Passenger prediction in metro stations: Analysis of passenger data from security cameras

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Abstract
Underground transportation systems have significant impacts on energy consumption. While trains has been observed regarding energy efficiency, the subsystems of metro stations and surroundings, such as ventilation, escalator and lightning are mostly unexplored. For energy optimal control of these subsystem the SEAM4US project developed a predictive control architecture. The control architecture proactively perform energy management tasks based on situations taking place in the future. The passenger model provides prediction about the count of persons. In this work we analyse the CCTV data which are basis of the passenger density prediction.

Author Keywords
subway, passenger density, CCTV cameras, prediction, predictive controlling

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.

To investigate on energy efficient subsystems (ventilation, escalator, lightning), the EU funded in the Seventh Framework Programme the project "Sustainable Energy mAnageMent for Underground Stations" (SEAM4US). The SEAM4US project develop a predictive control architecture, which controls proactively the metro station subsystems, taking current and predicted count of persons within the station into account. The count of persons is provided by an enhanced CCTV system. On the same time the count of persons is the bases for the prediction.

The remainder of this paper is organized as follows. First an overview of SEAM4US project is given. Followed by a description of the pilot station. Subsequently the count of persons extraction is described, followed by a detailed view on the passenger density data. Last, our conclusions are drawn.

SEAM4US project

The aim of SEAM4US "is to develop advanced technologies for optimal and scalable control of metro stations [...]" [1].

For optimal control, a predictive control architecture was developed. The control architecture proactively perform energy management tasks and controls the metro station subsystems, taking different passenger densities into account [2]. Also situations taking place in the future are considered by utilizing, beside others, the passengers prediction model. The passenger prediction model predicts the count of persons in a certain section, on a certain time in the future.

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

Cofely Cofely Italia Spa (Italy):
Energy-efficient system management.

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.

UniKassel 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 Transports Metropolitans De Barcelona Sa (Spain):
Metro network operator.

The control architecture, the prediction models as well as hardware components compose the SEAM4US system, which is installed in a pilot station in Barcelona (Spain). The following section gives more details about the pilot station.

Pilot Station "Passeig de Gràcia - Line 3"

The SEAM4US system is implemented in the pilot station Passeig de Gràcia - Line 3 (PdG-L3), which is a station within TMBs metro network in Barcelona. This section describes the station more in detail. Before the difference between "line stations" and "metro stations" is pointed out.

In general, a metro network consists of one or more metro lines. Each line has a defined railway with a given number of stops to allow passengers to get on or off the trains. Each of these stops is called "line station". In contrast, a "metro station" represents the point in space through which passengers get 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 holds more than one line stations.

As mentioned (line) station PdG-L3 serves as pilot station. In the following, details about the metro station Passeig de Gràcia (PdG) are given, followed by details about the pilot (line) station PdG-L3.

The metro station PdG lies in the iconic and touristic part of Barcelona. Some popular buildings designed by Antoni Gaudí (Casa Batllò, Casa Milà) as well as the city's most renown and exclusive boutiques are in the proximity. The metro station is one of the oldest of the Barcelona metro network. First opened in December 1924, as station for Line 3 (L3), nowadays PdG holds three different line stations: Line 2, Line 3, and Line 4. The line stations were built in three different periods, using different construction technologies. All line stations have 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 too but remain the entire night and day until Sunday midnight. Figure 1 depicts an entrance/exit of metro station PdG.

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

PdG-L3 was as pilot station selected since it turned out to be representative for many station within TMBs metro network [3]. The count of fans, escalators, and the platform schema is comparable to other stations. Moreover, PdG-L3 is a crowded station which have low-rate usage hours as well. Therefore a wide range of data are available, that allows to test with very busy peak hours as well as with off-peaks.

Spaces

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, whereas public spaces, such as halls, transit areas, accesses to the platforms, and platforms are, in the focus for the energy efficient control. The platforms are a essential part of (every) line station, since it allows passengers to leave and enter the trains. For the passenger model it is essential because every passenger who uses the line station is visible here. PdG-L3 laid out on a PRRP schema - Platform-Rail-Rail-Platform. The PdG-L3 platforms are depicted on Figure 2.

Figure 2: PdG-L3 Plattforms. [3]

A schematic representation of PdG-L3 is drawn in Figure 3, where the platforms are highlighted in red. At the beginning and end of the platforms, the accesses to the platforms are visible.

