Smart IoT-based security system for residence

Muhammad Irsyad Haziq
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
TP040034@mail.apu.edu.my

Ilanur Muhaini Binti Mohd Noor
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
ilanur@staffemail.apu.edu.my

Raed Abdulla
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
raed@staffemail.apu.edu.my

***Abstract*— The main aim of this project is to develop an IoT-based security system for resident which include biometric authentication, plate recognition, and movement detection system. In this proposed method, the programming platforms such as the Python, and the Arduino, were used to develop to demonstrate the proposed system. The performance of the developed proposed system is evaluated by testing the system with several sample tests and from there, the performance was examined. The system performed well in recognizing the different person and capable of returning the correct output in almost all the face samples as well as the plate number detection which can successfully extract the string information from the pictures. It is observed that the system has an overall accuracy of 77% after considering several important factors that may affect the system's performance.**

***Keywords*— Smart IoT, security system, biometric authentication, plate recognition, movement detection system.**

I. INTRODUCTION

The smart IoT-based security system for residence is the method that can be used in a work to increase the home security. This method was developed due to several flaws that have been detected in the traditional method on house monitoring. As suggested by [1], the traditional method which only can perform house monitoring as it could not trigger an alarm to notify the owner if there is a burglar attempt.

With the advancement of technology that was enhanced by day, the involvement of technology can be seen in almost every field where new method were developed to minimize human work in obtaining their needs, with utilization of concepts such as Internet of Things (IoT) which involved data transition between two party with a use of networks [2]. In the recent years, advancement of technology has led to an increase in research and development of IoT devices [3-15].

This issue came out looking at how the technology advances which eases everyday activities as it could lead to security breach due to the traditional method which is considered as passive method, where no feedback was given to the owner if security breach is about to happen. This will lead to potential successful burglar attempt where the thief can escape easily without being caught by the authorities.

This issue also was in a hot discussion due to the human nature which can lead to a potential security threat. There are cases where people forget to keep the house door locked when they leave the house and this can be an open opportunity for intruders to rob the house, as suggested by [2]. This is due to the lack of information on the door status which could lead to a possible intruder. The main objective of this research is to design and develop a smart IoT security system for residence for house monitoring purpose by the concept of data monitoring and image processing

The idea of proposing the smart IoT-based security system for residence is to provide maximum security for the residents. The system was implemented by utilizing the concept of data processing which the sensors will be placed to the place accordingly at which, the data will be monitored and actions will be taken if the data exceeds its threshold value, triggering an alert to warn the house owner by using an alarm.

The concept of image processing also will be utilized on developing a biometric authentication based from face recognition which will read the facial pattern and comparing to the data that is in-stored in the database, which will grant the access to the residence. Another system will be developed to read the plate number of the vehicle that is placed in front of the residence which is also utilized by the image processing by using OpenCV program to alert the owner on people in front of the house fence based from the plate number of the vehicle.

For data monitoring process, the cloud network will be developed for cloud monitoring purpose that will be using Node-RED software, which the Graphical User Interface will be developed for a systematic and standardized monitoring. For the data transmission from the system to the cloud network, the Message Queuing Telemetry Transport (MQTT) will act as the messaging protocol for data transmitting by the concept of publish and subscribe.

[16] discusses on the era of big data which involved face recognition as one of the methods of biometric recognition. This is due to the fact that the lacking capability of the face recognition system at which, the traditional method did not fulfil the social needs when it comes to handling big data. The authors proposed a method on standardizing the current algorithm in face recognition by suggesting a deep learning multi feature fusion face recognition algorithm which is by observing the face recognition method driven by big data. Instead of extracting the main features from the large samples by using 2DPCA which has its cons where the minor features of the sample are hard to process, this method utilizes the Local Binary Pattern (LBP) in detecting the textural features from the face, to be integrated by the main features from the 2DPCA method, creating better recognition result by considering both main and minor features for the fused features, before training the data in a CNN method which can work on multi-feature fusion recognition by obtaining the common characteristics between the sample data and the training data.

