Vehicle-to Everything Communication Project

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Overview

- Motivation
- Background
- Objectives
- Experimental Setup
- Methods
- Future Work

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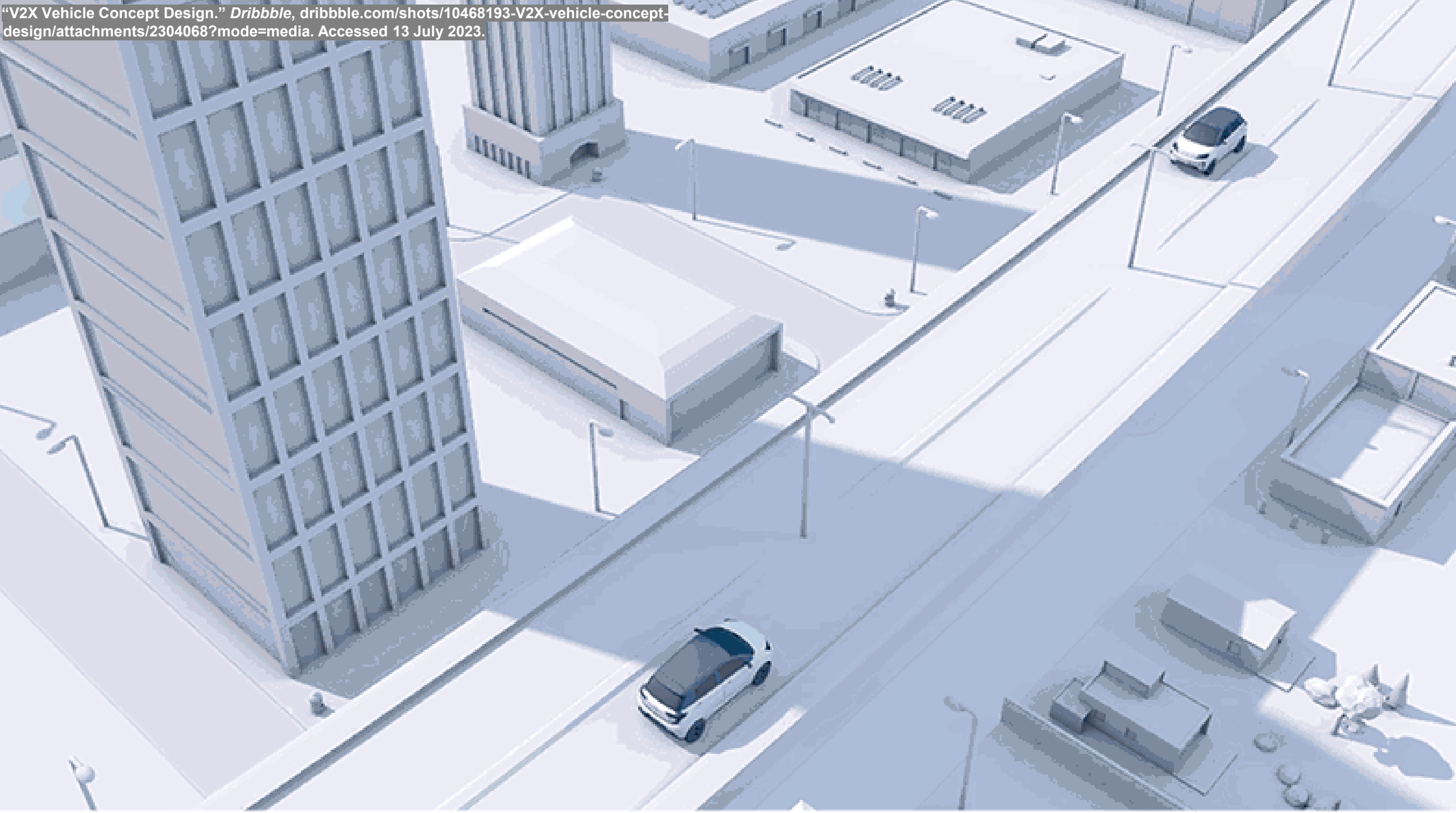
Mitchell, Chaffin. *Why It's Not Safe to Flash Hazard Lights While Driving in the Rain*, 29 Sept. 2020, www.accuweather.com/en/accuweather-ready/why-its-not-safe-to-flash-hazard-lights-while-driving-in-the-rain/600709



"V2X Vehicle Concept Design." *Dribbble*, dribbble.com/shots/10468193-V2X-vehicle-concept-design/attachments/2304068?mode=media. Accessed 13 July 2023.

Goals of V2X

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Improve Safety

“What Is Vehicle-to-Everything (V2X) Technology?” Built In, builtin.com/transportation-tech/v2x-vehicle-to-everything. Accessed 14 July 2023.

- Average human reaction time: ¾ of a second [1]
- Nearly instant communication
- Identify and communicate hazards, pedestrians, poor weather conditions, and more

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Move Efficiently

"Harmonize Speeds, Save Lives - Rekor Systems." *Rekor*, www.rekor.ai/post/harmonize-speeds-save-lives. Accessed 14 July 2023.

- Optimize intersections
- Harmonize speed to allow vehicles to follow each other closely
- Reduced fuel emissions with platooning and efficient intersections [2]

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Current State of V2X

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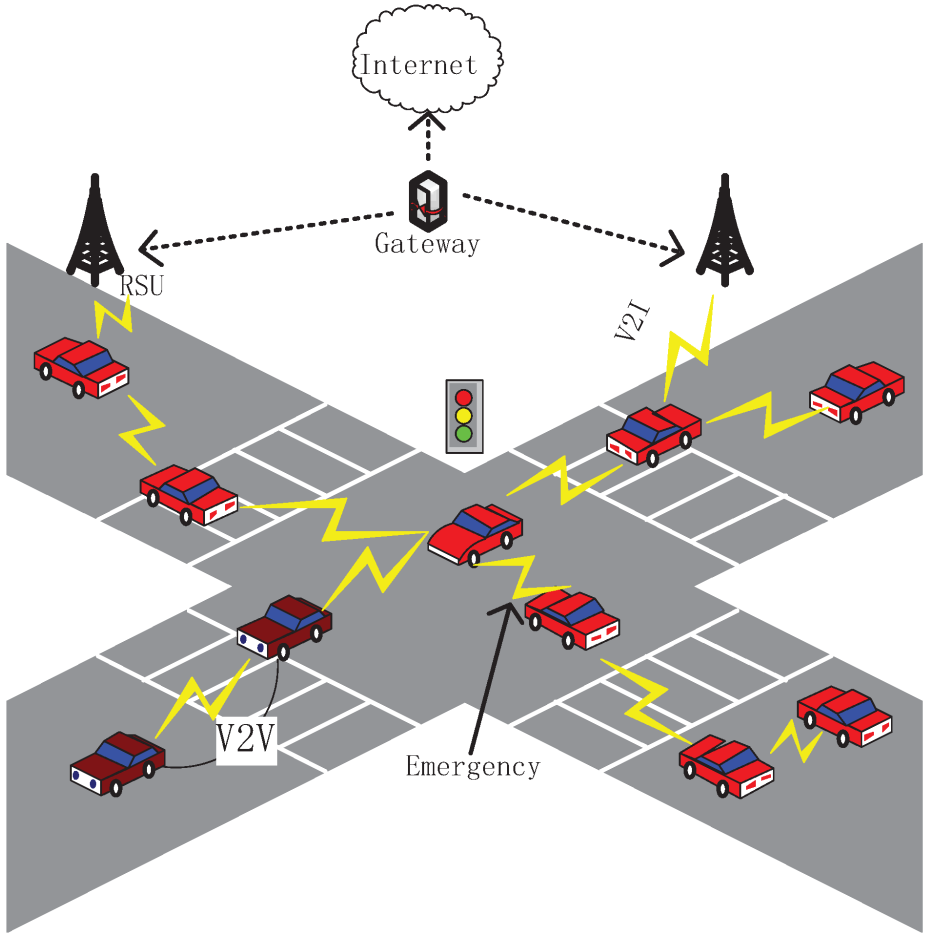
Vehicle Ad-Hoc Network



- A VANET provides internet access and connectivity between vehicles [3]
- VANET's are being researched to prevent collisions, dynamically schedule routes, and monitor conditions [3]

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Wang, Leilei, et al. "An Opportunistic Routing for Data Forwarding Based on Vehicle Mobility Association in Vehicular Ad Hoc Networks." MDPI, 7 Nov. 2017, www.mdpi.com/2078-2489/8/4/140.

