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LOW COST IOT BASED SMART HOME AUTOMATION

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Abstract

The proposed system aims to develop an IoT based smart home automation system integrated with Artificial Intelligence based surveillance. With the aid of machine learning algorithms, it will be possible to reduce energy waste by providing remote access to monitor the state of each electronic device installed in each room and control them via mobile phone or any other device. A CCTV with custom object detection model will help to monitor the neighbourhood and identify various threats, for example: car accidents, home burglaries, and other suspicious activity. Multiple sensors installed in each room will monitor the humidity, temperature, as well as motion. The system will be developed with Raspberry Pi 3 microcomputer. At the end of the development, the model is going to be tested for accuracy and precision scores, usability, performance, and energy waste. Overall, the system consists of a various sensor that are connected to a common microcontroller, which in turn transmits information to the server. In addition, the microcomputer is programmed to detect threats through camera installed outside the house. Further, all data is transmitted to the server where the user can monitor and control the house through GUI.

Keywords: CNN, IoT, Machine learning, Neural networks, Raspberry Pi, Sensors, Smart home.

1. Introduction

Smart home provides a convenient and secure way for monitoring and controlling the comfort of the apartment. According to International Housewares Association, Americans purchased millions of home automation devices in 2018, looking to save time, money, and energy. The smart system represents a single and interconnected network in which all the components work mutually and can be controlled by artificial intelligence which adjusts the settings based on the owner's needs. It can include various functions depending on the client's wishes, for example, voice control, home health, lighting, video broadcasting and more. The main advantage is that the functionality of the system can be expanded over time.

The interaction between the user and house components is done with the aid of Internet of Things. It connects all devices with the network through APIs so that the user is able to control them in the presence of the internet on his mobile phone, computer or tablet. Various sensors installed in the apartment collect all necessary data and transfer it to the web hosting. Owner only needs to connect to the host to monitor and adjust the settings in each room.

With the development of machine vision, it is now possible to monitor residential streets and identify threats using Convolutional Neural Networks. The main advantage of smart CCTV is that it can help to enhance the safety of the street near the house. Therefore, the integration of IoT home automation with custom trained neural network model can help to develop a single product that will have an increased security.

The following project will focus on the development of the smart home automation system integrated with computer vision model, the study of existing methodologies, their pros, and cons, as well as the search for the new methods of solving current problems in the field.

2. Aims and Objectives

2.1. Aims

The proposed research aims to develop an IoT-based low-cost and publicly available home automation system with custom trained AI surveillance.

2.2. Objectives

The objectives of the proposed research aims to develop

- To design smart home prototype integrated with Neural Networks to provide remote access with increased security to the house holder.
- To develop a logic of the workflow for the web-based apartment control panel application.
- Examine the performance and innovativeness of the developed system.

3. Literature Review

In order to understand at what stage of development is the field of application of artificial intelligence and blockchain in IoT based smart homes, it is necessary to

conduct a literature review where all similar projects and research will be analysed and took into consideration [1].

The application of artificial intelligence in smart homes becoming more and more popular. In the following section, the existing automation systems based on machine leaning algorithms will be explored. The topics to discuss are application of CNN model in smart home surveillance and artificial intelligence in smart home [2].

A proposed *a design for* smart and low-cost surveillance system to control units with certain devices installed. It helps to detect and analyse various situations happening on CCTV [3]. The developed system gathers data from the ultrasonic sensor and when it detects any movement it sends a signal to the camera that recognizes image and assesses the type of situation. If any threat was identified by the system, it tracks the suspects and sends an alarm to the surveillance officers. Authors used Python as a main programming language and Convolutional Neural Network as a model to identify the potential threats [4]. The developed algorithm analyses the scenes continuously and classifies any motion. The researchers state that the system performs facial recognition in order to isolate human movements from others.

As a result of the discussed work, the researchers, activity were able to achieve a recognition accuracy of 99.2%. Furthermore, the smart system can track multiple humans in 0.9 s. Also, the developed model was run on PC and Raspberry Pi separately in order to compare the results.

