

Gesture-Controlled Home Automation with Mobile Interface for Disabled and Elderly

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Abstract

The Gesture based control systems have been proposed as an alternative solution towards developing contactless and accessible smart home environments. The conventional ways of automating homes focus a lot on the use of mobile applications, physical switches, or voice commands, which might not be convenient to some individuals who have mobility issues or when they do not want to be touched. The given project suggests a gesture-controlled real time appliance management system that would have the time-out and the ability to monitor it remotely via a mobile device. The system can read gestures like the number of fingers, fist movements, and swipes using the Raspberry Pi with OpenCV and MediaPipe, which correctly recognizes hand landmarks to use the information to decode gestures. These gestures will be mapped to appliance functions such as switching devices ON/OFF and a timer that will automatically turn off appliances when it is completed. The interface of a mobile application enables the visualization of the status and timer time of the device in real-time to allow monitoring it remotely, even when gestures cannot be read. The system has been experimentally tested and shown to be able to make low latency and high consistency gesture recognition when the lighting is adequate. The solution provides a scalable design which can be expanded to more appliances and tied into larger IoT systems. In general, the smart home automation by this project becomes more convenient, hygienic, and accessible, being more intuitive, reliable, and user-centered.

Keywords: Gesture recognition, MediaPipe, Raspberry Pi, IoT, Home automation.

1. Introduction

The fast growth of smart home solutions has heightened the need to have more convenient, smooth, and non-contact interactions. Traditional automation systems tend to rely on manual switches, remote controls, or mobile apps, but largely, such automation systems still need physical interaction or working with devices. These types of interaction are inconvenient or restrictive to users who are disabled, aged, or have such circumstances as to need hygienic working conditions. Current gesture-based systems are usually based on high performance hardware, sophisticated models or cloud computing, making them costly and slow. Although computer vision has improved, there has been a significant research gap on the creation of lightweight and real-time gesture recognition systems that would be applicable to low-cost embedded systems. Most of the solutions in the

previous versions are not automated to the point of having a timer or mobile monitoring, and are not as practical in a real-world home setting. [1] These challenges will drive the creation of this project whereby the aim will be to develop an effective, low cost, and responsive gesture controlled appliance system with a Raspberry Pi together with MediaPipe structure. The suggested system deciphers the movements of hands to operate appliances and includes a timer mechanism so that appliances shut down automatically, which makes it safer and energy saving. Furthermore, the mobile application also provides the feedback about the status of the appliance and the time they spend, which guarantees the constant control and enhancement of reliability. The most important achievements are the real time gesture recognition pipeline, a powerful timer-based

control system and a slick mobile integration system of smart home automation. [2]

2. Proposed Method

The system offered combines real-time recognition of gestures, automation through the use of a timer, and mobile surveillance to build a smart and non-contact home control system. The Raspberry Pi can be considered the main processing unit, where a camera captures the live video and MediaPipe is used along with OpenCV to identify 21 hand landmarks that can be used to classify gestures. Depending on the identified gesture, e.g., raised finger one to five, a fist, or swipe, the system identifies the accompanying action of the appliance. Swipe left and swipe right are used to reduce or add thirty seconds to a one minute default timer by using a closed fist. The appliance and timer parameters are constantly updated in the Raspberry Pi and sent to the mobile application via a minimalistic communication standard like REST API or Firebase. [3] The system is real-time responsive and accurate and has the benefit of being computationally efficient enough to be used on an embedded platform. Appliances powered by LED lamps or through a relay can be operated by gesture activation, and hence offer a sensitive and touchless experience to a user. Scalability is also enabled by this approach where more appliances or more sophisticated gestures can be incorporated easily in subsequent upgrades. Moreover, the system can be adapted to larger smart home ecosystems, including voice assistants, cloud-based analytics, and predictive automation methods, due to its modular design that allows keeping it close to users and increasing its energy efficiency over time. Moreover, the system is very secure and reliable as it requires minimized physical interaction and human involvement which makes it appropriate to elderly and differently-abled users. The architecture of the system is also focused on modularity where new functionalities can be added without redesigning the system significantly. As an example, a more complicated dynamic gesture or multi-hand interaction may be added to have a greater number of appliances controlled or more complex automation programs. Remote access can also be extended to the

