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Design of the Hybrid Passenger Density Information System

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Abstract

The passengers suffer much inconvenience in a crowded subway during rush hour. The hybrid passenger density estimation (PDE) or information (PDI) system is proposed for maximizing the metro-users' convenience and saving their elapsed time to the destination. The hybrid PDIS technology is comprised of image processing for extracting passengers' head colors/motion vectors and RFID/NFC sensing for measuring the number of passengers. As a result, we can estimate fully the state of passenger density. As the system and its administrator reflect the apprehended crowd context, the passengers can improve their safety and convenience easily.

Keywords: *Hybrid Passenger Density Information System, PDIS, Motion Vector, Load Cell*

1. Introduction

A metropolitan mass transit system uses trains composed of multiple cars. Generally, a passenger waiting for a train on the platform does not know the level of crowdedness in each car (passenger car), and a passenger on a train does not know the levels of crowdedness in cars other than the one in which the passenger is riding [1-3]. As a result, the passengers on a train may not disperse into other cars, and a train may include cars with high levels of crowdedness and cars with low levels of crowdedness. What is more is that it is difficult to ascertain the level of crowdedness in a car for the driver of the train or even the operator managing the mass transit system. Meanwhile, the intervals between trains may be kept at constant times. However, it would be more desirable in terms of the convenience of the passengers if the intervals from a particularly crowded train to a preceding and/or succeeding train were shortened in order for the passengers to be suitably distributed over the respective trains.

The problem above also applies to the case of buses. That is, the passengers waiting for a bus at a bus stop do not know how crowded the buses are, so that even if multiple bus lines are available to a passenger, or if two buses of the same line reach the bus stop at the same time, the passenger is not able to easily select the bus that is less crowded. In the case of buses also, it would be more desirable in terms of the convenience of the passengers if the intervals from a particularly crowded bus to a preceding and/or succeeding bus were shortened in order for the passengers to be suitably distributed over the respective buses. However, in order to adjust the operating intervals as above, the levels of crowdedness of the cars of a train (or buses) must be known accurately.

To this end, a method of providing the density level of passengers as an approximated value (for example, as a percentage) was proposed. It applies a system of weight estimation system using load cells to a mass transit train or a bus to measure the changes in weight loads [4-6]. However, such approximated values provide an ambiguous basis for estimating the passenger density information and can increase the confusion of a user making a subjective judgment.

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To solve the problems above, an aspect of the proposed system design aims to provide accurate information on passenger density for the cars of mass transit trains or buses.

The remaining structure of this paper is outlined as follows. Section 2 briefly establishes our design goals and approaches. Section 3 designs the server-centered centralized architecture for providing passenger density information in a metropolitan mass transit system. The basic structure of the proposed design platform and its procedure is described from engineering and designing viewpoints, respectively. Section 4 proposes the learning mechanism of the proposed PDIS system and the empirical and theoretical analyses follow to investigate its characteristics. Concluding remarks follow in Section 5.

2. Design Goals and Approaches

To achieve the objective above, the proposed design provides a service server for providing passenger density information of a car that includes: a motion vector detection unit that detects motion vectors generated by the movements of passengers from a captured image of the inside of the car, a head recognition unit that recognizes the heads of passengers from the image, and a density information generation unit that generates the passenger density information of the car by using one or more of the motion vectors, a result of head recognition of the passengers, and tag sensor information received from sensors installed in the car.

With an embodiment of the proposed design, the following results are expected.

First, it is possible to provide passenger density information with greater accuracy for each car of a mass transit train or for a bus. The delays experienced by trains or buses can be reduced during times of high levels of crowdedness such as morning and evening rush hours by having the passengers distributed over different cars.

Second, passengers can use a train or bus in a comfortable environment, with higher levels of safety for the elderly and handicapped.

Third, it can help prevent incidents that may occur in crowded places (e.g. pick-pocketing, sexual molestation, and other accidents).

Fourth, since the passengers can be dispersed over the cars of a train, the likelihood of the train malfunctioning can be reduced, contributing to the train's longer life expectancy.

