A Reservation-Based Multiagent System for Intersection Control

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Intersections: Inefficient and Dangerous

- Wasted resources
  - Time
  - Energy
  - Patience
- Statistics
  - 1/3 of all accidents
  - 1/4 of fatal accidents

MAS to the Rescue!

- Computers will be better drivers
  - Don't get distracted, tired, aggressive, or drunk
  - Precise
  - Efficient
- Technology exists
  - Intelligent cruise-control
  - Autonomous steering
  - GPS navigation
- More forthcoming
  - DARPA Grand Challenge
  - Hands Free Across America

Intersection Control Today

- Traffic lights
- Stop signs
- Traffic circles

Limited Model of Traffic at Intersections

- Vehicles roughly uniform
  - Size
  - Performance
- No turns (yet)
- All “thru” traffic

Measuring Success – Delay

- Ideally, no intersection
- Delay is just how much longer the trip takes
- Consider both average and maximum

Custom Simulator

- Time-based
- Parameters
  - Number of lanes in each direction
  - Probability of spawning a car in each direction
- Main loop
  - Spawn new vehicles
  - Sense (distance to vehicle in front)
  - Decide (accelerate, coast, decelerate)
  - Act (update locations, velocities)
  - Remove finished vehicles

The Simulator In Action

- Overpass – the optimal solution
  - Optimal only for the restricted model
  - Zero delay

Run Simulation

Implementing the Traffic Light

- The "one to beat"
  - Most ubiquitous intersection control policy
  - Room for improvement
- Simulation
  - 2 lanes each direction
  - .01 probability to spawn vehicles
  - Period of 30 seconds, light green 45% of time in each direction
  - Average delay: **9.45 seconds**

Run Simulation

Replacing the Traffic Light: Desired Properties

- Safety!
- Feasible to deploy incrementally
- Realistic sensors
- Maximize efficiency
- Minimize centralized infrastructure
  - Multiagent systems
  - Minimal protocol
- Drivers
  - Complete control outside the intersection
  - Safe in intersection as long as they follow the rules
  - Need not know how intersection manager works

The Reservation System

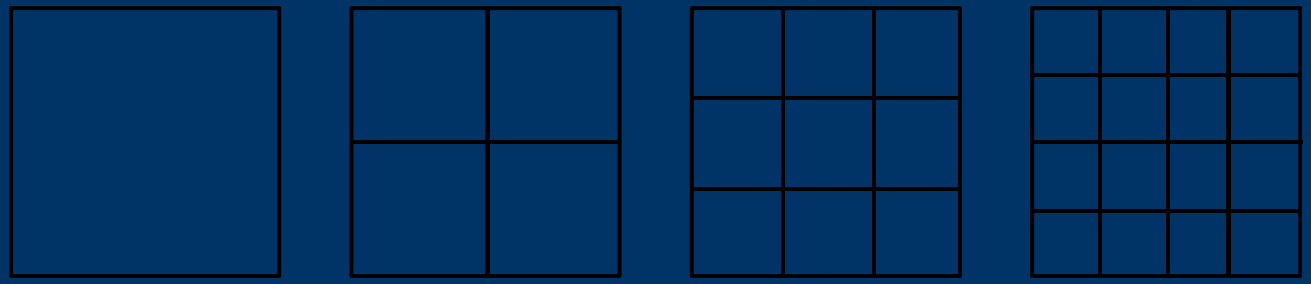
- The idea
  - Vehicles “call ahead” for space-time
  - No vehicle may enter the intersection without a reservation for that time
- Drivers choose all details of reservation request
- Intersection managers
  - Can have different internals
  - Can make “counter offers”

Vehicle-Intersection Communication

- Standardized protocol
  - Multiple implemenations of driver agents and intersection managers
  - Limit communication complexity
- Reservation requests
  - Arrival time
  - Arrival velocity
  - Arrival heading
  - Maximum velocity
  - Maximum and minimum acceleration
  - Length and width

