

Study on digital twin computing for predicting general road traffic volume

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Abstract— There is active research being conducted into systems that can simulate a town's road traffic on a digital twin based on information sensed in the real world, making it possible to plan measures to alleviate congestion and optimize travel routes. A transportation digital twin is a computerized reproduction of real-world road traffic. By using a transportation digital twin, it is possible to grasp the state of road traffic in real time and predict future traffic conditions. In order to reproduce real-world traffic flows and predict future traffic flows using a digital twin, traffic data with fine temporal and spatial granularity is required. For this reason, research and development is being carried out based on 5G and Beyond 5G, which enable large-volume communication. However, this method requires the continuous collection of large amounts of data, which makes it difficult to utilize in regional cities in terms of cost. Therefore, we propose a method to build a digital twin by collecting small amounts of data, inputting them, and supplementing them with machine learning.

Keywords—Transportation, Digital Twin, Bus, Traffic Jam, Optimal Route, Traffic Flow Control

I. INTRODUCTION

A transportation digital twin is a computerized reproduction of real-world road traffic. By using a transportation digital twin, it is possible to grasp the state of road traffic in real time and predict future traffic conditions [1-3]. In order to reproduce real-world traffic flows and predict future traffic flows using a digital twin, traffic data with fine temporal and spatial granularity is required. For this reason, research and development is being carried out based on 5G and Beyond 5G, which enable large-volume communication.

The population continues to decline in regional cities in Japan. This makes it difficult to maintain public transportation. The number of buses, trains, and other services is steadily decreasing. It is not uncommon for bus services to be discontinued or to run only two or three times a day. How to maintain regional public transportation is an important issue. On the other hand, when public transportation is discontinued, the only means of transportation available is by private car. This is why regional cities experience traffic congestion during morning and evening commute times. As you can see, regional transportation faces many challenges. To address these issues, various initiatives have been undertaken in recent years, including shared buses, on-demand buses, and self-driving buses. To support new forms of transportation, we need a new type of transportation digital twin system, one that can solve problems unique to rural areas.

The biggest problem in rural areas is the limited amount of money that can be invested in the system. It would be ideal to place sensors in every corner of town, collect data, and build a system, but this is difficult to do in regional cities. We propose to build a highly accurate transportation digital twin system using little data.

First, a private network will be created in a regional city using LPWA such as LoRa. A transportation digital twin will be built on this private network. Since it is difficult to deploy a large number of sensor information, the information will be location information installed on buses, and the basic data for traffic information will be input using existing congestion information from Google Maps, etc. The performance we aim for is real-time data provision. With existing information from Google Maps, etc., it takes time for congestion information to actually appear on the map after a traffic jam occurs. We will solve this issue.

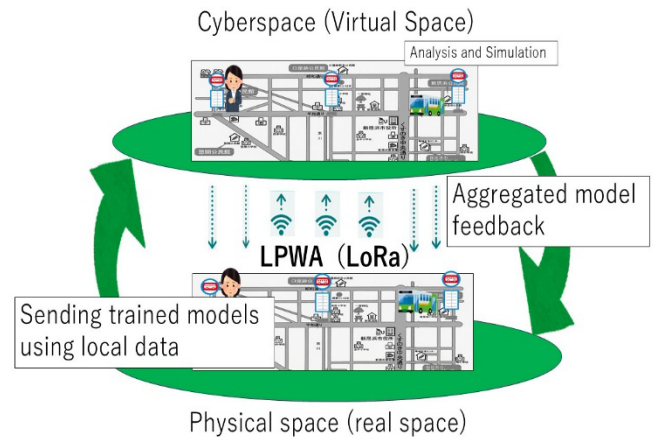


Fig. 1. Diagram of the proposed transportation digital twin configuration built on an LPWA network.

II. TRANSPORTATION DIGITAL TWIN

In rural areas, there are concerns that public transportation will be reduced or cut back due to the aging of local residents and declining birthrates[4,5]. In order to address these issues, measures such as the development of efficient public transportation, the introduction of traffic management technology, and the promotion of sustainable mobility have been cited. At the consideration stage, the use of a transportation digital twin has attracted attention. We are working on developing digital twins for transportation systems to solve regional transportation issues.