Vehicle Infrastructure Integration

Vehicles, IEEE Connected. "Qualcomm and LG Bring 5G and Cellular-V2X Communications into Vehicles." IEEE Web Hosting, 11 Mar. 2017, site.ieee.org/connected-vehicles/2017/02/23/qualcomm-lg-bring-5g-cellular-v2x-communications-vehicles/

- Siren sensors
- Road-side units
- Weather sensors
- Traffic detection
- License plate recognition

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Primary Objectives

1. Create connections between vehicles
2. Map real-time vehicle locations via a Web GUI
3. Create occupancy grids

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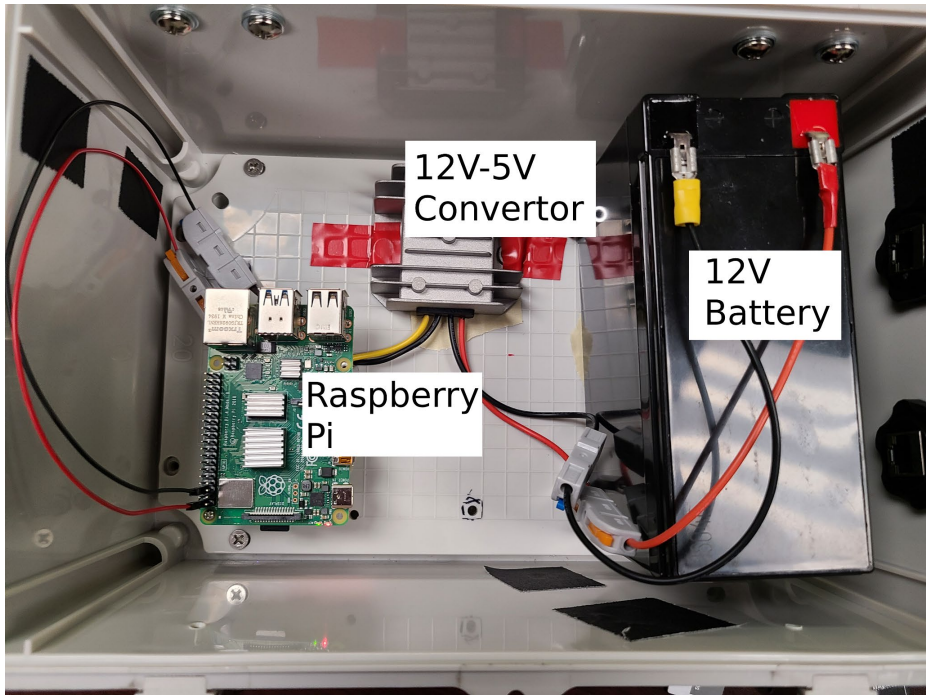
Experimental Setup

HARDWARE



Roadside Unit

Autonomous Campus Transport (ACTor) Vehicle

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Time, Position, Navigation

SOFTWARE STACK

C++

ROS

Python

MariaDB

NodeJS & HTML

SocketIO

Google Maps API

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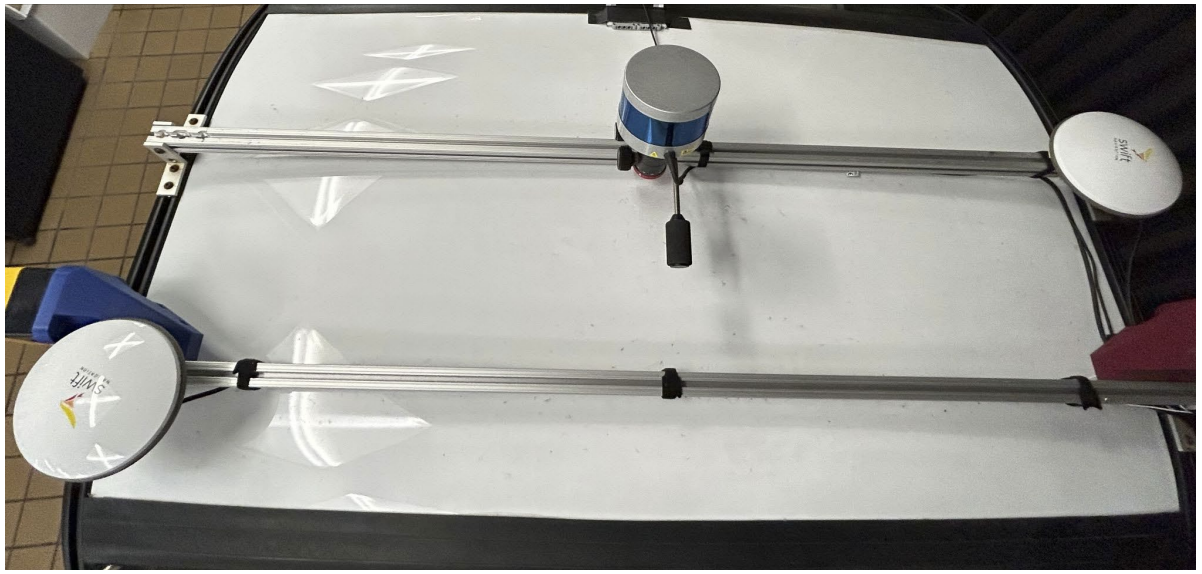
Swift Navigation

- Swift Piksi Multi Receivers
  - GNSS with GPS and RTK capabilities
  - ECEF, UTM, LTP, LLH formats
  - Reference and Attitude Receivers
  - ROS compatible



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Time, Position, Navigation

- tpn_node
- Subscribe to LLH and DBW topic
- Custom Position Message
  - Latitude, Longitude, Heading, Velocity, and Angular Z
- Future location prediction
- Live map updates

```
lat: 42.4751091003418
lon: -83.24995422363281
heading: 354.0
velocity: 2.25
angZ: -0.6365689635276794
---
lat: 42.47511291503906
lon: -83.24995422363281
heading: 2.0
velocity: 2.1777777671813965
angZ: -0.616135835647583
---
lat: 42.47511291503906
lon: -83.24995422363281
heading: 2.0
velocity: 2.299999952316284
angZ: -0.6507148742675781
---
lat: 42.47511291503906
lon: -83.24995422363281
heading: 11.0
velocity: 2.2333333492279053
angZ: -0.6318536400794983
---
lat: 42.47511672973633
lon: -83.24994659423828
heading: 11.0
velocity: 2.1416666507720947
angZ: -0.6057875156402588
---
```


