Emergency Routing

Final Presentation

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Introduction

- **Focus**: North York, Toronto, Canada
- **Services considered**: Ambulances and Fire Trucks
- **Target Users**: Emergency Responders and Bystanders
- **Challenges**: Runtime and emergency responder data
- **Live Traffic Data:** Bing Traffic API

- Hospitals
- Fire Stations

Problem Formulation and Modeling

Objective Equations

1. Minimize risk of delays

$$E(R) = \sum P(\text{Severity}) \text{ x Penality}$$

2. Minimize emergency responders dispatched

$$\min\left(\sum_{i=1}^{N} D_i\right) \text{ s.t. } D_i <= N \ \forall D_i \in D$$

3. Minimize response travel time

$$\min\left(\sum_{j=1}^{K} \sum_{i=1}^{M} R_{ij}\right)$$

M = total number of emergencies

K = total number of emergency responders available

N = total number of emergency responder centers

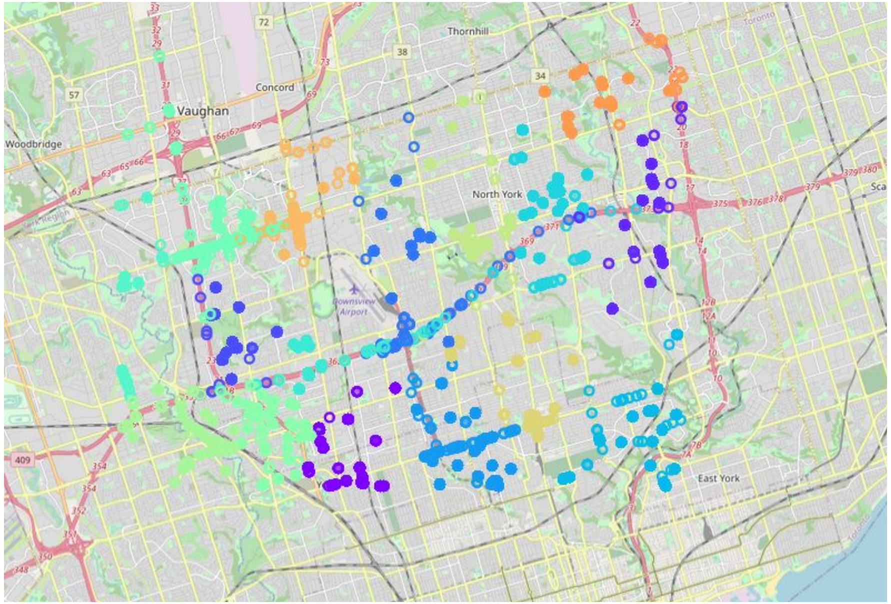
D_i = number of emergency responders dispatched from location i (i [1, N])

ER_i = location of emergency responder i (i [1, K])

E_i = location of the emergency i (i [1, M])

