Paper ID #

How object tracking and remote validation can improve capacity management, revenue analytics and the passenger experience

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Abstract
Passenger throughput at gated and ungated stations is a growing problem in three regards; capacity management, revenue analytics and passenger experience. By utilising top-down, 3D stereo vision sensors, innovatively integrated with existing ticket validation infrastructure such as tap on/off systems, the system has the ability to anonymously track passengers within a railway environment, know their validity status and be able to provide feedback to that individual based on that status. Personalised yet anonymous feedback is achieved using a fusion of visual and acoustic cues. The same system can be integrated with paddled gates and can be triggered based on the validity. The system is scalable as the sensors can be stitched together for an increased field-of-view. This paper reports how the proposed solution targets revenue protection at un-gated stations and the ability to use the same system to create Gateless Gatelines.

Keywords:
Object Tracking, remote validation, ticketing

Introduction
To date, the installation of automatic fare collection systems at transit stations (in particular, the installation of fare gatelines) represents the most effective deterrent to fare evasion on public transport. In addition to protecting revenue, fare gates also help transit agencies manage overcrowding on the platform, and collect invaluable data on where, when and how commuters like to travel. However, fare gates require significant infrastructure investment such that it is often only cost-effective for agencies to deploy them at high-risk and high-volume stations in central and inner-city zones. Not only does this make un-gated stations more vulnerable to both accidental and deliberate fare evasion, it impairs the collection of patronage data. As an example, in 2018, the reported figure for fare evasion in London was ~£100m (Dilley, 2019) and although this cannot all be attributed to accidental or deliberate fare evasion at ungated stations, it does highlight an opportunity where the proposed system would be able to provide an indication of how much of that lost revenue is accounted to un-gated stations. There is currently no system in place that can collect the data on lost revenue at un-gated

stations accurately.

Although tapping in and out when travelling is second nature to many customers, in gateless environments they are can forget and are subsequently charged a maximum fare. Whilst this can be refunded, many do not contact the operator and as such, the operator may hold millions of pounds sterling which they cannot use and is costly as an operations team have to manage the administration and reimbursement of those funds.

Congestion at ticket gatelines is also becoming a growing problem. According to travel projections in the United Kingdom, the number of journeys for rail passengers is likely to double over the next 30 years. In Sydney, Australia, train stations in the Central Business District will need to accommodate a one third increase in patronage by 2026. In response to these issues, Cubic is trialling how object tracking technology and remote validation can be incorporated into future station design to help manage station capacity, protect revenue and improve data collection while providing passengers with an improved customer experience.

Remote Validation in Ticketing

'Remote Validation' is a concept derived from Cubic's earlier research into creating 'Gateless Gatelines' (Kayhani, 2018). The premise of Gateless Gatelines involved using emerging ticket detection technologies such as Bluetooth Low Energy (BLE) and biometric authentication, integrated with existing ticketing systems, to seamlessly detect passenger tickets without the need for them to stop or validate at a physical fare gate. Remote validation enables 1:N (one to many) validation by removing the validation point away from the gateline, as opposed to the current fare gate system of 1:1 validation at the gateline. The latter impedes the overall flow of passenger movement in and out of fare gates whereas the former lends itself to an unimpeded flow at the gateline as there is no action required by the passenger at the point of passing the gate (whether that is a physical faregate or a virtual faregate with other forms of feedback).

Object Tracking

Cubic's current research into remote validation in ticketing, centers on utilising object tracking technology to anonymously determine the status of validity, based on real-time events, of passengers. 'Status of validity' refers to whether a user has validated a travel token or not i.e. tapped their contactless travel card. This outcome is used to trigger real-time feedback to passengers.

Object tracking technology is commonly used in applications such as queue management and analytics in airports and retail environments. To date, object tracking has not been used as a means of ticketing or revenue management. A key benefit of using object tracking for remote validation over using biometric technologies, or scanning Bluetooth signals on mobile phones, is its ability to track people completely anonymously through top-down, 3D stereo vision sensors, and is ticket agnostic which serves to provide the equity that is sometimes not considered in a world which is continually shifting towards mobile phone payments.

