OpenSCENARIO 2.0 Concept Project

Section 3 – “Use Cases”

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Content

Introduction and overview

Goal of the use case section

- User stories/use cases describe expectations from actors (users, developers, engineers, testers, etc.), formulated from the actor's perspective
- User stories/use cases describe requirements to the standard (e.g., features that the standard should provide)

➔ User stories/use cases can be used to define the goals of the standard and to check, if the included/developed features relate to customer needs

- Use case examples are used throughout the document to exemplify descriptions or explanations

Structure of the use case section

- User stories
  - Different categories of user stories, clustered regarding the topics

- Use case examples
  - Examples on different levels of abstraction, partly with corresponding images, that contain example scenarios or example use cases
  - Structure:
    - Summary
    - Related user story(s)
    - Covered abstraction levels
    - Description
    - Example scenario

User Stories

A) SHARE
B) CERTIFY & ANALYSE
C) DEVELOP
D) CREATE
E) SOTIF-BASED RISK CONSIDERATION
F) DRIVING MISSION-BASED SCENARIOS
G) TRAFFIC MODEL INCLUSION
H) EXECUTE
I) DESCRIBE OBSERVATIONS

Foundation & Purpose

A) SHARE | B) CERTIFY & ANALYSE

A1. Scenario sharing	A2. Scenario search/reuse	A3. Test reuse/execution	A4. Test execution platforms	A5. Reuse for research
As a developer…	As a developer…	As a test engineer…	As a test engineer…	As a researcher…
I can share scenarios with other companies	I can search/reuse scenarios from other companies	I can run tests from other companies with my scenarios	I can run tests similarly on different execution platforms	I can reuse public scenarios for research purposes

B1. Scenario understanding	B2. Outcome comparison	B3. Condition recommendation	B4. Public transparency	B5. Verification tracking
As a regulator…	As a regulator…	As a safety engineer…	As a person…	As a government…
I can understand, how the products are tested	I can compare the outcome of different test platforms	I can recommend test conditions for test runs	I can learn more about how the products are tested	I can understand, which parts of the operational domain are verified

Foundation & Purpose

C) DEVELOP

C1. Reutilization	C2. Tool integration	C3. Verification traceability	C4. Compare external scenarios	C5. Migrate information
As a tool provider… I can reuse artifacts to create compatible tools	As a provider… I can integrate different tools from various vendors to a single solution	As an engineer… I can trace, which hardware/software is verified by which tests	As a developer… I can compare scenarios from different sources (SW/HW releases)	As a tool provider… I can migrate information from previous OSC versions

C6. Decompose use cases
As an engineer… I can decompose high-level use

Foundation & Purpose

D) CREATE | E) SOTIF-BASED RISK CONSIDERATION | F) DRIVING MISSION-BASED SCENARIOS

D1. Scenario provision	D2. Scenario transformation	D3. Stakeholder discussions	D4. Functional behavior	D5. Technical knowledge
As a developer… I can create scenarios, which I can provide futher developers as basis	As a test engineer… I can transform abstract scenario descriptions to concrete ones	As a project lead… I can describe abstraction scenarios for stakeholder discussions	As a project lead… I can describe the functional behavior for legal reasons in an abstract way	As a stakeholder… I can create abstract descriptions without the necessity to have technical knowledge

E1. Safety hazards	E2. Unknown unknowns	F1. Driving mission	F2. Evaluate the success
As an engineer… I can use scenarios to uncover safety hazards that occur even if the function is working properly	As an engineer… I can use scenarios to discover unknown unknowns	As a V&V engineer… I can specify the driving mission by using multiple maneuvers	As a V&V engineer… I can check, if the driving mission has been accomplished and evaluate the KPIs

Foundation & Purpose

G) TRAFFIC MODEL INCLUSION | H) EXECUTE | I) DESCRIBE OBSERVATIONS

G1. Traffic models/agents	G2. Scenario transformation	H1. Execution on same tool	H2. Execution on foreign tools	H3. Scenario to test
As a developer… I can include traffic models and/or AI-based traffic agents	As a test engineer… I can transform high-level to low-level scenarios and vice versa	As a test engineer… I can execute scenario descriptions automatically within a toolchain	As a test engineer… I can execute the same scenario on different toolchains	As a test engineer… I can convert abstract scenarios into tests

