Development of a Nowcast Activity-Based Simulation Framework to Understand Travel Behaviours and Visualize Future Situations

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Abstract

This study aims to develop a nowcast simulation framework using an activity-based multimodal agent simulation model to reproduce individual activities on a city scale in real-time, based on the observed data such as transient population in the target area and traffic volumes. The framework we proposed here supports understanding people's behavioral changes to optimize transport and the environment in urban areas, tourist attractions, etc. In addition, the framework aims to forecast the impact of changes in travel demand and evaluate measures. In this paper, we first explain this study's motivation, the framework's concept, and the methodology of the travel demand estimation in the nowcast process of the framework. After the demonstration using the framework is introduced, we share the issues of operating the framework in real-time and the idea of the backcast system with the digital twin we are working on a project as the future works.

Keywords: Nowcast, Multimodal Agent Simulation, Real-time

Introduction

The background of this study basically consists of the "sustainability" and "resilience" of the urban environment. Here, "sustainability" means the continuous improvements of the urban environments and quality of life, and "resilience" is the strength to adopt uncertain risks such as disasters under climate change and events that concentrate large crowds. The urban environment has been accelerating change in recent years, and the current situation in urban activities must be understood through the various data in high spatiotemporal resolution. On the other hand, the quality and quantum of data we collect are limited by cost and sensor performance. The overall situation of urban activities can be interpolated or estimated by combining data and models as a general solution. In addition to quick feedback on city planning, spatial design, and transport systems, developing a method to quickly understand the issue for everyone is needed by experiencing the future we want to realize and the other futures we must avoid. To solve the two issues, the combination of a simulation model and metaverse, which can build a "digital twin" environment, is one of the solutions. Therefore, we aim to develop a simulation framework by applying an activity-based multimodal simulation model driven by real-time data and building the visualization framework using metaverse technologies. In this paper, we focus on discussing the simulation framework and our future work on the backcast system[1] with the digital twin.

Model Concept

Figure 1 shows the concept image of the nowcast simulation framework. The framework is a mechanism that calibrates activity demands to reproduce daily people's activities in the target area, referring to the observed data of the recent period, and visualizes people's movements using an activity-based simulation model. The operation process using the framework is shown in Figure 2. The observed data drive the framework. The observed data assumes dynamic population data and traffic volume of crowd flow, and the basic agent's activity patterns need to be prepared as input for the agent simulation model. First, the observed data based on the basic agent's activity patterns estimate the agent's activity demands. Next, the travel demand data is imported into the activity-based simulation model, the agent's movements are simulated, and the traffic situation of the target area is visualized.

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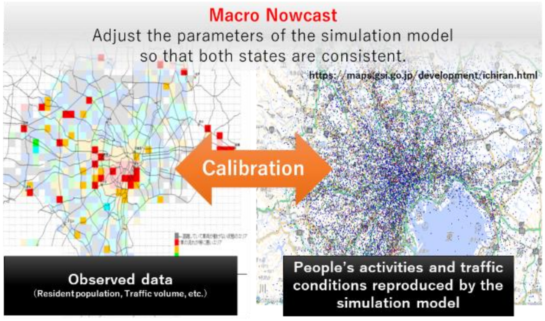

Figure 1 Concept image of Nowcasting.

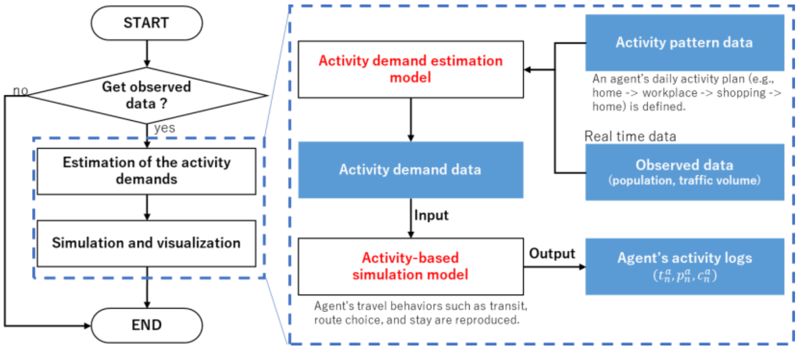

Figure 2 Nowcast simulation process.

