Application of AI Detection and Machine Learning Optimization in Traffic Signal Management

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Problem: Modern Sensors are not Fully Exploited for Signal Control

- Zone-based detection and control logic limit the usefulness of high-resolution data

- Timing plans limit flexibility of a real-time control system

- Positional / classification data is more commonly being used for ATSPM or virtual zones - but rarely for realtime control

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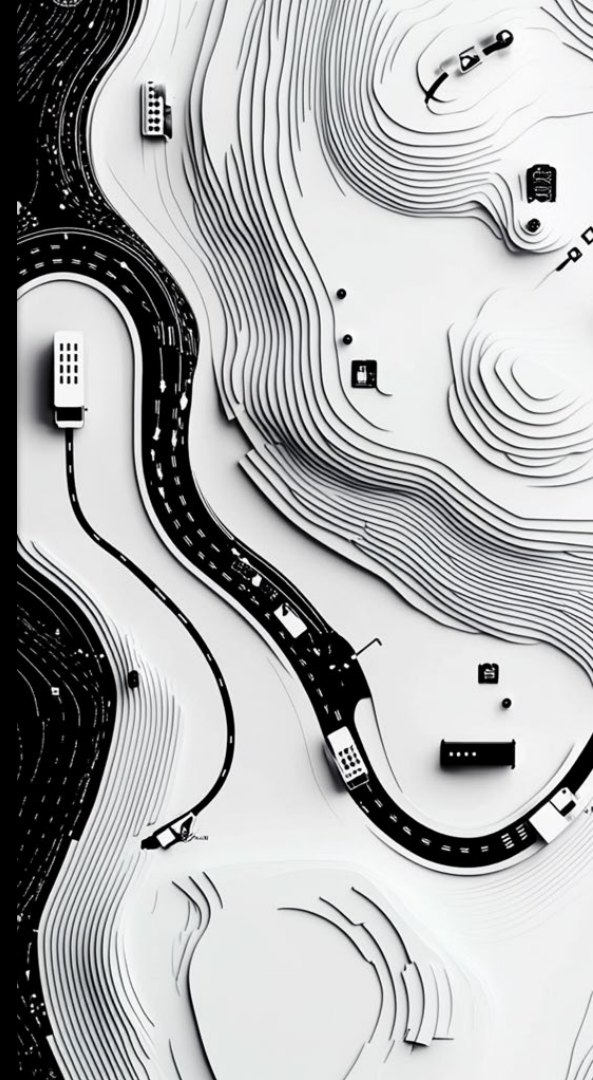
Solution: Real-time, Closed Loop Control

