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Design of Face Detection and Recognition System to Enhance Security of Safe Locker

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Abstract— In recent years, safe lockers have been spread in public places to secure valuable belongings. The people are concerned about losing safe locker keys or use of the spare key by others and will remain worried about their things. To solve the forenamed matter, this paper proposed a system that depends on biometrics to secure valuable things and can minimize their concerns and worries. The proposed system consists of two major parts, software, and hardware. In the hardware part, A microcontroller with a camera and an electronic lock will be used to securely open or close the door of the safe locker. In the software part, the images that are pictured by the camera will be prepared by an image processing algorithm and then Support Vector Machines (SVM) will be trained in the images of a person. The images and information of the person will be saved until the belongings come out and after that deletes everything to prepare for another one.

Index Terms— Safe Locker, Face Detection, Face Recognition, Machine Learning, Cyber Security.

I. INTRODUCTION

The bank or the financial institution uses a safe locker to place the documents and valuable belongings of the user because a convenient way is provided to protect these things [1]. The safe locker is also used in public places to store and keep the valuable belongings of people while they do something. Fig.1 is shown safe locker use in public places. In public places, the safe locker operates by the concept of dual keys which one is provided to the user and the other is held by the head of the branch. The primary goal of the dual key system is to effectively operate the complete safe locker system under the supervision of one head of a branch designated by the central head office in the place where it is used. Thus, the safety of the valuable belongings of people depends on the branch office.



FIG. 1. A SAMPLE OF A SAFE LOCKER USED IN A PUBLIC PLACE.

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Security is an important issue for everyone to protect valuable items such as documents, money, jewelry, etc. [2]. Security creates a safe environment for to people go about their business and activities. many things make security important like protection from harm physical or digital. Overall, security is important because it helps to protect individuals, organizations, and societies from harm, preserves privacy, maintains trust, and ensures legal compliance [3]. Also, security is digitally important which is called information security to protect files and Personal Computers (PC) from attackers. A set of steps taken to guarantee information security is known as information security [4]. Therefore, information security is progressing at the same time as computer technology. At the same time, this development of security is used to protect smartphones or to control the opening and closing of doors [5].

Face detection is a technique that detects human faces in digital images as shown in Fig.2 and is utilized in many different applications [6]. One instance of object-class detection is face detection. Object-class detection seeks to locate and measure each object in an image that belongs to a specific class. Human faces, pedestrians, cars, and so on are examples of object-class detection. Face detection merely provides an answer to two simple questions: (1) Are there any human faces in the images or videos that have been collected? and (2) Where is the face located?

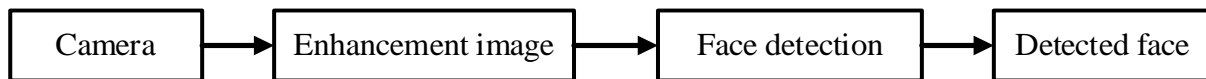


FIG. 2. THE BLOCK DIAGRAM TO DETECT FACE.

Definition of face recognition is the method for recognizing individuals from facial images. Face recognition of people has drawn a lot of attention because of its numerous uses in a variety of industries, including security applications, video surveillance, biometric systems, and criminal identification, among others [7]. Face recognition technology is now widely used in a variety of everyday applications, including smartphone unlocking, monitoring student attendance, secure online banking, and improved border control, to mention a few. Fig. 3 is shown a general block diagram of face recognition.

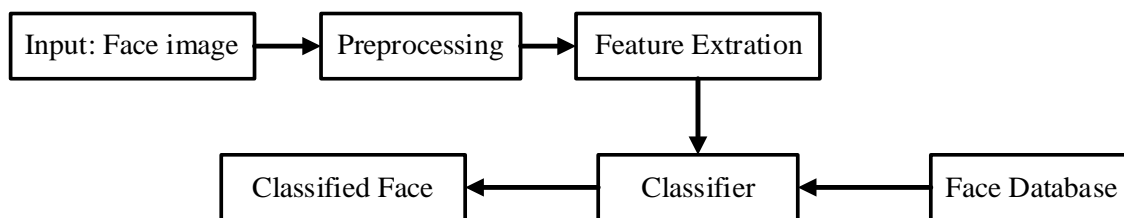


FIG. 3. THE BLOCK DIAGRAM TO RECOGNIZE FACES.