R_{ij} = travel time from E_i to E_j

Traffic Incidents Data



Historical Traffic

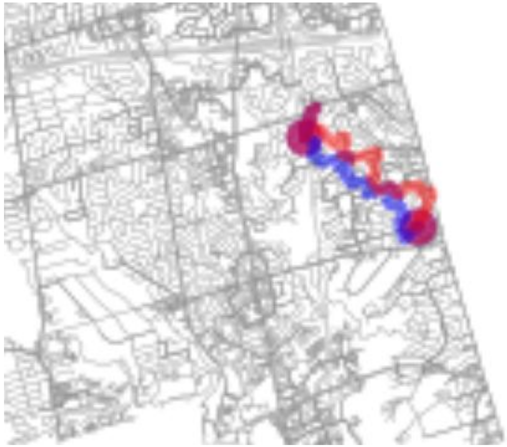
- K-Means

Live Traffic

- Node and edge risk scores

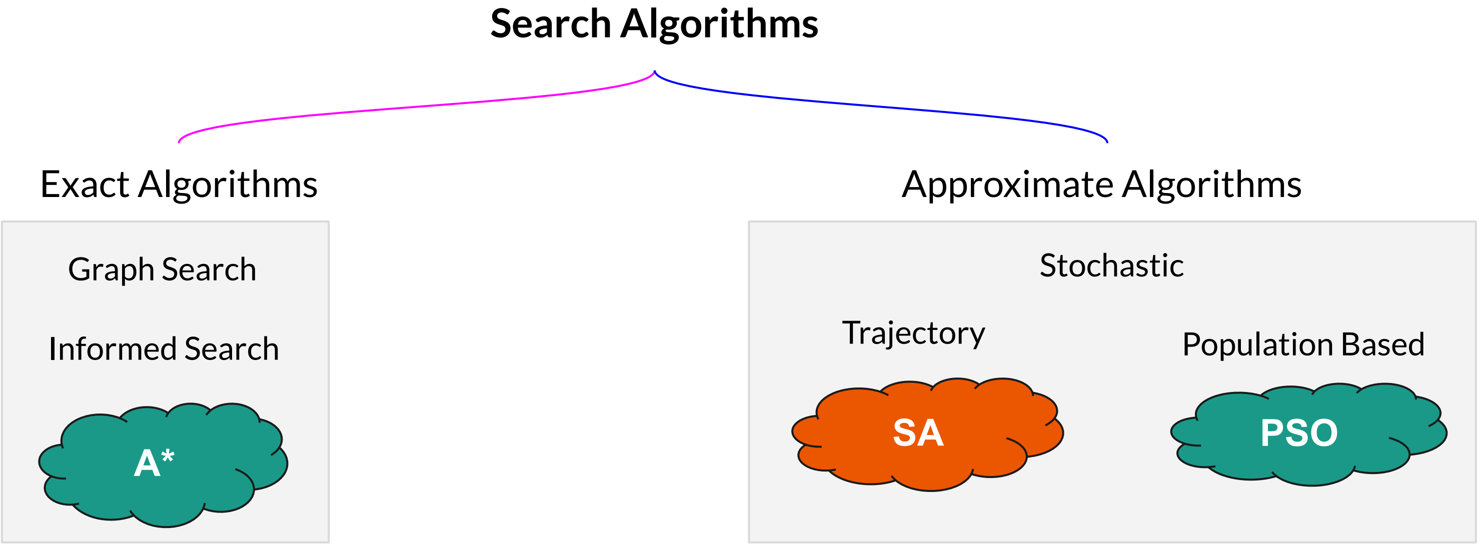
```
for incident in traffic_incidents do
  radius ← random_int_between(50, 100)
  subgraph ← generate_subgraph(incident.location, radius)
  for node in subgraph.nodes do
    severity ← incident.severity
    distance ← distance_in_meters(incident, node)
    risk ← severity / distance
    node.risk ← node.risk + risk
  end
end
```

