# Enhancing sensor capabilities of open-source simulation tools to support autonomous vehicles safety validation

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# Agenda

1. Introduction
2. Improvement in the Framework Obstacle Detection Capability
3. Experiments and Results
4. Conclusion and Future Works

# 1. Introduction

Autonomous Vehicle (AV) is a **safety-critical system**

when operating in an undesirable, not properly way, it can…

**Fatal collision btw vehicle and pedestrian/bike (March 2018)**
https://www.ntsb.gov/investigations/AccidentReports/Reports/HWY18MH010-prelim.pdf

**Mandatory** to ensure that the AV is going to operate safely, mainly when navigating on public roads.

U.S. National Highway Transportation Safety Administration (NHTSA) released a policy framework to support the **safe deployment of Avs**

- Safety validation based on <u>simulation</u>, <u>test track</u> and <u>on-road testing</u>.

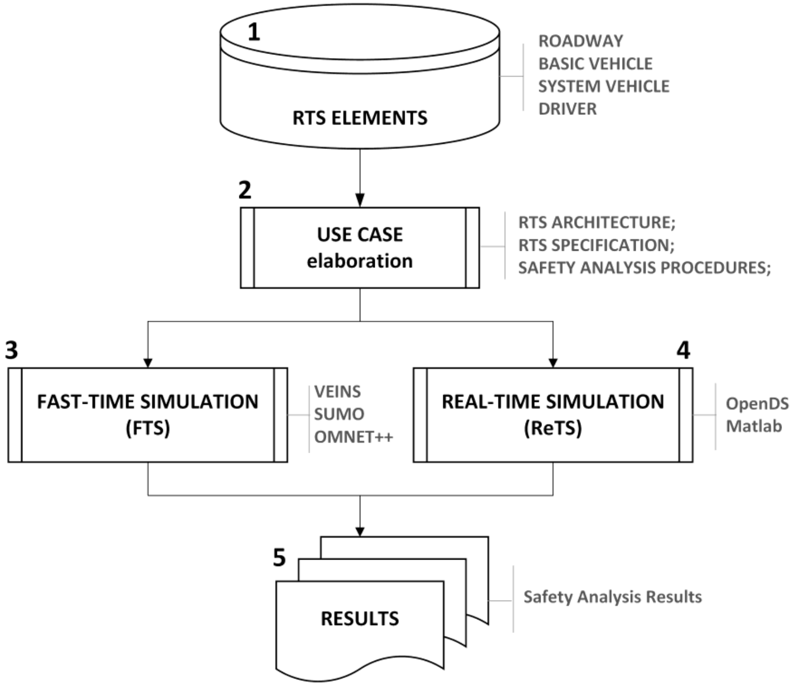
**Toyota's Facility**
https://mashable.com/2018/05/03/toyota-uber-autonomous-driving-test-facility/#qO8MJsXL.sqa

**MCity**
https://spectrum.ieee.org/cars-that-think/transportation/self-driving/riding-in-a-robocar-that-sees-around-corners


**Waymo (on-road testing)**

# 1. Introduction

- Real-world **testing** is a practical, but not a feasible approach to validate AV safety:
  - Demands exposing AVs to **any plausible** combination of "operational scenario" + "faulty condition".
  - Demonstrating reliability in terms of fatalities and injuries requires AVs driven by 10^9 to 10^12 miles (Kalra, Paddock, 2016)
- ✓ **New virtual testing and simulation approaches**: improve the confidence on system safety;
- ✓ We've proposed a **simulation-based safety analysis framework** that enables analyzing the impact of technologies and concepts over the future Road Transportation System safety and efficiency.




**Module 1:** contains ACPS elements considered;

**Module 2:** uses ACPS elements to model a ACPS-based RTS Use Case scenarios.

**Module 3 and Module 4**: implement the simulation-based safety analysis approach to ACPS-based RTS (over a specific Use Case). These modules are instantiated by the Tools 'Veins+Sumo+OMNeT++' (FTS) and 'OpenDS + Matlab' (ReTS).

**Module 5:** contains Safety Analysis Reports (results obtained after Safety Analysis Procedures application).

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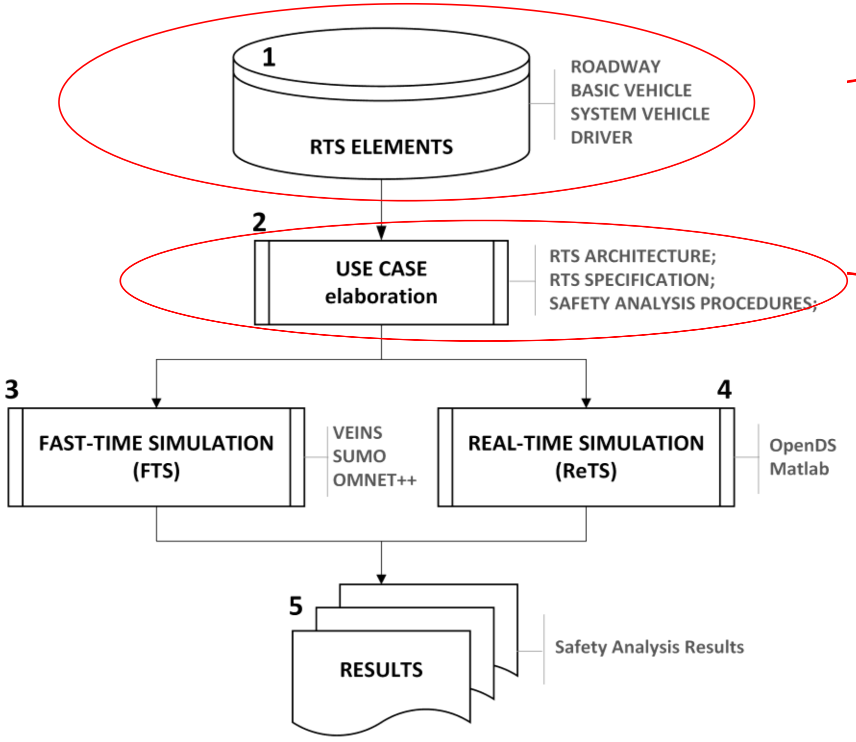
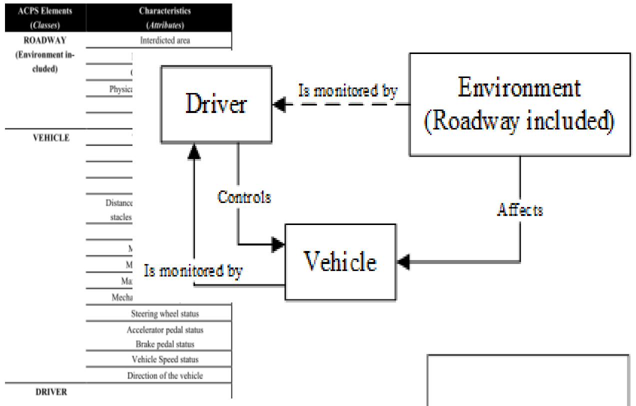
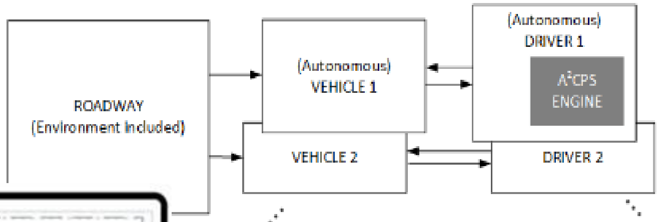
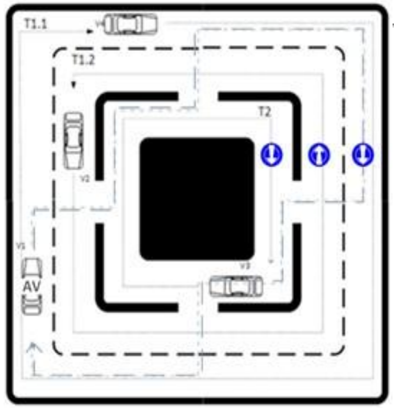
# 1. Introduction

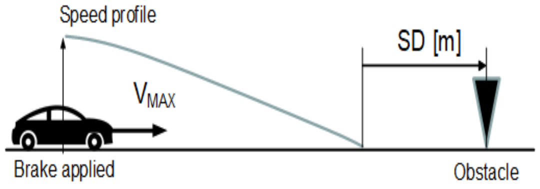
***A FRAMEWORK*** *capable to* ***model the*** **future ACPS-based RTS**, <u>including embedding any driving algorithms on vehicles ("autonomous vehicles" modeling ready!)</u>, **simulating** them using **fast-time and real-time approaches**, and obtaining results which allow to analyze the impacts of concepts, technologies and procedures on system safety properties.



