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Smart Home Automation Using Machine Learning Algorithms

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***Abstract*— A home automation system controls lighting, temperature, multimedia systems, and appliances. Since these devices and sensors are connected to common infrastructure, they form the Internet of Things. A home automation system links multiple controllable devices to a centralized server. These devices have a user interface for controlling and monitoring, which can be accessed by using a tablet or a mobile application, which can be accessed remotely as well. Ideally, anything that can be connected to a network can be automated and controlled remotely. Smart homes must be artificially intelligent systems that need to adapt themselves based on user actions and surroundings. These systems need to carefully analyze the user needs and the conditions of the surroundings in order to predict future actions and also minimizes user interaction. Traditional home automation systems that provide only remote access and control are not that effective in terms of being 'smart', so in this paper we put forward the use of concepts of different machine learning algorithms along with computer vision to shape together a smart learning automated system that controls lighting, sound and other devices based on the user's emotion.**

Keywords—Machine Learning, Home Automation, Camera Vision, Neural Network, Internet of Things.

I. INTRODUCTION

Smart Home Systems are the subset of everyday computing which includes smart technology for providing comfort, health, safety, security and energy reduction. When this application is controlled by machine intelligence to provide circumstance-aware settings, services and facilitate remote control it significantly improves user comfort. Further addition of automated appliance control and accessibility services can improve the quality of life as well. Internet of things that contain multiple sensors can detect temperature, light, sound, distance, air pressure, motion which act as different points of data sources. Since there is a huge amount of data involved Machine learning can be applied to the existing Home automation systems to make it perform exceptionally well based off the users emotions. In this paper we define an improved Home automation system using multiple machine learning algorithms that can detect human facial expressions and adjust the environment conditions accordingly [1].

II. RELATED WORK

The top leading industries launch smart hardware and software more often that can be used in home automation systems. However they do not provide an open communication protocol or introduce a way to integrate these different ecosystems. Most of them use proprietary software and set-top boxes or hubs that works well with their own-devices, but limits the interoperability with other smart hardware devices that is available in the market. A broad range of appliances in home automation systems use different machine learning and deep learning techniques yet they need manual interaction and do not offer intelligent cross device functionality. Nowadays, the research area in this domain focuses on making smart homes an intelligent decision making systems. This Paper is based on application of Internet of things along with the use of machine learning algorithms. IoT Devices constitute large number of devices and sensors that can monitor/control different physical quantities. With the dawn of Big Data, there is a need for proper automated data storage solutions and cloud based applications to analyze and extract required information from the data [2]. This data can be used for helping or predicting the users action and provide optimized automation.

III. PROPOSED METHOD AND ANALYSIS.

In this section, we discuss the principle and methods in which a smart home automation system using machine learning is implemented. The proposed system is connected to the existing Home Wireless Network.

The Proposed system has three modes of operation :

- Manual Mode: In this mode the User must use the user interface like a remote control for controlling the appliances. The System will respond by Automating only those devices that the User requests.
- Automatic Mode: In this mode the system will automate the devices automatically based on the dataset that is created according to the user's pattern. There is no need to configure or schedule manually as in in traditional home automation systems. This is why Data-Driven Approach is always better than Traditional Scheduling systems.
- Emotion Recognition Mode: The system will use the connected camera to detect the users facial expression and accordingly will automate the lights, fan etc.

A. Principle Of Working.

Different Sensors and devices are interfaced with the input/output ports on the Raspberry Pi (Single Board Computer) as displayed in Fig. 1.

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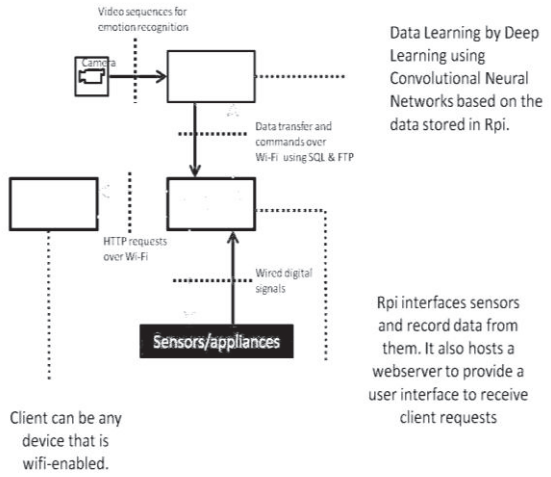

Fig. 1. Overall setup of the home automation system.