The system works by reminding passengers to pay for their journey using personalised (yet anonymous) feedback systems and it allows for the validation to occur prior to a gateline, meaning there is an opportunity to operate a 1:N as opposed to a 1:1 validation system that traditional gatelines operate. Operating multiple validation points prior to a gateline (1:N) means that ticket mis-reads, fumbles or other user-related actions that cause a delay to the throughput at the gateline, would be eliminated as the validation would happen away from the gateline and the validation points would also be increased if necessary.

Object Tracking and Remote Validation in Un-gated stations

The frequency of fare evasion is typically higher at un-gated stations as it is not immediately obvious who has a valid travel token. Not only can this threaten transit revenues, it also limits the amount of patronage data existing ticketing systems are able to collect. By introducing object tracking integrated with the current ticketing equipment, transport operators will be able to determine the number of people who entered and exited the station and derive how many people validated a travel token.

In an ungated station, the object tracking system and validation is linked to a feedback mechanism via a server that receives real-time coordinate and event data from the object tracking system. The same server then pushes API commands to the feedback mechanisms (such as the green ‘successful validation’ visual LED light shown in Figure 1) to trigger a response that is comprised of both visual and acoustic cues. These act as reminders and to some extent, a deterrent, to ensure travellers remember to validate their token prior to travel or to complete a journey.

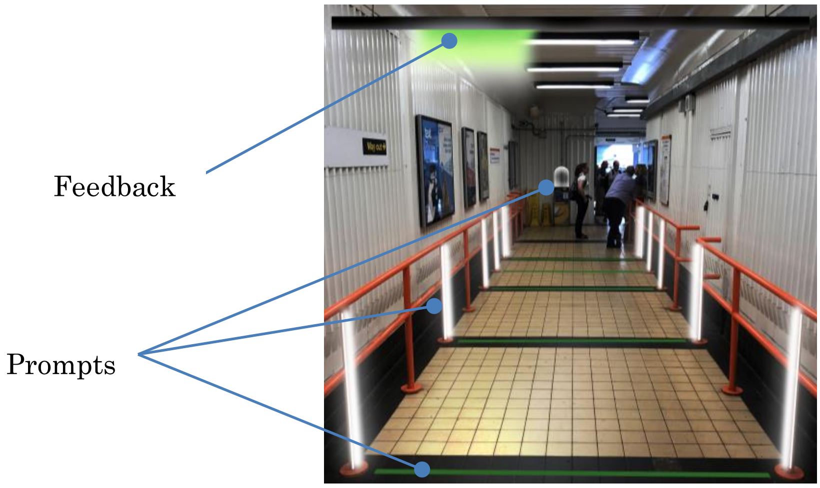

Figure 1 – Remote validation and feedback at an un-gated station (London)

Object Tracking and Remote Validation for gated stations

Using object tracking for remote validation is also feasible in gated stations though is aimed more towards capacity management. Although the physical gate will remain the same, passengers are given the ability to validate their token at a point separate from the gatelines (e.g. at the station entrance). In this scenario the prompt element is the only one which can be re-utilised from the ungated station environment. The reminder is the physical gateline and the feedback is the paddles on the fare gate opening and closing.

A passenger will be able to validate their travel token in the railway station and make their way across to the gateline. As they appear in front of a gate, the paddles will open based on the validity status of that passenger. Throughout this process the tracking system knows nothing about the individual or their travel token, only whether they have successfully validated a token or not.

Object Tracking Pilot

Our pilot was aimed at improving the number of validations (linked to revenue management) and to determine the usefulness of the data that an object tracking system can record on potential revenue leakage at an un-gated station in London. Prior to the pilot, we researched specifically when, where and how to provide the right type of feedback to passengers. This was an important step that shaped our setup and design for both the lab environment and station pilot.