Finally, additional aspects and advantages of the present design will be set forth in part in the description which follows in Section 3. They will be obvious from the description, or may be learned by practice of the design.

3. Design of Hybrid Passenger Density Information System

This section proposes a system for providing passenger density information and illustrates its mechanism and engineered design.

A system for providing passenger density information - hereinafter referred to as passenger density information system (PDIS) - can include a density information measurement device, a service server, a display device inside a station, a display device outside a station, and a user terminal. The passenger density information system (PDIS) can be applied to a transport system such as the subway or bus systems. The descriptions that follow will be provided for an example in which the proposed scheme is applied to a subway system.

Here the density information measurement device can include a CCTV camera, an RFID/NFC sensor, and so on. First, the CCTV camera can be installed in each car of a train, to capture an image of the inside of the car, and transmit the image to the service server. Second, the RFID/NFC sensor can be installed near an entrance to the car, to sense the boarding of passengers carrying user terminals that include RFID/NFC tags, and transmit the tag sensor information, which may include the information of the sensed tags, to the service server. Here, the tag sensor information can include one or more of an identifier of the car in which the RFID/NFC sensor is installed, an identifier of the corresponding sensor, and an identifier of the sensed RFID/NFC tag.

3.1. Service Server for Providing Hybrid Passenger Density Information

The service server can generate passenger density information for each car based on the information received from the density information measurement device and provide the passenger density information to one or more of the display devices at the station and the user terminal. For example, the service server can receive the image of inside the car from the CCTV camera, detect motion vectors that are generated according to the movements of the passengers from the received image, and reflect the motion vectors in generating the passenger density information for each car.

The service server can reflect the sensor information received from the RFID/NFC sensors in generating the passenger density information for each car. For example, the tag sensor information received from RFID/NFC sensors installed near the entrances to the car can be used in determining the number of passengers in the car, and the sensor information received from RFID/NFC sensors installed on the floor of the car can be used in estimating the area of floor space occupied by passengers.

In this way, the service server can generate the passenger density information for each car based on one or more of the motion vectors generated according to the movements of the passengers, the results of head recognition of the passengers, the area of exposed floor space in the image of inside the car, and the tag sensor information utilizing RFID/NFC sensors.

The service server can process errors in the passenger density information of each car by using a learning algorithm (e.g. the error back-propagation algorithm) to reduce the error range and accumulate data to provide highly accurate estimates of the number of passengers in each car, rather than vague approximates. Also, the service server can provide the passenger density information of each car to the display devices at the station (refer to Section 3.2) and to user terminals. Here, the ‘passenger density information for each car’ can include one or more of an estimated number of passengers and a passenger density level in each car (where the density level can be represented by ranks or colors) and can further include information related to unoccupied seats. A more detailed description of the passenger density information displayed on the user terminal will be provided later on with reference Section 3.3.

3.2. Hybrid Indoor Pdis

Figure 1. Passenger Density Information Displayed on a Display Device at a Station

Figure 1 shows an example of passenger density information displayed on a display device at a station according to the proposed design. A display device at a station can be installed at the platform of the station, within a car, or along passageways such as stairs or elevators, and can receive the passenger density information of each car of a train from the service server and display it on a screen. In the case of a display device at a station, the passenger density information of a train approaching the corresponding station can be displayed on the screen as shown in Figure 1.

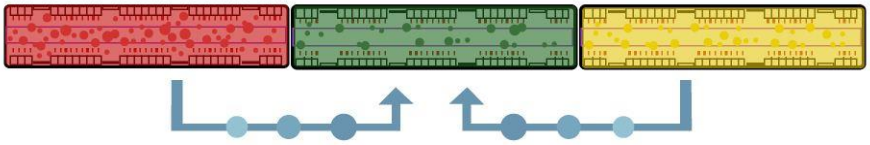

Figure 2. Voluntarily Distributed Passengers

As shown in Figure 2, the passengers can check the passenger density information of each car for a particular train on a display device at the station and use a car having a low passenger density level, as a result of which the passengers can be suitably distributed over the cars of the train. Each car of the train can be matched with a color representing a corresponding density level, according to the level of density of each car as shown in Figure 2. The user terminal can also display the passenger density information of a train approaching a corresponding station on the screen when the user searches and selects a particular subway station (refer to Section 3.3).