It also hosts an Apache powered Web-server that incorporates the User interface for any device on the network to remotely trigger any other appliances in the home. These requests are forwarded by typical Hypertext Transfer Protocol (http) to the Raspberry Pi. Various requests from the User to the sensors/ devices that were used are recorded in a database so that they serve as the data that can be used by the server running deep learning algorithms. This is done to learn the pattern of how the user uses different sensors at different times of the day. Using this data, while the system is in Automatic mode the Server can predict which sensors need to be activated without the user's input like switching off lights past 11pm, or if the temperature rises, cooling devices kick in.

While using the system in Emotion detection mode, a camera is used to detect the user's face and by the deep learning algorithm implemented using convolutional neural networks it sets the room environment as per the emotion recognized. For this purpose, each emotions have a pre-set configuration of lights, music, temperature level, and specific devices like television can be turned on. User can disable this mode on command. All these Control functions for various devices can be accessed by any device that is Wi-Fi enabled like a smartphone, tablet or a computer. With further modifications (like port forwarding from the internet router), this system can be even connected to the Internet which enables access from outside the home network. The Server shown in Fig. 1. is only used for training and testing purposes. This can be removed since the trained Machine learning model can be directly loaded on to the raspberry pi. During such modification, the camera is to be interfaced directly with the raspberry pi.

B. Emotion Recognition.

Here, we use the application of emotion recognition to detect the user's state (emotion) and using this emotion to create a comfortable environment throughout the house by using appropriate lighting, sounds and other parameters. Camera vision and image recognition concepts are important in-order to achieve face detection and emotion recognition. Apart from identifying the user's face, the computer will utilize the composition, order and shape of different facial landmarks like eyebrows, lips to aid in the detection of facial expression and gives us the detected emotion of the user [3].

We used following three methods as a major part of our proposed automation system:

1. Convolutional Neural Network (CNN) approach.
2. Fisher Face Classifier approach.
3. Support Vector Machine (SVM) approach.

CNN has an input layer, output layer and other hidden layers. Convolutional layers, pooling layers, fully connected layers and normalization layers comprise the hidden layer of a Convolutional Neural Network. First, Haar Cascade classifier is used to detect faces in each frame of the webcam feed. The region of image containing the face is resized to 48x48 and is passed as input to the ConvNet. The network outputs a list of softmax scores for the seven classes (emotions). The class with the maximum score is displayed. The architecture of neural network is shown in Fig. 2.

Fisher Face classifier is a face detection algorithm which can be used to classify different emotions based on the input image data. The extracted features can be applied in multiple ways for image pattern identification and facial recognition. The Training data set is labelled images, so a better optimized method can implemented by Dimensionality Reduction.

A Support Vector Machine is the classifier that is defined by a separating hyper plane. By using Supervised Learning, the algorithm will output a hyper plane which categorizes new examples. To use SVM to recognize facial expression, we extract facial landmark key points first and then it is given to SVM classifier to detect user's mood [4].

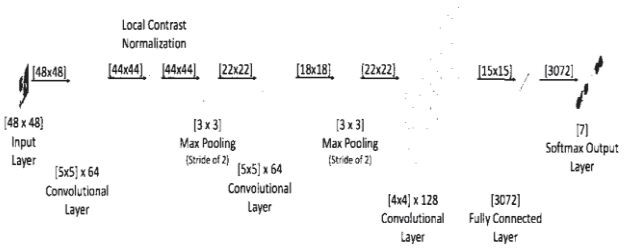

Fig. 2. Architecture of used CNN.