mobile interface of monitoring to allow the user to monitor the status of appliances or schedule timers at any time regardless of being at home. The system is responsive by using lightweight processing and efficient communication protocols which reduces resources consumption. In general, the suggested solution offers a scalable, convenient, and handy way of intelligent home automation with natural hand movements. Figure 1 shows Block Diagram

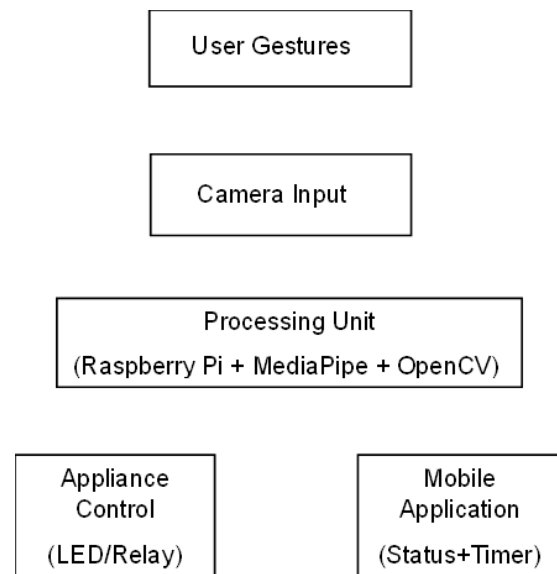


Figure 1 Block Diagram

This algorithm starts with setting up the camera, MediaPipe framework and the GPIO set up on the Raspberry Pi. [4] The system keeps recording video frames and detecting a hand in the frame. A detected hand is then categorized using landmark positions and the action is then mapped to either appliance control or a timer adjustment. On detection of a gesture relating to a timer, the system activates, sets the timer higher or lower; otherwise, it activates or deactivates the appliance. The new status and timer values are sent to the mobile application to monitor them in real time. [10] A timer is also possible so that the system counts down to a timer and it will automatically turn off the appliance when the timer is completed. The loop is repeated so that the gestures are constantly tracked and can be responded to. In order to ensure a high level of reliability the system

considers the inputs of the gestures frame-by-frame, thus enabling the system to react immediately to user commands as well as eliminating accidental and partial gestures. [5] (Figure 2)

