Proposing a Real-Time Ticket Monitoring System for Public Transport in NSW, Australia

Rawdah Rawdah and Syed Shafin Ali
School of Engineering
RMIT University
Melbourne, Australia
rawdah.eee@gmail.com; shafin.eee@gmail.com

2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) | 978-0-7381-3042-2/20/$31.00 ©2021 IEEE | DOI: 10.1109/ICREST51555.2021.9331127

***Abstract*— The public transport system of New South Wales (NSW), Australia is impotent to receive 100% of the fare from light rail and buses due to the unavailability of a continuous real-time monitoring system. This scheme thereby seeks to help update the NSW public transport ticket collection system, with the aid of a counter that will be integrated into the public transportation within the Ticket Tapping Machine, to provide passenger count against the number of touches occurring at each stop; and thus, increasing the revenue. The product comprises of hardware and software components – the hardware system is located within the public transport while the software system incorporating a web portal is positioned for the authorities to have access to the real-time passenger data. At the hardware end, the ultrasonic sensors and the raspberry pi would detect the number of passengers on the transport and the LCD screen would display the number of passengers who had not tapped their smart card ticket. Additionally, the raspberry pi module used in the hardware component can denote the transportation location with the help of an in-built Wi-Fi component. With this designed technology, the authorities would be able to monitor and record the movements of the passenger in real-time system addressing the existing challenges faced by the NSW public transport authority, especially in the case of light rail and buses being used for free by certain passengers.**

Keywords— Real-time monitoring system, Ticket tapping machine, ultrasonic sensors, raspberry pi module, Wi-Fi component, LCD screen, NSW public transport

I. Introduction

It has already been shown that an integrated fare structure can cause a modal change towards public transport, which can contribute, in the long run, to a substantial rise in the number of sustainable modes users [1]. Free public transit rides, also called fare-dodging are possible because of easily accessible public transport services. Generally, across the world, fare-dodging on public transportation imposes the cost of more than 100 million Euro annually [3]. So, fare-dodging is a serious challenge and there are not so many strategies to prevent it from occurring when using RFID (Radio Frequency Identification)-based tickets. Radio Frequency Identification (RFID) is a common term for technologies that automatically utilize the radio waves to identify and track product, animal, people by means of using RFID tags integrated within them. RFID application is being used in widespread, to monitor public transport ticketing scheme [2].

The designed project is a real-time data collection and transmission system that helps to track passenger counting against public transport card taps. Opal is a contactless smart card ticketing device used for the electronic payment of tickets for all public transit systems in New South Wales, Australia. While it is mandatory to pay for the fare using light rails or buses, passengers prefer to prevent this by not tapping their tickets and travelling for free. This is where the initiative of this project plays an important role in the public transportation market.

This paper presents an enhancement to the existing ticketing system by introducing two important features of passenger counter and comparator that will ensure the correct usage of the ticketing system. Implementation of ultrasonic sensors over each door is connected to a counting system running programme that detects the entrances and exits of passengers. It would then cross-check the number of passengers using the Opal taps on the device, alerting the authorities to the number of passengers riding free of charge along with the location of the transit. An internal system announcement will also be made that would notify the number of passengers left to tap their Opal cards, insisting the passengers to use the smart ticketing system along with increasing the revenue for the transportation sector.

II. Literature Review

In public spaces such as shopping malls, transport, and airports, information on crowdedness in each location is useful for various purposes, such as promotion, protection, and emergency planning. The paper in [4] suggests a camera-based approach relevant to deep learning to estimate the number of individuals. However, camera blind spots are a big downside that might require additional camera installation involving privacy concerns as major drawbacks. Another approach related to complex machine learning process includes a density estimation system working on complex crowded places utilizing the centroid algorithm in the form of video surveillance [5]. Similarly, methods relevant to digital image processing has been integrated into facial/object recognition, counting the number of people, and the related wireless digital communication methodology has made it possible to integrate the intelligent module within the embedded system, computing the aspects of human/object motion [6][7][8]. Furthermore, **Irisys** [11] individual counting technology has been equipped with thermal sensors in various mall locations that help to quantify footfall around the mall. This helps retailers manage their workers' schedule as well as their cleaning times. It also shows the common and unpopular areas of the mall, which in turn will help with the marketing strategy of the mall authorities [12]. **Bionic systems**, on the other hand, counts and measures customer activity that helps to understand peak and off-peak hours and to decide on the allocation of workers for different activities.

