

DESCRIPTION

TITLE: Method and system for automated supervision of short-term passenger flow in a transport network

The present invention relates to a method and system for automated supervision of short-term passenger flow in a transport network, more particularly an urban rail transport network.

The invention belongs to the field of automated management systems for urban transport networks, e.g. metro networks, and more generally in any passenger transport network.

In such transport networks, regulation according to passenger flow is critical, as flow exceeding a certain threshold can lead to safety risks for passengers, on top of discomfort.

A passenger transport network, more particularly an urban rail network, is characterized by a set of stations and a set of lines, a line being defined by the set of stations served by a transport vehicle, generally in two opposite directions of flow.

In addition, such a transport network includes, in each station, a set of platforms for loading and/or unloading passengers, e.g. subway platforms.

Such a network has its own topology, some stations including a plurality of such platforms and being served by a plurality of lines of the network.

In modern transport networks, e.g. in a metro network, each station is equipped with ticket validation gates, and each user is equipped with a ticket, e.g. a card readable by a sensor, to validate the transport ticket for a journey, a time etc. Some networks may contain such validation portals on platforms providing access to a plurality of stations or platforms of the network. More generally, a place of validation will refer to any place in the network including one or a plurality of portals for validating transport tickets.

Thereby, the transport network is equipped with a system for recording validation data of transport tickets, in connection with a place of validation and a validation date, e.g. of entry into the network.

The methods and systems for predicting the flow or load of the loading/unloading platforms of a transport network are generally based on a processing of historical validation data for a so-called long-term prediction, which makes it possible to derive load predictions, e.g. according to weekdays or weekends, and according to schedules during the day, thereby making it possible to distinguish periods of high flow and to characterize the expected load, e.g., during the working week during slots generally known as "office hours".

Load or people flow prediction allows an operator, operating the transport network, to predict various network parameters, i.e. operating parameters of the vehicles and of equipment of the stations, and also the number of assistance agents in the station, to keep passengers safe and comfortable. For example, more frequent, larger-capacity transport vehicles, such as double-deck vehicles, are provided for high-flow days and hours, and conversely, vehicle frequency spacing is provided for low-flow hours. In addition to ensuring safety and quality of service, the above makes it possible to better adjust the consumption of resources (e.g., of electrical energy spent), the wear of vehicles.

However, such automated prediction methods do not allow adaptation in real-time to unexpected peaks of flow, due to events that are not recurring over a long period of time, and there is thus a too high risk of overload or large, unanticipated flow which can go as far as compromising the safety of passengers.

A goal of the present invention is to remedy such drawback of the prior art.

To this end, the invention proposes, according to one aspect, a method for automated supervision of short-term passenger flow in a transport network, in particular an urban rail transport network, the transport network comprising a set of places of validation of passenger entries and/or exits and a system for recording actual validation data per place of validation. The method includes the following steps implemented by a computation system: at an initial frequency of execution,

- learning and applying long-term statistical prediction models, each long-term statistical prediction model being associated with a place of validation and being calculated to obtain, for a first prediction time, a time series of predictions of validation numbers per time interval of selected unit time, said time series forming reference validation predictions;

- learning a single short-term prediction model, applicable for all places of validation, and allowing, for a second prediction time less than the first prediction time, a number of validations per time interval of unit time and per place of validation to be predicted, forming short-term predictions of validations;

at a second execution frequency, higher than the first execution frequency, of steps implemented at an execution instant:

- aggregation of actual validation data by place of validation and by time interval of unit time during a historical period relative to the execution time, to obtain aggregated validation data,

- application of said single short-term prediction model to the aggregated validation data to obtain short-term predictions of validation over the second prediction time, by place of validation and by time interval;

○ comparison, by place of validation and by time interval, of the reference validation predictions and the short-term validation prediction, and in the event of a difference greater than a predetermined alert threshold, raising the alert.