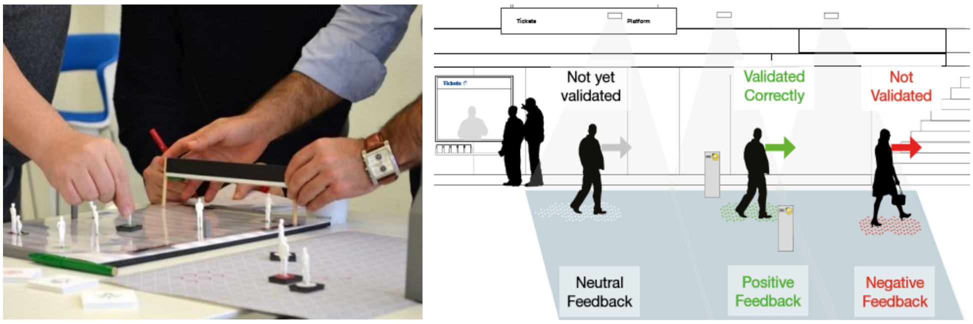

Figure 2 – Researching the Feedback System (Onida and Hughes, 2019)

The scope the trial was to use object tracking technology integrated with stand-alone validation systems to provide personalised, yet anonymous feedback to passengers as they enter and leave a railway station.

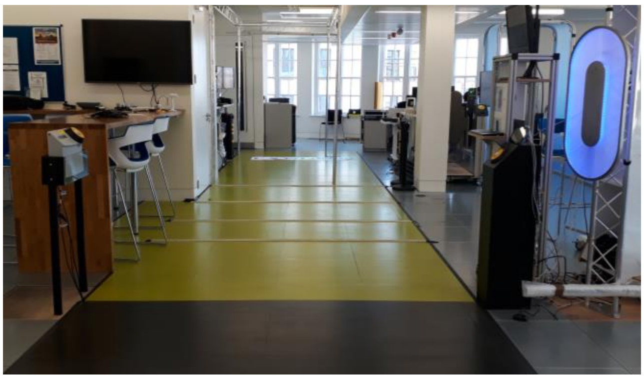

Figure 3 – Remote validation and feedback at an un-gated station (London)

We selected a station without faregates to develop the personalised feedback mechanisms as faregates, by their nature, is already a prompt and feedback mechanism itself. We wanted the station to have more than one validation point and for there to be peaks of high capacity. Our chosen station was Cambridge Heath in London.

Having analysed the station, we developed a representative trial in our lab (Figure 3) to gain an understanding of the setup and how users may react to our design choices when exposed to the lab version. Design modifications were necessary to prepare the system for the trial. These modifications considered the findings from the lab tests and any environmental, operational or practical constraints for the selected station. We explored how to adapt the station layout to ultimately remind users to tap in/out at a gateless station. These designs were dynamic and iterative, by means of user feedback.

Object tracking and data collection

Through its ability to anonymously track objects in a given space and determine the status and validity of people with existing payment systems with integration to an object tracking system; this solution provides new insights to transport operators that were previously not available.

Figure 4 – Data Stream – Sensor Push to Server & Tracking UI

Figure 4 shows the data from the events that are streamed from the object tracking sensor(s) to a server. The data is limited to what is shown. As an event, such as crossing a pre-defined line or entering a zone is triggered, it is streamed to a server through a wired Ethernet connection. This same connection is used to provide power to the sensors (PoE).

As the data is streamed to the server, it is parsed and the data that is of interest is momentarily kept, specifically the objectId, object coordinates, timestamp and the zone that was entered – note that the data contains no personal identifiable information and the video feed is extremely low quality to reduce latency as well as protect users with their privacy. With the integration to a validation point, the system can determine the object (person) that validated a travel token with a high-level of accuracy. The system compares the event received from the validator to the event received from the object tracking system and makes a comparison. This data can be useful for revenue management and analytics, specifically determining how many people entered and exited an area compared with how many transactions occurred. Currently, operators only know how many transactions occurred, not how many passengers entered and exited the transit system, let alone linking the two together.

Method

The system was installed, tested and modified in three phases (Pre-Wave, Wave 1 and Wave 2) for the duration of three months. The purpose of the phases was to develop an understanding of the user responses to different designs that were introduced as part of the phases. As part of our research to determine the effectiveness of the system, thirteen headline questions were asked for the qualitative and quantitative analysis (Goldthorpe, 2019.) as well as capturing transaction data to determine the effectiveness of the system regarding improving revenue. Interventions to collect data from passengers were completed at the end of each wave to allow new design iterations to have settled.

Diagram

Figure 5 provides a high-level system diagram that outlines the core functionality of the system and the components in use and how they interact at a basic level.

