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Combining Coordination Strategies for Autonomous Vehicles in Intersection Networks

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Goals & motivations

- Autonomous and connected vehicles will soon* relieve us from driving duties
- Most of current research deals with
  - enabling **individual** vehicles to hit the roads safely
  - coordinate vehicles movements at **isolated** intersections
- We investigate the *impact of different coordination strategies on a intersections network*
  - crucial during transition with mixed human-driven and self-driving vehicles

**perhaps*

Outline

1. Problem definition
    a. intersections management
    b. coordination strategies
2. Scenarios simulation
    a. tech. stack
    b. implemented strategies
3. Results
    a. combined strategies
    b. progressive deployment

Problem definition

- **Intersection management** concerns the need of coordinating vehicles while concurrently crossing intersections
  - competitive problem
  - junction as shared resource
- Solutions need **coordination strategies**
  - **safety**: no collisions
  - **liveness**: all vehicles eventually cross
  - **quality**: min. delay / max. throughput / ...

Coordination strategies

- Traffic light
  - safe
  - inefficient (red light on empty junction)
- Precedence
  - unsafe (delegates to vehicles)
  - efficient (vehicles can cross simultaneously)

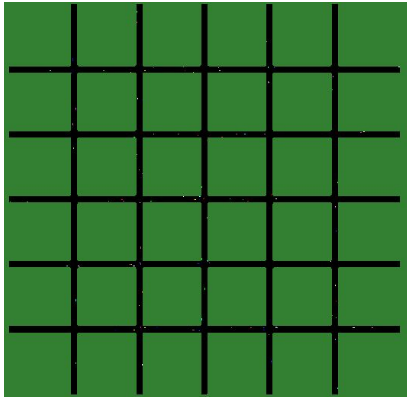
Current

Future

- Reservation-based
  - centralised intersection manager (IM)
  - vehicles request right of way
  - *IM decides*
- Negotiation-based
  - centralised/decentralised
  - collaborative/competitive (e.g. ContractNet vs. auctions)
  - *vehicles can influence decision*

Scenarios Simulation

- **SUMO (Simulation of Urban MObility)** used for implementation
  - scalable
  - custom vehicle behaviour
  - intersection networks
  - **Python** bindings (*TraCI* package)
- Scenarios configuration
  - **5x5** intersection network
  - 3 lanes per direction (turn left, go straight, turn right)
- Simulations params:
  - **vehicles/s**
  - # runs
  - RNG seedc



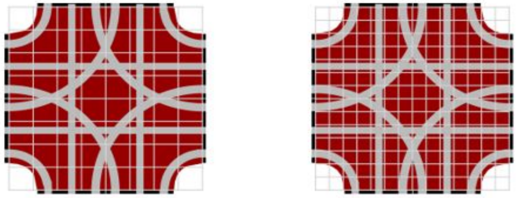
Implementation

^ Giacomo Cabri, Luca Gherardini, Manuela Montangero:
Auction-based Crossings Management
GOODTECHS 2019: 183-188

- Precedence already in SUMO

- Reservation-based
  - based on Dresner & Stone* seminal algorithm
  - based on **occupancy matrix**
  - **FCFS** for colliding vehicles

- Auction-based
  - based on recent research^
  - colliding vehicles participate
  - queue leaders do bids
  - following vehicles sponsor bids
  - 1st variant: only highest wins
  - 2nd variant: bids are ranked

