The Foretelling Subway: Environment and Situation

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ABSTRACT

In this work we introduce the environment for passenger occupancy prediction

1. INTRODUCTION

Underground transportation systems are big energy consumers and have significant impacts on energy consumptions at a regional scale [?]. So far, the optimization of the energy efficiency of transportation equipment, the trains, have been considered. However, although a single train is the largest individual consumer of energy from the overall energy load necessary to run a complete underground system, the investments required for this kind of optimisation are also tremendous. Considering the cost and amount of energy that can potentially be saved in different components of an overall underground metro system, it is suggestive to instead intensify the effort towards other directions. In particular, the optimization of the energy efficiency of the metro stations involves much less investments than the ones that are usually applied to transportation means and equipments. Although only a relatively small percentage can be gained with optimal management of a single metro station compared to optimizing trains, the high number of stations in the underground transportation system in total will yield large energy savings in overall terms. For example, all Barcelona (Spain) metro stations consume 63,1 million kWh annually [?]. A relatively small saving of, for instance, only 5% in the electricity consumption of a single metro station is equivalent to the electricity consumed in more than 700 households during one year. In other words, the management of energy consumption in individual metro stations is a high multiplication factor that boosts each relative small saving at a station level to tremendous savings at a metro network level.

Yet, optimization of the energy efficiency of the metro stations operations, is only minimally exploited. Possible directions are the optimized management of stations and surroundings, such as ventilation, vertical transportation and lighting which would have a significant impact on the overall energy consumption. Currently, the controller for these systems follow simple time and experience-based coarse schedules. In particular, these systems are optimised for peak times and are therefore operating in an inefficient mode over most part of a day.

A seminal opportunity to optimize the energy efficiency and to realize energy savings is to enable the station to control the surroundings, such as ventilation, vertical transportation and lighting adaptively according to the current situation. For instance, the ventilation-fans of a station could be slowing down when the count of passengers does not necessitate full speed.

In order to achieve such context-aware pro-active behaviour in a metro station, basically three parts are required.

A: Sensors that are suited to capture the situation over time accurately

B: A controller which is able to calculate the appropriate actions.

C: Prediction mechanisms that can anticipate the future evolution of the situation in a metro station

An underground metro system features a high number of sensors (A) that can be employed to realise pro-active operation. These cover even the tracking of people movement and count which is easily possible via the prominently installed CCTV surveillance systems. Recently, also a controller (B) which is adaptive on the basis of various environmental factors, forecasts and passenger occupancy has been developed [?]. The predictive component (C) is necessary since changes applied to the system do not immediately take effect. Staying in the above example with the ventilation-fans, it is sufficient for the controller to be aware of the current count of passengers in order to decrease the fan frequency. However, increasing the fan frequency is more complex. Since the increasing of the fan frequency does not have an immediate effect for the air quality, the fan frequency needs to be increased an appropriate time before the station fills again. It is important to note, that such events can typically occur abruptly in an underground metro system. Examples are, for instance, periodic events such as rush hours or the arrival of connecting trains but also rather spontaneous events like sudden strong rain downfall or simply one of the frequent excursion trips from schools where groups of several hundred people float a station in a short time.

To guarantee the required air quality on every point in time, the ventilation needs to be controlled in a foreseen

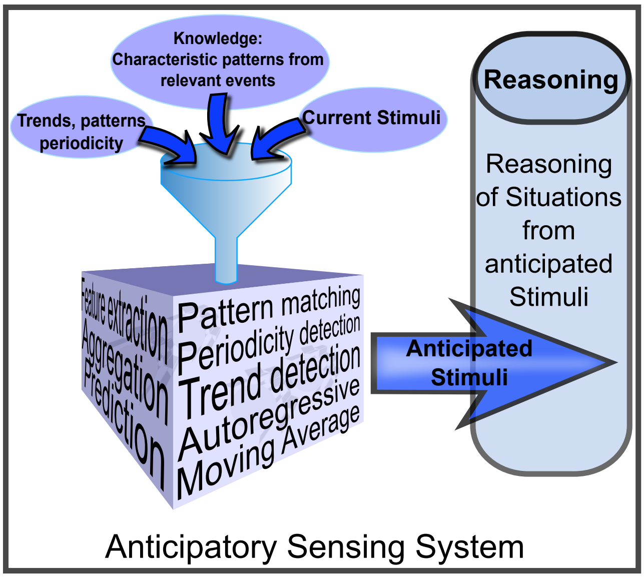

Figure 1: TODO: Improve figure; Schematic illustration of an anticipative sensing system

manner, that means based on the prospective number of passengers in a station.