Advantageously, the automated supervision method of short-term passenger flow in a transport network makes it possible to predict the number of validations over time intervals following an instant of execution, taking into account recent data thereby allowing changes from reference validation predictions, calculated at a lower frequency, to be captured. The method is thereby apt to provide a better forecast of flow in the event of a non-recurring one-time change.

Advantageously, an alert is raised in the event of a change, greater than a first predetermined threshold, with respect to the reference validation predictions.

The method of automated supervision of short-term passenger flow in a network according to the invention can further have one or a plurality of the features below, taken independently or according to all technically feasible combinations.

If the short-term validation prediction exceeds the reference validation prediction by a value greater than a first alert threshold for at least one place of validation, a first priority level alert is raised.

If the predicted short-term validations exceed the predicted reference validations by a value greater than a second alert threshold for at least one place of validation, a second priority level alert is raised, the method further including a real-time implementation of a corrective measure in the transport network to regulate the flow of passengers arriving on platforms associated with the validation site.

If the reference validation prediction exceeds the short-term validation prediction by a value greater than a third alert threshold for at least one place of validation, a network equipment control measure is implemented.

Furthermore, the single short-term prediction model takes as input reference, validation predictions over a period subsequent to the execution instant and reference data of the transport network.

The reference data of the transport network includes vector data representative of place of validations and vector data representative of distances between places of validation of the transport network.

The single short-term prediction model is a deep neural network with a plurality of layers, trained on actual validation data to perform a short-term validation prediction for each place of validation and each time interval.

Each long-term statistical prediction model is an autoregressive model suitable for predicting a time series of reference validation numbers.

The first execution frequency is equal to one week, the first prediction time is equal to one day, the method including learning a long-term statistical prediction model by day of the week, by type of day of the week and by place of validation, on the basis of actual validation data collected for the same day of the week, of the same type and for said place of validation.

The second execution frequency is less than one hour, the second prediction time is equal to a number of hours, and the unit time of the time interval is equal to one quarter of an hour.

According to another aspect, the invention relates to a system for automated supervision of short-term passenger flow in a transport network, in particular an urban rail transport network, the transport network including a set of places of validation of passenger entries and/or exits and a system for recording actual validation data per place of validation. The supervision system includes at least one computation system configured for implementing:

at an initial frequency of execution,

- A module learning and applying long-term statistical prediction models, each long-term statistical prediction model being associated with a place of validation and being calculated to obtain, for a first prediction time, a time series of predictions of validation numbers per time interval of selected unit time, said time series forming reference validation predictions;

- A module learning a single short-term prediction model, applicable for all places of validation, and allowing, for a second prediction time less than the first prediction time, to predict a number of validations per time interval of unit time and per place of validation forming short-term validation predictions;

at a second execution frequency, greater than the first execution frequency, at an execution instant:

- an aggregation module for aggregating actual validation data by place of validation and by time interval of unit time during a historical period relative to the execution time, to obtain aggregated validation data,

- an application module of said single short-term prediction model to the aggregated validation data to obtain short-term predictions of validation over the second prediction time, by place of validation and by time interval;

- a comparison module for comparing, by place of validation and by time interval, the reference validation prediction and the short-term validation prediction, and in the event of a difference greater than a predetermined alert threshold, a module for raising the alert.

This system is configured to implement an automated supervision method for short-term passenger flow in a transport network as briefly described hereinabove, according to all of the embodiments thereof.

According to one feature, if the short-term validation prediction exceeds the reference validation prediction by a value greater than a first alert threshold for at least one place of validation, the alert raising module is configured to raise the first priority level alert.

According to one feature, if the short-term validation prediction exceeds the reference validation prediction by a value greater than a second alert threshold for at least one place of validation, the alert raising module is configured to raise a second priority level alert, the system further including a module for the real-time implementation of a corrective measure in the transport network to regulate the flow of passengers arriving on platforms associated with the place of validation

According to another aspect, the invention relates to an information recording medium, on which software instructions are stored for the execution of an automated supervision method for short-term passenger flow in a transport network as briefly described hereinabove, when such instructions are executed by a programmable electronic system.

