Optimization of Passenger Distribution at Metro Stations through a Guidance System

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Abstract. The steady growth of population in cities demands an efficient subway management system. To alleviate crowding on certain trains and subway lines, especially during rush hours, we propose a system which optimizes passenger distribution. Through visual cues directly displayed on the waiting platform, the passengers are informed about the wagons' occupation rates, so that they can make a decision about which wagon to use before the subway arrives. Experimental results show that the relevance of the implementation is significant for both passenger satisfaction as well as train operators. In combination with a graphical user interface, the advantages of a guidance system could be demonstrated. The acceptance of our system was guaranteed by 75 % of the passengers questioned, who stated they would use such a guidance system.

Keywords: Metro Stations, Optimal Passenger Distribution, Guidance System, Surveys, Passenger Comfort

1 Introduction

The trend of population growth in cities causes higher dependency on public transportation and therefore a greater need for its optimization. This growth demands consideration of more efficient subway management systems that alleviate overcrowding on popular trains and subway lines, especially during the busiest travel times. The benefits of an optimal passenger distribution at metro stations include more efficient use of existing trains, increased capacity and more average space for every passenger.

In traffic planning road users' needs should be catered to for the sake of efficiency, and safety. We present in this paper an approach for the optimization of passenger distribution that we then evaluate through a model and software platform.

2 Related Work

The behavior of passengers on the station platform in terms of their distribution among train doors has been investigated in several works [1], [2]. These studies showed that the position and number of platform exits and entrances has a significant

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influence on passenger distribution. For example, as stated in [3], a station with several platform entrances results in a more balanced passenger dissemination. Uneven distribution causes delays for trains when the operator needs to allow extra time for boarding, which results in longer waiting times for passengers. In order to alleviate this situation, passengers on the train platform should be directed to doors where there are less people waiting to board, thereby orienting themselves better before the train arrives.

In [4] an approach was proposed in which the train adjusted its position while stopping depending on passenger distribution on the platform. However, this solution requires longer platforms that are not always available.

Relying on this idea, several field experiments involving adjustments of the train stopping position have been performed at the Schiphol airport train station in Amsterdam, Netherlands, this measure resulting in a 20 % decrease of station dwell times during peak demand and a dwell time variation decrease of approximately 50 % [5].

The Austrian train service operator ÖBB has also planned measures to lighten congestion at railway platforms. However they do not include any technical implementation, but rather use a system based on a manual count of passengers [6].

In June 2016 Siemens introduced a new system to guide passengers to less occupied areas [7]. However, the guidance system is only implemented within the train. Therefore, there are no benefits that reduce passenger exchange time. Additionally, this method of redistribution of passengers once already inside the train is inefficient if passengers must navigate around luggage, other passengers, or doors at gangway connections in order to get to other sections.

We propose in this paper a technical solution based on a guidance system where the passengers can see from outside the approaching train which wagons are less crowded.

3 System Design

Our proposed concept of passenger distribution aimed to increase the capacity of the existing transport fleet and ensure a smooth passenger exchange, which would result in fewer delays and an overall improved passenger experience through increased interior space and personal comfort.

Using a user-centric approach in order to find out what the specific needs of the passengers were, we deployed a questionnaire among railway users. The functionality of the approach was then tested by a system consisting of a model and software application that simulated a real scenario and several possible variants by means of a further survey and expert analyses.

Our system consisted of a platform that conveyed information related to the occupancy at each carriage. The goal was to direct waiting passengers to the areas of the platform that corresponded to the doors of less crowded wagons on the oncoming train. As the information was provided prior to the train's arrival, passengers could orient themselves ahead of time to the most convenient doors.

To this end, we computed the number of passengers by calculating the weight of each carriage via a control system. This measurement was implemented before the train left the previous station and its result was then broadcast to the next station. The system was developed to be extended to all existing stations.

4 Implementation

As previously mentioned we implemented a model in order to calculate the passenger distribution in one carriage in real time that was then inferred to the remaining set of carriages.

The program graphically simulated a subway station and showed the optimum distribution of passengers through the control system, indicating entrances with less occupancy rate. By determining the distance between the undercarriage of the subway train and its axis, the degree of capacity utilization of the carriage could be inferred.

The measuring time corresponded to the period of time before the departure during which the passengers are aboard and the doors of the train closed. The system read 100 values per second of each distance sensor and calculated the average of the last 20 records. In addition, outliers on the basis of a deviation of plus/minus 20 % of the mean value were identified and discarded.

4.1 Requirements Analysis and Results

In order to determine the need for the implementation of a guidance system in Vienna, we measured the movement of passengers inside a train on a regular working day (Wednesday), between 12:00 and 16:00 in 101 trips. We found out that in 45 % of the cases the wagons occupancy rate ranged between 0 and 20 % moving on average 0.93 people to another place. In 39 % of the cases the wagons occupancy rate was 21-69 % moving on average 0.79 people to another location inside the wagon. In 16 % of the cases the wagons occupancy rate was 70-100 % moving on average 0.19 people to another place.