I1. Simulation observations	I2. Real-world observations	I3. Test track observations
As a user… I can describe the observations of randomly executed simulation runs	As a driver… I can describe real world observations	As a test engineer… I can describe observations on test tracks

Use Cases for Scenarios

Examples and their intention

Use Case Examples

Use Case 1: Evaluation/validation/checks

Summary & Intention

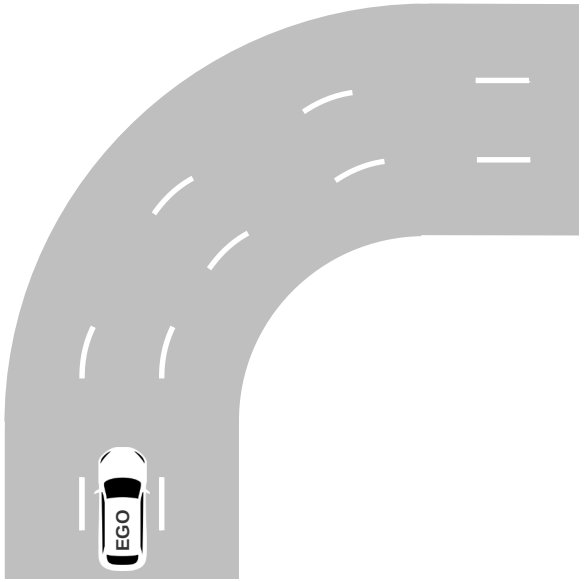
- Evaluator checks/validation for scenario descriptions

Description

- If the ego car is between two outer lanes, the evaluator checks, whether the ego car is able to keep driving between the lanes
- **Expected outcome:** Car must drive segments of oval map with lane keeping assistance feature enabled at all times and without any failures.

Example scenario

- Ego car starts driving with 40 km/hour speed at a given location in oval map
- **Test description:** Enable assistant at 10 seconds. Let the car drive in oval map for another 120 seconds.



EgoStartPosition = centered in EgoLane

EgoStartSpeed = eg. 40 km/h

EgoStartLK = e.g. after 10s of driving

SetWatchdog = e.g. 120s duration

Use Case Examples

Use Case 2: Regulations

Summary & Intention

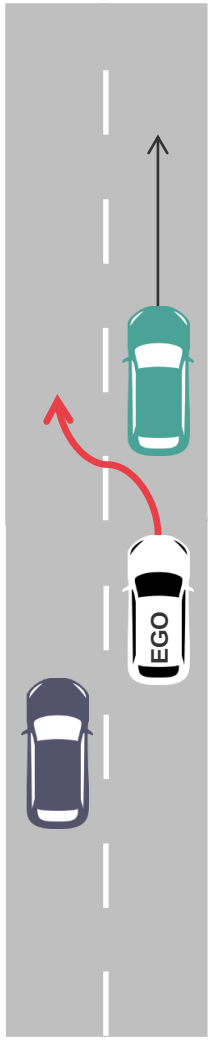
- Regulations contain requirements that shall be fulfilled by vehicles and corresponding test descriptions.

Description (Regulation example)

- Lane change procedure shall be suppressed automatically by the system when the system detects a critical situation before the lane change maneuver has started.
- A situation is rated as critical, e.g., when at the maneuver start, an approaching vehicle in the target lane would have to decelerate at a higher level than 3m/s.

Example scenario

- Ego car starts driving in a lane of a straight two lanes test track
- The Automatically Commanded Steering Function of category C (UN R79) shall be activated (standby mode) and a vehicle shall approach from the rear to enable the system
- The approaching vehicle shall then pass the vehicle under test entirely
- A lane change procedure shall then be initiated by the driver



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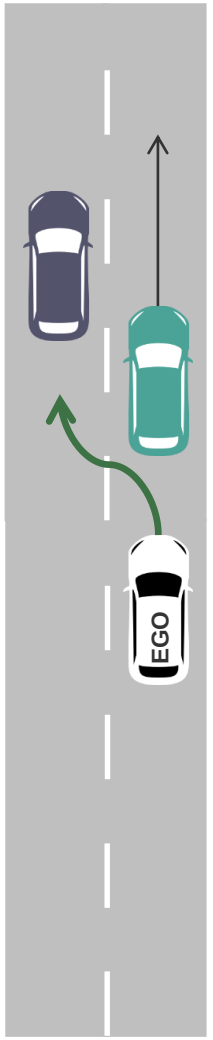