[17] focused on improving the efficiency of the system used in smart homes. This is due to the fact that the burden

was observed in the recording and analysis system where it consumed a lot of memory space which produces a huge burden on the platform on computation. The authors proposed a solution to the problem by introducing the event-triggering based system for video recording for the smart homes. The video recording will be initiated under effective sensing approach where PIR sensors assisted the IP-camera by enabling the recording in a specific direction as well as triggering the recording function for the other IP-cameras which are placed in other rooms, where the wireless camera initiates recording function during the targeted motion interval by implementing the Multi-Scale Structural Similarity Detection technique. RFID tags were utilized in this project for identification purpose at which aided the PIR sensor to transmit a signal to trigger the video camera at the place where the motion was detected.

[18] discusses on the possibility of applying the concept of computer vision in IoT in improving the security system in Smart Cities, Smart Homes, and Smart Towns. The authors proposed after looking at the drawbacks from the current system which still rely on human involvement on monitoring the footage. proposed an approach of utilizing Internet of Things as one of the alternatives to work with the IP cameras. This is by using the computer vision concept to study the pictures that was captured from the camera for people detection purpose, leading to the work of obtaining the pictures which contain people and the process of handling the pictures that mimics the sensor with two states. This paper also provides a solution by analysing the entire sequence, replacing the method of using pictures as sensor to isolate the picture in IoT.

[19] proposed one of the approaches by using the visual cryptography where it involves the process of secret sharing which encrypts the secret image to shares which hides the data about the original secret image. This will make the face recognition process to be more secure as the face was dithered in two different host images which were kept in different data servers. This enables the process of extraction of the original image by analysing the both sheets together at which the private image will not be shown in single data sheet. This was proposed under an algorithm which combines CVC and Siamese network which is vital in representing the learning feature for one shot learning. This system brought a tremendous result where it achieved an accuracy rate of 93% compared to the current methodology that were used in the industry. the limitation of this system that the difficulties to handle the data when handling larger dataset which will affect its accuracy and consistency of the system.

II. SYSTEM IMPLEMENTATION

Fig1. shows the block diagram for the project. The input of the system will be based from the sensors that will be placed to the specific place where the data input will expect to be extracted such as the camera and the PIR sensor.

The processing center also will be utilized by the Microcontroller Unit (MCU) which uses the Arduino Mega 2560 as the main programming board as well as the Raspberry Pi 4 which handles image processing related activities. The output of this project will be expressed by the behavior of every actuators that were used in this project that were programmed from the programming board which decide the output based from the condition that were satisfied from the input data. The output of this project also will be displayed from the cloud network for better monitoring experience with the aid of the wireless network.

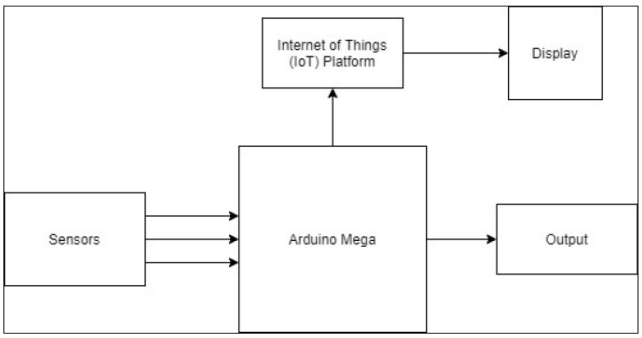

Fig. 1. Overall lock diagram

This project uses sensors such as the PIR sensor, and the camera to detect any input before being transferred to the microcontroller board such as the Arduino Mega at which, the input data will be processed, generating an output such as the alarm to alert the user at which all the decisions will be computed via programming language that was uploaded inside the microcontroller board. For the cloud network, it will be uploaded via the MQTT network which enables the function of IoT and it will be displayed in the GUI that have been developed by using the Node-RED software.