Importance of Weights



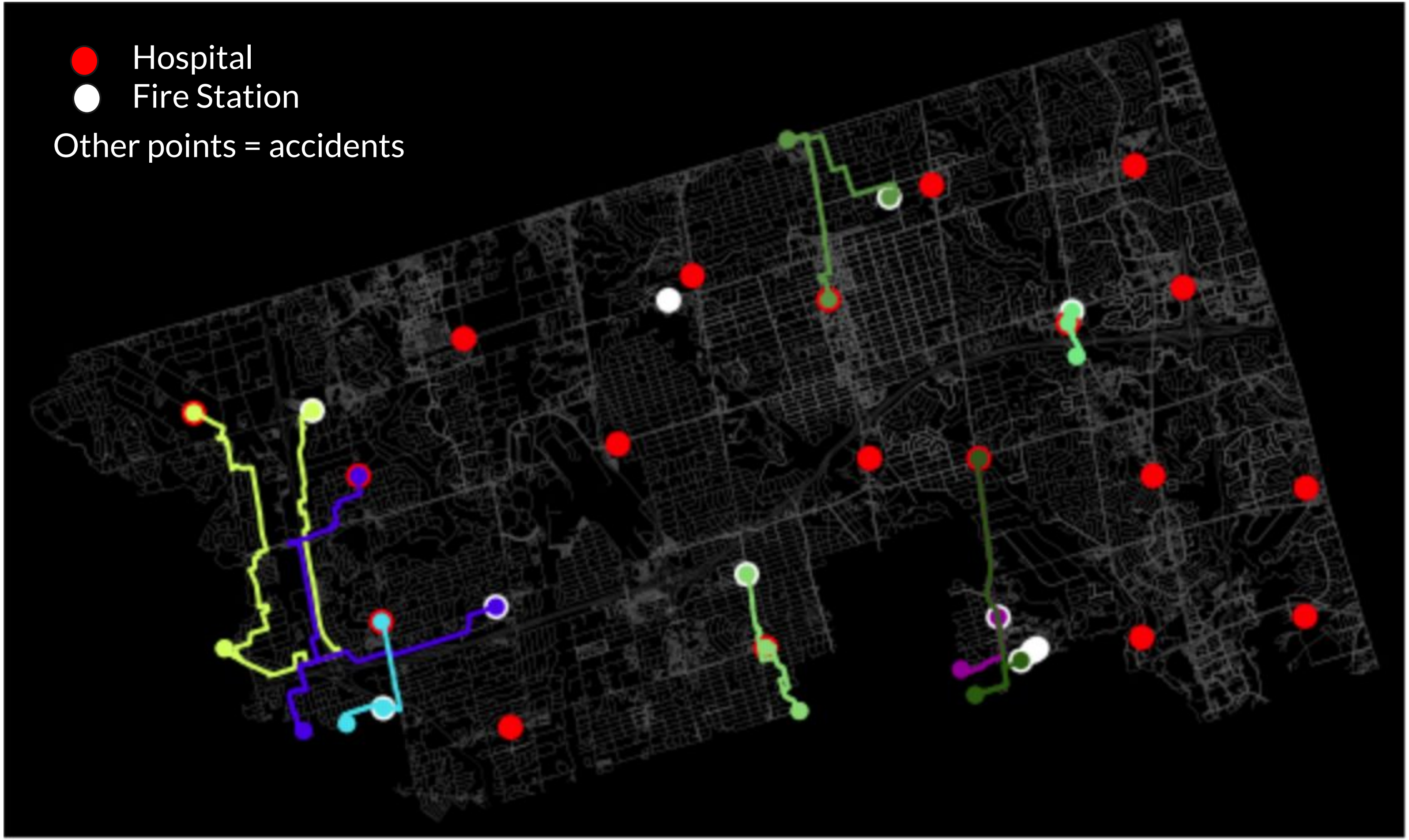
- ➔ Risky nodes have inflated weights
- ➔ Blue → Path nodes with low risk
- ➔ Red → Path nodes with high risk

