Routing Autonomous Emergency Vehicles in Smart Cities Using Real Time Systems Analogy: A Conceptual Model

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OVERVIEW

• **Problem:** *reduce* the travelling time of emergency vehicles (EVs).

• **Approach:**
  • A *systematic literature review* of existing techniques.
  • Develop new algorithms using *analogical mapping* between real-time systems (RTS) and EV routing.

• **Contribution:**
  • A conceptual model of autonomous EV routing in smart-cities (an ideal scenario).
EV ROUTING

In the USA alone, a 1-minute delay in EV response causes:

1. 1% increase in mortality.
2. $7B increase in healthcare expenses yearly (RapidSOS, 2015)
EV ROUTING

- 4500 accidents involving ambulances each year
- 3160 accidents involving fire vehicles
- 300 fatalities during police pursuit

(NHTSA, 2014)
Background

• Emergency services have target times to respond to different level of emergencies.

• For purple and red incidents, response time is:
  • NZ: 8 minutes for 50% of cases and 20 minutes for 95% of cases (St. John’s, 2016).
  • UK and Canada: 75% of cases within 8 minutes (NHS England, 2015),
  • USA: 90% of cases within 8 minutes 59seconds (Pons & Markovchick, 2002),
  • Australia: 50% of cases within 10 minutes (Department of Health, 2015),
  • Hong Kong: 92% of cases within 12 minutes (J.Fitch, 2005).
Overall Approach

• Dynamic road-network parameters prevent EVs achieving desired response times (Gedawy, 2013)
  • Congestion, Halts on road
  • Pedestrian flow, Queued vehicles

• These parameters are required for dynamic optimization and pre-emption
  • In smart cities, this data can be more easily accessed.
  • In autonomous vehicles, driver-behaviour can be more deterministic.

Proposal: A conceptual model of routing autonomous emergency vehicles (AEVs) in smart cities using mixed criticality real-time system (MCRTS) analogy.
Smart-Cities and AEVs: The Ideal Scenario

• **Dynamic parameters are available in real-time**: EVs can provide high assurance for meeting expected response times (Yaqoob, 2017)

• **Autonomous vehicles eliminate uncertainty** due to driver behaviour (McAllister, 2017)

• The system can coordinate actions like creating **green wave**, **lane reservation**, and informing other vehicles (Kokuti, 2017)

• **Analogically mapping emergency levels to criticality levels** in a mixed-criticality real-time system allows designing algorithms to cater to all emergency levels.
# Analogical Mapping to MCRTS

| Inputs                                                                 | Outputs                                      |
|-----------------------------------------------------------------------|----------------------------------------------|
| Number of periodic, aperiodic or sporadic tasks                       | Assigning task to processor                  |
| Number of Pre-emptive and non-pre-emptive tasks                       | Assign new deadline                          |
| Number of Fixed or dynamic priority tasks                             | Queue task                                    |
| Number of Independent or dependent tasks                              | Alter priority                                |
| Number of processors                                                 | Assign pre-emption etc.                      |
| Number of reserved processor                                          |                                              |
| Release time, completion time, deadlines, priority, precedence, constraints |                                              |

![Diagram showing communication between AV and Traffic network](image)

- Parameters from traffic networks to AV
- Inverse Task Function
- Routes and instructions to AV
- Communication between AV and Traffic network

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Case Study: Using Task Scheduling for Intersection Control

• Traffic intersection designed with random flow of traffic in SUMO.

• Vehicle types are mixed type and spawn randomly.

• Arrival time and departure time of each vehicle is randomised.

• Traffic intersection control is fixed time.
Case Study: Using Task Scheduling for Intersection Control

- Vehicles are grouped together to form a platoon.
  - Variable integer lengths.
  - Has a leader.

- Platoon leader negotiates with the traffic controller to set green-time that allows platoon enough time to pass by.

- Each vehicle can communicate with each other and traffic controller using V2X communications

- Implemented using OmNET++ and Veins.
Case Study: Using Task Scheduling for Intersection Control

• Platoon containing an emergency vehicle uses pre-emption.

• A continuous green signal is provided until emergency vehicle crosses the intersection.
Extension: Routing EV through multiple connected intersections (WiP)

• A shortest path for EV is determined.

• Once a intersection processes an EV it communicates with next intersection in the EV’s path to request timely pre-emption.

• Multiple EVs negotiate their priority based on criticality level.

• Implementable as a virtual traffic light.
# Experimental Results

| Optimized Webster’s Method | Variable quantum | Round Robin Algorithm | Improvement                  |
|----------------------------|------------------|-----------------------|------------------------------|
| Throughput                 | Waiting Time     | Throughput            | Waiting Time                 |
| 2757 pcu/hr                | 18.18 sec/veh    | 2828 pcu/hr           | 15.60 sec/veh                |

2.57% in throughput & 14.19% in waiting time
Conclusions and Future Work

• The proposed system shows considerable reduction in EVs response time.

• An adaptive real-time traffic control system has improved throughput and waiting time.

• Next steps:
  • Complete experiments in calibrated real-life city traffic networks.
  • Further experiments and evaluations to justify our claims.

• Future Works:
  • How can dynamic parameters be made available in real-time?
  • Real-time cooperation between vehicles.
Thank you
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