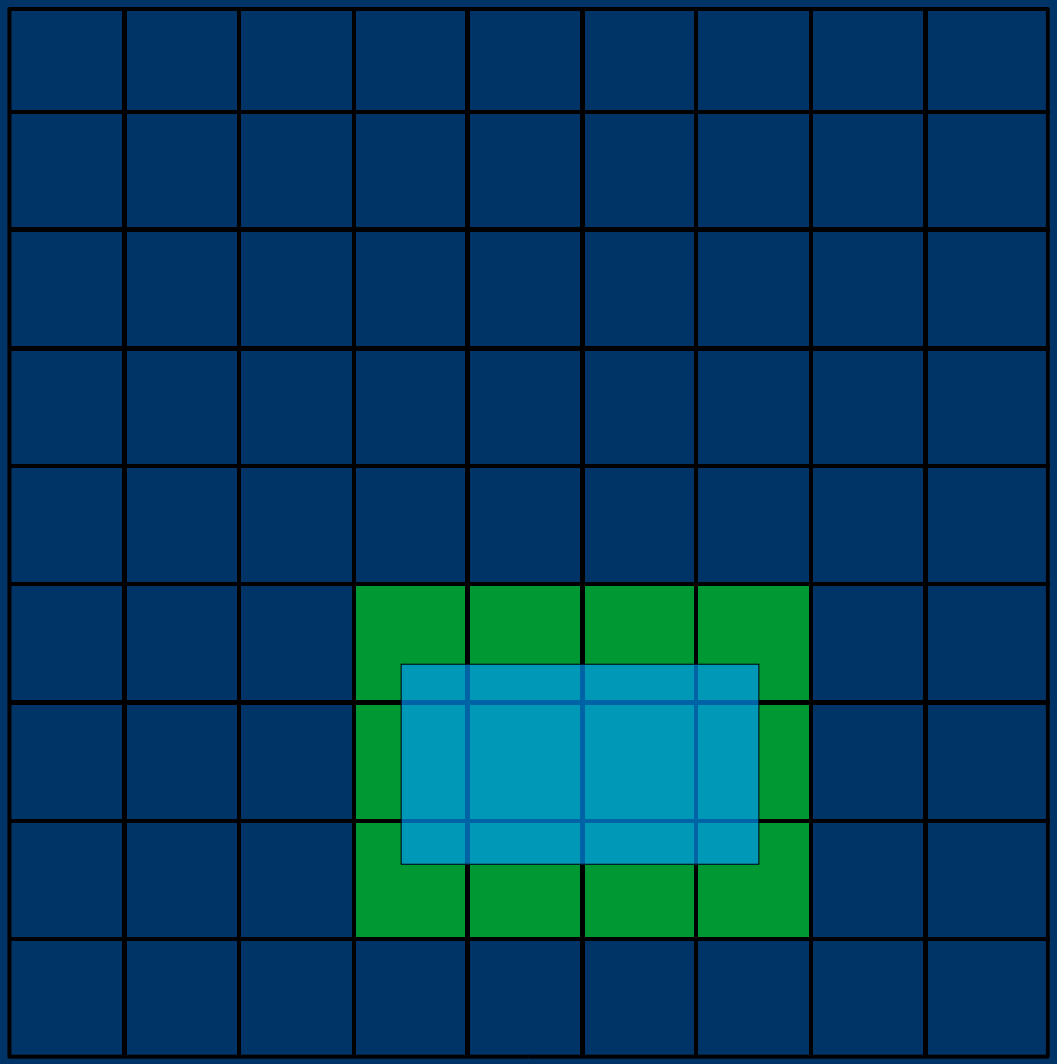
Our Implementation

- Divides intersection into *n* by *n* grid of cells
  - *n* is the "granularity"



