Scenarios@run.time – Distributed Execution of Specifications on IoT-Connected Robots

10th International Workshop on Models@run.time at MODELS 2015, Ottawa, Canada

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SOFTWARE ENGINEERING

29 September 2015

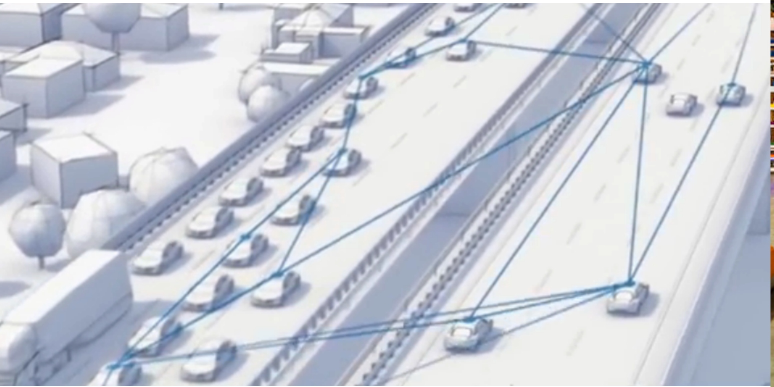
Leibniz Universität Hannover

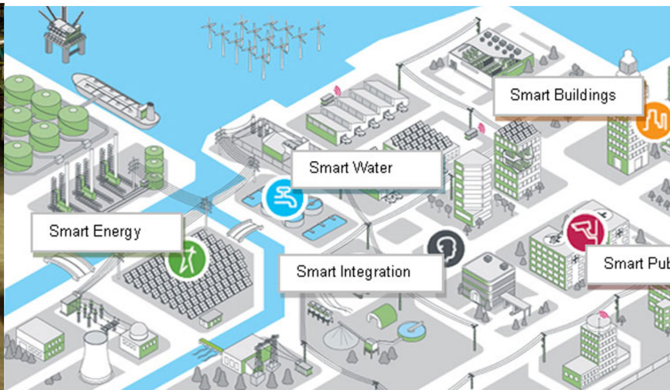
Student Project UbiBots 2015

Student Project Website: http://ubibots2015.scenariotools.org/
Youtube Video: http://youtu.be/g0hcGSYC2Wk
ScenarioTools Website: http://scenariotools.org

Motivation

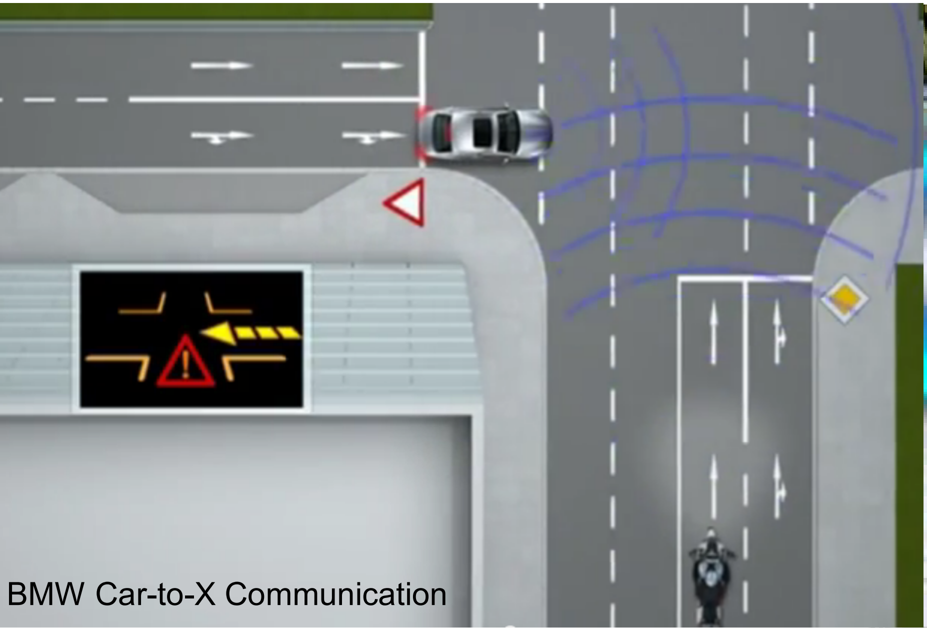
- **Examples**: CarToX, Intelligent Factories, Smart Cities, …
  - **reactive**: software continuously reacts to environment events
  - **cyber-physical**: multiple software components communicate to control processes in the physical world
  - **ubiquitous**: software interacts with users in diverse ways
  - **safety-critical**: failures can cause damage or cost lives
  - **dynamic structures**:
    - **relationships** between objects **change** (real and virtual)
    - **relationships affect** the communication behavior and **vice versa**





Example: An Advanced CarToX Driver-Assistance System

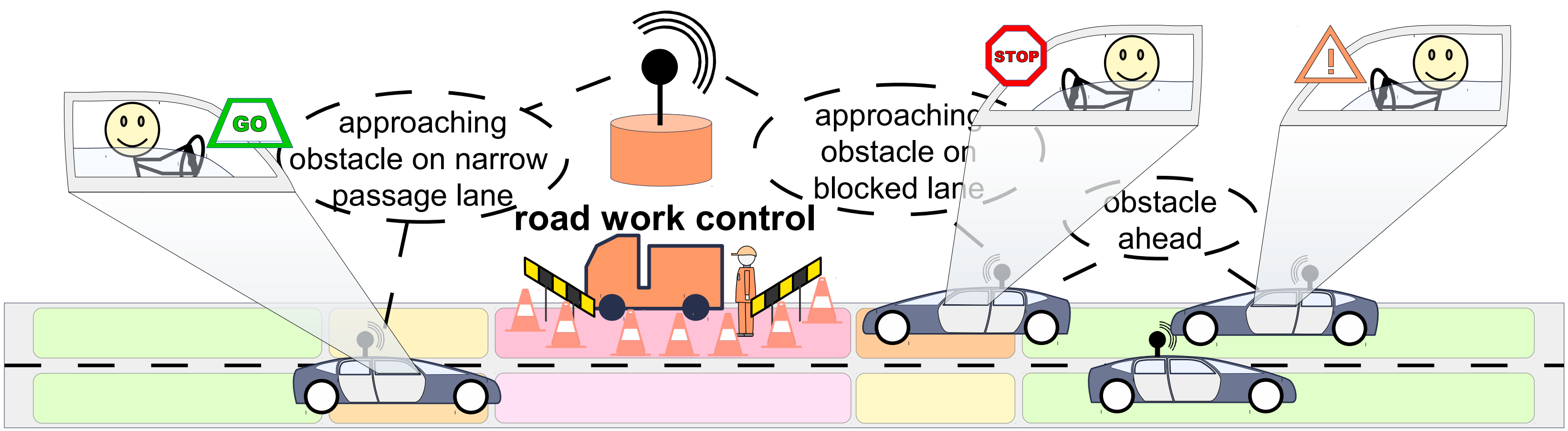
- Car-to-Car / Car-to-Infrastructure (**Car-to-X**) communication
  - provides advanced driver-assistance features
  - controls traffic more efficiently
- Examples:


BMW Car-to-X Communication


https://www.car-2-car.org/

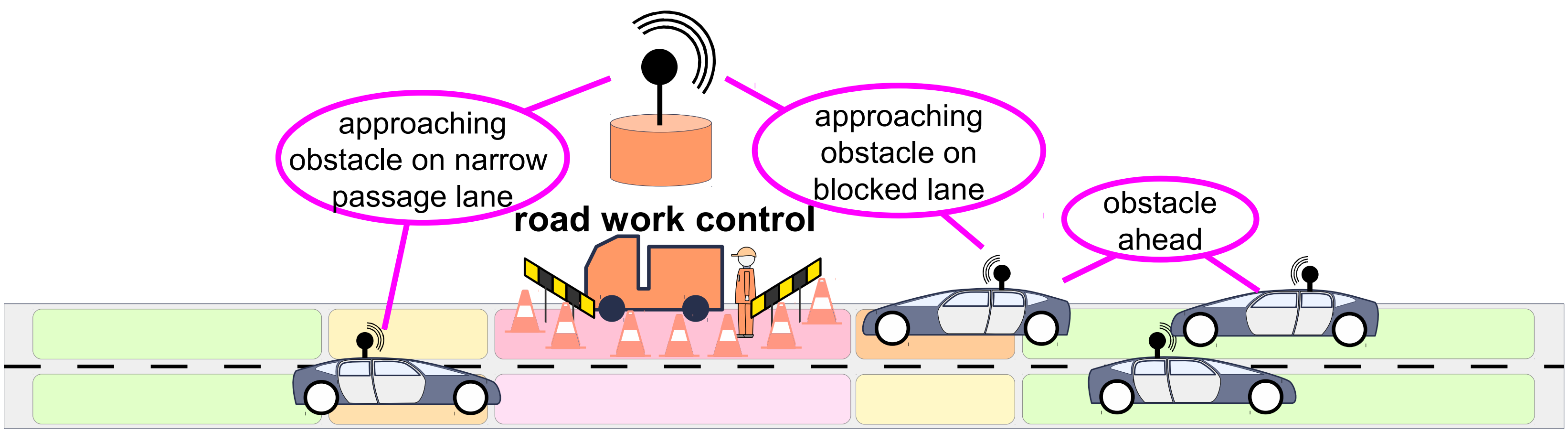
Example CarToX Use Case: coordinated passage of a road work site

- One lane of a two-lane street is blocked by road works
- cars communicate with a control station for a safe passage
  - instead of using traffic lights
  - an on-board display shows drivers whether they are allowed to enter the narrow passage or not



Example CarToX Use Case: coordinated passage of a road work site

- What kinds of dynamism do we see here?
  - **Message-based communication** of cars and control station



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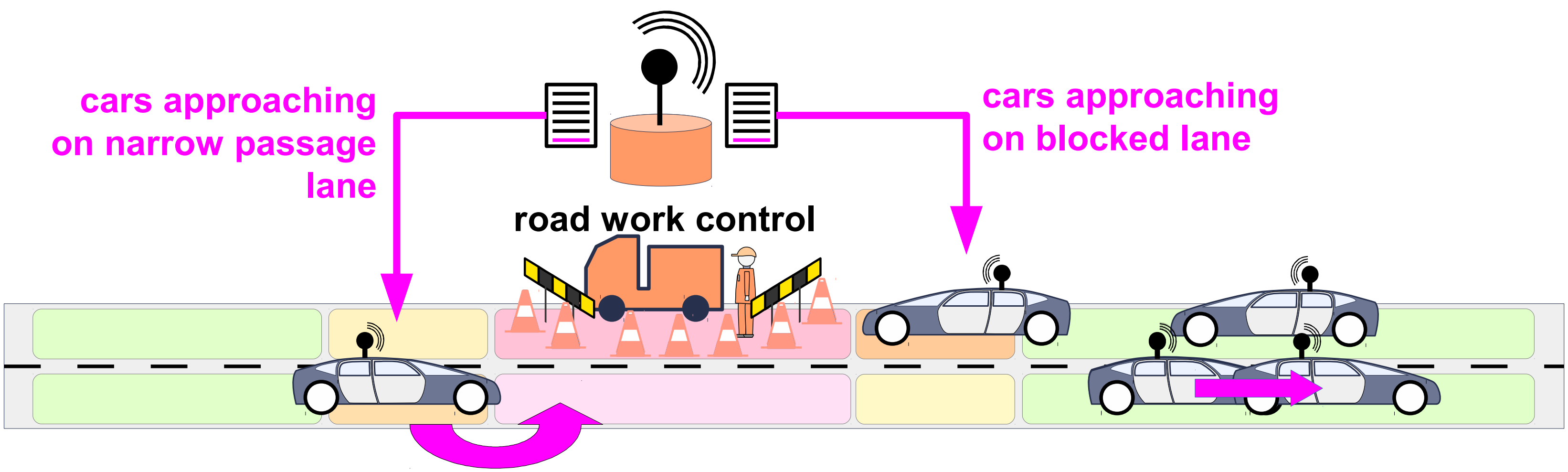
- What kinds of dynamism do we see here?
  - **Message-based communication** of cars and control station
  - Structural dynamism:
    - **Physical**: cars move along different sections of the road
    - **Physical**: cars change their relative position relationships
    - **Virtual**: the control station registers approaching cars



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  - **Message-based communication** of cars and control station
  - Structural dynamism:
    - **Physical**: cars move along different sections of the road
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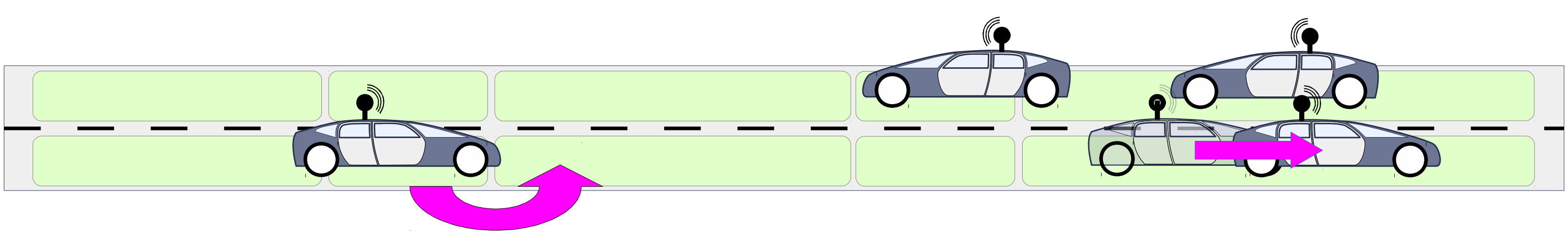
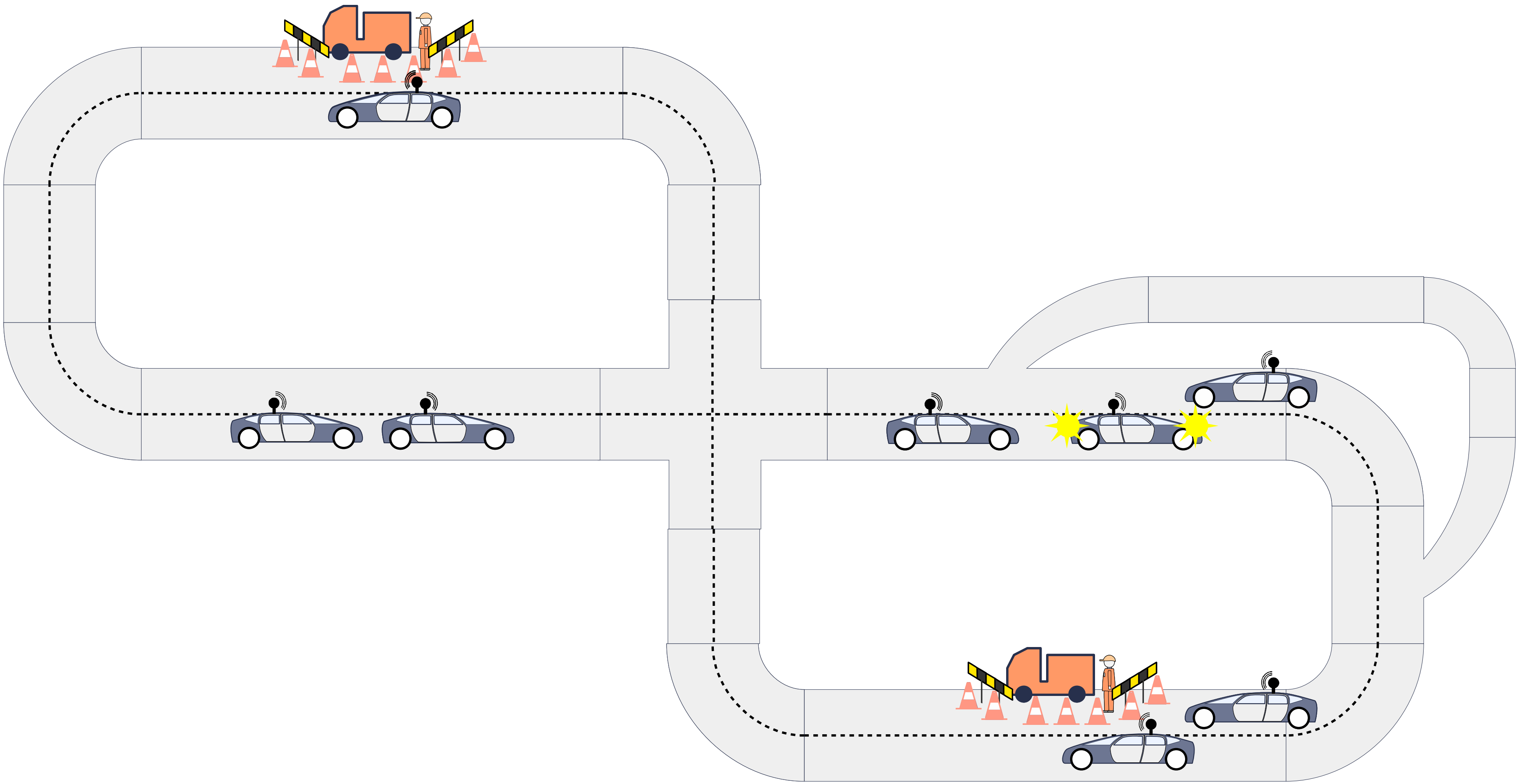
    - **Virtual**: the control station registers approaching cars
    - **Physical**: even road works may appear and disappear



