In-Station Delivery Service Safety Monitoring

Project Plan

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Background

The Mass Transit Railway (MTR) is a major public transport network in Hong Kong. Operated by the MTR Corporation Limited (MTRCL), it consists of heavy rail, light rail and feeder buses plying to and from stations. There are 11 lines in the network with over 160 stations spread all over Hong Kong [2]. Managing about 5 million trips on an average weekday it is the busiest mode of public transport in Hong Kong [1].

These MTR stations are home to about 1400 shops of different types ranging from ATMs to 7-11s to bakeries, most of which require frequent delivery of stock. Each shop has their own delivery schedules with delivery men coming periodically with goods to restock. These deliveries take place through the public exits with cartons piled upon delivery carts. At any point in time, there are hundreds of people/customers in an MTR station and their safety is of key priority. The safety of the public might be jeopardized due to a number of reasons. They may pile up the carts with towering cartons, which means that the delivery men can’t see where they are going, they may overspeed, crashing into passengers at times, or they may linger in areas where they are prohibited. In 2018, the Electrical and Mechanical Services Department (EMSD) which is the regulatory authority concerned, deemed that this was a hazard to the public and the risks associated must be mitigated.

In 2019, a solution involving iBeacons, was proposed, tested, and deemed to be successful. The MTRC later mentioned that the solution, although tested successfully, could only fulfill one of the three requirements and a more wholesome solution would be preferred. Over the course of this project, we shall try to achieve this objective and make a system which effectively and efficiently fulfills all of the given requirements.
Objectives and Scope

This industrial project aims to mitigate the risk of in-station delivery by the tenants of the MTR shop. The solution will bring forward a monitoring system to identify the malpractices of the delivery men in the MTR station. It will also alert the respective delivery men and send relevant and analytical information about the incident to the MTR department. Consequently it can be hoped that such misconduct will be abated in future and the safety of the walker byes will not be compromised with the introduction of this monitoring system.

As discussed in the background, the malpractices identified by the MTR department are over speeding, carrying goods above a certain threshold height and the entry of the delivery men into restricted areas. Therefore the requirement is a Real Time System to

1. Monitor the speed of delivery men
2. Monitor the height and number of delivery men
3. Monitor the path followed and detect entry into restricted areas
4. Alert the violation

The requirements stated above are what the MTR requires out of this project. However, due to restrictions pertaining to privacy and security issues, this project would be unable to take advantage of the CCTV footage of the stations. Moreover, the MTR department is reluctant to use hardware on trolleys or install any complicated infrastructure in the station. Therefore the fulfilment of Requirement 2 would not be feasible on the basis of these restrictions placed on the project. Thus, the scope of the project would be limited to requirement 1, 3 and 4.
Methodology

The project is currently at a young and evolving stage, which requires research and improving proficiency in hardware as well as software concepts, the methodology proposed in this report is tentative and could potentially see alterations, depending on updated findings and changing needs of the project.

Overview

The project involves building and experimenting with hardware, and the relevant software, to find a solution that addresses the safety needs of the MTRC. The technology produced must adhere to various constraints identified - with an emphasis on generalisation over all MTR stations, low administration and minimal intrusion. This will be followed by a system to alert the relevant entities regarding any violation of safety protocols and lastly, an application to aid in visual monitoring and breakdown of statistical information generated. We will be using RFID tags and readers to track the delivery men movement across the MTR station. We will be using two approaches.

One would be where the RFID tags would be stationary and the reader(delivery men) would be moving around. In this approach, the RFID tags will be installed on the walls of the stations and due to the advantage of them being very small and almost unnoticeable to the human eye, it will not affect the infrastructure of the MTR station. The reader would be worn by the delivery men and will act as a moving signal for the tags to catch.

In the second approach, we will install the reader into the MTR station and put the tags on the delivery men. This approach is the conventional method of using RFID but involves installation of hefty equipment which may affect the infrastructure of the station.

In both approaches, the interplay of signals between the tags and the reader will ultimately help to determine the speed and position of the delivery men.

Finally, the two methods will be compared and the best one would be adapted.
Materials, Equipment and Setup

The hardware that will be used for this project will be RFIDs. RFIDs are Radio Frequency Identification tags that use electromagnetic waves to track and identify objects. The RFID system involves two parts - RFID tags and a reader. The reader sends out waves through its antenna and and the tags are tuned to catch these waves. Once it catches the waves, it sends new waves back to the reader with relevant information and data and it is this data which is used for various purposes.[3][4]

Therefore, the hardware that we will require would be multiple RFID readers and tags. For the setup we will purchase and conduct the preliminary experiments in two unique environments -

1. Where the RFID reader is stationary which is a standard practise, with widespread application already - such as ATC.
2. An inversion of the above-mentioned system, where the RFID reader will be mobile and the tags will be stationary. The feasibility of such an approach will be researched in phase 1 of the schedule.

Considering cost, manufacturing and size implications, the final equipment chosen to tackle the issue may be commercially available RFID readers and tags or those built by the team.
As we do not have permission to conduct trials in the MTR, we will recreate real-life scenarios occurring in the MTR stations in environments we have access to. Once the hardware aspect has been setup and tested, we will draw comparisons and provide our conclusions with respect to the pros and cons of each system along with a SWOT analysis of the same.