Here, let us assume that the transient population of a target area is observed every hour. The framework estimates the activity demands that match the observed data based on activity patterns related to the area, such as traveling, staying, and transiting. The premise here is that the activity patterns used for the demand estimation are prepared in advance as known information, and it is assumed here that pseudo data created based on actual data, such as person probe data, is applied. Considering the system's operation, preparing several activity patterns that can be assumed from past data is desirable. For example, average conditions on weekdays, holidays, and unusual days during events. Basically, this method does not consider changes in the departure time and place of stay in each agent's activity. Still, by adopting this method, traffic conditions from the past to the present can be reproduced. At the same time, it is possible to predict (forecast) traffic conditions several hours later. Achieving this mechanism requires a model that estimates travel demand and a simulation model that reproduces the agent's behaviors and the congestion situation of the entire area based on the estimated activity demands. Figure 3 shows the image of the estimation of the activity demands.

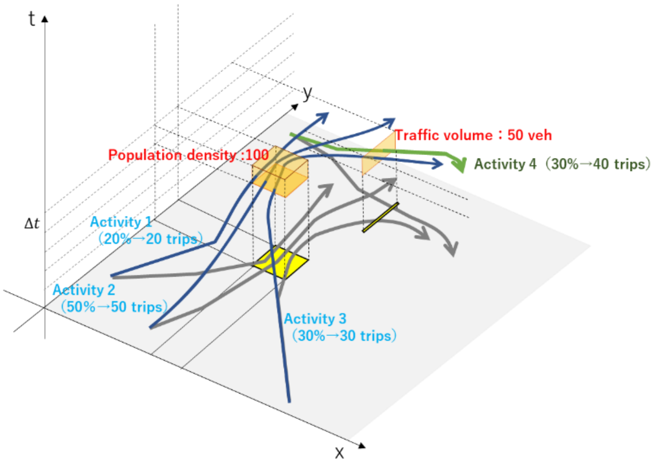

Figure 3 Concept of agent's activity demand estimation.

Methodology of Activity Demand Estimation

In this study, activity demands in the target area are treated as unknown variables, and the constraints are set to match the observed values of the transient population and the traffic volume (pedestrian, vehicle, etc.) on the transportation network in the time and area. Here, we adopt a method to estimate the activity demands by the entropy maximization method inversely. As for the method of estimation of traffic demand by the entropy maximization method, for example, models proposed by Willumsen[2], Oneyama[3] et. al., and Miwa et al. [4] Based on the model of Oneyama et al., we construct a method to estimate the activity demands that describes agent's behaviors of a day from the relationship between transient populations and traffic volumes. The probability density function P for estimating the estimated activity demands is shown below.

$$P = \left[\frac{q!}{\prod_{\omega} q_{\omega}!}\prod_{\omega}\left(\frac{\hat{q}_{\omega}}{\sum_{\omega}\hat{q}_{\omega}}\right)^{q_{\omega}}\right]\cdot\left[\frac{v!}{\prod_{a,h} v_a(h)!}\prod_{a,h}\left(\frac{\hat{v}_a(h)}{\sum_{a,h}\hat{v}_a(h)}\right)^{v_a(h)}\right]^{r1}\cdot\left[\frac{\sigma!}{\prod_{z,h}\sigma_z(h)!}\prod_{z,h}\left(\frac{\hat{\sigma}_z(h)}{\sum_{z,h}\hat{\sigma}_z(h)}\right)^{\sigma_a(h)}\right]^{r2},$$

$$q = \sum_{\omega} q_{\omega}, \qquad v = \sum_{a,h} v_a(h), \qquad \sigma = \sum_{z,h}\sigma_z(h).$$

Where q is the total amount of estimated activity demands, q_{ω} is the estimated travel demand of an activity ω, $\hat{q}_{\omega}$ is the prior demand of an activity ω, v is the total amount of the observed traffic volumes, $v_a(h)$ is the estimated traffic volume at observed location a and time h, $\hat{v}_a(h)$ is the observed traffic volume at observed location a and time h, σ is the total amount of estimated population, $\sigma_z(h)$ is the estimated population in zone z and time h, $\hat{\sigma}_z(h)$ is the observed population in zone z and time h, and $r1$, $r2$ are weighting parameters. Activity ω defined by q_{ω} and $\hat{q}_{\omega}$ has the time, position, and transportation mode of each point prepared in advance and is treated as a pattern of activity like OD traffic volume. The departure times and arrival times in the activity ω are not subject to estimation. Also, q_{ω} is priori activity demand and the activity demands for the current period are estimated by replacing it with the activity demands for the previous period when the real-time process is performed. The time h defined in eq.2, eq.4, and eq.5 is the time from the present to the past and is introduced to use the observed values. This problem can be solved by finding the logarithm function for P, applying Stirling's formula, and Lagrange's method of undetermined multipliers.