The original network starts with an input layer of 48 by 48, matching the size of the input data. This layer is followed by one convolutional layer, a local contrast normalization layer, The network initially has input layer of 48 x 48, which is matched to the input data size. The next layer is a convolutional layer followed by a contrast normalization layer and max-pooling layer. The neural network is displayed in Figure 2. The CNN is finished with convolutional layer followed by a fully connected layer. These are connected to a output(softmax) layer. Dropout given to the fully connected layer and other layers contain ReLu units. Also another max-pooling layer is added to reduce the number of parameters [4]..

To detect the landmarks that are crucial points required for identifying the emotions/expressions, we use DLib library for python. This will result in some useful key-points

like eyebrows, lips, eyes. The landmarks are of course important because it is what makes emotional expressions possible. Normalization of key-points is done by calculating the mean of x and y axes which gives us the coordinates for center of gravity in all facial landmarks. Now calculation of position of points that are relative to the center of gravity is possible. In case of Tilted or disoriented faces, the classifier might make mistakes. This can be prevented by Rotation of the face which is done by offset angle calculation by assuming the nose bridge angle [5].We used was the Extended CohnKanade (CK+) [6] dataset with 80-20 training and testing ratio.

IV. EXPERIMENTAL ANALYSIS.

The experimental setup consist of ambient lighting LED strip, a fan, temperature sensor , Mq-2 gas sensor and buzzer. This circuit is shown in Fig. 3. Once the user's emotion is detected by the machine learning model as defined earlier, the ambient lighting changes its colors as per different color profiles corresponding to that particular facial expression according to [7]. In case the detected emotion is anger, the Machine learning model can turn on the fan to assist the user. Similarly multiple actions can be set for any trained criteria. In order to control the system in special conditions a user interface was developed which is depicted in Fig. 4. The User interface can also be accessed from the Internet. Temperature from DHT-11 is saved to a database and also visualized in the User interface. Based on this the Fan can adjust its speed automatically. In case of fire the system can open all doors, set lighting to bright and turn off other heavy duty electrical devices thus leading the user to safety.

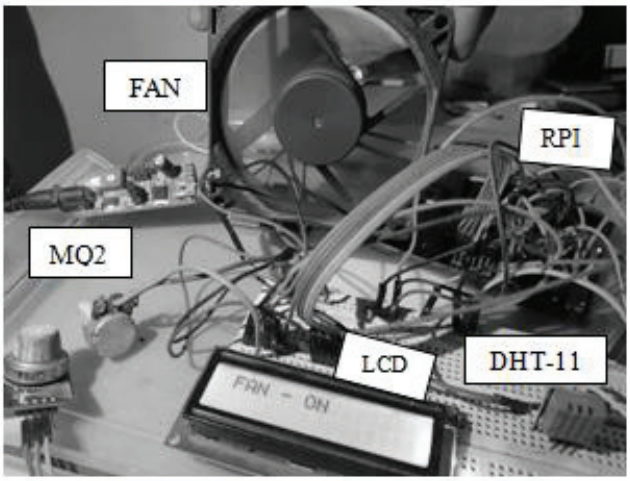

Fig. 3. Experimental setup of the system.

From Table 1, it is clear that linear SVM is a powerful Machine Learning Classifier algorithm for the CK+ dataset that we have used. It is also observed that on reduction of number of classes from 8 to 5 the accuracy improves from almost 82% to 91%. On further reduction of number of classes from 5 to 3 the accuracy goes up to 92.86% which is a better result. Hence, we have saved this particular learning model and have deployed it into the application where it recognizes if the user is angry, sad or happy. These results are solely on the basis of the dataset that we have used. In case we use a different dataset for training, these results will vary.

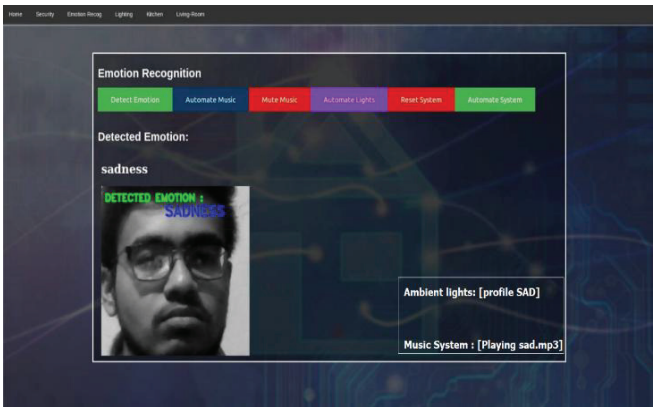

Fig. 4. Developed User Interface.