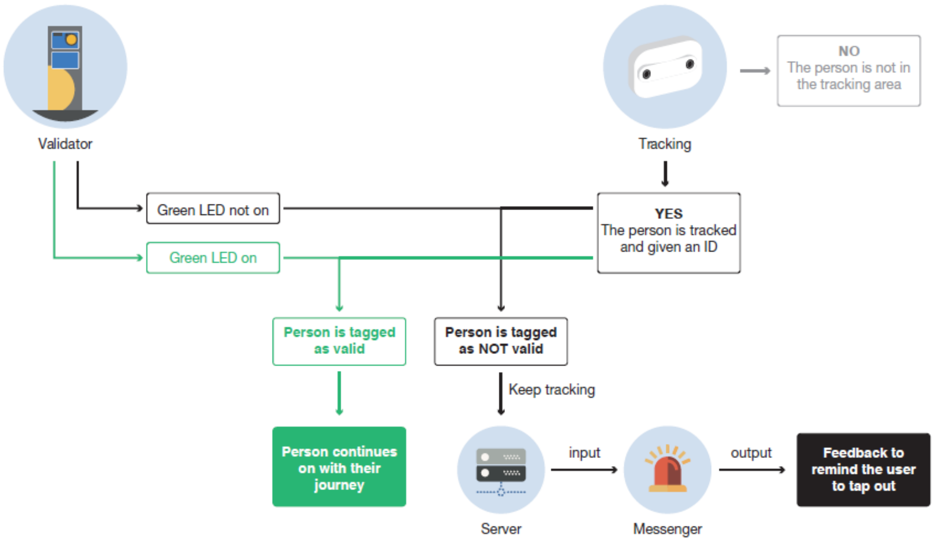

Figure 5 – Visual System Flow for Trial (Onida and Hughes, 2019)

Wave 1

First intervention, Wave 1, (Jan 2019) consisted of:

- Overhead light that changes colour, with sound as people passed through
- Blue lanes on the floor with contactless card symbol
- Blue circles around validators with Oyster branding

Figure 6 – Wave 1 Designs

Wave 1 consisted of low-level visual feedback at floor level, visual LED feedback ceiling mounted and directional sound.

Wave 2

Second intervention, Wave 2, (Feb 2019) consisted of:

- Overhead light that changes colour with sound (sound adjusted from W1)
- Halo around validators that changed colour based on validation*
- More prominent blue lanes on the floor with Oyster branding
- Blue circles around validators with Oyster branding

*Qualitative only. The Halo was not in place during the quantitative research.

Figure 7 – Wave 2 Designs

Wave 2 included enhanced visual messaging added to the validator as well as more immersive and impactful visuals to the floor to highlight validation points that are currently in use, how much they are being used and using the object tracking system, to direct passengers to the validation points which are available during busy periods of high passenger throughput.

Results

As part of the project we analysed changes in transactions by comparing the transaction data before, during and after the trial and Cambridge Heath Station and we used a similar station (London Fields) as a baseline comparison. Although there are a number of factors in-play such as actual usage, holiday periods, all of which cannot be compared to a baseline without historic data, the results did indicate a quantitative improvement in the number of taps during the trial – the Oyster transaction on entry to Cambridge Heath showed to improve when compared to a similar station (London Fields) during the same time period.

The quantitative results showed that the trend in Oyster entry transactions at Cambridge Heath and London Fields were similar, however during the pilot, the percentage decrease in entry taps was less in Cambridge Heath in January through to March 2019 compared with London Fields, suggesting there may have been more taps on entry into Cambridge Heath as a result of the of the system. Since there was no baseline data prior to the introduction of the system, the result cannot be fully conclusive. However, the qualitative data on station entry and the comparison across London Fields does suggest that the percentage of people tapping in on entry to Cambridge Heath was higher compared with that of London Fields for the same time period that had similar trends in entry transactions. Our qualitative results (Figure 8) echo these findings as passengers stated that it was easier to remember to tap in on station entry during the pilot.

