Intelligent Intersection

Věra Škopková
Plan of the Presentation

- Introduction
- Reservation-based system
- Communication Protocol
- Mitigating Catastrophical Failure
"People are often hesitant to put their well-being in the hands of a computer unless they can be convinced that they will receive a significant safety benefit in exchange for surrendering precious control." [5]
Survey 1981: 80% of asked people placed themselves in the top 30% of drivers

“It is insufficient for autonomous cars to be safer for the average user, they must be the very paragon of safety.”[5]

Autonomous cars will prevent 94% of all crashes involving human error
Statistics

- 2.5 million intersection accidents per year
- 40% of all crashes – in intersections
- 50% of serious crashes – in intersections
- 20% of fatal collisions – in intersections

- 165 000 accidents caused by red light runners
- Americans burn 5.6 gallons of fuel while idling in heavy traffic
Why are intersections unsafe

- Paths of all participants cross each other
- Need to separate movements of different agents in time or space
- The most problematic turn – left
- Drivers have uncomplete information
  - Optimistic drivers: proceed at a normal speed and risk an accident
  - Pessimistic drivers: slow down or stop and make delays
Missing Information at Intersections

- What other lanes have green
- Remaining time to change green to red
- Blind spots
- Red light runners
Motivation – Real Accident

Crash Diagram (Source: Tampa Police Department)
a) Left-turning Honda and Uber’s AV Volvo are on the collision course
b) Left-turning Honda does not see Uber’s AV Volvo
c) Uber’s AV Volvo does not see left-turning Honda
Intelligent Intersection

Reservation-based Approach
Intelligent Intersection

- Supplies missing information to vehicles
- No red when it is not necessary
  - "Give me green" requests from agents
- Red light violations prediction
- Traffic data from intersection can be analyzed

- "Upgrade to intelligent intersection: from $25k to $100k (depending on sensors already in place)." [2]
Kurt Dresner, Peter Stone

Reservation based policy
- Drastically increases the throughput of the intersection
- Vehicles crossing an intersection experience much lower delay

„For any realistic intersection control policy there exists an amount of traffic above which vehicles arrive at intersection more frequently than they can go through it.“ [3]
Two Types of Agents

- **Intersection Manager**
  - One at every intersection
  - Responsible for directing vehicles through the intersection

- **Driver Agent**
  - One in every car, responsible for driving
  - Request space–time in the intersection
FCFS

- First Come, First Served
- Intersection divided into grid of $n \times n$ tiles
- Intersection manager simulates the journey of the vehicle across the intersection
- At each time step determines which tiles will be occupied by the vehicle
- If a required tile is occupied by another vehicle at given time step, request is rejected
- Limited to use for autonomous vehicles only
FCFS

(a) Successful

(b) Rejected
FCFS–Light

- Accommodates human drivers, cyclists, pedestrians, ...

- Set of physical lights at the intersection
  - Intersection manager knows about them

- During the green light phase corresponding tiles cannot be reserved

- Less efficient than FCFS
Properties for being realistic and practical

- Sending only the necessary information
- Accessing information reliably obtained with current technology
- Communication failure should not violate the system’s safety properties
- No centralized controller should control the agents more than necessary
- Simple communication protocol
- Every vehicle should eventually make it through the intersection
Communication Protocol

- "If all intersections "speak" the same language, the driver see the intersection as a block box and vice versa." [3]
  - Intersection managers and driver agents can have different policies

- 2 message types
  - Vehicle to Intersection
  - Intersection to Vehicle
Vehicle to Intersection

- Request
- Change–Request
- Cancel
- Reservation–Completed
Intersection to Vehicle

- Confirmation
- Rejection
- Acknowledgement
Acceleration in the Intersection

- Reservation at low velocity $\rightarrow$ large amount of the space–time in the intersection $\rightarrow$ might delay other vehicles

- 1st attempt
  - Reservation with acceleration to maximum allowed velocity

- 2nd attempt
  - Reservation at the constant velocity

- Rejection
Reduction of Communication Complexity

- Agent only cancels a reservation if there is absolutely no physical way it could reach the intersection on time.

- Fewer total messages → the bandwidth required to send messages is lower.

- Given the available bandwidth, messages are much less likely to be delayed or lost.
Intelligent Intersection

Mitigating Catastrophic Failure
For efficiency – vehicles are missing each other by the smallest margins

Problem when mechanical failure or slippery patch of road appears

1980: fewer than 5% of accidents

In the future: prevalent cause of collisions
Robustness of the Mechanism

- Mechanism robust against:
  - Dropped and corrupted messages
  - Small sensors errors
  - Small delay

- Mechanism non-robust against:
  - Software errors in driver agent
  - Physical malfunction in the vehicle
  - Meteorological phenomena
Assumption: intersection manager is able to detect problems

2 basic ways of detection

- The vehicle can inform the intersection manager
- Intersection manager can detect the vehicle directly

The first priority: safety of all persons and vehicles nearby

Lower priority: re-establishing normal operation of the intersection
Intersection Manager Response

- No new requests accepted
- Cannot cancel already confirmed requests
  - Broadcasts information about incident to all vehicles
- FCFS–Light: all lights turn red
Vehicle Response

- After receiving emergency signal
  - Starts to use sensors
  - If the vehicle is not in the intersection, it will not enter

- It is safer to try to go out of the intersection than to stop in the middle of it
Sources

2. O. Germbek, A. A. Kurzhanskiy, A. Medury, P. Varaiya, M. Yu: Introducing an Intelligent Intersection
3. K. Dresner, P. Stone: Multiagent traffic management: An Improved Intersection Control Mechanism
4. T.-C. Au, P. Stone: Motion Planning Algorithms for Autonomous Intersection Management
5. K. Dresner, P. Stone: Mitigating Catastrophic Failure at Intersections of Autonomous Vehicles
7. K. Dresner, P. Stone: Sharing the Road: Autonomous Vehicles Meet Human Drivers