For the process, the scanned face will be converted to a 128-dimensional unit hypersphere by applying deep neural network. This type of representation gave a good view on differentiating different person through a large distance between the two embedded faces in the system. The feature classification will be applied by using clustering method to compare the scanned face to the database. All the activities will be sent to the cloud network for the owner to monitor anywhere and anytime.

Fig 2. shows the flowchart to explain the working principles for the face recognition system. The system will start by opening the camera to perform the face scanning process. Firstly, the user input will be asked so that the face that will be scanned will be classified by the input that will be entered by the user. After the face scanning process was completed, the input which is the image of the scanned face will be stored in the database which is the directory that will be created upon completion of the face scanning process for the first time.

After that, the process of training will be performed by the system. The training process is one of the concepts under machine learning that was applied to this project. to explain this, the training process was performed to let the system learn the facial pattern that was saved into the database so that the system will recognize the incoming faces that will be scanned on the second phase of the face scanning process. Going for the second phase of face recognition system, the camera will be opened again to scan the incoming faces for authentication purpose and thus, decide whether the person can enter the house from the system output. Once the face was detected, the facial pattern that was captured by the system will then brought to compare from the pattern saved from the database and as the input data which is the facial pattern from the second phase of the face recognition system compared to the pattern in the database, it will produce an output based from the result of the comparison at which, the door lock will

behave accordingly from the actuator that was installed at the house door. If the input facial pattern matched with the database, the door was set to unlock and vice versa if the system does not recognize the input face that was scanned.

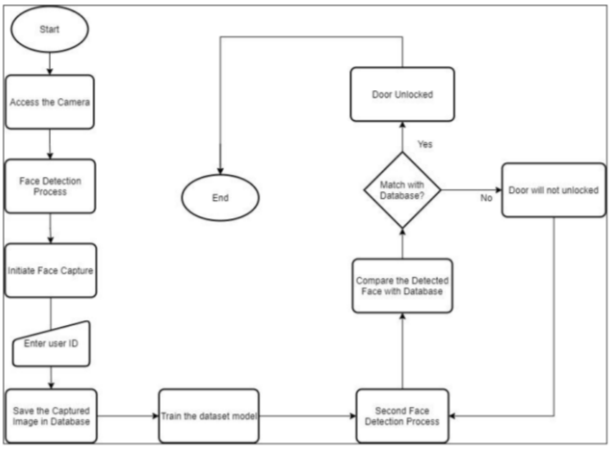

Fig. 2. Flowchart for face recognition system.

Fig 3. shows the final flowchart for the process of number plate detection. This system will be initiated upon the input that have to be entered by the user whereas the plate number's credential was entered as a registration method for this system. After that, the plate number's information was then saved and stored to database.

For the main system, the system was executed by assessing the camera for scanning the incoming plate number. After it detects the plate number, it will draw the rectangle as the area of interest at which the contour will be drawn to indicate that the plate number was detected. After that, from the contour detected, the plate number information will be extracted and followed by the area of contour that was cropped upon the activity. It was then, the information from the plate number was converted to string form and then information will be displayed to compare from the input data. After compared with the data from database, the output will be based from how same the plate number information the input is with the database. If the input matches the database, the gate will be unlocked which grant access for the user to enter and vice versa if there is an unmatched data.

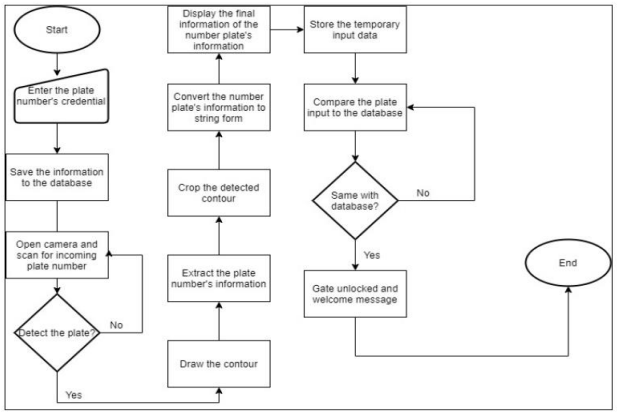

Fig. 3. Flowchart for the plate number recognition system.