Since the following project aims to apply machine learning algorithms to monitor the situation outside the house, the research can help to understand how Convolutional Neural Network can be applied in home security system. A proposed a facial recognition model for door opening in order to increase security and replace the standard key or RFID methods [5, 6]. The proposed system was divided into three parts: data collection, data training and testing. The whole system was connected to Raspberry Pi module that serves as a microcontroller and Convolutional Neural Network (CNN) model was implemented for facial recognition. The testing was performed on three different distances, namely 0.5 m, 1.0 m, and 1.5 m.

4. Concept Design and Methodology

The machine learning models and algorithms that will be used in the proposed project will be analysed. There are a lot of machine learning algorithms that can be used for smart home surveillance. The aim of the following chapter is to identify the best that suits the project needs. Different programming languages will be compared with each other in order to find the best solution that fits the project's needs [7]. In addition, various microcontroller models will be differentiated in terms of their application, advantages, and disadvantages. Furthermore, every assumption made during the methodology writing will be examined and discussed in more detail. It is important to provide an in depth understanding about machine learning model that will be used in the proposed methodology.

4.1. Investigation tools and techniques

The main task of the surveillance system is to classify the input image from the CCTV into two categories: threats and non-threats. To perform the following differentiation, Deep Neural Network models with supervised learning will be

taken into consideration [8]. There are different techniques that help to apply such model, but the main ones are Recurrent Neural Network (RNN), Convolutional Neural Network (CNN), Long Short-Term Memory networks (LSTM), and Region-based Convolutional Neural Network (R-CNN). Below is the Table 1 that helps to differentiate the listed machine learning types:

Table 1. Investigation tools and technique's part.

ML Model	Output	Advantages	Disadvantages	Accuracy
RNN	Depends on the previous calculations	Module size is not affected by the input	Gradient Vanishing	Low
CNN	The interaction of the convolutional and subsampling layers together with the fully connected layer	Does not need supervision for target features detection	Large training data required	Average
LSTM	Depends on the previous hidden state	Can store data for a long period of time	Easy to overfit and sensitive to weight initializations	Good
RCNN	Selective search checks target object in the image divided into boxes	Faster detection and training time	Requires a lot of space	Average

The following project will use Convolutional Neural Network since the aim of the AI surveillance system is not an object detection, but detection of unusual and abnormal activity.

- Since the proposed system is going to consist of a big number of sensors connected with each other, Python can become a good solution for the problem. It is supported by the majority of microcontrollers and computers. In addition, there is a huge amount of available and free libraries for python in the machine learning field.
- Raspberry Pi 3 Model B microcomputer will be used to connect and control all sensors and modules. Furthermore, the following device can be used as a gateway for the smart home control panel.
- Motion sensor, humidity and temperature sensor, DC motor, relay, solar panels, led lights, as well as Raspberry Pi camera will be connected to microcomputer.

4.2. Proposed methodology

For the proposed project a graphical user interface (GUI) will be developed in order to provide the user with all necessary data from the sensors and control. The project was separated into varies categories. It will be split into different categories, for instance, house health category where the humidity and temperature data will be displayed or security category. The CCTV image was used to view the images

shown to the user. It is important to develop a solid UX design for the workflow of the user interface in order to make the app logical and easy to use.

The following program will run on the Flask server in order to provide remote access to house control panel. The network setup will be installed on the Raspberry Pi 3 module using Python library. It is worth to mention that before initializing the network, it is necessary to establish and connect all sensors to the microcontroller. The sensors will be split by sets into each room and few cameras will be installed around the house. For a better understanding, Fig. 1 shows the system's flow chart:

