A new diagram forecasting system for the Tokaido-Sanyo Shinkansen

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Summary:
We have developed a new diagram forecasting system for the Tokaido-Sanyo Shinkansen, which simulates actual train movements. This system has made great contributions to improving transportation quality by providing accurate diagram forecast.

Key Word: diagram forecast, simulation, operation management, operation adjustment, high speed railway
1. Introduction

The Tokaido-Sanyo Shinkansen, the main artery of the Japanese transportation network, is a high volume (about 500,000 passengers daily) and tightly scheduled (about 1000 trains daily including out of service trains) railway. Therefore, the delay of Tokaido-Sanyo Shinkansen trains has an enormous effect on society and economy, and prompt recovery to an on time schedule is expected. In the case of delayed trains, the conductors play a key role in restoring the schedule by taking various measures to adjust train operation, such as changing passing/waiting stations, platforms and so on. For the restoration work, they have to predict the future traffic; however it is very difficult for conductors because many trains are operated in the Tokaido-Sanyo Shinkansen.

2. The features of the new diagram forecasting system

The former traffic control computer used diagram forecasting algorithm that calculates the arrival time by adding fixed station - to - station running time to the departure time. However, this algorithm cannot reflect a delay that occurs between stations (Figure 1). Since the delay is critical to the traffic controllers because of the Tokaido-Sanyo Shinkansen’s features (tightly scheduled operation and relatively long distance between stations), we have developed a new diagram forecasting system that simulates actual train movements (Figure 2). The main features of this system are the following.

1. to offer a real-time and accurate diagram forecast which reflects delays between stations.
2. to propose diagram modifications based on the accurate diagram forecast.
3. to show a diagram forecast which reflects diagram revisions by controllers.

Using this diagram forecasting system, the controllers can attempt various modifications of the diagram, reference the operation adjustment proposal, and confirm the forecasting diagram that reflects the modification in the diagram format. Therefore the optimized diagram adjustment becomes easy to operate.

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**Figure 1: Former diagram forecasting system**
3. System configuration

The new diagram forecasting system consists of 4 functions, the PTTR function in PRC, the current condition detecting function in TCS, the train movement simulation function and the station unit simulation function in IWS (Figure 3).

Figure 2: New diagram forecasting system

Figure 3: System configuration
3.1 PTTR (PRC Train Tracking) function

The PTTR function in PRC tracks the trains using the track circuits sequential ON/OFF movement that is obtained from CTC (Centralized Traffic Control System). This function renews the train tracking information and sends it to the current condition detecting function, every time the function receives information from CTC.

3.2 Current condition detecting function

The current condition detecting function in TCS (Traffic Communication Server) always calculates current conditions. Using the train tracking information from PTTR, this function makes the current ATC speed signal, the speed and the position of all trains.

First, it calculates ATC speed signal based on the information obtained from the PTTR function. After that, the speed of all trains is calculated as follows:
- If the train exists in the border of a track circuit, the speed of the train is calculated as follows:
  \[ \text{Speed} = \frac{\text{the length of the train}}{\text{the time between ON/OFF movement of the track circuit}} \]
- If the train exists in the middle of a track circuit, the speed of the train is calculated as follows:
  1) The target speed is calculated, using minimum of ‘ATC speed signals – 5km/h’, ‘speed limits of tracks – 2km/h’, and ‘maximum speed of the car’.
  2) The train’s acceleration or deceleration (if any) is decided by comparing the former speed with the target speed.
  3) The speed of the train is calculated using the table of acceleration and deceleration and the slope of the existing position.

Finally, it renews the positions of all trains, using the calculated speed above.

3.3 Train movement simulation function

On the basis of the position and the speed of trains, the train movement simulation function simulates the future operation of all trains and makes the forecasted diagram. The function consists of four parts: setting current conditions, PRC route set forecasting, ATC and interlocking forecasting, and forecasting train running.

The setting current conditions part sets the necessary conditions for the sake of simulating actual train movement, such as the speed and the position of all trains, the starting order of trains and so on.

The other three parts work together. The PRC route set forecasting part simulates the route control of PRC and sets the route. ATC and interlocking forecasting part simulates the interlocking switches and the ATC signal speed. The forecasting train running part moves trains for 3 seconds, which is the cycle of taking the information from CTC, reflecting all necessary conditions such as the train performance, ATC speed signals, slope of the position, speed limits and so on. According to the movement of the trains, the ATC and interlocking forecasting part renew the existing conditions of signals. PRC route set forecasting part sets the route by the renewed condition. Repeating the above cycles, these three parts simulate 30 minutes of train movement. Every 15 seconds, this function simulates actual train movements, and sends the forecasting diagram to station unit simulation function.

3.4 Station unit simulation function

The station unit simulation function fills up the forecasting diagram from the train movement simulation function using the conventional method, which adds station to station fixed running time to the departure time. This function predicts up to 6 hours every 15 seconds. Furthermore, this function evaluates the forecasted diagram, and proposes operation adjustment, such as changing passing/waiting of the train at each station, to the controllers.

The command input/output devices, called IWS (Intelligent WorkStation), serve the diagram forecast and operational adjustment proposal in the diagram format.
4. The effect of new diagram forecasting system

Figure 4 and Figure 5 show the effect of the new diagram forecasting system. These are the results of the diagram forecast in the case that train No.200 stops between Toyohashi and Mikawa-Anjo stations and approximately 30 minutes delay occurs. Figure 4 shows the result of the new diagram forecasting system and Figure 5 shows the result of the former diagram forecasting system. As you can see, the former forecasting system cannot reflect the delay between stations until the train arrives at the next station; however, the new forecasting system reflects the delay in real time and proposes operational adjustments.

Figure 4: New forecasting diagram in case of delay
The advantages of using the new diagram forecasting system for restoration work are summarized as follows:

1. Based on the precise forecasting diagram, this system detects route conflicts and delays immediately after train operation deviates from the schedule, and displays warnings, such as an increase of delay, the platform conflicts and so on.
2. Controllers have enough time to find effective dispatching measures because the forecasting system reflects the delay in real time.
3. Controllers can attempt various modifications of the diagram, referencing the operation adjustment proposal, and confirm the forecasting diagram that reflects the modification in the diagram format.

Using this system, the optimized diagram adjustment becomes easy to practice, and as a result, the traffic recovery procedure becomes even faster.

5. Conclusion

The system mentioned above has been in operation since 12/1999 in the General Control Center, and its forecasting diagram has proved to be precise. The usefulness of the diagram forecasting system has been well approved by the controllers, and it is mainly used when train operation deviates from the schedule. Using the precise forecasting diagram, the controllers have dispatched diagrams appropriately. This system has made great contribution to improving transportation quality of Tokaido-Sanyo Shinkansen.

In the near future, the information of the diagram forecasting system will be also used for Passenger Information System of stations.

Figure 5: Former forecasting diagram in case of delay