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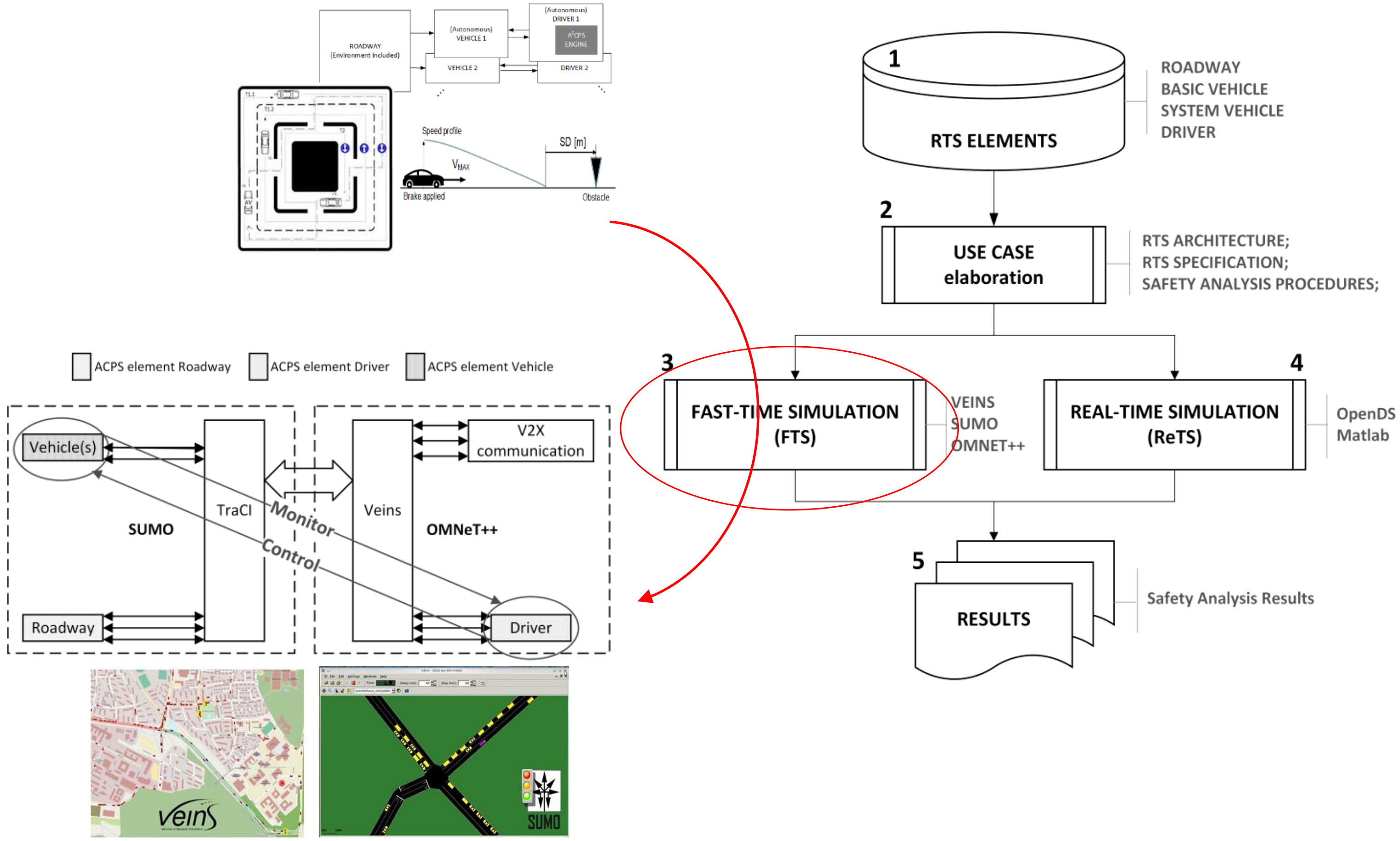


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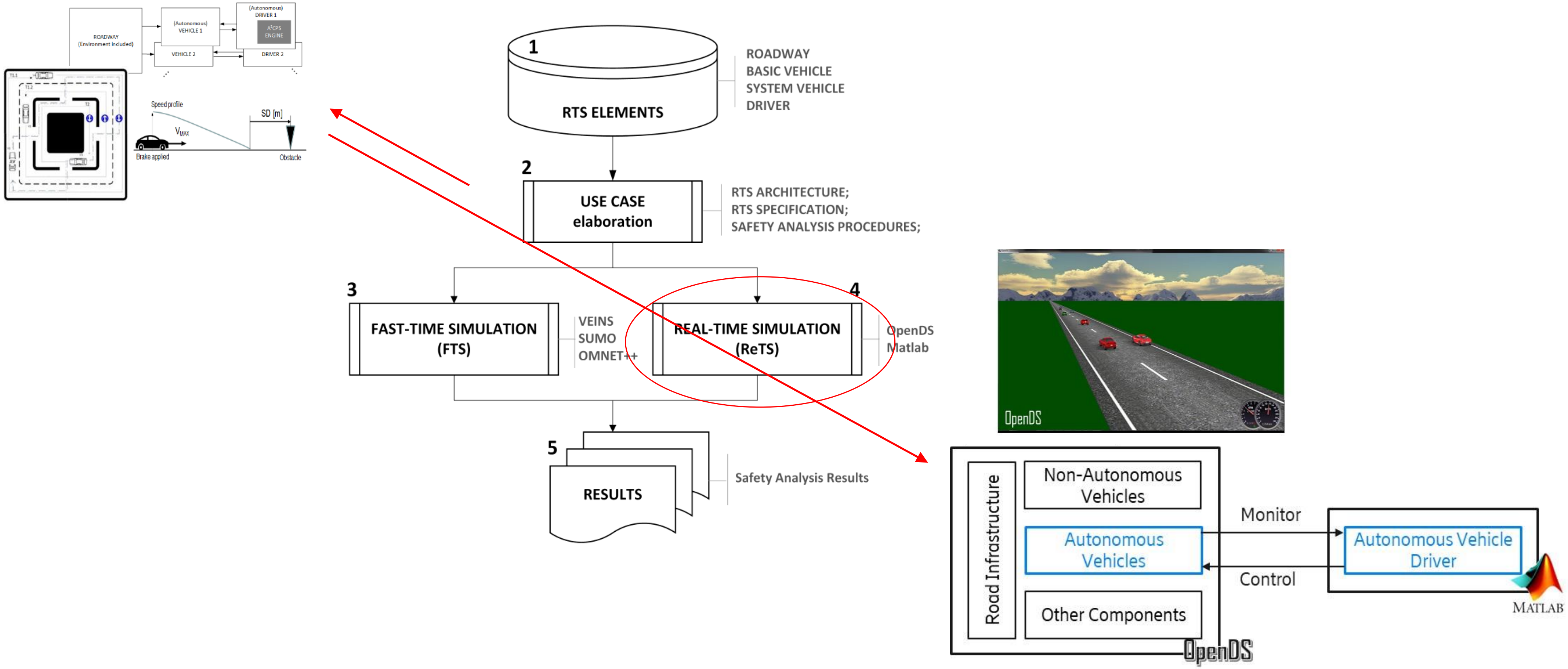