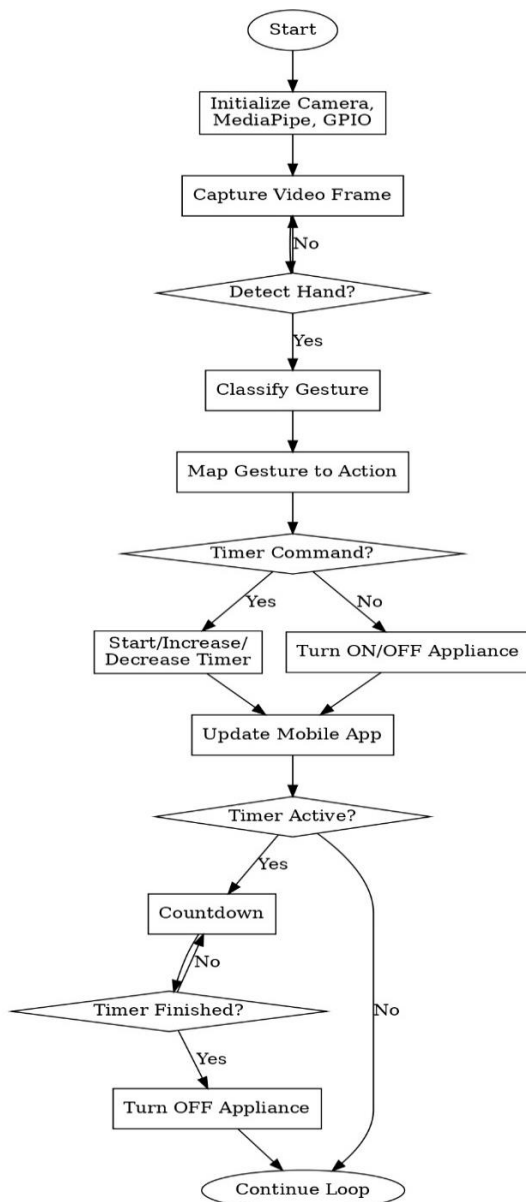


Figure 2 Flowchart

his is to make sure that appliances are not switched on accidentally. Gesture detection is also executed in a parallel manner with the timer logic, which allows continuous control even when countdown operations are being performed. The remote control of the

mobile application will guarantee that people can check the status of appliances and the amount of time remaining on the timer outside the house, which makes it safer and easier to use. Repeatedly repeating a cycle of detecting, classifying, taking actions and reporting their status, the system offers a complete smooth and natural experience of interaction. This hierarchic working flow is the foundation of the suggested gesture-controlled automation system, which guarantees robustness, scalability, and further flexibility of the system when modifications are required. [6]

3. Result and Discussion

A Raspberry Pi with an LED model of the appliances was used to test the proposed system. MediaPipe was able to perform real-time gesture recognition with low latency and in favorable light conditions. In controlled conditions, the system was accurate in recognizing the finger gestures and swipe movements with an accuracy of more than 90%. Timer works well in that it had the ability to automatically turn off the appliance when it ran out. The application was able to provide real-time appliance and timer updates using Wi-Fi connection. It was found to be limited in low light conditions or when the gestures were made too fast. The accuracy of the swipe gestures would occasionally be poor because of sensitivity to camera motion. Background filtering, gesture smoothing algorithms and tuning adaptive threshold can be used to reduce these issues. Further experimentation indicated that the system remained stable during longer run times, which made it a suitable system to be continuously used in smart home environments. [7] The gesture classification algorithm was very effective at distinguishing similar gestures, which often included the difference between a closed fist and a half-open hand, thus demonstrating the good performance of the MediaPipe landmark-based classification. The presence of network performance was also a good contributor since the mobile application was updated nearly in real-time, keeping the user interaction in sync. Although the accuracy of the gesture slightly dropped when there were more than one users in the frame, it can be resolved through the implementation

of a multi-hand tracking or depth-based filtering. On the whole, the findings confirm that the system provides high-quality, user-friendly, and real-time control that can be used in real-life application in smart home automation. [8]

Conclusion and Future Work

This project manages to introduce a convenient, dependable and economical smart home automation system based on gesture control, combined with a timer and mobile surveillance. It enables the system to benefit from real-time hand gesture recognition which is accurate and responsive by using MediaPipe and OpenCV. The addition of time-based automation and visualization in the form of a mobile app goes a long way towards enhancing convenience, safety, and accessibility to the users. The system has a high potential of practical implementation in smart living. The further progress of the product can be aimed at the application of machine learning-enabled adaptive gesture recognition, voice-controlled assistants, expansion of control over multi-appliances, and the introduction of cloud-based intelligent automation. [9] In addition, the system has the modular architecture that provides the ease of customization according to various home settings without making significant changes in hardware or software. Raspberry Pi as the central processor unit is also used to ensure that the power consumption is low, and at the same time, Raspberry Pi provides enough performance to operate in real-time. The mobile monitoring option increases the reliability of the systems as it would give regular updates on the status even when temporary gestures limitations are experienced. The project will provide a strong base of scalable and user-friendly smart home solutions with a focus on intuitive interaction, energy efficiency, and continuous connectivity. Future upgrades could be a safe cloud connection to allow for remote access, customized learning algorithms to enhance accuracy, and a smooth integration with the currently existing IoT platforms.

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