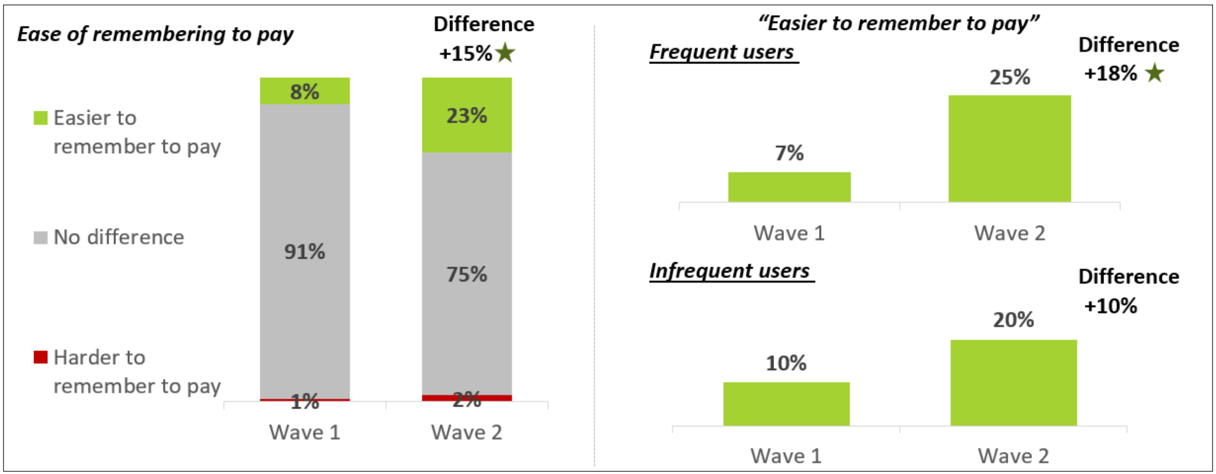

Figure 8 – Ease of Remembering to Pay

Baseline: Wave 1 (168), Frequent travellers (117), Infrequent travellers (51) Wave 2 (182), Frequent travellers (113), Infrequent travellers (69)

In relation to tap card compliance, the system proved that it became 'easier to remember to pay' with Wave 1 to Wave 2 interventions increasing by 18% for frequent travelers and 10% for infrequent travelers. This result is directly related to the feedback mechanisms that were introduced in the different trial phases and as expected, Wave 2 had the most impact as it created a more immersive environment that stimulated visual senses, specifically aimed at floor level which our research suggested is more visible compared to signage at heights. The visual and audio experience around the prompt, feedback and reminder elements were designed to remind passengers to pay for their travel to avoid being charged a maximum fare and the results suggest that the design elements made it simpler to remember to pay, especially for frequent travelers.

Revenue Performance

To further understand the quantifiable results from the trial, we compared the transaction data before, during and after the trial. It is important to note that we did not have baseline data on the number of passengers entering and exiting the station prior to the introduction of the system.

We knew that by looking at Cambridge Heath station only was not going to provide enough insight to determine the effect of the system, so we also looked at the transactional data for a similar period for a station close by, on the same network with similar infrastructure and size – London Fields. This would allow us to determine if there was a similar trend at both stations, and if the transaction data had changed as a percentage comparison, we would stipulate that the system at Cambridge Heath will have made a quantitative impact to card tap compliance.

Figure 9 and 10 shows the transaction data for Cambridge Heath and London Fields. During the pilot, there was nothing in the results to suggest that there was any impact to people tapping in or out with the introduction of the system when comparing Cambridge Heath and London Fields stations. *This* *result is not conclusive as we will see below once we further dissect the data*.

