The queries are triggered for the maneuver's specific timestamp (0.5s). A maneuver accomplished in several timestamps. For example, a 5s maneuver consists of 100 timestamps (0.05s). [See chapter 7 for more about timestamps explanation].

# **Atom 1: driver\_IsOvertakingByCrossingADividingLine\_anotherDriver (19)**

# **Atom 3: driver\_HasPassed\_anotherDriver (19)**

# **Atom 4: anotherDriver\_IncreaseTheSpeed (19)**

# **Atom 5: driver\_IsOvertakingByCrossingToTheRightOfTheCentreOfTheRoad\_anotherDriver (19)**

# **Atom 10: driver\_IsAtASufficientDistanceToAvoidACollisionInFrontOf\_anotherDriver (19)**

## **Query 1: Which vehicle is driving in time (t)? (AV\_Environment)**

SPARQL:

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?vehicle

WHERE

{

ab:time ab:driving ?vehicle

}

Answer Example:

Vehicle1 (AV)

Vehicle2 (TV-1)

Vehicle3 (TV-2)

### **Explanation**

From this query result, it is identified how many vehicles is around the AV.

## **Query 2: How many lanes in the road? (AV\_Environment)**

SPARQL:

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_totallane

WHERE

{

as:time as:is\_totallane ?is\_totallane.

}

Answer Example: "3.0"^^<http://www.w3.org/2001/XMLSchema#string>

### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result > 1)

then “It is Multi-Lane Road”;

multilaneroad = 1;

else

multilaneroad = 0;

## **Query 3: What is AV Lane Number? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_lanenumber

WHERE

{

ab:vehicle-1 ab:is\_lanenumber ?is\_lanenumber

}

Answer Example: "2.0"^^<http://www.w3.org/2001/XMLSchema#string>

## **Query 4: What is TV lane number? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_lanenumber

WHERE

{

ab:vehicle-2 ab:is\_lanenumber ?is\_lanenumber

}

Answer Example: "2.0"^^<http://www.w3.org/2001/XMLSchema#string>

## **Query 5: What is AV speed? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_speed

WHERE

{

ab:vehicle-2 ab:is\_speed ?is\_speed

}

Answer Example:

"56.1796836853"^^<http://www.w3.org/2001/XMLSchema#string>

## **Query 6: What is road allowed speed at the time (t)? (AV\_Environment)**

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_roadspeed

WHERE

{

as:time as:is\_roadspeed ?is\_roadspeed.

}

Answer Example:

"80.0"^^<http://www.w3.org/2001/XMLSchema#string>

## **Query 7: Is AV is at a safe distance? (AV\_Behaviour)**

### **Subquery 1: What is AV curvilinear coordinates in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_positionx ?is\_positiony

WHERE

{

ab:vehicle-1 ab:is\_positionx ?is\_positionx.

ab:vehicle-1 ab:is\_positiony ?is\_positiony

}

Answer Example:

"285.551116943"^^<http://www.w3.org/2001/XMLSchema#string>

"164.853302002"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

From these curvilinear coordinates, the distance of the vehicles is measured by the following equation,

Vehicle\_distance = abs | root (x\*x + y\*y) |

### **Subquery 2: What is TV curvilinear coordinates in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_positionx ?is\_positiony

WHERE

{

ab:vehicle-1 ab:is\_positionx ?is\_positionx.

ab:vehicle-1 ab:is\_positiony ?is\_positiony

}

Answer Example:

"277.459075928"^^<http://www.w3.org/2001/XMLSchema#string>

"164.853302002"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

From these curvilinear coordinates, the distance of the vehicles is measured by the following equation,

Vehicle\_distance = abs | root (x\*x + y\*y)

### **Subquery 3: What is the velocity of AV in time (t)? (AV\_Behaviour)**

#### **Nested Subquery 1: What is the speed of the AV in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_speed

WHERE

{

ab:vehicle-1 ab:is\_speed ?is\_speed

}

Answer Example:

"56.1796836853"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Nested Subquery 2: What is the direction of AV in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_heading

WHERE

{

ab:vehicle-1 ab:is\_heading ?is\_heading

}

Answer Example:

"0.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

From the speed and heading, the velocity of the vehicle is determined.

