

A Study on the Population Distribution Prediction in Large City using Agent-Based Simulation

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Abstract— In the smart city, digital twins replicate buildings, urban infrastructure, and utilities into a virtual space. In this paper, we create a virtual city simulation platform that can simulate the movement of people and present infrastructure such as urban buildings, roads, and public transport to predict urban change and population movement. In particular, we analyze mobile phone statistics data and exploit it as a movement distribution model to replicate the movement of population within a city and between neighboring cities. The urban simulation platform can estimate population movement and various urban problems and infrastructure changes.

Keywords— Modeling and Simulation, Agent based Modeling, Smart City, Digital Twin, Geographic Information Systems

I. INTRODUCTION

Most large cities are challenged by various urban problems such as housing problems, traffic congestion, lack of parking spaces, air pollution, imbalance in economic development, and aging city infrastructure due to population growth. Many problems in the city cause adverse effects on the safety of citizens and environment, and threaten urban sustainability and competitiveness in the long run. In order to solve urban problems, many cities are trying to combine ICT technologies to create a “Smart City” that maximizes value by effectively utilizing existing urban infrastructure. Smart cities are defined as a platform for leveraging innovative technologies to improve the quality life for citizens, the sustainability and the competitiveness of the city. Smart cities combine new technologies such as ICT and big data with cities to solve various city problems, enable database city management and new city models that can create sustainable cities.

As the smart city service progresses, there are many researches to simulate and predict cities using big data which is open to the public by collecting and processing urban resources citizen data.

Agent-based modeling (ABM) is a simulation modeling technique that exploited to simulate cities and calculate urban changes. Agent-based modeling systems are modeled as a collection of autonomous decision-making entities called agents, and each agent can individually evaluate a situation, make decisions according to a set of rules, and execute various actions ([1]). Agent-based modeling and simulation of urban society analyzes social phenomena applying computationally

intensive methods and simulates complex social processes employing large-scale entities ([2], [3], [4]).

In this paper, we represent the infrastructure of urban buildings, roads, public transportation, etc. to predict changes of the city and the migration of the population. In particular, we analyze smartphone statistics data and uses it as a movement distribution model to replicate the movement of population within a city and between neighboring cities. Proposed virtual city simulation platforms can estimate population migration and various urban problems that can occur due to changes in infrastructure.

The rest of the paper is organized as follows. Section 2 addresses a proposed virtual city simulation platform. In Section 3, we present a virtual Sejong City on the simulation platform. Section 4 addresses the result of the proposed model. Finally, we provide concluding remarks on our scheme in section 5.

II. VIRTUAL CITY SIMULATION PLATFORM

In order to create and simulate a virtual city, we design a virtual city simulation platform consisting of a simulation engine, a virtual city model, and a digital twin city of the real city to be simulated.

To support virtual models of more than 300,000 metropolitan cities, we use the RepastHPC simulator. Repast for High Performance Computing (RepastHPC) is an open source agent-based modeling system for large distributed computing platforms ([5]). It implements the basic Repast Symphony concept to work in a parallel distributed environment.

