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Evaluating network elements using random walk for resilient route planning

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Abstract

Accessibility- and serviceability-based vulnerability analyses highlight the accessibility and operational consequences of network degradation, respectively, and are primarily governed by failure probabilities. However, they fail to capture the network's resilience or its ability to perform in a complete failure of critical nodes irrespective of their failure probabilities. This research uses topological-based vulnerability and proposes a PageRank variant algorithm to determine these critical nodes for a road freight network (modelled as a weighted directed graph). The topological-based vulnerability here refers to the identification of vulnerable locations within the network.

The application is demonstrated on a real network, namely the provincial road network of Saskatchewan, Canada. The application demonstrates how a more resilient network of optimized routes can be established by exploiting the top-k critical nodes' location and vulnerability information in the routing optimization process. The shortest path may not always be the best path in terms of vulnerability (see figure). With a compromise on the length, better routes can be chosen which may exhibit lesser vulnerability in terms of the value of the criticality and the number of most critical nodes on the route. By avoiding these potentially critical nodes, a potential cost can be saved in case of network elements' breakdown (naturally or by a malicious attack) or in case of traffic congestion. The results show that PageRank is effective in highlighting busy network elements and can be personalized based on the origins of the freight trips. Since PageRank accumulates node criticality from the nodes and its neighbors, the relationship among the nodes is a vital outcome. These relationships can be personalized based on the choice of the source(s) of the random walk which can be deemed as the freight origin(s).

The proposed model is potentially dynamic in the sense that it can update the results based on the new information on freight traffic, which may evolve over time. In future work, the implication of the 'supervised random walk' in the proposed method would be investigated. An estimation of the Origin-Destination pairs based on the link flows would be explored by i) improving the proposed PageRank model with supervised random walk, and ii) integrating supervised random walk with the deep learning framework.

Keywords: critical nodes, PageRank, route planning, resilient network design, topological network vulnerability

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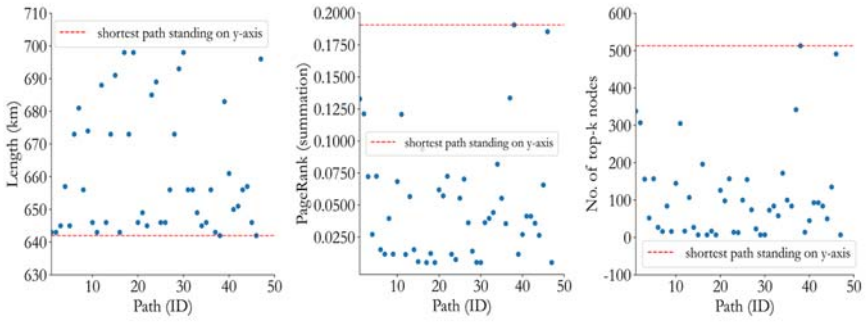

Standing of the shortest OD path in terms of vulnerability within a sample of optimized paths

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