This paper presents the approach of Anticipatory Sensing for the prediction of the number of passengers in a station.

Anticipatory Sensing relies on current stimuli from the sensing system, recent historical stimuli that represent trends, typical patterns or periodicity over time and explicit knowledge about relevant events and their corresponding characteristic patterns as depicted in figure 1.

From this information, the series of the current and recent stimuli are analysed for decisive patterns that allow the computation of likely continuation of the observed series of stimuli. In particular, in this Anticipatory Sensing step, first, features are extracted from the recent historical time series of stimuli, aggregated and then this series of aggregated features is analysed following multiple approaches from context prediction, pattern matching and time-series forecasting in order to enable a reasoning on possible continuation of this series of stimuli together with their probability.

These anticipated stimuli, which are expected to be observed via the sensing system in the near future are then forwarded to a reasoning component where the anticipated low-level stimuli are classified for situations. Note that this order of prediction and reasoning also follows a recent recommendation from [?] where the inpact of the order of computations on the prediction accuracy was analysed.

Based on these reasoned situations, the controller of the underground metro system is then in the position to take informed actions, such as, for instance, to increase the fan frequency an appropriate time prior to the actual arrival of the crowd in the station.

The remainder of this paper is organized as follows. In Section **??** an overview of the related literature is given. Section **??** focuses on the data acquisition and the experiments, followed by Section **??**, the evaluation and results. Last, Section 3, draws our conclusion.

2. ENVIRONMENT

2.1 SEAM4US

The seam4us project...

The prediction is based on occupancy data gathered in a metro station. Following the environment were the research takes place, i.e. the metro station is described more in detail.

2.2 Underground Station Passeig de Gràcia

In this section the "station" is described. First the word "station" in the area of metro networks needs to be defined.

A metro network is composed by one or more metro lines. Each line has a fixed railway with a given number of stops to allow people to get on or off the trains by means of a platform: each of these stops is called "line station". A "metro station" is the concept that represents the point in space through which a passenger gets underground and into a line station. Metro station and line station can be the same physical entity, but it is possible that there are some "metro stations" that receive two or more "metro lines" in different platforms, and have therefore, two or more "line stations" within.

The data, used in this work, are gathered in line station in Passeig de Gràcia - Line 3 (PdG-L3) in Barcelona. Passeig de Gràcia (PdG) is a station in the metro network of "Transports Metropolitans de Barcelona" (TMB) and lies in a very iconic and touristic part of Barcelona. Some of the most popular buildings designed by Antoni Gaudi are in the proximity (Casa Batllò, Casa Milà), as well as the city's most renown and exclusive boutiques. The metro station is a historic icon of the Barcelona metro network. First opened in December of 1924, as a (line) station for Line 3, nowadays PdG holds three different line stations: L2, L3, and L4. The stations were built in three different periods and using different construction technologies in each of the premises (contemporary to the building periods). All line stations station has been refurbished a few times since 1924 and new equipment has been added recently.

Depending on the weekday PdG is open 19 hours, 21 hours or 24 hours. Between Monday and Thursday PdG service starts at 5:00 and ends at 24:00 (19 hours). Friday service starts at 5:00 and ends at 2:00 (21 hours). On Saturday service starts at 5:00 to but remain the entire night until midnight on Sunday.

Passeig de Gràcia - Line 3 (PdG-L3) turns out to be representative for many station within TMBs metro network [?]. Moreover PdG-L3 is a crowded station which have low-rate usage hours as well. This provides a wide range of data which allows to test with very busy peak hours as well as with off-peaks. Figure 2 depicts the platforms of PdG-L3.

The line station PdG-L3 consists of several public spaces: halls, transit areas, accesses to the platforms, and platforms. Furthermore there are private spaces such as technical rooms or staff dependencies. The private spaces are not part of the investigation in this work. Figure 3 depicts the line station schematic where the accesses to platforms are highlighted in red.

