Mechatronic Systems Engineering

Truck platooning system

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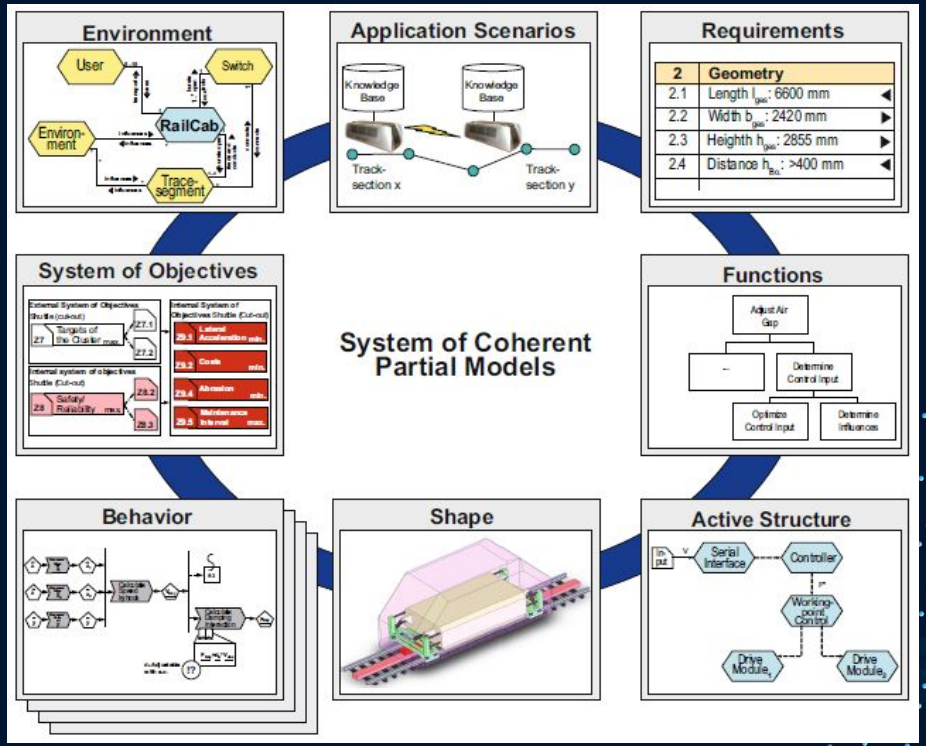
System Engineering according to INCOSE

System engineering is an interdisciplinary approach and means to enable the realization of successful systems.

System Engineering: CONSENS

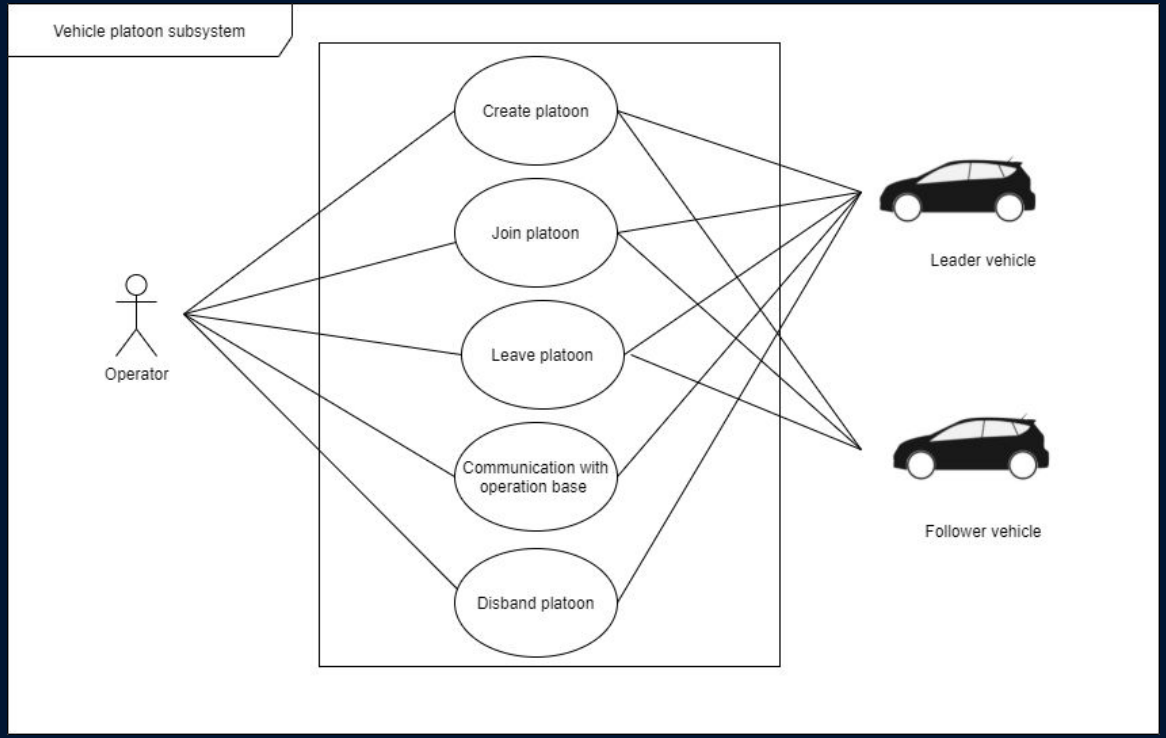


Requirements

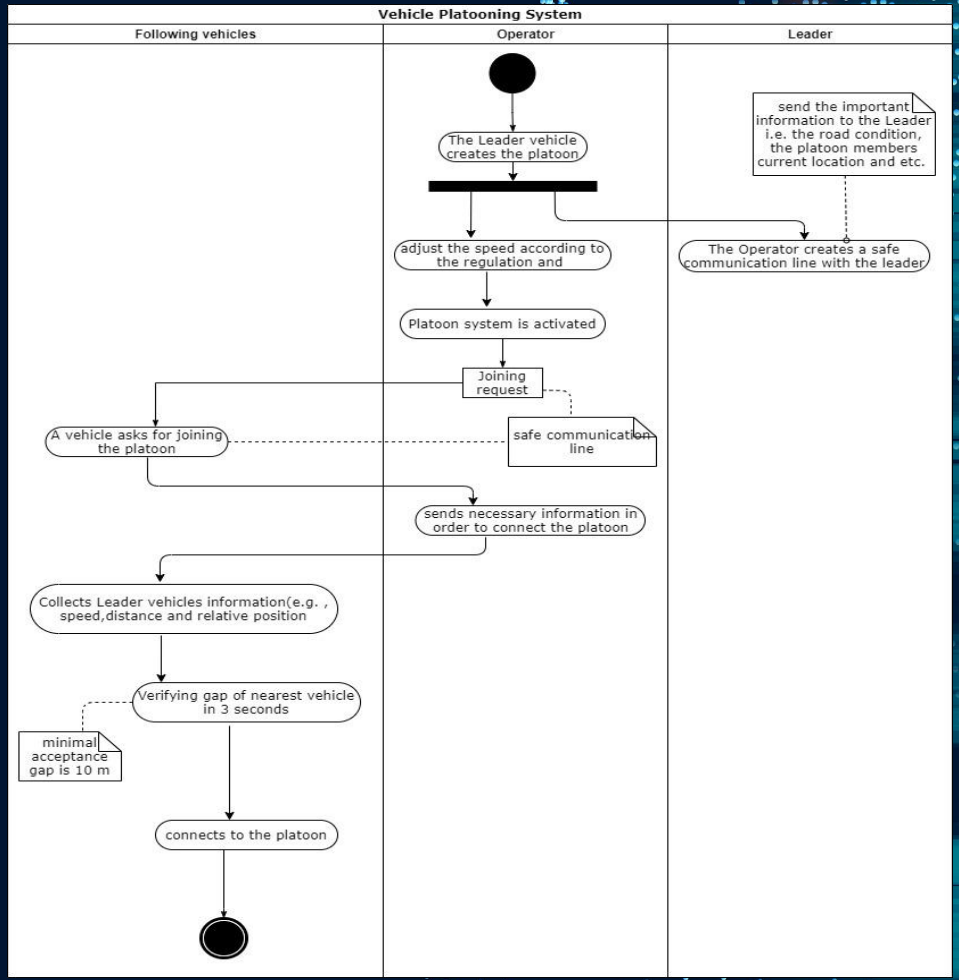
1. Geometry
2. Communications
3. Safety
4. Driver satisfaction
5. System interaction

