Intelligent Intersection

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Plan of the Presentation

- Introduction
- Reservation-based system
- Communication Protocol
- Mitigating Catastrophical Failure

Intelligent Intersection

Introduction

„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]

Statistics

- 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

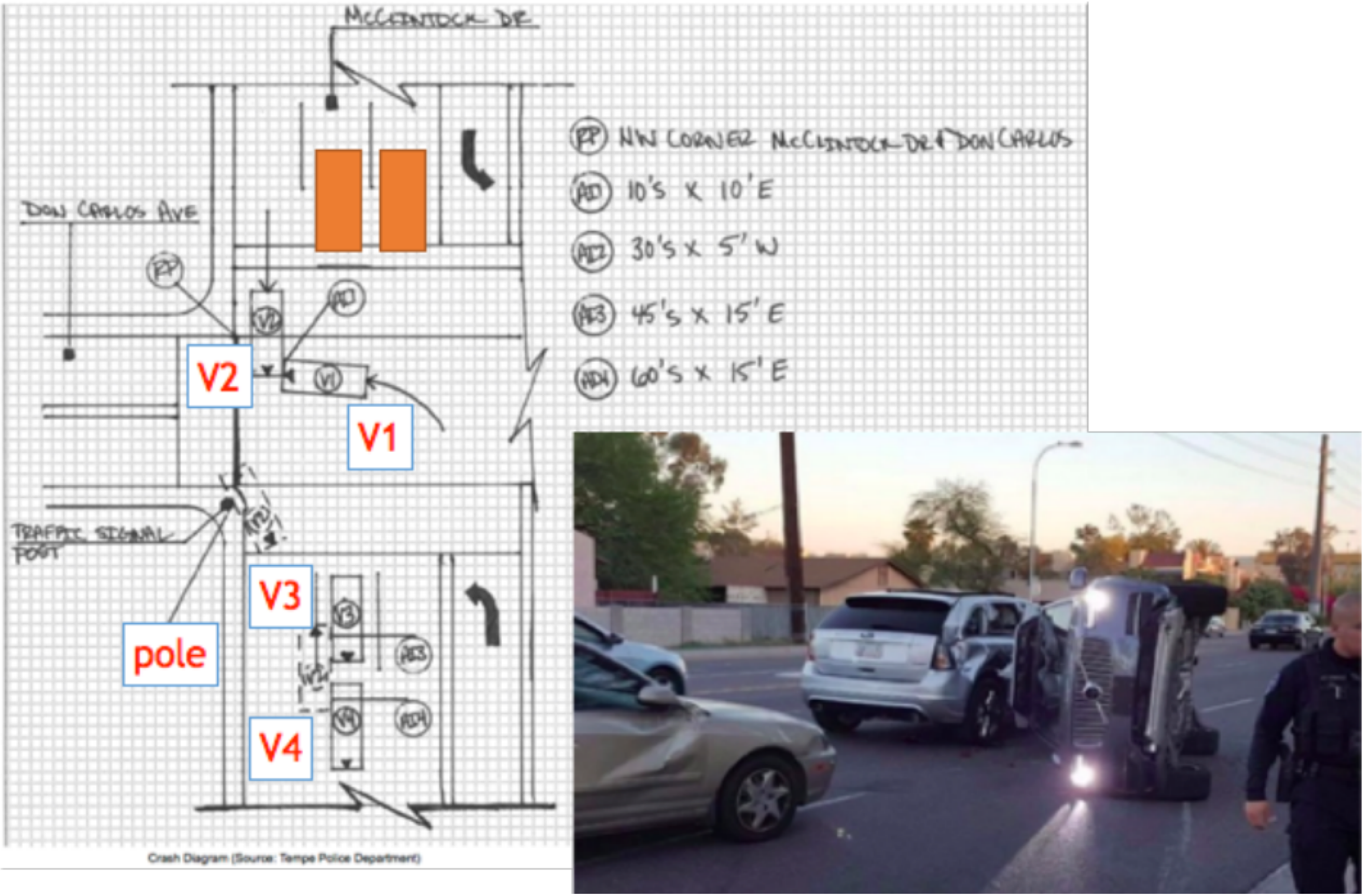
Why are intersections unsafe

- 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