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Object Detection

SOFTWARE STACK

- C++
- ROS
- Python
- MariaDB
- NodeJS & HTML
- SocketIO
- Google Maps API

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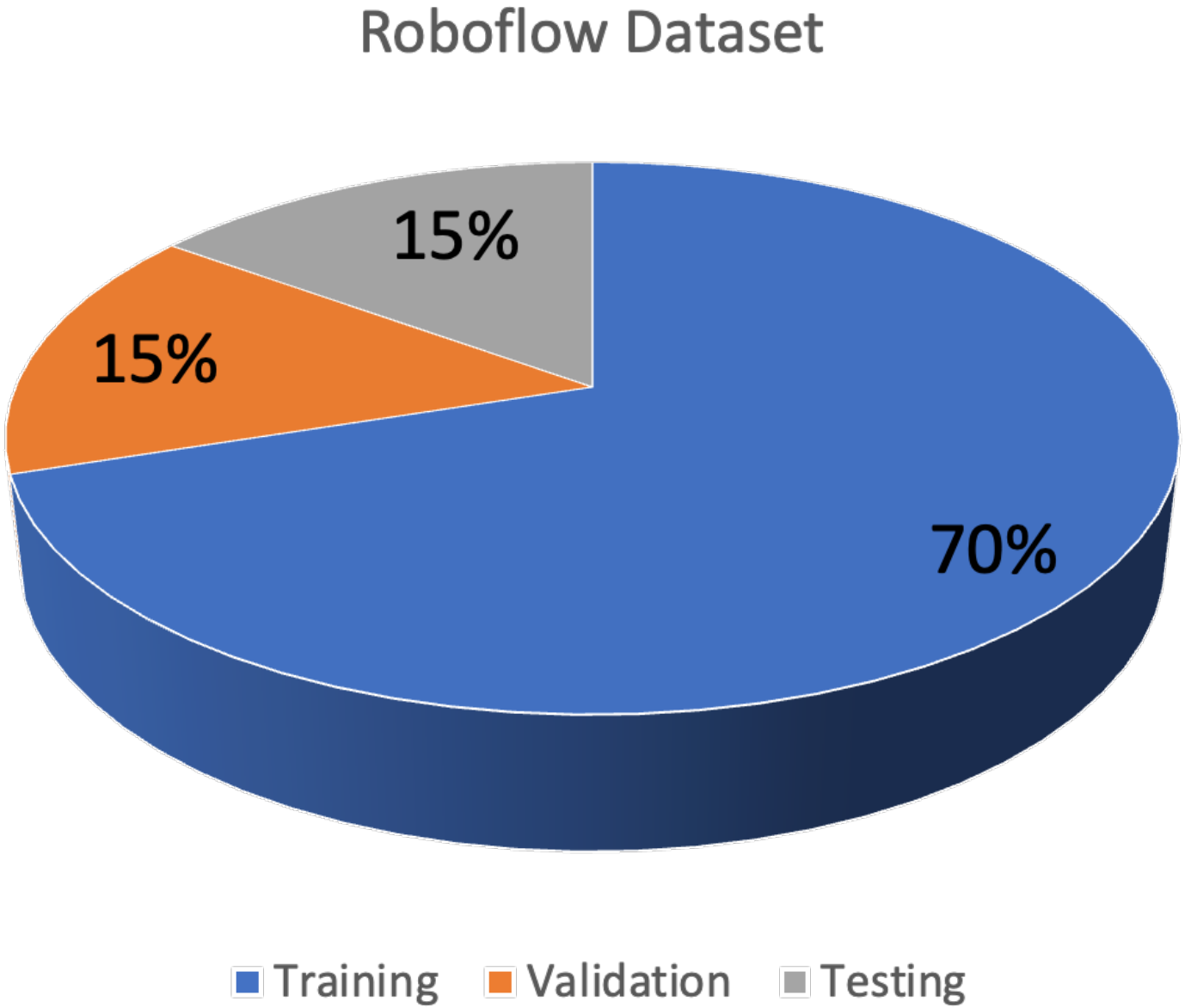

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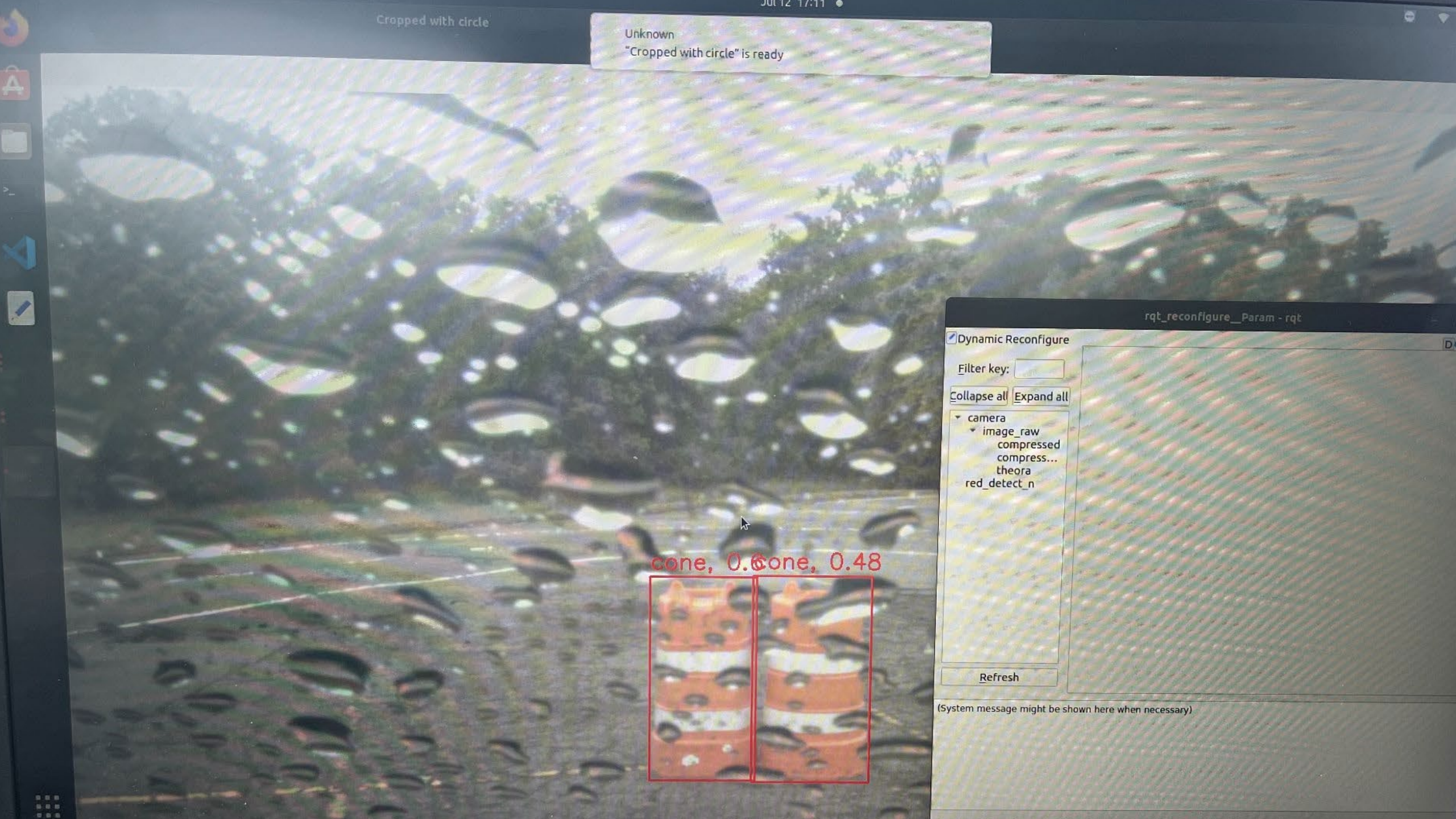
```
    box:
      x_offset: 618
      y_offset: 681
      height: 260
      width: 128
      do_rectify: False
---
boxes:
  -
    title: "cone"
    confidence: 0.9145516753196716
    box:
      x_offset: 593
      y_offset: 745
      height: 301
      width: 152
      do_rectify: False
---
^Cmichael-khalfin@michaelkhalfin-HP-ZBook-Studio-x360-G5:~/catkin_ws/src/yolov8ros_pkg/launch$ cd ../..
michael-khalfin@michaelkhalfin-HP-ZBook-Studio-x360-G5:~/catkin_ws/src$ cd v2x/
```