In order for a system to be user friendly, it needs to be effective and as simple as possible, ensuring that it is understood intuitively. To find out which system could provide the carriages occupancy information in the best possible manner, we designed several messages that we then evaluated through an online survey distributed to 121 participants (males =73, females =48), that belonged to the following age groups: 15-25: 57 people; 26-45: 50 people; 46-65: 14 people.

Questions related to the color code and text labels, as well as fields for comments were also included in the survey. Fig. 1 and Fig. 2 show the messages that could be selected within the online survey. The first three displays were designed to be located between two door sections at a station. The last variation consists of light indicators in red or green according to the capacity of the oncoming carriage, located above each entry section in the metro. The latter variation obtained the highest scores and was selected for implementation in an evaluation platform that included a train model with several wagons.

Additionally, we performed a study related to preferences for entering the train. Results from both surveys show that the majority of the passengers entered the metro or train following a precise strategy. Moreover 75 % of the participants stated that they would use a guidance system to improve their travel experience with a user interface similar to the one presented in this paper (see Fig. 3).

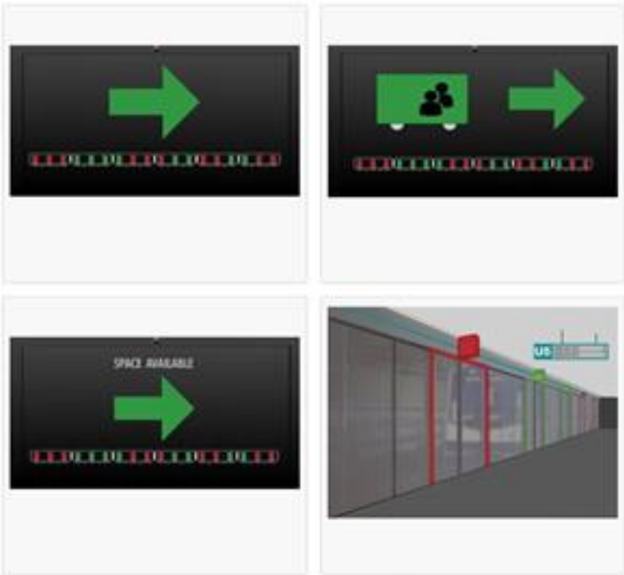

Fig. 1. Design of potential messages to display within a guidance system.

Fig. 2. Guidance system selected as favorite among the participants in the survey.

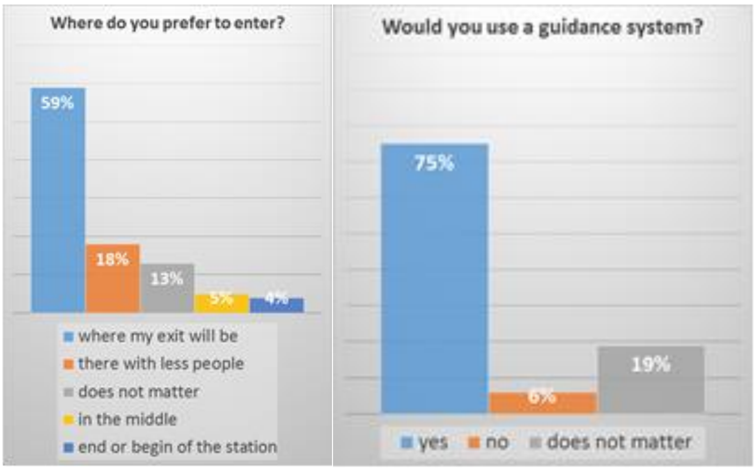

Fig. 3. Results from survey 1 and 2 indicating the preferred entrance location in the metro and the willingness to use a guidance system for find the carriages with less occupancy.

4.2 System Implementation

To compute the passenger distribution in one carriage in real time, we built a model consisting of one carriage for which we calculated the distance of the carriage floor to the ground in real-time. Pressure sensors are already available in trains and are used for regulating the breaking force according to the load of the train and also for compensating the balance immediately as soon people enter the wagons. Relying on this, the air spring was replaced by an ordinary spring that compressed with the weight of a load in the carriage. Fig. 4 illustrates the functioning of the developed system.

We then inferred the passenger distribution for the remaining wagons. To this end we used an ultrasonic sensor mounted between the bogie and the wagon body. The sensor acquired the real-time data from the center-line distances to determine the carriage load through a Raspberry Pi 2 board that was connected via wireless to a laptop.

