

Creating Digital Twins of Cities with FutureScape™

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Abstract. As the world becomes more dense, connected, and complex, it is increasingly difficult to answer “what-if” questions about our cities and populations. As cities expand and technology evolves, urban planners must find new ways to build more cohesive environments for infrastructure, communications, power distribution and transportation. However, testing these problems in the real world could take an infinite amount of time and money and/or be dangerous or impossible. FutureScape is a new platform for creating digital twin simulations of city infrastructure and populations from open source and commercial data. It provides users an immersive experience where they can test scenarios and answer their most pressing “what-if” questions.

Keywords: Digital Twin, Cities, Immersive Experience, Transportation, Urbanization, Simulation.

1 Introduction

Modeling and simulation are commonly used techniques for gathering data from complex systems, in part because of their ability to run cost-efficient and safe experiments in real time or faster. Simulation allows researchers or analysts to create synthetic environments that are comprised of other modular components, perturb them, and then gather insights. Testing complex systems without simulation can be dangerous, costly, or otherwise infeasible, and can be limited by insufficient data or a lack thereof. For example, it is not possible to block off a major bridge and then see how traffic patterns are impacted and rerouted for research purposes. In this demo, we introduce FutureScape, a modeling and simulation platform designed to create digital replicas of large systems, such as entire cities or large industrial infrastructure, by using open source data. Inside the digital twin, FutureScape puts users in control to run scenarios and experiment with solutions through its easy-to-use interface and ability to create massive-scale simulations with fine-grain details. In this document, we will outline FutureScape features and what our future work may encompass.

2 Features

2.1 Car Artificial Intelligence

Individual cars in the simulation use the Intelligent Driver model [1]. Car acceleration is a function of its current speed and its distance from the car in front. Cars adhere to road speed limits and follow activity schedules, traveling between different locations (e.g., home, work, leisure). This allows users to make observations in the absence of data. Conversely, it is possible to reverse-engineer realistic schedules from input user data. If a user wants to experiment with traffic patterns and behaviors, car dynamic pathfinding can be optimized for shortest path, shortest travel time, or to prefer main roads.

2.2 Road Alterations and Events

Roads in the simulation can be created and removed easily. They can also be opened or closed off to car traffic. The directions cars travel on roads can be reversed and their speed limits can be changed. Stop light intersections exist throughout the simulation and can be replaced with stop signs, or vice versa. An example of one of FutureScape's road alteration features can be seen in figure 1. Cars can also be scheduled to converge upon an area or a location at a specific time. For example, a user might want to observe potential convergence upon an arena or stadium during a sports game. These road alterations and events can be made in real time, as well as occur at scheduled times within the simulation. Users can create many simulations with different road alterations and events from which users can compare and contrast the outcomes of different scenarios.

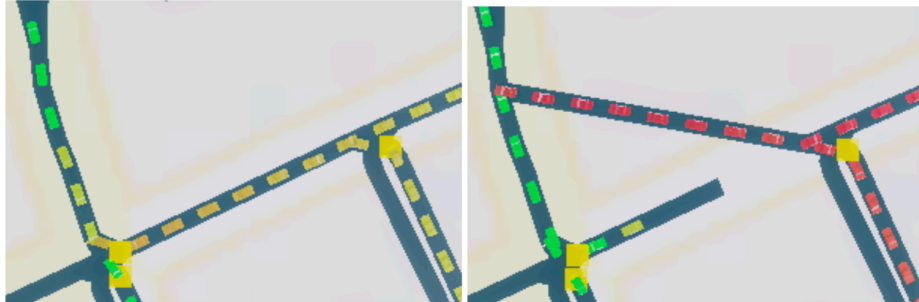


Fig. 1. A before and after example of rerouting by adding and removing a road.

2.3 User Interface and Dashboard

The simulation is designed to be user-friendly and easy to navigate due to a variety of features. A search bar allows users to move the camera to specific cars, roads, and buildings. The player camera can follow moving objects in the simulation, or snap its position to view objects. When a user clicks on a car, viewable information pops up,

including a schedule panel, path highlighting, and the vehicle's speed, location, and time in current path. Viewable road information also exists, including tags from Open Street Map (OSM), corresponding OSM webpages, and the ability to color code roads by type and speed limit. The aforementioned open/close and add/remove road capabilities can also be used directly with the client. A command line console allows users to pause and resume the simulation, as well as enable/disable road events. A more comprehensive and detailed view of the user interface can be seen in figure 2. The FutureScape dashboard (figure 3) is an interface to quickly view the road level of service key performance indicators (KPIs) in the simulation(s). Time series data is visualized in the dashboard through line-plot graphs and heatmaps report spatially distributed data for specific times within the simulation. With this tool, it is possible to compare the KPIs of multiple scenarios.

