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SIMULATING INFRASTRUCTURAL INTERACTIONS IN DIGITAL TWIN CITIES

Eric Christensen
Steven Hardy
Ben Frederick Martir Intoy
William J. Porter III

Deloitte Consulting LLP
1919 North Lynn Street
Arlington, VA 22209, USA

ABSTRACT

City infrastructure is becoming more complex and no one system is in complete isolation from others. A method of constructing digital twin cities with traffic, electrical, and telecommunication layers using open- and crowd-sourced data is outlined. The digital twin can be then perturbed to study how changes and failures in any one system can propagate to others.

1 INTRODUCTION

Systems are increasingly becoming interconnected, exchanging command and controls and not just data. This connectivity leads to risks and vulnerabilities which may go unnoticed, and testing of such systems may not be feasible due to their importance for day-to-day operations as well as the risk of repercussions if a catastrophic failure were to occur. An example of upcoming interconnecting systems would be smart cities, where communication allows for more efficient use and management of infrastructure. To simulate this a digital twin of a city, complete with traffic, telecommunication, and electric infrastructure as well as dependent entities is used as an exemplar.

2 CREATING THE DIGITAL TWIN AND THE ENTITIES

Open- and crowd-sourced data sets are used to create the simulation environment which has buildings, roads, traffic lights, and cell phone towers. Due to its sensitivity, only partial data can be gathered about the electrical network, however, the electrical power network can be inferred by assuming building, traffic light, and cell phone tower power usages, using first principles to solve how power should be distributed.

The entities which reside within the simulation are cars, traffic lights, cell phone towers, and power grid nodes. Cars go from destination to destination, obeying traffic lights and laws, and connect to the nearest powered cell phone tower. Cars that are unable to connect to a powered cell phone tower will prefer high usage roads such as highways. Traffic lights influence the traffic flow at intersections and are powered by the electrical network, and if not powered, the traffic light behaves like an all-way stop at an intersection. Cell phone towers provide cars navigation while powered and can be overburdened if there are too many cars connected to it. Power nodes can be power sources, stations, or sub-stations which create, distribute, and redistribute power respectively.

3 RESULTS

Perturbations can now be performed on the system to study the effects. For example, a power node can be disabled which may disable other power nodes if the original disabled power node is a source or station node. The cell phone towers connected to the disabled power node(s) will also be disabled. Cars whose

Figure 1: Example images of effects of a power failure cascade. The left figure shows the effect of two disabled cell phone towers (red triangle exclamation points, dark regions represent those cell towers service area) overwhelming an adjacent cell phone tower (medium shaded area). The right figure shows cars (red squares) backed up at an intersection with a disabled traffic light (red circular disk).

nearest cell phone tower is disabled will attempt to connect to the next nearest enabled cell phone tower, which may overwhelm the enabled cell phone tower. Cars that are unable to connect to an enabled cell phone tower will traverse main roads. However, the traffic lights are also disabled since they do not have power, so cars will treat them as all-way stops. This will cause traffic backups that will worsen with time. Visualizations of these effects can be seen in figure 1. Data, such as car positions and cell phone tower load, can be collected from the simulation and saved to a database for real time viewing and detailed analysis.

4 DISCUSSION

Experiments that might be costly or infeasible can be performed through simulation to ask "What if?" questions. As an exemplar, a digital twin of a city with its many different infrastructural layers can be used to study externalities and propagating effects from changing one aspect of the system. This capability can be used by federal and state governments to test system robustness and for simulating catastrophic events, whether natural or man-made, to help plan evacuations. Using an improved traffic infrastructural layer, the transportation sector can use simulation to study the effects of changing road structure or improve mobility during large events. The traffic realism can also be improved by using synthetic travel schedules (Baeder, Christensen, Doanvo, Han, Intoy, Hardy, Humayun, Kain, Liberman, Myers, Patel, Porter, Ramos, Shen, Sparks, Toriel, and Wu 2019).

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