According to another aspect, the invention relates to a computer program including software instructions which, when implemented by a programmable electronic device, implement an automated supervision method for short-term passenger flow in a transport network such as briefly described hereinabove.

Other features and advantages of the invention will be clear from the description thereof which is given hereinbelow as an example, but not limited to, with reference to the enclosed figures, among which:

[Fig 1] Figure 1 is a schematic example of an automated supervision system for short-term passenger flow in a transport network according to an embodiment of the invention;

[Fig 2] Figure 2 is an organization chart of the main steps of an automated supervision system for short-term passenger flow in a transport network, according to an embodiment of the invention;

[Fig 3] Figure 3 is a schematic graphic representation of time series of numbers of validations;

[Fig 4] Figure 4 schematically illustrates the time distribution of validation data as entries and exits of the short-term prediction according to one embodiment.

The invention will be described below in the application thereof in the supervision of an urban rail transport network, typically a metro network.

Figure 1 schematically illustrates a system of supervision 2 of a passenger transportation network.

5 The supervision system comprises sensors 4A...4N, e.g. integrated into validation gates, hereinafter simply called gates, configured to retrieve validation data from passenger tickets, e.g. entry validation data when entering the transport network and/or exit validation data from the transport network.

10 In one embodiment, the validation data used is the entry validation data, a ticket validation, hereinafter referred to as effective validation, being recorded when a passenger presents their ticket upon entry into the transport network.

Each sensor 4A ... 4N is associated with a spatial location in the network, e.g. with a station.

15 A validation datum includes a spatial location identifier in the network and dating information including a validation date/time. The dating information may also include an indication of the day of the week. The time is given in any known standard form, e.g. hour/minute/second over an interval of 24 hours.

In addition, a validation datum includes, in one embodiment, a ticket identifier.

20 The supervision system also comprises a central computing system 6, including one or a plurality of programmable electronic devices (e.g. computers) suitable for communicating with each other.

In one embodiment, the computation system 6 is a programmable electronic device.

25 The computing system includes a communication interface 8 suitable for communicating with the sensors 4A to 4N, by a wired or wireless communication protocol, the communication interface 8 being in particular, suitable for receiving the actual validation data recovered by the sensors. The actual validation data 10 are stored progressively in an electronic memory unit 12 suitable for storing data.

30 The computation system 6 further includes an electronic computation unit 14, composed of one or a plurality of computation processors, suitable for communicating with the electronic memory unit 12 and with the communication interface 8 via a data communication bus.

The computing processor 14 is apt to execute computations and computer program code instructions or software instructions when the programmable electronic device 6 is powered on.

The computation processor 14 is configured for executing modules produced in the form of software instructions for implementing an automated supervision method for short-term passenger flow in a transport network according to the invention.

Such modules comprise:

- 5 - a module 18 for learning and applying long-term statistical prediction models, each long-term statistical prediction model being associated with a place of validation and being calculated to obtain, for a first prediction time, a time series of predictions of validation numbers per time interval of selected unit time, said time series forming reference validation predictions;
- 10 - A learning module 20 for learning a single short-term prediction model, applicable for all places of validation, and allowing for a second prediction time less than the first prediction time, a number of validations per time interval of unit time and per place of validation to be predicted, forming short-term validation predictions.

15 The reference validation predictions 25 are stored between two implementations of the module 18.

In one embodiment, the long-term statistical prediction models are not stored after having been computed and applied for the prediction.

20 The various parameters 27 defining the single short-term prediction model are stored in the electronic memory unit 12. For example, the single short-term prediction model is a neural network using a vector representation of the data as explained in more detail hereinafter.

The modules 18 and 20 are e.g. implemented at a first execution frequency, e.g. every week.

25 The first prediction time is, e.g. equal to one day, the number of statistical prediction models trained being sufficient to predict a complete week, per place of validation and per time interval in the day. The time interval has a chosen unit time, e.g. equal to a quarter of an hour, half an hour, an hour.