Use Case Examples

Use Case 3: Electronic stability control (ESC) testing

Summary & Intention

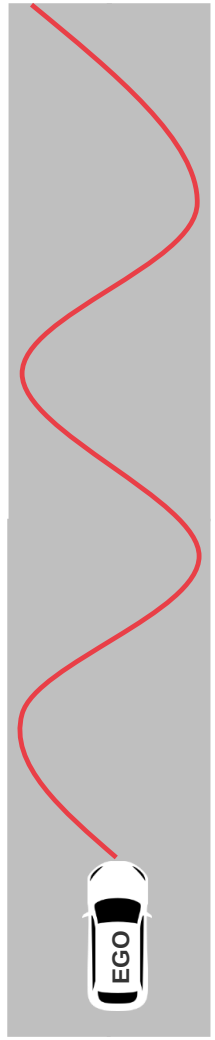
- Coverage of ISO 19365: Sine with dwell test sequence, including slowly increasing steer as preparation maneuver

Description

- The main purpose of ISO 19365 is to provide a repeatable and discriminatory method for comparing simulation results to measured test data from a physical vehicle for sine with dwell tests, which are typically used to evaluate the performance of an electronic stability control (ESC) system

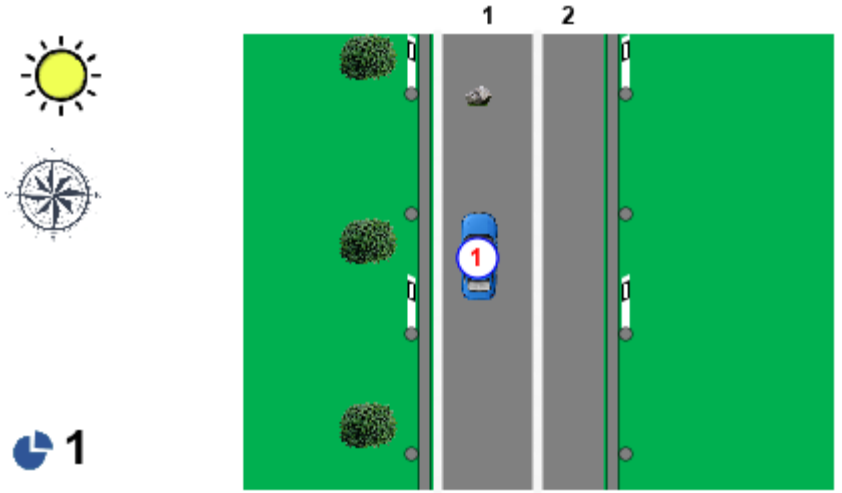
Example scenario

- Vehicle is subjected to two series of runs of the slowly increasing steer test, using a constant vehicle speed and a steering pattern that increases until a lateral acceleration of 0.5 g is obtained
- Goal is to determine a reference steering wheel angle A, which represents the steering wheel angle leading to a steady-state lateral acceleration of 0.3 g



Use Case Examples

Use Case 4: Stakeholder Discussion



Summary & Intention

- Scenario usage as a basis for stakeholder discussions.

Description

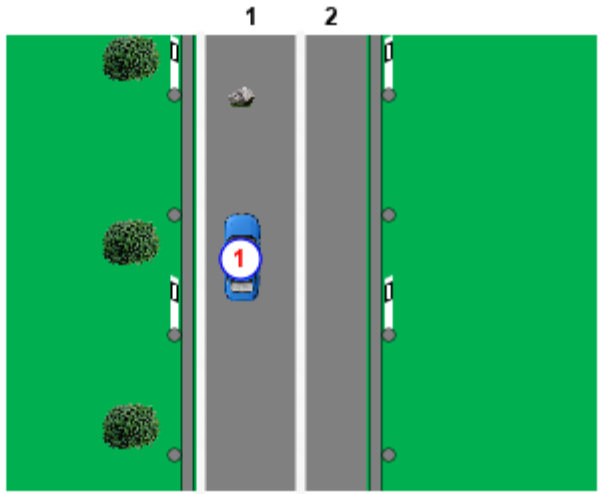
- To define the driving function, the project lead needs to discuss the function goals and behavior with the stakeholders
- A short and easily comprehensible scenario description, which is understandable without detailed technical knowledge, should be available
- A corresponding two or three dimensional visualization can help.