Requriement list			
No	**Requriement description**		**Type (D/W)**
1	Geometry		
1.1	The gap between following trucks should be not more than 3 meters.		D
1.2	Road clearance of each truck should be not less than 30cm.		W
1.3	Turn radius of each truck should be less than 15m		D
1.4	The minimum load should be more than 10 tonns		W
1.5	Each fully loaded truck should be able to make a trip on a distance at least 1500km.		W
1.6	Size of trucks:		
1.6.1		lenght not more than 20m	W
1.6.2		width not more than 2.5 meters	D
1.6.3		height not more than 3.5 m	D
1.7	The length of a platoon should be limited to 7 vehicles		D
2	Communications		
2.1	All trucks should be able to broadcast and recieve platooning information through V2V		D
2.2	The system in the ego truck shall broadcast its actual and intended acceleration via V2V to enable following vehicles to detect emergency braking events.		D
2.3	The ego truck shall be informed in case of emergency braking events of the preceding trucks in the platoon. Therefore at least the requested and actual acceleration value of the preceding platoon truck must be received and to be compared with a defined acceleration threshold value.		D
	All trucks should be able to use folowing protocols and standards for communication: Wifi,		

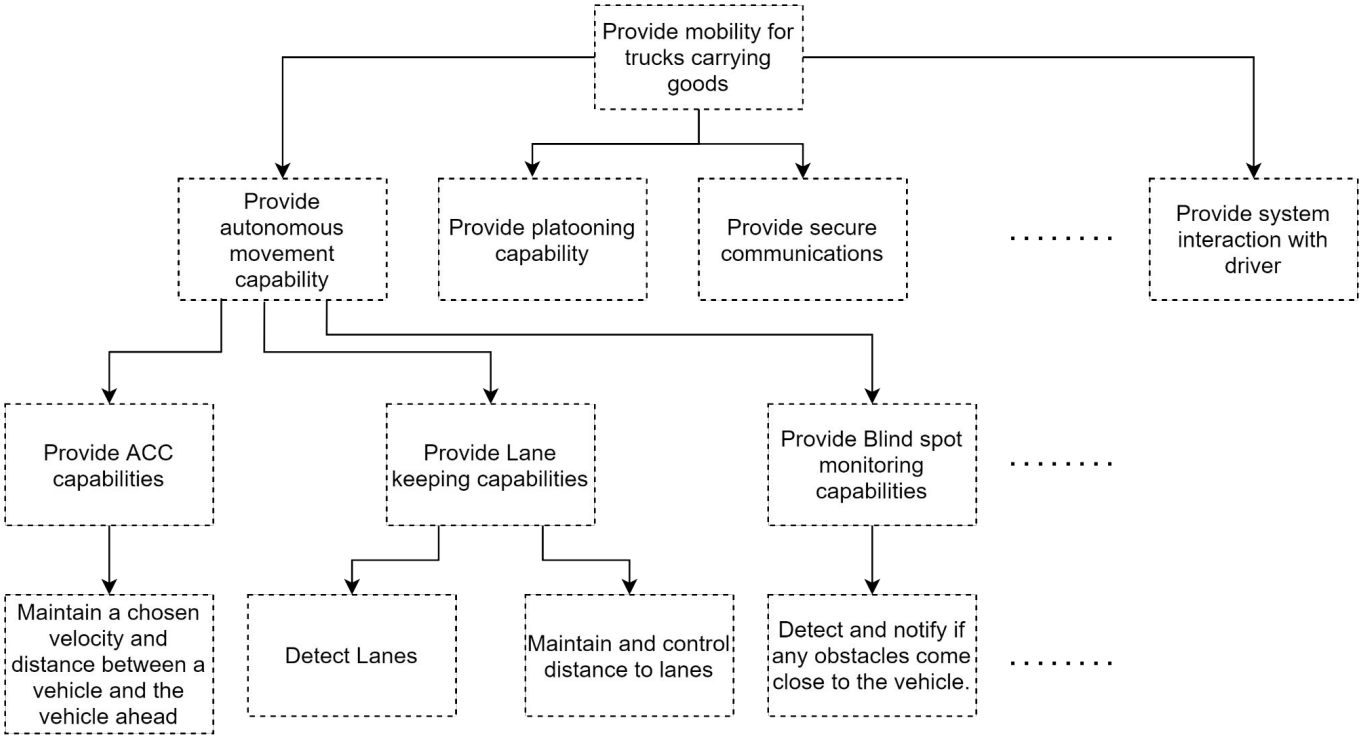
Use Case Diagram



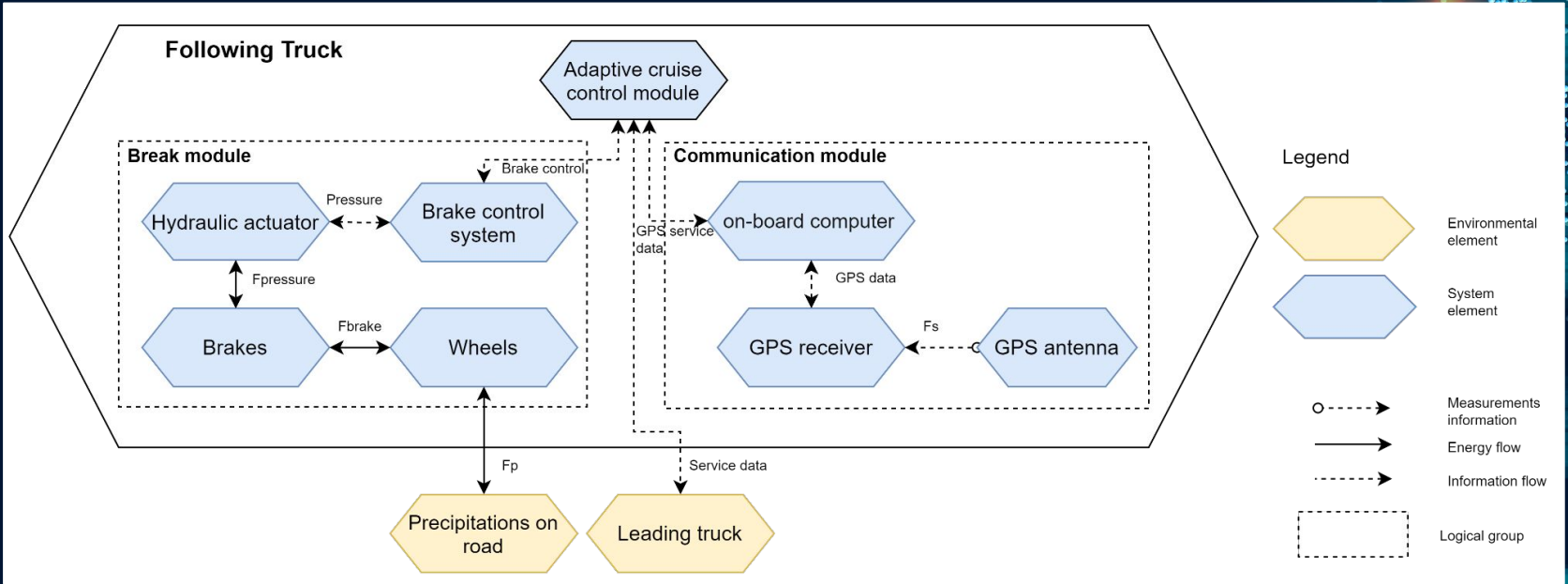
Activity Diagram



Functions


Provide mobility for trucks carrying goods
Provide autonomous movement capability
Provide platooning capability
Provide secure communications
.....
Provide system interaction with driver
Provide ACC capabilities
Provide Lane keeping capabilities
Provide Blind spot monitoring capabilities
.....
Maintain a chosen velocity and distance between a vehicle and the vehicle ahead
Detect Lanes
Maintain and control distance to lanes
Detect and notify if any obstacles come close to the vehicle.
.....