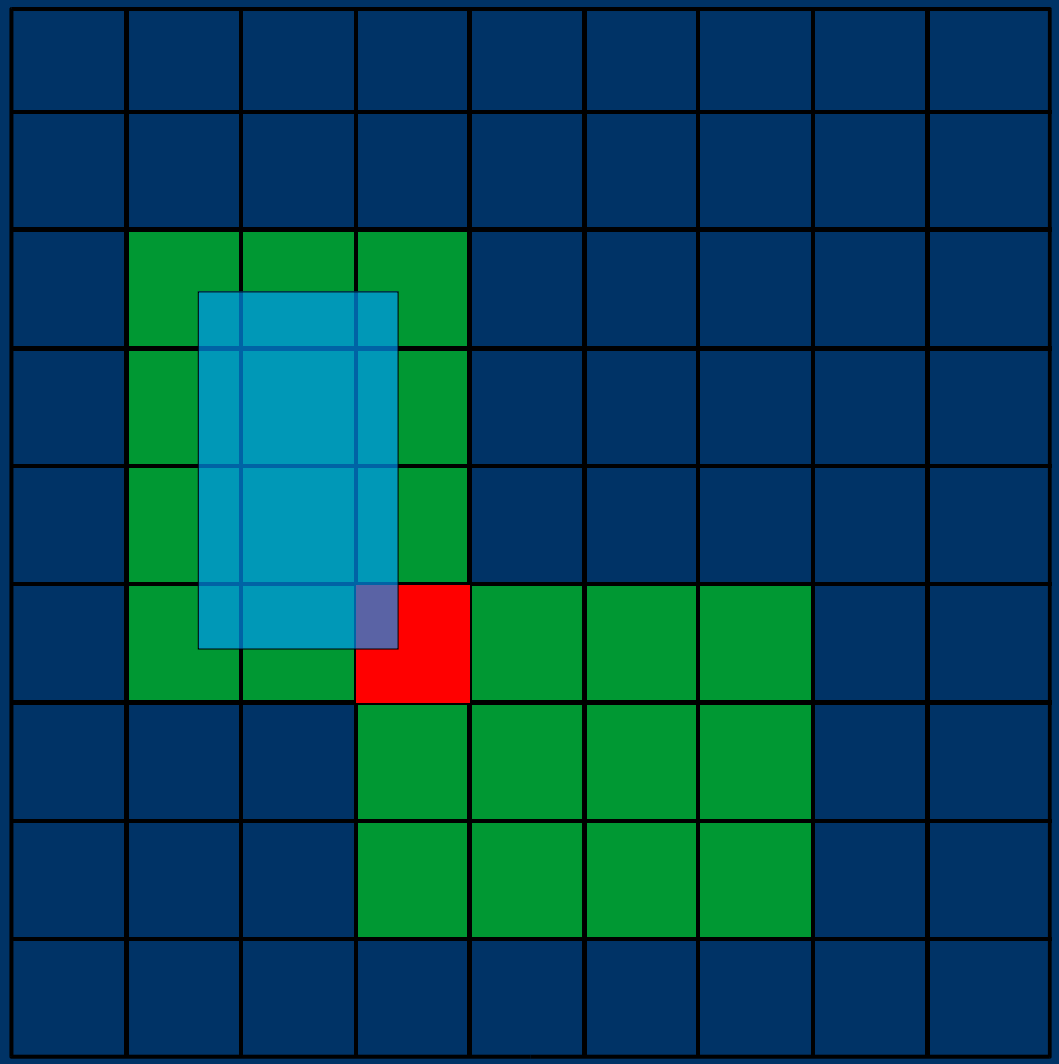
- On receiving request
  - Simulates vehicle's journey through intersection
  - Determines which cells are occupied at each time step
  - Checks if those cells are already reserved
  - Marks the cells reserved if the journey is successful
  - Responds to the vehicle with a confirmation or rejection

A Successful Reservation



Time *t*

A Failed Reservation



Time *t*

Car Control Policy

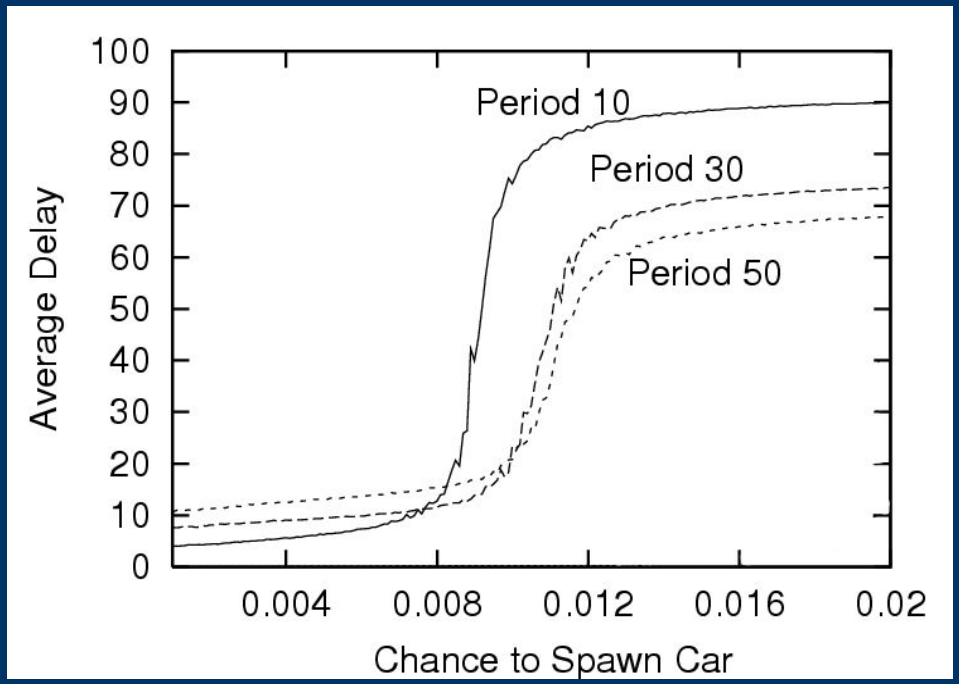
- Can be different for every car
- Reservation system doesn't need to know
- Ours is very simple, naïve
  - Attempts to make reservation
  - If rejected
    - Slows down
    - Tries again
  - If accepted
    - Tries to keep it
    - Cancels if it determines it can't keep it