CarToX-System

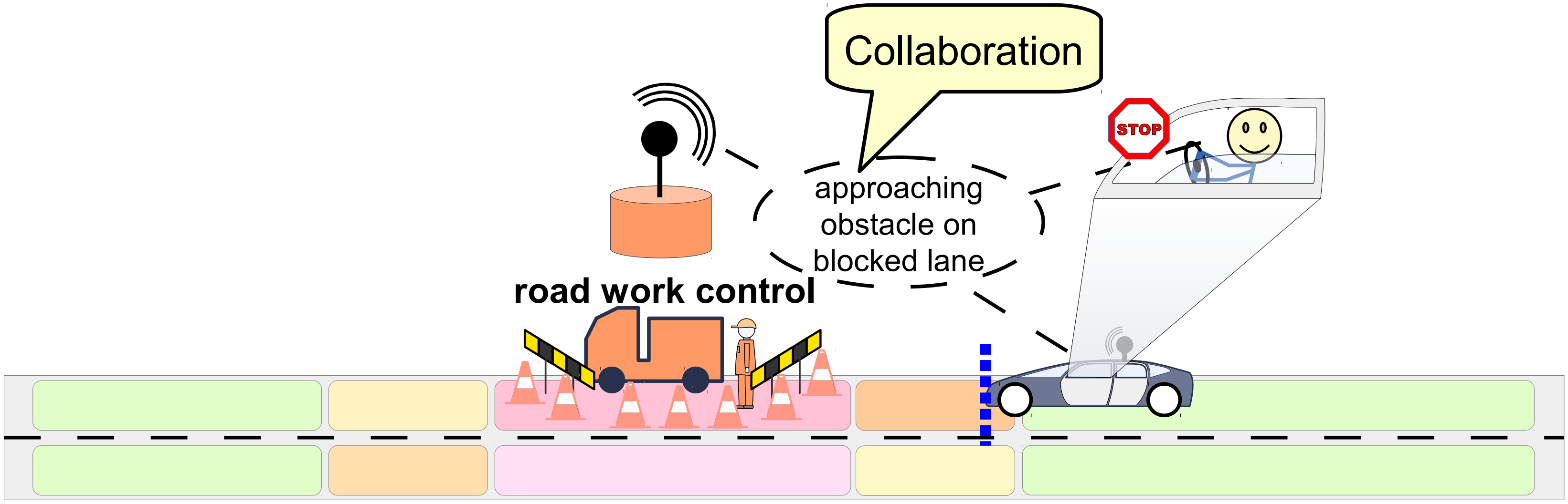
- **Question**: How would you approach the design of the software for such a system?



Collaboration: “approaching obstacle on blocked lane”

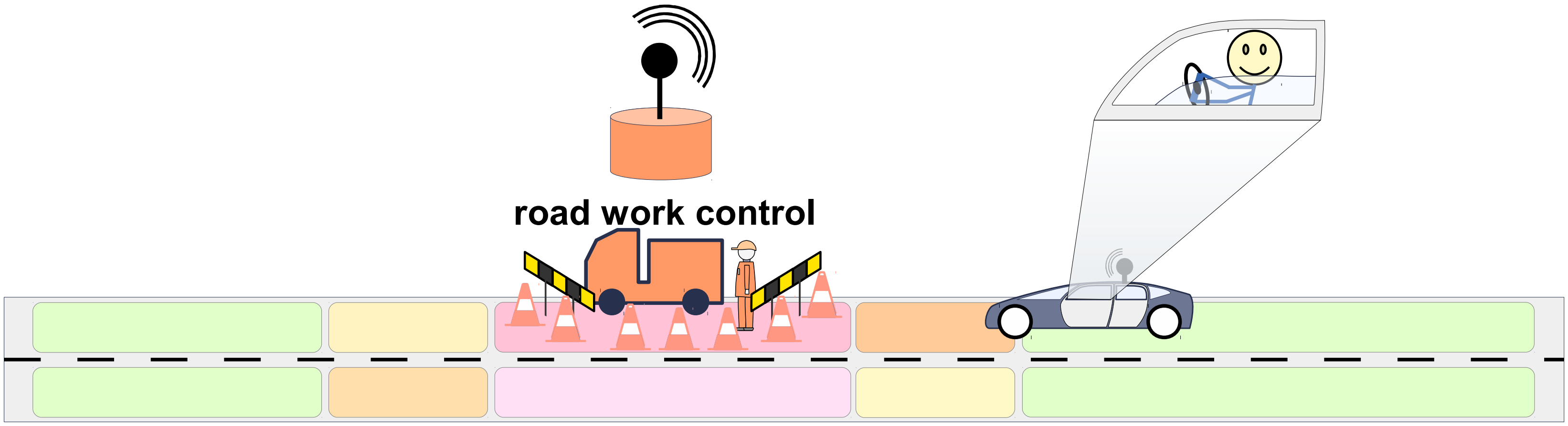
- Identify the **different situations** in which system and environment objects interact to fulfill a certain functionality
  - We call them **Use Cases** or ***Collaborations***

- Describe what the objects **may**, **must**, and **must not** do in the form of **scenarios**



