The Foretelling Subway: Environment and Situation

Andreas Jahn and Klaus David
Kassel University
Wilhelmhöher Allee 73
Kassel, Germany
{andreas.jahn,david}@uni-kassel.de

Stephan Sigg and Xiaoming Fu
Goettingen University
Goldschmidtstr. 7
Göttingen, Germany
{stephan.sigg,
fu}@informatik.uni-goettingen.de

ABSTRACT

In this work we introduce the environment for passenger occupancy prediction

1. INTRODUCTION

Underground transportation systems have significant impacts on energy consumption at a regional scale. While the transportation systems, i.e. trains, has observed regarding energy efficiency, the subsystems of metro stations and surroundings, such as ventilation, escalator and lightning are mostly unexplored.

Although a nominally small percentage of energy can be saved with an efficient management of these subsystems, a large energy saving in absolute terms can be obtained. In other words, a 5% energy saving in non-traction electricity consumption in one year, is equivalent to the electricity consumed in more than 700 households.

The remainder of this paper is organized as follows. In Section 2 an overview of SEAM4US project is given. Followed by Section 3, the metro station. In section 4 the passenger density data extraction is described. Section 5.1 discusses the passenger density data. Last, Section 6, draws our conclusion.

2. SEAM4US PROJECT

To investigate on energy efficient subsystems, the EU funded in the Seventh Framework Programme the project "Sustainable Energy mAnageMent for Underground Stations" (SEAM4US). The aim of SEAM4US "is to develop advanced technologies for optimal and scalable control of metro stations [...]. The project's main outcomes will be the creation of systems for optimized integrated energy management..." [1]. The integrated energy management is realized by using passenger density models and thermal models, integrating sensors and control algorithms. All models and algorithm compose a model predictive control architecture [2]. The control architecture proactively controls the metro station surroundings (ventilation, escalator, and lightning) under different passenger density and thermal conditions.

The SEAM4US consortium consists of nine partners from six different EU countries, namely Cofely, UniVPM, UPC, Fraunhofer FIT, VTT, Almende, Uni Kassel, CNET and TMB. Each partner supports the consortium within its expertise:

Cofely Cofely Italia Spa (Italy):
A major player in energy-efficient system management sector

UniVPM Universita Politecnica Delle Marche (Italy):
Building and environmental physics and construction.

UPC Universitat Politecnica De Catalunya (Spain):
Building and environmental physics and construction.

Fraunhofer FIT Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V (Germany):
R+D experts in middleware.

VTT Teknologian Tutkimuskeskus VTT (Finland):
R+D experts in middleware.

Uni Kassel University of Kassel (Germany):
User and agent-based scheduling modeling.

Almende Almende B.V. (Netherlands):
User and agent-based scheduling modeling.

CNet CNet Svenska AB (Sweden):
System integrator.

TMB Metropolita De Barcelona Sa (Spain):
Metro network operator.

3. METRO STATION "PASSEIG DE GRÀCIA"

The developed technologies were implemented in one of the underground stations of the TMB metro network in Barcelona. This section describes the "station" in detail, while the word "station" in the area of metro networks needs to be defined first.

A metro network consists of one or more metro lines. Each line has a defined 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". In contrast 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 a "metro stations" consists of one or more "line stations".

The metro station Passeig de Gràcia (PdG) is a station within the metro network of TMB and lies in a very iconic and touristic part of Barcelona. Some popular buildings designed by Antoni Gaudí are in the proximity (Casa Batllò, Casa Milà), as well as the city's most renown and exclusive boutiques. The metro station is one of the oldest of the Barcelona metro network. First opened in December 1924, as (line) station for Line 3, nowadays PdG holds three different line stations: L2, L3, and L4. The line stations were built in three different periods and using different construction technologies. All line stations have been refurbished a few times since 1924, and new equipment has been added recently. Figure 1 depicts an entrance of metro station Passeig de Gràcia.

Figure 1: Passeig de Gràcia Entrance/Exit Gran Via. [3]

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 too but remain the entire night and day until Sunday midnight.