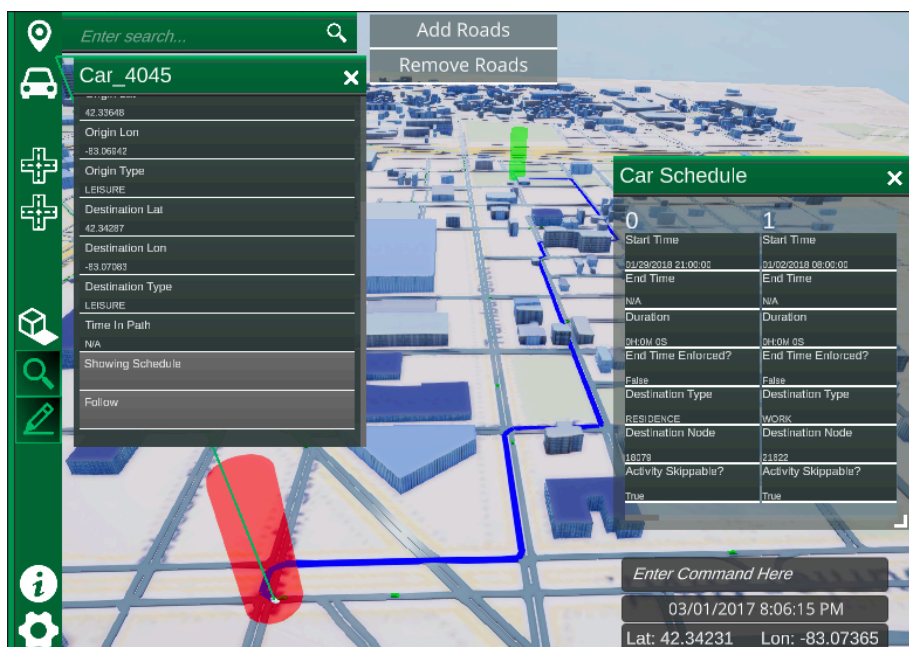


Fig. 2. An example of the FutureScape user interface. Features include a sidebar for different view and editing modes, options to add/remove roads, a search bar, panels for the details of a selected car and its schedule, a car's path including its start and end locations, a command line input, the current time in the simulation, and the cursor position.

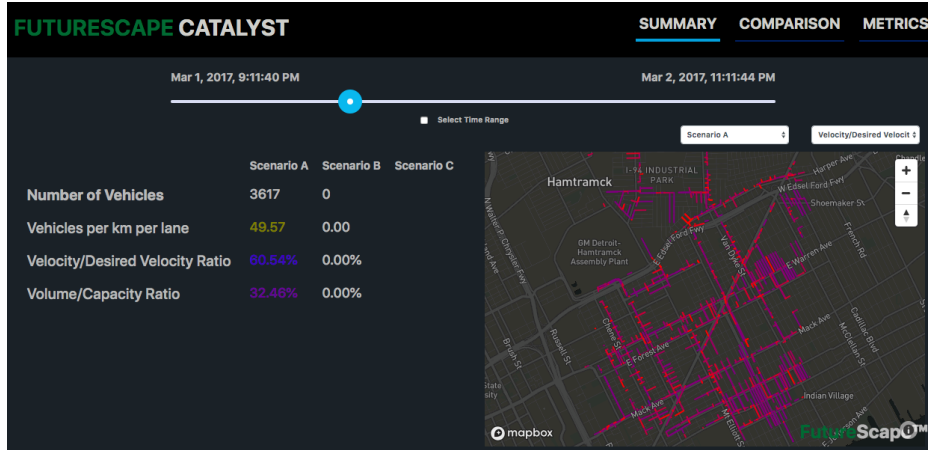


Fig. 3. An example of the FutureScape dashboard. The summary tab contains a time slider on the top, the comparison of KPIs across up to three different simulation scenarios on the left, and the heatmap of a KPI for a specific scenario on the right. The comparison tab (not shown) contains more details of the KPI comparisons between the scenarios and the metrics tab (not shown) contains simulation metrics.