Preferably, a distinction is made between working days and non-working days (weekends or holidays).

30 Preferably, the module 18 implements statistical prediction models distinct by place of validation, type of day of the week (working day or non-working day) and day of the week. Such statistical prediction models will be described in detail hereinafter.

35 The second prediction time is, e.g. on the order of H hours, e.g. 2 to 5 hours, the only short-term prediction model being suitable when implemented, for predicting validations for all places of validation during the H hours following the execution time, in other words during the second prediction time, in time intervals lasting one unit time.

The computation processor 14 is further configured to implement, with a second execution frequency higher than the first execution frequency:

- an aggregation module 22 for aggregating actual validation data by place of validation and by time interval lasting a unit time during a period of history relative to the execution time, to obtain aggregated validation data;
- an application module 24 for applying the single short-term prediction model to aggregated validation data, to obtain short-term validation predictions over the second prediction time, by place of validation and by time interval lasting one unit time;
- a comparison module 26 for comparing reference validation predictions and short-term validation predictions and
- an alert module 28 in case of exceeding alert thresholds.

More particularly, two alert thresholds are considered, a first alert threshold indicating passenger discomfort induced by a higher flow than the flow predicted by the reference validation predictions, and a second alert threshold indicating a safety risk for passengers.

The alerts can be transmitted via a notification system to one or a plurality of network operators.

Preferably, the second execution frequency corresponds to the unit time, e.g. the execution is performed every 15 minutes.

In addition, the computation processor 14 is configured to implement, optionally, a module 30 for controlling the equipment 32A, 32B, 32M of the network, the equipment being e.g. escalators or moving walkways 32A, gantries 32B, display panels 32M, etc. following the exceeding of one of the alert thresholds, in order to take corrective actions almost in real-time. Of course, the list of equipment 32A to 32M is not exhaustive.

The control module 30 is e.g. programmed to automatically order corrective measures to slow down access to certain stations or loading platforms of the transport network by: slowing down the speed of escalators or moving walkways, modifying the direction of certain entry/exit gates; to order displays on station panels; to order changes in vehicle flow frequency and dynamic modification of schedule tables, or change in capacity of vehicles put into circulation.

In one embodiment, the modules 18, 20, 22, 24, 26, 28 and 30 are embodied in the form of software instructions forming a computer program which, when implemented by the programmable electronic device, implements an automated supervision method for short-term passenger flow in a transport network according to the invention.

In a variant (not shown), the modules 18, 20, 22, 24, 26, 28, and 30 are each in the form of programmable logic components, such as FPGAs (*Field Programmable Gate Array*)

microprocessors, GPGPU (*General-purpose processing on graphics processing*) components, or further in the form of dedicated integrated circuits, such as ASICs (*Application Specific Integrated Circuit*).

The computer program including software instructions is further apt to be recorded on a non-transitory computer-readable medium for storing information. The computer-readable medium is e.g. a medium apt to store electronic instructions and to be coupled to a bus of a computer system. As an example, said medium is an optical disk, a magneto-optical disk, a ROM, a RAM, any type of non-volatile memory (e.g. EPROM, EEPROM, FLASH, NVRAM), a magnetic card or an optical card.

Figure 2 is a flowchart of the main steps of an automated supervision method for the short-term passenger flow in a transport network according to one embodiment.

The method comprises a preliminary step 40 of obtaining alert thresholds, consisting in configuring the first alert threshold indicating passenger discomfort induced by a greater flow than the flow predicted by the reference validation predictions, and the second alert threshold indicating a safety risk for passengers.

In one embodiment, the first and second alert thresholds are set by experts and stored for the entire transport network.

In an alternative embodiment, first and second alert thresholds are associated with the places of validation, according to information characterizing the transport network, e.g. size of the station, number or accommodation capacities of loading/unloading platform passages in a station, etc.

The first and second alert thresholds are stored.