Public transport in NSW operates with the help of Opal ticketing system which through tapping collects fare from passengers. However, this ticketing system faces a concern with the misuse of Opal card i.e. the passengers tend to travel for free within the peak and off-peak hours. Thus, the project intends to design a product that addresses the loss of revenue

faced by the public transport sector including electronic devices integrated within the system to provide data that counts the number of passengers using the vehicle free of charge. It is implemented to collect, compute, record and send data to the transportation authorities. Since public transport ticketing plays a major role in boosting the economy of the country, the design schematic is likely to improve the annual earnings, along with mitigating the existing problem of fare revenue loss.

III. Methodology and Implementation

A. System Specifications

Ultrasonic sensor: The Ultrasonic sensor serving as the counter is required to track the movements of both passengers travelling inside and outside the transport. So, the data from the sensors is being continuously recorded and processed by a chip device (raspberry pi) connected to it. In other words, there will be 4 sensors mounted at each door, 2 sensors at one end and 2 sensors at the last end. Based on the sensor trigger, the individual count will be monitored with the sensors being connected to the raspberry pi.

RFID module: The module functions in a similar manner to that of the Opal tapping machine monitoring the touch on and touch off. It works by transmitting radio signals between the reader and the tag. The reader thus transmits a radio signal and, when the tag is within range, it receives a signal and sends feedback that enables the reader to identify it and receive other data that it contains. So, there will be 2 RFID modules for each door, both linked to the same raspberry pi where the data will be processed periodically for each RFID module.

Raspberry Pi module: The raspberry pi module collects data from both the ultrasonic sensors and the RFID module where it then conducts computations to extract the difference between the number of passengers who have not tapped their Opal card. The module runs on a Linux based operating system known as Raspbian, and python language is utilized in programming the raspberry pi. Furthermore, the operating system comprises of an in-built Wi-Fi and Bluetooth support. The Wi-Fi module sends data from the pi to the cloud (Google Firebase) respectively, which can allow the higher transportation authorities to keep a track of the passengers using Opal in real-time. Concerning this, the data being sent from the Wi-Fi module uses separate key IDs and IP addresses.

GSM module: This module sends the computed raspberry pi data i.e. the time and location of the passengers not tapping Opal, to the authority's user interface.

LCD module: A 16x2 LCD display is used to demonstrate the discrepancy in the passenger count.

Fig 1. Proposed design schematic for the public transportation in NSW

B. System Architecture

Raspberry pi is a chip device that acts as a controller; ultrasonic sensors detect incoming and outgoing passengers and send data to Raspberry pi. RFID reader will count the number of touches and touch off when a particular RFID tag falls within its range acknowledging it to the raspberry pi. Then Raspberry pi manipulates the incoming signals from the RFID reader and ultrasonic sensors, determining how many passengers have not touched and displays the discrepancy count on LCD display along with an internal announcement. The recorded count and vehicle position will also be sent to the public transport authorities. This system process flow has been illustrated in Fig 2.

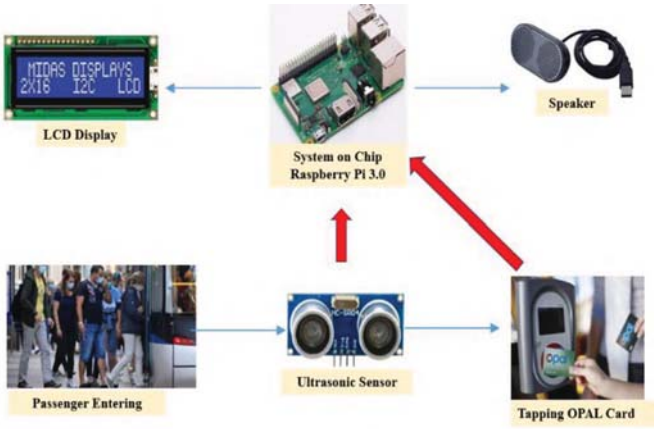

Fig 2. System process block diagram for NSW public transport

C. Programming Database

Python has been used for the interfacing of the relative sensors and modules using Mobatek server comprising of SSH client (secured server connection). The ultrasonic sensors have been programmed using the raspberry pi GPIO pins. Following the trigger of the sensors, a time delay has been initialized to monitor the passenger count. RFID module is coded in a manner that upon the module reading the card, the count increases or decreases with Opal touch on and off. Additionally, within the python code, the pyrebase library is imported to transfer and record real-time data over the google firebase using the accumulated Wi-Fi module of the raspberry pi.

Firebase is a web application development platform developed and accompanied by both Firebase and Google [9]. Pyre base is a Python interface to Firebase's REST API, allowing to manipulate the Firebase database with the aid of Python [10].

Subsequently, the ultrasonic sensors used include four pins of which the echo and the trigger pins connected to the GPIO pins of the raspberry pi model are used in determining the distance covered by the passengers. Thus, the python program has been coded in a manner that a threshold of the distance covered has been initialized. The distance covered will be reflected as the output in the RFID module so if the distance is less than the threshold value, it would count as 1. This count will increase according to the passenger entrance and decrease upon exit. However, if the distance is above the threshold, the count will remain 0.

