A Smart City Simulation Platform with Uncertainty

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ABSTRACT

Smart city simulators are useful tools for simulating various scenarios with the impact of human/non-human factors, and evaluating efficiency and influence of services. Although current simulation platforms have made achievements in aspects like energy consumption modeling and urban planning, there are still gaps in integrating various domains together and involving the randomness of reality at the same time. Thus, we propose an open-source smart city simulator to provide more comprehensive features to satisfy diverse demands in scenario construction, information exchange, and urban services with more similarity to the real world, which can suit the needs of both city designers in plan evaluation and researchers in multi-domain data generation for data-driven models. Functions of the proposed simulator including three main components: (1) basic structure layers for constructing networks with map data, (2) event layers for receiving and exchanging information of (emergency) events, and (3) service layers for providing urban services in transportation, emission, and energy domains and responding to events. To better simulate unexpected circumstances in the real world, the randomness of reality is embodied in the uncertainty of sensing, devices, and events. Finally, two cases are designed in the demo to present functions of different layers and data generation with uncertainty.

CCS CONCEPTS

• **Computing methodologies → Modeling and simulation**; • **Computer systems organization → Embedded and cyber physical systems**.

KEYWORDS

Smart city, Simulation platform, Cyber-Physical System

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1 INTRODUCTION

A smart city is capable of providing various services with smart devices and facilities located throughout the city. Before making any changes in reality, planners need efficient tools to simulate possible scenarios and evaluate the impact of different plans for choosing the most efficient plans after comparing through simulations. There are already some smart city simulation platforms for simulating different services in the smart city. For example, [2, 3] are designed for traffic simulation, [1] supports various applications in transportation, safety, and environmental monitoring, while others focus on long-term urban planning [4]. Nevertheless, existing simulators also have their shortcomings, such as focusing only on one domain[1, 3], or not capable of real-time simulation [4]. Most importantly, they ignore the uncertainty existing in every aspect of the city. Therefore, it is meaningful to develop an open-source smart city simulator that is full-featured for simulating various services and events in a smart city and take the randomness of the real-world into consideration.

In our design, we develop a more comprehensive data-driven smart city simulator by integrating other open-source platforms and constructing corresponding service layers. Our main **contributions** include 1) offering services in multiple domains like transportation, environment, event, energy, and integrating uncertainty in the reality in simulation for urban designers to better evaluate the impact of different plans and 2) providing researchers a tool to generate data that integrates features in various domains and support data-driven research on smart city.

2 SIMULATOR OVERVIEW

2.1 Simulator structure

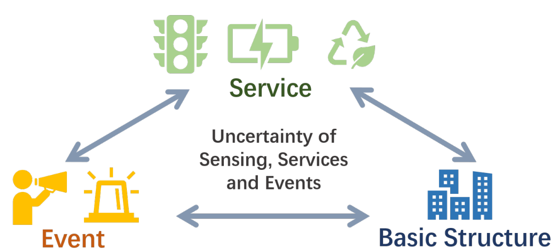

Figure 1: Simulator Structure

Our proposed smart city simulator is developed in following domains with corresponding functions and features (Figure 1).

(1) **Basic structure layers** include the road network layer and building layer, which are built as the foundation of other services.

Network: the network layer is for constructing basic scenarios of simulations. With the open-source platforms, OpenStreetMap

(OSM) and Simulation of Urban Mobility (SUMO), real road network is simplified into key elements like nodes, edged, and links with information extracted from OSM. Current functions contain gathering information about specific traffic facilities or roads as requested and locating nearby facilities within a given range.

Building: users can initialize all buildings of the same Amenity property in OSM with initial values of other attributes like energy consumption rate at one time. It allows users to search for the information of all buildings having the same Amenity property or building types (Point/Polygon), or particular buildings by their object IDs. It is also capable of locating nearby buildings around given coordinates or with specified types.

(2) **Event layer** is responsible for exchanging information of both expected and unexpected events among other layers.

Planned Event: the planned event layer is for generating expected events in the simulation. Event objects can be set up to specified buildings with predetermined attributes like start time given building ID and Amenity property. After initialization, those event objects will also contain the geological information of the buildings. All the information can be used for other services for agent control and decision-making. Users can also obtain coordinates of event objects and check their states.

Accident: the accident layer is for generating random unexpected accidents in the scenario with a given probability at random/predetermined locations for adding uncertainty to the simulation and simulating emergency events. Accident objects are initialized with chosen coordinates and the state of the accidents is set as ongoing as soon as they are generated. Besides, the duration of accidents can be adjusted into a specified time range as needed.

(3) **Service layer** is for providing multiple services in different domains with data gathered and generated by other layers.

Transportation: the transportation layer is built based on SUMO for simulating traffic control and management. This layer allows users to search for information of target traffic facilities like traffic lights in the scenario with a given object ID or within a certain range. It utilizes data from other layers like emission and event for setting parameters of customized control models according to users' needs. For example, the layer is able to simulate the impact of an accident on the nearby traffic lights by adjusting control logic.

Emission: the emission layer is used for evaluating the pollution and noise level of buildings and traffic. The emissions generated by the traffic can be simulated via SUMO, and emissions from other sources can be calculated by certain models that are either preset ones or data-driven models trained with deep-learning models by users. This layer is capable of calculating emissions of roads and buildings around a given spot for monitoring air quality.

Energy: the energy layer is for calculating energy consumption of objects in the simulation, allowing users to set parameters for different types of objects and obtain energy consumption data during the simulation. The energy consumption rates of objects like buildings can be predefined when they are initialized, and users can request or change energy consumption rates during the simulation.

2.2 Uncertainty

Uncertainty exists in almost every aspect of a smart city from accidents to unexpected weather conditions and represents the inevitable randomness of reality. Thus, it is necessary to add this feature to make the simulation closer to the real world. Currently, for this simulator, uncertainty is embodied in the aspects of sensing, devices, and events.

Uncertainty of sensing is realized by transferring the certain data gathered from the sensors or generated by the simulator to randomized data within a range around the raw data to simulate potential bias during the sensing process.

Uncertainty of devices reflects in simulating the malfunction of sensors or other devices in the scenario with predefined probabilities. The simulator is capable of checking the states of the devices at some time steps during the simulation and deciding whether some devices will have errors according to preset probabilities.

Uncertainty of events is realized by the accident layer, which can generate accident objects at random/self-defined locations with a random probability within a certain range. The information of those unexpected events can be taken as the input of control models for simulation like conducting traffic regulation due to a fire.

3 DEMO DESCRIPTION

Two cases are designed in the demo to show functions of the simulator and the capability of integrating uncertainty into both simulation scenarios and data.

Case 1: Uncertainty of events and devices. Simulate a random traffic accident at an intersection, which causes the traffic light to break down and under repair. In this case, a random traffic accident happens at a random intersection in the scenario with some probability distribution and causes the traffic light to be damaged. Then, the event layer will generate a repair event for the traffic light, which will last until the repair is done.

Case 2: Uncertainty of sensing. In this case, the uncertainty of sensing will be presented through acquiring traffic demand data by adjusting given original data with a chosen probability distribution. Original data can be gained from an outside database, and the simulator will generate new data within a certain range surrounding the original one considering chosen probability distribution like Gaussian distribution, which shows its capability of adding uncertainty to data and simulating bias during data collection process.

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