The method further comprises a step 42 of learning and applying long-term statistical prediction models. Step 42 is implemented at a first execution frequency, e.g. weekly, in order to make predictions of validation data for a following week, each statistical prediction model being suitable for making a prediction of validations in the transport network over a following week.

In one embodiment, the statistical prediction models are auto-regressive prediction models for predicting time series, e.g. ARIMA (Auto-Regressive Integrated Moving Average) models.

For example, step 42 comprises learning eight statistical prediction models of time series per place of validation, one for each day of the week, and another for public holidays.

Thereby, for a network including P places of validations (7+1) XP statistical prediction models are developed.

The learning of a model is based on a history of actual validation data previously stored. For example, for a given day of the week, e.g. a non-holiday Monday, validation data of the Q preceding non-holiday Mondays recorded are extracted from the validation data 10 recorded, with Q lying e.g. in the range 10 to 30.

Figure 3 schematically illustrates an example of time series of numbers of validations. In the present example, a time series 45 of numbers of validations recorded per time unit, e.g. per quarter of an hour, for a given place of validation, is illustrated in graph form. The x-axis is a time axis and the y-axis represents the number of validations per unit of 1000 validation (1K).

Time series 43A, 43B, 43C corresponding to the chosen day of the week, e.g. Monday, when Monday is not a holiday, are extracted and aggregated to form a new time series 45, which is used as a training sequence for learning a statistical prediction model (e.g. ARIMA model).

Learning makes it possible to obtain the coefficients of the model to be applied to obtain a validation prediction, i.e. a prediction of the number of validations per time interval of unit time (e.g. quarter of an hour) for the day of the week considered. If a time interval of a quarter of an hour is considered, an entire day is represented by 96 points. The prediction then makes it possible to obtain a time series of 96 samples $\{n_i\}$, each sample of index i having a value n_i being equal to the number of validations predicted for the time interval t_i . The load according to the time of day can thereby be predicted, with fine granularity.

The numbers of validations calculated by the prediction are subsequently called reference validations D1, which are stored until the next application of step 42.

In one embodiment, the statistical prediction models are not stored, same are re-trained at the first chosen execution frequency, e.g. weekly.

Returning to Figure 2, the method then comprises a step 44 of learning a short-term prediction model, for a second prediction time, e.g. equal to 3 hours, and for all the places of validation considered.

Preferably, the short-term prediction model is a dense and deep neural network including vector representations.

In a known manner, a dense neural network is composed of a succession of layers, each layer comprising a plurality of elements called neurons. In a dense neural network, each neuron of a layer receives as input, results supplied by each neuron of the previous layer and calculates an output value, supplied as input to the next layer. Each input of a neuron is associated with a weight, also called synaptic weight, which is typically a real number. The neuron performs a summation of the weighted inputs thereof, the result of the summation being supplied to a function called the activation function. The activation function

is a function serving to bring a non-linearity into the treatment. Various activation functions (hyperbolic, sigmoid, rectified linear) are applicable. As an optional addition, each neuron further applies a multiplicative factor, also called bias, the value delivered at the output of the next layer is then the product of the bias value and of the output value of the activation function.

The architecture of a deep neural network as described hereinabove is defined by the number of layers, the number of neurons per layer, the number of input and output parameters.

The neural network is also defined by the values of the various parameters (synaptic weights and, if appropriate, bias values), the values being obtained in a learning phase on training data.

For example, the training makes it possible to determine values of neural network parameters that minimize a distance between predicted validation data and recorded actual validation data, e.g. the numbers of predicted and recorded validations per time interval of unit time, the distance to be minimized being e.g. the mean square error.

In the application thereof in the method described, the deep neural network forms a short-term prediction model making it possible to predict, for each time interval (e.g. quarter of an hour), the second prediction time (e.g. $H=3$ hours), a number of validations for each place of validation of the transport network.

As an example, but not limited to, the short-term prediction model is formed by a neural network with 5 layers, implementing a ReLU (Rectified Linear Unit) activation function and comprising a decreasing number of neurons per layer (e.g. 600, 480, 300, 240, 12) for an input number of 1500 and an output number of 12.