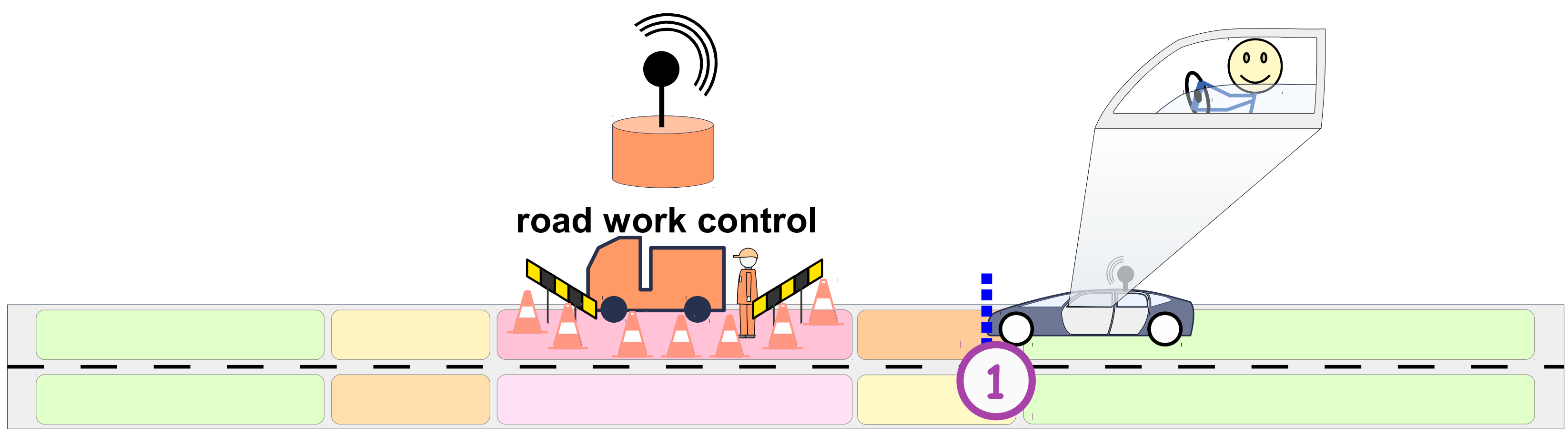
Collaboration: "approaching obstacle on blocked lane"

- Scenario "Dashboard Of Car Approaching On Blocked Lane Shows Stop Or Go":



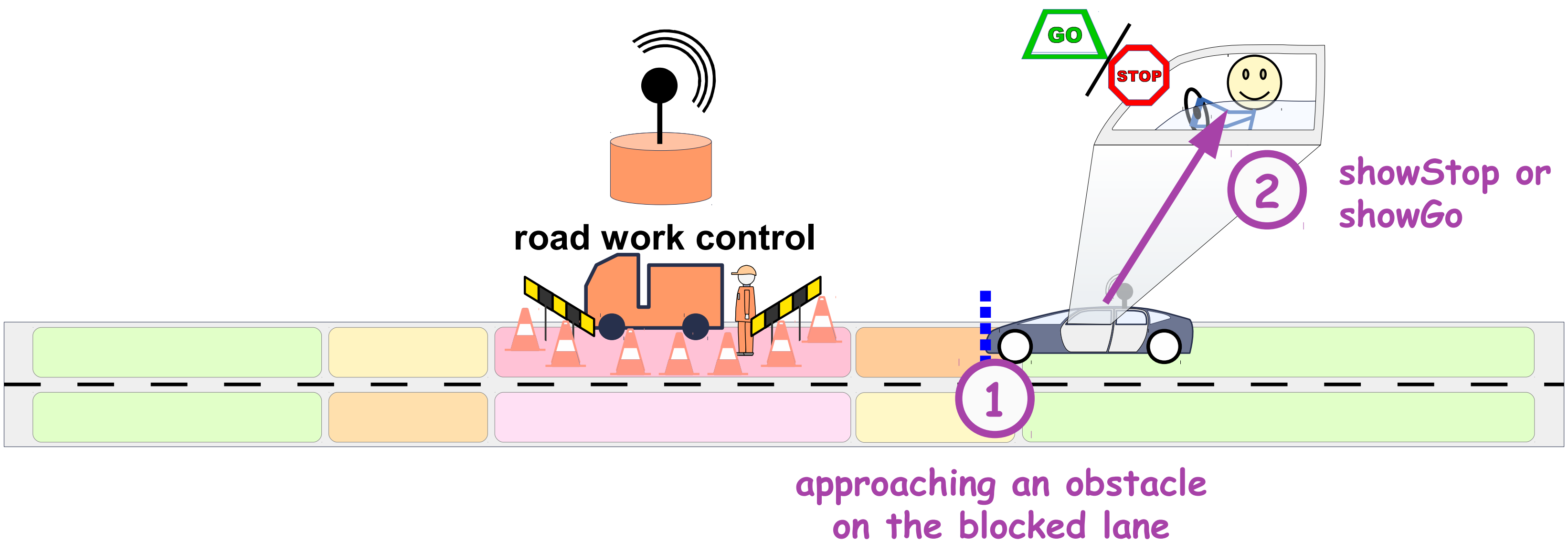
Collaboration: “approaching obstacle on blocked lane”

- Scenario “Dashboard Of Car Approaching On Blocked Lane Shows Stop Or Go”:
  1) When approaching an obstacle on the blocked lane



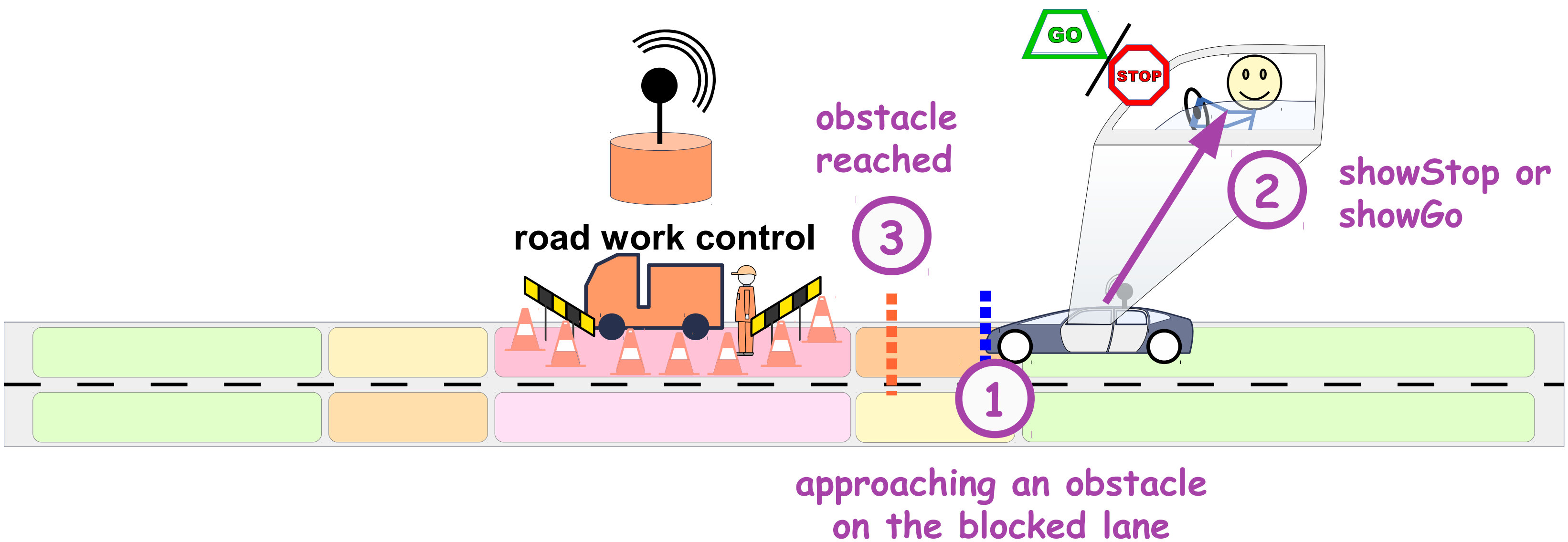
Collaboration: "approaching obstacle on blocked lane"

- Scenario "Dashboard Of Car Approaching On Blocked Lane Shows Stop Or Go":
  1) When approaching an obstacle on the blocked lane
  2) Then the dashboard must indicate to STOP or to GO



Collaboration: “approaching obstacle on blocked lane”

- Scenario “Dashboard Of Car Approaching On Blocked Lane Shows Stop Or Go”:
  1) When approaching an obstacle on the blocked lane
  2) Then the dashboard must indicate to STOP or to GO
  3) Before the car finally reaches the obstacle