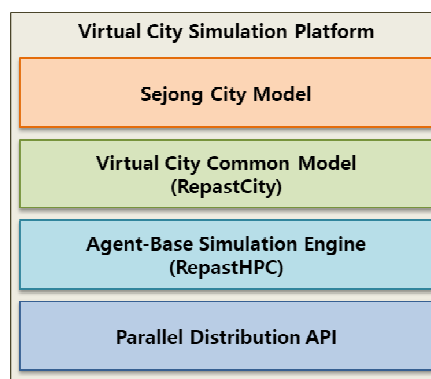


Figure 1. The structure of the proposed virtual city simulation platform

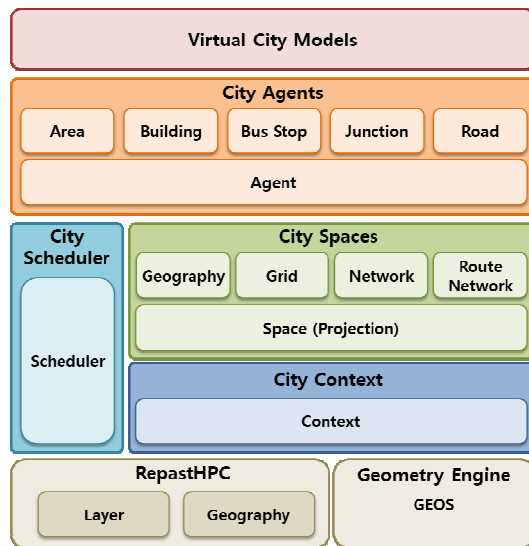


Figure 2. The proposed virtual city common model

We design the virtual city common model to represent the city's diverse infrastructure such as buildings, roads and agents. Based on the RepastCity project which is an agent-based simulator built on the Repast Symphony ([6]), we rewrite some of the features and add more functionality to original project. The Proposed virtual city common model aims to stimulate the interaction between the transportation and the urban infrastructure.

III. VIRTUAL CITY MODEL

In this paper, we implement Sejong City as a virtual city on a proposed virtual city simulation platform. Sejong City is an administrative city with a population of about 350,000, a planned city created in 2012 and is a rapidly changing city that grows at an annual population growth rate of over 10%.

In order to build a virtual city of Sejong City, we use public data and administrative data such as building information, road network, traffic network, and citizen data described in Table 1.

TABLE 1. INFRASTRUCTURE AND POPULATION DATASET

Dataset	Description	Volume
Building	Building information including location and industry type	36,313
Road	National standard unit of traffic information network such as road, bridge, etc	7,879
Junction	National standard unit of traffic information network such as intersection, starting point, etc	3,090
Area	Administrative district including neighboring cities	37
Zone	The smallest unit area divided by topographic features	476
Bus Route	City bus and metropolitan bus routes	167
Bus Stop	City bus and metropolitan bus station	1,979
Citizen	Citizen in the city and neighboring cities	354,740

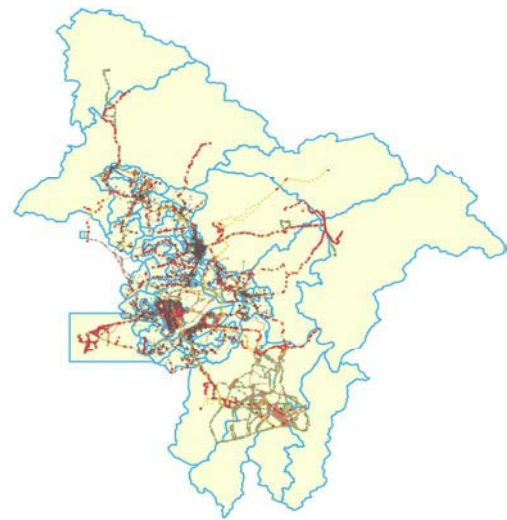


Figure 3. Infrastructure of virtual Sejong city

Figure 3 shows the infrastructure information of Sejong City and nearby cities (Daejeon-si Cheongju-si, Cheonan-si, Gongju-si) on a map.

In Figure 4, citizens and transportation are modeled to simulate citizens' behaviour and movement. Citizen agents are classified by occupation and autonomously perform behaviours such as going to work, attending school, shopping, visiting relatives, going to hospital, and shopping according to the probability of actions by occupation in the National Living Time Survey.

The destination of agents is determined according to the movement distribution model that is generated by analyzing LTE signal from base station of the carrier. The movement distribution model includes the number of living populations by time and movement patterns within and between cities.

After the agent's destination is determined, transportation decision model determines the means of transportation in consideration of the distance, presence or absence of transportation, and route.