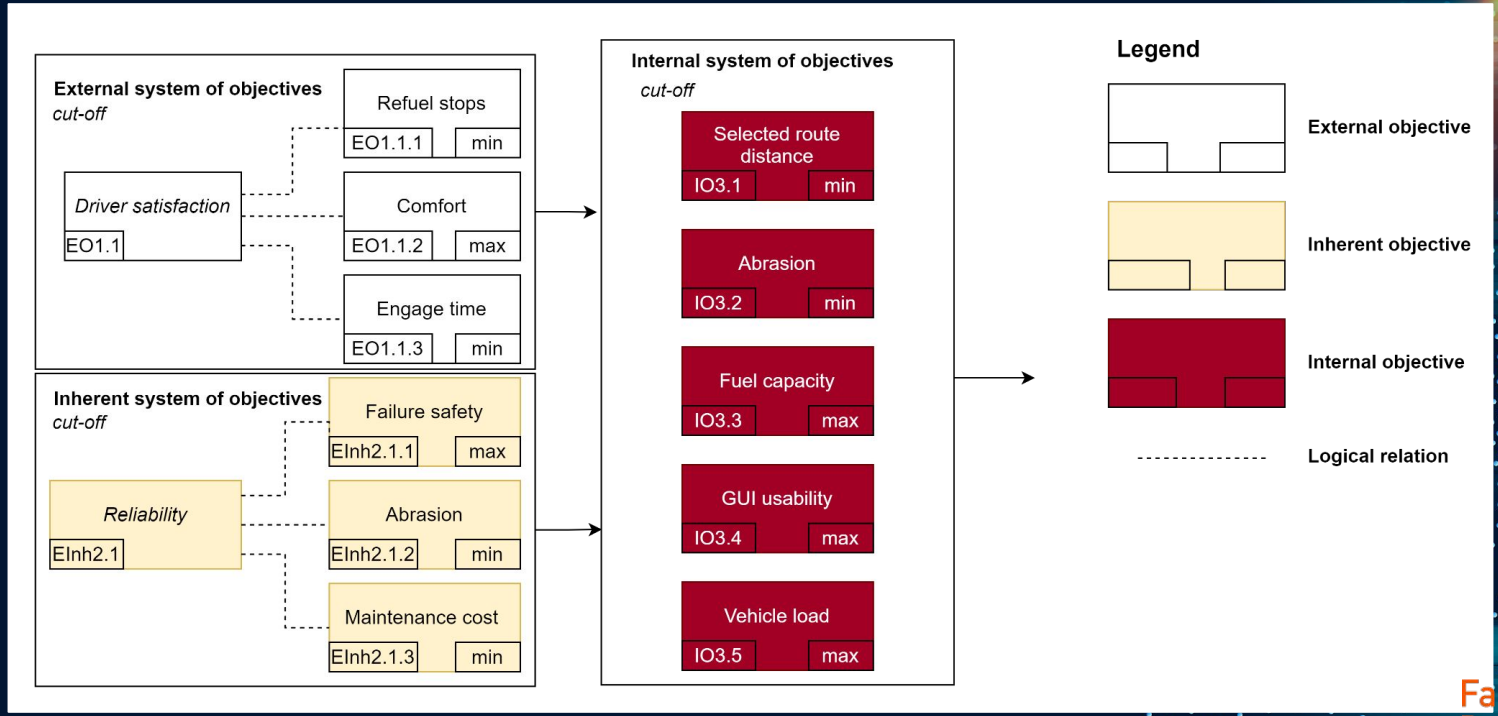
Active structure



Shape

The shape is from Carla , Tesla Truck model

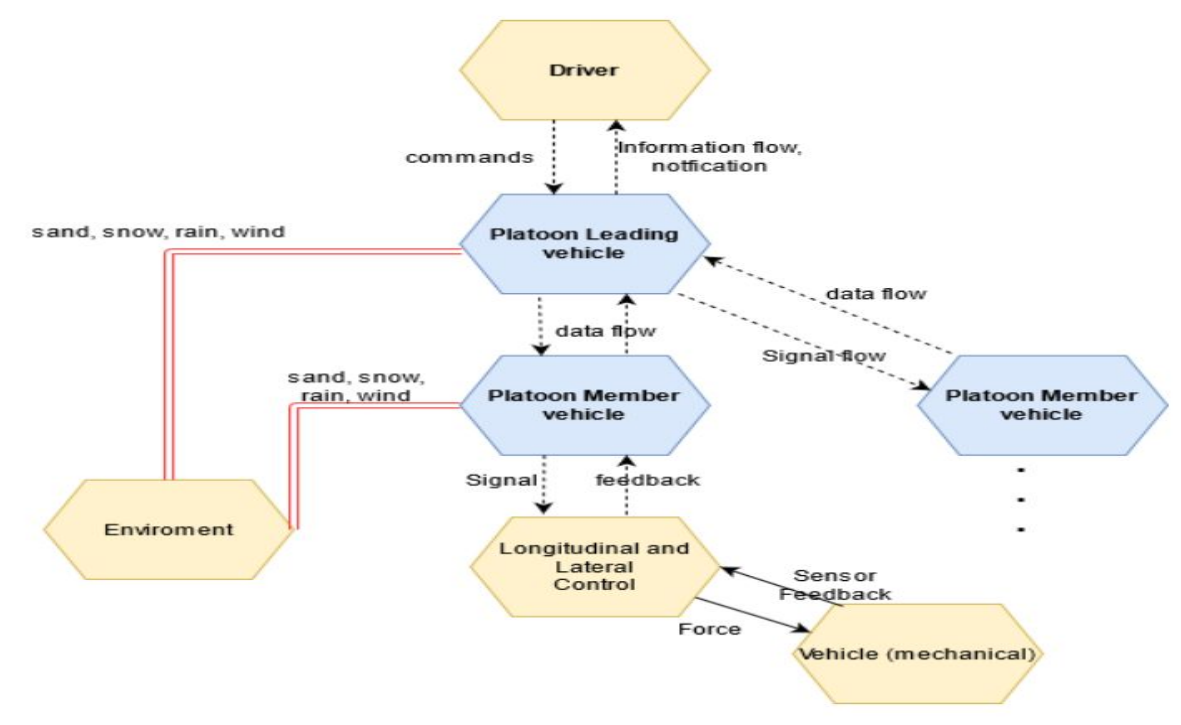
System of objectives



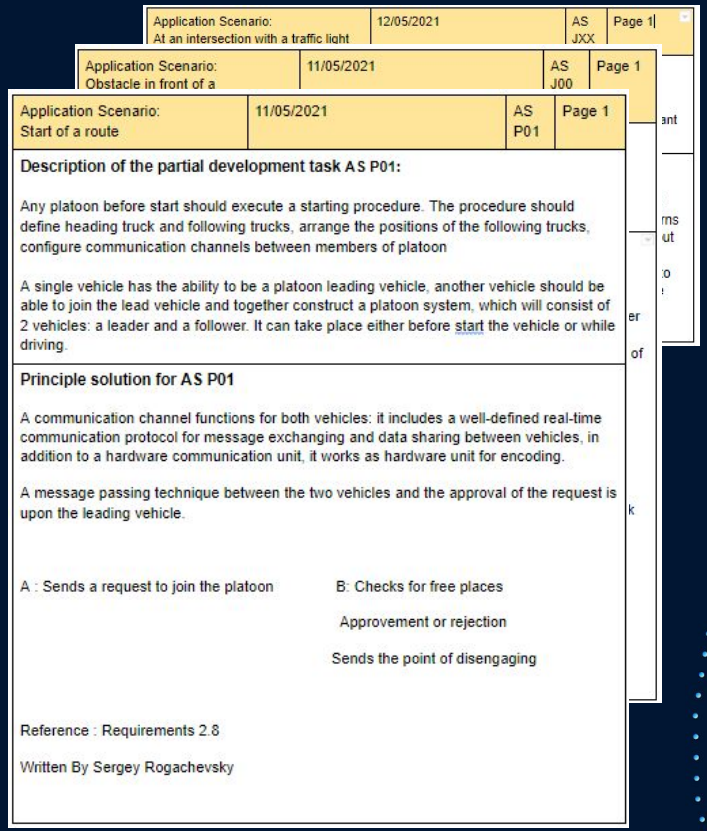
Correlation of objectives

	IO3.1	IO3.2	IO3.3	IO3.4	IO3.5	IO3.6	IO3.7
IO3.1							
IO3.2	+						
IO3.3	-	-					
IO3.4	0	0	0				
IO3.5	0	-	-	0			
IO3.6	0	-	-	0	-		
IO3.7	0	0	0	-	0	0	

Environment



Application scenarios



Application Scenario: At an intersection with a traffic light	12/05/2021	AS JXX	Page 1

Application Scenario: Obstacle in front of a	11/05/2021	AS J00	Page 1

Application Scenario: Start of a route	11/05/2021	AS P01	Page 1

Description of the partial development task AS P01:

Any platoon before start should execute a starting procedure. The procedure should define heading truck and following trucks, arrange the positions of the following trucks, configure communication channels between members of platoon

A single vehicle has the ability to be a platoon leading vehicle, another vehicle should be able to join the lead vehicle and together construct a platoon system, which will consist of 2 vehicles: a leader and a follower. It can take place either before start the vehicle or while driving.

Principle solution for AS P01

A communication channel functions for both vehicles: it includes a well-defined real-time communication protocol for message exchanging and data sharing between vehicles, in addition to a hardware communication unit, it works as hardware unit for encoding.

A message passing technique between the two vehicles and the approval of the request is upon the leading vehicle.

