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An Automatic Door Lock Security System Based on Convolutional Neural Network

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Abstract
Door lock security is important because it prevents intruders or unauthorized individuals from entering our homes or offices. Previous door lock security systems based on password, radio frequency identification and facial recognition are unreliable. Therefore, this project developed an automatic door lock security system using Convolutional Neural Network. Fifty faces of home owners were captured and trained using CNN. The system was tested at different distances and lightning condition and evaluated using accuracy, precision and f1 score. Results show that the developed system is 91.67% accurate. However, it is recommended that future work considers increasing dataset for model training to obtain more accurate results.

Keywords: Door, Security, Accuracy, Lightning, Model

INTRODUCTION
Security is essential in our daily lives and home security is crucial to keeping our family and valuables safe from intruders. Conventional method of locking and unlocking a door is a lock and a physical key but the limitation of this method is that if the key is lost, misplaced or stolen, the entire locking mechanism has to be replaced (Aiswarya, 2020). Big companies find it difficult to maintain the use of several keys because it is regarded as extra burden to employees and the keys are vulnerable to getting lost and the approach is dependent on personal security practices such as ensuring doors are locked and windows are closed. Therefore, automated home security systems become a necessity.

Home security system is a system designed to secure our properties using some devices and interworking components and the purpose is to secure all entry points of a house through a command center or sensors that communicate with a control panel that is conveniently installed within the house or building. Such sensors are commonly placed in areas that lead to and from a house like doors and accessible windows, especially those at the ground level (Ahlawat et al. 2020). Automated home security systems also employed security hardware such as: motion sensors, surveillance camera, high decibel alarms among others (Nikhil and Subramanya, 2012; Nourman et al. 2020). These approaches are still inadequate for

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safeguarding a home or property, hence artificial intelligence was introduced to automatic home security in order to strengthen home security (Anandh and Kishan 2018).

Artificial intelligence-based home security systems employed the following approaches: password authentication, facial recognition (Gawande *et al*, 2017), fingerprint recognition, Radio Frequency Identification (RFID) (Srinivasa et al., 2013), Bluetooth based system (Lia *et al*, 2014) and GSM-based (Donatus and Akaiso, 2013; Jayashri and Arvind, 2013) and android-based (Agbo *et al*. 2017). Although, these systems were able to solve the problems with conventional approach but there are some drawbacks. The RFID card can get lost or be stolen, password of password-based home security systems can be hacked or forgotten (Amrita and Vishwakarma 2016). In addition, the moisture content of the fingertip may change over time which affects the quality of the finger print image being acquired from a user and minor cuts or bruises may alter the ridge structure of a finger print in fingerprint-based home security systems. The limitation of facial recognition-based home security systems is that the faces of human beings change daily due to illumination variations, makeup, aging effects and accessories and this affects the accuracy of face recognition systems (Ujwalla *et al,*2017).

Hence, this research developed a Convolutional Neural Network-based door-lock security system to mitigate the shortcomings of existing systems and leverage on the capabilities of CNN such as computational efficiency which makes it to run multiple experiments easily and the ability to train larger networks easily (Li and Cha, 2015; Krizhevsky et al., 2012).

Many approaches have been employed for home security systems, they include: GSM, micro-controller-based, facial recognition, WiFi technology, among others. Swathi *et al*., (2018), proposed a survey on home security surveillance system based on Wi-Fi connectivity using Raspberry Pi and IOT Module. Adding wireless fidelity to the systems open up various possibilities such as worldwide monitoring and control, reliable data storage etc. The IoT module eliminates the need for a microcontroller and wireless transceiver module in a sensor node, thus it makes the node compact, cost-effective and easy to use. The main advantage of the system is that the user can seek surveillance from anywhere in the world and can respond according to the situations. Karina (2018) focused his research on Convolutional Neural Networks and the Viola-Jones algorithm. The research revealed that CNNs are much faster although they require more memory space and are therefore more expensive to implement while Viola-Jones algorithm requires minimal memory requirement which makes its implementation easier.