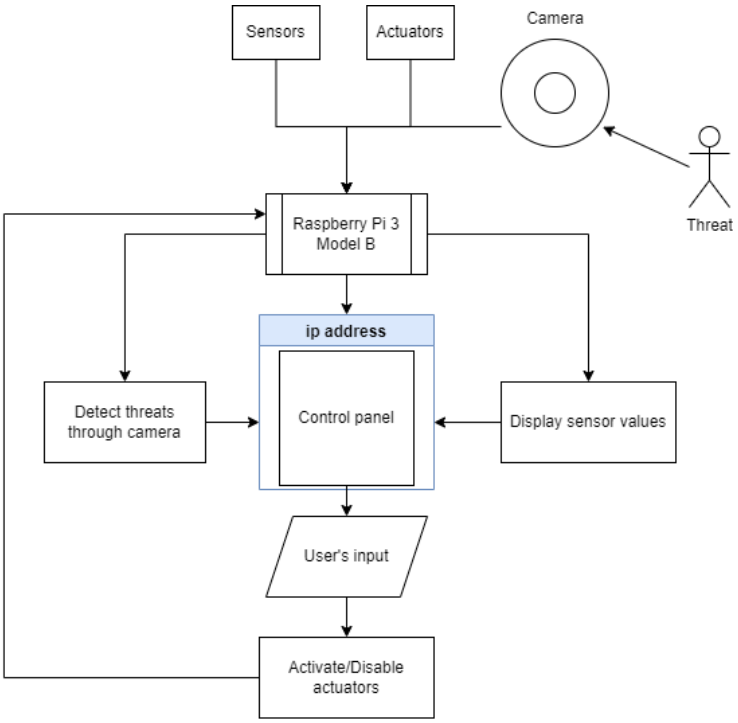

Fig. 1. System flow chart diagram.

In addition, a custom convolutional neural network model will be trained and tested on the microcontroller with Python and YoloV5. A dataset of more than 1000 images will be split into training and test sets in a ratio of 80 and 20 respectively. The prototype was analysed accordingly as soon as all components were installed and upon the completion of the programming codes.

5. Results

Upon completion of the project, a smart home prototype was developed using computer vision to control and monitor the situation near the house. The whole system has various sensors connected to Raspberry Pi 3 Model B microcomputer [9]. Using the Flask library, a smart home control panel was developed that allows owner to monitor the values from sensors and control devices remotely through a web browser. To update the readings of the temperature and humidity and motion sensors in the browser, without constantly refreshing the page in the web browser,

AJAX (Asynchronous JavaScript and XML) nutshell was used [10]. The security system consists of three motion sensors that are connected to the buzzer, and it can be disabled accordingly. In addition to controlling the light, one can turn on a fan that uses a solar panel as a power source. The following method will reduce the energy costs, since in hot climates the fan is used on a regular basis.

A custom trained model with the aid of Convolutional Neural Network was developed to detect 5 classes of threats: Gun, Knife, Fire, Car Crash, and Menace (Suspiciously dressed people). Raspberry camera with 5MP is used as a source for class detection. The accuracy score for each class depends on the various conditions. For example, low light conditions negatively affect the recognition, while too bright light can lead to incorrect class assignment. Thus, the most accurate results were obtained in the state of medium light conditions. It is worth noting that the disadvantage of such a system is the low level of frames per second. In general, recognition accuracy ranged from 88 to 97 percent, which is a good result for threat recognition [11]. The system coped best with the recognition of fires, while car accidents, on the contrary, had the lowest percentage of recognition from the listed classes [12]. The following difference may be since fires have almost the same colour scheme and pattern, while in car accidents, vehicles of different brands, colours, and shapes interact. Therefore, there are various levels of car damage that needs to be detected. That is why increasing the volume of training dataset will help to solve this problem as indicated in this research.

6. Conclusion

Summarizing, a low-cost smart home automation prototype was developed with integration of computer vision surveillance. All sensors and actuators connected to the main microcomputer can be controlled either by the owner through web-based control panel or autonomously with the aid of programming. A custom trained model consisted of five different threat classes, each of which demonstrated a good accuracy score. However, the recognition of car accidents can be improved by increasing the dataset volume. The following system can be installed in private houses to provide a remote control to the owner, increase the security around the apartment and reduce the crime rate in the neighbourhood. It has great benefits that is affordable by anyone.

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