The Reservation System in Action

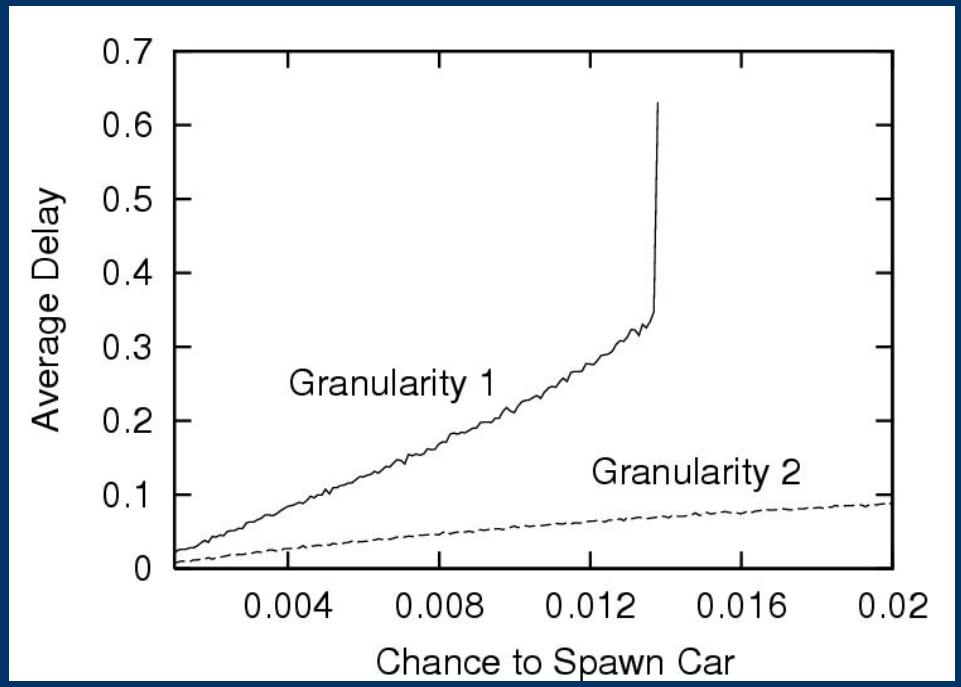
- 2 lanes in each direction
- .01 probability of spawning vehicles
- Granularity of 4
- Average delay: **0.076 seconds**