Pranav and Manikanadan (2020) proposed the design and evaluation of a real-time face recognition system using Convolutional Neural Network (CNN). The research achieved an accuracy of 98.75% and the system can be easily adapted for various consumer applications such as face detection based home automation, device control, attendance system, intruder detection, etc. A robust 4-layer Convolutional Neural Network (CNN) architecture was used by previous research for door lock security. The system was capable of handling facial images that contain occlusions, poses, facial expressions and varying illumination. Results show that the system higher recognition accuracy of 99.5% and reduced processing time (Syafeeza,*et al*). Another method which has been used for door lock security systems is Internet of Things (IoT) and Artificial Neural Networks (Sung *et al*., 2020). In the research, users were identified and authenticated using camera based visible light communication (VLC) technology with real-time door lock access of 5 meters distance from the door location. The system improved previous systems as users do not need to be close to the access controller interface to get door access. Feature extraction approach was also use by previous systems to develop door lock security systems. Ujwalla *et al* (2017) employed novel feature sets and RBFSVM classifier for

door lock security and research show that the system achieved reduced computational complexity and fast response time.

In order to reduce the computational time of door lock security systems, feature extraction and Principal Component Analysis (PCA) were used by (Teddy 2017). The approach achieved reduced training and testing time as well as improved recognition accuracy of home security systems. Adaboost algorithm was used by Prathamesh *et al*. (2014) for Face Recognition in Door Lock security System and research show that the system achieved some level of accuracy.

METHODOLOGY

The home security developed was designed using the convolution neural network model. The dataset used in model training was obtained locally and it contains fifty images. 80% of the data was used in training while 50% was used in testing the model. The developed model was evaluated using confusion matrix. The block diagram of the developed system is shown in figure 1 and a screenshot of some images in the dataset are shown in figure 2.

Figure 1: Block diagram of the CNN-based Model

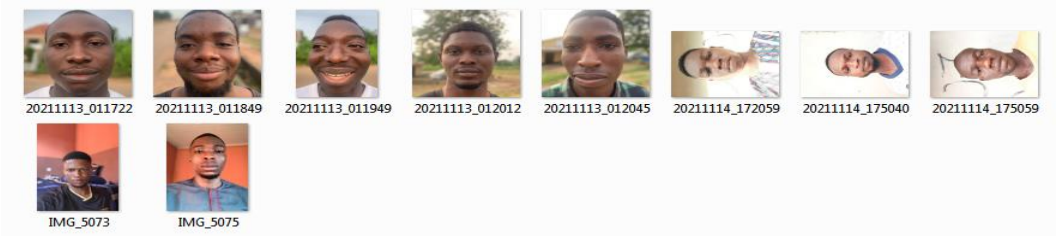

Figure 2: Some of the images in the dataset

Training of the CNN Model

The training process was carried out on a separate computer. For face detection, we calculate the gradient of the image in both x and y directions and from that we finds the gradient vector of each pixel as shown in equations 1-3. Gradient vector include magnitude and angle of the vector. Both magnitude and angle are stored in a matrix form.

$$\nabla g = \begin{bmatrix} f_x \\ f_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad 1$$

Where ∇g is the gradient of the image and $fx = \partial f/\partial x$ is the gradient of the image in x-direction and $fy = \partial f/\partial y$ is the gradient of the image in y-direction.

$$\rho = \sqrt{f_x{}^2 + f_y{}^2} \quad 2$$

Magnitude of the gradient σ is calculated and it is stored in matrix form.

$$\phi = \frac{f_y}{f_x} \quad 3$$

Where ∅ is the angle of the gradient vector. The gradient vector is calculated for each pixel and stored in a matrix form.