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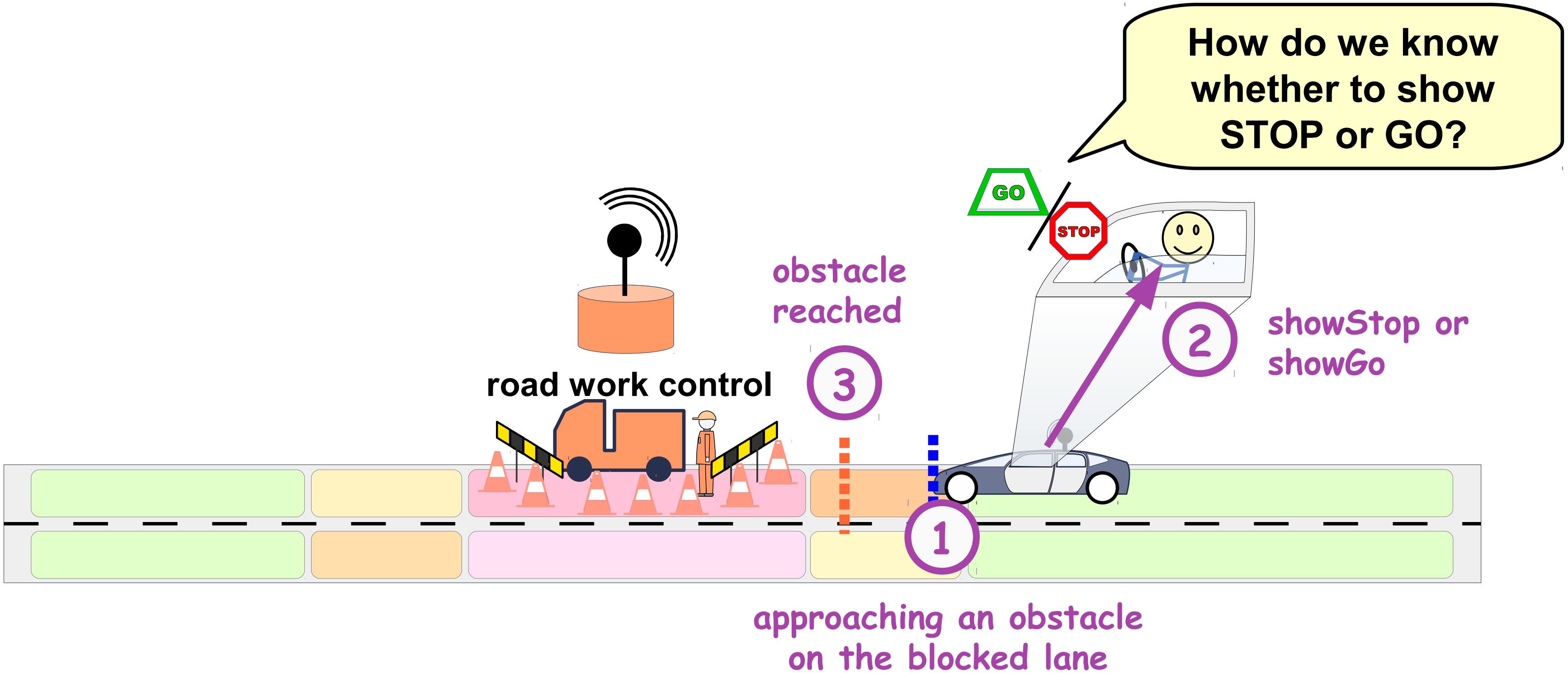

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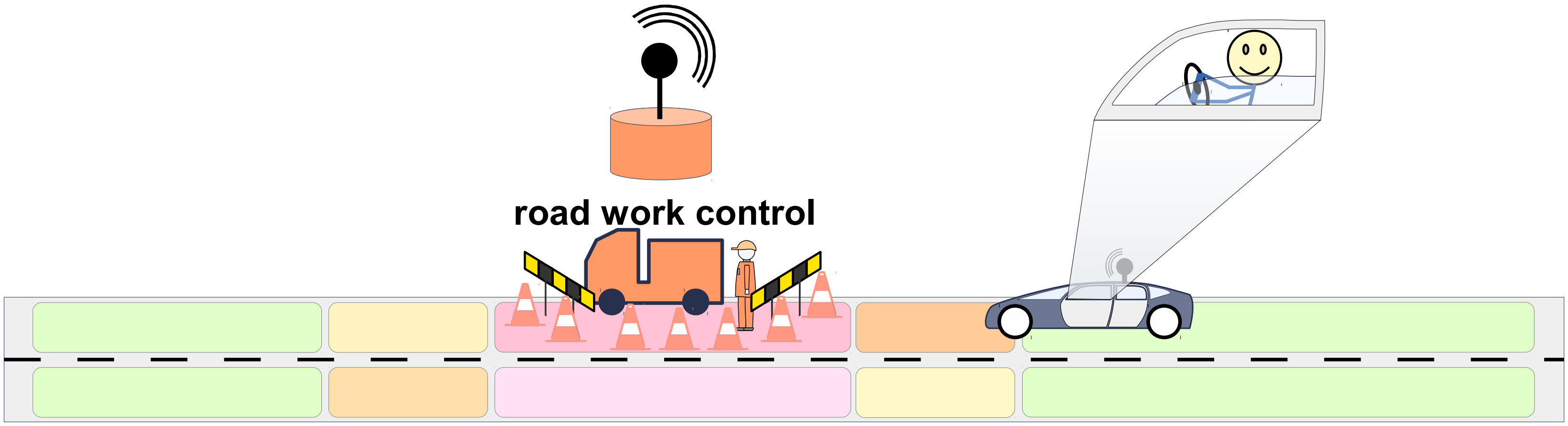
- Scenario “Control Station Checks for Car Approaching On Blocked Lane Entering Allowed Or Not”:



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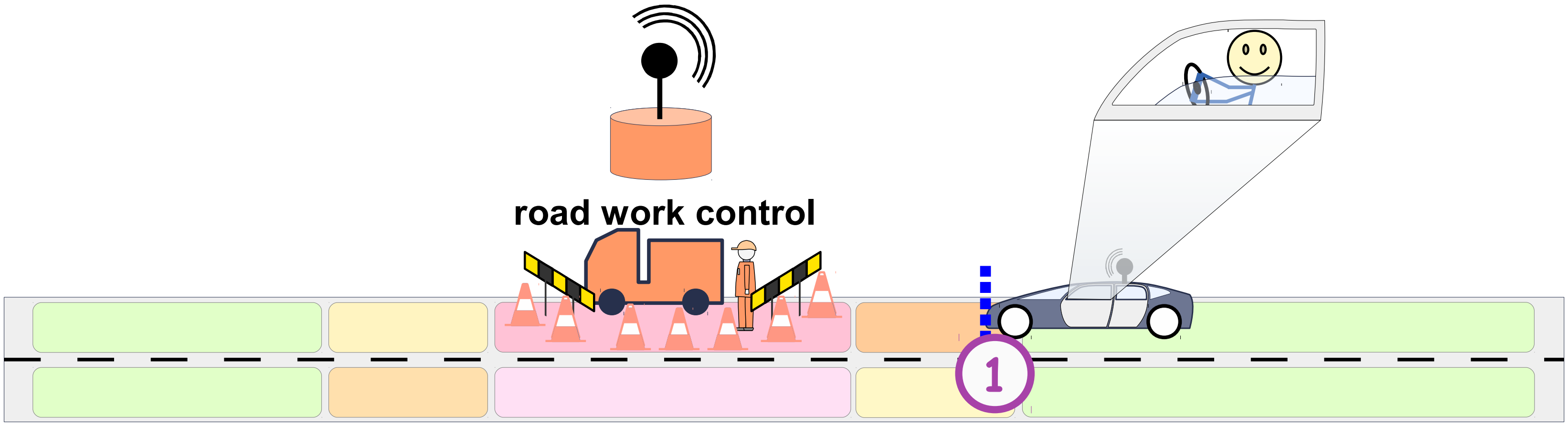
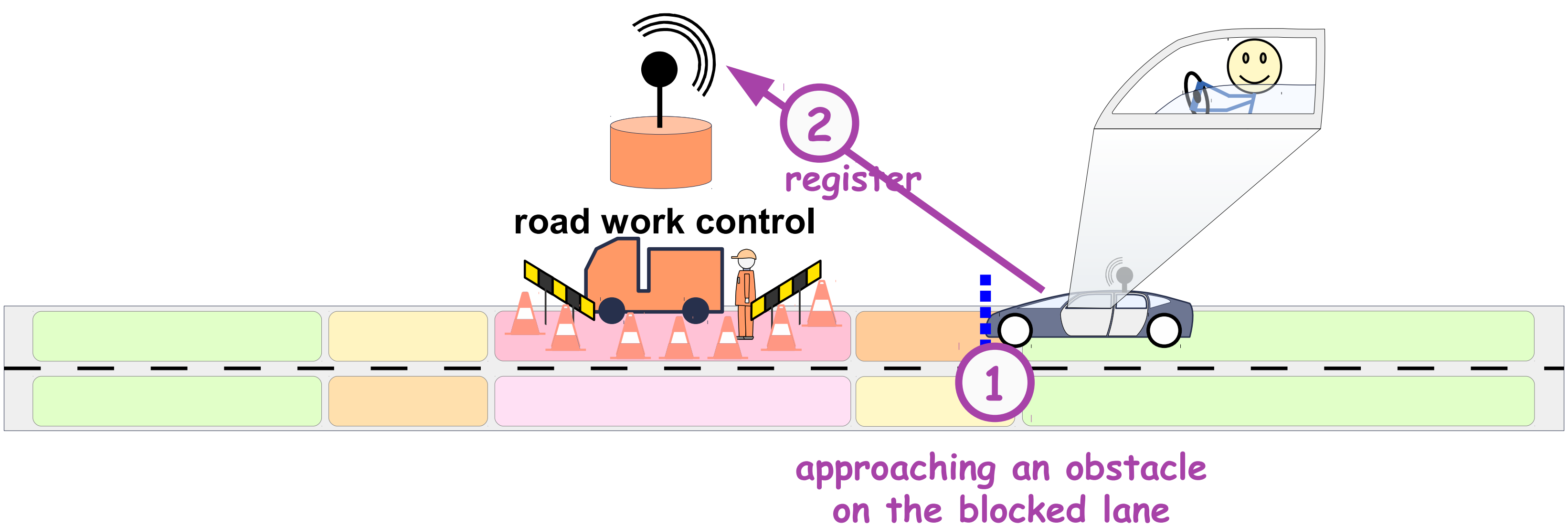


Collaboration: "approaching obstacle on blocked lane"

- Scenario "Control Station Checks for Car Approaching On Blocked Lane Entering Allowed Or Not":
  1) When approaching an obstacle on the blocked lane
  2) The car must register at the obstacle's control station



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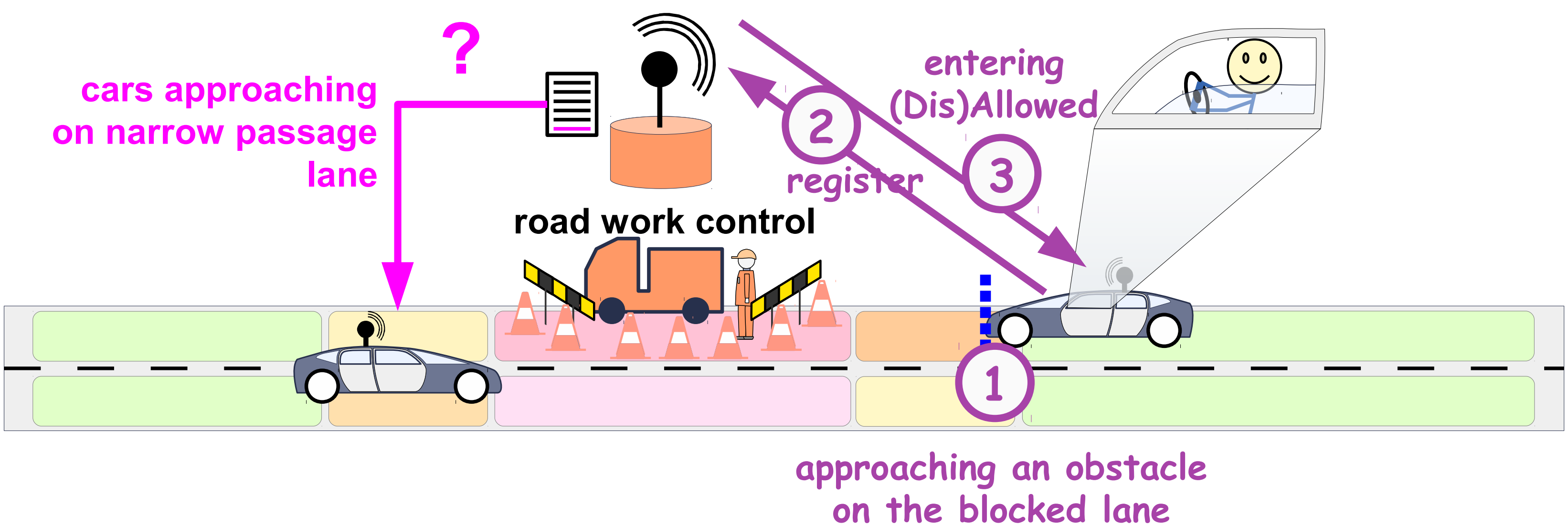
  - otherwise allow it