II. PROBLEM DEFINITION

In public places, such as locker rooms, everyone needs their valuables to be protected. Classical protection uses a key and a lock to protect a safe locker that may be lost. So that, if no backup of the key, it will be broken to take things from it. In addition, it is considered an old and vulnerable method of protection. These forenamed matters motivated us to propose and design a smart system that uses machine learning by face detection and recognition to secure a safe locker.

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III. RELATED WORK

Machine learning has been widely used to detect and recognize a face that use in several applications such as security in smartphones [8]. In 2020, Sharma et al. introduced a method using a machine-learning algorithm for face recognition [9]. In their method, principal component analysis (PCA) was used to extract features from images. Multilayer perceptron, Naive Bayes, linear discriminant analysis, and support vector machine were used in their experiments. The linear discriminant analysis with the PCA got the best result in their proposal. The two key drawbacks of the PCA algorithm are that it can only process faces with the same facial expression and that it is computationally demanding [10]. Thus, it will be difficult to apply to limited devices. While in 2022, Khandelwal et al. suggested a system that protects a specific area from unauthorized people [11]. If the person is not identified, an alarm is set off instead. In their system, they used a camera to capture a series of images and delivered them to a convolutional neural network (CNN) which is trained on images of the person belonging to that organization. The AT&T standard database was used to conduct experiments on their model. The architecture of CNN used the LeNet5 structure in their system. CNN will be difficult to apply to limited devices because computationally demanding and contain many layers. The system for face recognition system based on Sparse AutoEncoder (SAE) which is a Gabor filter bank and deep learning was proposed by Hammouche et al. in 2022 [12]. Their system was to improve the features which extract using the Gabor filter bank. The linear discriminant analysis (LDA) and the principal component analysis (PCA) techniques were used to enhance features which extract using SAE. Cosine Mahalanobis distance was used to match and decision. Seven publicly available databases like JAFFE and AT&T were used to perform experiments to evaluate their system which had good results. When a multistage of algorithms is often used, it leads to improving results but leads to slow implementation, especially when implemented on limited devices.

In the security locker field, the keypad and RFID were used by Mohammed and Alkeelani in 2019 to secure the locker system [13]. They designed and implemented a system based on a password and an RFID that contained two setups and action procedures. In setup, it had a definition of a new RFID while in action, they used known RFID to open or close the door. In their proposed system there is no intelligent method that uses machine learning. In 2022, A cost-effective security locker system had been designed by Sobur et al. and prototyped to guarantee the safety of valuables and possessions of people and in public areas [13]. They used Radio Frequency Identification (RFID) which technology automatic identification to close or open a lock via a microcontroller. Their system increases the cost because it needs employees to store keys and serve people.

The novelty of this work lies in the development of an intelligent method to protect valuable things for people. Thus, the main objective is to provide a safe place to store valuables for people in public places. Also, one of the objectives of this work is to design a safe locker at a low cost and with high safety. This system will be reduced the number of employees supervising the safe lockers thus saving money for the beneficiary company or country.

IV. DATASET DESCRIPTION

The proposed system will evaluate by using the AT&T standard database which is a collection of facial images from the AT&T Laboratories Cambridge obtained between April 1992 and April 1994 and are available in the AT&T database of faces (formerly known as the "ORLDatabase of Faces") [15]. The AT&T standard database contains four hundred

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images with size 112×92 for forty individuals. The samples of images and their label from the AT&T database are shown in *Fig. 4*.