- **Sensing - Continuous State Feedback**
  - Sample position, speed, classification, and <u>driver intent</u> —updated many times per second
  - Vehicles and pedestrians alike
- **Realtime Control - Rapid Control Cycle**
  - Directly selects optimal phase transitions based on real-time traffic sampling, both <u>locally (intersection)</u> and <u>globally (citywide)</u>
  - Incorporate City preferences and priorities
  - No reliance on adaptive systems, fixed timing plans, or time-of-day logic
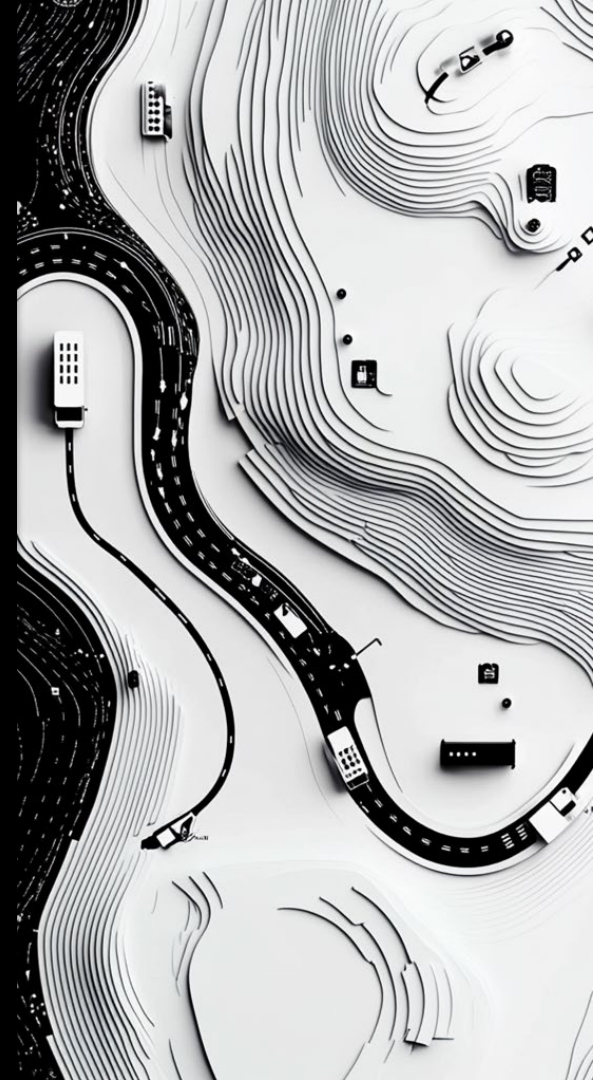
Realtime Control - Global (II/II)
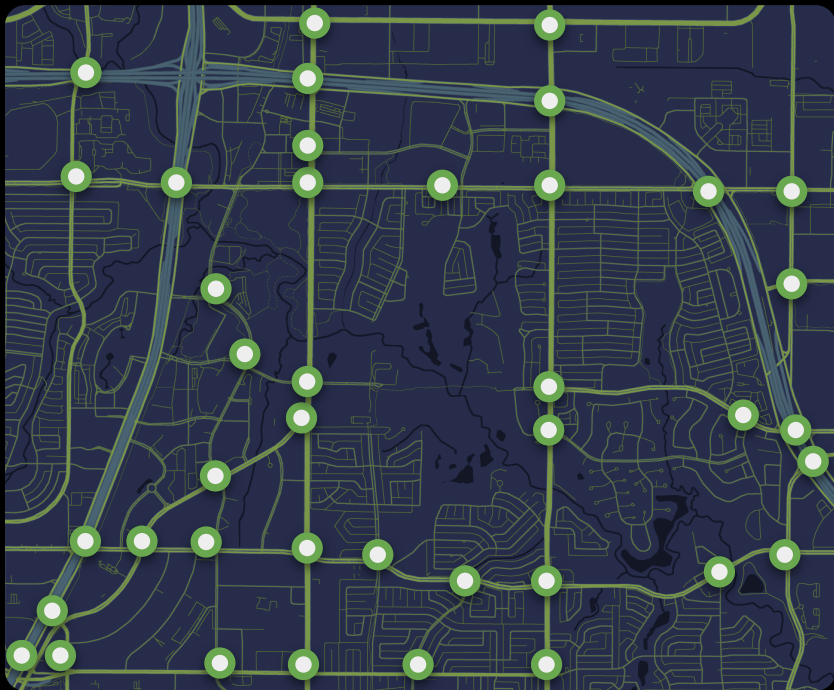
Corridor or Citywide Level (Global)
- Every intersection can see live data from its neighbors
- Build and route Platoons with minimal delay, maximum arrivals-on-green

The Challenges:
- Balance demand across available roadway capacity (aka: pressure)
- Handle dynamic volumes during rush hours, events, inclement weather

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Potential Operational Benefits

**A Brain in Every Intersection allows:**
- Automated learning and response
    - No signal retiming
    - Detects and acts on large traffic events and macro traffic patterns
    - Less alerts, more action
- Seamless **preemption** for various vehicle classes
- **ATSPM provided** as a side benefit to the data collection needed for the control process