Lastly, to aid in reading and visualisation, we will develop an application to provide analytics to the MTR to help them identify the shops that are responsible for these malpractices.

**Location**

To start off, we will test the system in our local surroundings trying to emulate the conditions of the actual environment inside an MTR station. This can be achieved by testing it on the HKU campus. By emulating the conditions of an actual MTR station with respect to the crowds, the architecture and the signals, we will have a good estimation of how our system would perform ideally in the actual setting.

The next step would be to get a to-scale map of the MTR stations to get an idea of where to place our equipment and finally do the actual testing there and obtain data for data analysis in the future.

**Restrictions and Limiting Conditions**

Due to data security and privacy of MTRC:

- Since MTR stations are operational for almost 20 hours a day, it gets hard to do even the smallest changes inside, therefore, the MTRC has made it clear that it is not possible to install any heavy-duty hardware.
- Due to privacy issues, we cannot make use of MTRC resources like CCTV footage, internet and existing hardware equipment.
- The MTRC has also advised us to involve minimal machinery in terms of resources and people.
Algorithm Design

The placement of multiple RFID tags or readers, depending on the results of experimentation and approved solution, will provide the capability to track the position of the delivery-men inside the MTR station facilities. Once the Proof of Concept is tested and verified, we will have an idea of what strategies to employ when considering placement of the devices. This would allow us to create a digital and to-scale map of the MTR stations. Then, using the readings of live positions and the time the RFID devices were triggered, we can calculate the speed at which the delivery man is travelling, i.e., using the formula:

$$v = \frac{d}{t}$$

$v$ = speed  
$d$ = distance travelled  
$t$ = time taken

Here, distance will be constant, and the readings will provide time, thus, enabling calculation of speed.

Furthermore, ability to determine live positions of the delivery-men will allow for identification of the routes taken, and consequently, identify whether or not a restricted route is being used.

The current plan is to use the **Kalman Filter** algorithm to convert the data generated by the RFID devices into valuable information. Kalman filter is an optimal estimation algorithm. It can be used to measure the state of a system when it cannot be used directly. This seems like an ideal algorithm as position is not accurately tracked within MTR stations from more direct methods such as GPS. It allows for extraction of information of what cannot be measured from what can be measured. The Kalman filter is applicable to dynamic models, wherein there are some controlled or known inputs, and the unknown or varying quantities are determined with the help of sequential measurements over time. The Kalman filter produces an estimate of the system, and is a recursive algorithm that requires only the last reading, not the entire history.

The resulting weighted average is closer to true values and has improved measures of uncertainty [5][6][7].
Again, depending on performance, the Kalman filter will be tuned or another - more suitable - technique will be picked up.

**Testing Techniques**

In preliminary testing stages, we will recreate an MTR environment in our local surroundings. Such an emulation will help us get an evaluation of our MVP. Finally, we will conduct tests in a localised and simulated environment in various MTR stations across Hong Kong. The RFID technology will be used in these mock sessions to provide data on the malpractices which will be done in a controlled environment.

**User Interface Design**

There will be two users of our application

- The delivery men, who will be alerted via the handheld device provided to them for position and speed tracking.
- The MTR department which will be provided with an application that will send alerts to station authorities, flag the store that has breached protocol, and also record the data for analytics and reporting.
Schedule and Milestones

September, 2020 - November, 2020
- Meetings with the MTRC to gather requirements
- Zero Down on approach
- Material procurement

End of Phase I
Deliverables
Detailed Project Plan
Preliminary Website
List of Hardware Materials

December, 2020 - February, 2021
- Construction of the MVP
- Prepare for the Interim presentation to be held in January second week

End of Phase II
Deliverables
MVP
Detailed Interim Report
Updated Project Website

March, 2021 - April, 2021
- Add data analytics to the application
- Test finished product in a local and simulated environment

End of Phase III
Deliverables
Final Report
Final tested Solution
Final Project Website
Final Presentation

Success
As shown in the figure above our schedule will be divided into 3 Phases

**Phase 1 (September to November)** - In Phase 1 or the Inception period we will be researching on the problem statement and having various meetings with the MTR to discuss and zero down on our approach. We will also use this period to theoretically think of our solution and decide the software and hardware requirements.

The **deliverables** for this phase would be - a Detailed Project Plan, Preliminary Website and List of hardware requirements.

**Phase 2 (December to February)** - Phase 2 will be a crucial period where all the research and on paper designs made in Phase 1 will be converted to a minimum viable product that can be tested in a local environment. The testing would be part of Phase 3. We will also be preparing for our First Presentation which is to be held in the second week of January.

The **deliverables** for this phase would be - a Detailed Interim Report, Updated Website and the MVP.

**Phase 3 (March to April)** - Phase 3 will be the final phase which will consist of robust testing of the finished product in both a local environment and in various MTR stations across Hong Kong. We will also be implementing the data analytics application which can be used by the MTR to analyse the violations and identify shops whose delivery are responsible for such malpractices.

The **deliverables** for this phase would be - a Final tested Solution, Final Report, Final Website and the Final Presentation.
References

5. Understanding Kalman Filters, Part 1: Why Use Kalman Filters?