Cropped with circle
Unknown
"Cropped with circle" is ready
cone, 0.6
cone, 0.48
rqt_reconfigure__Param - rqt
Dynamic Reconfigure
Filter key:
Collapse all
Expand all
camera
image_raw
compressed
compress...
theora
red_detect_n
Refresh
(System message might be shown here when necessary)

Database

SOFTWARE STACK

C++

ROS

Python

MariaDB

NodeJS & HTML

SocketIO

Google Maps API

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Client Vehicle Table

Variable	Description	Type
index	Unique identifier label for each vehicle connected to the RSU	INT
latitude	Most recent latitude of the vehicle	FLOAT
longitude	Most recent longitude of the vehicle	FLOAT
heading	Most recent heading of the vehicle	FLOAT
speed	Most recent linear x velocity of the vehicle	FLOAT
angular_z	Most recent angular z velocity of the vehicle	FLOAT

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Identified Objects Table

Variable	Description	Type
index	Unique identifier label for each object detected	INT
latitude	Most recent latitude of the object	FLOAT
longitude	Most recent longitude of the object	FLOAT
type	Type of object detected	CHAR(50)
time	Time that the object was detected	CHAR(8)

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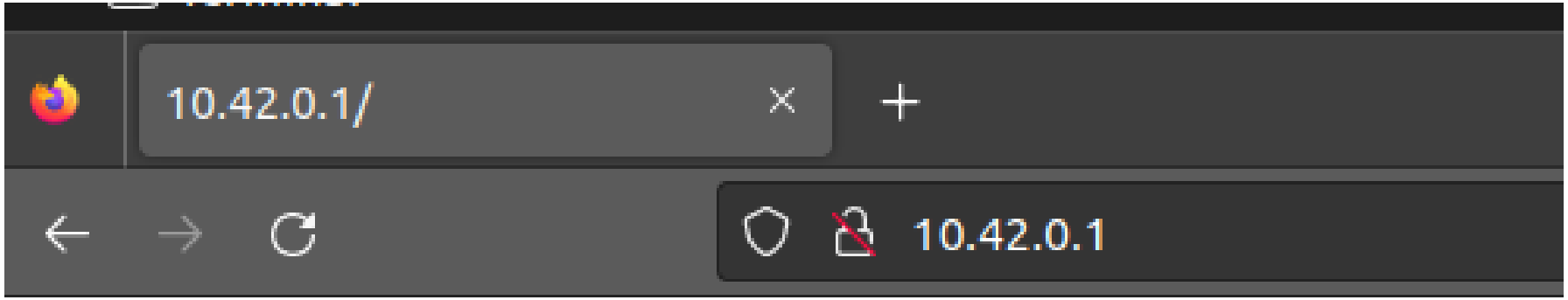
Remote Host

Any computer can connect to the database!

"What Is a Computer Network?" *Types & Definition from Field Engineer*, www.fieldengineer.com/blogs/what-is-a-computer-network. Accessed 14 July 2023.



Client Vehicle Table

index	latitude	longitude	heading	speed	angular_z
1	37.7749	-122.491	90.5	50.2	1.8
2	34.0522	-118.244	180.0	45.8	-0.5

Identified Objects Table

index	latitude	longitude	type
1	37.1234	-122.568	Cone
2	38.4321	-121.877	Cone
3	39.5678	-120.988	Pedestrian

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Web GUI

SOFTWARE STACK

C++

ROS

Python

MariaDB

NodeJS & HTML

SocketIO

Google Maps API

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Web GUI - Development

- NodeJS, GoogleMaps API, & MariaDB → plot and display markers per query
- Pull from the database every 500 ms – SocketIO
- Verify represented objects

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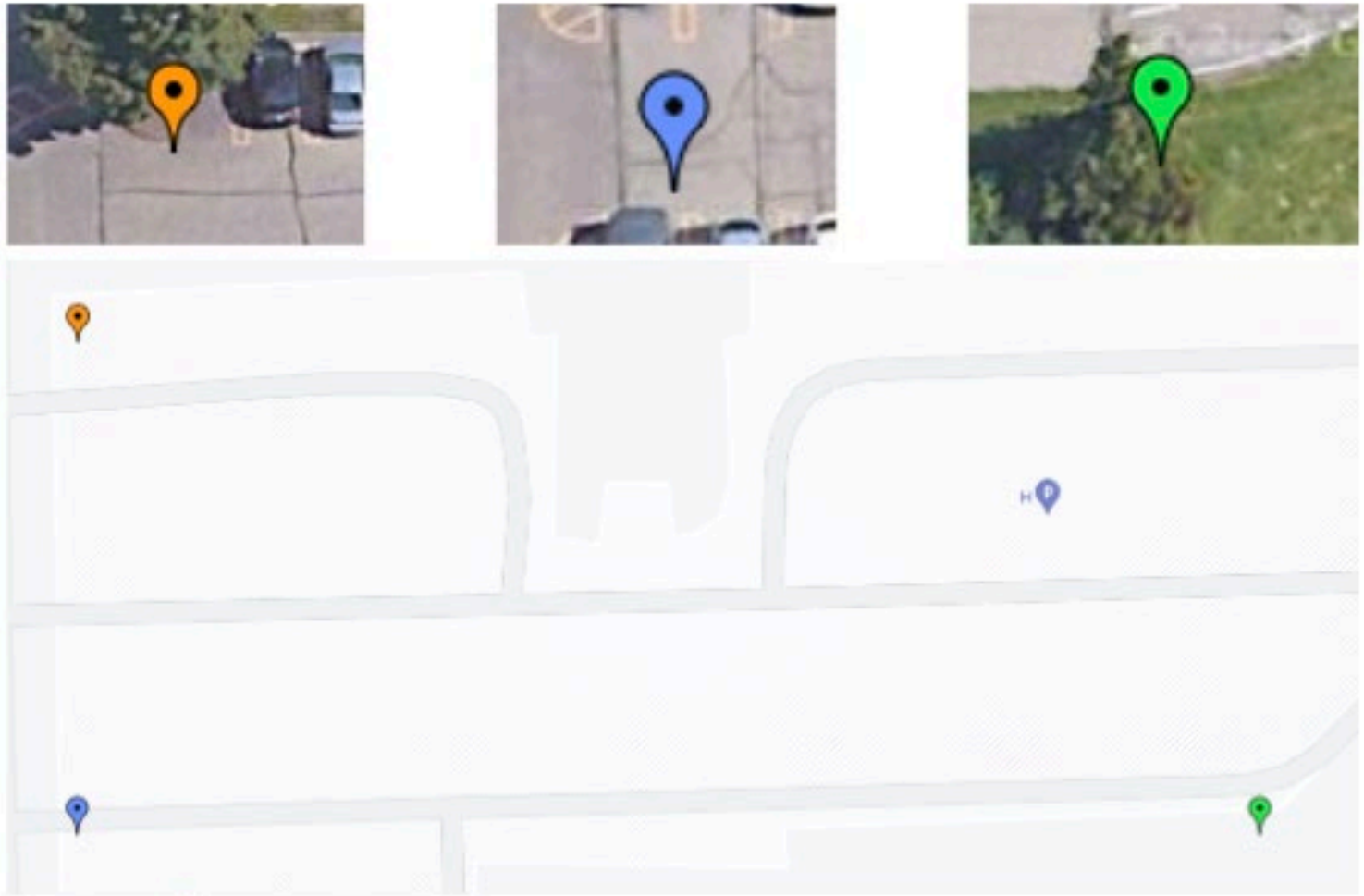