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Potential Safety Benefits

**High-rate, realtime control with object data allows:**
- Action, not observation, to protect Vulnerable Road Users (VRUs)
- Sync phase changes with minimal dilemma zone occupancy
- Extend red to avoid collisions from red-light runners
- All implemented passively to minimize configuration or tweaking
- Compliance (jay walking, red light running, etc)
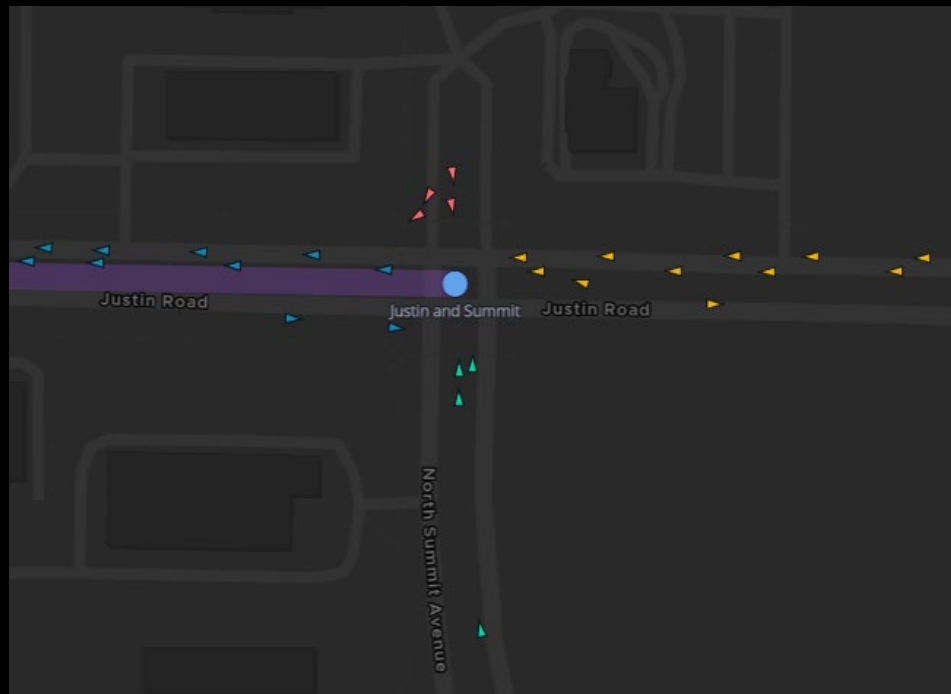- Dilemma zone decisions

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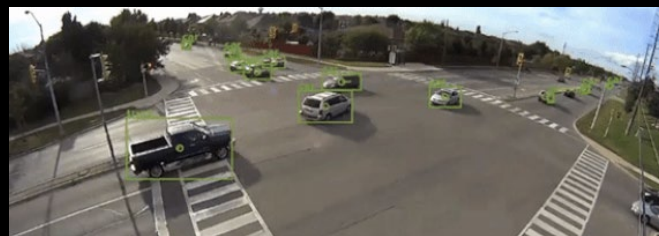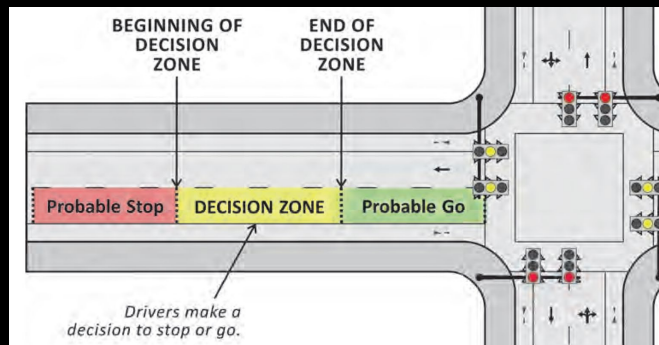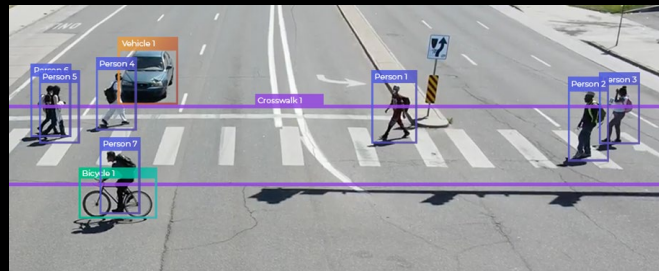
Sensing