A : Sends a request to join the platoon

B: Checks for free places

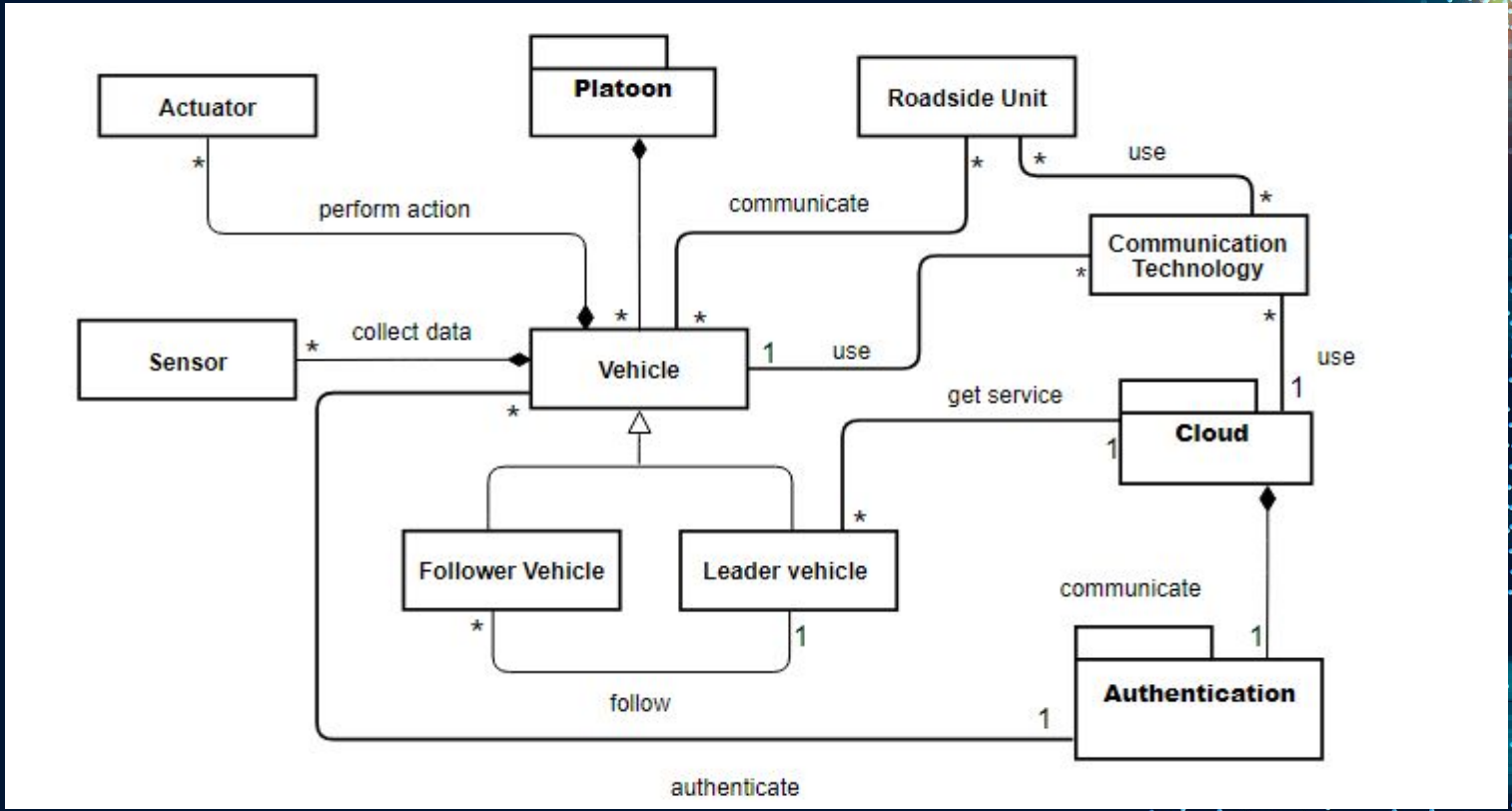
Approvement or rejection

Sends the point of disengaging

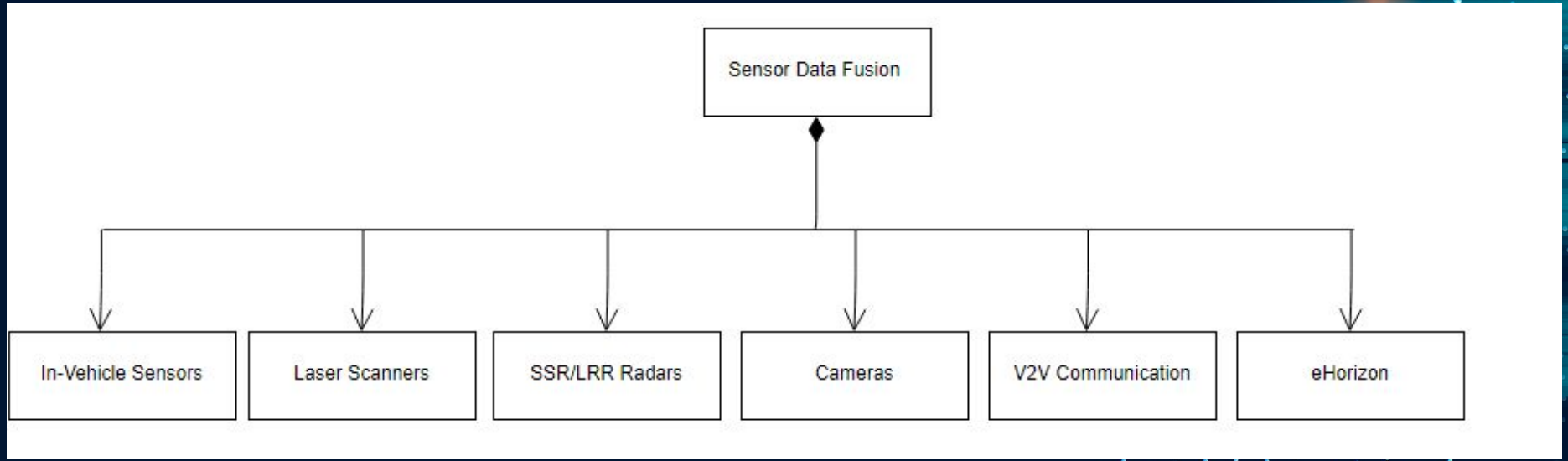
Reference : Requirements 2.8

Written By Sergey Rogachevsky

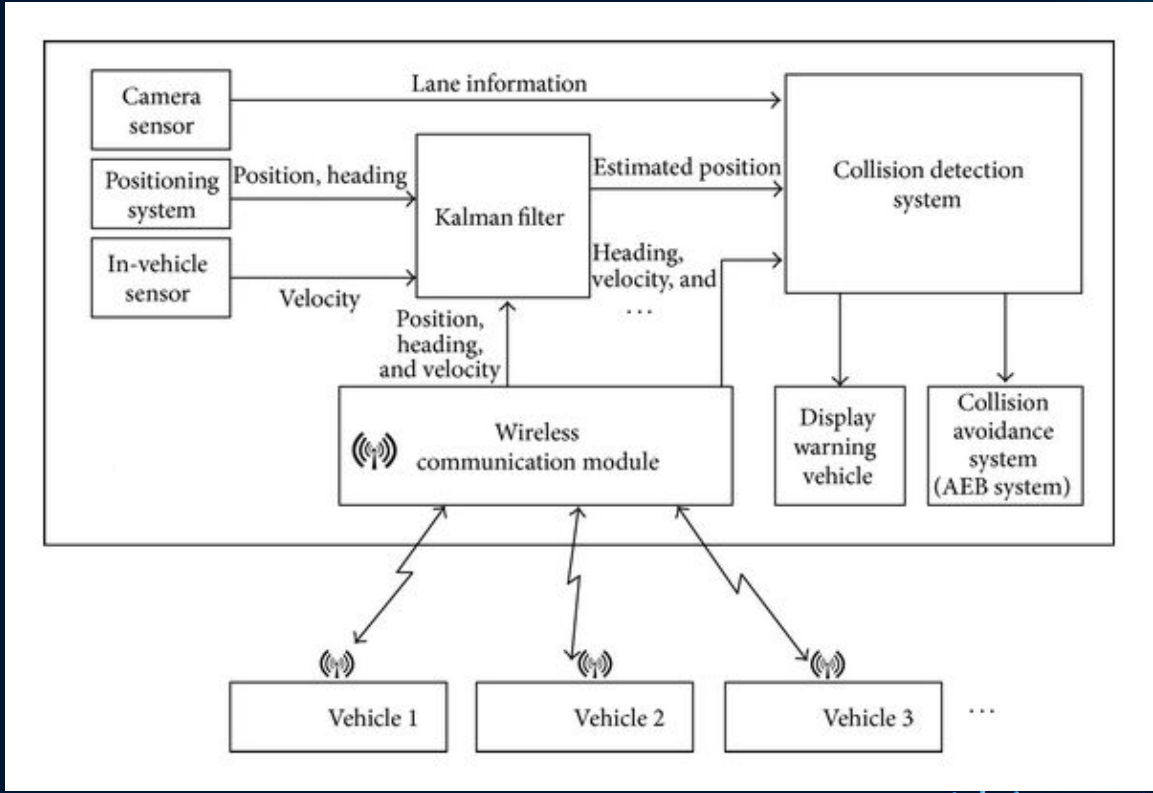
Macro architecture



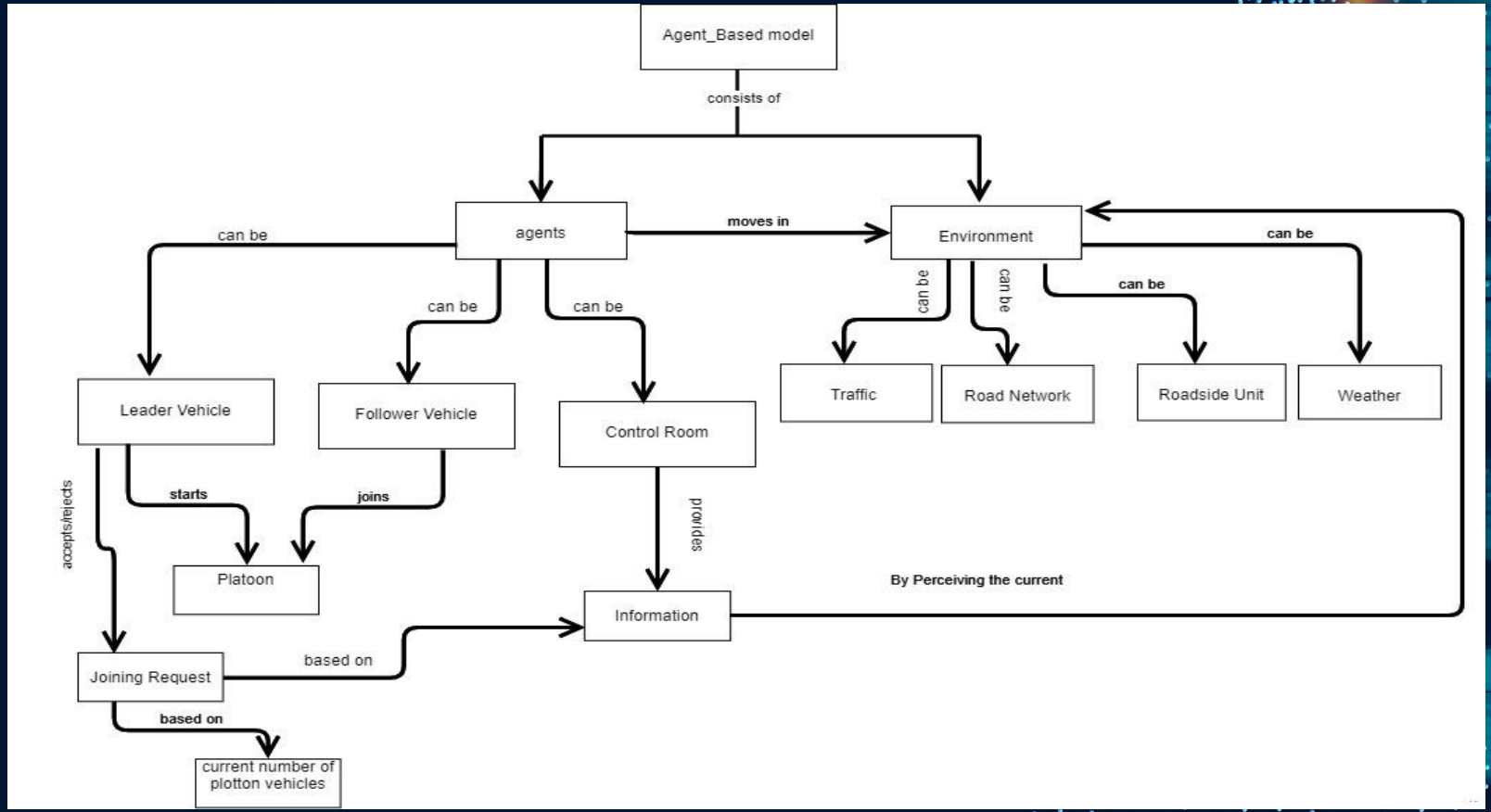
Micro architecture (Sensors)