Example scenario

- **Customer function level:** My driving function (emergency brake assist) has to perform an emergency braking
- **System behavior level:** If the distance to an object in the trajectory falls below threshold C1 and the speed is above V1, inform the user visually. If the user does not react within X seconds, perform an emergency brake with -15 m/s^2.
- **Abstract description:** Highway with at least one lane, a car follows one lane, an object is in front of the car. The distance is Y meters.

Use Case Examples

Use Case 4: Stakeholder Discussion



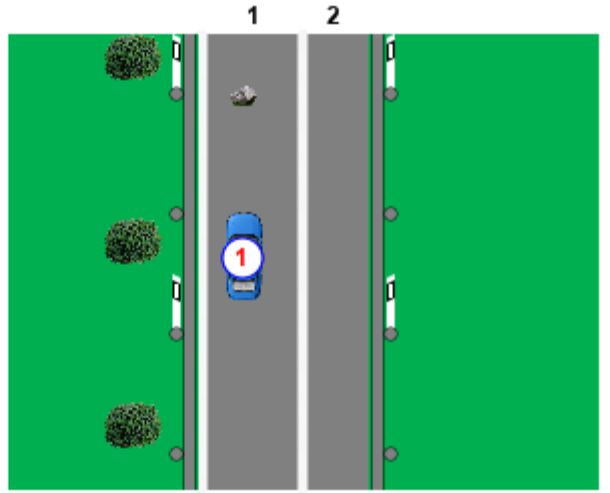

```
Layer 1 (Road Model): ▲
  Segment #1 has a main roadway (🔒).
    The main roadway has a straight geometry , 1 driving lane(s) and  the stop lane.
      The stop lane #2 has a narrow width.
Layer 2 (Infrastructure): ▲
  Segment #1 contains following elements:
    No Traffic Regulating Elements
    The road  has guideposts  and guardrails on the median and the right shoulder.
    The lateral vegetation consists of bushes on the median of 50 cm height with low density .
Layer 3 (Temporary Modifications): ▼
Layer 4 (Positioning and Velocity): ▲
  The following Vehicle group #1 drives  on  Segment #1 with  a normal traffic density.
  Following Vehicle group #2 drives  on  Segment #1:
    Ego Car #1  drives  with high speed  on driving lane #1.
  On Segment #1 , an obstacle #1 is  in front of the Car #1 and blocks driving lane #1.
Layer 4 (Maneuvers): ▼
Layer 5 (Environmental Conditions): ▼
```

stiEF

Functional level

Use Case Examples

Use Case 4: Stakeholder Discussion



Layer 1 (Road Model): ▲
  Segment #1 has a main roadway (🔒).
    The main roadway has a straight geometry , 1 driving lane(s) and the stop lane .
      The stop lane #2 has a [3.00 ; 3.25] m width .

Layer 2 (Infrastructure): ▲
  Segment #1 contains following elements:
    No Traffic Regulating Elements
    The road has guideposts and guardrails on the median and the right shoulder.
    The lateral vegetation consists of bushes on the median of 50 cm height with [20 ; 40] % density .

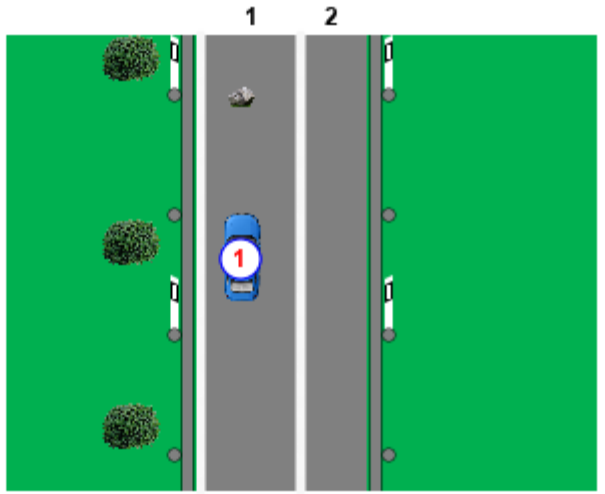
Layer 3 (Temporary Modifications): ▼
Layer 4 (Positioning and Velocity): ▲
  The following Vehicle group #1 drives on Segment #1 with a time interval between [5.1 ; 7.5] s.
  Following Vehicle group #2 drives on Segment #1:
    Ego Station wagon #1 drives with [112 ; 126] km/h on driving lane #1.
  On Segment #1 , an obstacle #1 is and at position (x:[0.0 ; 3.5] ; y:[0.0 ; 700.0] ; z:[0.0 ; 0.0]) m .

