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Face Recognition Based Multifunction IoT Smart Mailbox

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***Abstract*— The abundance and variety of the Internet of Things (IoT) applications in the recent couple of years has reach a new record. From smart home, smart traffic, smart city, to industry, logistics and agriculture IoT applications are penetrating in every facet of our life and our society. A lot of simple and more complicated solutions benefit from the flexibility and diversity of connections that this new technology provides. In order to provide better management, better visualization, increase scale and reduce response times logistics and warehouse management are embracing new ways to improve upon the already "old" RFID technology. In this sense IoT provides an unprecedented technology to meet all these requirements in a uniform and easy to manage way. In this work a specific smart application – IoT mailbox with face recognition is discussed. Combining cellular connectivity with image processing it ensures the user that his valuable documents will be securely delivered. The developed prototype consists of a fingerprint reader, a camera, electromagnetic lock, a small LCD screen, a microphone and a loudspeaker all connected to an Arduino Uno which processes the data and establishes the network connectivity through a GSM module. Additionally, to perform face detection and recognition based on a prerecorded image set the camera is connected to Raspberry Pi and OpenCV and Python software is employed. The remotely controlled electromagnetic lock ensures that shipments are kept protected until the designated receiver takes possession of them.**

Keywords— IoT, Cellular Network, face detection, face recognition, electromagnetic lock component

I. INTRODUCTION

Logistics and transportation were one of the first sectors to embrace the RFID technology when it first appeared over a decade ago. [1] Requiring object identification and secure connectivity over large geographical areas and seeking to improve the supply chain solution upon RFID technology the transportation industry has already embraced IoT as a great tool to visualize location and manage critical goods in real time. The new IoT supply chain streamlines field operations, reduces inefficiencies and delivers better insights that improve client service levels. [2,3] Today, more than ever millions and billions of goods travel thousands of miles, changing hands many times or more, before they reach their final destinations. In this complex landscape, missteps along the supply chain are unavoidable. No matter how well established the logistics network is, at some point a truck will get stuck in traffic, or a packet will be delayed at a warehouse, or an asset will go missing altogether.

There is a lot of work related to solving these and similar problems especially using IoT. ADDSMART is a research project focused on digitizing addresses of locations and building a smart mailbox by combining wireless sensors, cameras, locks, and RFID readers and tags into a system controlled by an Arduino microcontroller board. [4] In [5] the authors describe the overall topology and prototype implementation of an intelligent mailbox using concepts of IoT to facilitate monitoring of physical mailbox installed at homes and offices. The system uses Nvidia Jetson TX1 controller and on board Wi-Fi module as preferred medium of communication between devices. Other hardware modules include secondary controllers which are Raspberry Pi 2B, RP2B Camera module with 5 megapixel fixed focus camera and TP-Link TL-WN722N wireless adapter for RP2B. Another interesting application is described in [6]. The authors propose a multi-functional parcel delivery locker (MFPDL) which utilizes C51 MCU and GSM/GPRS modules to send customers SMS with passwords in order to validate the acceptance of the shipment.

In this paper an example IoT application related to secure delivery of shipments and assets is described. "Smart Mailbox" addresses the secure and reliable delivery of mail and informs the user of the actions of the courier or logistic service. Different from other similar systems it uses several alternative methods (SMS, voice and face recognition) to realize the above mentioned functions and using off-the-shelf elements keeps the overall cost quite low. From here on the paper is organized as follows: in the next Section II the system architecture is presented, followed by details on the hardware components and software design in Section III. Section IV describes the experimental part and evaluates the results.

II. SYSTEM ARCHITECTURE

The proposed system aims to make one specific link of the logistics chain more secured. Usually when important documents and shipments are delivered the courier request a signature. However, to do this, the recipient has to wait at home and sometimes this might be quite inconvenient. The designed prototype allows the user to receive a document or shipment in a secured way irrelevant or whether he is at home or not. With the Smart Mailbox, the courier can leave the shipment in the mailbox only after it is remotely opened by the user and the user can retrieve the shipment at a convenient time only if he is cleared by the system as a legitimate user. When the courier arrives and tries to access the mailbox a notification is sent to the related user. Verifying that the shipment is the one he is expecting, he can remotely open the Smart Mailbox so that the courier can leave the shipment. Upon arriving home, the user's identity is checked against a predefined image set using face recognition and the mailbox

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is opened so he can retrieve his shipment. The architecture of the system realizing this functionality is given in Fig. 1.