Micro Architecture (V2V Communication System)



Agents behaviour



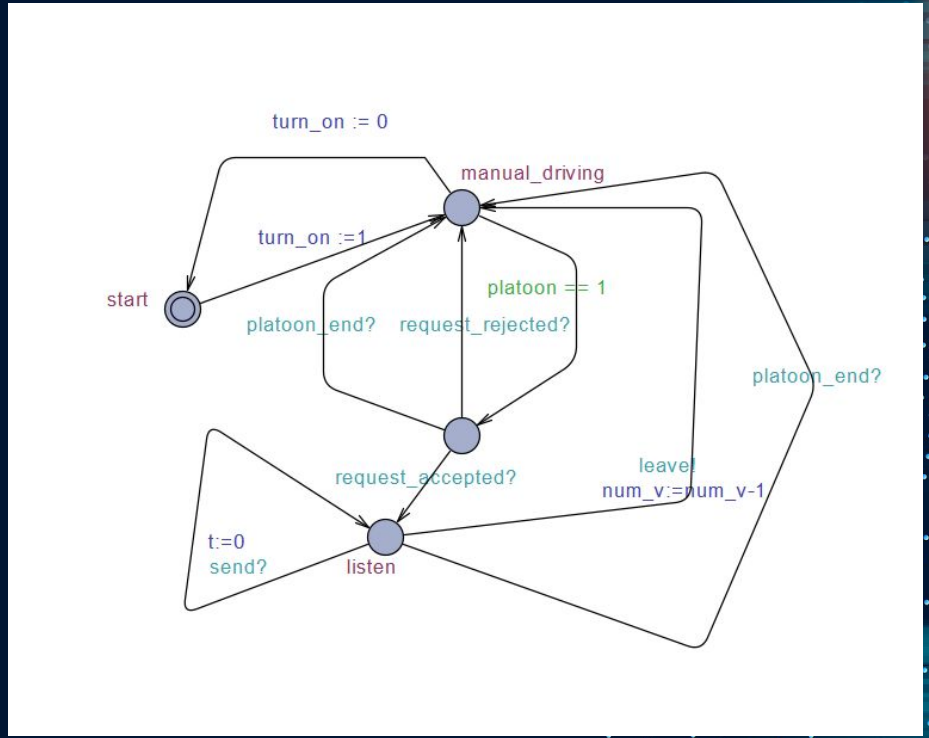
Time Automaton

- Our system contains of 2 main actors, leading vehicle and following vehicle. Each one has a different role.
- In the Time Automatons, they reflect part of the total logical behavior. Some properties are checked to make sure that the system behaves properly.
- Some Requirements also have been verified.