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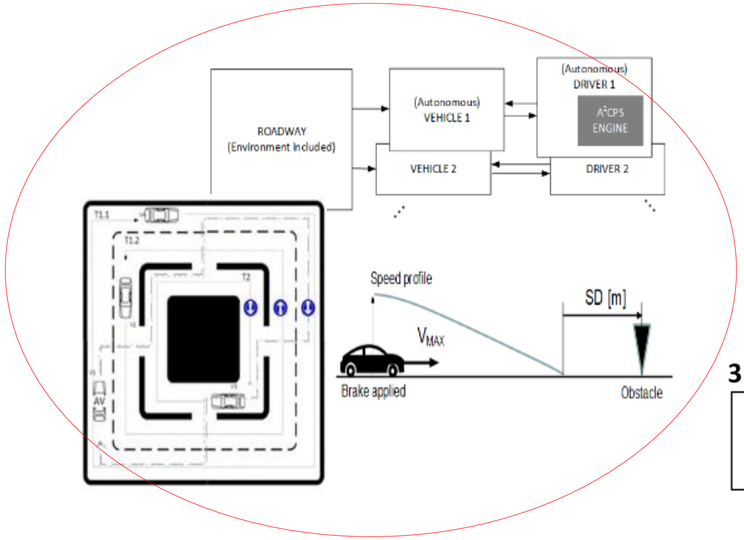


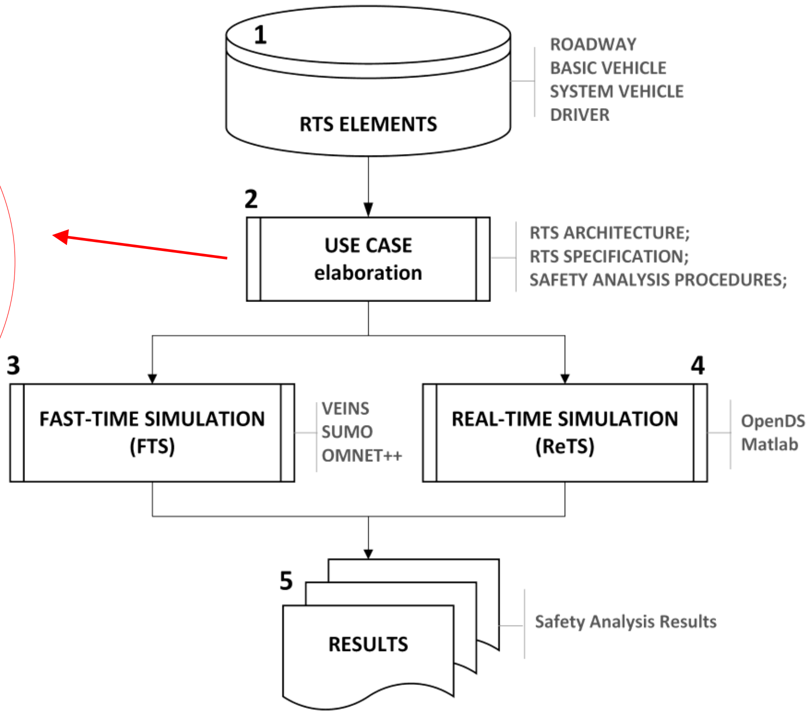


| Metrics | $V_{MAX}$ (AV) [m/s] 15 | 20 | 30 |
|---|---|---|---|
| IZW_1 = {20; 60; 95; 180} | | | |
| #collisions | 28 | 28 | 28 |
| Average speed [m/s] | 5.0 | 5.0 | 5.0 |
| Standard deviation | 3.1 | 3.1 | 3.1 |
| Total distance [m] | 50,050 | 50,049 | 50,049 |
| IZW_2 = {20; 60; 150; 180} | | | |

| $V_{MAX}$ (AV) [km/h] | Stopping Distance (SD, in [m]) IZW_1 | IZW_2 | IZW_3 | IZW_4 |
|---|---|---|---|---|
| **30** | 10.00 | 10.10 | 1,9 | **collide** |
| **60** | 7.47 | 9.92 | **collide** | **collide** |
| **120** | 6.67 | 8.80 | **collide** | **collide** |

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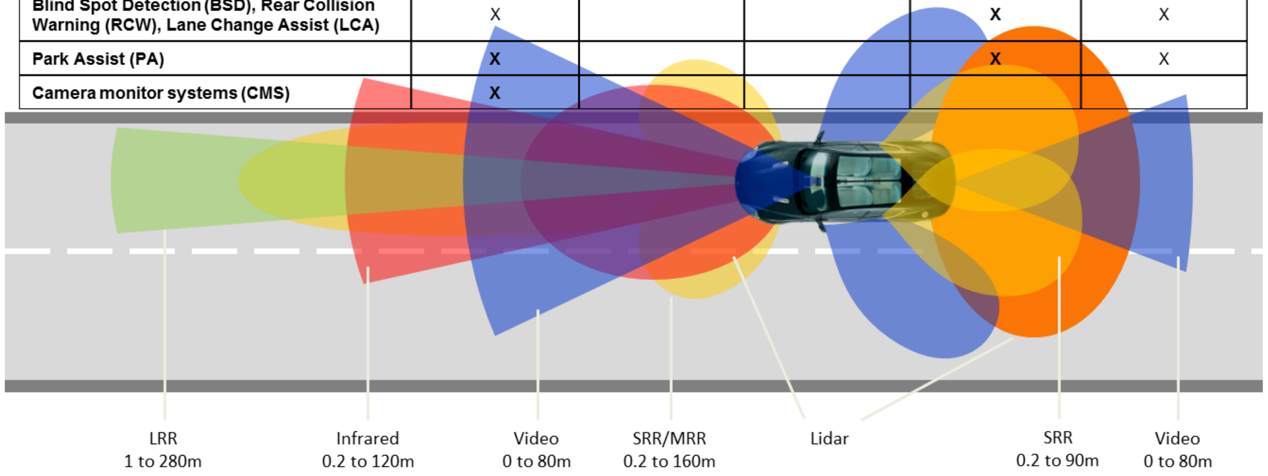
# 1. Introduction

**A simulation-based safety analysis must be able to <u>model the system elements</u> as close to the real-world as possible.**

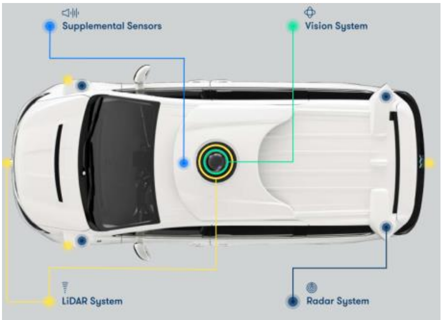
**(mainly to safety validation purposes)**