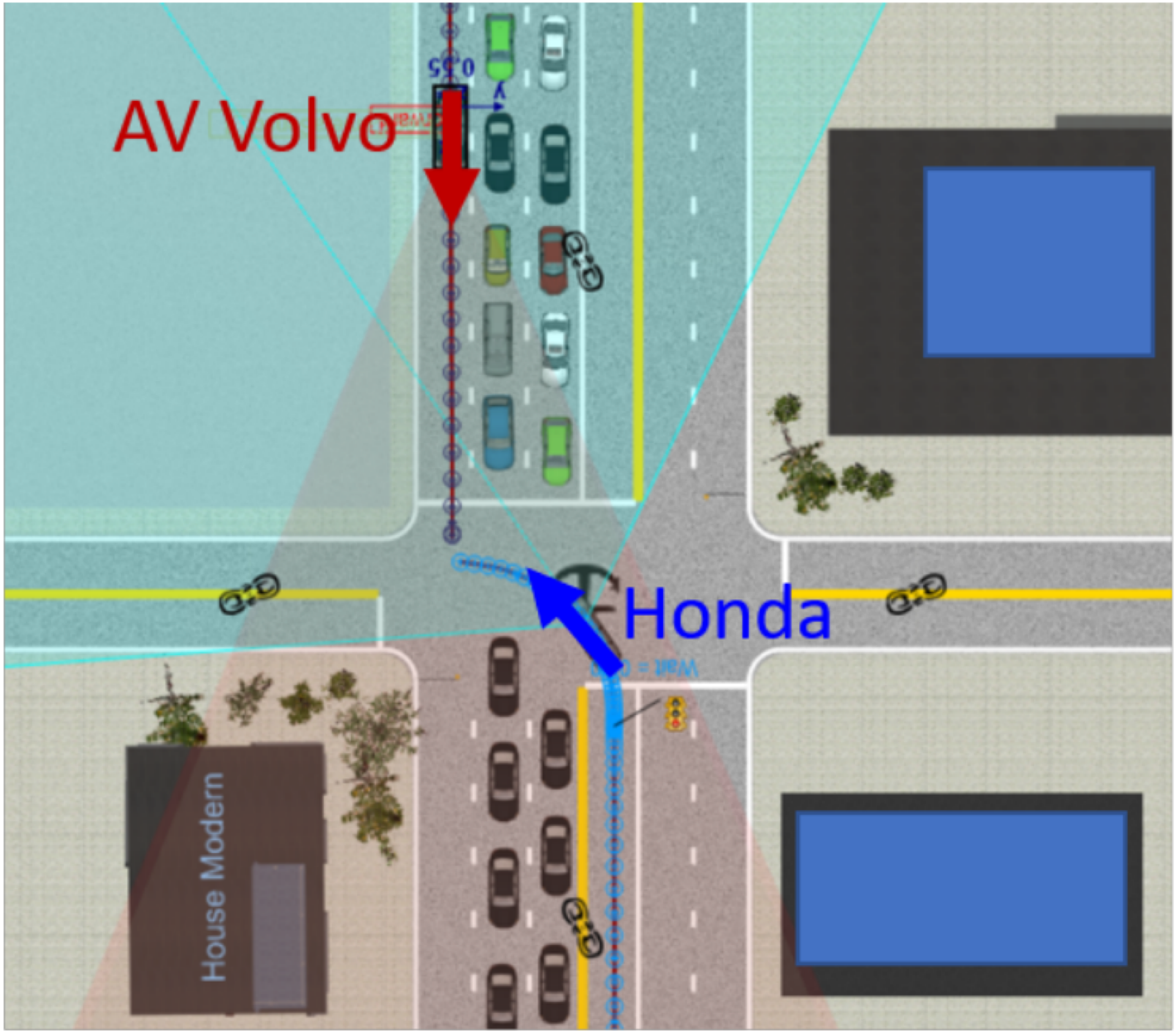
Missing Information at Intersections

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

Motivation – Real Accident



Crash Diagram (Source: Tempe 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

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Reservation-based Approach

Intelligent Intersection

- Supplies missing information to vehicles
- No red when it is not neccessary
  - „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]