The following concept has been represented in a manner of the flow chart in Fig 3.

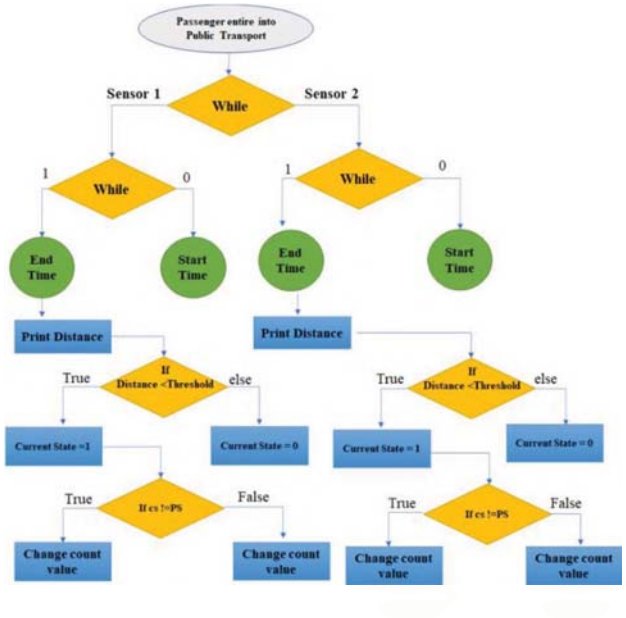

Fig 3. Flow chart for the proposed system programing database

A. Simulation Procurement

For the purpose of validation, a sample model has been implemented in MATLAB/Simulink. The model has been simulated to testify the design schematic.

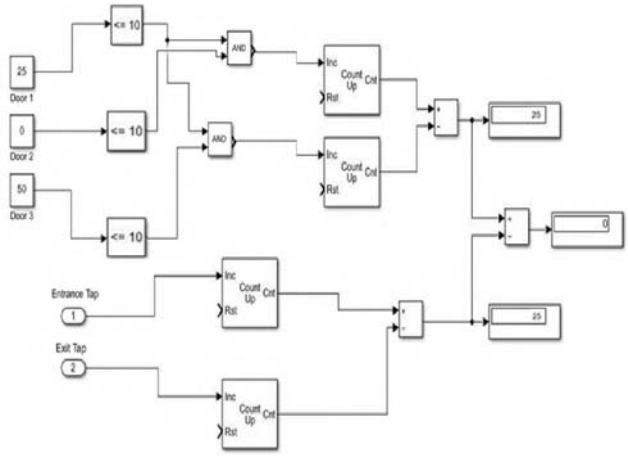

Fig 4. Simulink model for the proposed design schematic

The constant blocks in Fig 4 refer to the ultrasonic sensors used for counting the number of the individuals along with two tap buttons (entrance tap and exit tap) referring to the RFID module. Both the sensors and the RFID block behave as the input of the design schematic. The first two constant blocks have been initialized for the passengers entering the transport while the first and third constant block has been designated for the commuters exiting the vehicle. The condition has been set in such a way that if the constant number in the door 1 and door 2 is less than 10, it would refer to passenger entering and thus count 1. The difference in the count between the three-door counts would display the total number of passengers travelling. Accordingly, the buttons representing the RFID module is gathering the touch on and off counts. The difference in the count between the two taps gives the total number of passengers utilizing the Opal card. Similarly, the difference between the door count and the tap count would reflect the number of passengers who have not used the Opal card.

B. Design Prototype

The components have been accumulated together develop the designated design scheme with the interconnection to the pi model and the firebase for monitoring the passenger taps. In the prototype model, the ultrasonic sensors will be placed on the top end of the vehicle door, detecting the object moving through the door. Based on the door height, a threshold of the distance is to be set. Therefore, when the sensor detects any distance below the threshold limit, a count is increased.

Accordingly, the RFID module/reader will be placed on the top of the vehicle together with the LCD display and speaker. Thus, in case of any discrepancy on the passenger count and tap, the speaker will generate an announcement on the passenger count who has not tapped the Opal card. With the development of firebase, the raspberry pi module would have a connection with NSW public transportation where they can monitor the real-time passenger data.

In Fig 5, the block diagram defines the components of the product and the interconnections. The input system consists of the ultrasonic sensor and the RFID module connected to the Raspberry pi. A 5V battery source powers the raspberry pi model. The output system consists of a speaker unit, LCD and a google firebase, which will be accessible at the authorities' end.