Layer 4 (Maneuvers): ▼
Layer 5 (Environmental Conditions): ▼

Logical level

Use Case Examples

Use Case 4: Stakeholder Discussion



Layer 1 (Road Model): ▲
- Segment #1 has a main roadway (🔒).
  - The main roadway has a straight geometry , 1 driving lane(s) and the stop lane.
    - The stop lane #2 has a 3.25 m width.

Layer 2 (Infrastructure): ▲
- Segment #1 contains following elements:
  - No Traffic Regulating Elements
  - The road has guideposts and guardrails on the median and the right shoulder.
  - The lateral vegetation consists of bushes on the median of 50 cm height with 30 % density .

Layer 3 (Temporary Modifications): ▼

Layer 4 (Positioning and Velocity): ▲
- The following Vehicle group #1 drives on Segment #1 with a time interval of 5.1 s.
- Following Vehicle group #2 drives on Segment #1:
  - Ego Station wagon #1 drives with 119 km/h on driving lane #1.
- On Segment #1 , an obstacle #1 is and at position (x: 1.75 y: 400.0 z: 0.0) m .

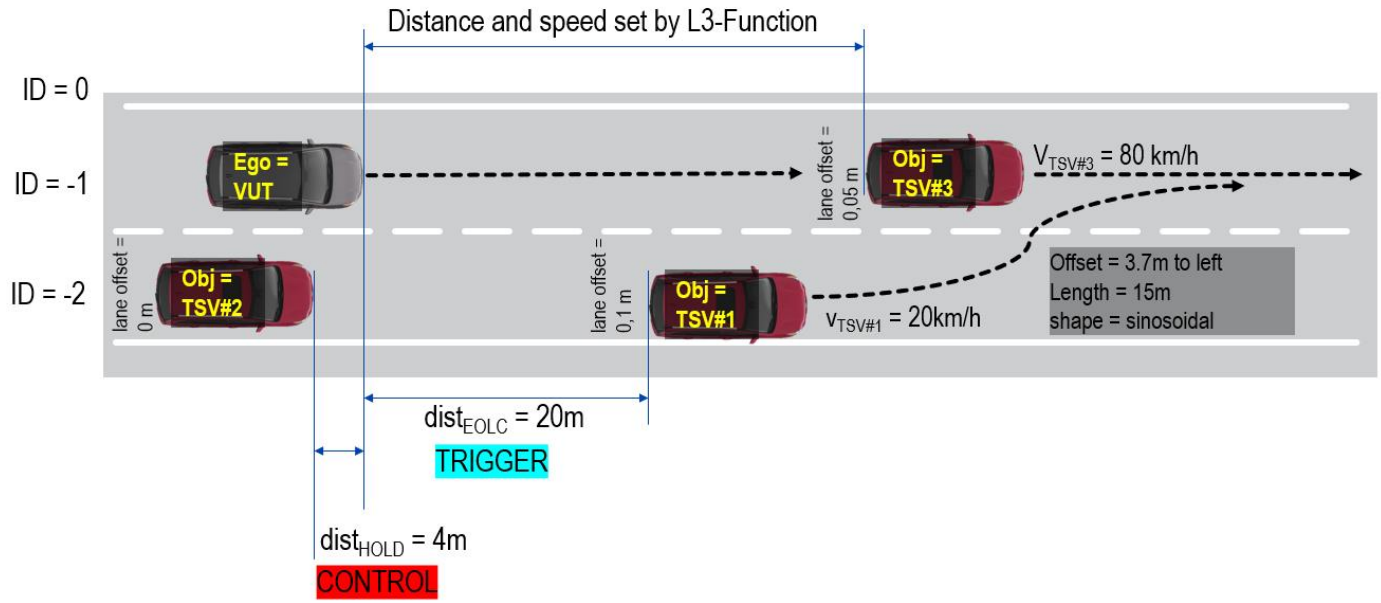
Layer 4 (Maneuvers): ▼

Layer 5 (Environmental Conditions): ▼

Concrete level

Use Case Examples

Use Case 5: Proving ground testing



Summary & Intention

- Scenarios for proving ground testing.