Run Simulation

Traffic Light vs. Reservation



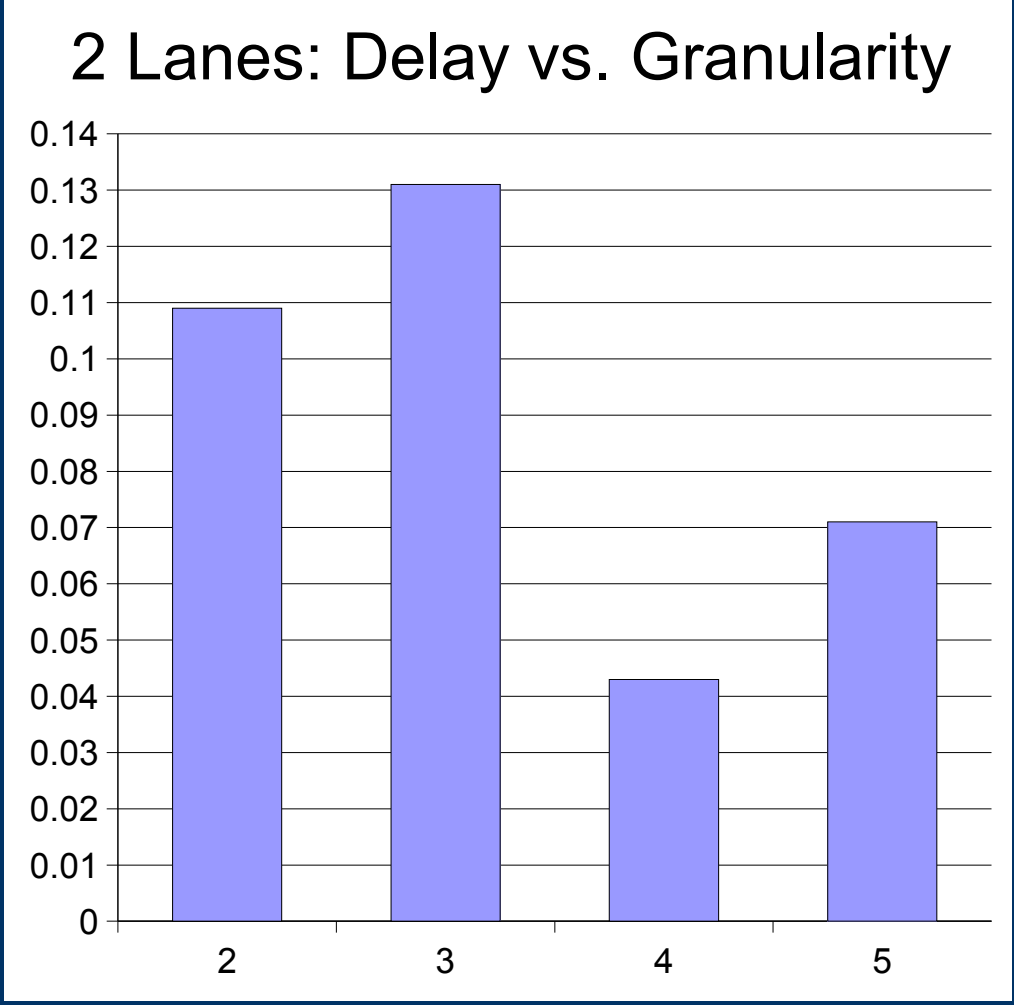
Traffic Light



Reservation System

Choosing Granularity is Important!

- Increased granularity does not always lead to decreased delay
- Minimize contention between parallel traffic



Tradeoffs: Efficiency, Computation and Safety

- Higher granularity
  - More computation
  - "Close calls"
- Lower granularity
  - Fewer vehicles in intersection
  - Possibly more waiting

The Solution: Explicit Time Buffers

- Allows high granularities while still ensuring safety
- Automatically accounts for direction of traffic flow

Insanity!

- 6 lanes in each direction
- .05 probability of spawning vehicles
- Granularity of 48
- Average delay: **0.7 seconds**

Run Simulation

Recent Developments

- Implementing other policies under the standardized protocol
  - Traffic light
  - Stop sign
- Switching between policies on the fly
  - Perhaps allow for human drivers, pedestrians, cyclists

Future Work

- Turns
- Lane changing
- Fault tolerance
- Strategy-proofing
- Incorporate pedestrians, cyclists, human drivers into simulation

Related Work

- Scheduling with conflicts [Irani and Leung 96]
  - Applications to traffic signal control
- Multiagent approach [D.A. Roozemond 99]
  - Traffic signals autonomous, cooperative
- Cooperative autonomous driving [Kolodko and Vlacic 03]
  - Similar to granularity-1 reservation system

Questions?

Measuring Success – Delay

- C – set of all vehicles crossing the intersection
- $t(v)$ – time it takes vehicle v to cross the intersection
- $i(v)$ – ideal time for v to cross the intersection

$$\frac{1}{|C|}\sum t(v)-i(v)$$

Conflicts In Parallel Traffic Flow