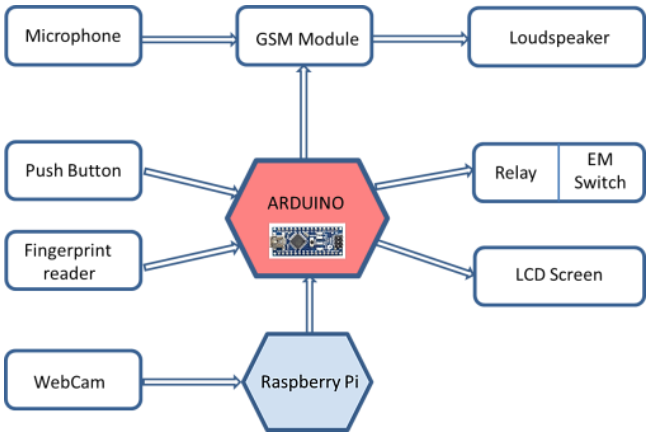

Fig. 1. General system architecture

Upon arrival the courier can contact the user either vocally by placing a call or sending an automatic sms by pressing one of the options ("Call" or "Send SMS") on the LCD screen of the mailbox. These functions are realized using the GSM module and related MIC and Loudspeaker blocks. The user checks the delivery and opens the lock by sending an opening code followed by a registered signature. The code activates the electromagnetic lock and the box is opened so the shipment can be placed inside. Upon arrival home the user is identified either by his fingerprint or by face recognition (fingerprint reader, camera and Raspberry Pi). The result activates the electromagnetic lock block and the mailbox is opened for the user to retrieve the shipment.

The above described elements are controlled by an Arduino Uno, while the face detection and recognition are realized using the OpenCV software running on the Raspberry Pi.

The initial LCD screen is as given on Fig. 2.

Fig. 2. Initial State of the LCD screen

Upon receiving a call or an SMS from a courier the user has two options: to accept and send a positive message "I accept" or reject by sending a negative message "I do not accept". These messages are received through the GSM module of the Smart Mailbox and interpreted based on the software designed. To increase security and privacy at the end of each message a special predefined signature code is added. In case the message is positive the software activates the relay and the switch is released; in case it is negative an additional notification is sent, shown on the LCD screen to inform the courier that the shipment is rejected.

If the mailbox opens the courier places the item and closes the door. It locks automatically and a message is sent to the user "Delivery accepted". At the same time, the information that the delivery is confirmed for the courier is sent to the screen of the mailbox.

The webcam controlled by the Raspberry Pi can also be kept active to check whether the person sending the sms is really a courier not just somebody who is tempering the mailbox. For this feature a continuous uninterrupted internet connection is required over cellular or wireless network, which turns it into a full scale real-time IoT application.

III. System Components

A. Hardware

The main hardware components used to realize the functionalities described above are: The Arduino Uno, the Mic and the loudspeaker, the fingerprint reader, the relay and the electromagnetic lock, the webcam and the Raspberry Pi.

The electromagnetic lock is an enameled copper wire with a diameter of 0.2 mm and length of 9 meters is wrapped around hollow cylinder with a length of 15 mm and 10 mm diameter. The core is temporarily magnetized when the coil is supplied with 5V 230 mA. To control this switch by the Arduino (max 45 mA) an additional relay is required.

The LCD screen used in the project is 5110 with 84X48 pixel resolution, DPI serial connection interface, working voltage 2.7V - 3.3V. An Arduino Pro Mini compatible fingerprint module which can store up to 1000 fingerprints was used. It supports fingerprint entry, image processing, fingerprint comparison and fingerprint search mode.

The brain of the system is the Arduino Uno with GSM shield. These hardware components are mounted together on the control panel at the front of the Smart Mailbox.

B. Software

There are two main components of the software designed for this prototype: the main operational algorithm and the face recognition related software.

The main algorithm is given below in Fig. 3.

The main algorithm controls 3 variables. These are send_message_button, call_button, and mail_compartment's reed switch information. If the courier clicks the send message button, the message with the shipment will be forwarded to the recipient and the "message has been forwarded please wait" information will be displayed. Remote receiver confirmation is required to open the mailbox. If the recipient types "open the box", the cargo_compartment function works which causes the electromagnetic lock to open. Information about the opening of the compartment is transmitted to the courier via display. After the courier leaves the shipment and closes the cover, both parties (the recipient and the courier) are informed.

If the courier has clicked the make call button, voice calls are made with the receiver via the speaker and microphone in the mailbox via the GSM module. After the interview is over, the process continues through the message receiving and decision functions.

If the postman leaves mail in the mail compartment, reed switch sends information to Arduino Uno and the recipient is informed by SMS.