System Implementation

The designed CNN-based model was implemented by installing the trained dataset on a raspberry pi. The hardware prototype was designed by connecting the modified Pi Camera as a camera module to identify the face of homeowners. The Raspberry Pi was connected via WLAN to identify the homeowners thereby enabling the doors to open and close automatically. The Flowchart of the CNN-based home security system is shown in Figure 3.

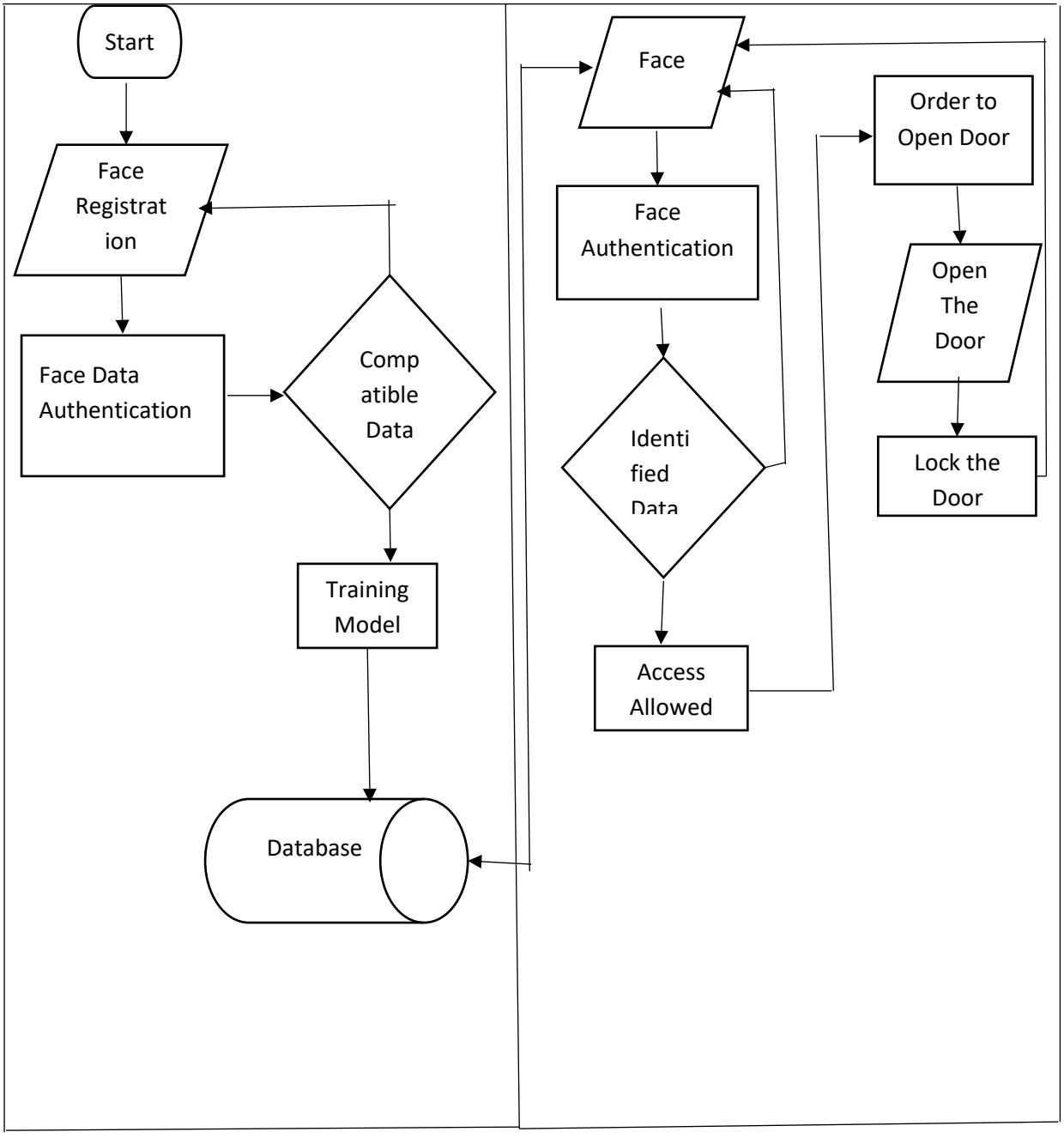

Figure 3: Flowchart of the CNN-based home security system

RESULT AND DISCUSSION

The login page enables users to login to the system while the admin page allows the administrator to add and view home users as shown in Figures 4a and 4b respectively.