The service server for the hybrid indoor PDIS can generate passenger density information for each car based on the information received from the density information measurement device and provide the passenger density information to one or more of the display devices at the station and the user terminal as follows.

3.2.1. Extraction of Passenger Motion Vectors: Figure 3 shows a motion vector image extracted by the service server from the image of inside or outside the car. From this image, the density of passengers in the car can be identified and can be used to increase the accuracy and efficiency of the passenger density information. The motion vector can be extracted through various kinds of algorithms and filters in image processing [7-9].

Figure 3. Motion Vector Image Extracted by the Service Server From the Image of Inside/Outside the Car

3.2.2. Recognition Of The Passenger Heads Colors: Figure 4 shows the recognizing of the heads of the passengers by the service server, where the heads of the passengers can be recognized by detecting head colors from the image of inside the car and filtering by size. The head recognition for the passengers can be used in identifying the number of passengers in a car. Furthermore, the service server can recognize the heads of the passengers and can reflect the results when estimating the number of passengers in the car.

Figure 4. Recognition of the Heads of the Passengers using Head Colors

The service server can calculate the amount of exposed floor area from the image of inside the car to estimate the floor area within the car that is occupied by passengers, and reflect the result in generating the passenger density information for each car.

3.2.3. Recognition of Passenger-Carrying RFIDS and NFCS: Figure 5 shows an RFID/NFC sensor installed at the entrance to a car sensing a smart phone or smart watch including an RFID/NFC tag [10-11] carried by a passenger. The service server can receive tag sensor information from the RFID/NFC sensor and reflect this information in identifying the number of passengers in the car.

Figure 5. RFID/NFC Sensor Installed at the Entrance to a Car Sensing a Smart Phone or Smart Watch Including an RFID/NFC Tag Carried by a Passenger

3.2.4. Recognition Of Passenger-Wearing RFIDS and NFCS: Figure 6 shows RFID/NFC sensors installed on the floor of the car sensing smart shoes or antenna bands including RFID/NFC tags worn by the passengers. The service server can receive tag sensor information from the RFID/NFC sensors to estimate the area of floor space occupied by the passengers and can reflect this information in generating the passenger density information. The RFID/NFC sensor can attempt to sense tags periodically (for example, when stopping at each station or in particular intervals) and transmit the tag sensor information to the service server. Furthermore, the floor area occupied by passengers can also be incorporated [12-13].

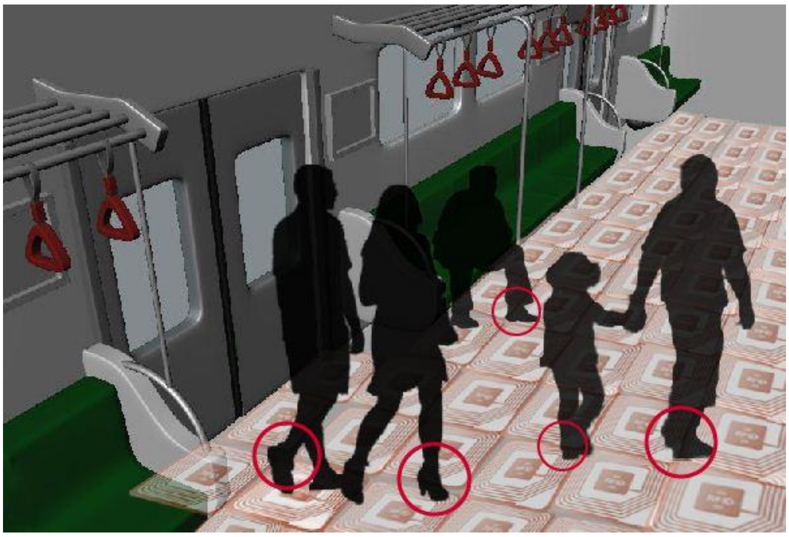

Figure 6. RFID/NFC Sensors Installed on the Floor of the Car Sensing Smart Shoes or Antenna Bands Including RFID/NFC Tags Worn by the Passengers

The proposed designs set forth above are for illustrative purposes. It would be appreciated by those of ordinary skill in the field of art to which the present design pertains that the embodiments above can be easily modified to other specific implementations without departing from the technical spirit of the present design and without changing the essential features of the present design.

