Visualization of Passenger Flows on Metro

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Abstract

Visualization is one of the most important techniques for examining influences of various kinds of phenomenon such as natural disasters, public gatherings, or accidents on changes in behavior of Metro system passengers. In this paper, we visualize the propagation of the effect of troubles and changes in transportation flows in a wide area using data on the Tokyo Metro extracted from a smart card system from March 2011 to April 2013. Our system enables us to not only explore changes in passengers' actions after accidents or disasters but also to discover unusual and unexpected phenomena and explore their details and reasons.

1 Introduction

Railway and metro systems in big cities often suffer delays and accidents, and it is critical to keep track of their influences on the flows of people for operating trains and allocating staff. Natural disasters such as earthquakes and typhoons stop several lines, making people take detours. Events such as concerts and baseball games gather thousands of people into the nearest stations. Understanding such changes quantitatively is important for optimizing usual operations and preparing for the next disasters.

Visualization of changes in the flows of people in a wide range of spatio-temporal space enables us to explore the influence of such phenomena. Ceapa et al. [1] analyzed congestion patterns of Tube stations in London. Sun et al. [2] analyzed spatio-temporal density of passengers for one MRT line in Singapore. Tominski et al. [3] showed the usefulness of 3D trajectory bands to visualize trajectory attribute data. Their system treats a single kind of attribute value at once on simple trajectories. Tokyo has the world's most complicated route map for a transportation system. It is not enough for us to analyze data while focusing on each station or a single line independently. We must analyze the propagation of the effect of troubles in a wide area. However, there is no research on the visualization of such propagation of influences spreading over a wide range of metro lines.

In this paper, we visualize temporal changes in passenger flows on the complicated route map of Tokyo. Our system enables us not only to explore changes in passengers' actions after accidents or disasters but also to discover unusual and unexpected phenomena and explore their details and reasons. It first visualizes an overview of spatio-temporal crowdedness on a 2D HeatMap View to observe unusual phenomena easily from a large spatio-temporal space. Second, it visualizes changes in passenger flows on a 3D RouteMap View using 3D colored bands to represent crowdedness on each section of each line to explore changes in behaviors of passengers in detail. For this purpose, we use a large scale data set of travel records (two years' worth) on the Tokyo Metro extracted from the smart card system. Each record consists of the origin, destination, and exit time. Identifiers of cards are not used in this research. To visualize them, we estimate the probable route of each trip and then count how many passengers were on each section of each line for every 10 minutes. Average and standard deviation are calculated for discovering whether it is less or more crowded than usual. We report the usefulness of our visualization system by using various case studies.

2 Analysis of Passenger Flows

There are several possible paths to travel from an origin station to a destination station. A smart card log contains information about where a passenger touched in and where and when he/she touched out. It does not include the entrance time and transfer stations' information. We therefore speculate the most probable path for each trip (origin and destination pair) by assuming that they travel through the shortest time path. In the speculation process, we take into consideration average travel time of each section, estimated walking time for each transfer (which differs at every station), and average waiting time for the next train. We can estimate in which section of a line a passenger passes in a particular timing from the speculated shortest time path and exit time.

We analyzed large scale log data covering almost all of the business area of Tokyo. It consists of 28 lines, 540 stations, and about one billion trips (this includes lines and stations besides Metro ones because of transfers.) We want to find unusual phenomena that differ from the usual cyclical patterns of the passengers. We therefore accumulate a number of passengers who traveled a certain section in a certain time period and calculate their average and standard deviation. Data for weekdays and weekends are separately analyzed. The average and standard deviation are used for detecting unusual patterns, especially in weekdays' cyclical patterns.

3 Visualization of Passenger Flows

HeatMap View (Fig. 1 (I)) visualizes spatio-temporal crowdedness of sections. It uses x-axis for the timeline and y-axis for lines. The timeline is divided every 10 minutes. Each line is represented by different colors, and both directions (up and down) are treated separately. Each up/down line consists of sections (pairs of stations). The color code represents the difference (d) normalized by standard deviation. Red represents higher d, and blue represents lower d.

RouteMap View (Fig. 1 (II)) visualizes animated temporal changes in the number of passengers and d value of each section. The number of passengers is represented by the height of stacked 3D bands, which consists of bands for two directions, on each section. Color represents d. A bar on each station presents the number of passengers who exited from the station. Colors of bars also show d for the number of passengers.

HeatMap View and RouteMap View are coordinated with each other. Users can select time stamps and lines on HeatMap View, and then RouteMap View starts animated changes in values for selected lines and time.