- Use <u>existing hardware</u> where possible (sensors, controllers)
- Sensors across multiple intersections feed powerful AI model
- Does not require specific zones or configuration
- Recognize, track, and map vehicles to <u>real world location</u>
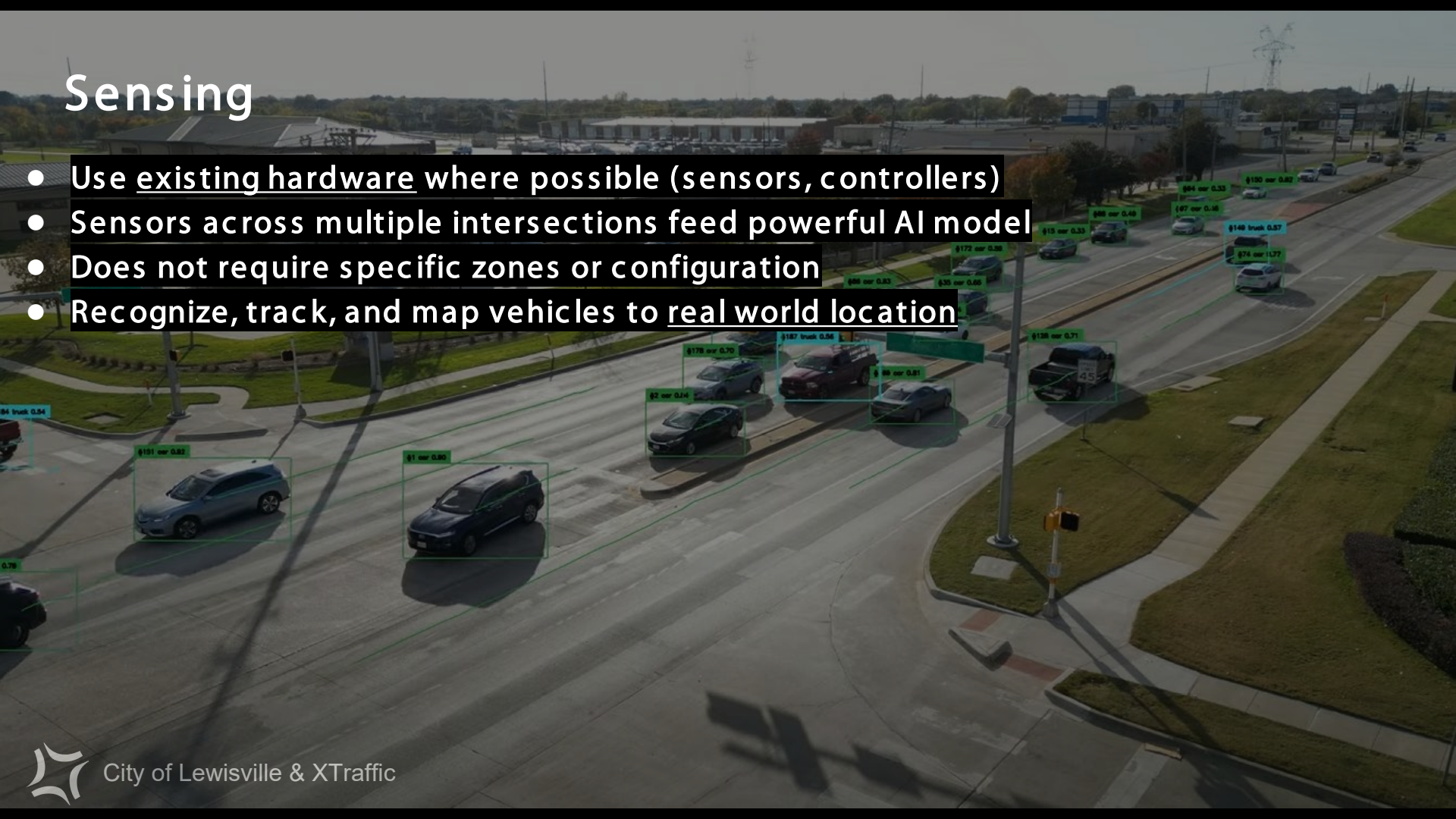
Realtime Control - Local (I/II)

Intersection Level

- Command existing traffic controller over NTCIP
- Local Control based on live data of all vehicles and pedestrians within local radius (hundreds of meters)
- Selectively consider high-level preferences and city traffic data

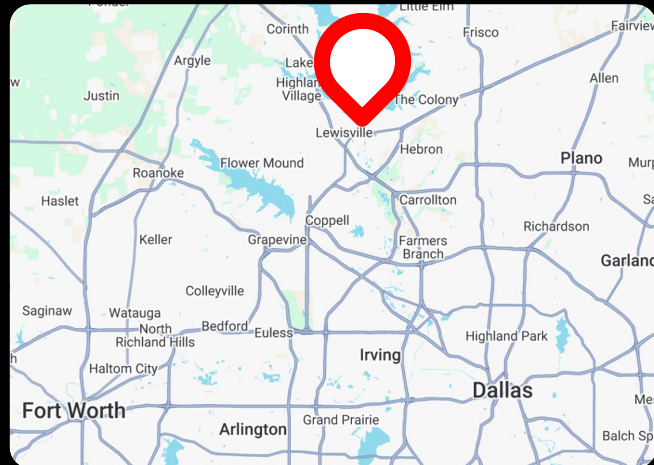## The Challenges:

- Balance fairness and safety with efficiency
- Handle sensor uncertainty, outages, occlusions/obstructions

Pilot Project

- FM 407 corridor (46,500 vehicles per day)
- Activated in October 2024

Justin Rd.