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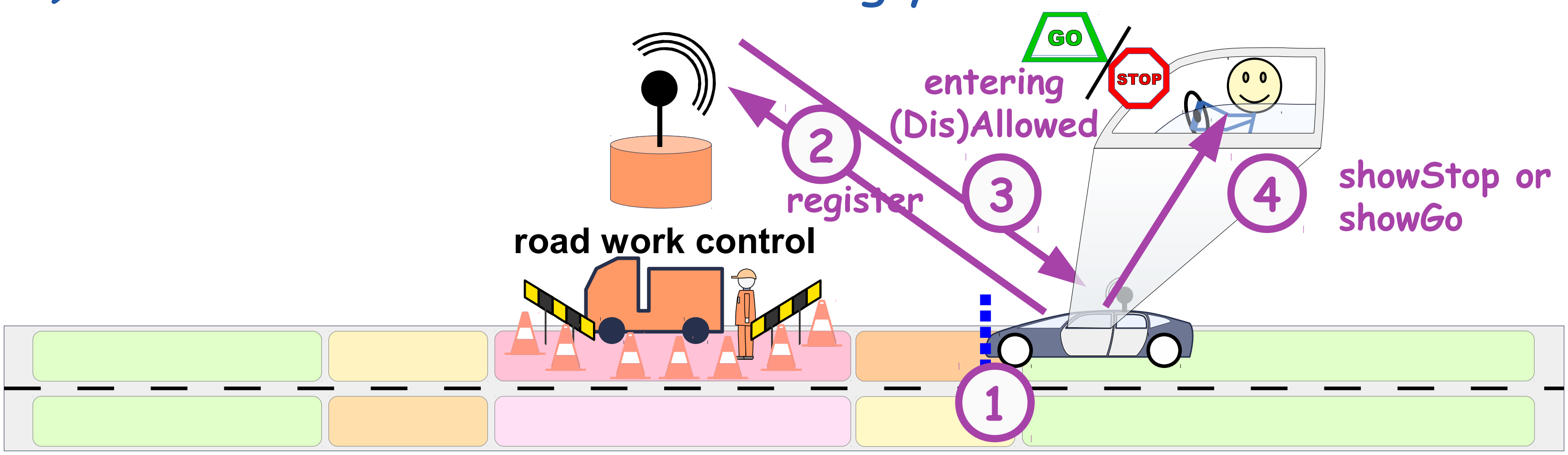
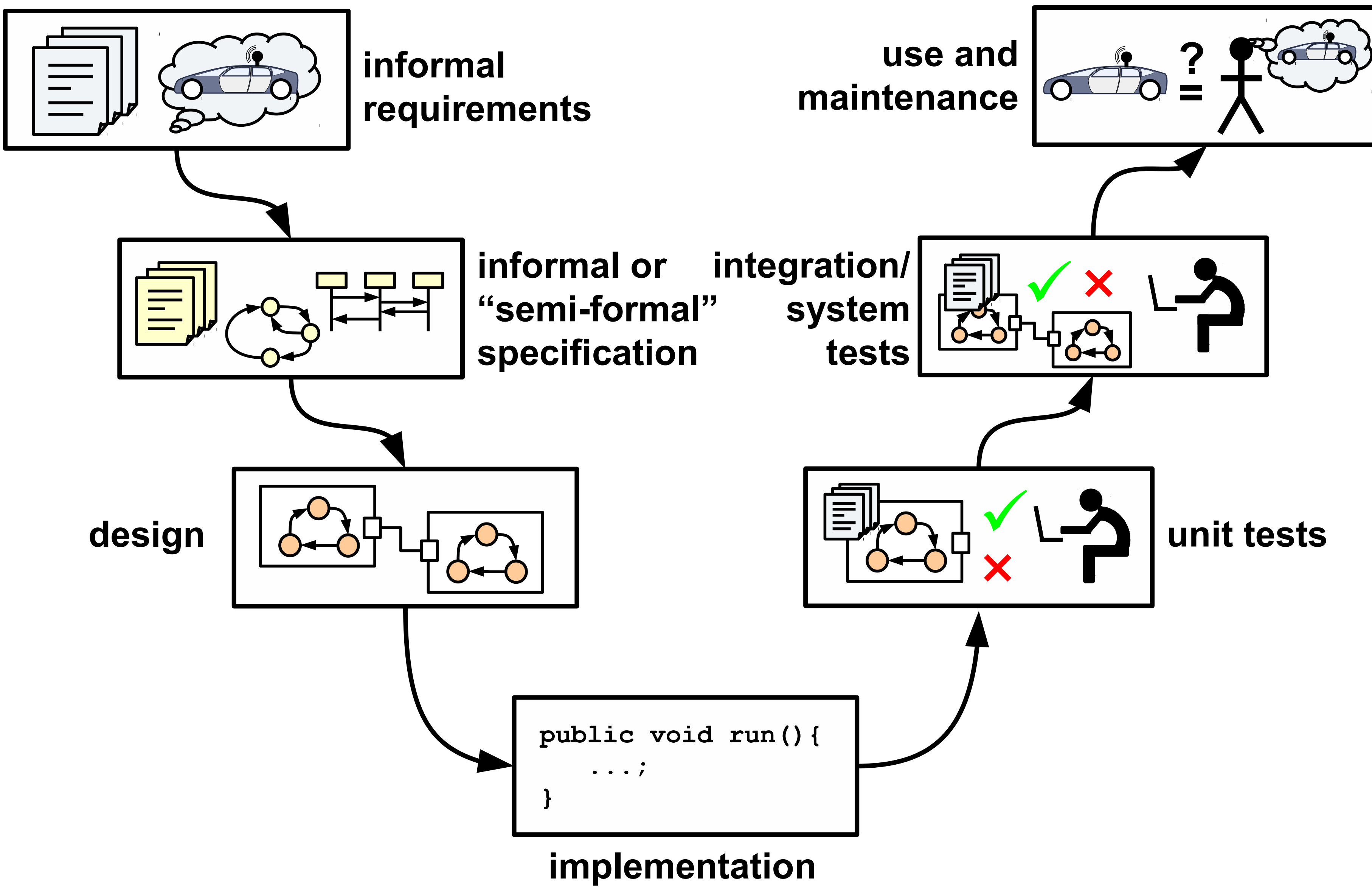
  3) If there is an approaching car in or before the narrow passage area: disallow the car entering the narrow passage
     - otherwise allow it
  4) Then show STOP/GO accordingly on the driver's dashboard



A typical Software/Systems Development Process...



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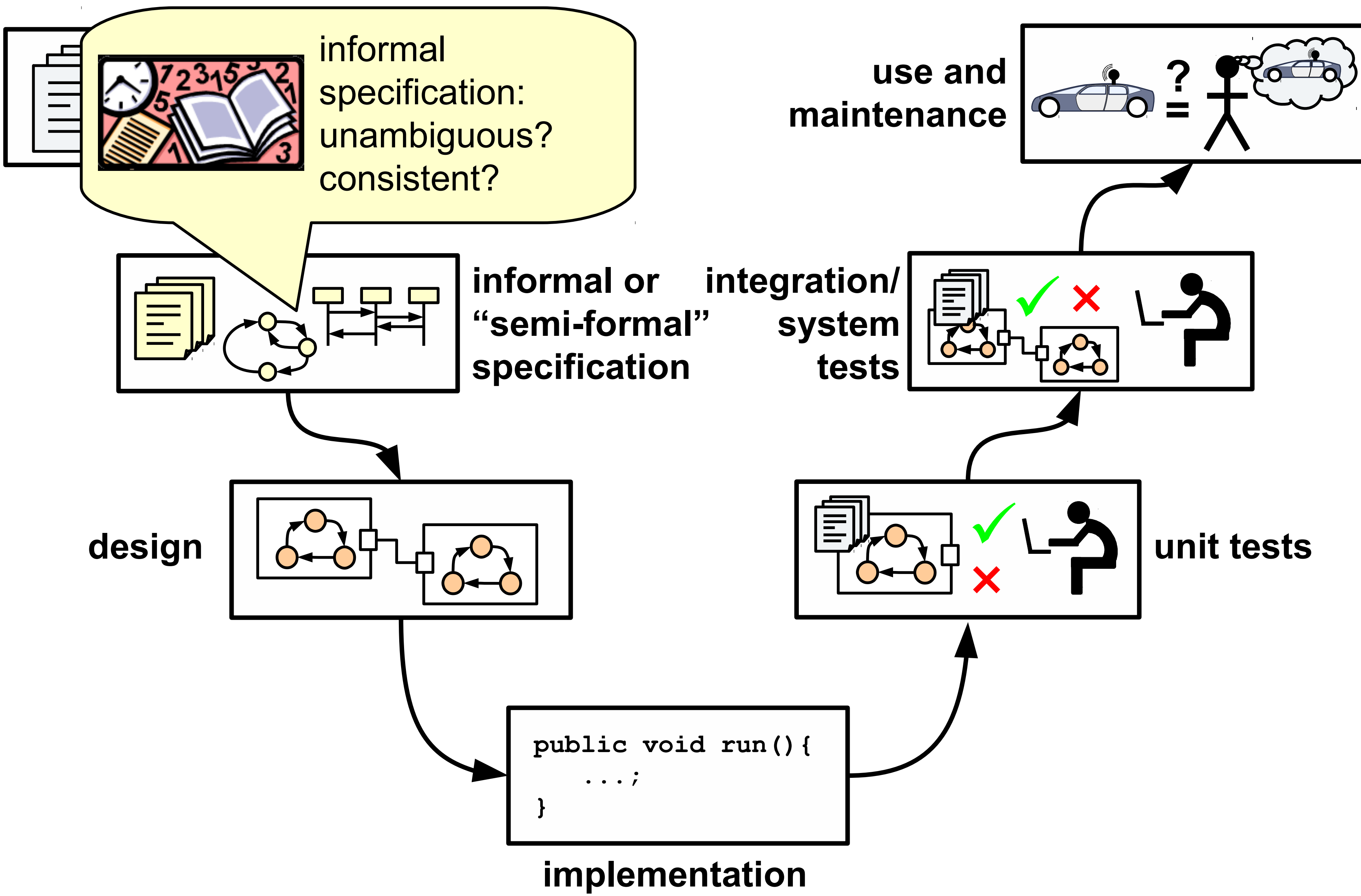