Blue Marker: ACTor 1
Green Marker: ACTor 2
Orange Marker: Object

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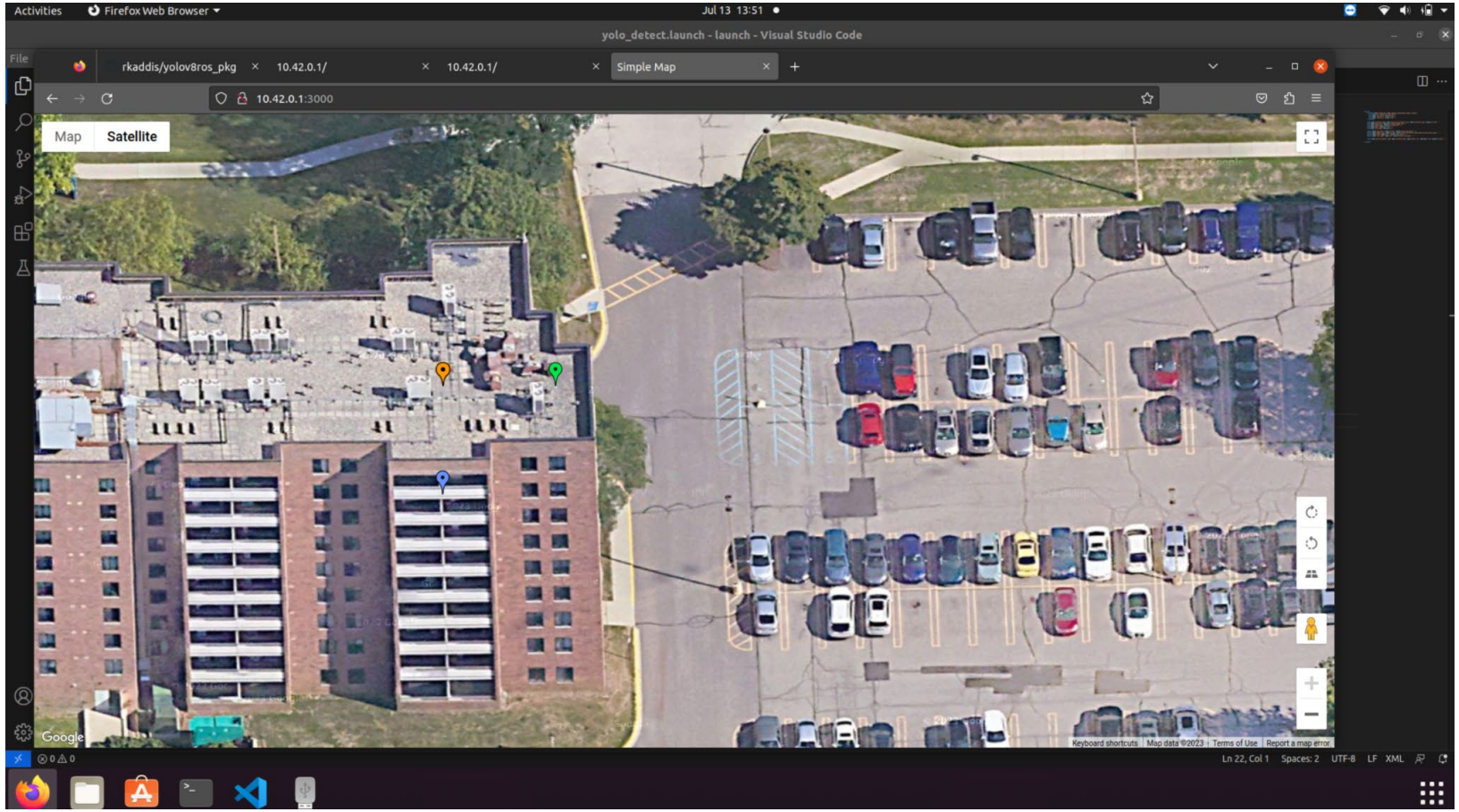
Web GUI - Features

Automatically updates based on info from DB



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Occupancy Grid

SOFTWARE STACK

C++

ROS

Python

MariaDB

NodeJS & HTML

SocketIO

Google Maps API

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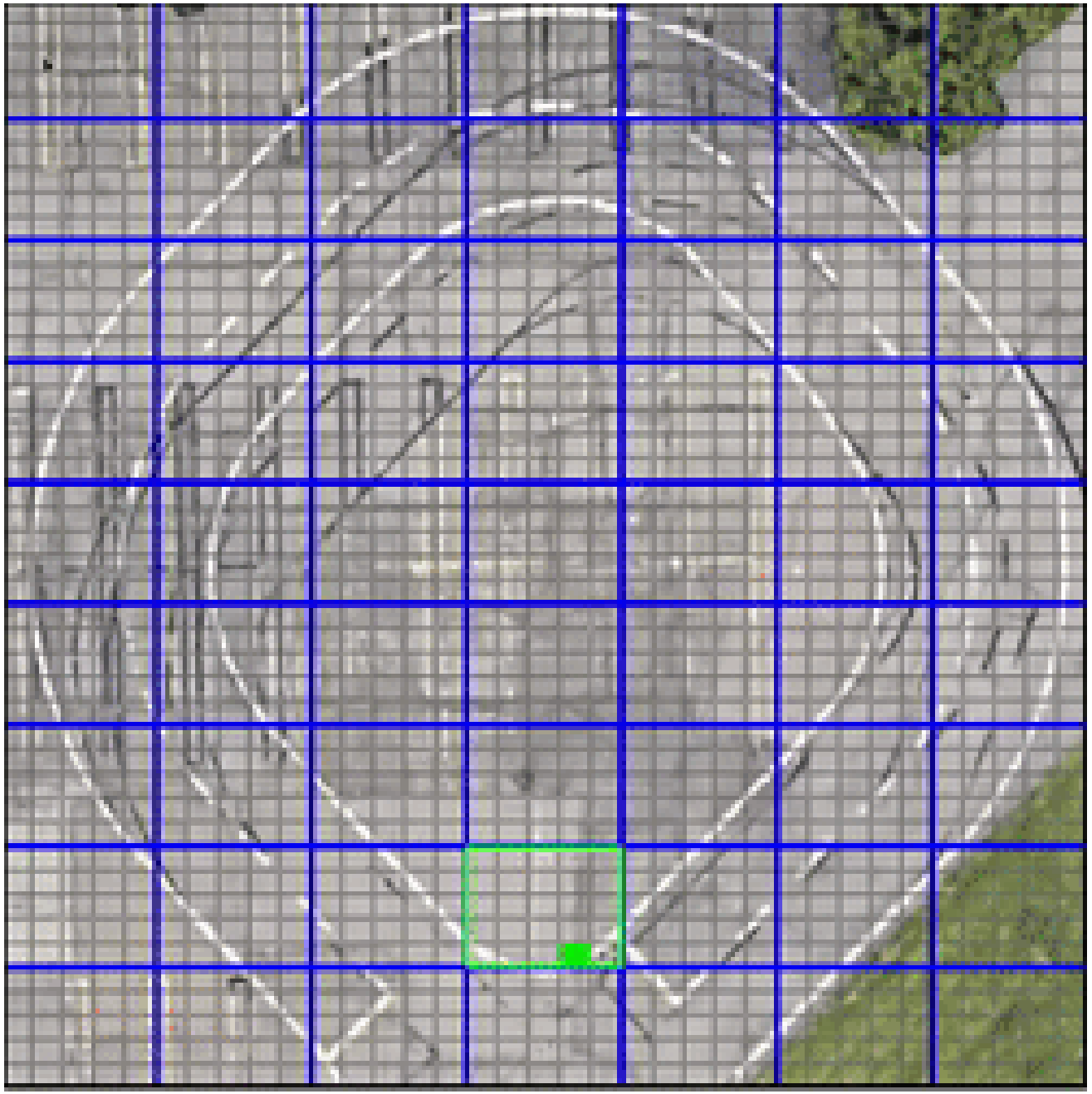

