

Urban Traffic Planning Simulation with Time and Weather Dynamics

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ABSTRACT

Urban traffic planning ensures the efficient design and management of traffic systems, reducing congestion, and improving the safety. Applying virtual reality for urban traffic planning helps city planners visualize and interact with complex traffic systems in a realistic, immersive environment, resulting in an improvement of the decision making process. In this paper, we investigate the integration of the time and weather dynamics into the immersive urban planning system. In particular, we implement the lighting mechanism for rendering the urban simulation scenes in both daytime and nighttime sessions. In addition, we integrate the weather dynamics into the simulator to improve the realism. The user study demonstrates the realism and the engagement of our proposed system.

Keywords: urban traffic planning, virtual reality, simulation

Index Terms: Computing methodologies—Modeling and simulation—Simulation evaluation

1 INTRODUCTION

Heavy traffic in big cities and urban areas causes numerous problems, including increased travel time, environmental pollution and noise pollution. Virtual reality (VR) visualization is important to city planners for urban traffic planning simulation because it provides an immersive and interactive way to understand and analyze complex traffic patterns and infrastructure. Actually, virtual reality is widely adopted in education and training in many domains such as safety training [2] and medical education [5]. Regarding traffic planning, Wang et al. [6] introduced a VR based integrated traffic simulation for analyzing the current and future traffic flows of the East Pilgrim Street area in Newcastle upon Tyne. In another work, Weißmann et al. [7] proposed an interactive urban traffic system for the simulation of different traffic scenarios. However, these works only focus on the traffic flow simulation while disregarding other factors.

We argue that there are many factors worth considering in addition to the traffic flow. Visualizing the urban traffic in daytime/nighttime scenes and different weather conditions provides a realistic presentation of how the urban environment changes throughout the day and under different weather conditions. This helps urban planners better understand the dynamics of traffic flow and urban activity. In addition, simulating different times of day and weather conditions allows planners to identify potential stress points in the infrastructure, such as areas prone to congestion or flooding, and plan accordingly to mitigate these issues. Therefore, this paper investigates the integration of the time and weather dynamics into the urban planning system and visualize the results in VR.

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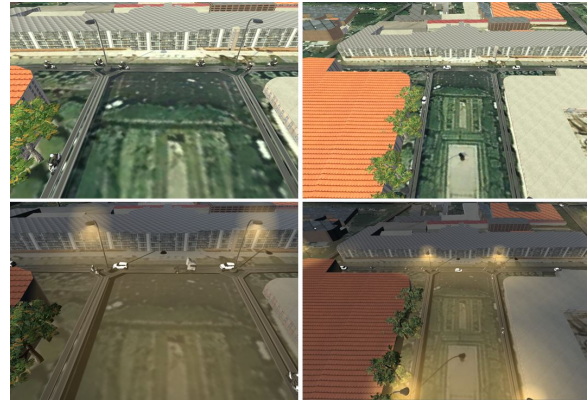


Figure 1: The time of day visualization in our simulation: daytime (top), nighttime (bottom).

2 PROPOSED SYSTEM

2.1 Urban Traffic Planning Simulator

We first develop an urban traffic planning simulator with input data such as time, traffic flow with volume, speed, and different vehicle types, spawning N_t vehicles at time t . These information can be manually input by the city planners. We simulate urban traffic as a graph G with intersections and key points as nodes, and road segments connecting these nodes as edges. Each edge has weights such as length, capacity, speed limit, and congestion level. The simulator allows users to select any time period to analyze city updates, featuring a user-friendly interface and supporting common infrastructure additions like roads, overpasses, bridges, tunnels, and traffic lights, linked via OpenStreetMap data [4]. For example, a new bridge is added as a parallel route between two existing nodes, without altering adjacent connections. Note that OpenStreetMap provides detailed geographic data that is essential for accurately modeling the graph G . Users can also change traffic direction from one-way to two-way and update the graph G by adding/removing edges or altering graph weights, affecting neighboring nodes. The traffic is then recomputed to fit the updated graph. For the implementation, we use Unity3D engine to model an Asian city.

2.2 Day of Time Simulation

Effective representation of a night-time cityscape necessitates suitable street lighting, often characterized by a yellowish or orange glow in a wide-angle cone shape. Existing game engines and 3D simulation software provide basic lighting options such as directional lights, spotlights (as depicted in Figure 1 - top), and point lights, but they do not accurately simulate street lights. To overcome this limitation, volumetric light beams are proposed to simulate the color and wide-angle cone shape of realistic street lights (as shown in Figure 1 - bottom). Positioned at the uppermost section of the street light 3D model is a spotlight emitter that illuminates its sur-



Figure 2: The illustration of weather visualization in our simulator: rainy (left), and cloudy (right).