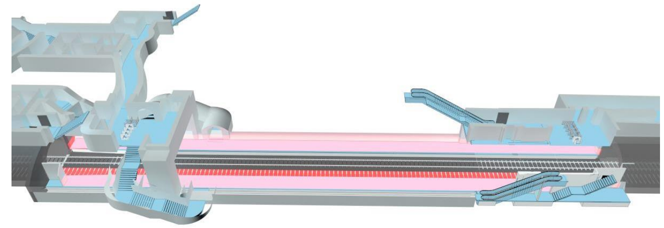

Figure 3: Schematic representation of PdG-L3. The platforms are highlighted in red. [3]

CCTV System
Throughout the station a Closed Circuit Television (CCTV) surveillance system is installed. 20 CCTV cameras on different locations provide images for security reasons. Figure 4 show exemplary CCTV cameras on the platform (Figure 4(a)) as well as in the

transit area (Figure 4(a)).

(a) CCTV camera installed in a PdG transit area. [3]

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

Figure 4: Count of persons distribution of one CCTV camera in PdG-L3.

The CCTV System provides the basis for the predictive passenger model. In the following the data extraction is explained.

Count of persons extraction

The SEAM4US system utilizes prediction model for proactively controlling the subsystems. Besides others, the passenger model is a part of the predictive controlling architecture. To predict count of persons for a point in future, the model utilizes the output from the CCTV monitoring. The count of persons is extracted by enhancing the CCTV-system with image processing.

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

1. All CCTV images are processed within the station.
2. All CCTV images are processed "on the fly". For the purpose of count of persons 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.

With respect to these design constraints, the count of persons extraction was implemented. The workflow is described briefly in the following.

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

The video recorder is connected to a local computer and transfer the images subsequently. On the local computer, a extraction algorithm processes the transferred images and extracts the count of persons. The extraction algorithm uses 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, the extraction algorithm can fail. In these cases, the algorithm returns the error value "-1".

The extracted count of passenger as well as date, time and the camera-ID of the image are transmitted to the database. The general approach is depicted in Figure 5.

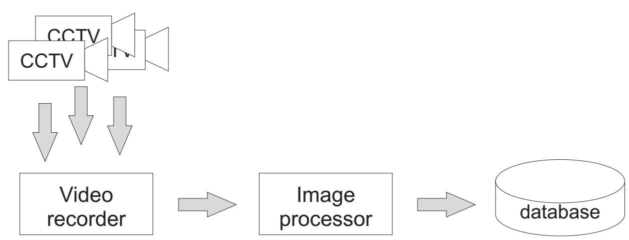

Figure 5: Gathering count of persons out of the camera images.

The CCTV system as well as the image processing running 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.

Count of persons data

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 6 illustrates exemplary the available values of a camera and week. The PdG service times are visible due to the low passenger density level between 01:00 and 05:00 on weekdays.

Prediction by Artificial Neural Fuzzy Inference System

Conclusion

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Acknowledgements

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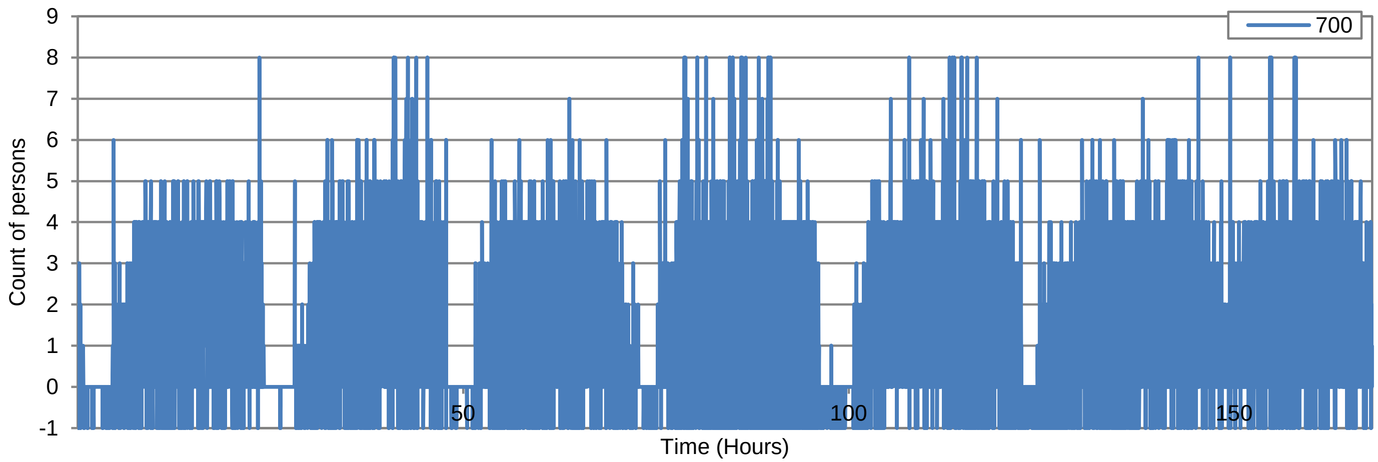

Figure 6: Passenger density distribution of one camera during one week.