3.3. Hybrid PDIS for user Terminals

The user terminal can include devices that can access the service server over a network such as smart phones, cell phones, PDA, PMP, wearable devices such as smart watches, tablet computers, laptop computers, desktop computers, IPTV connected with set-top boxes, and the like. A user terminal can access the service server for checking the stations and the operating schedules at a corresponding station as well as for requesting the passenger density information of each car of each train. The user terminal can receive the passenger density information for each car of a particular train from the service server and show it on the screen.

Figure 7. Passenger Density Information Displayed on a user Terminal Like a Smart Phone

Figure 7 shows examples of passenger density information displayed on a user terminal like a smartphone. Furthermore, the passenger density information can be the detailed information displayed on the user terminal when a particular car of the train is tapped from the passenger density information of Figure 8 below.

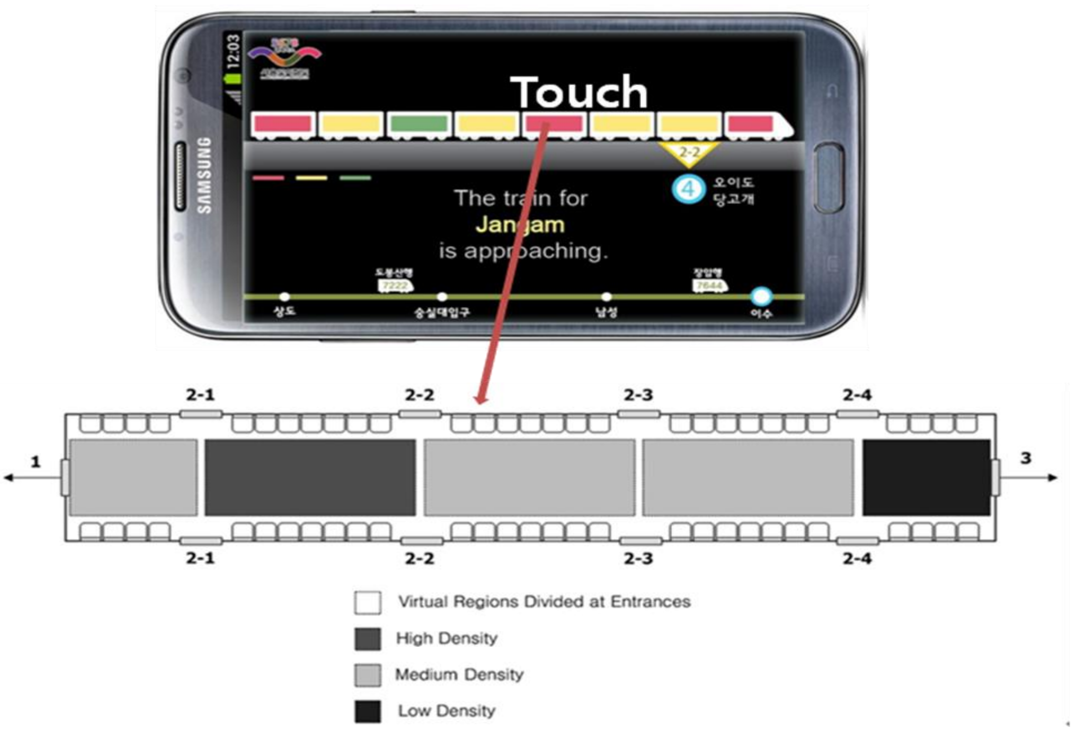

Figure 8. Detailed Passenger Density Information inside a Particular Car of the Train

As shown in Figure 8, the detailed passenger density information can be displayed such that the inside of the car is divided at the entrances into a multiple number of virtual regions, with the density level of each region matched with a color. That is, even though a car is shown as having a high passenger density level in Figure 7, there may be a region of relatively lower density level within the car, and the user can consider this passenger density information to board a desired car.