## Autonomous vehicles will be "rolling sensors platforms"

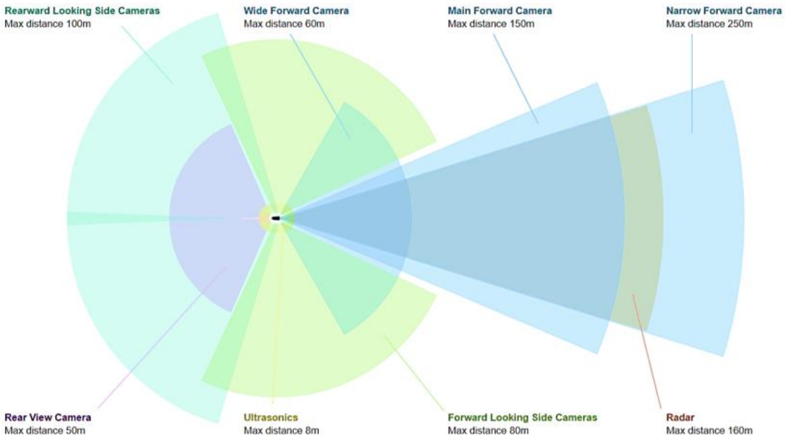
| Sensor Type / Application | Vision | Infrared / Thermal | Long Range Radar 76..81MHz | Short / Mid Range Radar 24..26 / 76..81 GHz | Lidar |
|---|---|---|---|---|---|
| Adaptive Front Lighting (AFL), Traffic Sign Recognition (TSR) | X | | | | |
| Night vision (NV) | X | X | | | |
| Adaptive Cruise Control (ACC) | X | | X | X | X |
| Lane Departure Warning (LDW) | X | | | | |
| Low-Speed ACC, Emergency Brake Assist (EBA), Lane Keep Support (LKS) | X | | | X | X |
| Pedestrian detection | X | X | | X | |
| Blind Spot Detection (BSD), Rear Collision Warning (RCW), Lane Change Assist (LCA) | X | | | X | X |
| Park Assist (PA) | X | | | X | X |
| Camera monitor systems (CMS) | X | | | | |




https://e2e.ti.com/cfs-file/__key/communityserver-blogs-components-weblogfiles/00-00-00-08-94/1263.sensor-2.png



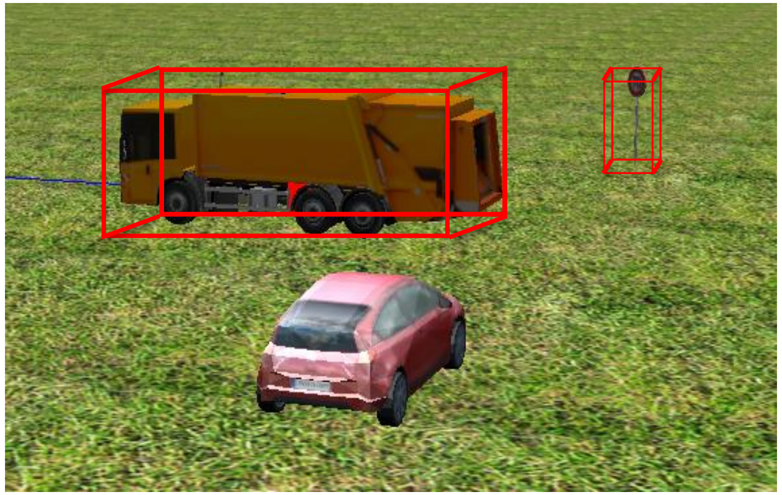

WAYMO Safety Report (2018)



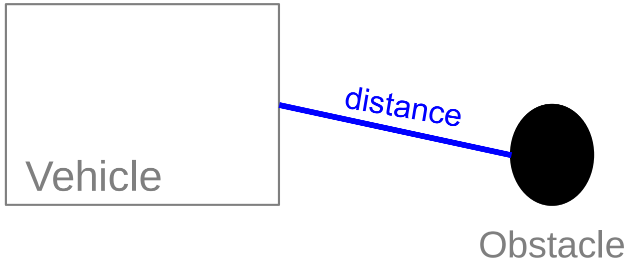

Source: https://www.tesla.com/autopilot

# 1. Introduction

**PROBLEM: OpenDS have limitations in modeling perception sensors for obstacle detection (“*what is around the vehicle?*”)**

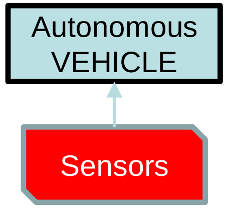


**OpenDS native obstacle detection capability**




Distance obtained using JME-based functionalities (on OpenDS simulation kernel)

**WHAT IS DEMANDED:** the capability of instantiating generic obstacle detection sensors to be used over the autonomous vehicle model on OpenDS



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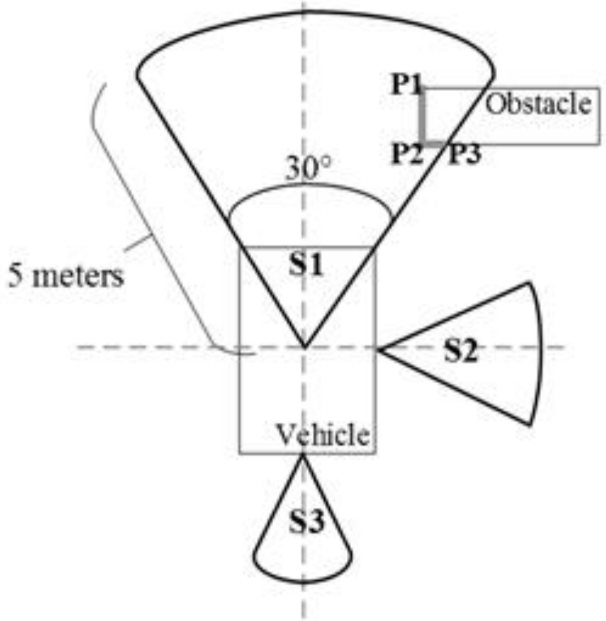
# 2. Improvement in the Framework Obstacle Detection Capability

**OpenDS.sensor class** must enable the instantiation of generic obstacle detection sensors to be used over the autonomous vehicle model on OpenDS

**Three** main requirements:

- [**Req.1**] The OpenDS.sensor class model **must enable** the **instantiation of a set of obstacle detection sensors**;
- [**Req.2**] The OpenDS.sensor class model **must enable** the **configuration of each sensor** in an **independent way**. So, each instantiated has a maximum detection range and maximum detection angle; position of the sensor in the vehicle; and sensor rotation (direction of the sensor in relation to the longitudinal axes of the vehicle, in degrees);
- [**Req.3**] The information provided by the sensor class **must return** the **surface(s) of an obstacle(s) detected** in the line-of-sight (field of view) by each instantiated sensor, not just the geometric center of the obstacle.