Description

- A scenario description is required to enable the tester to test a scenario on the proving ground.

Example scenario

- Scenario description: Cut-In on highway. Only option for ego car is to emergency brake.
- Scenario takes place on a 2-lane highway. Ego car is following another vehicle (TSV#3) with Highway-Pilot (L3) active. Ego car and lead-vehicle are on the left lane. An additional vehicle (TSV#2) is right next to the ego car on the right lane. It stays besides the ego car with an offset of 4m from front bumper to front bumper. A slow vehicle (TSV#1) is changing lane from right to left and cuts in between TSV#3 and the ego car. The ego car has only the option to emergency brake and not to change lane.

Use Case Examples

Use Case 6: NHTSA Scenario Descriptions

Summary & Intention

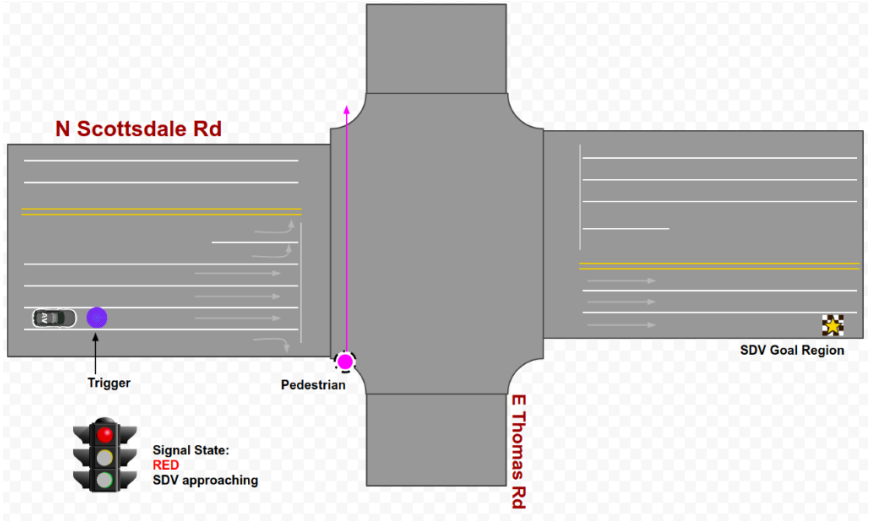
- Scenarios from National Highway Traffic Safety Administration test description formats should be fully coverable by an OpenSCENARIO 2.0 description

Description

- The ego car is travelling straight in the second rightmost lane at 40 mph (lane speed). The ego car is approaching a signalized intersection with a red signal state while a pedestrian is crossing at a speed of 1.2 m/s.

Example scenario

- Depictured on the right



Use Case Examples

Use Case 7: Replay Observed Traffic Situation

Summary & Intention

- A traffic camera observes certain traffic situations. This measured data will be transformed into an OpenSCENARIO2.0 file, that contains the concrete scenario description.

Description

- A highway section is observed from the bird perspective. In one period of observation, a cut-in maneuver is observed and this traffic situation shall be converted into a concrete scenario description.

Example scenario

- Following section of highway is observed.
- Data from different measurements channels are available (e.g. frame, x and y velocity, lane ID, etc.)
- A compiler transforms the measured data into a scenario file.

Use Case Examples

Use Case 8: Scenario definition for entering a roundabout

Summary & Intention

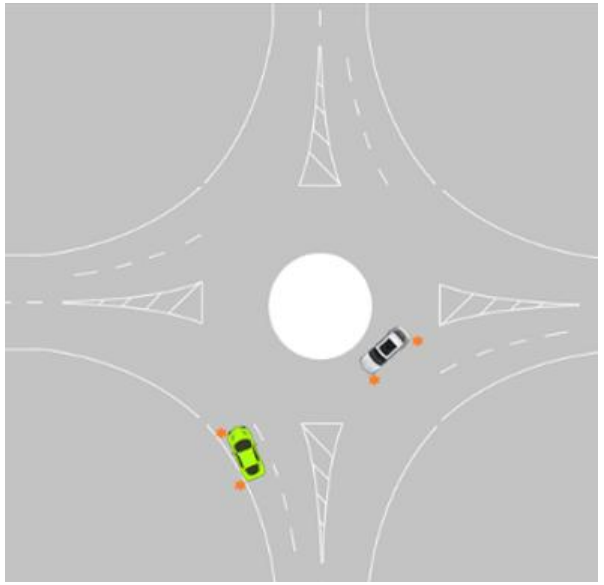
- A left turn at a roundabout should be described as a scenario

