Research Project Highlight

City-scale Multi-infrastructure Network Resilience Simulation Tool

TSRP Topic T4 - Complex models & large networks

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Start-End Dates:
1/1/2018-6/30/2020

Abstract

The goal of this project is to deliver graph-parallel distributed network simulation tools that can quantify the performance of the transportation network and water pipeline network at city-scale under different ground motion scenarios. In this project, a large-scale traffic network analysis model for the San Francisco Bay Area road network, and a pipeline network analysis model for the entire EBMUD water distribution are developed. The main research objective is to demonstrate a unified network model capable of simulating the interactions between the two networks in the cases of normal operational and various earthquake damage scenarios. These two models are run independently and jointly with feedback exchange, so as to interrogate the connections and serviceability loss of these two systems after earthquakes. The meso-scale traffic simulation model serves as a tool to understand the complex behaviors of the entire transportation system and to evaluate various performance metrics (e.g., traffic flow, delay, accessibility) in a large-scale hazard event. Traffic is simulated as movements and interactions between large numbers of individual vehicles. The development includes an optimized and scalable shortest path routing algorithm, which allows distribution of the computational demand across hundreds of threads on high performance computing clusters to achieve the desired simulation speed. The entire EBMUD network model is modeled using a newly developed hydraulic network simulator that has been optimized to conduct large scale (city scale) water pipeline network simulations. Water distribution change under

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many earthquake damage scenarios is explored all at once. By coupling the two city-scale simulations, the functionality dynamics of the damaged traffic and water distribution networks after an earthquake are examined by considering their interdependence.

Deliverables

A PEER report, several conference and journal papers describing the developed network simulation models, and implementation of the codes into the NHERI SimCenter framework.

Research Impact

The ultimate aim of this project is to provide tools that enable city-scale resilience planning for infrastructure planners in the Bay Area. The loss of accessibility due to damages/closures of the transportation network can greatly affect the rescue and recovery of a city after natural disasters. Transport asset managers need to know the route availability, traffic distribution, reduction in speed and reconstruction resources required under disaster scenarios, so as to evaluate the impacts and plan for relief measures. The proposed tool can potentially be used for analysis in real-time and enables probabilistic analysis through multiple runs for different recovery scenarios after an earthquake. Both HPC-based network simulation tools are available under the open source MIT license on GitHub (https://github.com/cb-cities). The web-based visualization engine is also available under MIT license on GitHub (https://github.com/cb-cities/sierra-charlie). This tool will allow visualization of transport network performance regarding traffic volume, speed, route closure and estimated recovering time under different damage scenarios in an earthquake.

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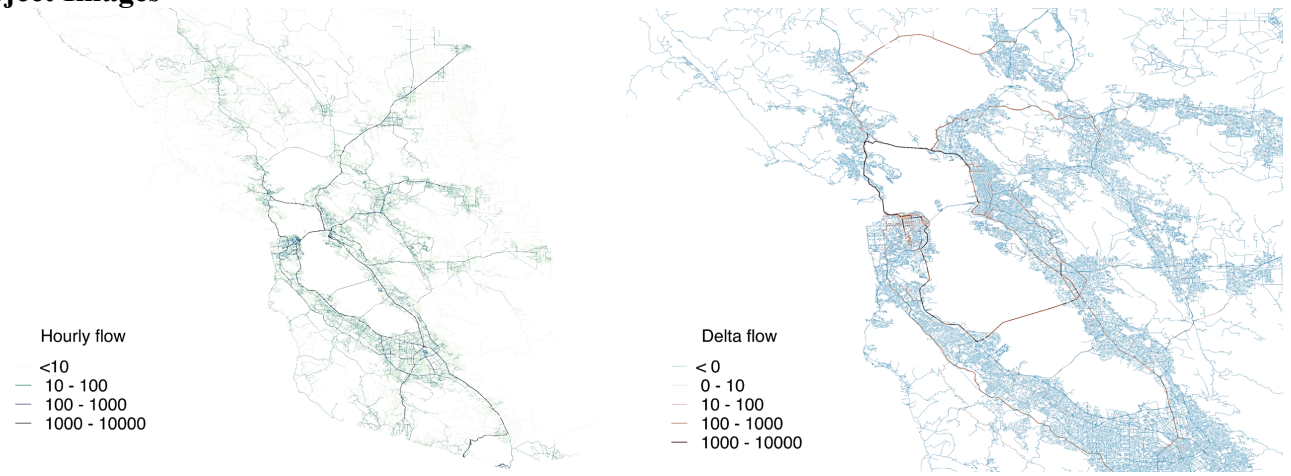
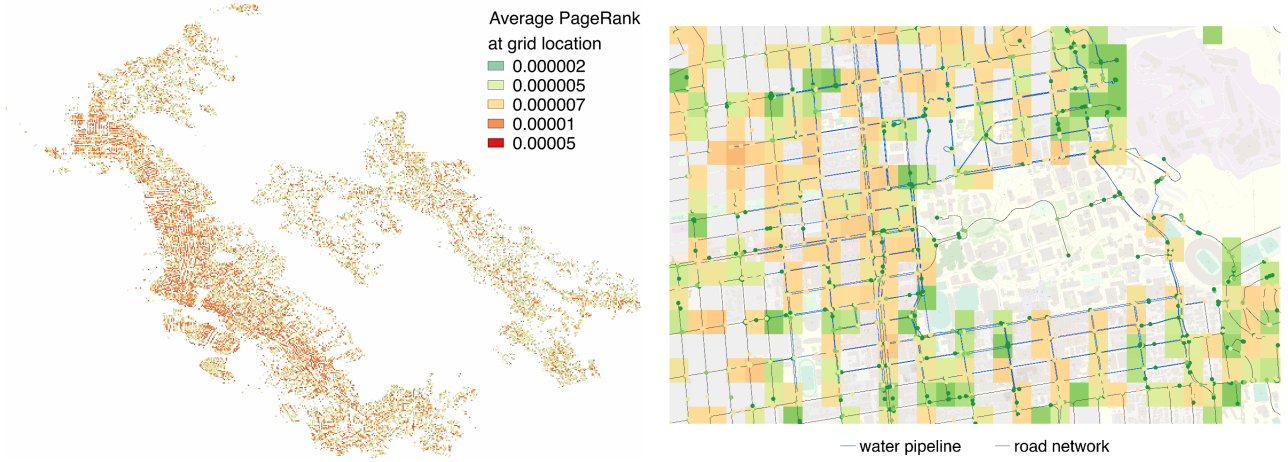
Project Images



(a) (b)

Figure 1. Agent-Based Model (ABM) for Traffic Simulations for the Bay Area. (a): traffic distributions under undamaged network. (b): Additional traffic distributions under damaged network (Bay Bridge closure scenario).



(a) (b)

Figure 2. Overlapping the PageRank of the traffic network and the water pipeline network in (a) the East Bay Area and (b) Berkeley area. Red/Orange means the mean PageRank from the two networks are high in a grid cell, indicating areas where important traffic intersections meet important pipe joints.

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