Incidentally, the density information of each region illustrated in Figures 7 and 8 can be generated by further applying weights to the results of calculating the area of the floor (floor color) in the car from the image of inside the car. Furthermore, the floor area occupied by passengers, as measured based on the tag sensor information received from the RFID/NFC sensors installed on the floor in the car, can also be incorporated.

3.4. Hybrid Outdoor PDIS

Figure 9. Passenger Density Information Displayed on a Display Device Outside a Station

Figure 10. Location Information of Subway Patrolmen and Temperature of each Car

Figure 11. Passenger Density Information Displayed on a Display Device at a Bus Station

As designed in previous sections, the hybrid outdoor passenger density information system can be applied as shown in Figures 9, 10, and 11 in the same way.

4. Learning Mechanism of Hybrid Passenger Density Information System

This section describes the learning mechanism of the hybrid passenger density information system. The service server for the hybrid passenger density information system consists of a motion vector detection unit, a head recognition unit, and a density information generation unit.

4.1. Head Recognition Unit and Motion Vector Detection Unit

The head recognition unit can recognize the heads of the passengers from the image of inside the car received from the CCTV camera. The head recognition unit can recognize the heads of the passengers by detecting head colors from the image of inside the car and then filtering them by size. To this end, the reference values for filtering by head color and size can be set beforehand, such as the head colors, and the aspect ratios of heads and head widths for filtering by head sizes, and the like. For example, the head colors can be black and brown (of course, other colors are also possible), the aspect ratios for head shapes can be between 1:1 and 2:1 for elliptical shapes, and the head widths can be set with an average of 156.38 mm, a minimum value of 122 mm, and a maximum value of 191 mm for a typical Korean adult man, and with an average of 147.24 mm, a minimum value of 120 mm, and a maximum value of 186 mm for a typical adult woman.

The motion vector detection unit algorithm can be extracted through various kinds of algorithms and filters in image processing. More detailed description is omitted for being beyond the scope of this paper.

4.2. Density Information Generation Unit

The density information generation unit can generate the passenger density information of each car by using one or more of the motion vectors detected by the motion vector detection unit, the heads of the passengers recognized by the head recognition unit, and the tag sensor information received periodically from the RFID/NFC sensors. Here, the density information generation unit can periodically remove redundant tag information from the received tag sensor information, so that even when certain passengers are sensed repeatedly within the same car, the number of passengers can be identified with high accuracy as follows.

First, the density information generation unit of the PDIS service server can estimate the floor area occupied by passengers in the car by calculating the area of the floor within the car that is exposed from the image of inside the car, and reflect the result when generating the passenger density information.

For example, if it is highly crowded in the car, the number of passengers occupying the floor in the car would be high, and as a result, the area of exposed floor space (the color of the floor) in the image of inside the car would not be large. Conversely, if it is not very crowded in the car, the number of passengers occupying the floor in the car would not be high, so that the area of exposed floor space (the color of the floor) in the image of inside the car would be large.

Second, the density information generation unit can apply different weights when generating the passenger density information of each car by using one or more of the motion vectors, the recognized heads of the passengers, and the tag sensor information.

For example, the weights can be applied differently according to the time of day at which the train is running. That is, between 7 and 10 o'clock in the morning on weekdays, many of the passengers would be young office workers, so that there may be more black or brown head colors, and the accuracy of head recognition for the passengers may be higher. In this case, the weight applied for the head recognition can be set higher than the weights for the motion vectors and tag sensor information in generating the passenger density information of each car. Also, between 10 and 11 o'clock in the morning on weekdays, there may be more senior citizens who may take advantage of free transit passes and who have come to enjoy more active lifestyles in recent times, so that there may be more grey head colors rather than black or brown, and the accuracy of head recognition based on black and brown head colors may be somewhat lower. In this case, the weight applied for the motion vectors can be set higher than the weights for the head recognition and tag sensor information in generating the passenger density information of each car.