Description

- Ego Vehicle has arrived to the roundabout and is waiting for the actor to leave the roundabout before proceeding
- Acceptance criteria: Ego Vehicle waits for the actor to leave the roundabout / clear the way before proceeding

Example scenario

- Depicted on the right



```
scenario Scenario014:
    set_map("MFM_map.xodr")
    ego: car
        keep(ego.color == green)
        keep(ego.category == sedan)
        car1: car
        keep(car1.category == sedan)
        p: path
            path_type(p, roundabout)
            path_min_lanes(p, 2)
            path_min_arms(p, 4)
        set_weather: weather(kind: nice, temperature: 20c)
        do parallel:
            get_ahead_ego: ego.drive(p) with:
                speed(0mph, at: start)
                lane(1, in: segment1, at: start)
                lane(1, in: segment2, at: end)
            get_ahead_car1: car1.drive(p) with:
                speed(30mph, at: start)
                lane(-2, in: segment5, at: start)
                lane(1, in: segment2, at: end)
```

Use Case Examples

Use Case 9: High-level/low-level description of a motorcycle cut-in

Summary

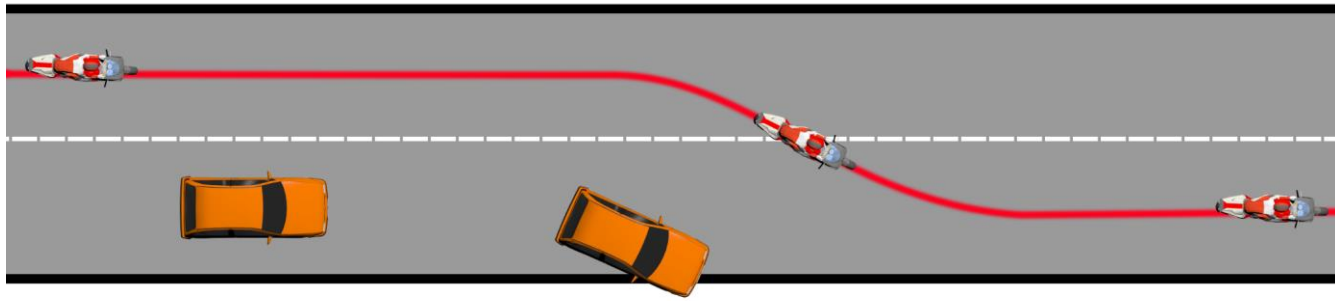
- The motorcycle cut-in as an example for high-level and low-level description

Description

- A motorcycle is driving on the left lane next to a car. The motorcycle cuts in. The car brakes suddenly and crashes.