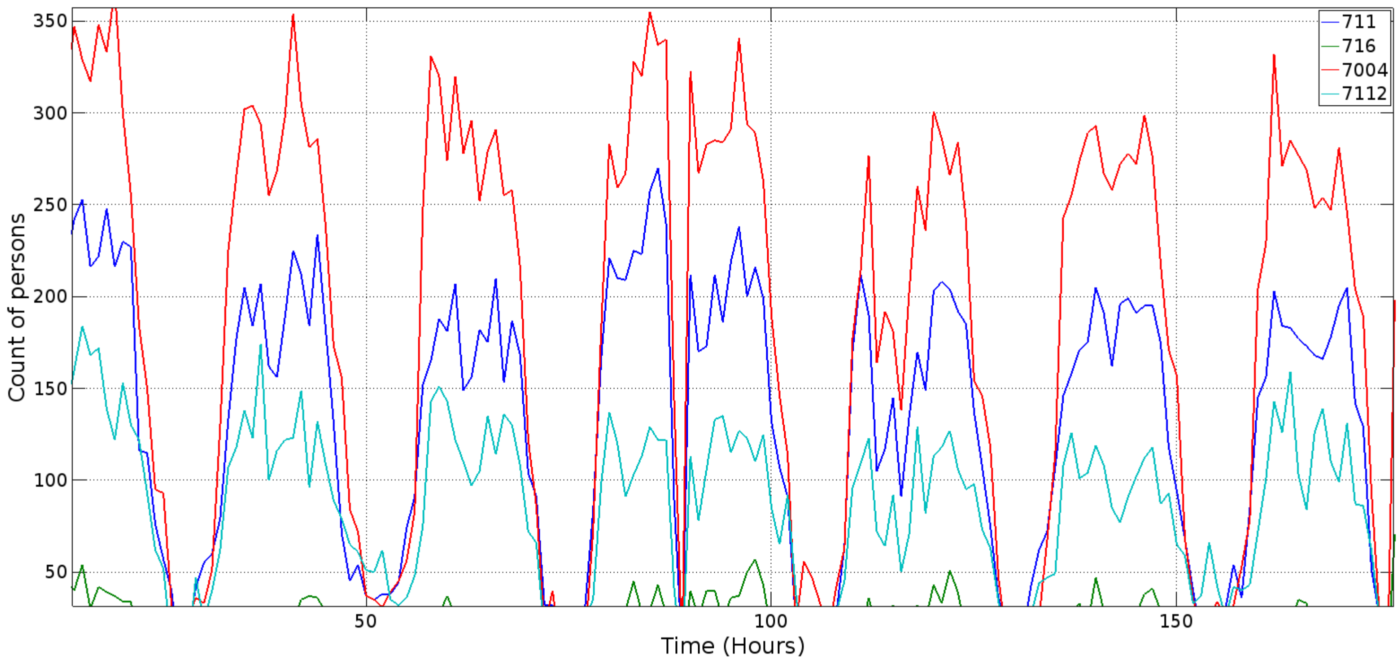

Figure 7: todo

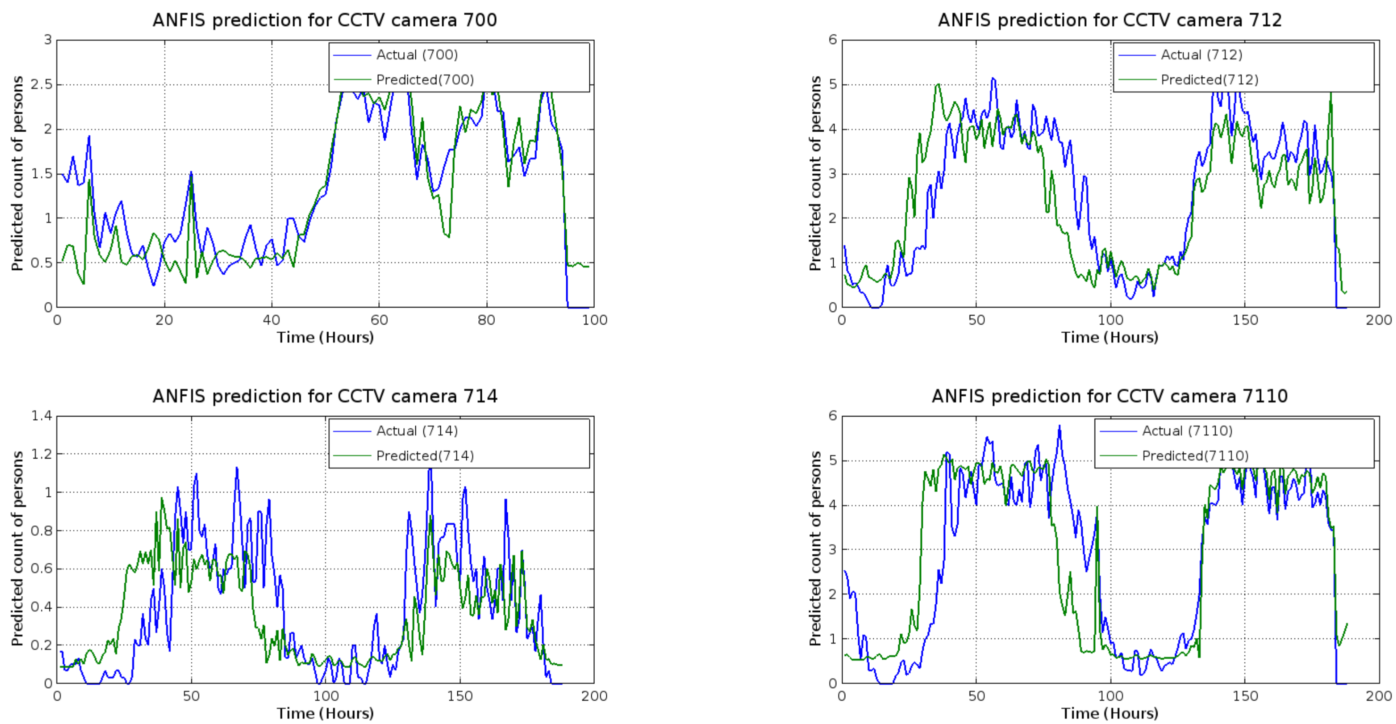