Our proposed agent-based simulation model framework consists of a macroscale model (Macro Nowcast) and a microscale model (Microscale Nowcast) using a hybrid simulation approach to reproduce the agent's activities in the urban area and the crowd flows in pedestrian spaces. Figure 6 shows the structure of the simulation model framework. MATSim[5], customized to link with the traffic simulation model "SOUND" is used for the macro. MATSim is a large-scale activity-based transport simulation model of an open-source framework, and SOUND[6] is a mesoscopic traffic simulation model to simulate road traffic on a large scale. MATSim applies a day-to-day simulation approach of a microscopic traffic model and co-evolutionary algorithms for planning the agent's activity schedule in the simulation loop ("mobsim", "scoring" and "replanning"). SOUND is linked to "mobisim" and reproduces people's movement by using several types of transportation careers (e.g., vehicle, taxi, bus.) on road traffic.

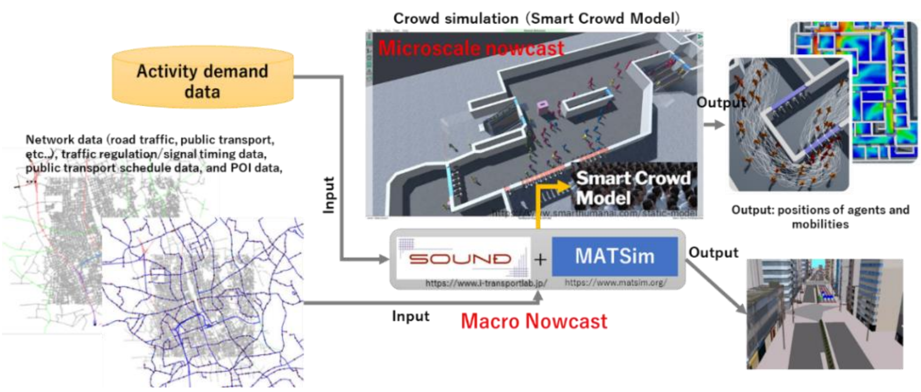

Figure 6-Agent-based simulation model framework.

Demonstration and Future work

To demonstrate this framework, we built the prototype using a crowd-forecasting model and a generation model[7] of pseudo-activity data[8]. In our future work, accuracy improvement is one of the important issues, and the application should be considered. We plan to build a cooperative system of the framework and the metaverse environment in the research project 'Shonam Future Verse'. The system visualizes the current situation in the metaverse and the future situations (the desirable future we expect and the future to avoid), helping the backcast process that the stakeholders consider the countermeasures and milestones on the present situation.

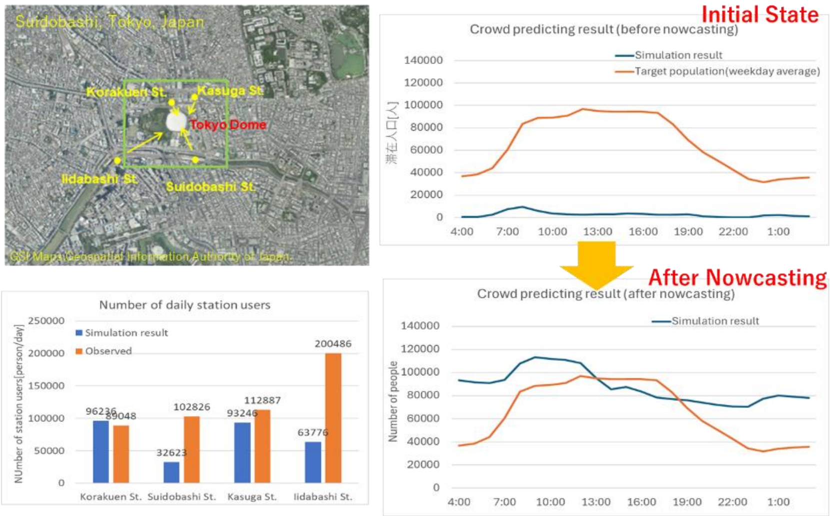

Figure 6 Nowcasting result on the demonstration.

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