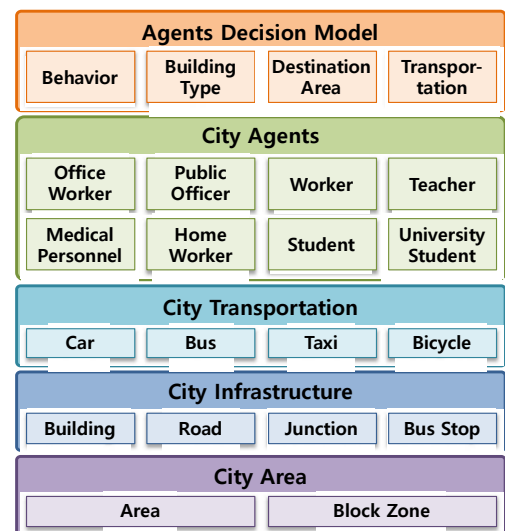


Figure 4. Virtual Sejong City model

IV. SIMULATION RESULTS

We simulated the virtual Sejong model to analyze the movement of citizens during the day. Citizens modeled as agents decided their actions and destinations according to their probability of behaviour by jobs and the movement distribution. And the agents selected the means of transportation according to the conditions and moved along the road to Sejong City and neighboring cities. Figure 5 shows the movement of agents collected as result of the simulation.

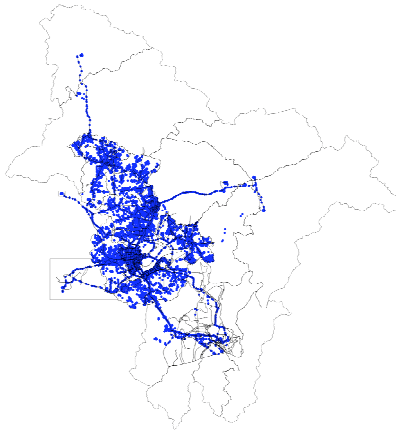


Figure 5. The movement of agents in simulation result

For verification we compared the simulation result with VDS (Vehicle Detection System) data, which is the number of vehicles that has passed on the actual road. The simulation results of the proposed model showed an error of 5.5% and 15% with VDS data, respectively.

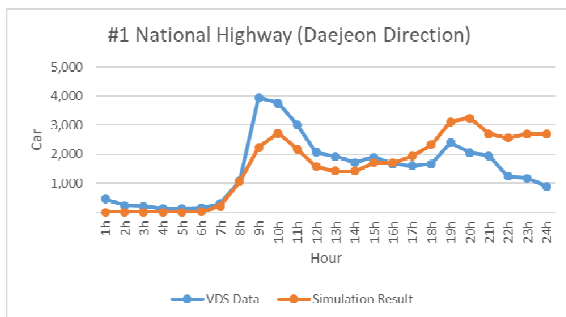


Figure 6. VDS data vs. simulation result (Daejeon direction)

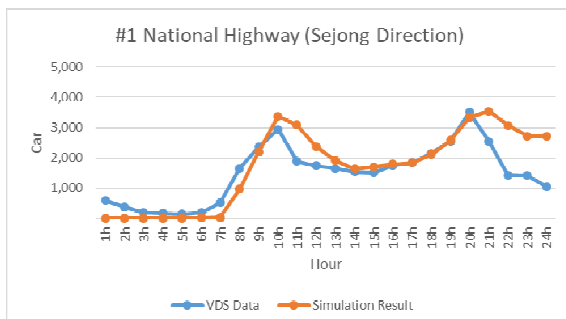


Figure 7. VDS data vs. simulation result (Sejong direction)

V. CONCLUSIONS

Using digital twins that replicate the physical city to create a virtual city, we can simulate urban planning before implementation. In this paper, we created a virtual city model that can simulate the movement of people and present infrastructure such as urban buildings, roads, and public transport to predict urban change and population movement. In particular, we analyzed mobile phone statistical data and exploited it as a movement distribution model to simulate the movement of population within the city and between neighboring cities. The proposed virtual city simulation platform can estimate population movement and various urban problems.

As a future work, we plan to expand the virtual city digital twin platform that can respond to changes in infrastructure.

ACKNOWLEDGMENT

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