Summit Ave.

Businesses to the north

I-35E to the east

Neighboring intersections are uncoordinated

Residential and school to the south

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Initial Results and Pilot Expansion

Time Period	Average Delay (sec)		Benefit (%)
	Before	After	
Entire Weekday	16.7	10.3	38.7%
AM Peak (6AM-9AM)	17.1	10.7	37.4%
Midday Peak (9AM-4PM)	19.1	11.0	42.3%
PM Peak (4PM-7PM)	20.4	12.6	38.1%

Time Period	Arrival on Green (%)		Benefit (%)
	Before	After	
Entire Weekday	52.6	71.0	18.5
AM Peak (6AM-9AM)	53.0	70.3	17.3
Midday Peak (9AM-4PM)	47.3	68.7	21.4
PM Peak (4PM-7PM)	45.2	65.8	20.6

❖ Sep 2023 VS Dec 2024.:

- Increased Arrival on Green and reduced average delay for every time period

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Results to Date

Time Period	Arrival on Green (%)		Benefit (%)
	Before	After	
Entire Weekday	56.3	63.3	7.0
AM Peak (6AM-9AM)	57.0	60.8	3.8
Midday Peak (9AM-4PM)	54.4	64.0	9.6
PM Peak (4PM-7PM)	50.6	58.0	7.4

Time Period	Average Delay (sec)		Benefit (%)
	Before	After	
Entire Weekday	20.1	16.8	16.4%
AM Peak (6AM-9AM)	20.1	17.3	14.0%
Midday Peak (9AM-4PM)	20.2	16.1	20.3%
PM Peak (4PM-7PM)	24.1	21.0	13.1%

❖ Sep 2025 vs. Dec 2024:
- Improved intersection performance along corridor
- Eliminated 3,580 hours of delay
- Correlates to $12 million of delay savings over 10 years (FHWA methodology)

❖ In March 2025, activated additional 4 intersections to control corridor.
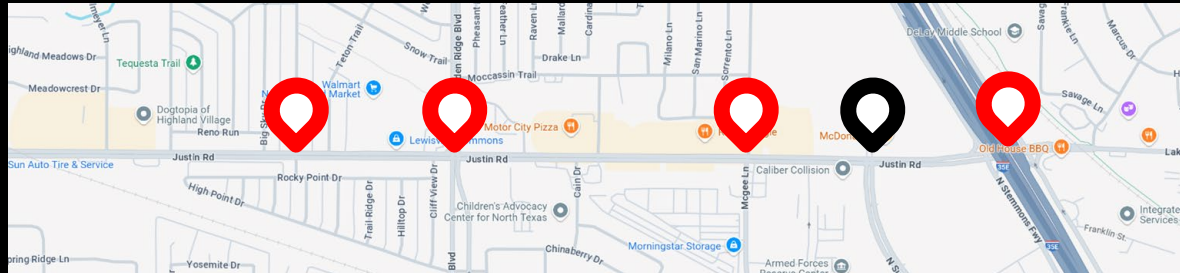
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Advantages and Disadvantages

Advantages
- Minimal configuration needed from the City
- Able to quickly handle high traffic variations
- Benefits seen throughout the day
- Automatically adapts to lane closures and incidents

Disadvantages
- Requires reliable video stream
- Weather impacts
- Black Box
- No Fixed Sequence
- No Offset / Lag time
- Prone to Constraints

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Challenges and Next Steps

- Merge "black box" style control with engineer-specified requirements and preferences

    - Balance fairness and individual wait times against a global optimized system

- Transition from Delay-oriented model to safety-oriented approach

- Automation vs notification

    - When to involve end users, and when to leave them alone

- Large scale implementation - tackle issues that arise from deployment on a true citywide scale

- Coming up with an innovative approach to progression and priority

- Changing the traditional signal timing mindset and creating a new approach to signal timing

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