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# 2. Improvement in the Framework Obstacle Detection Capability



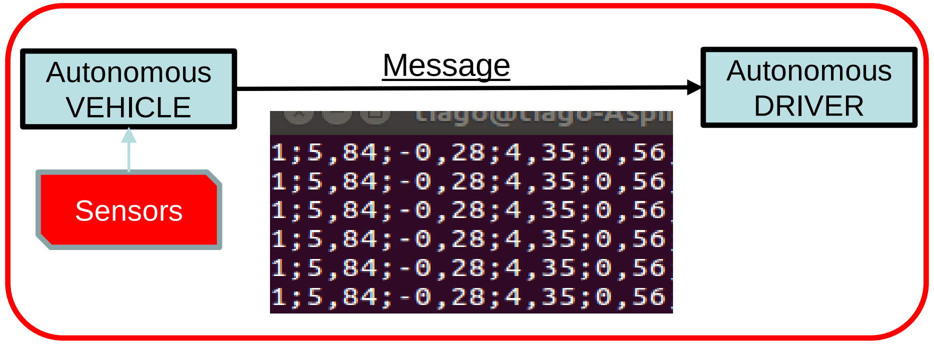
**Implementation of the Sensor.java class**: defining the **sensors attributes** and the **methods** used.

| OpenDS.sensor | |
|---|---|
| #range: float | the maximum detection **range** of the sensor |
| #angle: double | the maximum detection **angle (aperture)** of the sensor |
| #position: Vector3f | a vector representing the sensors **position** in the vehicle |
| #rotation: double | **rotation** of the sensor in relation to the longitudinal axes of the vehicle |
| +measure(boxList:List<Node>):List<Float[4]> | responsible for returning a **list of all the obstacles** detected by the sensor |
| #getVisibleVertices(vArray:Vector3f[4]):List<Vector3f> | used by the method <measure> to obtain the correct points of the detected segment |

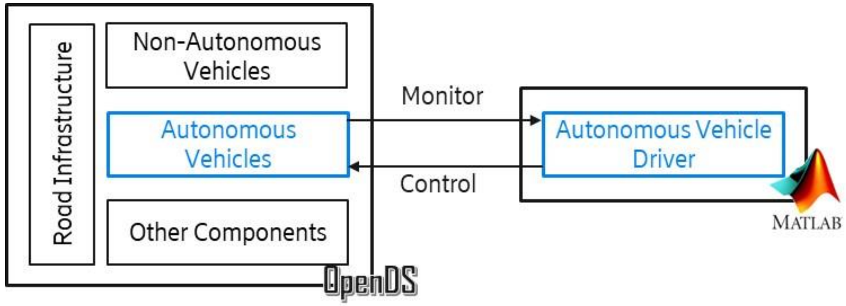
- **Implementation of methods used to manipulate the detected surface (line) segment** in order to adequate them to the sensor's characteristics. It is implemented in two methods:
  - ***getIntersection*** (that provides the intersection between two line segments or between a line segment and a circle, depending on the arguments received by the method) and
  - ***getAngle2*** (that provides the angle between three points).

# 2. Improvement in the Framework Obstacle Detection Capability

**Modifications in the structure of messages** exchanged **between** OpenDS (**Vehicle component**) **and** Matlab (**Driver component**): including fields to inform receiver (Driver) about the number of line segments and the array of line segment points, as specified by Req.3.


Message: Number of segments identified by the sensor; d1; a1; d2; a2

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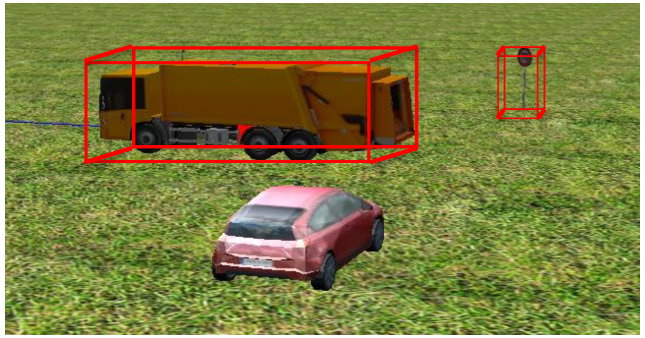
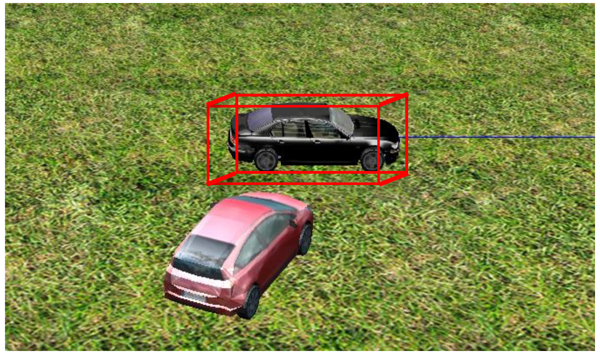
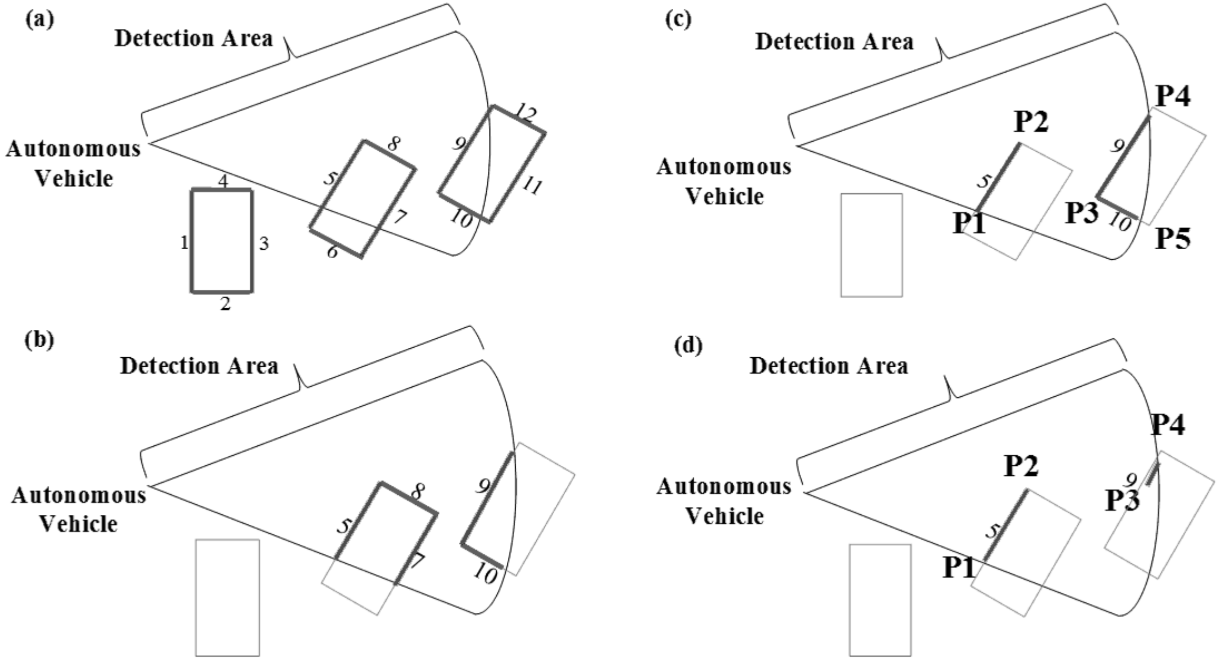




Obstacle detection process:




a. Obstacles are represented by its **line segments**;
b. Parts of the segments that are inside the detection area (FOV sensor) are selected;
c. For each individual selected **part of segment**, segments that could be in the sensors line-of-sight are selected;
d. After identifying the set of potential segments to be detected by the sensor, the next step is to identify which segment parts shall be detected by a real-world obstacle detection sensor.

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# 3. Experiments and Results

Three experiments were conducted to evaluate whether the improvements in the obstacle detection of the simulation-based safety analysis framework meet the specified objectives.