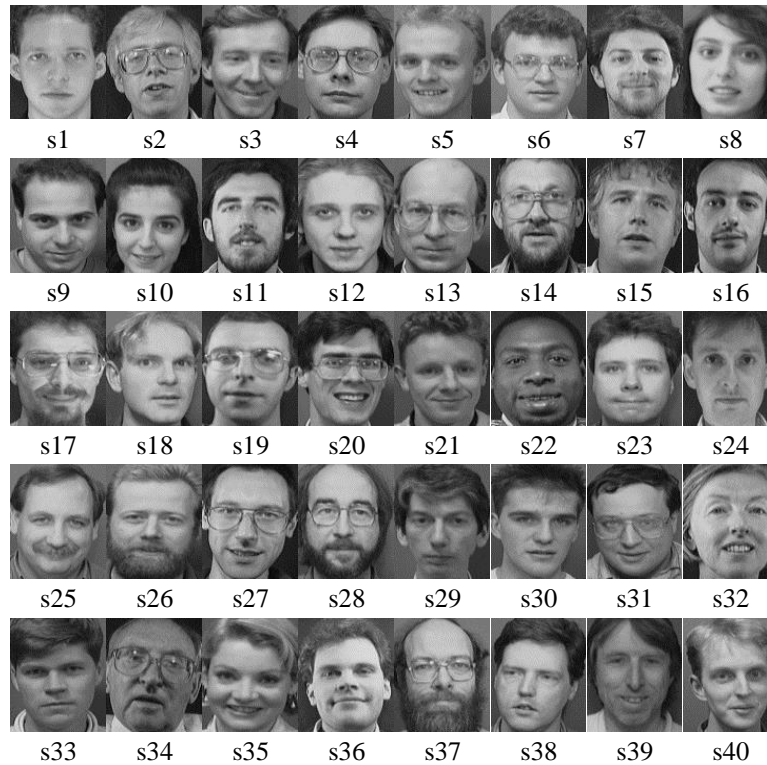


FIG. 4. SAMPLE IMAGES AND THEIR LABEL ON THE AT&T FACE DATABASE.

V. PROPOSED APPROACH

The proposed system consists of two major parts, software, and hardware. Hardware includes physical pieces, which are a camera, Personal Computer (PC), an Arduino Uno, and an electronic lock. Where PC sends the signal to the electronic lock via Arduino Uno if a face is matching to open the lock. The software includes face detection, feature extraction, and face classification. These parts will together generate the appropriate signal for the electronic lock.

A. Software

As shown in *Fig. 5*, the image will be processed after it is inputted to produce a classified face. If the classified face is matching to the real user, PC sends the command to the electronic lock via Arduino Uno to open the safe locker. Her block in the diagram of *Fig. 5* explains below.

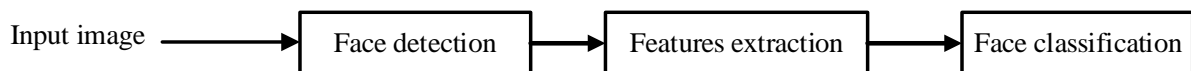


FIG. 5. THE BLOCK DIAGRAM OF THE PROPOSED SYSTEM.

i. Face detection

To detect faces from an image, the Viola-Jones algorithm will be used. The Viola-Jones algorithm is a machine-learning technique proposed by Paul Viola and Michael Jones for object detection proposed in 2001 [16]. The algorithm was primarily designed for face

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detection. The algorithm was designed to detect faces in images in real-time. The algorithm uses Haar-like features to detect faces from images using four main steps: selecting Haar-like features, creating an integral image, running AdaBoost training, and creating classifier cascades [17]. In MATLAB R2018b which is used as an environment in the proposed system, the following command is used to create the object that detects faces by the Viola-Jones algorithm from an image:

```
Detector = vision.CascadeObjectDetector
Faces = Detector (image)
```

If the image contains faces, the Faces variable will contain the borders of the face. the face will be cut from the image and changed its size to 112×92 . The color image of the face will be converted to grey and saved in Database.

ii. Features extraction

To extract features from the image, Local binary patterns (LBP) will be used first. One of the visual descriptor types is LBP which is used for classification in computer vision [18]. The LBP texture operator labels each pixel in an image by thresholding its immediate surroundings and treating the result as a binary integer. It is simple to use but incredibly powerful. After LBP, the histogram of oriented gradients (HOG) algorithm will be used to extract features that the classifier will be used to train. HOG is a feature descriptor that is used in image processing and computer vision to detect the target object [19]. The method records the number of times a gradient orientation appears in specific areas of an image. HOG extracts edge orientation histograms from selected patches in pictures [20].

iii. Face classification

In face classification, Support Vector Machines (SVM) will be used as a classifier. SVM is a type of machine learning algorithm that is used for problems of classification and regression analysis [21]. SVM works using finding the hyperplane that maximizes the margin between the classes. The hyperplane is the decision boundary to separate the data into different classes. this work selected SVM because SVM is simple and light computational [22]. The SVM is effective in high-dimensional spaces. SVM classifiers have outstanding accuracy and perform well in high-dimensional space. Because SVM classifiers only use a portion of the training data, they use less memory [23].