Vehicle\_velocity = vehicle\_speed \* heading (direction).

### **Subquery 4: What is the velocity of TV in time (t)?**

#### **Nested Subquery 1: What is the speed of the TV in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_speed

WHERE

{

ab:vehicle-2 ab:is\_speed ?is\_speed

}

Answer Example:

"39.31300354" ^^<http://www.w3.org/2001/XMLSchema#string>

##### **Explanation**

From the speed and heading, the velocity of the vehicle is determined.

Vehicle\_velocity = vehicle\_speed \* heading (direction).

**Nested Subquery 2: What is the direction of TV in time (t)? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_heading

WHERE

{

ab:vehicle-2 ab:is\_heading ?is\_heading

}

Answer Example:

"0.0" ^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

From the speed and heading, the velocity of the vehicle is determined.

Vehicle\_velocity = vehicle\_speed \* heading (direction).

### **Subquery 5: What is the reaction time of AV1 and TV in time (t)?**

#### **Nested Subquery 1: What is the reaction time of AV in time (t)? (AV\_Behaviour)**

Reaction time is considered as 0s

#### **Nested Subquery 1: What is the reaction time of TV in time (t)? (AV\_Behaviour)**

Reaction time is considered as 0s

### **Explanation**

After retrieving all these subqueries (1⎯5) result, the query-7 result is made through the below assumptions and equations.

Based on three specific assumptions, this safe distance mechanism works. These assumptions are:

* 0 ≤ vav  ˄ 0 ≤ vtv  ; the velocity of automated vehicle (vav) and target vehicle (vtv) are non-negative.
* aav ˂ 0 ˄ atv ˂ 0 ; acceleration of automate vehicle (aav) and target vehicle (atv) is negative.
* s0, av ˂ s0, tv ; target vehicle position (s0, tv) is ahead of automated vehicle position (s0, av).

Equations are:

|  |  |
| --- | --- |
|  | (3) |

|  |  |
| --- | --- |
| = | (4) |

|  |  |
| --- | --- |
|  | (5) |

Here = 0.7 is coefficient friction, and 9.8 ms-2 is the gravitational acceleration.

|  |  |
| --- | --- |
|  | (6) |

|  |  |
| --- | --- |
|  | (7) |

|  |  |
| --- | --- |
|  | (8) |

This research considered these safe distance equations as the ground truth for the safe distance terms. Based on the above assumptions and equations, if any of the safe distances (equation 7, 8, 9) becomes true, this research considered that the AV is at a safe distance and yields the result '1' as a positive outcome for this Query 7. Otherwise, the result becomes '0' indicates the Query 7 outcome is negative (AV is not in the safe distance).

## **Query 8: Can AV safely change the lane? (AV\_Behaviour) (AV\_Environment)**

### **Subquery 1: Is the road is marked lane? (AV\_Environment)**

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_markedlane

WHERE

{

as:time as:is\_markedlane ?is\_markedlane.

}

Answer Example:

"1.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

This query result determines whether the road is a marked lane or not. The '1' indicates the road is a marked lane.

## **Explanation for Atom 1,3,4,5,10**

Based on the Query 1-Query 8 result, atom 3 is determined whether it is true or false. For this atom, some queries result can be determined through the outcome, such as Query 3, Query 4, etc. However, some queries result is made based on the computational processes of their subqueries outcome, such as Query 7, Query 8, etc.

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | AV and there is TV | True |
| Query 2 | The road is a multi-lane road | True |
| Query 3 | AV lane number > 0 | True |
| Query 4 | TV lane number > 0 | True |
| Query 5 | AV speed > 0 | True |
| Query 6 | No condition | True / False |
| Query 7 | AV is in safe distance with TV and other vehicles. | True |
| Query 8 | The road is a marked lane | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (if any of the query results becomes opposite to the expected outcome)

The atom is considered a False atom.