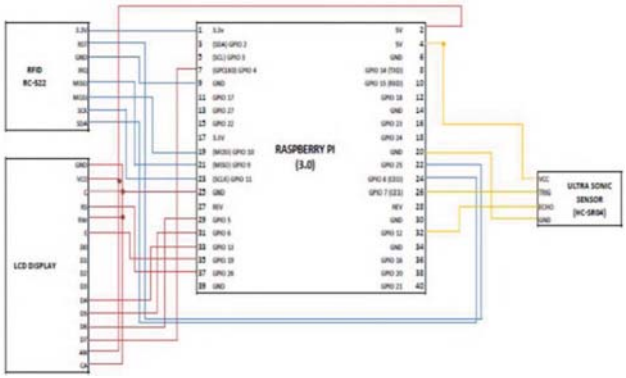

Fig 5. Model architecture and pin connection of the prototype

C. Prototype case scenario

Considering 26 out of 25 passengers inside the public vehicle have tapped the Opal i.e. tapping on the RFID tag of the reader, a discrepancy of 1 will be displayed on the LCD screen as shown in Fig 6.

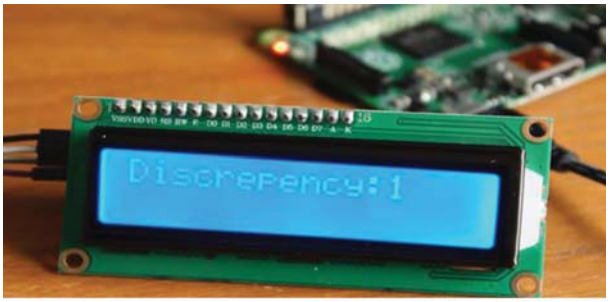

Fig. 6. A discrepancy of 1 displayed on the LCD Screen

V. FUTURESCOPE OF THE WORK

Integrating additional cameras for counting passengers with the aid of image processing technique will improve the accuracy of the design schematic. However, it would increase the cost and complexity of the model. Inclusion of the high range GPS module will help in updating count with relative location per minute notifying the authority for quick ticket check inside the vehicle comprising higher discrepancies.

VI. COST ANALYSIS FOR PROPOSED SCHEMATIC

To build the prototype and justify the proposal validation, the total cost of the schematic is approximated to be equivalent to AUD (Australian Dollars) $197. The breakdown of the component pricing is provided in the following table:

TABLE I
COST DISTRIBUTION FOR DESIGN PROTOTYPE

System Components	AUD ($)
4 X Ultrasonic Sensor	$16
2 X RFID module	$40
Raspberry Pi module	$75
LCD display	$16
USB speaker	$30
Opal Card	$20
Total = $197	

VII. CONCLUSION

The design aspect for this prototype included the selection of appropriate sensors for passenger counting and the type of contact to be used for the smart ticketing card. The sensors that were eligible for passenger counting comprised IR sensors, Ultrasonic sensors, Laser sensors and PID sensors. The ultrasonic sensor, which is based on the application, was the most relevant of all and therefore, been used. The next phase was to specify the number of ultrasonic sensors that can be used for each door and the orientation of the sensors to count the passengers. The Opal tapping machine operates on the NFC-based communication concept, and for this prototype design, the Opal tapping system cannot be used, so a similar RFID-based technology was chosen to track the number of tapings that occurred.

Accordingly, with python coding of the components within the Raspberry pi model, the system structure has been generated and any occurring difference in the passenger count is displayed on the LCD screen with an announcement made on the speaker. Along with this, the NSW transport authority can track the real-time data stored over the developed google firebase. It is also to be noted that the real-time data is sent to the authority using the Wi-Fi module built on the Raspberry Pi model. Considering this design schematic, not only do the authorities curtail the bypassing of the processing of public transit tickets but helps officials to gather data for further analysis – such as the detection of peak hours that can contribute to the enhancement of facilities like staffing, the frequency of trams, the measurement of revenue losses, and the detection of alternatives to minimize them.

VIII. ACKNOWLEDGEMENT

We would like to record our sincere gratitude and inspiration from the work titled 'RFID-based Ticketing for Public Transport System: Perspective Megacity Dhaka' which encouraged us to propose a real-time ticket monitoring system for NSW, Australia. In addition to this, we would also like to thank the 'Opal-Transport NSW' authorities for providing us with insights into the public transport system operation. Alongside, the project named 'Real-Time Data Acquisition and Data Transmission of MYKI Ticketing System' implemented in RMIT University has also provided us with some aspects with the progressing on the current proposal. We also thank the 'Power Electronics Laboratory' at RMIT University to provide us with access to work with this proposal. Accordingly, we also acknowledge the anonymous referees for their useful suggestion.

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