B. Hardware

In this work, a safe locker contains an electronic lock that opens or closes after receiving an appropriate signal from Arduino Uno. The main components of the proposed system are shown in Fig. 6. The camera will be captured images which are processed on a PC to generate the appropriate signal for opening or closing the electronic lock.

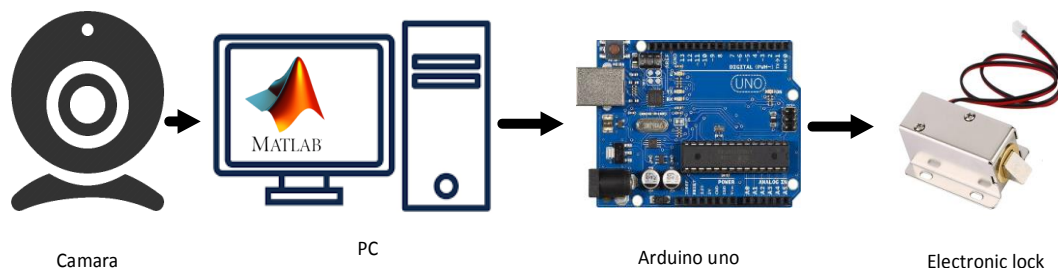


FIG. 6. THE USED COMPONENT OF THE PROPOSAL SYSTEM.

DOI: <https://doi.org/10.33103/uot.ijccce.23.4.9>*i. Personal Computer (PC)*

On a personal computer (processor: Intel® Core™ 7-8550U CPU @ 1.80GHz 2.00 GHz; memory: 16 Gb; operating system: Windows 10 64 bits), the complete model training and testing process was conducted. The NVIDIA GeForce MX130 2 Gb graphics processing unit (GPU) mode was used to optimize training speed. The PC will be generated the appropriate signal and send it to Arduino Uno via Universal Asynchronous Receiver/Transmitter (UART) communication. Additionally, MATLAB R2018b was used to implement the proposed system. The reason to choose MATLAB to implement this work is very reliable and stable to implement a proposal model [24].

ii. Arduino Uno

The Arduino Uno is a microcontroller that contains the Microchip ATmega328P microprocessor developed by Arduino.cc, it is open-source[25]. It has sets of digital and analog input/output (I/O) pins that can be interfaced with a range of expansion boards (shields) and other circuits [26]. It has 14 digital I/O pins, including six that can generate PWM and 6 analog I/O pins. It is an asynchronous system that has the ability to communicate with other devices, such as a PC. In MATLAB, there is a library that connects to and controls Arduino inputs and outputs. The following commands are used to connect MATLAB by Arduino Uno and put the digit one on pin8, after 5 seconds put the digit zero on pin8.

```
ab = arduino('COM6','Uno')
writeDigitalPin(ab,'D8',0)
pause(5)
writeDigitalPin(ab,'D8',1)
```

iii. Electronic lock

An electronic lock is a locking device that operates using an electric current to lock or unlock. One type of electronic lock is the solenoid lock that is used in this work. The Solenoid lock, which combines a key and a solenoid, is frequently used to electrify devices like automatic locks and others. It can be expected that the length of a solenoid, which is a form of coil made of long, tightly wrapped cables, is bigger than the diameter [27]. Andre Marie Ampere, a French physicist, made the Solenoid Principle known [28]. Engineers use this term to describe a transducer that transforms energy into linear motion. When an electric current passes through a coil, an electromagnetic force appears and pulls the iron in the coil's center linearly. The Arduino Uno can offer a maximum of 5V but the solenoid lock in use needs a 12V input supply. As a result, the solenoid lock is supplied with DC power from an external source. The solenoid lock is attached to one terminal of the 12 V supply, and the common port of the relay module is connected to the other terminal as shown in Fig.7. Another side of the relay module which is worked as an electrical switch connects with the Arduino Uno.