For example, for a network comprising $L=100$ places of validation, the short-term prediction model provides 100×12 predicted validation numbers.

The data supplied at the input of the neural network are e.g.:

- a vector representation of the validation sites, the validation sites being the stations of the transport network in an application case;
- a matrix of distances, representative of distances between places of validation, e.g. by using a distance of 1 between adjacent locations on a line of the network;
- a vector representation of the days of the week and a Boolean value representing a holiday;
- a vector representation of the time interval indices to be predicted, e.g. numbered from 0 to 95 over a day when the interval time lasts a quarter of an hour;
- first validation data, which are actual validation data previously recorded in the past with respect to the computation instant over a period of history, e.g. for each

time interval e.g. quarter of an hour over a time of 12 hours, or 12x4 time intervals per place of validation;

- second validation data, which are reference validation predictions predicted during step 42, for each place of validation, for the second prediction time, e.g. for the 3 hours starting at the computation instant, for each time interval, e.g. quarter of an hour, i.e. $3 \times 4 = 12$ values (the output number of the model).

The vector representation of the places of validation and the distance matrix are obtained from reference data of the transport network, the reference data being data that define the transport network (the topology thereof, the number of lines, stations, platforms, etc.).

Advantageously, the use of reference validation predictions at the input of the short-term prediction model, the reference validation predictions being calculated, e.g., at the beginning of the week, makes it possible to correct the model according to recent information.

Figure 4 diagrammatically illustrates, on respective time axes T1 and T2, a segment 51 representative of the first validation data on the axis T1, and a segment 53 representative of the second validation data on the axis T2, with respect to an execution instant t considered. The two segments form the input data of the short-term prediction model.

When implemented, the prediction model performs a prediction of the validation data over the second time period (e.g. 3 hours), represented as segment 55 in Figure 4.

As already indicated hereinabove, steps 42 and 44 are repeated with a first execution frequency, e.g. weekly.

The method further comprises repeated steps with a second execution frequency, higher than the first execution frequency, e.g. every quarter of an hour. Thereby, the second execution frequency corresponds to the unit time of the time interval.

The steps comprise a step 46 of aggregating the effective validation data by place of validation and by time interval to obtain aggregated validation data. The actual validation data being provided at the most detailed level, per individual transaction, same are aggregated by station and over the time interval (e.g. last quarter of an hour) at each time interval and stored so that same can be used in step 48, combined with the previous aggregations. The aggregation will also be used later during steps 42 and 44.

The method then includes a frequent prediction step 48, by applying the single prediction model developed during step 44, e.g. the deep neural network, to obtain predicted validation data for the second prediction time (e.g. 3h), according to the instant of

execution, in other words, for the next 3 hours, and for each time interval and each place of validation.

The prediction model is applied in the frequent prediction step 48, as explained hereinabove, on an input data set including first aggregated effective validation data, obtained over a period of history, and second validation data, which are reference validation predictions, obtained during step 42.

At the end of the frequent prediction step 48, short-term D2 validation predictions are obtained. More particularly, step 48 provides, for each validation site, a predicted number of validations per time interval for the next H hours, e.g. the next 3 hours.

A comparison 50 is then implemented which performs, by place of validation and by time interval, the comparison of the reference validation prediction and the short-term validation prediction. For example, the comparison consists in making the difference, between the predicted number of validations and the corresponding reference number of validations for each place of validation and each time interval.

If the short-term validation prediction, i.e. the number of validations predicted by the short-term prediction model, exceeds the reference validation prediction, over the same time interval and the same place of validation, by a value greater than or equal to the first threshold alert, an alert indicating a deterioration in the quality of service (passenger comfort) is raised at the step of alert raised at the raise alert step of 52.

If the short-term validation prediction exceeds the reference validation prediction, over the same time interval and the same place of validation, by a value greater than or equal to the second alert threshold, an alert indicating a safety risk for passengers is raised at the step of alert raise 52.