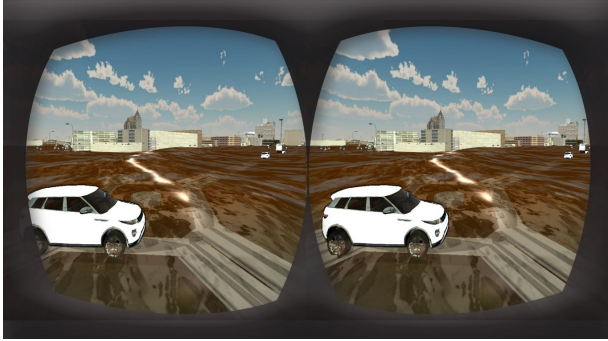


Figure 3: Our urban traffic planning simulator with VR headset setting.

roundings, emitting light from the center and covering a significant range. The light beam includes parameters like a wide spot angle and a side thickness to ensure proper light dispersion and softening of edges. The city planners can tune these parameters to observe the night-time effects.

2.3 Weather Dynamics

Weather simulation is one of our key features, providing a realistic landscape depiction and immersive VR experiences. To accurately represent the climate of the developed area, we incorporate additional weather states such as sunny and cloudy, which impact traffic conditions. In particular, for sunny weather, we utilize a skybox with the sun and white clouds, with lighting in preset color to create a golden sunlight hue. For cloudy weather, we use a skybox with layered clouds, lighting, and fog with preset colors. Fog density is set to 0.006 units using the Exponential Squared mode. The results are shown in Figure 2 (right). Regarding rainy weather, we use a particle system to generate rain, with each particle representing a raindrop. A box shape defines the raining area, and we emit 6,000 particles at a rate of 1,500 per unit of time, with each lasting 3 seconds. The rain speed is adjustable, and a user interface allows users to turn the rain on or off (as shown in Figure 2 - left). In addition, we also simulate flood by developing a water system using the Fresnel effect. We set the effect with an intensity of 4 to create a realistic brownish hue. Water waves are simulated using the Gerstner displacement method [1]. Finally the users are able to experience the system with time and weather dynamics in virtual reality as shown in Figure 3.

3 EVALUATION

Our study received approval from the Institutional Review Board (IRB). 31 people (9 female) participated in this study. The participants, whose average age is 27.1, are university students and staff with expertise in civil engineering and urban planning. We provided participants the instructions for the experiment after they completed

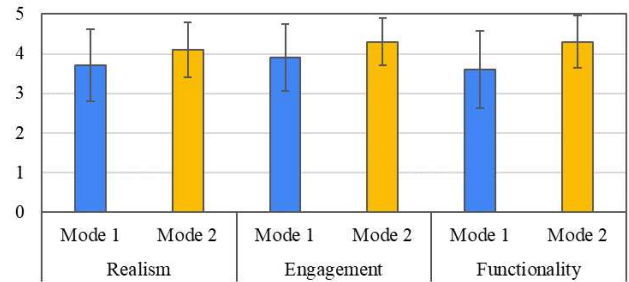


Figure 4: The results of user study on two modes over three criteria.

the consent form. The participants evaluated 2 modes, namely, conventional urban simulation (Mode 1), and urban simulation with time and weather dynamics (Mode 2). Each participant took part in a 30-minute session, namely, a 10-minute trial for each mode. We then asked for feedback regarding the following perspectives:

- Realism: How does the mode look realistic to you?
- Engagement: How engaging and immersive to you?
- Functionality: Are you satisfied with the available functions?

The participant rated each criterion on a 5-point Likert scale [3] from the best (5) to the worst (1). Note that “realism” is a critical criterion for urban planners since it ensures that simulations accurately reflect real-world conditions for effective planning and decision-making. As shown in Figure 4, Mode 2 outperforms Mode 1 for all of criteria with larger means and smaller standard deviations. The participants highly appreciate the integration of time and weather dynamics into the simulation. Some participants comment to consider adding pedestrians into the simulation while others recommend adopting our system for the virtual city tour.

4 CONCLUSION

In this paper, we have introduced an urban traffic planning simulator with time and weather dynamics. In particular, we allow the city planners to simulate the urban traffic planning along with the factors of time and weather. The city planners are able to observe the results in the VR mode. The user study highlights the preference of the participants of the integration of time and weather dynamics. In the future, we plan to simulate pedestrians and various types of vehicle such as emergency vehicle into the simulator.

ACKNOWLEDGMENTS

This work is funded by National Science Foundation (NSF) under Grant 2025234.

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