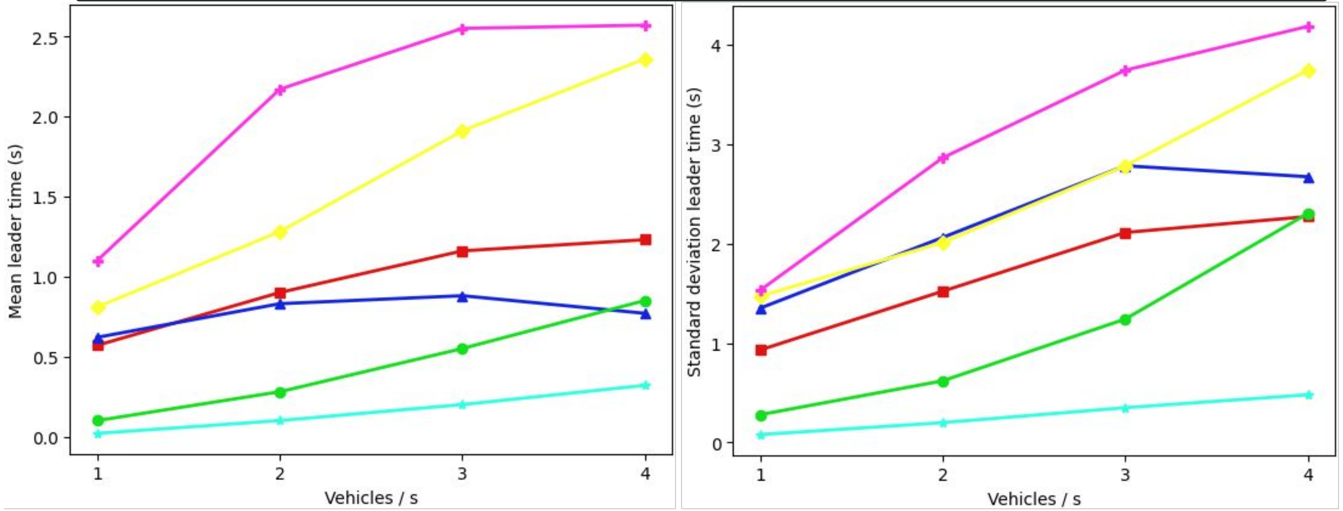


* Kurt M. Dresner, Peter Stone:
A Multiagent Approach to Autonomous Intersection Management
J. Artif. Intell. Res. 31: 591-656 (2008)

Results

Main takeaway: *both strategy and location of deployment do matter*

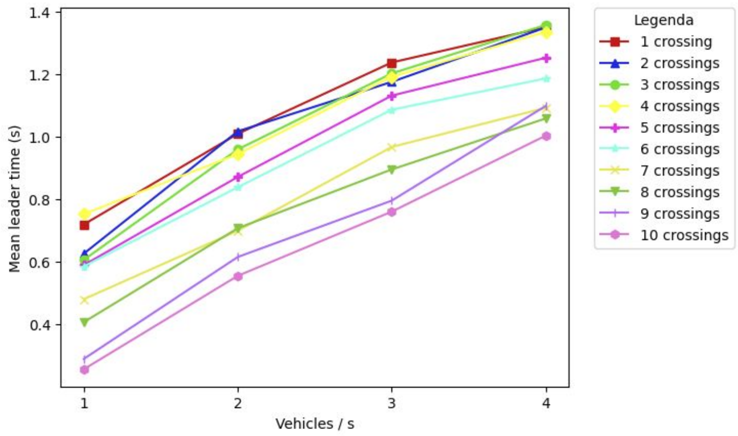
- Mean time spent as leader of queue
- Different combinations of strategies



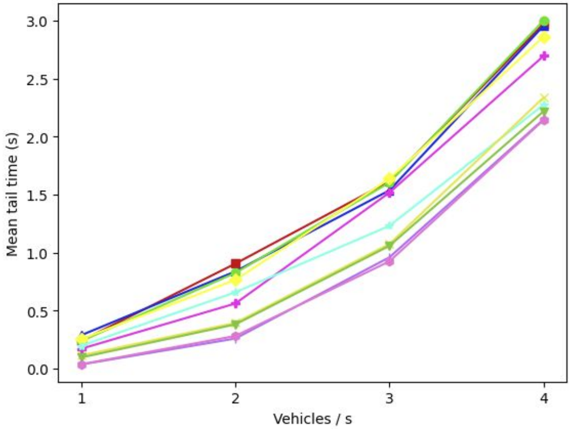
- **Best combination** is
  - reservation-based on inner intersections
  - precedence on outer intersections

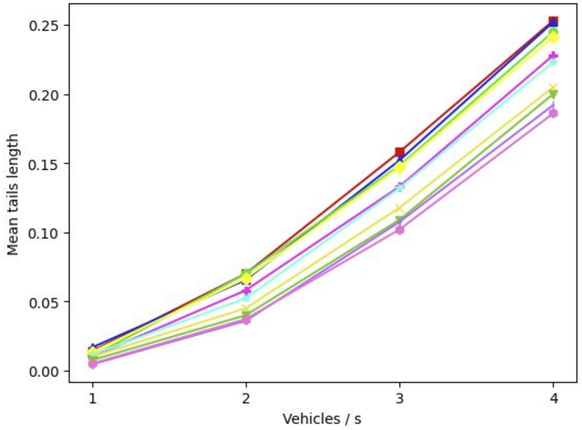
- Same metric
- Different coverage of reservation-based deployment

- Improvement/degradation of performance is **graceful**



Main takeaway:
also the number of deployments do matter





Conclusion

1. Reservation-based strategies work best even in combination with others
2. **3 factors** contribute to performance
   a. coordination strategy
   b. # of deployments
   c. location of deployments

Outlook

1. Model human-driven vehicles, too
2. Consider changing coordination strategy at run-time

Thanks for your attention :)

Questions?

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