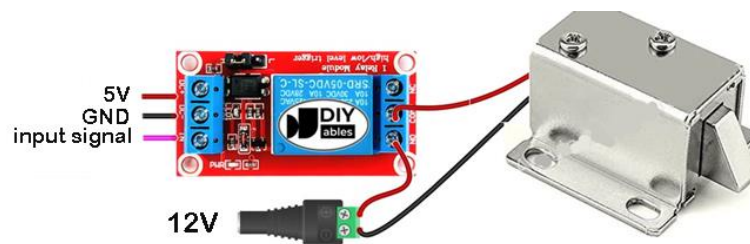


FIG. 7. THE ELECTRONIC LOCK CONNECTED TO THE RELAY MODULE.

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VI. EXPERIMENTS AND RESULTS

The proposed approach to Enhance the security of the safe locker will be evaluated by using the AT&T standard database. After that, the safe locker prototype will be implemented using Arduino Uno. The evaluation and implementation of the proposed system will be described below.

A. Evaluation

The work used 80% of images in AT&T standard database for training while 20 % was used for testing. The SVM model obtained an accuracy of 93.75% on the testing. As shown in Fig. 8, the proposed approach had incorrect predictions in S16, S36, S28, S39, and S21 classes where it predicted the S1, S19, S35, S4, and S39 classes respectively.

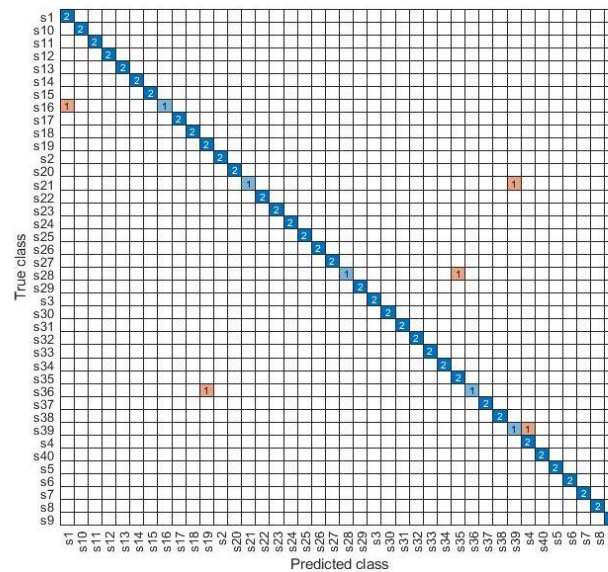


FIG. 8. THE CONFUSION MATRIX OF FACE RECOGNITION IN THE AT&T STANDARD DATABASE.

Predicted scores in Table I refer to the predicted values of a model for a given input data. Predicted values are the probability that predicted classes is truth class that is given by a number between 0 and 1. Where zero indicates that a given sample does not completely belong to the targeted class, while one indicates that a given sample completely belongs targeted class.

TABLE I. EXAMPLE OF PREDICTED PROBABILITY

Truth Class	Predicted Class	Predicted Values
S16	S1	0.27411
S36	S19	0.03634
S28	S35	0.08470
S39	S4	0.47194
S21	S39	0.37861
s11	s11	1.00000
s17	s17	0.99887
s23	s23	0.49369
s26	s26	0.99993
s27	s27	1.00000
s28	s28	0.92192
s30	s30	0.99999

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B. Implementation

In implementing the proposed system, the component is connected as shown in *Fig. 9*. The Arduino Uno is connected to the PC using UART to receive the commands to lock or unlock the safe locker. The relay module relates to the Arduino Uno via pin8. The solenoid lock connected the 12-volt power supply via the relay module.