The developed technologies were implementation line station in Passeig de Gràcia - Line 3 (PdG-L3). In the following, all information are respective to PdG-L3.

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

The line station PdG-L3 consists of private (staff only) and public spaces. Private spaces such as technical rooms or staff dependencies are not part of the investigation of the SEAM4US project. Public spaces, such as halls, transit areas, accesses to the platforms, and platforms are, however, in the focus.

Essential part of (every) line station are the platforms, which allow passengers to leave and enter trains. PdG-L3 laid out on a PRRP (Platform-Rail-Rail-Platform) schema. The PdG-L3 platforms are visible on Figure 2. To leave the platforms, several escalators are available. Figure 3 depicts exemplarily an escalator.

Figure 2: PdG-L3 Plattforms. [3]

A schematic representation of PdG-L3 is drawn in Figure 4, where the platforms are highlighted in red. At the beginning and end of the platforms, the accesses to the platforms are visible.

Throughout the station a Closed Circuit Television (CCTV) surveillance system is installed. 20 CCTV cameras provide images for security reasons. Figure 5 show exemplary CCTV cameras on the platform (Figure 5(a)) as well as in the transit area (Figure 5(a)).

4. PASSENGER DENSITY DATA EXTRACTION

One part of the predictive controller is the passenger density model. The passenger density model is based on real density seen by the CCTV cameras. Therefore, the CCTV system is reused and enhanced with image processing in order to extract the passenger density within the station. The image processing is described briefly in section.

Whenever camera pictures are processed privacy issues are tackled. In order to ensure the passengers privacy several design constraint where defined:

1. All CCTV images are processed within the station.
2. All CCTV images are processed "on the fly". For the purpose of level of passenger density extraction, no CCTV image is saved.
3. The image processing is performed on a separate computer, which is not connected to other TMB Systems and is only accessible via a dedicated VPN connection.
4. The image processing works without human interaction.
5. The image data are filtered to avoid recognisability of individuals.
6. The image processing results are transmitting only in terms of integer numbers to the database.

(a) CCTV camera installed in a PdG transit area. [3]
(b) CCTV camera installed in PdG-L3 platform. [3]

Figure 5: Passenger density distribution of one CCTV camera in PdG-L3.

Figure 3: Escalator in PdG-L3 for leaving the platform. [3]

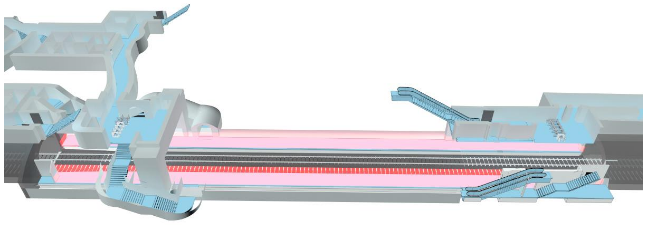

Figure 4: Schematic representation of PdG-L3. The platforms are highlighted in red. [3]

With respect to these design constraints, the passenger density extraction was implemented. The workflow is described in the following.

First, the video streams coming from all cameras are combined into one single video stream by a video recorder. This video recorder creates a carousel video composed of sections for the individual camera appearing in a predefined order. The duration of the camera sections is set to 3 seconds. With 20 cameras and 3 seconds hold on each, one turn of the carousel is completed in about one minute.

The video recorder is connected to the local computer and transfer the images subsequently. On the local computer, the density estimator processes the transferred images and extracts the passenger density.

The density estimator algorithms use a combination of edge detection and background subtraction. In the following, the algorithm is described briefly. First the algorithm separates background and foreground. Followed by creating the foreground mask. Through filtering the edges of the foreground only are extracted. The foreground edges are combined with the foreground mask. Finally, the result is refined by dilating (and then eroding) the segmented the blobs. For different reasons, e.g. occluded or damaged camera, it is possible that the crowd density estimator fails. In this case, the image processing returns the error value "-1". Finally the extracted passenger density level as well as date, time and the camera-ID of the image are transmitted to the database. The general approach is depicted in Figure 6.