Likewise, the weights can be set differently for each month (or other period). In warmer seasons (weather) such as summer, the passengers may wear brightly colored tops and may not wear hats, so the accuracy of head recognition for the passengers can be higher. In this case, the weight for the head recognition can be set higher than the weights for the motion vectors and the tag sensor information. However, in colder seasons (weather) such as winter, the passengers may wear dark colored jackets and coats and may wear hats, so the accuracy of head recognition for the passengers can be lower. In this case, the weight for the motion vectors can be set higher than the weights for the head recognition and the tag sensor information. Moreover, the weights can also be set differently according to the operating region (running path), of the train.

Third, the density information generation unit can match the passenger density level with one or more of a number, letter, and color, when generating the passenger density information of each car. For example, a high passenger density can be matched to 1, a medium passenger density can be matched to 2, and a low passenger density can be matched to 3, while a high passenger density can be matched to a red color, a medium passenger density can be matched to a yellow color, and a low passenger density can be matched to a blue color. The passenger density can be determined according to the proportion of the estimated number of passengers on board with respect to the recommended number of passengers for each car. The passenger density of each car can also be represented as the number of passengers riding on each car.

5. Conclusions

This paper presented the first steps towards the creation of the hybrid passenger density information that consists of various kinds of passenger recognition devices and their convergent calibration-learning ability. It is also envisioned that in the future, a component described as an integrated form can be used in a distributed form, while components described as being in a distributed form can be used coupled together.

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References

[1] T.-J. An, J.-R. Shin, G.-J. Kim and M.-H. Kim, "Scenario for Measurement of Crowd Density in Urban Transit", Proceedings of the 2010 Conference on Information and Control Systems, (2010) October 22-23 ; Ulsan, Korea.
[2] Helbing, Dirk, A. Johansson and H. Z. Al-Abideen, "Dynamics of crowd disasters: An empirical study", Physical review E. 75, 4 **(2007)**.
[3] V. Toll, W. G., A. F. Cook and R. Geraerts, "Real-time density-based crowd simulation", Computer Animation and Virtual Worlds. 23, 1 **(2012)**.
[4] J. Kim, G. Yun., K. Jung and K. Kim, "Implementation of smart floor Using RFID tag for Indoor Localization System", Proceedings of the 31th Congress of the Institute of Electronics and Information Engineering, June **(2008)**, Seoul, Korea.
[5] J. Lee, "Development of weighing in motion system by digital load cell", Ph.D. Thesis, Kangwon National University, **(2004)**.
[6] K. A. Umit, "Strain detecting load cell", U.S. Patent 3,695,096, October 3 **(1972).**
[7] Johansson, Anders, D. Helbing and P. K. Shukla, "Specification of the social force pedestrian model by evolutionary adjustment to video tracking data", Advances in complex systems, 2, 10 **(2007).**
[8] Lakoba, I. Taras, D. J. Kaup and N. M. Finkelstein, "Modifications of the Helbing-Molnar-Farkas-Vicsek social force model for pedestrian evolution", Simulation, 5, 81 **(2005).**
[9] Helbing, Dirk and A. Johansson, "Pedestrian, crowd and evacuation dynamics", Springer, New York, **(2009)**.
[10] J. Kim, G. Yun., K. Jung and K. Kim, "Implementation of smart floor Using RFID tag for Indoor Localization System", Proceedings of the 31th Congress of the Institute of Electronics and Information Engineering, June **(2008)**, Seoul, Korea.
[11] S. Shafer, J. Krumm, B. Brumitt, B. Meyers, M. Czerwinski and D. Robbins, "The New Easy Living Project at Microsoft Research", Proceedings of the 1998 DARPA/NIST Smart Spaces Workshop, **(1998)**, July 30-31; Gaitersburg, Maryland, USA.
[12] S. E. Sarma, S. A. Weis and D. W. Engels, "RFID Systems and Security & Privacy implications", Lecture Notes in Computer Science, 2523 **(2003)**.
[13] S. Jung, "A Design of Passive RFID Tag Antenna for Embedded Use in the Concrete Floor", Master Thesis, Chonbuk National University, **(2011)**.

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