Figure 1 shows the configuration of the transportation digital twin we are building. Figure 2 shows the function

diagram of the transportation digital twin. The transportation digital twin is a technology that virtually reproduces actual transportation systems and infrastructure, and simulates, monitors, and optimizes their operation. This aims to solve various transportation issues and enable more efficient and safer traffic management. The main roles of the transportation digital twin we are aiming to build are as follows:

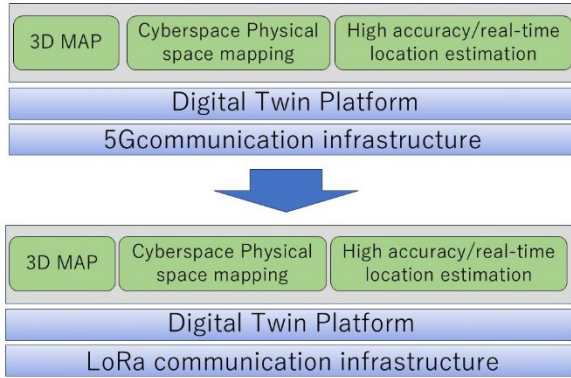


Fig. 2. Functional diagram of the transportation digital twin.

- 1) Real-time monitoring and management: A transportation digital twin monitors road transport infrastructure in real time and aggregates data. This allows immediate identification of problems such as congestion, crowding, and accidents, and allows for rapid response.
- 2) Simulation and forecasting: Traffic flows are simulated to predict future transport demand.
- 3) Transport optimization: Digital twins are used as tools to optimize traffic flows. On-demand bus routes can be determined to avoid congestion, leading to congestion relief measures.
- 4) Urban planning and infrastructure development: Digital twins are used to simulate different scenarios in the design of new infrastructure and urban planning. This allows for more effective designs by predicting future traffic volumes and infrastructure needs.
- 5) Improved safety: Digital twins help assess the risk of road accidents and identify dangerous locations. This can improve the safety of roads and public transport.
- 6) Transport policy planning and evaluation: Governments and local authorities can use digital twins to plan new transport policies and simulate their impacts in advance. For example, the impact of road regulations and environmental regulations on traffic can be predicted, leading to more effective policy decisions.
- 7) Environmental friendliness: A transportation digital twin can also assess the environmental impact so measures can be devised to reduce the environmental burden.

Overall, transport digital twins play a role in contributing to solving problems in a wide range of fields, including traffic efficiency, safety improvement, environmental protection, and urban development.

The feature of the proposed system is that it uses LPWA such as LoRa as the communication infrastructure. By constructing a private network within the city that does not require communication line usage fees, a cost-free system is realized.

LPWA such as LoRa does not require communication line usage fees, but there is a limit to the amount of data that can be transmitted. Therefore, only limited information such as numerical information can be sent and received. It is necessary to build a system on such a limited network. It is difficult to install many sensor devices in a city and collect data. Therefore, we will adopt a method to collect data in real time only from public transportation, analyze it, and publish only the analysis results on the web and in an app.

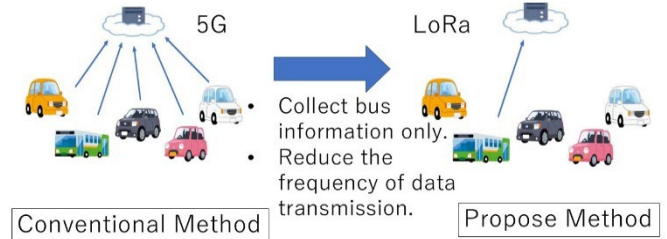


Fig. 3. Unlike traditional methods that use mobile phone travel routes, the proposed method leverages public transport travel route data.

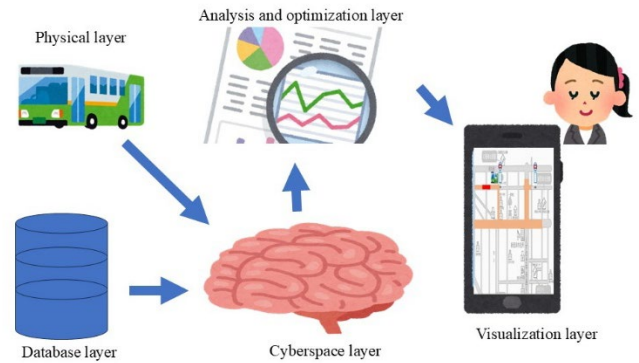


Fig. 4. Transportation digital twin system concept diagram.