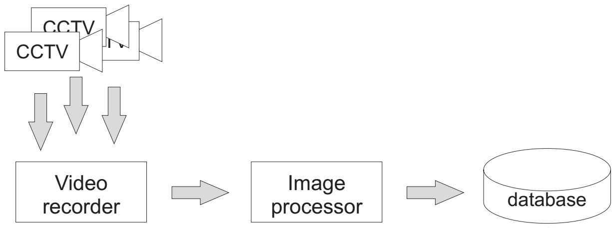

Figure 6: Gathering number of people out of the camera images.

The CCTV and image processing runs 24 hours, 7 days a week. Each day 28800 datasets are transmitted to the database. Overall the database contains 90 days of data. The available data are discussed in the next section.

5. PASSENGER DENSITY DATA

5.1 Properties of the data

In order to model the passenger density an understanding of the available data is necessary. In this section the data, visible pattern and other features are discussed.

Figure 7(a) illustrates exemplary the available values of a camera and week. At a more detailed view Figure 7(b) shows the passenger density level of a camera and (week)day. On both Figures, the PdG service times are visible due to the low passenger density level between 01:00 and 05:00 on weekdays.

5.2 Prediction by Artificial Neural Fuzzy Inference System

6. CONCLUSION

Conclusion

Acknowledgements

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7. REFERENCES

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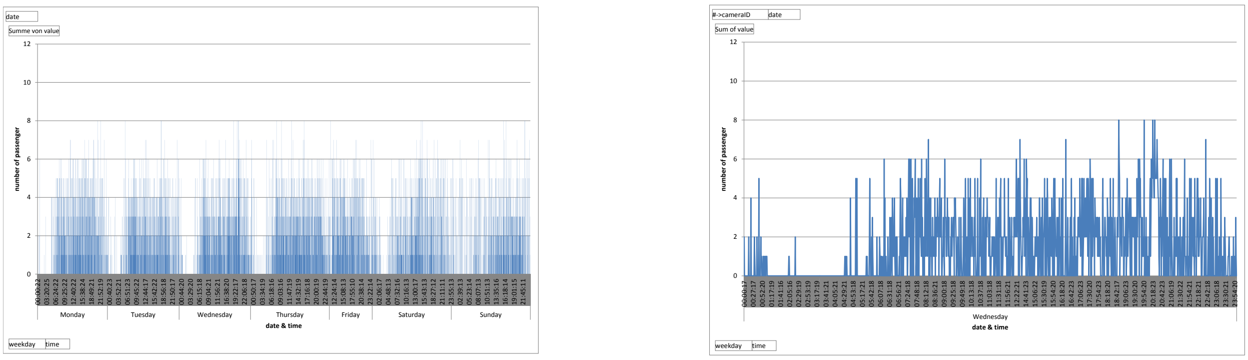
[2] Roberta Ansuini, Massimo Vaccarini, Alberto Giretti, and Sara Ruffini. Models for the real-time control of subway stations. Chambéry, France, August 2013.

[3] Metropolita De Barcelona (TMB), 2014.



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

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

Figure 7: Passenger density distribution of one CCTV camera in PdG-L3.