Fig 4. shows the overall circuit diagram for the proposed project. It is powered by two peripherals which are Arduino Mega and Raspberry Pi 4 2GB Model. Since the Arduino did not have the Wi-Fi built in to support cloud computing, the ESP-01 will grant access to Wi-Fi network to the Arduino program. From Fig 4., it was observed that the logic converter was used to connect the Arduino to the NodeMCU model. It is because the difference in operating voltage for both microcontrollers at which, voltage standardization was executed.

The sensors that were observed from Fig 4. such as the PIR sensor, magnetic contact switch, and 12VDC Solenoid Door Lock, and the camera. The PIR sensor will be placed at the door for motion detection, as well as the camera that will be placed at the door to undergo biometric authentication by face recognition method. The magnetic contact switch will be placed at the window which will trigger alarm if the contacts were separated, indicating the window is opened. For the solenoid door lock, it will be placed at the door and will unlocked upon the matching pattern that will be conducted via biometric authentication process. For the connection, it was connected via relay due to different operating voltage from the Arduino Mega board.

For the camera, it will be placed at the front gate as well as at the front door to implement computer vision system to recognize face and the vehicle registration number. The program will be computed inside the Raspberry Pi 4 2GB model which can handle python language. The output which act as a trigger alarm such as the LED and the buzzer alarm to notify the owner in case the threshold value was exceeded, were also connected to the system.

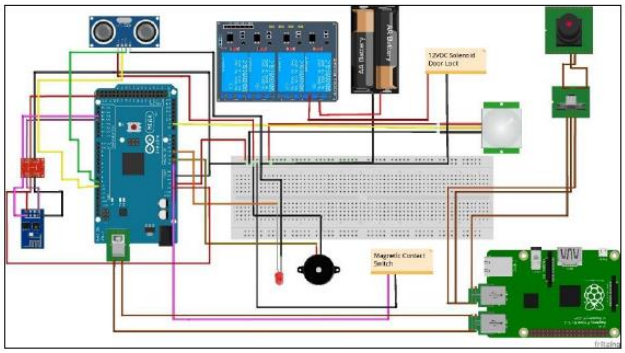

Fig. 4. The schematic diagram

III. HARDWARE RESULTS

For the face recognition system, the system will begin by entering the usernames to be saved in the database. For this system, a number of 5 names can be saved in the database. After that, the face scanning process was performed. For this stage, an input from user was required to enter their designed user ID to be aligned with the usernames in the database. After the face scanning process was successfully executed, it will be saved to a directory as shown from Fig 5.

Fig 5. shows the list of scanned faces that were executed during the second process. As seen from the names, the user ID that was entered was being assigned for every designated faces. After that, the face images from the database will be set to train to enable the machine to recognize every facial pattern based from the user ID and the names entered from the beginning process. The final process will be the recognizing the face from the database where a video stream will be loaded and the user will place their face to it to let the system read the facial pattern and thus, comparing from the one from the

database, if there is a match, it will return the username as well as the welcome message. In the event of matching pattern, the lock will be unlocked to let the user to enter the house.