Thereby, an alert is raised as soon as the predicted number of validations is greater than the corresponding reference number of validations by a value greater than or equal to the first alert threshold.

The alerts are e.g. differentiated by an associated processing priority, the exceeding of the first alert threshold causing the rise of a first priority level alert, the exceeding of the second alert threshold causing the rise of a second priority level alert, higher than the first priority level. In other words, if the second alert threshold is exceeded, the processing priority is higher.

Following an alert, transmitted e.g. to a system of alert notifications to be managed, indicating that the second alert threshold has been exceeded, provision is also made, in one embodiment, to carry out an automatic control of network equipment, the equipment being e.g. escalators or moving walkways, gates, display panels. For example, the speed of escalators, moving walkways and entry gates is reduced depending upon the alert, to

slow down the flow of passengers arriving on the platform and regulate the flow with queues upstream of the platform. The supervision system receiving the alert informs the operators and can e.g. trigger a standard operating procedure, i.e. a predefined sequence of events provided for such use case.

5 It will also be possible to define alert thresholds under the reference function (e.g. a third alert threshold which is a lower alert threshold) in order to alert and automatically regulate electrical equipment consuming electrical energy such as air conditioning. For example, if the difference between the reference validation prediction and the short-term validation prediction, over the same time interval and the same place of validation, is a
10 positive number greater than said third alert threshold, a resource regulation alert is raised.

It is thereby possible to adjust the operation thereof in anticipation of passenger flow predicted consecutively several times below the lower alert threshold, e.g. a low prediction for a station for the next 2 hours.

15 Steps 42 and 44 form a first group 60 of steps of the method performed repeatedly at the first frequency of execution, e.g. weekly.

Steps 46 to 50 form a second group 62 of steps of the method, which are the frequent steps, carried out repeatedly at the second execution frequency which is preferably less than one hour, e.g. every 15 minutes or every 30 minutes.

20 Steps 52 and 54 are performed only if need be, following a positive comparison during step 50.

Advantageously, the proposed method provides a short-term prediction with good accuracy by combining the stored effective validation data and reference validation data predicted by a long-term statistical prediction model.

25 Advantageously, the learning of the parameters, or in other words, the training, of the various prediction models, is done at a first frequency whereas a short-term prediction is done at a second, higher frequency, which makes it possible to save computational resources.

Advantageously, since learning of the models is done very regularly, e.g. weekly, it is possible to absorb the annual seasonalities.

30 Advantageously, the method presented achieves an automated regulation the resources of the transport network according to the prediction of short-term flow, making it possible both to improve the comfort and safety of passengers and to save resources (e.g. electrical energy consumption) of the network.

CLAIMS

1. A method for automated supervision of short-term passenger flow in a transport network, more particularly an urban rail transport network, the transport network including a set of places of validation of passenger entries and/or exits and a system for recording actual validation data per place of validation, the method being characterized in that same includes the following steps implemented by a computation system (6):

- at an initial frequency of execution,
 - learning and applying (42) long-term statistical prediction models, each long-term statistical prediction model being associated with a place of validation and being calculated to obtain, for a first prediction time, a time series of predictions of validation numbers per time interval of selected unit time, said time series forming reference validation predictions;
 - learning (44) a single short-term prediction model, applicable for all places of validation, and allowing, for a second prediction time less than the first prediction time, a number of validations per time interval of unit time and per place of validation to be predicted, forming short-term validation predictions;
- at a second execution frequency, higher than the first execution frequency, of steps implemented at an execution instant:
 - aggregation (46) of actual validation data by place of validation and by time interval of unit time during a historical period relative to the execution time, to obtain aggregated validation data,
 - application (48) of said single short-term prediction model to the aggregated validation data, to obtain short-term validation predictions over the second prediction time, by place of validation and by time interval;
 - comparison (50), by place of validation and by time interval, of the reference validation prediction and the short-term validation prediction, and in the event of a difference above a predetermined alert threshold, the raise of alert (52).