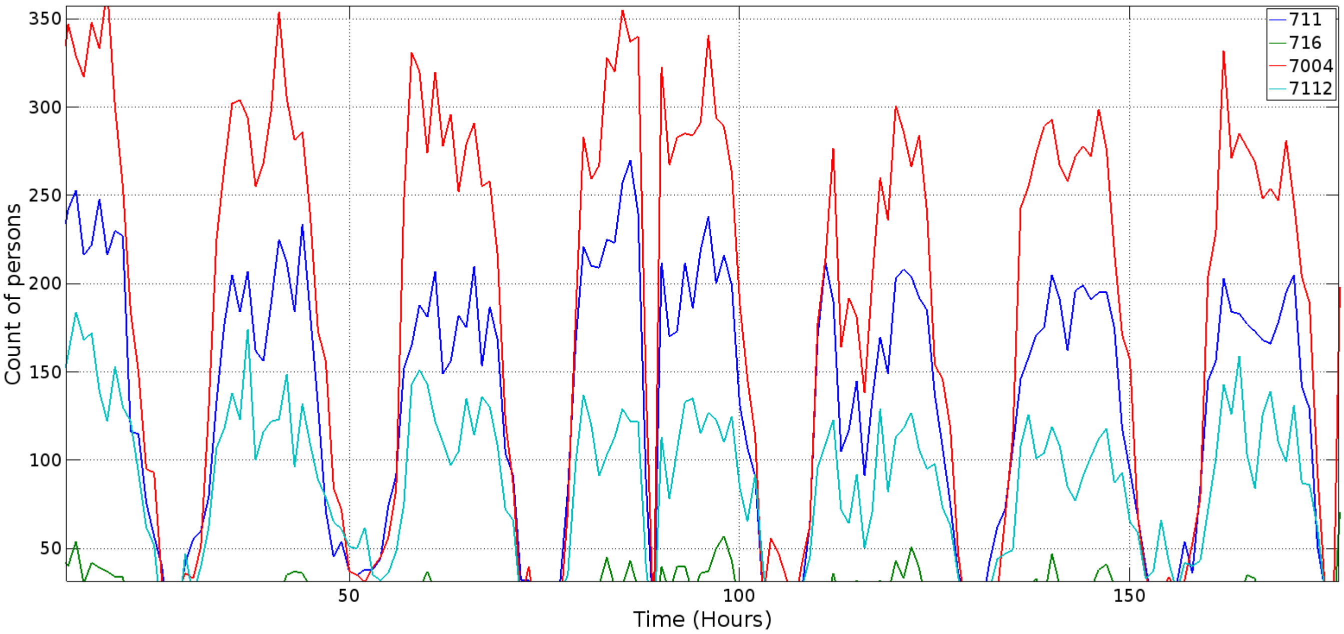


Figure 8: todo

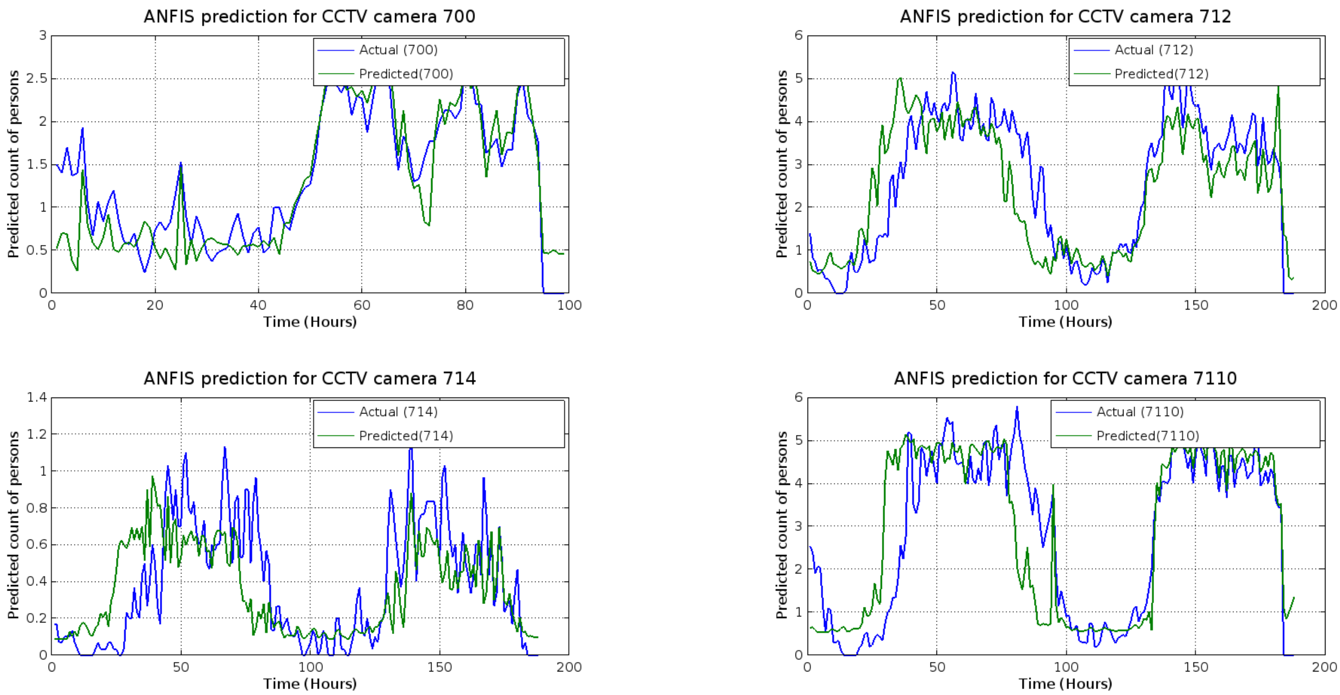