Intersection Control Mechanism

- 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]

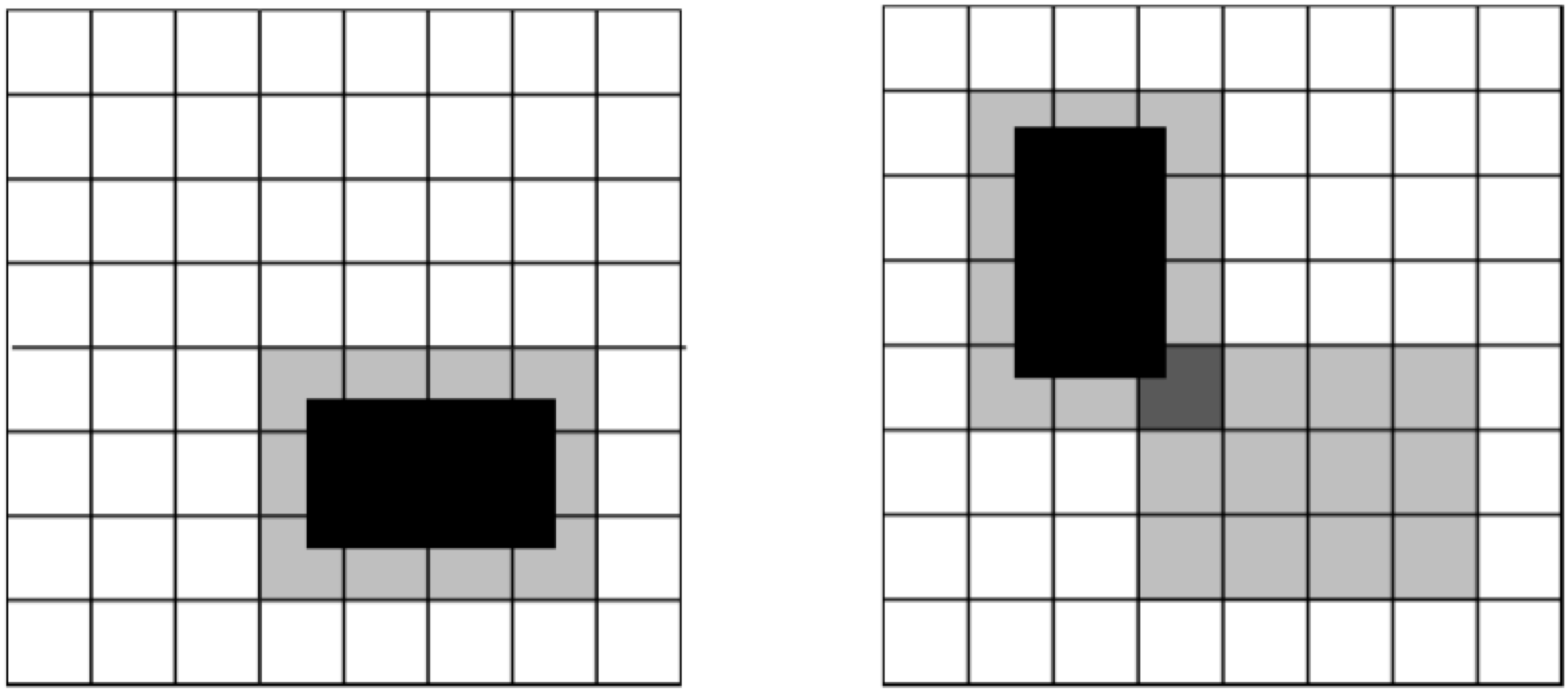
Two Types of Agents

- 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 *nxn* 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

- Accomodates human drivers, cyclists, pedestrians, …
- Set of fysical lights at the intersection
  - Intersection manager knows about them
- During the green light phase corresponding tiles cannot be reserved
- Less efficient than FCFS

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- Communication Protocol

Properties for being realistic and practical

- Sending only the necessary information
- Accessing information realibly 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 ->large amount of the space-time in the intersection ->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

Video

Intelligent Intersection

» Mitigating Catastrophic Failure

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

Mitigating Catastrophic Failure

- 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-estabilishing 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

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