In addition to the hardware setup, a Java program, (see section of the code below) was developed to evaluate the measured values from the sensors related to the spring deflection, and to show the data in the user interface. Once TCP/IP connection was established, data was retrieved and processed into a readable format for later evaluation. The mean distance for the middle entrance was then calculated and stored. After verifying outliers and backing up values, GUI and LED data were displayed. When the train left, the pressure levels of each entrance were set to the corresponding state through a color code in the relevant station.

The user interface displayed a subway station with several entrances and a guidance system indicating the occupancy of each carriage based on the computed data. Fig. 5 depicts the setup of the developed platform.

```
connectTCPIP;
while(true) {
        stringData=readDataLine();
        checkInput();
        pressures=stringData.split(",");                //
split csv; string
        pressure[0]=Integer.parseInt(pressures[0]);    //
assign the parts as integer
        pressure[2]=Integer.parseInt(pressures[1]);
        pressure[1]=(pressure[0]+pressure[2])/2;       //
calculation for the door in the middle
        checkValues();
        createBackups();
        drawGUIGraph();        // for system view
        if trainLeavingNow do for all i {
// send all wagons' data to station as soon the train
leaves; next wagons next 3 i's
                if pressure[i]<=50% nextStationEn-
trance[i].Color = green;
                if pressure[i]>50%  nextStationEn-
trance[i].Color = yellow;
                if pressure[i]>80%  nextStationEn-
trance[i].Color = red;
                updateNextStationLEDs();       // update
them accordingly
        }
}
```

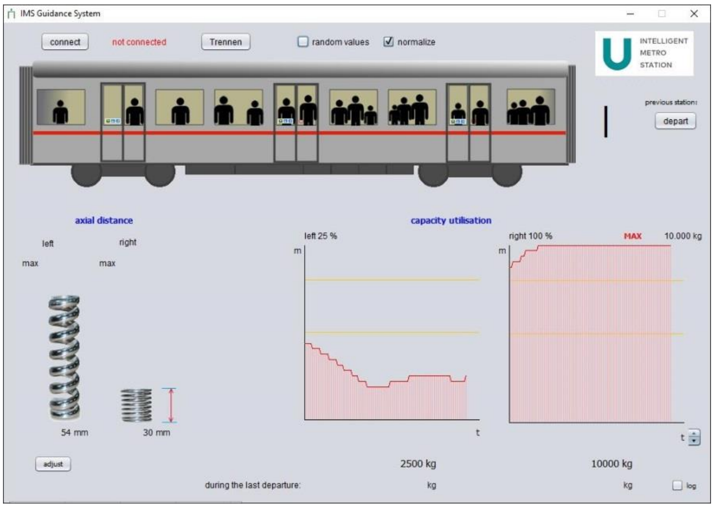

Fig. 4. Model consisting of one carriage for which we calculated the distance to the ground in real-time. The air spring compressed with the weight of a load in the carriage.

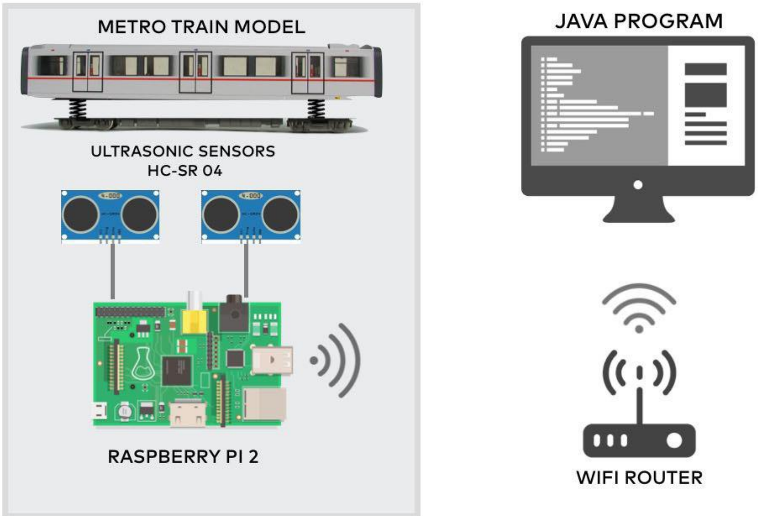

Fig. 5. System application components: ultrasonic sensors and Raspberry Pi 2, connected by a wireless communication.

5 Conclusion and Future Work

We proposed in this work a system for an even passenger distribution at metro stations. To this end we built a model to evaluate potential technical challenges and test the interactive components. In combination with a graphical user interface, the advantages of a guidance system could be demonstrated.

The acceptance of our system was guaranteed by 75 % of the passengers questioned, who stated they would use such a guidance system.

Next steps will include a real life demonstration in a metro station in Vienna that will show the effectiveness of better passenger distribution.

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