1. The capability of **detecting multiple obstacles** by a sensor.

2. The capability of **detecting dynamic obstacles** by a sensor.

3. The capability of **detecting the same obstacle by multiple sensors**.

# 3. Experiments and Results



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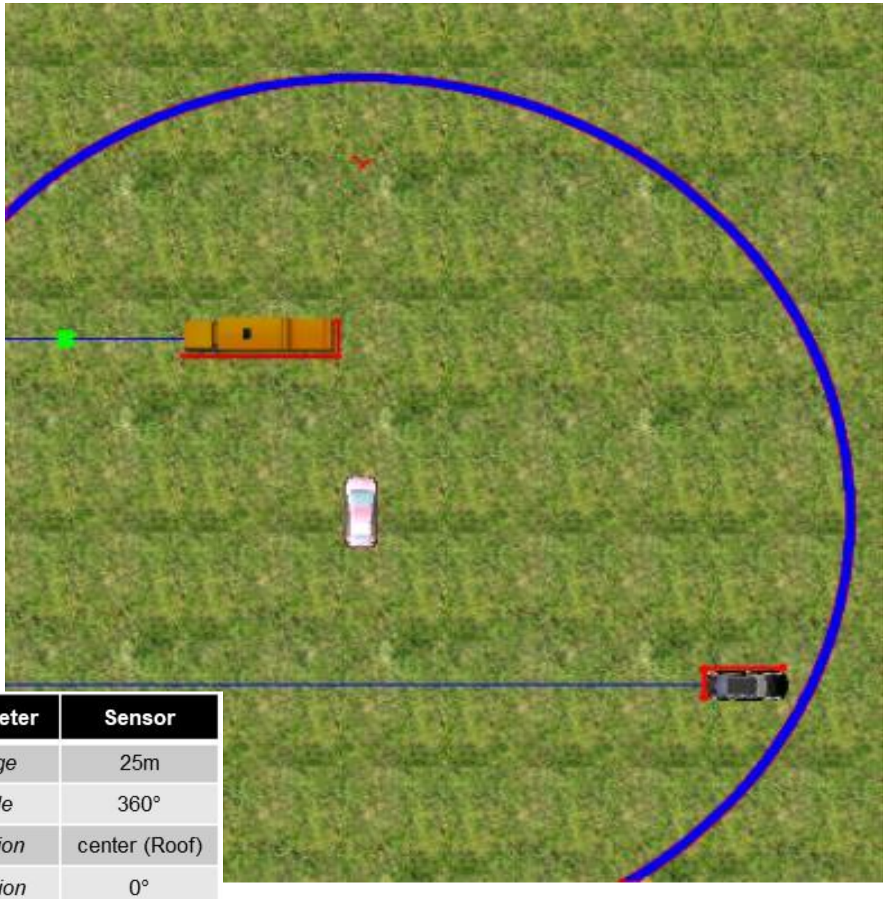
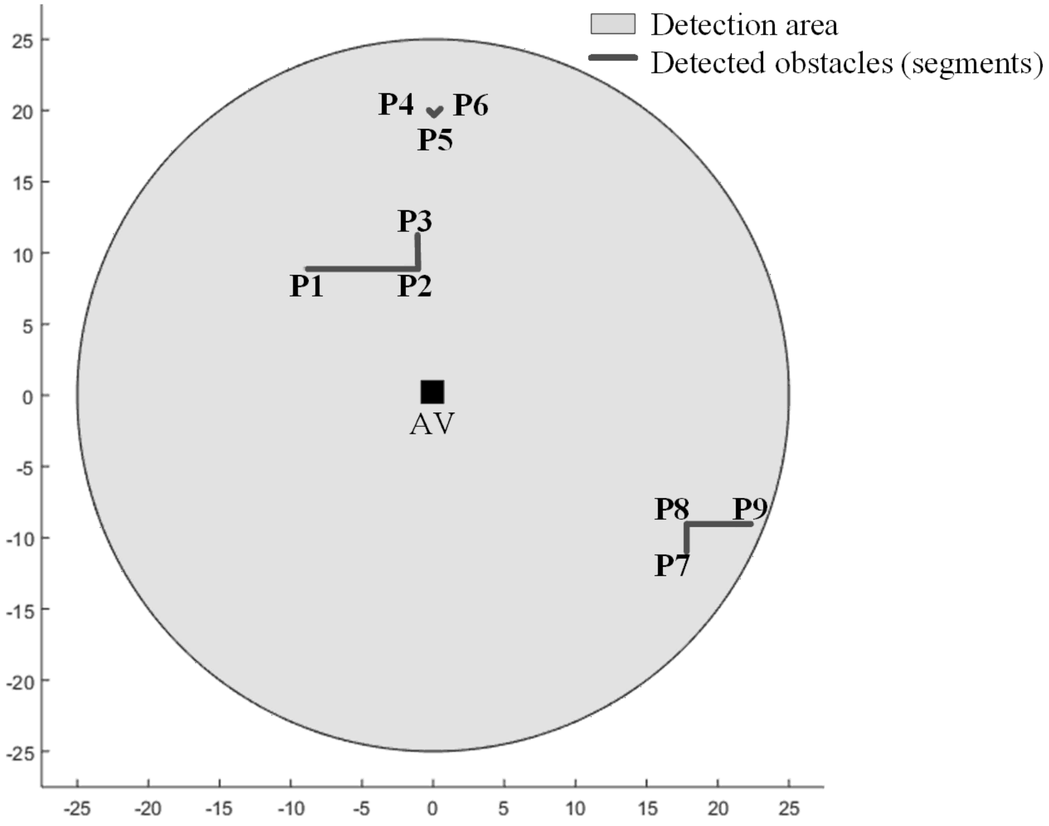


| Parameter | Sensor |
|---|---|
| *Range* | 25m |
| *Angle* | 360° |
| *Position* | center (Roof) |
| *Rotation* | 0° |

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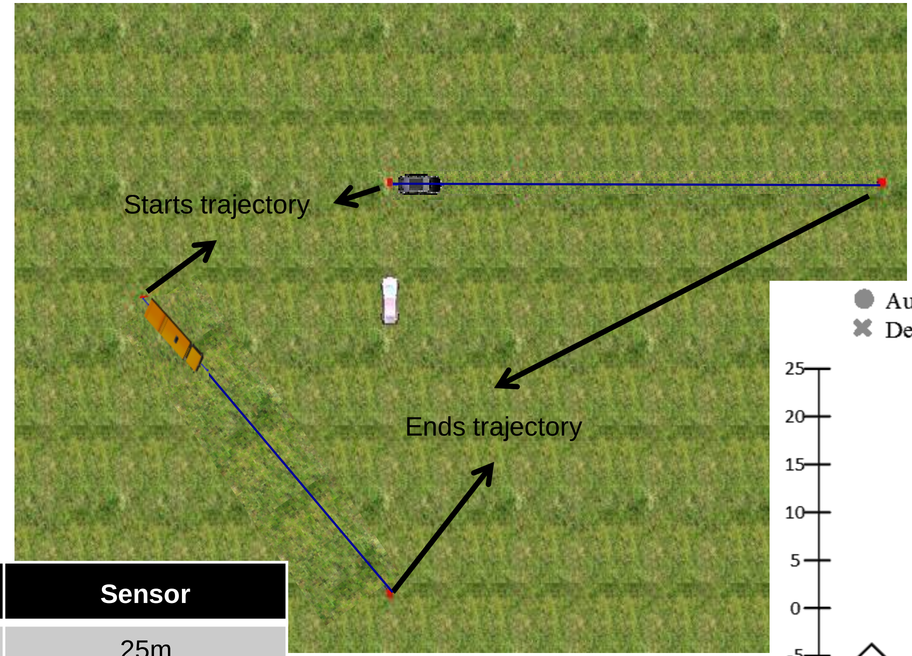
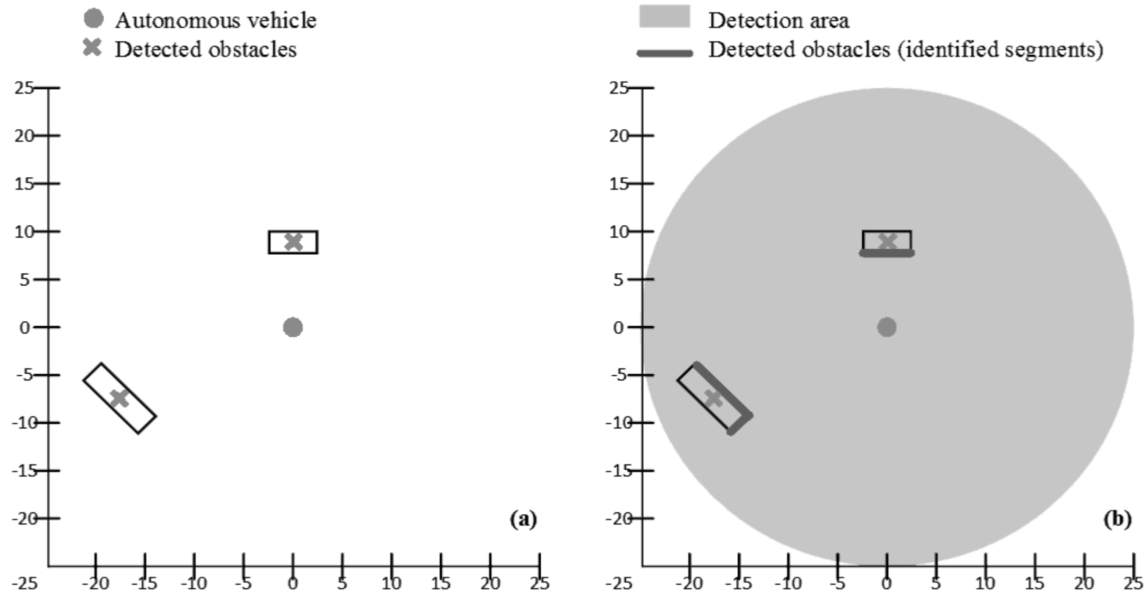