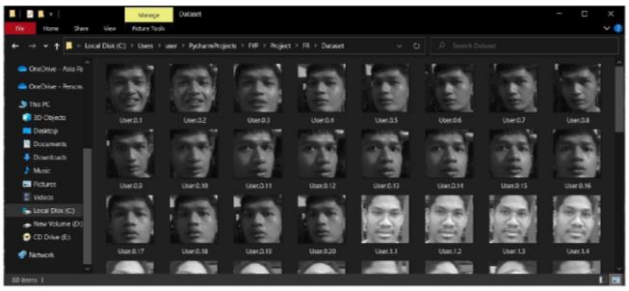

Fig. 5. The directory for all the saved faces

For the plate detection system, the user was again required to enter the plate number information to be saved from the database. Same as the face recognition system, the system can hold up to 5 plate number information in the database. For recognition process, a video stream will be loaded to detect any area that can be considered as the plate number based from the contour made to highlight the area of the plate number, before extracting all the plate information and displaying it in string format, with the help of numbers of filters applied in order to reduce the noise to the video stream. After the string information from the plate number was extracted, the recognition process was taking place by comparing the string information to the list of information from the database to check if the plate information matches any from the database. If there is a match, a welcome message will appear as well as deactivating the sensor located at the gate to let the vehicle in. For the data processing, both PIR sensor and ultrasonic sensor were used. The GUI that was developed was shown from Fig 6.

Fig. 6. The GUI for data monitoring

From Fig 6., all the data from both sensors were displayed here. For every status of '1' from the PIR sensor, a message of 'Motion Detected..' will appear and increasing the value of count, from the gauge from the top right from Fig 6., it will record how many motion detected and the middle indicator will display the distance fetched from the ultrasonic sensor.

IV. TESTING OF THE PROPOSED DESIGN

A) Detecting Different Person Using the Face Recognition

This test was conducted to examine the system developed perform when it comes to correctly detect the person based from its facial pattern. To recall, this system uses the Haar Feature-based classifier which was one of the methods used for detecting object. It gave an insight on the concept of machine learning where the cascade function was brought to train from the images so that it can function well in detecting the object in images or videos based from the pattern detected by the function. To run this system, the program will be uploaded to the Raspberry Pi 4 which act as the main board to handle the image processing related function. After that, the camera which is the Intel Depth Camera D435i was connected to the Raspberry Pi 4 model to enable the video to be loaded from the board when the program runs. During the program runs, the cascade function will predict the pattern and return the username as an output for this project.

In this test, the person's name which is in the video frame was 'Shahrul', and the system recognizes the facial pattern that was from the video input to be matched in the pictures from the database and thus, returning the username as the output according to the user ID name since the name 'Shahrul' was assigned the user ID 1 from the database. This output is based from the 20 scanned sample under this user ID which makes the face detection process to be easily performed. The matching percentage also was displayed from the output video which shows how many percentage the facial pattern from the video input matches the facial pattern that was saved from the database and for this case, the percentage of similarity between the face input and the database is at 23% and this is due to the obstacle that present at the face input as the sample wore a mask which covers a minor part of his face during the recognition process. The tabulated data shows the system's accuracy when it comes to detecting different people based from the face input to be compared in the database.

TABLE I. THE TABULATED DATA FOR RECOGNIZING PERSON.

Test	Face Sample Input	Output name return	Match Status
1	Shahrul	Shahrul	1
2	Amirul	Amirul	1
3	Irsyad	Irsyad	1
4	Zubair	Zubair	1

Table I shows the output name based from the face input. It shows that the system functions well in differentiating all 4 sample faces based from its facial pattern, making the system's accuracy of detecting different person to be at 100% based from the 4 sample faces that examined. Despite its superb performance in differentiating person looking from its accuracy, the fact that the factor that really contributes to this excellent performance is the lighting of the surroundings which made the process of extracting the facial pattern from the face input, to be far easier to be brought to compare from the images saved from the database. One factor also has to be noted that this only took place in detecting the frontal part of the face and the different angle of faces will conducted in another set of tests.