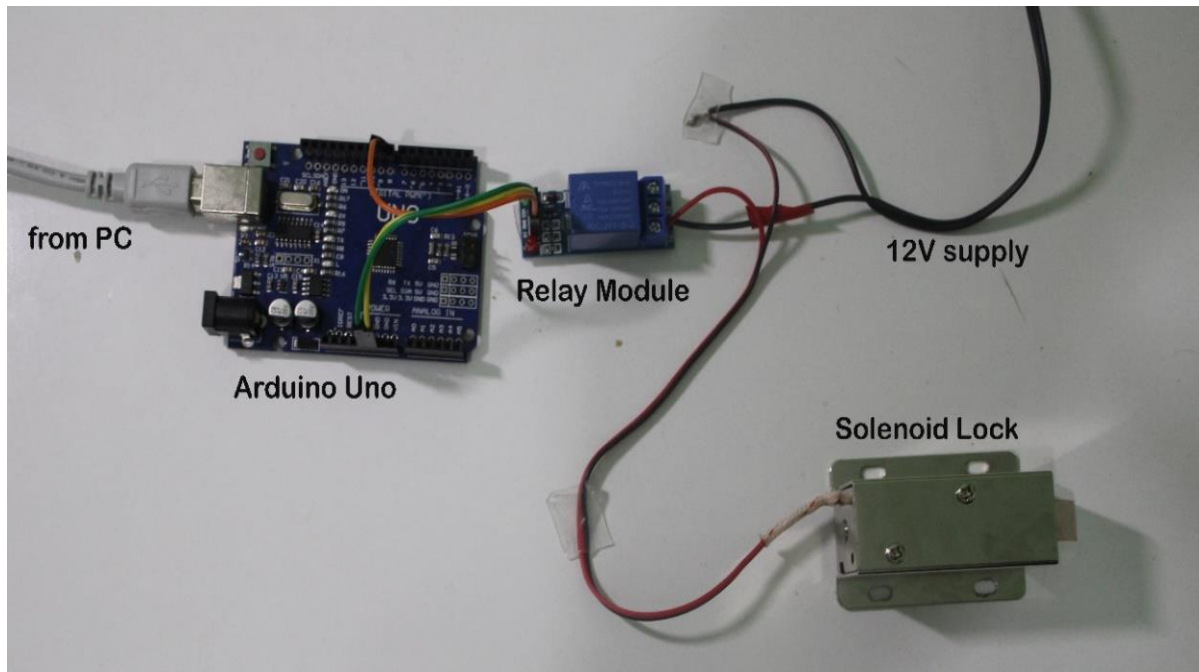
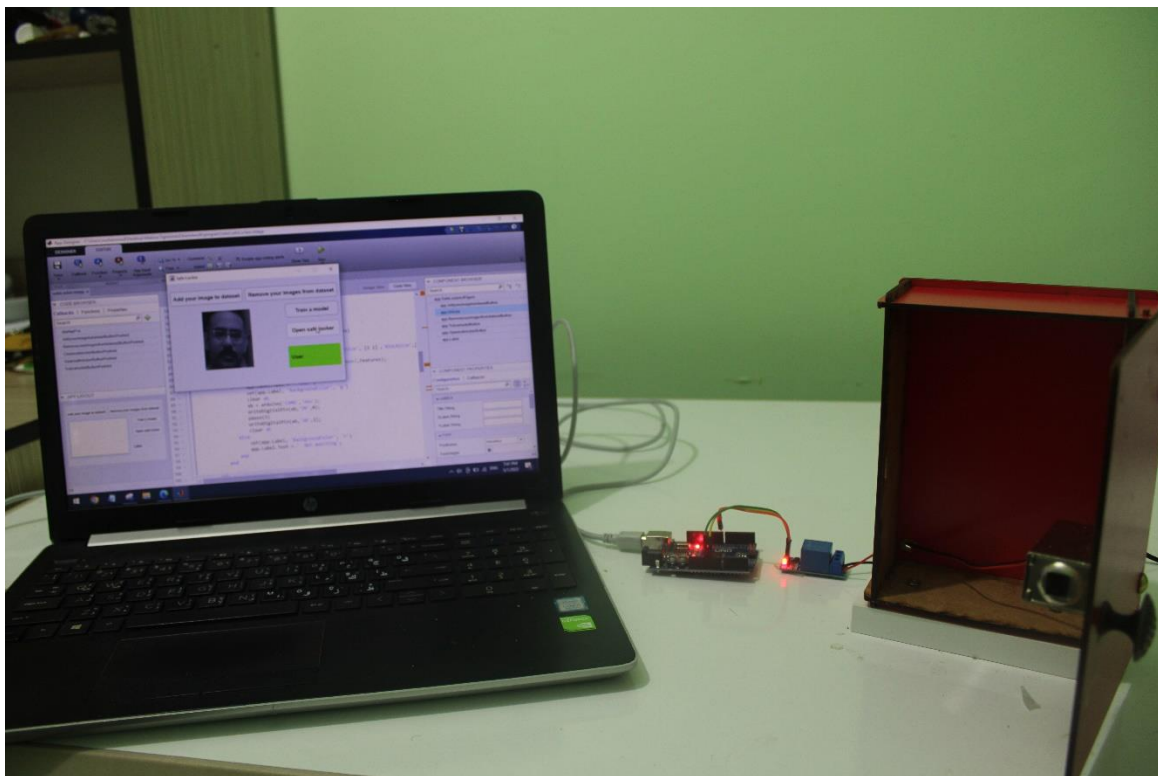
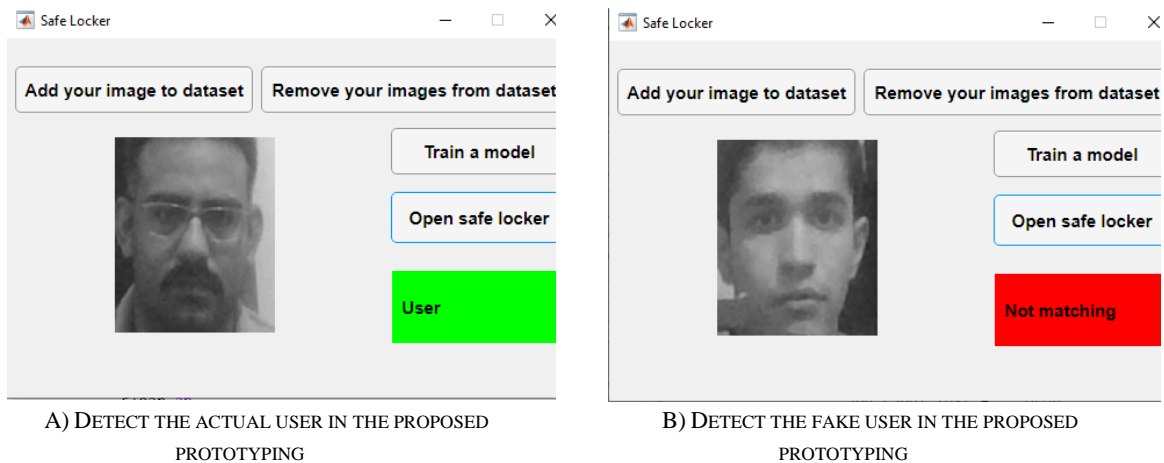