| Parameter | Sensor |
|---|---|
| *Range* | 25m |
| *Angle* | 360° |
| *Position* | center (Roof) |
| *Rotation* | 0° |
| *Truck and car – both at a speed of 30 km/h* | |

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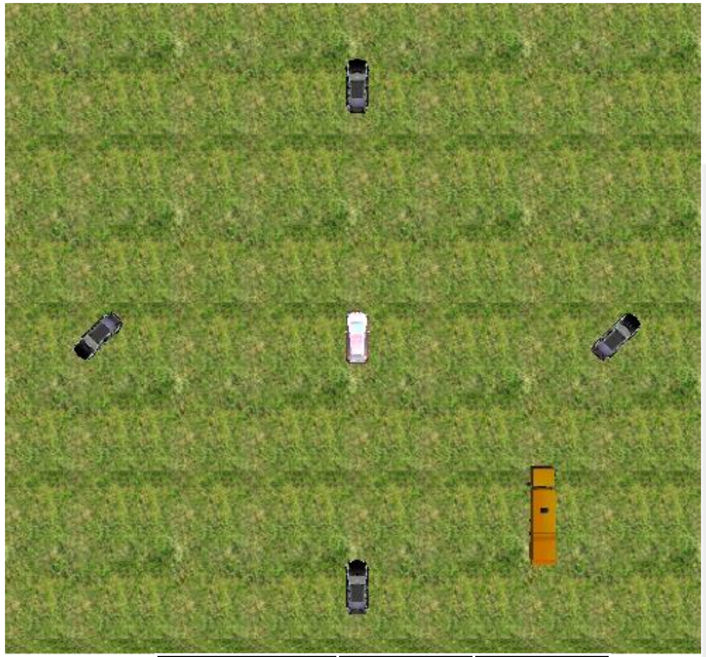
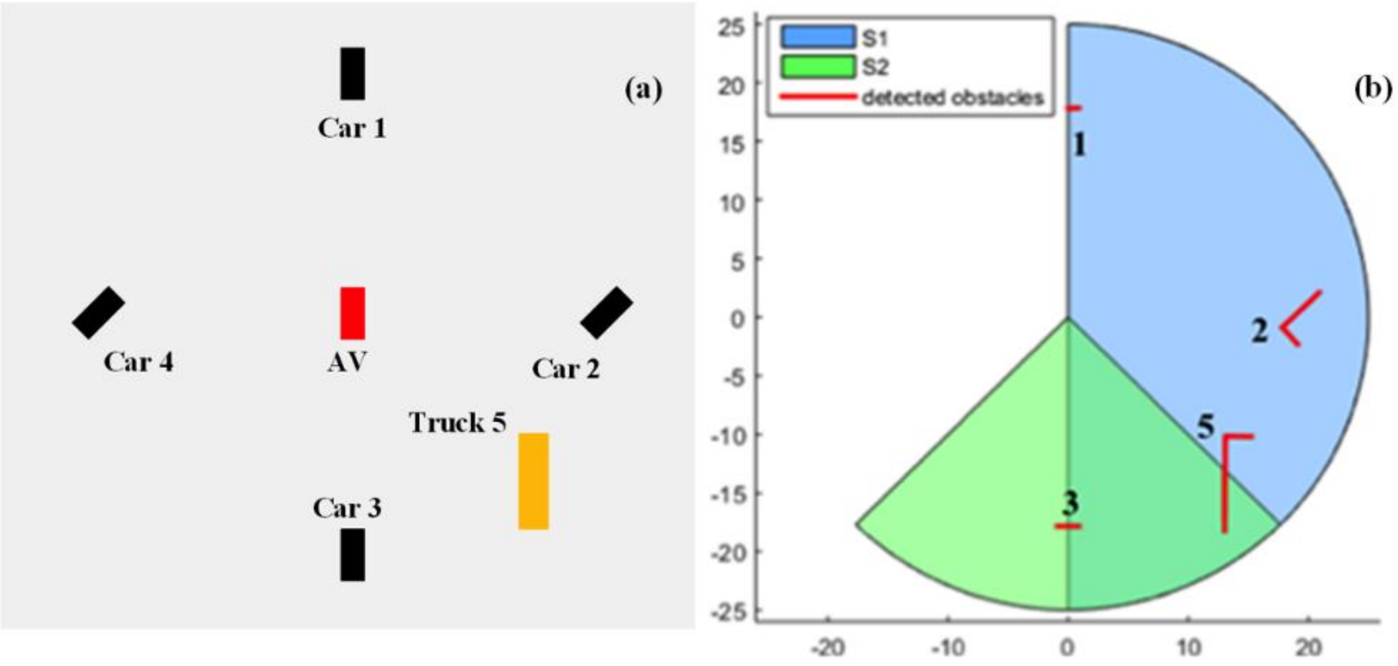


| Parameter | S1 | S2 |
|---|---|---|
| *Range* | 25m | 25m |
| *Angle* | 180° | 90° |
| *Position* | center (Roof) | center (Roof) |
| *Rotation* | -90° | 180° |



# 4. Conclusion and Future Works

## MAIN CONCLUSIONS

We developed a **model (class) of obstacle detection sensor** in the native **OpenDS** open-source tool, which **enables modeling embedded sensors on AVs that detects obstacles surrounding the vehicle**.

The sensor model implementation was **tested** and **validated**, demonstrating that instantiated **sensors** using this new class **can correctly detect obstacle in different scenarios**.

## NEXT STEPS:

Enhance this modeling capabilities including new characteristics (attributes) to the sensor class model, such as:

- **Minimum** detection distance;
- **Position resolution** (range and azimuth);
- **Position accuracy** (range and azimuth);
- **Update rate** (scanning frequency);
- **Sensor availability and reliability** (e.g. failure rate, failure modes) demanded to represent this class of real-world sensors.