Figure 8: todo

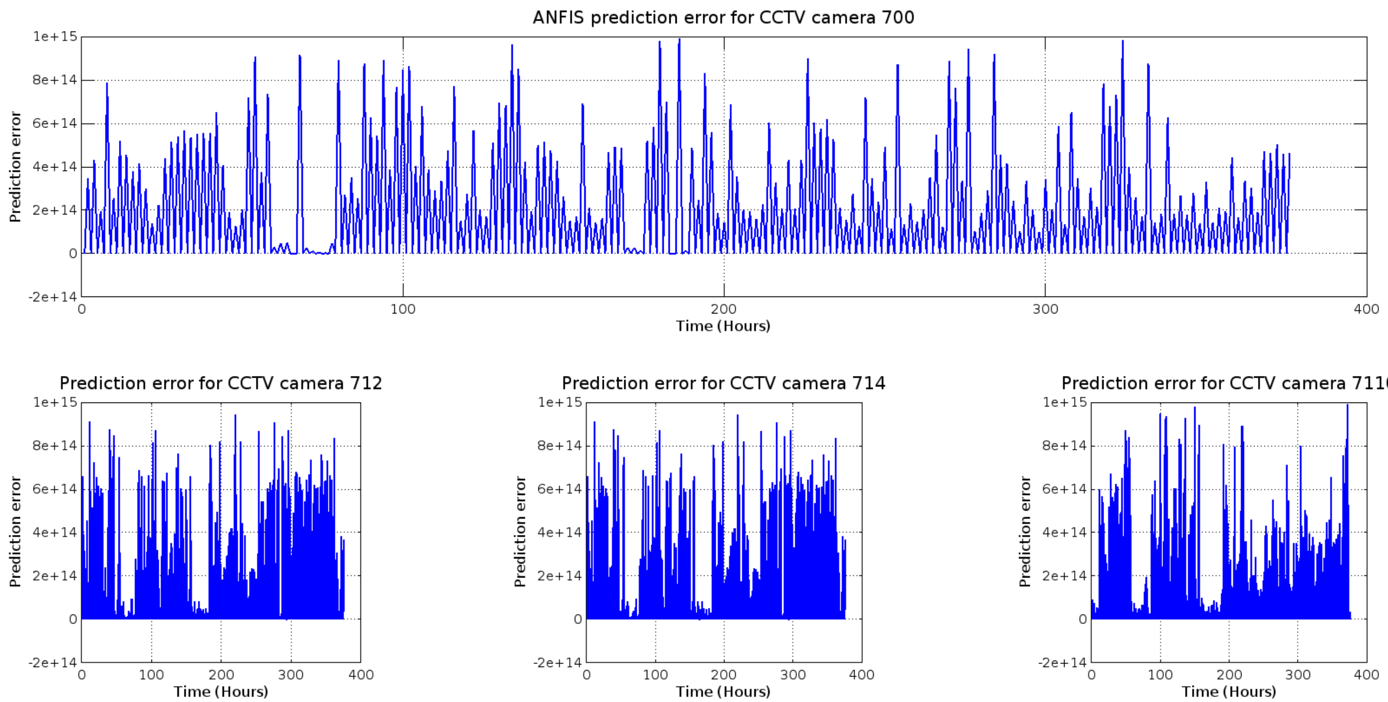

Figure 9: todo