FIG. 9. DESIGN AND PROTOTYPING OF THE PROPOSED SAFE LOCKER SYSTEM.

On PC, the program was designed to send commands to Arduino Uno to lock or unlock the safe locker. This program enables the user to lock and unlock the safe locker. At first, the user presses the "Add your image to dataset" button to add at least ten images of his or her face. After that, the user presses the "Train a model" button to train the model on his or her image of the face. After that, the user presses the "Open safe locker" button, where the image will be pictured for the face of the user and the trained SVM model predicts by matching the pictured image with his or her images in the database. If the pictured image is matching his or her images in the database, the safe locker unlocks. After the safe locker unlocks, the user can put the valuables inside it and close the door of the safe locker. When the user extracts the valuables from the safe locker, the user presses the "Remove your images from dataset" button to delete his or her images from the system to be initialized to another user. *Fig. 10* shows the unlocked safe locker prototype as in C and the program when detects the real user as in A and the fake user as in B.

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C) THE UNLOCKED DOOR OF THE SAFE LOCKER PROTOTYPE FOR THE ACTUAL USER.

FIG. 20. THE EXPERIMENT FOR THE SAFE LOCKER PROTOTYPE.

VII. CONCLUSIONS

The research proposed a new design using face detection and recognition to enhance the security of a safe locker. Where the Viola-Jones algorithm was used to detect faces while the SVM was used for recognizing individuals. The component of this design was a PC with a camera, Arduino Uno, and a relay module connected with an electronic lock. The electronic lock was locked or unlocked based on the received command from Arduino Uno. The safe locker program had to send the unlock command if the user is real otherwise send the lock command from the PC to Arduino Uno. For the next study that future work, it used raspberry pi which is an advanced microcontroller will use to implement this work. The raspberry pi is a minicomputer that implements instruction faster than Arduino Uno. Also, the other model of machine learning can use to enhance the accuracy of the system.

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