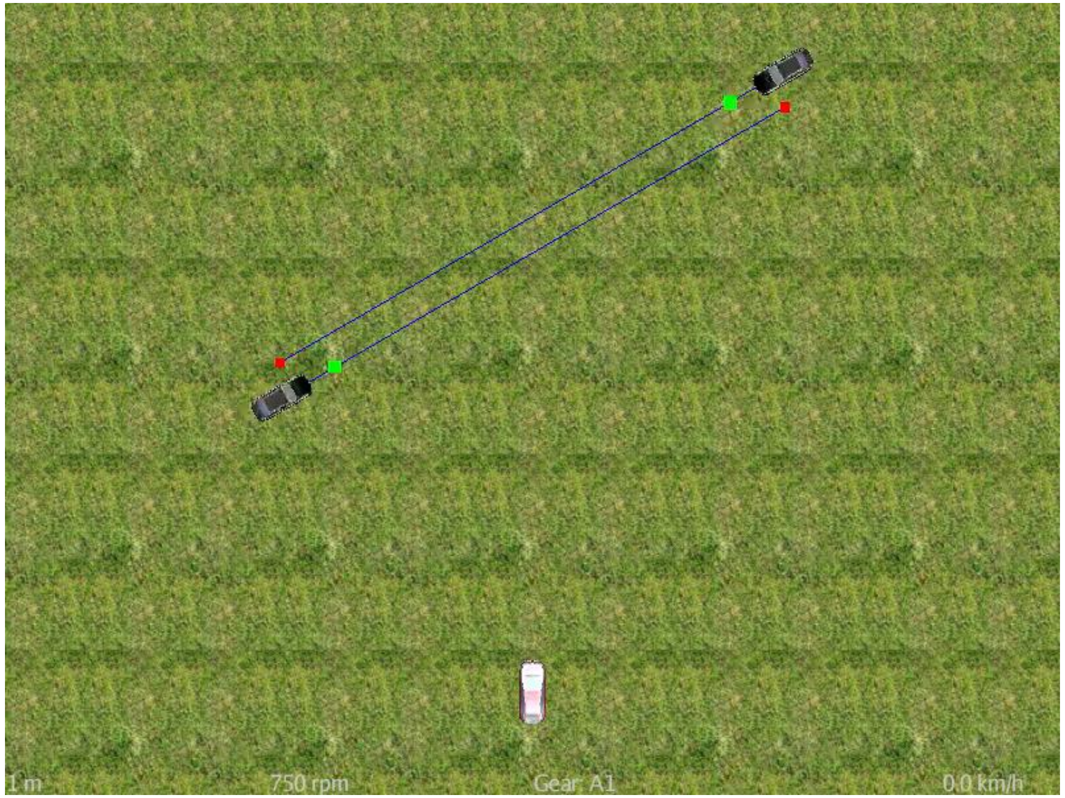
# 4. Conclusion and Future Works

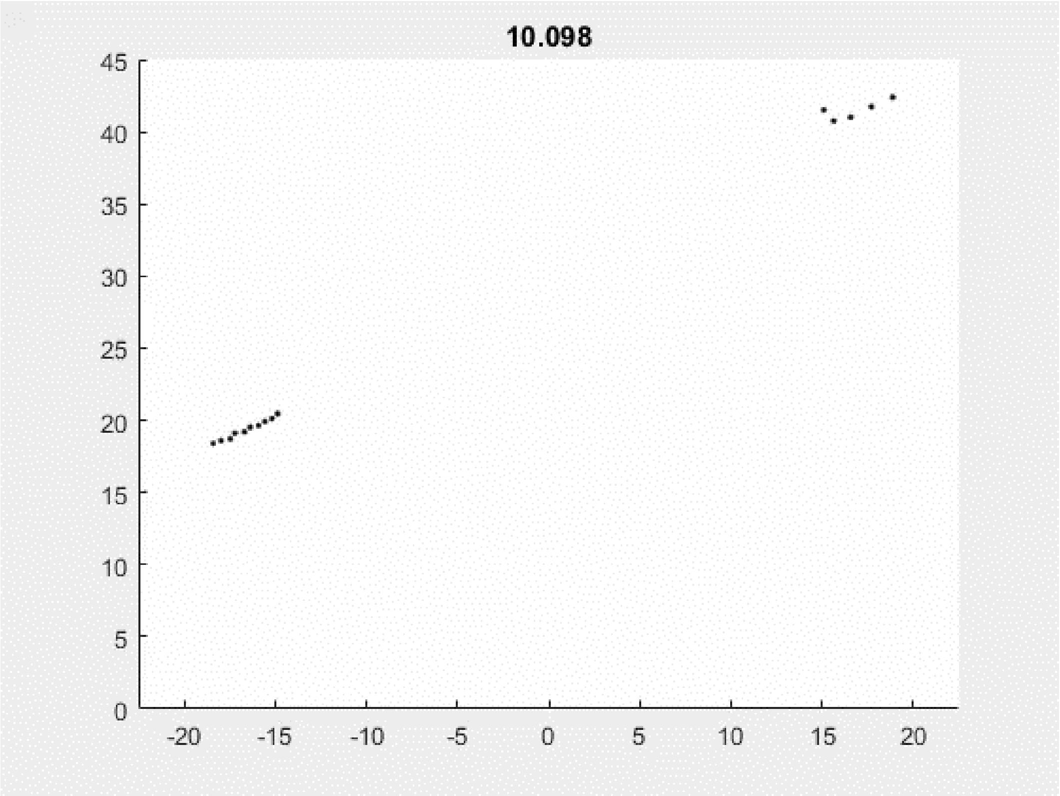
AFTER THIS PAPER SUBMISSION:

Enhancements on obstacle detection capability modelling:

- Obstacles detection results in a cloud of dots (not more its line segments).
- Position accuracy and resolution are being considered in the sensor model.

PLAY



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# THANK YOU FOR YOUR ATTENTION

# QUESTIONS?


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**OUR MISSION**: ***applied scientific research*** and ***specialized consultancy*** on **dependability** (*specially* ***safety***, ***reliability*** *and* ***availability***) of **cyber-physical systems** in **critical application domains**, such as Transportation Systems (Air, railway, subway, roadway), Defense Systems, and so on.

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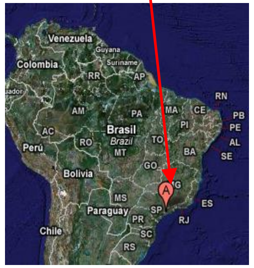
Population: 12 mi.
Most populous city in BR

School of Enginnering (POLI-USP)
Found.: 1893. (125 yrs)
15 Dept, 500+ faculty member
16 underg. courses, 12 grad. programs
(circa) 7k students (under/graduation)

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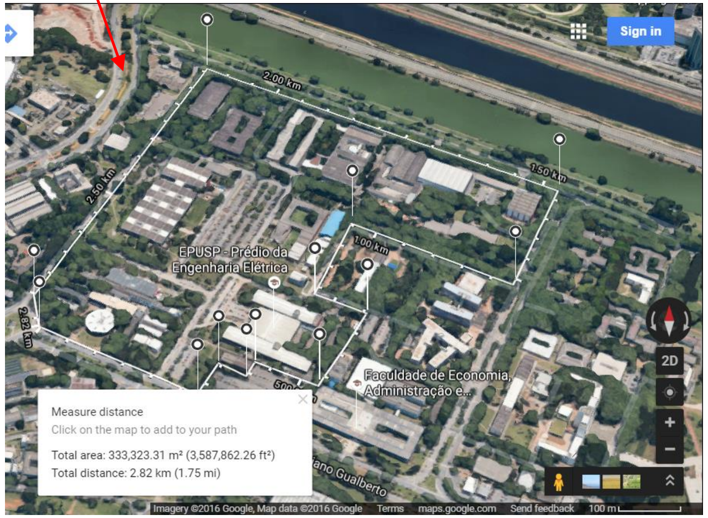


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