Throttle, break and Speed	Control Signals required for longitudinal control of any vehicle.
Existence of platoon, number of vehicles (follower),	Required to have a limited size platoon length
Request, approve reject	Joining the platoon by members.
Kill platoon	The leading vehicle kill the platoon

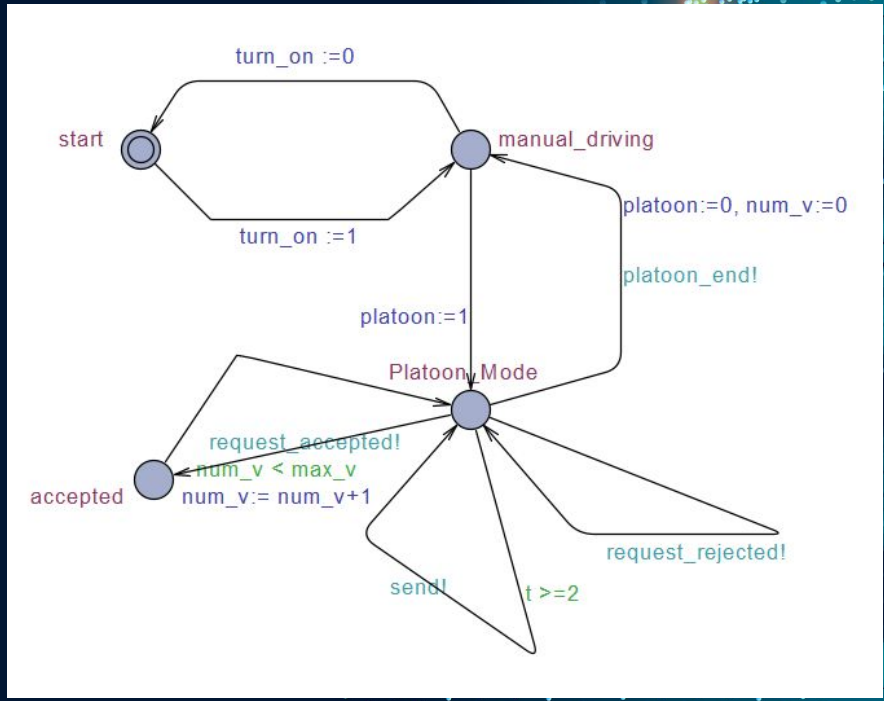
Time Automaton Follower Vehicle

Multiple Follower objects are instantiated to mimic The platoon system



Time Automaton Leading Vehicle

In a platoon, one leading vehicle only Existed.



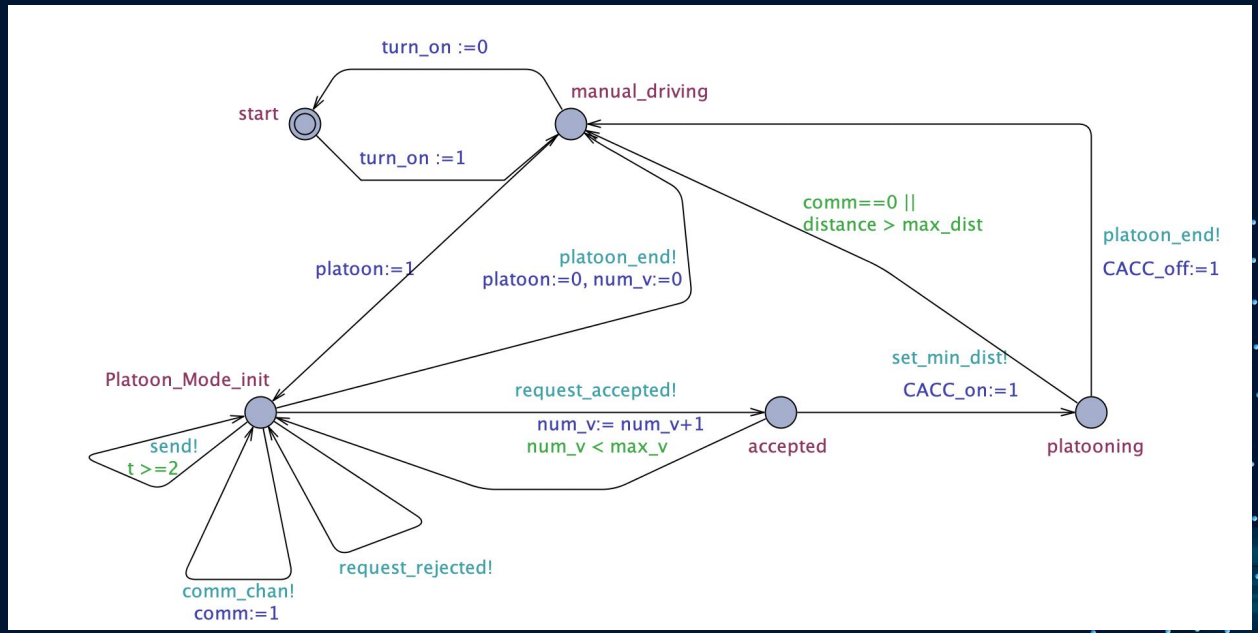
To enable safe communication more complicated model is required.

A Demo will show it in action.

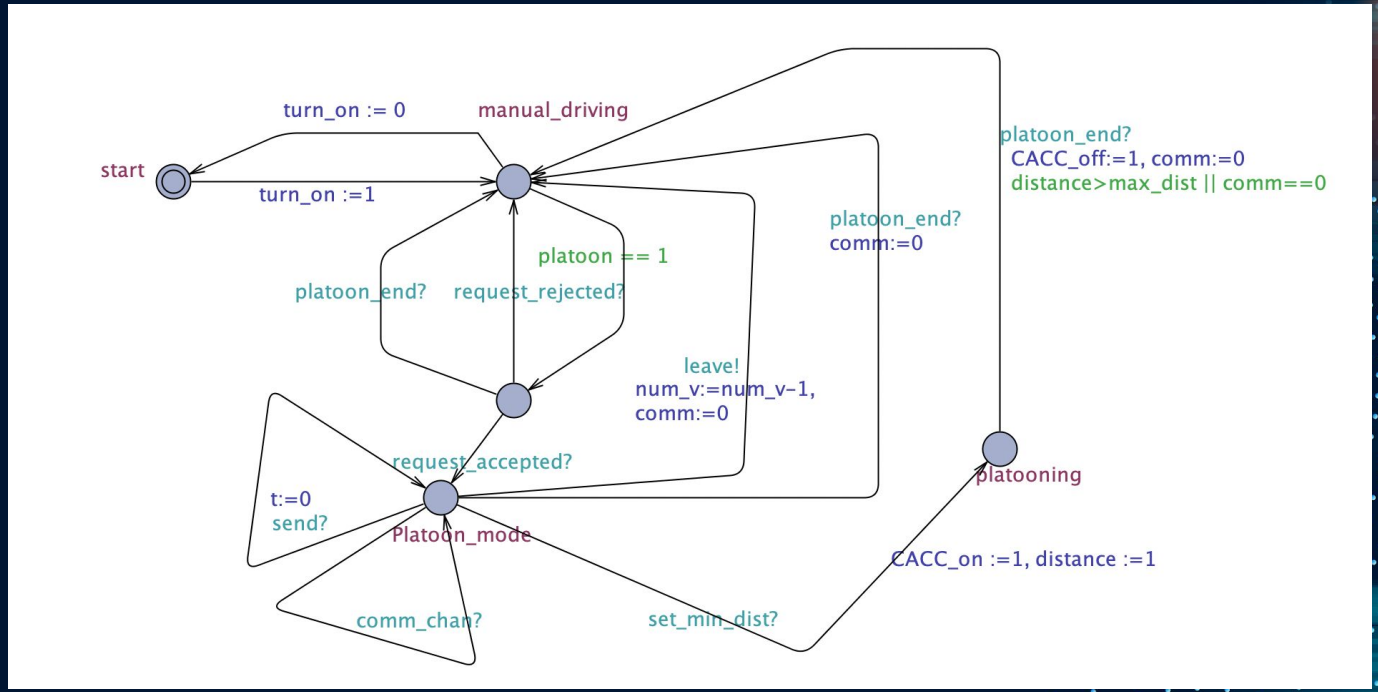
Correctness verification

Syntax	Property
E<> v1.listen	Is there a possibility to receive signals in a platoon
A[] num_v <= max_v	Always number of vehicles in the platoon less than max number of vehicles in the platoon(verified requirements)
A[] not deadlock	The system is free of deadlock(verified requirements)
E<> v1.listen and not vleading.manual_driving and not vleading.start	The platoon works when the leading vehicle in platoon states not manual driving nor start states.

