Soft-Restriction Approach for Traffic Management under Disaster Rescue Situations

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Traffic under Disaster Rescue Situations

- traffic resources become tight
- unusual and huge traffic
- must guarantee traffic of emergency vehicles
  - Emergency Route: exclusive route for emergency vehicles
  - Detour Route: for public vehicles

Issue

- How can the authorities field public vehicles?
Soft-Restriction Approach

Traditional Approach

- Useful routes are only for emergency vehicles.
- Different kinds of vehicles use different roads.

Soft-Restriction Approach

- Public vehicles can use useful routes. (minimal emergency routes)
  - Public vehicles get penalty while throughput of emergency vehicles is low.
- Sign which shows whether throughput of emergency vehicles is low
Road Network

- OD of all vehicles: O → D

Diagram:

[Diagram showing road network with nodes O, D, D1, T, S, and U connected by lines]

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Road Network – Traditional Approach

- OD of all vehicles: O → D
- S-D1: emergency route
- S-U-V-D1-D2: detour route
Road Network – Soft-Restriction Approach

- OD of all vehicles: O → D
- T-D1: emergency route
- T-V-D1-D2, S-U-V-D1-D2: detour route
Average Travel Time of Vehicles

- User Equilibrium: 5.75 : 4.25
- Traditional approach: 0 : 10 (fixed)
Model

- **Vehicles**
  - Emergency Vehicle (EV)
  - Public Vehicle (PV)
    * go to their destination as soon as possible

- **Traffic Control Center**
  - ensure throughput of EVs by using ‘penalty’ and ‘sign’
Traffic Control Center

Purpose

1. keep the recent average travel time of EVs under a threshold (200 sec.)
2. reduce costs of the management
Management policy

• Penalty
  – give penalties $b$ with a probability $p$ to travel time of PVs
    * which select the wide detour route (S-T)
    * while the recent average travel time of EVs is longer than the threshold
  – Cost = $b \times n$
    * $n$: number of times giving penalties

• Sign
  – is showed to PVs at deciding their route while the recent average travel time of EVs is longer than the threshold
Emergency Vehicle Agent

- go from O to D through the emergency route T-D1
- EVs have no option for actions.
Public Vehicle Agent

- repeat the travel from O to D
- action: select the detour route, wide or narrow
  - based on evaluation functions for each sign state
- learning: update the evaluation functions
Information for PV to Decide Route

- $C$: past experience
- $L$: number of vehicles on the lane of O-S near each route

Experimental Settings about information for PV

1. $C$
2. $C + L$
Evaluation Function of Each Route

1. $C$
   \[ \tilde{T}(r, s) = C_{r,s} \]

2. $C + L$
   \[ \tilde{T}(r, s, L_r) = K_{r,s}L_r + C_{r,s} \]

   - $r$: route
   - $s$: sign state (with or without the sign)

Action selection

- $\epsilon$-greedy selection ($\epsilon = 0.1$)

Update evaluation functions

- update values $C_{r,s}$, $K_{r,s}$ in the functions with travel time by hill-climbing method
Experiments

Settings

• Evaluation function (Information) of PV
  1. $C$
  2. $C + L$

• Traffic Control Center
  – Management policy
    1. only penalty
    2. penalty and sign
    – probability $p$: 0.2–1.0
Result \((C)\)

![Graph showing the result of average travel time of emergency vehicles in seconds (UE) and cost of penalties per hour (SO) with and without signs. The graph illustrates a correlation between the two variables, with a trend line indicating the relationship. The x-axis represents the cost of penalties per hour, ranging from 0 to 45,000, while the y-axis represents the average travel time in seconds, ranging from 160 to 300. The graph includes data points for 'No Sign' and 'With Sign' scenarios.]
Result \((C, L_r)\)
Conclusion

- Soft-restriction approach is better than traditional approach.
  - Travel time of EVs is able to be control by the cost.
  - Travel time of PVs is able to be shorter.

- In the case where PVs use the num of vehicles on each lane,
  - Traffic control center can reduce the cost by using sign.
Future Work

• Experiments with different information sets of PV
  – recent travel time of PVs
  – average speed of vehicles on each route

• Validation with other networks
  – network types
  – actual road network