III. TRANSPORTATION DIGITAL TWIN SYSTEM CONFIGURATION

We will explain the detailed structure of the proposed transportation digital twin. Figure 4 shows a conceptual diagram of a transportation digital twin system.

1) Physical layer

Sensor: GPS information installed on public transportation

Past traffic flow data: congestion information from Google Maps, etc.

Weather data: Data on weather and weather conditions (simulation of the effects of rain, snow, wind, etc.)

Event information: Event data

2) Database layer

Past physical layer data, analysis model, analysis result data

3) Cyberspace layer

An analysis model is constructed on a virtual map using data stored in the database as input

4) Analysis and optimization layer

A transportation model is created using machine learning, and a congestion map is created from the GPS information installed on current public transportation. The time required for travel is calculated using the congestion map.

5) Visualization layer

Disclosed on a web app for wide public release. Published as an iOS or Android app.

IV. GENERATING CONGESTION MAPS FROM BUS TRAVEL TIMES

We will explain how to create a machine learning model in cyberspace and how to calculate travel time using the machine learning model.

Figure 4 shows the congestion map that is input for machine learning. An image is used as input for the congestion map. Multimodal machine learning is used. In other words, the input is an image showing the congestion map and the position and speed of the bus. A traffic learning model is created by reading these and having it learn (see Figure 5). By providing the position and speed of the bus as input to the traffic learning model, a congestion map image is output. Using the output congestion map, a travel route is determined and the time required for travel is calculated.



Fig. 5. Input image for machine learning. The congestion map, bus location, and speed are input for machine learning.

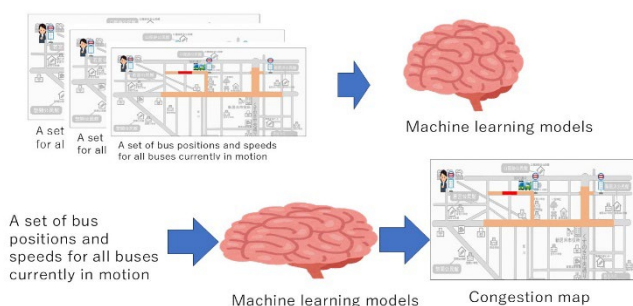


Fig. 6. Multimodal Machine Learning

The experiment was conducted in Niihama city. Figure 7 shows the bus routes. Many buses run near the station, which is a transportation hub. The number of buses decreases as you move away from the station, but the traffic volume is not very high in such places. Niihama city is about 4km long and wide. Figure 8 shows the results of a LoRa communication experiment. By placing a gateway in the center of the city, communication is possible with almost one hop.

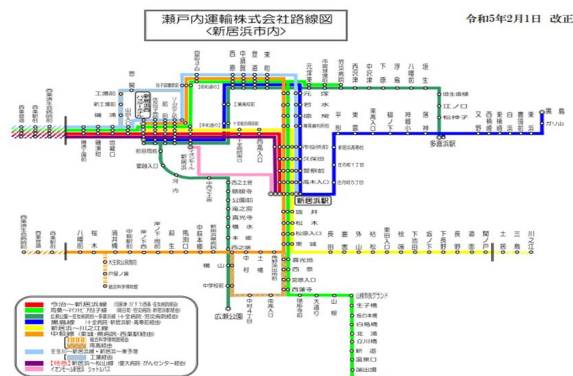


Fig. 7. Bus route map for Niihama City.

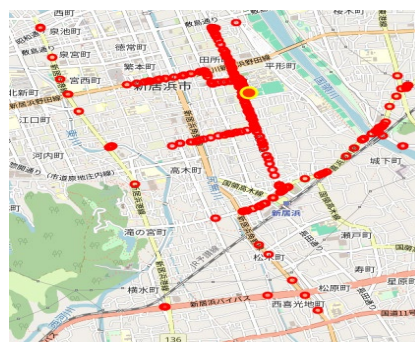


Fig. 8. Build a private network that covers the entire area using LoRa.

V. CONCLUSION

We proposed a method to build a transportation digital twin system for regions where maintaining public transportation is difficult. We aim to build a system that is highly accurate and real-time at low cost. We are exploring real-time capabilities compared to conventional systems such as Google Maps.

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