From our results, it is observed that decreasing the number of classes has increased the accuracy. This is because certain images in the dataset for emotions like Surprise and Fear are similar and they have a significant number of samples that are misclassified between them. The removal of such similar classes which have increased chances of being misclassified will decrease the errors. The effects of reducing the number of classes are dependent on both the algorithm and the data set.

TABLE I. ACCURACY OBTAINED FROM DIFFERENT METHODS

No.	*Approach used*	*No: of Classes*	*Emotions*	*Accuracy*
1	Convolutional Neural Network	8	Anger, Contempt, Disgust, Fear, Happiness, Sad, Neutral, Surprise.	66.6%[a.]
2	Fisher Face Classifier	8	All 8 emotions	70.80%
3	Linear Support Vector Machine	8	All 8 emotions	81.94%
4	Linear Support Vector Machine	5	Anger, Neutral, Disgust, Surprise, Happy.	91.66%
5	Linear Support Vector Machine	3	Anger, Sadness, Happy.	92.86%

[a.] This value is Limited by small Dataset

V. CONCLUSION

This Study shows the potential of combining concepts of Machine Learning to any existing automation system to achieve an intelligent control system. It benefits in strict power control that helps in achieving energy savings. It also provide control and reliability. It provides security and comfort at the touch of your fingertips. Moreover, remote monitoring can be setup easily and allows cost-efficient and intelligent conversion of existing home automation systems by incorporating machine learning technology. The goal of Home Automation systems powered by Machine Learning is to bring down any manual settings to zero [8]. Due to the ever expanding applications of Artificial Intelligence, it will not only change our workplace but will also change the way we live in our homes.

REFERENCES

[1] M. R. Alam, M. B. I. Reaz and M. A. M. Ali, "A Alam, Muhammad Raisul, Mamun Bin Ibne Reaz, and Mohd Alauddin Mohd Ali. "A review of smart homes: Past, present, and future." IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) 42, no. 6 (2012): 1190-1203.

[2] Enrique Correa, Correa, E., A. Jonker, M. Ozo, and R. Stolk. "Emotion Recognition using deep convolutional neural networks." Tech. Report IN4015 (2016).

[3] Minaee S, Abdolrashidi Minaee, Shervin, and Amirali Abdolrashidi. "Deep-Emotion: Facial Expression Recognition Using Attentional Convolutional Network." arXiv preprint arXiv:1902.01019 (2019).

[4] Amarappa, S., and S. V. Sathyanarayana. "Data classification using Support vector Machine(SVM), a simplified approach." Int. J. Electron. Comput. Sci. Eng 3 (2014): 435-445.

[5] Van Gent Paul, "Emotion Recognition using Facial Landmarks, Python, DLib and OpenCV," [Online]. Available: https://www.paulvangent.com/2016/08/05/emotion-recognition-usingfacial-landmarks/. [Accessed: 24-Nov-2019]

[6] Lucey, Patrick, Jeffrey F. Cohn, Takeo Kanade, Jason Saragih, Zara Ambadar, and Iain Matthews. "The extended cohn-kanade dataset (ck+): A complete dataset for action unit and emotion-specified expression." In 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition-Workshops, pp. 94-101. IEEE, 2010.

[7] Ou, Li Chen, M. Ronnier Luo, Andree Woodcock, and Angela Wright. "A study of colour emotion and colour preference. Part I: Colour emotions for single colours", Color Research and Application 29, no. 3 (2004): 232-240.Communicative Behavior Analysis (CVPR4HB 2010), San Francisco, USA, 94-101. September, 2010.

[8] Iot Evolution World. ,"Building Smarter Connected Homes with Machine Learning", June 2018 [Online] Available: http://tribeappsoft.com/newsview/28. [Accessed: 24- Nov- 2019].