Example scenario

- Depicted on the right/below



Abstract

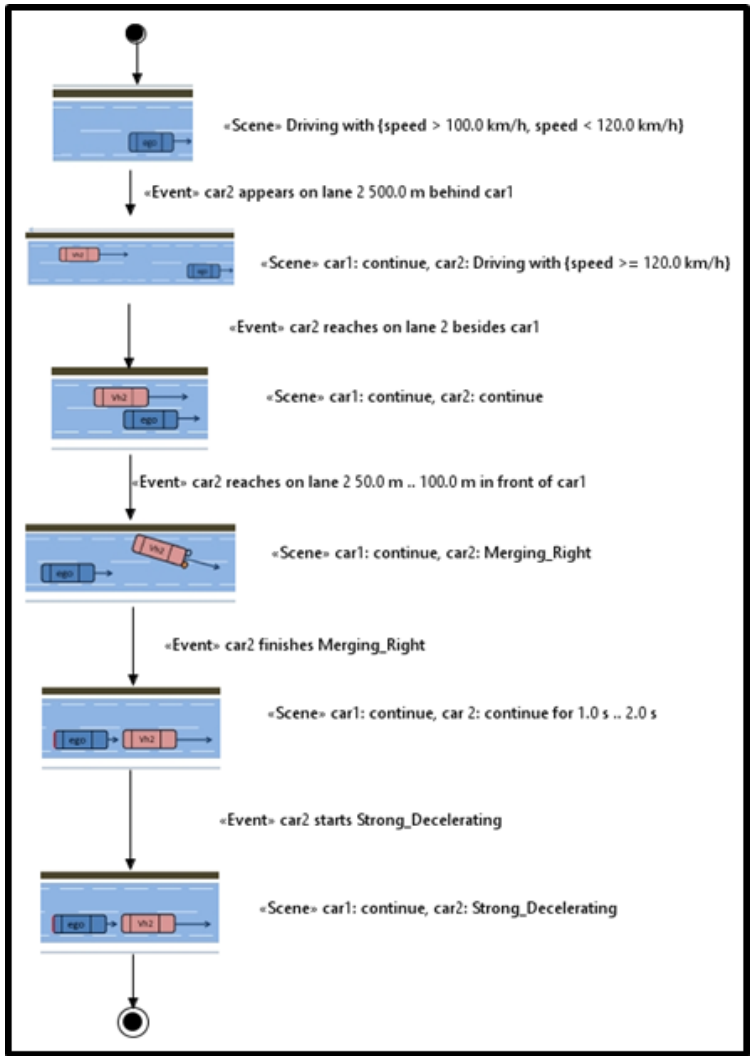
```
MotCyc: Motorcycle
PCar: PassengerCar

do serial():
    parallel:
        PCar.drive with:
            direction(straight)

        MotCyc.drive with:
            speed(faster_than: PCar)

       get_ahead: serial:
            left: MotCyc.drive with:
                direction(straight)
                lane(left_of: PCar,
at: start)
                position(behind: PCar,
                         at: start)
                position(front: PCar,
at: end)

             right: MotCyc.drive with:
                 direction(right, at:
start)
                 direction(straight,
at: end)
                 lane(same_as: PCar,
at: end)

    parallel:
        MotCyc.drive with:
            speed(faster_than: PCar)
            direction(straight)

        crash_and_stop: serial:
            brake: PCar.applyBrake
with:
                direction(right)

            stop: PCar.drive with:
                speed(0)
```

Concrete

```
MotCyc: Motorcycle
PCar: PassengerCar

do serial():
   parallel:
      PCar.drive with:
         speed(50kph)
         direction(straight)
         lane(0)

      MotCyc.drive with:
         speed(80kph)

      get_ahead: serial:
         left: MotCyc.drive with:
            direction(straight)
            lane(1)
            position(20m, behind: PCar,
                     at: start)
            position(2m, front: PCar,
at: end)

         right: MotCyc.drive with:
            direction(30degrees, at:
start)
            direction(straight, at:
end)
            lane(same_as: PCar, at:
end)

   parallel:
      MotCyc.drive with:
         speed(80kph)
         direction(straight)

      crash_and_stop: serial:
         brake: PCar.applyBrake with:
            direction(45degrees)

         stop: PCar.drive with:
            speed(0)
```

Use Case Examples

Use Case 10: Scenario usage for SOTIF



Summary

- Identification of hazards and their causal analysis to identify limitations, weaknesses and triggering conditions

Description

- The safety analyst uses established techniques to find out hazards of the automated vehicle
- The ability to specify abstract/functional scenarios, specifying only the details and objects that are relevant and only ranges for parameters, allows the safety analyst to concentrate on his core activities instead of forcing him to become a simulation professional

Example scenario

- Is it also critical if the new vehicle merges 200 m in front of the ego vehicle?
- What if the deceleration occurs only 10 s after merging in, so that the ego vehicle had enough time to qualify and adapt?
- Is the shape, color, or material of the vehicle in front a factor that makes the situation better or worse?

Summary

Summary and future

Summary

- 9 user story categories with 33 user stories
- 10 use case examples

Future

- During the standardization project, additional use cases/user stories will be identified
- Additional project members bring in new ideas
- During the work on existing use cases/user stories, missing ones appear
- Also modifications/deletions are possible, if necessary

Thank you for your attention!

Any questions?

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