Algorithms Utilized

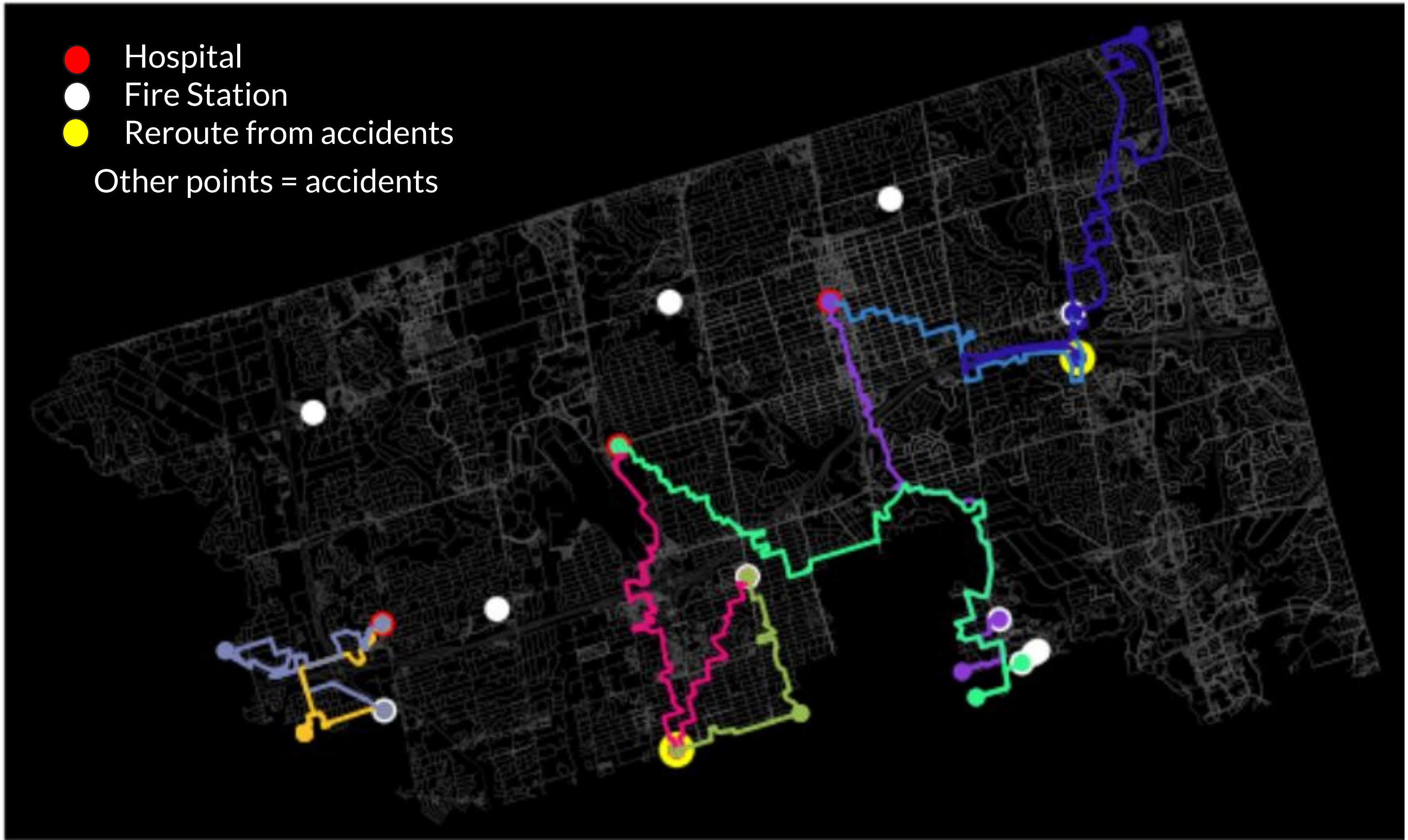


Demo 1: Accidents < EV - A*

Demo 1: Accidents < EV - PSO



Demo 2: Accidents > EV - A*



Demo 2: Accidents > EV - PSO

Which one is better?

	A*	PSO
Demo 1	1 min 37 sec	3 min 43 sec
Demo 2	3 min 24 sec	7 min 21 sec

CPU runtime for each case

The reason for the longer execution time of PSO is because of the longer routes and less amenities, due to which the algorithm routes the responders available at the farthest places in the city to the emergency locations.

Related Work

Paper	Algorithm(s)
A Discrete Inspired Bat Algorithm for Fire Truck Dispatch in Emergency [1]	Discrete Inspired Bat Algorithm
Performance Analysis of Genetic Algorithms for Route Computation Applied to Emergency Vehicles in Uncertain Traffic [2]	Genetic Algorithms
Dispatching fire trucks under stochastic driving times [3]	Markov Chain and heuristic based on a queueing approximation
An Optimization Model for Real-Time Emergency Vehicle Dispatching and Routing [4]	Dynamic shortest path algorithm
The Emergency Vehicle Routing Problem with Uncertain Demand under Sustainability Environments [5]	Hybrid algorithmic approach: particle swarm optimization algorithm and path relinking strategy

Conclusion

- **Algorithms explored**
  - A* and PSO
- **Heuristics used**
  - Live and Historical Traffic Incidents
- **Next steps**
  - Exploration of larger region than **North York**
  - Improving performance by reducing runtime
  - Evaluate the performance with more non deterministic algorithms

Q & A

References

[1] Trachanatzi, D., Rigakis, M., Marinaki, M., & Marinakis, Y. (2020). A Discrete Inspired Bat Algorithm for Fire Truck Dispatch in Emergency. Natural Risk Management and Engineering: NatRisk Project, 203.

[2] Constantinescu, Vlad & Patrascu, Monica. (2020). PERFORMANCE ANALYSIS OF GENETIC ALGORITHMS FOR ROUTE COMPUTATION APPLIED TO EMERGENCY VEHICLES IN UNCERTAIN TRAFFIC.

[3] Usanov, D., van de Ven, P. M., & van der Mei, R. D. (2020). Dispatching fire trucks under stochastic driving times. Computers & Operations Research, 114, 104829.

[4] A. Haghani, H. Hu, Q. Tian. “An Optimization Model for Real-Time Emergency Vehicle Dispatching and Routing”. In Transportation Research Board. 2013.

[5] Qin, Jin & Ye, Yong & Cheng, Bi-rong & Zhao, Xiaobo & Ni, Linling. (2017). The Emergency Vehicle Routing Problem with Uncertain Demand under Sustainability Environments. Sustainability. 9. 288. 10.3390/su9020288.