Visualization of train traffic records to realize more robust timetable

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ABSTRACT

One of the problems in urban railways in Japan is that small delays often happen during rush hours. Because trains are running very densely, a small delay propagates to other trains and the delays tend to expand. The first thing railway companies have to do to reduce the delays is to grasp the situation of train operation, which means to grasp how often delays are occurring, how much the delays are, where the delays are happening, how the delays are propagating to other trains and so on. At the same time, they need to analyze possible causes of delays such as an excess of dwell times, an excess of running times, an existence of knock on delays and so on. We can now obtain historical train operation data which contain arrival and departure times of all the trains for a long period. The volume of the data, however, is huge and it is impossible to know what are happening from these data. In this paper, we propose several visualization methods of the historical train operation data so that timetable planners can intuitively figure out the situation of train operation and get a helpful information for analysis.

INTRODUCTION

One of the problems in urban railways in Japan is that small delays often happen during rush hours. Because trains are running very densely, a small delay easily propagates to other trains and the delay tends to expand. Passengers are complaining about those delays and railway companies are now very keen to reduce such small delays; in other words, they have a strong intention to make their timetable more robust (Yamamura 2013). The first thing they have to do in this process is to grasp the situation of train operation, which means to grasp how often delays are occurring, how much the delays are, where the delays are happening, how the delays are propagating to other trains and so on. At the same time, they need to obtain various kinds of information to analyze possible causes of delays such as an excess of dwell times, an excess of running times, an existence of knock on delays and so on.

We can obtain historical train operation data which contain arrival and departure times of all the trains of every day. The volume of these data, however, is huge and it is impossible to know what are happening from viewing the raw data. Thus, it is strongly required to provide methods to visualize these data (Chen 2015) so that timetable planners can easily grasp the situation of train operation and analyze the cause of delays.

In this paper, we propose several formats of visualization of historical train traffic data. We propose the chromatic diagram in which train lines of a train graph is colored reflecting the amount of delay, a delay diagram from which we can easily figure out where a delay has occurred and if the delay has increased or
reduced, three dimensional diagram from which we can grasp the overall situation of occurrence and disappearance of delays and so on.

**THE PROCESS TO IMPROVE ROBUSTNESS OF A TIMETABLE**

We think the process to improve robustness of a timetable should be illustrated as in **Fig. 1** (Ushida2011).

In the **Overview** phase, we overview if some problems are occurring or not. For example, we overview the average delays and the number of trains that suffer from knock on delays. We observe not only for one particular day, but we are interested in effectively grasping occurrence of problems over a longer term. In the **Identify** phase, we identify the cause and the severity of the problem which was found in the overview phase. In the **Propose** phase, we pick up problems based on the severity measure calculated in the Identify phase and propose how we should modify the timetable. In the **Predict** phase, we predict results of the modifications taken in the Propose phase. This should be done considering the occurrence of initial and primary delay and propagations of those delays. In the **Evaluate** phase, we calculate a quantitative value to evaluate the proposal from the viewpoints of robustness.

In this paper, we focus on the **Overview** phase and introduce several methods to visualize train traffic record data.

**TRAIN TRAFFIC RECORD DATA**

We can now obtain historical train traffic record data from train traffic control system every day. The data contain train numbers, arrival times, departure times at stations, track and other related information such as the type of trains. All the information about train operation is included in the data and we can expect that we can know the every day results of train operation in detail (Graffagnino 2013)

**VISUALIZATION FORMATS**

**Chromatic Diagram** In ordinary time space diagram, a delay of a train is illustrated as a horizontal difference from its original position. Hence, it is easy to understand that the running time of a train is longer than others from the slant of the train segment for example. But it is not easy to observe how serious the delays are and how widely delays are propagating. The Chromatic Diagram is a two dimensional time space graph similar to the ordinary time space diagrams currently used, but each train segment between station lines is given a color reflecting its delay (departure delay or arrival delay, which is subject to users’ choice). We prepare 20 colors from indigo to red as illustrated in **Fig. 2**. Chromatic Diagrams make it easy to visually grasp how serious delays are, where delays are emerging and disappearing and how widely delays are propagating.

**Bubble Diagram** In the chromatic diagram, we can display circles (bubbles) which show the dwell time (or excess of the dwell time). The bubble diagram is very useful to know the cause of delays because in urban railway lines, the major cause of delays is an excess of dwell times.

**Delay Diagram** In ordinary time space diagram, the horizontal axis is the time, whereas in the Delay Diagram, horizontal axis means discrepancy from planned schedule (An example is shown in **Fig. 3**). Thus, if a train is totally on schedule from the start to the end, it is depicted just by one vertical line. From
the Delay Diagram, we can easily identify where trains began to be delayed, where delays are recovered and so on. Each train segment is given a color depending on its delay as in the Chromatic Diagram. We also prepare an Incremental Delay Diagram in which the horizontal axis is an increment or a decrement of delays so that we can learn how delays are growing or decreasing.

**3D Diagram** In the 3D diagram, horizontal axis (x axis - time) and vertical axis (y axis - station) are the same as in the ordinary time space graph. But 3D diagram has one more axis (z axis). Z axis depicts delay or dwell time (congestion in the future). In other words, a delay or a dwell time of a train at each station is depicted by a pillar. An example of a 3D diagram is shown in Fig. 4. From the 3D diagram, we can intuitively grasp where the delays are emerging and where the delays are disappearing and how serious the delays are. We can also show a “cut result” for a 3D diagram. An example is shown in Fig. 5. This figure shows a result which is obtained by cutting “vertically,” meaning to cut by time axis. From this visualization, we can intuitively know how the delays of trains are at each station. We can also “cut” horizontally. From the horizontal cut, we can know how delays are changing as time proceeds at one particular station.

**Visualization of other useful information** We have also prepared visualization of other information useful for analysis. Some examples are: box diagrams of delays, dwell times, running times, headways and scatter diagrams for delays etc. and so on.

We can output all of these diagrams for a day or an average or median of a certain period.

![Chromatic Diagram](image)

**Fig. 2. An example of a Chromatic Diagram (a part).**

**CONCLUSIONS**

We have introduced several methods to visualize historical train traffic records. The visualization is of course useful for analysis, but we learned that it is also useful to evaluate whether delay reduction measures were effective or not by comparing the results by visualization, the chromatic diagram in particular. These methods are practically used in railway companies now and highly appreciated.

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