The public spaces are equipped with a Closed Circuit Television (CCTV) for security reasons. The cameras of the CCTV-system provide images which contains the information how many people are on a dedicated time on a dedicated place. To gather these information the images needs to be

Figure 2: PdG-L3 Plattforms. [?]

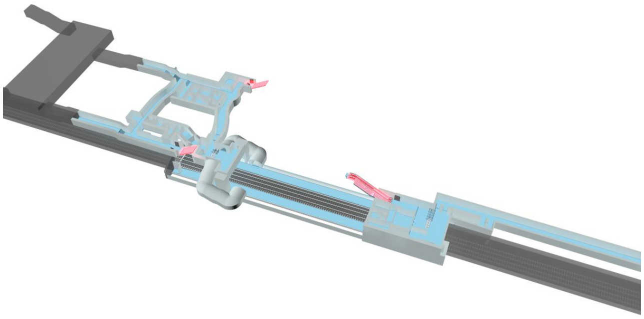

Figure 3: Schematic representation of PdG-L3. The accesses to platforms are highlighted in red. [?]

processed. In the following the processing of the CCTV images is described in short.

2.3 Passenger density data

Whenever the camera pictures are processed the privacy issues are tackled. To ensure the privacy restrictions several actions took place. First of all, all CCTV images needed for prediction purposes does not leave the station. To ensure this, the image processing is conducted on a dedicated computer especially bought for this purpose. The PC is located in technical room within the station. The images are just for "on the fly" image processing and are not stored on the PC. All information

Throughout the station a CCTV surveillance system already exists. 22 CCTV cameras are in place where each camera provides in a circuit design subsequently the images. The images provided by each CCTV-camera are stored on a video recorder. A crowd density estimator processes the images and returns the number of passengers on this image. The number of passenger as well as date, time and the camera-ID are saved in a database.

For different reasons, e.g. bad camera picture or network errors it is possible that the image processing fails. In this case the image processing return the error value "-1".

The process images are not saved for privacy reasons. Figure 4 depict the processing chain.

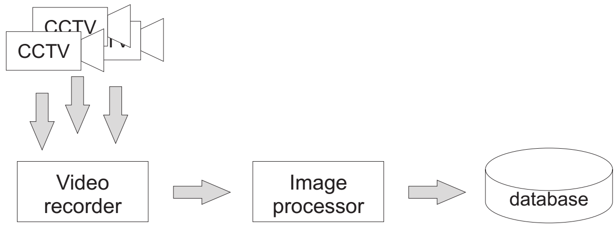

Figure 4: Gathering number of people out of the camera images.

The CCTV and image processing runs 24 hours, 7 days a week. Each day 31680 datasets are saved to the database. Overall the database contains 90 days of data. Figure 5(a) illustrates exemplary the available values of a week. At a more detailed view of a day the service times are visible (Figure 5(b)).

3. CONCLUSION

Conclusion

Acknowledgements

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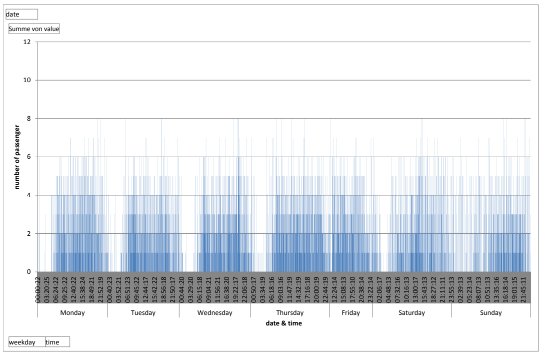
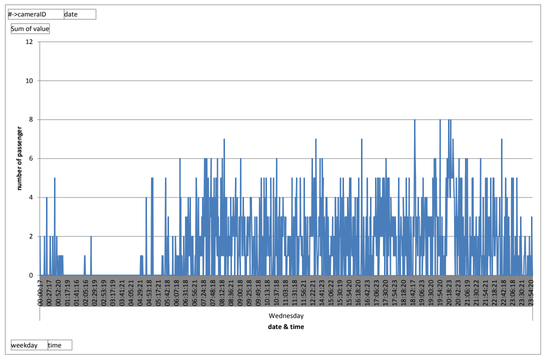


(a) Passenger density distribution of one camera during one week.



(b) Passenger density distribution of one camera during one day.

Figure 5: Passenger density distribution of one camera. [?].