its voice recognition system. The Google Translate framework can facilitate a collaborative multimodal communication experience by offering instantaneous translations in more than 100 languages and offline translations in almost 60 languages [53]. Incorporating voice recognition technology has enhanced Google Translate's proficiency in natural language processing (NLP). The framework comprehends the subtleties of verbal communication, including accents, intonations, and colloquial expressions. These facilitate the acceptance of various inputs through users' typing, speaking, or utilizing the camera translation feature. Several studies have investigated the use of Google Translate voice recognition in multiple applications. Wang [52] effectively employed Google Cloud's speech-to-text and translation services for video translation, despite encountering difficulties with loud background music and literal translation. Lee et al. [54] integrated facial and vocal recognition into a smart home security system, utilizing a Raspberry Pi as the central component and attaining enhanced convenience and security. Ali et al. [55] implemented an IoT security system with voice recognition. The system incorporates intelligent personal assistant (IPA) systems integrated with the Google speech-to-text API. The simulation results indicate that the system has a high level of proficiency in recognizing 90% of the device names linked to all commands and achieving a 100% accuracy rate in correctly classifying commands within an approximate time frame of 30 s.

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