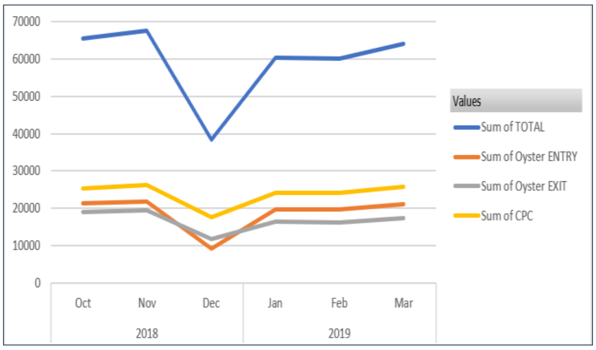

Figure 9 – Cambridge Heath Tap Data

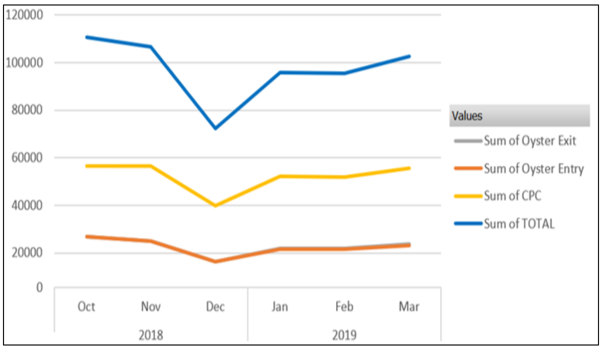

Figure 10 – London Fields Tap Data

An area to consider is the effect the system had for entry data, specifically for starting a journey. If we consider a passenger that accidentally forgot (or purposefully) to tap in at their origin and then exit from Cambridge Heath, they may decide not to tap-out to avoid being charged the full journey (even though they could have called the helpline to claim this back – but the effort of just not paying in this instance is a lot less, especially as there would be no prosecution at this point at an un-gated station). This means the effect of the system cannot be truly measured for exits unless the origin and destination station both had the new system in place, but if we look at the transactions from entering the station we could determine the effect the system had at the start of passenger journeys (we only had access to Oyster Card data for entry and exit counts, not contactless bank cards).

Taking October 2018 as the baseline (complete month prior to any interventions) and compare January – March 2019 (December 2018 was removed due to incomplete dataset for both stations) entry counts we see that there is less of a decrease in transactions at Cambridge Heath (Figure 11).

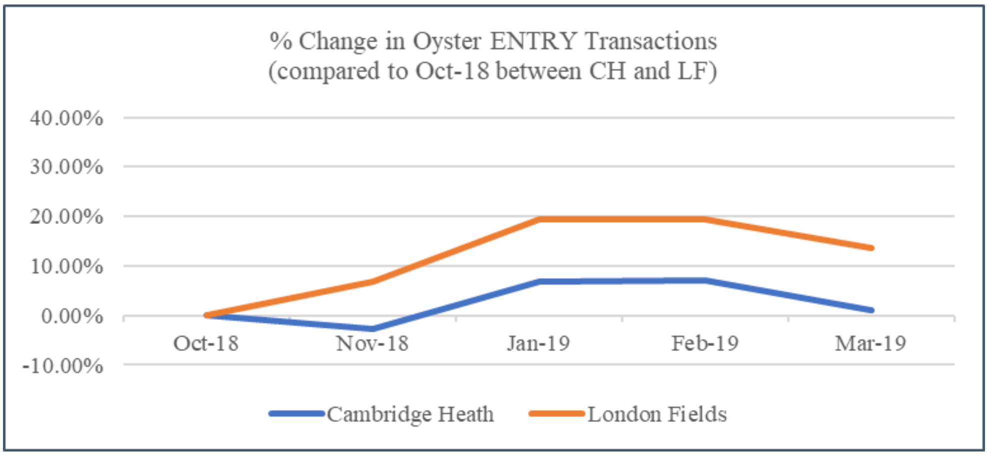

Figure 11 – Percentage Decrease in Oyster Entry Transactions

Figure 12 indicates the different experience looking into the station compared with looking out, and the results suggest that there has been an improvement in card tap compliance for entry only which may also coincide with the visual experience.

Figure 12 – Entry into Cambridge Heath Station (left), Exit out of Cambridge Heath Station (right)

Conclusion

The results suggest that there has been an improvement in card tap compliance by introducing feedback mechanisms that are powered by the integration of object tracking technology and contactless payment validation systems, particularly for entry into Cambridge Heath Station.

The results showed that object tracking technology, fused with effective feedback mechanisms could improve revenue performance at un-gated stations by prompting, warning, notifying and informing passengers of their validity status throughout their payment journey.

Being able to influence passengers to pay for travel using visual and audible cues lends itself to the possibility of influencing and ultimately, improving flow management in railway stations.

Having successfully integrated object tracking with existing payment systems in an un-gated railway station, the next steps would be to use the learnings from the trial and implement the system on a gated station to test the remote validation concept and to determine if we can also influence passenger flow and movement. This may enable gated stations to become truly gateless from a revenue protection standpoint, whilst understanding that physical gates have roles beyond revenue protection. The new source of data collection from the object tracking system, integrated with payment systems also provides new insights on where and when to accurately deploy revenue protection staff.

Acknowledgements

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