B) Recognizing Faces in Varying Lighting Environment

This test will be performed to test the system's capability in capturing the facial pattern under distorted environment which for this case will be the surrounding's lighting. To make sure everything is clear, all the saved images from the database was taken in an excellent condition of lighting which the rate of pattern acceptance and exposure to be highlighted is far more in-depth, to ensure every pattern of the face have successfully read by the system for easy detection. This system will be implemented same as the first test as the configurations and the program used is the same. What is different is the type of environment of the test being carried on.

The test result of the subject being tested under clear environment which provide good lighting for the face

recognize the face correctly as the output returns the name 'Irsyad' from the face sample test. However, the problem arises when it comes to recognizing the face under low light environment. As the result, the system returns the name 'Unknown' indicating that the facial pattern by the sample face 'Irsyad' does not match any pattern from the database. To add things up, the matching percentage also was observed at -6% which clearly explains that the facial pattern does not matched any facial pattern from the database. However, there are cases where the system successfully recognizes the face under low light condition.

TABLE II. TABULATED DATA FOR RECOGNIZING PERSON UNDER LOW LIGHT

Test	Face Sample Input	Output names return	Match Status
1	Amirul	Amirul	1
2	Irsyad	Unknown	0
3	Shahrul	Irsyad	0
4	Zubair	Zubair	1

Table II. shows the tabulated data regarding the performance of the system in recognizing the faces in low light condition. Among all 4 face samples that were tested, 2 face samples were successfully identified with correct name return while the other two face samples were given a mismatch name return and unknown condition. To conclude, the system's accuracy in recognizing the face under low light condition is at 50% which is average for a system to perform. Recognizing faces under varying lighting condition always been a challenge for a developer as the absence of light will reduce the system's capability in recognizing the facial part that cannot be read by the classifier due to the facial feature is hidden upon the insufficient amount of exposure and hence, leading to ID mismatch due to the insufficient amount of data packed to be compared to the saved faces in the database to return the correct output for the face samples.

C) Recognizing the face based on different angle and expression of Faces

This test was conducted to examine the system's capability in recognizing the faces based on the expression given by the face sample as well as the recognizing faces from different angles. This is to test the system whether it could recognize the face based from the less amount of facial pattern that present from the face sample to return the output name correctly. Same as the previous test, this system will be implemented same as the first test as the configurations and the program used is the same. What is different is the expression and the angle difference of the face sample that will be executed for this test. The test result of recognizing the faces when the face is at different angle shows that (from the video stream), the face sample 'Irsyad' was tilting his face slightly on his left side yet the system can return the correct output name according to the face sample. While the face sample 'Zubair' was tilting his face in a steeper angle towards his left side in the video stream. Even with such action performed by the face sample, the system successfully detects the facial pattern and return the correct output name 'Zubair' from the video stream.

TABLE III. TABULATED DATA FOR FOR DIFFERENT ANGLE AND EXPRESSION RECOGNITION

Test	Face Sample Input	Output name return	Match Status
1	Amirul	Amirul	1
2	Irsyad	Irsyad	1
3	Shahrul	Unknown	0
4	Zubair	Zubair	1

Based on Table III, the system's capability was studied to conclude the system's accuracy on detecting the person when the person shows different angle of face to the camera as well as giving an expression during the recognition process. It was studied that the system accuracy is at 75% as 3 face samples were successfully recognized by the system upon the criteria that have been satisfied for this test. Despite of not showing the overall facial region to the camera, the system done well in recognizing the face as the exposed part of the face can be read by the system and hence, returning the correct output and the same thing occurred in recognizing the face with expression as most of the facial pattern can still be read even there is a difference in the facial mapping at the face input, making the system could execute well in these kind of situations.

D) Plate Number Detection

This test was conducted to examine the performance of the system in recognizing the text from the plate number that was attached from the vehicle. Based from the program codes that were developed to build the system, apart from all the filters that have been applied to ensure the output of the system is on the best condition. all the programming work was compiled in the Raspberry Pi 4 as the main board to handle the image processing related function. A video stream will be loaded which is sourced from the Intel Depth Camera model d435i as the camera lens. With the aid of the Pytesseract function, the ability to extract the string information from the plate number can be done. Fig 7. shows the test results that were applied to the test images to test the system's ability to read the plate number.