2. The method according to claim 1, wherein if the short-term validation prediction exceeds the reference validation prediction by a value greater than a first alert threshold for at least one place of validation, a first priority level alert is raised.

3. A method according to claim 1 or 2, wherein if the short-term validation prediction exceeds the reference validation prediction by a value greater than a second alert threshold for at least one place of validation, a second priority level alert is raised, the method further including a real-time implementation (54) of a corrective action in the

transport network to regulate the flow of passengers arriving on platforms associated with the place of validation.

4. The method according to one of claims 1 to 3, wherein, if the reference validation prediction exceeds the short-term validation prediction by a value greater than a third alert threshold for at least one place of validation, a network equipment regulation measure is implemented.

5. The method according to one of claims 1 to 4, wherein the single short-term prediction model further takes as input reference, validation predictions over a time subsequent to the execution instant and reference data of the transport network.

6. The method according to claim 5, wherein the reference data of the transport network include vector data representative of the places of validations and of the vector data representative of the distances between places of validation of the transport network.

7. The method according to any of claims 1 to 6, wherein said single short-term prediction model is a deep neural network having a plurality of layers, trained on actual validation data to perform short-term validation prediction for each place of validation and each time interval.

8. The method according to any of claims 1 to 7, wherein each long-term statistical prediction model is an autoregressive model suitable for predicting a time series of reference validation numbers.

9. The method according to any of claims 1 to 8 wherein said first frequency of execution is equal to one week, the first prediction time is equal to one day, the method including learning a long-term statistical prediction model by day of the week, by type of day of the week and by place of validation, on the basis of actual validation data collected for the same day of the week, of the same type and for said place of validation.

10. The method according to any of claims 1 to 9, wherein said second execution frequency is less than one hour, said second prediction time is equal to a number of hours, and the unit time of the time interval is equal to one quarter of an hour.

11. A computer program including software instructions which, when implemented by a programmable electronic system, implement an automated supervision method for short-term passenger flow in a transport network according to claims 1 to 10.

12. An automated supervision system of short-term passenger flow in a transport network, in particular an urban rail transport network, the transport network including a set of places of validation of passenger entries and/or exits and a system for recording actual validation data per place of validation, the automated supervision system being characterized in that same includes a computing system (6) configured to implement:

- at an initial frequency of execution,
 - a learning and application module (18) for learning and applying long-term statistical prediction models, each long-term statistical prediction model being associated with a place of validation and being calculated to obtain, for a first prediction time, a time series of predictions of validation numbers per time interval of selected unit time, said time series forming reference validation predictions;
 - a learning module (20) of a single short-term prediction model, applicable for all places of validation, and making it possible, for a second prediction time shorter than the first prediction time, a number of validations per time interval of unit time and per place of validation to be predicted, forming short-term validation predictions;
- at a second execution frequency, greater than the first execution frequency, at an execution instant:
 - an aggregation module (22) of the actual validation data per place of validation and per time interval of unit time during a period of history with respect to the execution instant, to obtain aggregated validation data,
 - an application module (24) of said single short-term prediction model on the aggregated validation data, to obtain short-term validation predictions over the second prediction period, by place of validation and by time interval;
 - a comparison module (28) for comparing, by place of validation and by time interval, the prediction of reference validations and the short-term validation prediction, and in the event of a difference greater than a predetermined alert threshold, a module for raising the (28) alert.

13. The system according to claim 12, wherein if the short-term validation prediction exceeds the reference validation prediction by a value greater than a first alert threshold for at least one place of validation, the alert raise module (28) is configured to raise a first priority level alert.

14. A system according to claim 12 or 13, wherein if the short-term validation prediction exceeds the reference validation prediction by a value greater than a second alert threshold for at least one place of validation, the alarm raise module (28) is configured to raise a second priority level alert, the system further including a module (30) for implementing in real-time a corrective measure in the transport network serving to regulate the flow of passengers arriving on platforms associated with the place of validation.