If the Arduino Uno receives defined person Id information from the Arduino Pro connected to the fingerprint reader or Raspberry Pi connected to the camera, the cover is opened by running the cargo_compartment function.

```
Loop
Get send_message_button's information from left button
Get call_button's information from right button
Get mail_compartment's information from reed switch
If send_message_button is high
    Sms Print "You have shipment."
    Display "Message sent, please wait."
    Call take_a_message function
    Call decision function
Endif
If call_button is high
    Display "Call made, please wait."
    Call the box owner
    Display "Waiting for response."
    Call take_a_message function
    Call decision function
Endif
If mail_compartment is high
    Sms Print "You have mail."
    Display "Mail received, thanks."
Endif
If the identified ID comes from Raspberry Pi
or the identified ID comes from fingerprint reader
    Call cargo_compartment
Endif
If the unidentified identity comes from Raspberry Pi
    Sms Print "There is someone in front of your box."
    Sms Print "See from the camera, from address 192.168.0.107"
Endif
EndLoop
Function take_a_message
    If gsm module available for reading sms
      While gsm keeps sending sms
          Read sms as a character
          Save characters to sms buffer variable
      EndWhile
    Endif
EndFunction
Function decision
    If the message is "open the box"
      Call cargo_compartment
      Sms Print "Your box opened."
      Display "Cargo received."
    Else
      Sms Print "You indicated that the shipment is not yours."
      Display "The recipient refused the shipment."
EndFunction
Function cargo_compartment
    Set electromagnetic lock to high
    Display "Cargo compartment opened"
    If cargo compartment closed
        Set electromagnetic lock to low
        Display "Cargo compartment closed"
    Endif
EndFunction
```

Fig. 3. Main Algorithm

If unidentified contact information is received from Raspberry Pi, the owner of the box will be sent an SMS stating that there is a foreign person in front of the box and it is recommended to watch it from the specified internet address.

The face recognition algorithm in this study is based on the Haar Cascade Classification. [7] The face recognition algorithm compares a previously detected and registered source face with a new face and makes an identity decision based on the similarity. Using the already trained image database in OpenCV Phyton code is developed to define the limits for the recognition. Face recognition is done in real-time.Local Binary Pattern Histograms (LBPH) method is used because it is less susceptible to light compared to EigenFaces and FisherFaces. [8, 9] Comparison is pixel-based within given coordinates.

IV. Experimental Scenarios and Results

The finalized prototype, given in Fig. 4, was tested for all stages of the operational cycle.

Fig. 4. Final prototype

The accuracy of the fingerprint reader in the tests is 19 in 20 attempts. The remote operation was tested with "Send Message" and "Make Call" keys and the keys worked in all 20 attempts. There are no repercussions during the conversation. because the speaker and microphone were placed on different planes of the box. The display refresh rate is satisfactory. When the Mail compartment was opened, sms was sent to the recipient correctly every time in 20 attempts. In all trials, the cargo hatch was safely opened and locked. Information on whether the cargo is in the box was correctly provided in all 20 attempts.

Table 1. Success Results Table of 20 Experiments Performed Under Different Lighting Conditions and Face Conditions

Number Of Successful Results In Different Lighting Conditions (Lumen)			
20 experiments	***2200 lm***	***1600 lm***	***970 lm***
Pre-identified person	20	18	17
Unidentified person	0	0	0

Number Of Successful Results In Different Face States			
20 experiments	***Glasses***	***Beard***	***Face Mask***
Pre-identified person	18	16	5
Unidentified person	0	0	0

Another set of tests were performed to evaluate the face recognition process. Table 1 above summarises the conditions and correct result from 20 experiments. The facial recognition code is affected by different light and facial conditions. When the luminous flux fell, the number of successful attempts also

fell. In different facial conditions, the number of successful results decreases as the visible part of the face decreases. The code in the unidentified person has not been successful in any case.

A series of images and fingerprints of a specified user were initially recorded. Then the system was tested for recognizing the user, for establishing the cellular connection and for rejecting unknown users or people that temper the system. An example of an unknown user (unrecognized) is given in Fig 5. The legitimate user is "Erginay" (left) the unrecognized one is "Hatice" (right).

Fig. 5. Legitimate and non-legitimate user recognition test

V. CONCLUSION

In this paper we have focused on the use of IoT for logistics applications. An example of such an application called "Smart Mailbox" is described in detail. The design of the prototype including system architecture, hardware components and software is presented followed by experimental scenarios and results. The developed prototype is a good example of how simple off-the-shelf elements can be used to provide IoT functionality, increase the flexibility of logistics and supply services and ensure more reliable and safe experience for the user.

The advantage this prototype provides to The Courier is that it is unimportant whether the buyer is at home during cargo delivery. The advantage of the receiver is that he can remotely control the delivery. The prototype was tested for correct operation and the results of the tests are provided. Thanks to the facial recognition it is not possible for strangers or unauthorized people to open the box. Furthermore, the system allows tracking unauthorized attempts by saving the photographs of those who have not been identified.

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