# **Atom 2: driver\_isDrivingOn\_twoWayRoad (1)**

## **Query 1: Is the road is a two-way road? (AV\_Environment)**

SPARQL:

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_twowayroad

WHERE

{

as:time as: is\_twowayroad ?is\_twowayroad.

}

Answer Example: "0.0"^^<http://www.w3.org/2001/XMLSchema#string>

### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result > 1)

then “The road is a two way road”;

two\_way\_road = 1;

else

two\_way\_road = 0;

## **Explanation for atom 2**

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | The road is a two way road | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (the query result ≤ 1)

The atom is considered a False atom.

# **Atom 6: anotherDriver\_IsDrivingOn\_markedLane (1)**

## **Query 1: Is the road is marked lane?**

SPARQL:

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_markedlane

WHERE

{

as:time as:is\_markedlane ?is\_markedlane.

}

Answer Example:

"1.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result == 1)

then “Driving in a marked lane”;

markedlane = 1;

else

markedlane = 0;

## **Explanation for Atom 6**

Based on Query 1 result, atom 2 is determined whether it is true or false.

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | Driving in a marked lane | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (if any of the query results becomes opposite to the expected outcome)

The atom is considered a False atom.

# **Atom 7: driver\_HasReturnedTo\_markedLane (1)**

## **Query 1: Is the road is marked lane?**

SPARQL:

prefix as:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-139#>

SELECT ?is\_markedlane

WHERE

{

as:time as:is\_markedlane ?is\_markedlane.

}

Answer Example:

"1.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result == 1)

then “Driver has returned to marked lane”;

markedlane = 1;

else

markedlane = 0;

## **Explanation for Atom 7**

Based on Query 1 result, atom 2 is determined whether it is true or false.

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | Driver has returned to marked lane | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (if any of the query results becomes opposite to the expected outcome)

The atom is considered a False atom.

# **Atom 8: anotherDriver\_IsDrivingOn\_lineOfTraffic (1)**

## **Query 1: What is TV lane number? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_lanenumber

WHERE

{

ab:vehicle-2 ab:is\_lanenumber ?is\_lanenumber

}

Answer Example: "2.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result == 1)

then “TV is in line of traffic”;

line\_of\_traffic = 1;

else

line\_of\_traffic = 0;

## **Explanation for Atom 8**

Based on Query 1 result, atom 2 is determined whether it is true or false.

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | TV is in line of traffic | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (if any of the query results becomes opposite to the expected outcome)

The atom is considered a False atom.

# **Atom 9: driver\_HasReturnedTo\_lineOfTraffic (1)**

## **Query 1: What is TV lane number? (AV\_Behaviour)**

prefix ab:<http://www.semanticweb.org/bhuiyanh/ontologies/2020/5/untitled-ontology-137#>

SELECT ?is\_lanenumber

WHERE

{

ab:vehicle-2 ab:is\_lanenumber ?is\_lanenumber

}

Answer Example: "2.0"^^<http://www.w3.org/2001/XMLSchema#string>

#### **Explanation**

Through the below condition, it is determined whether this road is a multi-lane road or not.

**Condition:**

if (q.result == 1)

then “Driver has returned to line of traffic”;

line\_of\_traffic = 1;

else

line\_of\_traffic = 0;

## **Explanation for Atom 8**

Based on Query 1 result, atom 2 is determined whether it is true or false.

**IF:**

|  |  |  |
| --- | --- | --- |
| Queries | Result | Expected outcome |
| Query 1 | Driver has returned to line of traffic | True |

**THEN:** The atom is considered a True atom for the specific timestamp.

**ELSE**: (if any of the query results becomes opposite to the expected outcome)

The atom is considered a False atom

**Total 100 Queries including subqueries and nested subqueries**