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"Spatial Network Big Data Approaches to Emergency Management Information Systems"

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ABSTRACT OF DISSERTATION

Spatial Network Big Data Approaches to Emergency Management Information Systems

Emergency Management and Information Systems (EMIS) are defined as a set of tools that aid decision-makers in risk assessment and response for significant multi-hazard threats and disasters. Over the past three decades, EMIS have grown in importance as a major component for understanding, managing, and governing transportation-related systems. To increase resilience against potential threats, the main goal of EMIS is to timely utilize spatial and network datasets about (1) locations of hazard areas (2) shelters and resources, (3) and how to respond to emergencies. The main concern about these datasets has always been the very large size, variety, and update rate required to ensure the timely delivery of useful emergency information and response for disastrous events. Another key issue is that the information should be concise and easy to understand, but at the same time very descriptive and useful in the case of emergency or disaster. Advancement in EMIS is urgently needed to develop fundamental data processing components for advanced spatial network queries that clearly and succinctly deliver critical information in emergencies. To address these challenges, we investigate Spatial Network Database Systems and study three challenging Transportation Resilience problems: producing large scale evacuation plans, identifying major traffic patterns during emergency evacuations, and identifying the highest areas in need of resources.

To address the challenges of traffic congestion and chokepoints during or after disasters, we explore the problem of Conflict-Free Evacuation Route Planning (CF-ERP). First, we define the CF-ERP problem as an evacuation route planner which minimizes both the evacuation time and the number of movement conflicts in a static network. Given a transportation network with node and edge capacity constraints, initial node occupancy, destination locations, and the conflict resolution parameter *k,* CF-ERP finds evacuation routes that can minimize the evacuation time and the number of movement conflicts along these routes. CF-ERP is important for many societal applications, such as evacuation management and preparation in case of natural or man-made disasters. This problem is computationally challenging due to the large size of the transportation network and the constraints. Related works have considered the evacuation routing problem either solely as a network flow optimization problem or a conflict minimization problem, but not both. To address these issues, we propose novel approaches that produce evacuation routes which minimize evacuation time and the number of movement conflicts. Experiments and a case study on real-world datasets from Florida show the effectiveness and efficiency of the proposed approaches. Secondly, we redefine the CF-ERP to enforce the conflict-free constraint in both the spatial and temporal dimension. Given a transportation network, a population, and a set of destinations, the goal of Spatio-temporal Conflict-Free Evacuation Route Planning (CF-ERP*) is to produce routes that minimize the evacuation time for the population with no movement conflicts over the spatial and temporal dimension. The CF-ERP* problem is an essential component of civic emergency preparedness in the wake of man-made or natural disasters (e.g., terrorist acts, hurricanes, or nuclear accidents). This problem is challenging because of the large size of network data, the large number of evacuees, and the need to account for capacity constraints and the conflict-free constraint. Previous work has focused on minimizing the evacuation time on spatio-temporal networks. However, these approaches cannot minimize potential movement conflicts that cause traffic accidents, congestion, and delays. We propose novel approaches for CF-ERP* to meet the conflict-free constraint while minimizing the evacuation time for the population. Experiments using real-world datasets demonstrate that the proposed algorithms produce evacuation routes with no movement conflicts and have comparable solution quality to related work.

To address the challenge of understanding the spatio-temporal trajectory pattern, we explore the Coverage Constrained Spatial Co-clustering (CCSCO) problem. Given two geometric spaces, a set of matched points between the two geometric spaces, CCSCO produces *k* co-clusters that honor the coverage constraint and minimize the total distances of the spatial points to their cluster center. The CCSCO problem is important for many societal applications, such as the design of evacuation routes and resource allocation. The problem is NP-hard; it is computationally challenging because of the large size of spatial points and the coverage constraint. We propose a novel approach, called Bipartite Space Shrinking (BSS), for finding *k* clusters that minimize the total distances of the points to their cluster center under the coverage constraint. To improve the performance, we introduce the Distance Map data structure to efficiently construct a CCSCO. Experiments using real-world New York City Taxi Trip datasets demonstrate that the proposed algorithm significantly reduces the computational cost to create a CCSCO.

To address the challenge of resource and shelter allocation in the wake of man-made and natural disasters, we investigate the problem of Size Constrained k Simple Polygons (SCSP). Given a geometric space and a set of weighted spatial points, the SCSP problem identifies *k* simple polygons that maximize the total weights of the spatial points covered by the polygons and honor the polygon size constraint. The SCSP problem is important for many societal applications, such as hot-spot area detection and resource allocation. The problem is NP-hard; it is computationally challenging because of the large number of spatial points and the polygon size constraint. We propose a novel approach for finding *k* simple polygons that maximizes the total weights under the size constraint. Experiments using Chicago crime datasets demonstrate that the proposed algorithm outperforms baseline approaches and reduces the computational cost to create a SCSP.

BIOGRAPHICAL SKETCH

Born in Romania
B.S., Florida Atlantic University, Boca Raton, Florida, 2016
M.S., Florida Atlantic University, Boca Raton, Florida, 2017
Ph.D., Florida Atlantic University, Boca Raton, Florida, 2020

CONCERNING PERIOD OF PREPARATION
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Time in Preparation: 2017 - 2020

Qualifying Examination Passed: Fall 2018

Published Papers:

1. **Herschelman, R., Qutbuddin, A., & Yang, K. (2020). Conflict-Free Evacuation Route Planner. (Submitted to Geoinformatica).**
2. **Herschelman, R., & Yang, K. (2019, November). Conflict-Free Evacuation Route Planner. In Proceedings of the 27th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems (pp. 480-483).**
3. **Ohriniuc, R., Reich, A., & Yang, K. (2018, November). Coverage constrained spatial Co-clustering. In Proceedings of the 26th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems (pp. 492-495).**
4. **Reich, A., Ohriniuc, R., & Yang, K. (2018, November). Size constrained k simple polygons. In Proceedings of the 26th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems (pp. 500-503).**