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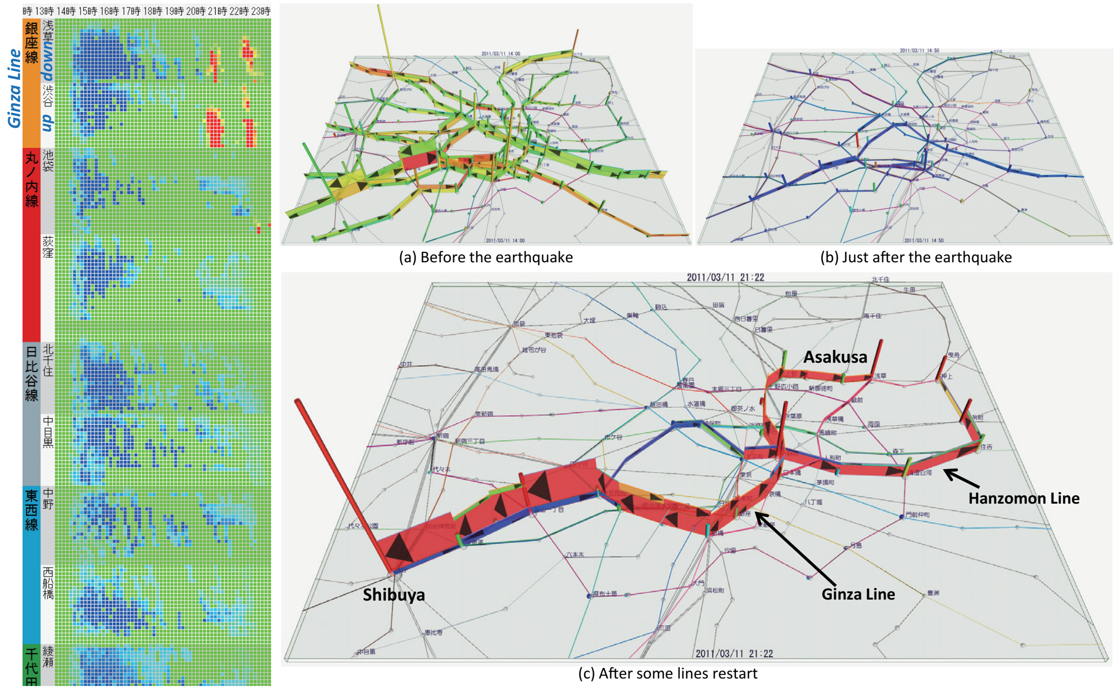


(a) Before the earthquake (b) Just after the earthquake

(c) After some lines restart

(I) HeatMap View (II) RouteMap View

Figure 1: Passenger flows on 11 Mar. 2011.

When users find unusual phenomena on HeatMap View or RouteMap View, they can explore evidence for such phenomena using a time stamp, names of stations, lines, and location information (geo-tag) from our Twitter archive constructed from 2011.

4 Case Studies

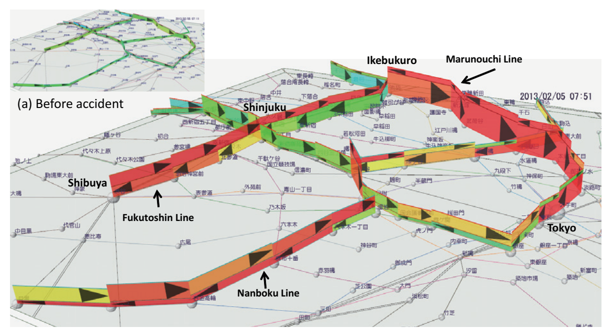
Fig. 1 visualizes passenger flows on 11 Mar. 2011, the day on which the Great East Japan Earthquake occurred at 14:46. Fig. 1 (II-a) shows the situation just before earthquake. Almost all lines were operating normally. We can see that almost all lines stopped operation after the earthquake from Fig. 1 (I) and Fig. 1 (II-b). There are large blue areas in HeatMap View. The color of each section turns blue in RouteMap View.

At 20:40, the Tokyo Metro Ginza Line and part of the Hanzomon Line recovered. From the red areas shown in the upper-right part of Fig. 1 (I) and Fig. 1 (II-c), we can find too many people were concentrated on the Ginza Line, and moved to Shibuya and Asakusa. We can find many people tweeted information such as "Ginza Line is running again" before and after it restarted (the spread of such tweets might accelerate concentration.)

Fig. 2 visualizes changes in passenger flows after an accident at JR (Japan Railway) Ueno station on 5 Feb. 2013. After the accident, the JR Yamanote Line stopped. The JR Yamanote Line is a loop line that connects most of the major stations in Tokyo. The accident happened during the rush-hour, so it affected many passengers. Fig. 2 shows many people changed their routes to their destination. For instance, in the route between Shibuya, Shinjuku, and Ikebukuro, many passengers switched to the Tokyo Metro Fukutoshin Line in place of the JR Yamanote Line. Passengers changed to the Metro Marunouchi Line to go to Tokyo station.

5 Conclusion

We proposed a novel system to visualize changes in flows of passengers in the Metro system using more than two years' worth of data extracted from the smart card system. It enables us to explore



(b) After accident

Figure 2: Effect of the accident at JR Ueno station on 5 Feb. 2013. (Only Fukutoshin, Marunouchi, and Nanboku Lines are selected.)

changes in passengers' actions after disasters, accidents, or public gatherings. Moreover, it helps us to discover unusual and unexpected phenomena and explore their details and reasons.

Future work includes automatic detection of unusual events and their reasons. We also plan to expand this system to simulate changes in passenger flows under manually specified accidents or events. This will supply very useful knowledge for improving services.

References

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