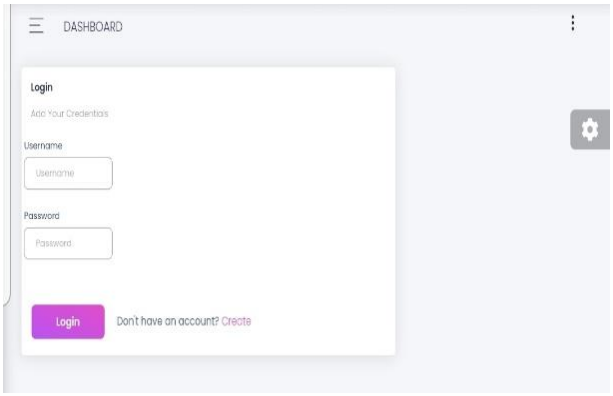

Figure 4a: Login page

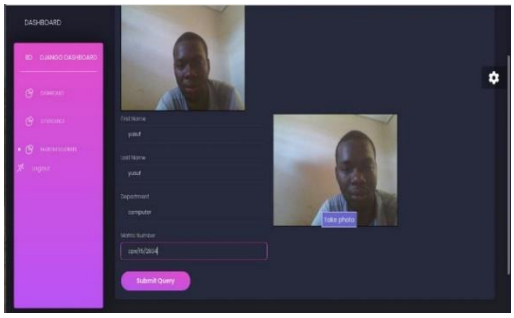

Figure 4b: Add user page

System Testing

Testing is carried out by providing input in the form of 25 homeowners and 25 faces of non-homeowners who have been tested in the following time duration 07.00a.m to 09.00a.m, 12.00p.m to 14.00p.m, 15.00p.m to 17.00p.m, and 19.00p.m to 21.00p.m with a distance 0.3 meters, 0.6 meter, and 0.9 meters, respectively from the door. The Homeowners and non-homeowners were requested to test the system with the same conditions: morning, afternoon, evening, and night and at three different distance under four different lighting conditions to obtain the results shown in Tables 1 and 2 respectively. Results from evaluation of the automated home security system gave an accuracy of 0.9167, precision of 0.8333, recall of 0.99999 and F1-score of 0.909. The result obtained was compared to the research by Leim et al. (2023) and the developed system outperformed the previous work.

Table 1: Homeowners test results by distance

TIME	FACE	DISTANCE					
		0.9m		0.6m		0.3m	
		S	F	S	F	S	F
MORNING	25	20	5	25	0	25	0
AFTERNOON	25	15	10	25	0	25	0
EVENING	25	20	5	25	0	25	0
NIGHT	25	10	15	15	10	20	5

Table 2: Homeowners test result by time of the day

TIME	FACE	DISTANCE					
		0.9m		0.6m		0.3m	
		S	F	S	F	S	F
MORNING	25	0	25	0	25	0	25
AFTERNOON	25	0	25	0	25	0	25
EVENING	25	0	25	0	25	0	25
NIGHT	25	0	25	0	25	0	25

CONCLUSION

This research developed a door lock security system based on Convolution Neural Network. The dataset for training the model was obtained locally from fifty different individuals and the model was deployed on the raspberry pi. A hardware prototype was designed and tested in three distances and observed under four different lighting conditions. The developed system was evaluated using confusion matrix and an accuracy of 91.7% was achieved. However, it is recommended that future work increases data-size for model training to achieve improved accuracy.

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