2.4 Data Science

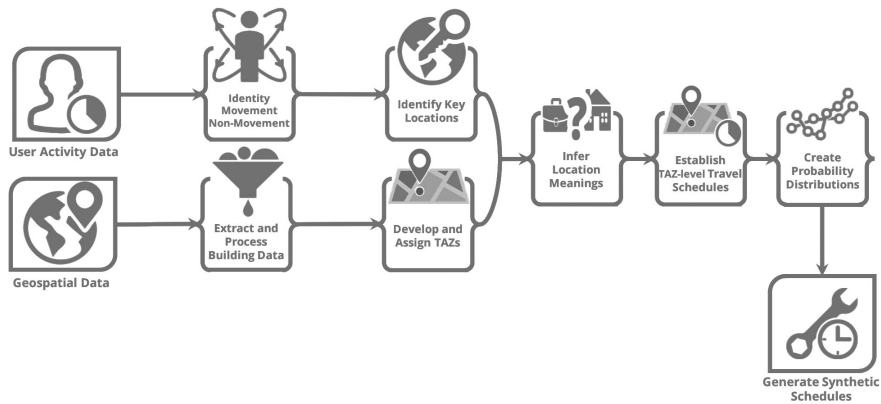


Fig. 4. Process of constructing synthetic user schedules.

We drive entity behavior with user travel schedules generated from geolocation data and a graphical outline of this process is shown in figure 4. These data, captured from cellular phones, are initially analyzed to identify periods of movement and non-movement. We apply density-based clustering to group nearby points of non-movement into single locations if certain criteria are met. Next, we infer location labels (home or not-home) with temporal characteristics and the inferred use type of the nearest building. We then link all stay locations to Census blocks as to not use exact coordinate locations,

and calculate transition time and geographic distributions across the dataset. This data science process is crucial in making the simulation as realistic as possible. It allows for the creation of synthetic schedules that are lifelike without compromising the personally identifying information from the original data set. Please see reference [3] for more detailed information.

3 Future Work

As FutureScape continues to grow and develop, we are constantly working to improve the platform and incorporate new features. Examples of new features include multi-lane roads, time dilation, and the creation of synthetic schedules from real user data. Furthermore, we are also working on the ability to make edits while the simulation is running to road speed limits, road directions, traffic light timings, and switching between stop signs and traffic lights. We are also developing a mechanism to verify scenario reproducibility. A user application for customizing a full project, and setting up scenarios is also in the works. See figure 5 for what is envisioned for those features.

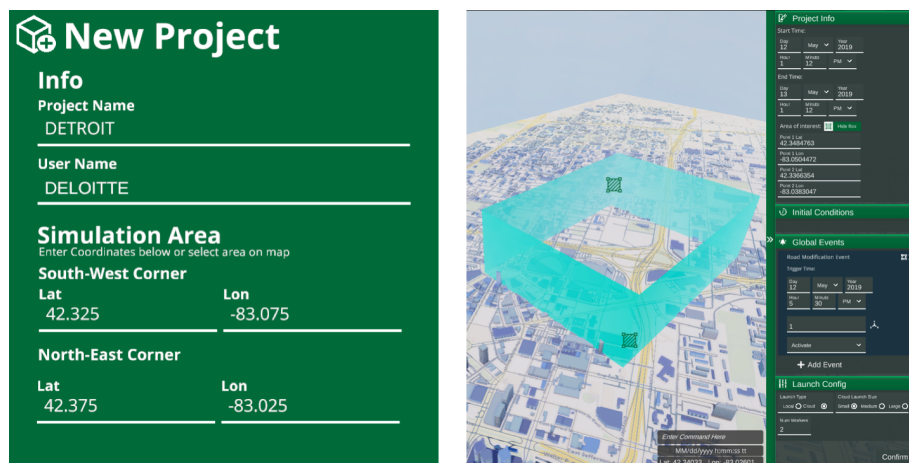


Fig. 5. Images of the New Project (left) and pre-simulation setup scene (right). When a user starts FutureScape they are able to create a new project with customizable parameters. The user is then brought to the pre-simulation setup scene where the user can select an area of interest (blue box). The setup scene also has a sidebar for more simulation parameters.

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