Figure 9: todo

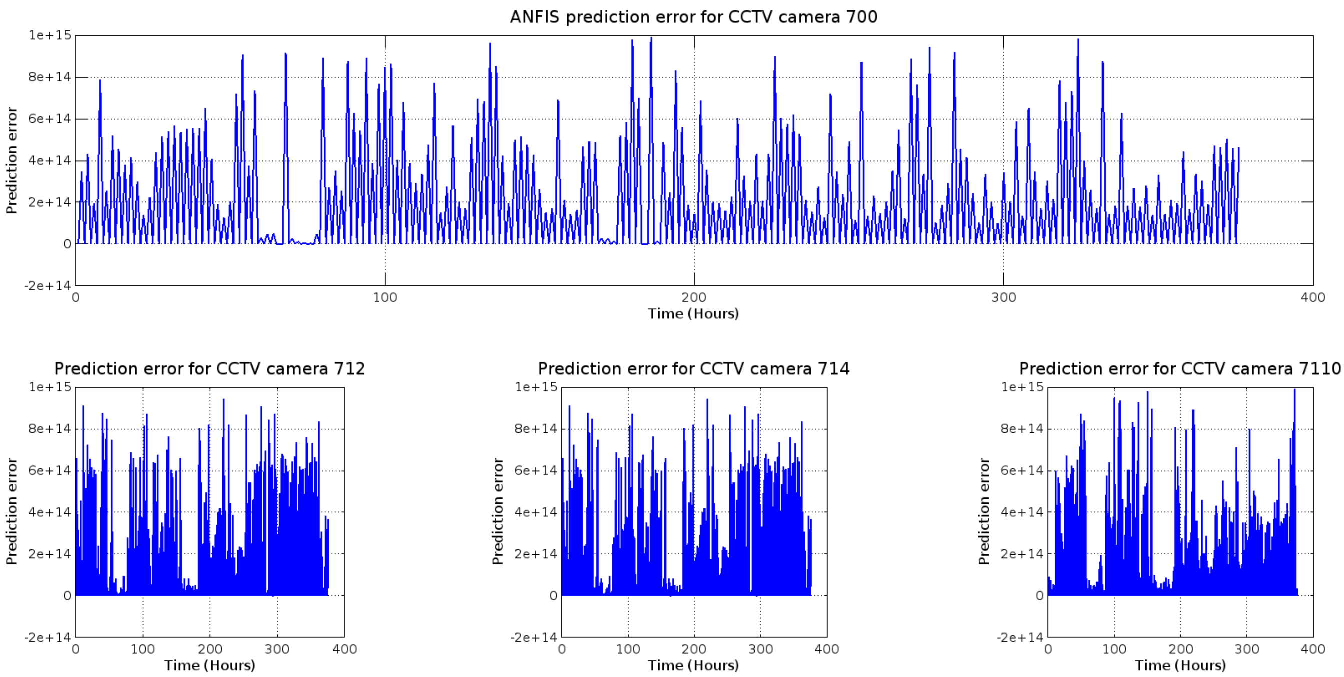


Figure 10: todo