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Occupancy Grid

- Manage intersections
- Plot vehicles connected to the RSU
- Predict their paths
- Plot obstructions detected by other vehicles
- Detect and avoid collisions

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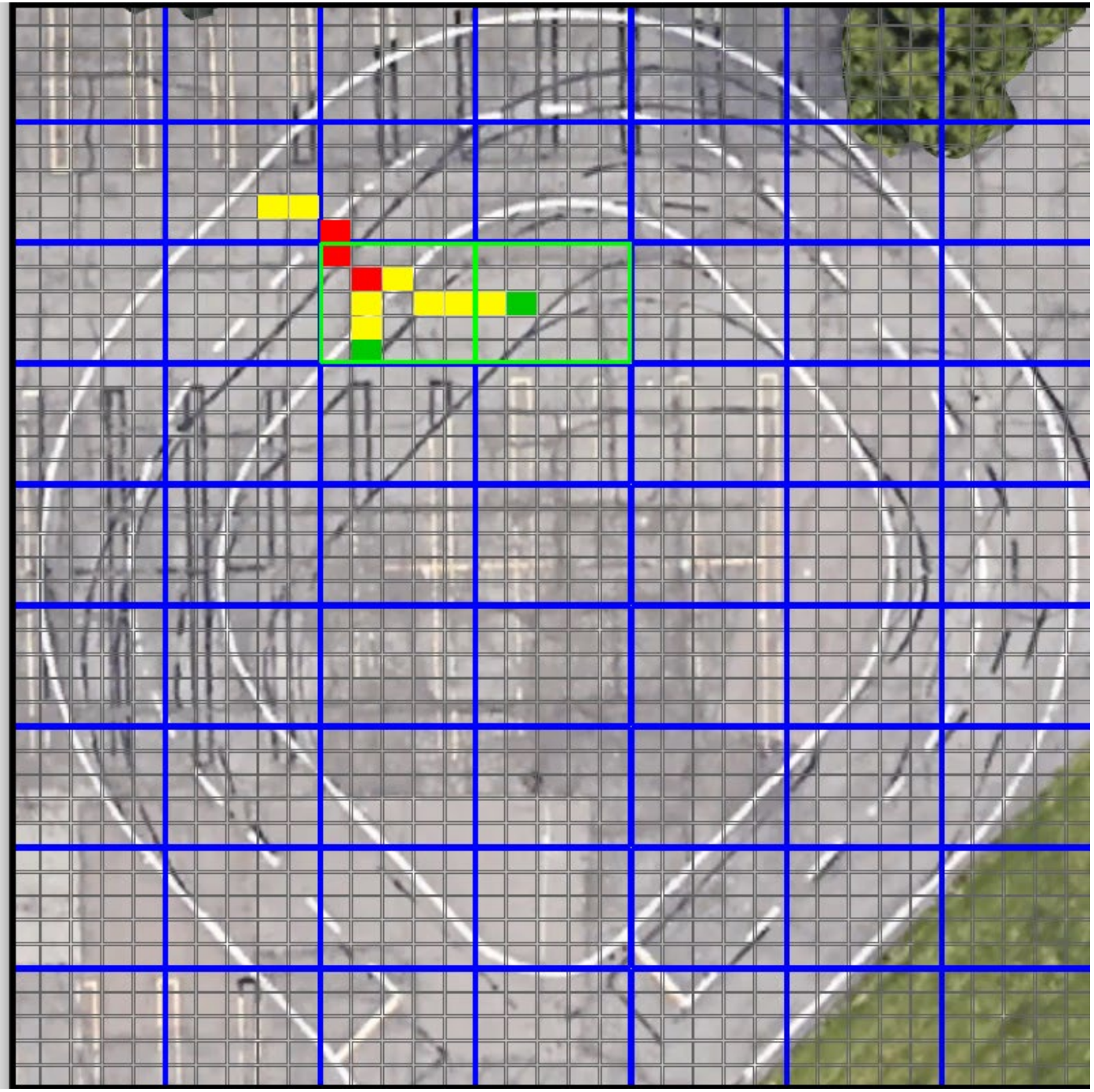
Tracking Vehicles:
actor1
actor2

Events:
actor1 hits actor2
Time to Impact: 1.51 s.
Actions: stop actor1
actor1 hits actor2
Time to Impact: 1.85 s.
Actions: stop actor1
actor1 hits actor2
Time to Impact: 1.97 s.
Actions: stop actor1