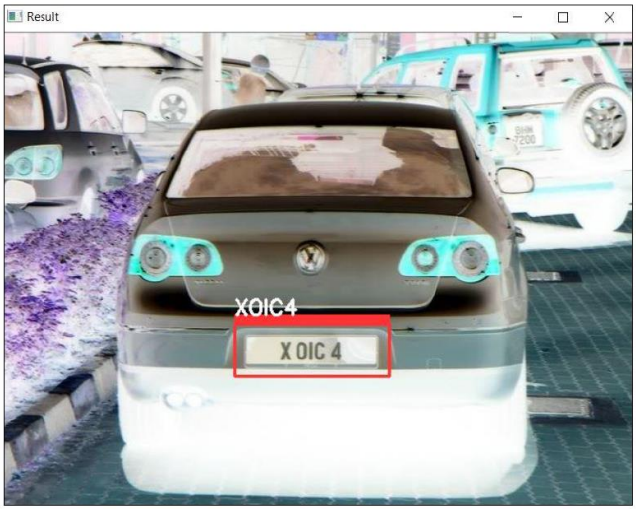

Fig. 7. The test result for plate detection system.

Based on Fig 7., the system handles the image well as it can detect the area that can be consider as the plate number and do its job to extract the string information and displayed at the result section, which states the string 'XOIC 4' which matches the text that was read from the result section. Apart from the Malaysian plate, this system also was brought to test in a foreign country's plate number which has the different color that was applied to its plate number.

Fig. 8. The test result for foreign plate number

Based on Fig 8., the system did perform well in detecting the string information from the plate number that belongs to foreign country as it can read the plate number information despite having different color applied for the plate number. From the test, the extracted string information was recorded as 'RR 1' which matches the information from the result.

TABLE IV. TABULATED DATA FOR PLATE DETECTION SYSTEM

Test Sample	Plate Input	Output String	Match Status
1	XOIC 4	XOIC4	1
2	RR 1	RR 1	1
3	E 63	E 63	1
4	WWW 1	WWW	0
5	W4062A	W406G2A	0

Table IV. shows the overall tabulated data for this system based on the 5 samples of plate number as the input at which, observed that 3 plate number information were successfully read and displayed correctly with matching input, another 2 plate number information were failed to read correctly as the output showed a slight difference in terms of the letter that have been generated via the Tesseract function, making the overall accuracy of this system is 60% based from this sample test's result. Despite its ability to detect the Malaysian plate number, the work can be done due to the additional filter that was used which is the color inverter which enables the system to detect the string information from the Malaysian plate. To possess the ability to detect the foreign plate number, the mentioned filter has to be eliminated to enable the system to detect the foreign plate number's information without having an error.

V. CONCLUSION

To sum up, all the objectives of this project have been successfully achieved. All the features included in the project have been designed according to the need of the residence nowadays and this include the face recognition system, the plate number detection, and the data monitoring system which include the ultrasonic sensor and the PIR sensor. All the programs that have been developed seem to function well with minimal amount of errors for the face recognition system, plate number detection system, and the data processing system. The programs developed was integrated well with conditions to make the system to function in a systematic way with all the conditions were satisfied nicely. Lastly, the integrated system also seems to communicate well with the system. this can be seen from the data processing system where the ultrasonic sensor and the PIR sensor can function well without having any errors. This also can be seen from the image processing system where the hardware mounted to the system also function well according to the condition that were satisfied from all the image processing's output. one of the most obvious limitation in this project is the performance of the face recognition process where it could not detect the facial pattern under extreme condition such as the lighting problem. For the plate number detection, this system can be used within the county which has the black plate number and white words.

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