Mission of the project

*Intro*

*As the height of the pandemic is past, the public has been gaining confidence in the safety of public transit, leading to a rise in the demand for rail travel thorough out the country. In fact, the number of individuals arriving by rail to England's major cities on an average day has at least doubled since 2021. Although total numbers have not reached the levels seen in 2019, the rise in passenger numbers over the last two years has been unprecedented, setting the scene for further growth of the rail industry in the following years [1].*

*It is clear that rail travel remains a common method of travel in the UK, however following a pandemic, some members of the public are still apprehenisve to board very busy trains which have little personal space, or even in some cases where only standing room is available. The chance of crowding would also appear to be increasing, this is because as the industry gears up in anticipation of a large increase in demandIntro*

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*It is clear that rail travel remains a common method of travel in the UK, however following a pandemic, some members of the public are still apprehenisve to board very busy trains which have little personal space, or even in some cases where only standing room is avaliable. The chance of crowding would also appear to be increasing, this is because as the industry gears up in anticipation of a large increase in demand, the total number of train seats arriving at most British cities is decreasing as a result of a reduction in rolling stock and the running of shorter trains since the beginning of the pandemic [1]. We believe that post pandemic train travel could be made safer and more comfortable if the public and train managers could have some way of tracking the exact numbers of passengers onboard and the distribution of those passengers between carriages, this would allow for better planning and management of rolling stock and additional carriages and also give the travelling public prior warning of how busy the arriving train is expected to be and which carriage they should expect to find enough space for them and their baggage.*

*National rail and London North Eastern Railway (LNER) have worked together to produce a system which shows an approximate level of occupancy within the train, which is displayed beside the platform, however this system produces inaccurate information because it only takes into account the pre-booked tickets and assumes that all of these pre-booking customers are sitting exactly at their assigned seats and that no one is getting on the train without a reservation. This is an inaccurate system because the nature of rail mass transit means that many patrons will show up for a train without prior booking and also because people often sit in a different seat that that printed on their ticket if a free seat is found elsewhere in the train. At Hotseats we believe that this system could be greatly improved to provide accurate real time information about train seat occupancy.*

*Hotseats applies the internet of things to the rail industry, creating a smart platform which is able to sense the presence of a passenger and accurately log and distribute exact information about where each passenger is actually sitting on the train thanks to pressure sensors located under each seat which could provide real time data about exactly which seats are occupied at any point in time. This information can be used by management and logistics to plan around trends, such as an increase in demand at certain section of the journey which may indicate that additional carriages may need to be added at certain points on the journey. Hotseats can also display less specific information to passenger waiting on the platform, so they can walk along the platform to the least busy carriage in anticipation of boarding.*

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Text

Description automatically generated

Graphical user interface, application

Description automatically generated

Technical Overview

Our IOT platform includes a sensor node, which senses when a weight is applied to the seat and this produces an logical positive signal, which is sent along the workflow as seen on the left.

Cloud storage is included to create a database of the previous states of the system such that historical data surrounding the train's occupancy can be reviewed by the train companies. Hotseats believe that with more accurate data rail management could better plan and provide a better and safer service for all. For example if a service from Edinburgh to London is reliably more busy with passengers on the section from York to London Kings Cross train managers and engineers can arrange the addition of fresh carriages in York as required.

Node red is employed such that this data can be visualised and processed as necessary, this also allows us to produce an alternative carriage occupancy graph which can be displayed above the platform, replacing the less accurate system already in use by LNER.

What is MQTT

MQTT is a standard messaging protocol, which is specifically designed as a very lightweight publish and subscribe messaging transport solution which is ideal for connecting multiple remote devices whist consuming minimal bandwidth. This provides a robust method for IOT devices to be connected regardless of the geographic location of those devices. This is important for Hotseats which requires connectivity over vast, cross country scale distances. MQTT’s lightweight design is also ideal for Hotseats because these long distance trains will often travel through areas with limited bandwidth and be transiting through vast spaces routinely.

Diagram

Description automatically generated

System detail and critical analysis

NodeMCU 1.0 (ESP-12E)- This ESP module is a low cost, low voltage ESP module which enables the user to connect to the network and communicate using WIFI. This is perfect for our project as its low cost makes it good for prototypic and would reduce costs of the whole project if implemented. The low voltage design also reduces total power consumption.

This project was coded using imbedded C, this is an extension of the C family of programming made possible by the C standards committee. Embeded C is chosen for this project because of the use of Arduino and due to its enhanced microprocessor abilities [8].

The following libraries were used.

ESP8266WiFi- This library is used to connect the ESP8266 module mentioned before to connect to the network. The module is operating as a client, so that it is capable of sending and receiving data.