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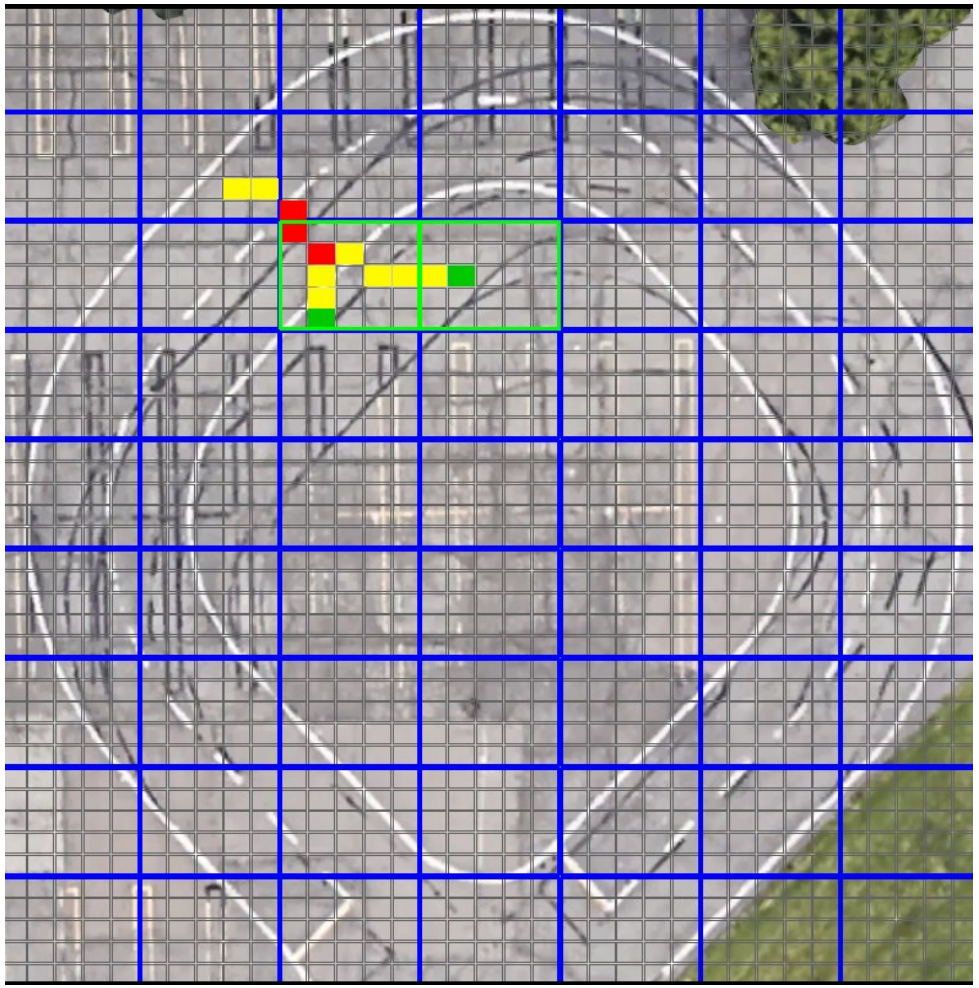
Trajectory Prediction

- Vehicles are stored with a unique ID
- Velocity and steering angle can be used to predict paths
- Collisions are avoided by changing velocity



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Remote Speed Limit Control

SOFTWARE STACK

C++

ROS

Python

MariaDB

NodeJS & HTML

SocketIO

Google Maps API

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Remote Speed Limit Control

Sandiw. "Establishing Speed Limits...the Right Way." *Delaware Center for Transportation*, sites.udel.edu/dct/2019/09/16/establishing-speed-limits-the-right-way/. Accessed 14 July 2023.

- Config and broadcast speed limit remotely
  - Rosnode on Raspberry Pi
  - Command line parameter on launch
- Enforce speed limit with firewall node
  - Receive speed limit from Raspberry Pi
  - Limit speed to vehicle

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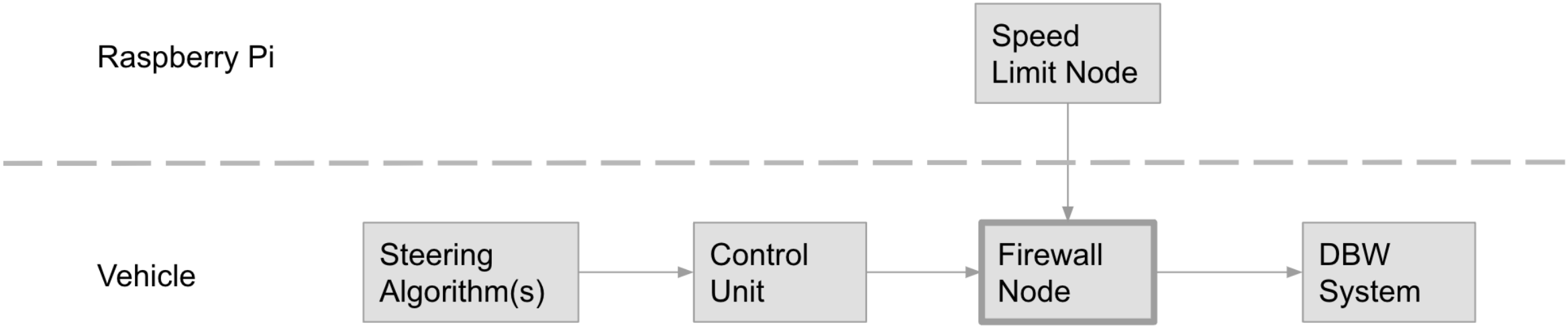
Remote Speed Limit Control



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Future Work for Our Project

"10 Fascinating Facts about Potholes." *Cityworks*, 14 Feb. 2023, www.cityworks.com/blog/10-fascinating-facts-about-potholes/.

Mushkatel, Zachary. "Do Pedestrians Always Have the Right-of-Way in Arizona?" *Mushkatel, Robbins & Becker*, 31 May 2022, www.phoenixlawteam.com/blog/pedestrians-right-of-way-in-arizona/.

- Finish integration in vehicles
- Expand network to 2+ roadside units
- Expand object detection to more and unfamiliar obstacles
- Time relevance of objects based on position

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Future Work for V2X

1. Reduce traffic on highways

"Stay in Your Lane: Why the Zipper Merge Is Texas' Best Chance to Reduce Traffic." *Texas Standard*, www.texasstandard.org/stories/stay-in-your-lane-why-the-zipper-merge-is-texas-best-chance-to-reduce-traffic/. Accessed 14 July 2023.

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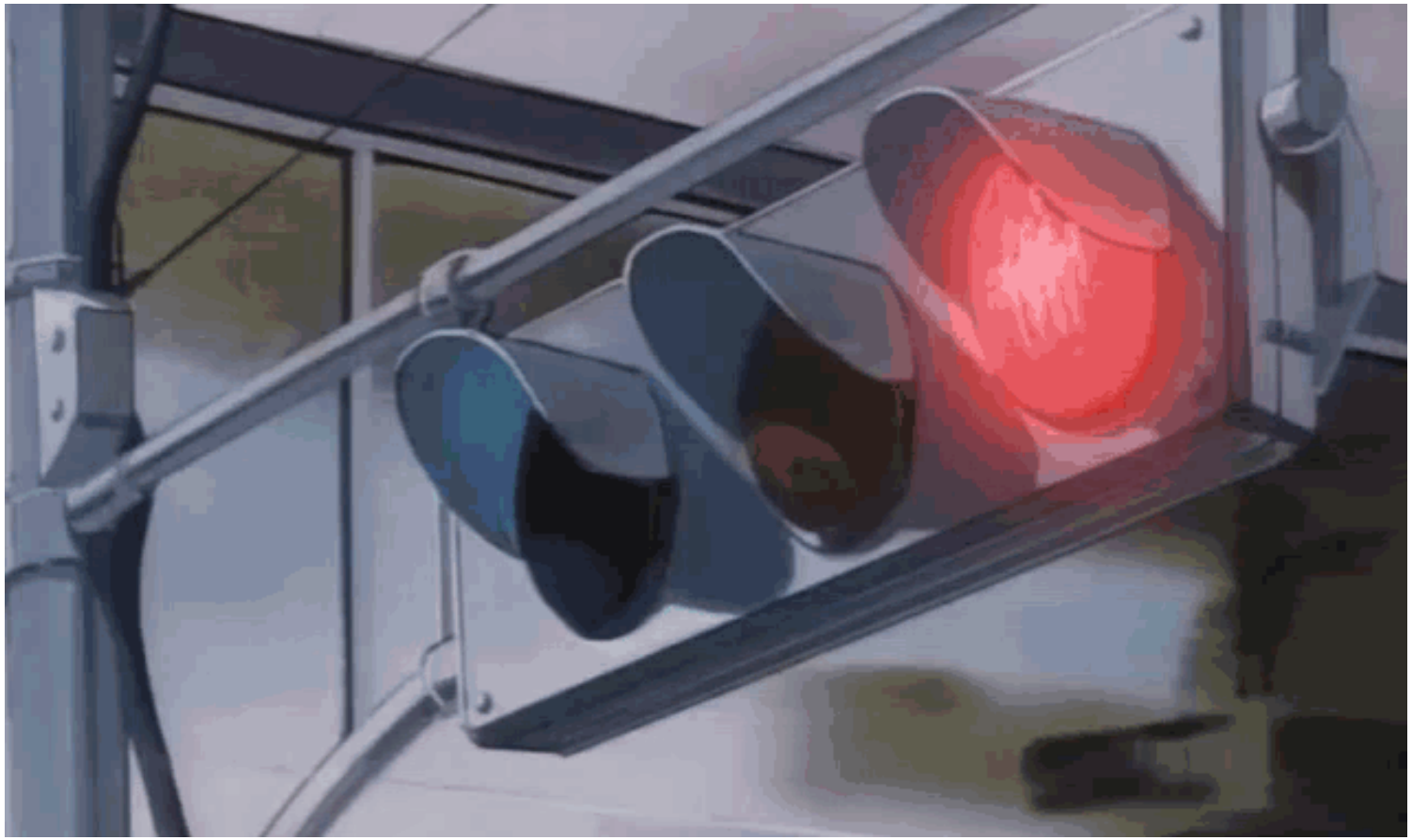
Future Work for V2X