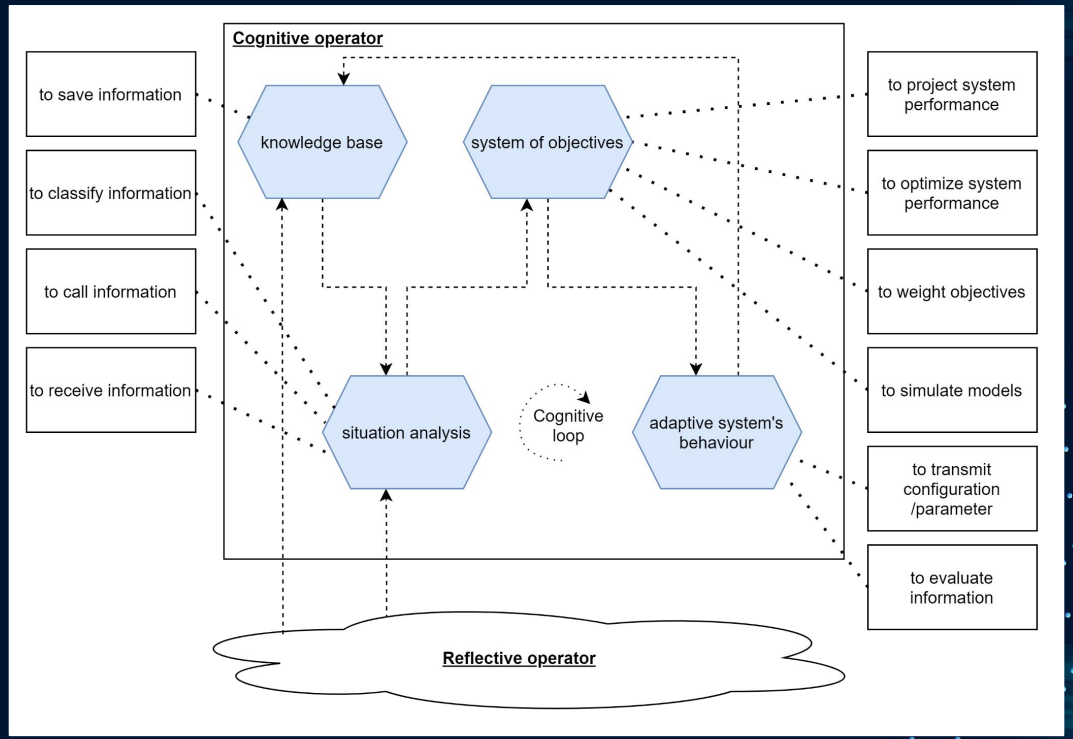
Overall Agent Behaviour Leading Vehicle



Overall Agent Behaviour Follower Vehicle



Cognitive operator



Cognitive operator. Scikit-learn. Random forest

Assigned_Role_Id

Route_Destination_Id

Distance

Platoon_Destination_Id

Platoon_Number

Max_Platoon_Size

Platoon_Size

Distance_to_platoon

Weather_condition

Truck_load

Truck_load_limit

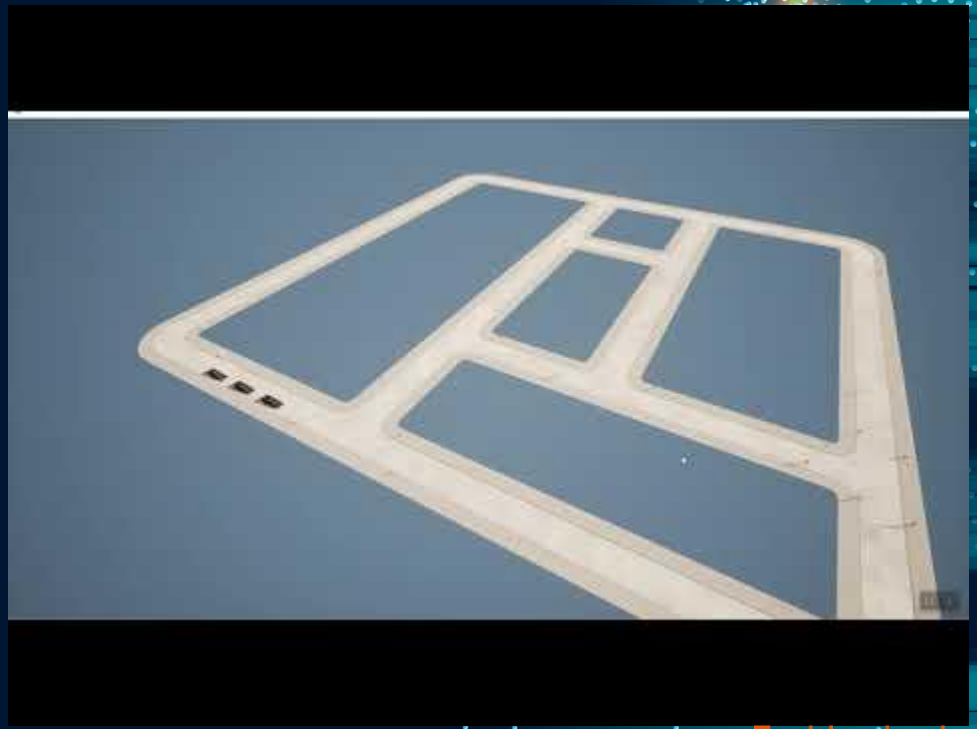
Timeout

	Assigned_Role_Id	Route_Destination_Id	Distance	Platoon_Destination_Id	Platoon_Number	Max_Platoon_Size	Platoon_Size	Distanc
0	0	1	400	1	1	1	1	
1	0	1	400	1	1	2	2	
2	0	1	400	1	1	3	3	
3	1	1	400	0	0	0	0	
4	2	1	400	1	1	2	1	

```
[[2 0 1]
 [1 2 0]
 [0 0 1]]
              precision    recall  f1-score   support

           0       0.67      0.67      0.67         3
           1       1.00      0.67      0.80         3
           2       0.50      1.00      0.67         1

    accuracy                           0.71         7
   macro avg       0.72      0.78      0.71         7
weighted avg       0.79      0.71      0.72         7

0.7142857142857143
```

Model representation in Carla

- A very simple demo via Carla.
- It is a Simple environment.
- The scenario is very simple, All vehicles are from the same type, same load.
- Control Signals are shared between them both brake and throttle.



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Thank you!