Pubsubclient- This library enables the use of the MQTT messaging protocol (see overview section for more information)

ESPnow- ESPnow allows data to be sent between ESP modules without the use of WIFI. Data payloads can be sent between modules, given that the payload is under 250 bytes in size [8]. This is suffice for Hotseats.

ArduinoJson- JSON or Javascript Object Notation is a common method of storing and transferring structured data using the network. ArduinoJson enables parsing, encoding and decoding of data packages.

Technical challenges

* Sometimes people place luggage on an empty seat, which may be counted as an occupied seat

* With so many sensors, i.e one on each seat the reliability of the system will reduce [9] (see below for more detail)

* The cost of implementing the system will be relatively large, as lots of sensor hardware will be required.

* Inspection of hardware will inevitably need to be done from time to time which may require further training of staff and could take time as there would be a lot of sensors to inspect.

A brief reliability analysis

Reliability of a component is a probabilistic measure of how likely it is to malfunction, although this number is normally tiny, with the inclusion of this many sensors the overall system reliability will decrease [9]. The use of MQTT also adds a reliability element from the broker itself. In reality the reliability of the system will be a function of the sensor reliability and the reliability of the network architecture. This could become a barrier to Hotseats adoption within the rail industry if not properly managed.

System Improvements

One way in which we could improve the system further is by the addition of machine vision, as this would add further sensing capabilities which could confirm if the load applied to a seat is a human or luggage. On the other hand this adds complication to the system which has further cost implications and further complicates the reliability function as breifly defined above.

Project Extensions

This IOT solution could be applied in a number of additional ways such as on busses and trams for example.

Using live time seat occupancy sensing technology, cloud storage, some localisation system to locate the bus or tram and a mobile app of some sort, bus and tram users would be able to evaluate the crowding on the approaching vehicle.

By the addition of an LED, a traffic light system could be introduced where a LED lights up at the train doors and vestibule areas, a red light displayed in these areas could discourage crowding.

The use of machine vision would help to confirm if the load applied to a seat is indeed a human, this could also be useful for underground systems, where a machine vision enabled camera could be placed in the vestibules to evaluate the level of standing room available.

Design Influences

When discussing a new innovation, it is important to discuss the developments of the past and how these technologies can help to inform the design and curation of a new project such as Hotseats. Through discussion and consideration of previous technologies, the phenomenon of accelerating change can also be facilitated [9] .

Considering the work of previous engineers and scientists paints a more detailed picture of the merits of a novel solution and the barriers that have been discovered in the creation of similar technologies in the past. Studying previous applications of similar technology also helps us to develop a more detailed viability study for our IOT platform.

1) Case study- GM Belt Assurance system

General Motors amongst other car manufacturers including Volkswagen have produced a system which is capable of detecting the presence of a driver in the drivers seat by the use of a similar pressure switch, when the system detects the presence of a driver and the vehicle is turned off or not in motion, a parking break is applied by the computer. The system also includes a sensor which detects the fastening of the seat belt.

The system has two main features, firstly the seat belt sensor is wired to the ignition system so that the engine can not start if the driver is not wearing a seatbelt, the system would not allow the parking break to be disengaged if the seatbelt is not latched.

Although this system is not an application of IOT, Hotseats share some of the hardware and technical goals. This safety system was overall a successful project and has become a common feature on many different cars [10].

2) GM belt Assurance system- Design issues

When researching projects of a similar nature to Hotseats, it was important to gain an understanding of some of the technical and design issues faced by GM and Volkswagen. Some of the drawbacks of the system included a common issue where baggage placed on the passenger seat could trigger the system which has no way of distinguishing between a load arising as a result of an object and a human, perhaps machine vision or any additional sensors could also help here [10] [11].

The addition of a sensor, designed to detect the presence of a latched seat belt and its integration into the vital ignition system causes the reliability of the system to decline.

The lack of a method to verify that the load applied to a seat is indeed human meant that drivers could still latch the clip into the buckle without actually wearing the belt correctly. Again this could be remedied by the inclusion of machine vision, which could also verify that the belt is correctly over the shoulder of the driver.

How can one apply IOT to belt assurance systems?

The application of IOT to these belt assurance systems could become useful for law enforcement, if the car could send data packets indicating that the driver may not be wearing a seatbelt along with the vehicle licence plate number, this information could be passed on to traffic enforcement similarly to ANPR which is already in use by police all over the UK. IOT could even be applied to more systems within the car such as speedometer readings which could alert traffic enforcement of dangerous and antisocial driving incidents in the area.

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