2. Eliminate need for turn signals and traffic lights [4]



GivsMaer. "Traffic Light Lights GIF - Traffic Light Lights Red Light - Discover & Share Gifs." *Tenor*, 9 July 2022, tenor.com/view/traffic-light-lights-red-light-green-light-red-gif-26169777.

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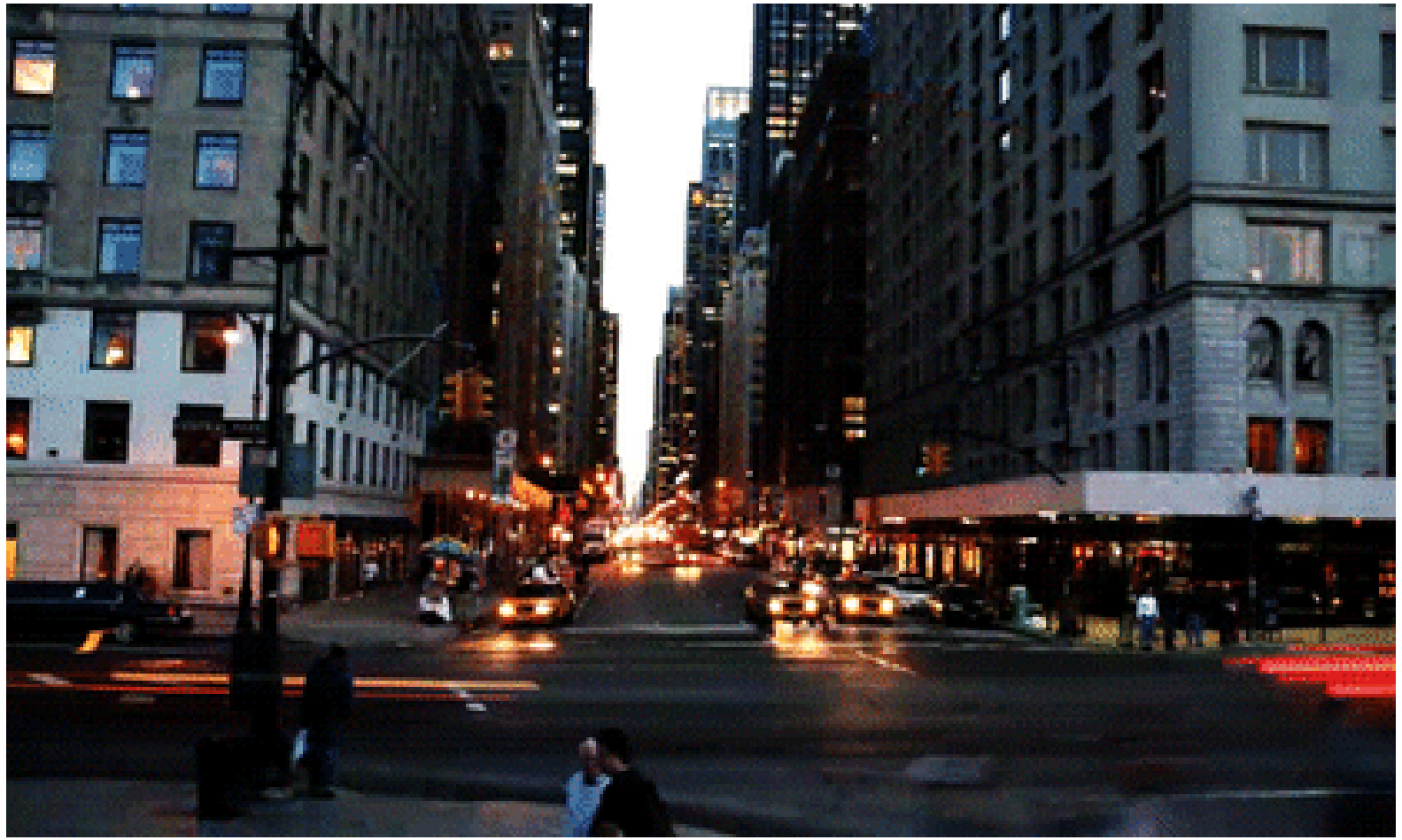
Future Work for V2X

3. Implement path scheduling with occupancy grid [5]



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References

1. Godoy, Jorge, et al. “A Grid-Based Framework for Collective Perception in Autonomous Vehicles.” *Sensors*, vol. 21, no. 3, 2021, p. 744, https://doi.org/10.3390/s21030744.

2. Muratori, Matteo, et al. “Potentials for Platooning in U.S. Highway Freight Transport.” *SAE International Journal of Commercial Vehicles*, vol. 10, no. 1, 2017, pp. 45–49, https://doi.org/10.4271/2017-01-0086.

3. Nagler, Charles Arthur, and William Merle Nagler. “Reaction Time Measurements.” *Forensic Science*, vol. 2, 1973, pp. 261–274, https://doi.org/10.1016/0300-9432(73)90041-1.

4. Toor, Yasser, et al. “Vehicle Ad Hoc Networks: Applications and Related Technical Issues.” *IEEE Communications Surveys & Tutorials*, vol. 10, no. 3, 2008, pp. 74–88, https://doi.org/10.1109/comst.2008.4625806.

5. Y. Toor, P. Muhlethaler, A. Laouiti and A. D. La Fortelle, "Vehicle Ad Hoc networks: applications and related technical issues," in *IEEE Communications Surveys & Tutorials*, vol. 10, no. 3, pp. 74-88, Third Quarter 2008, doi: 10.1109/COMST.2008.4625806.

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Thank you!
Questions?


Let's see it in action!

Demo 1

- TPN, Object Detection, Database, Web GUI

Demo 2

- Occupancy Grid, Collisions

Let's head out to the track!

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