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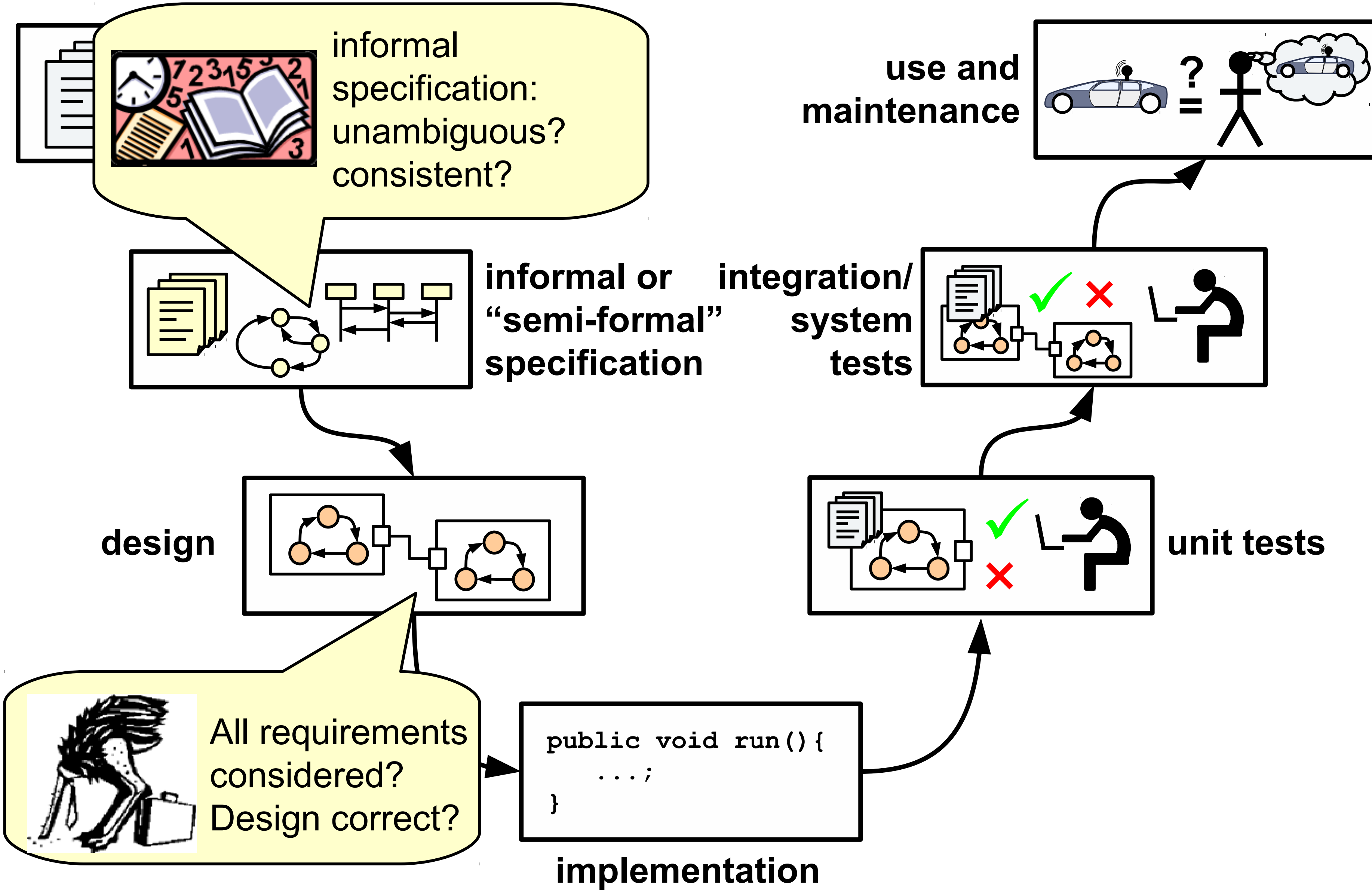

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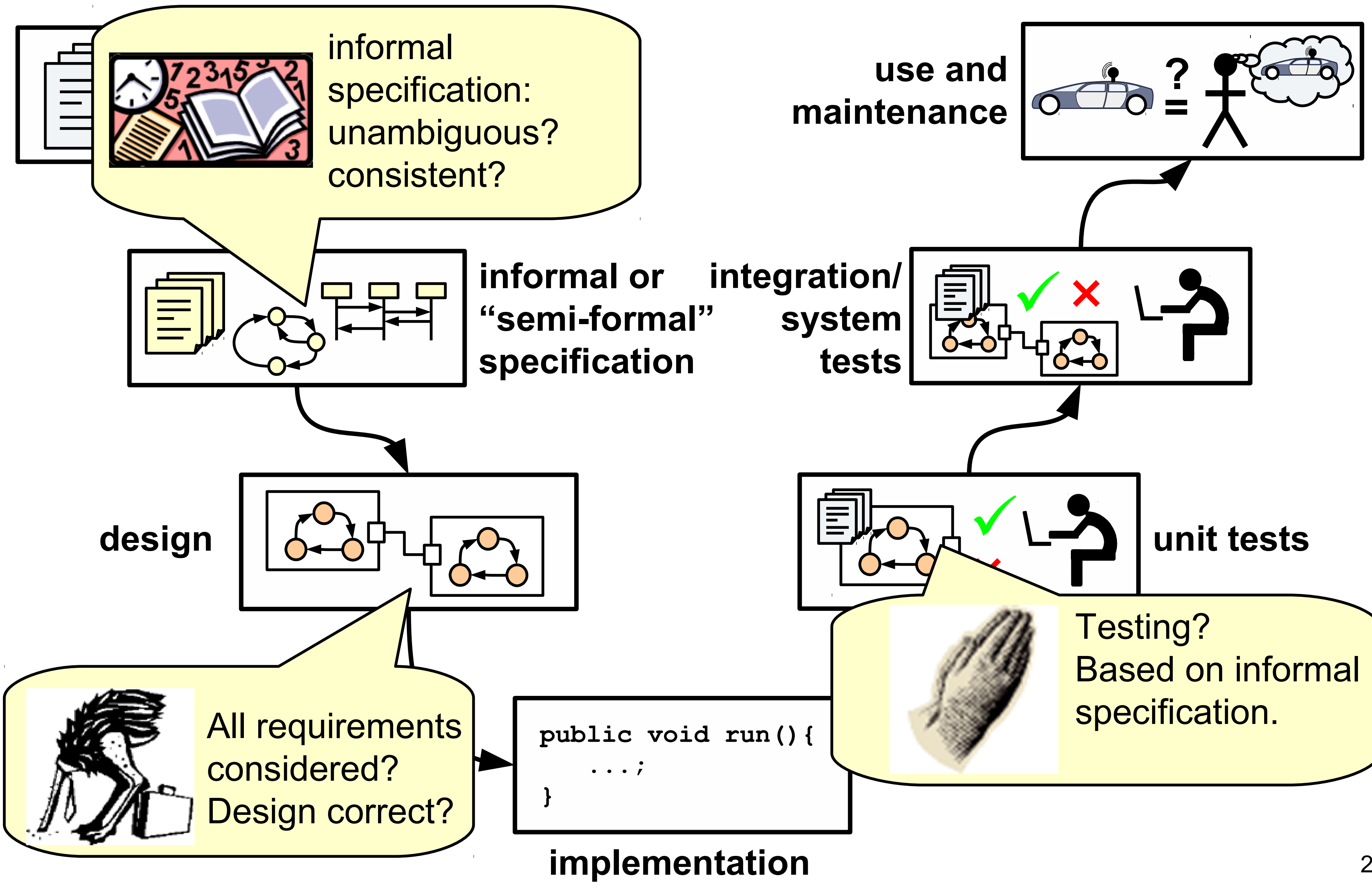

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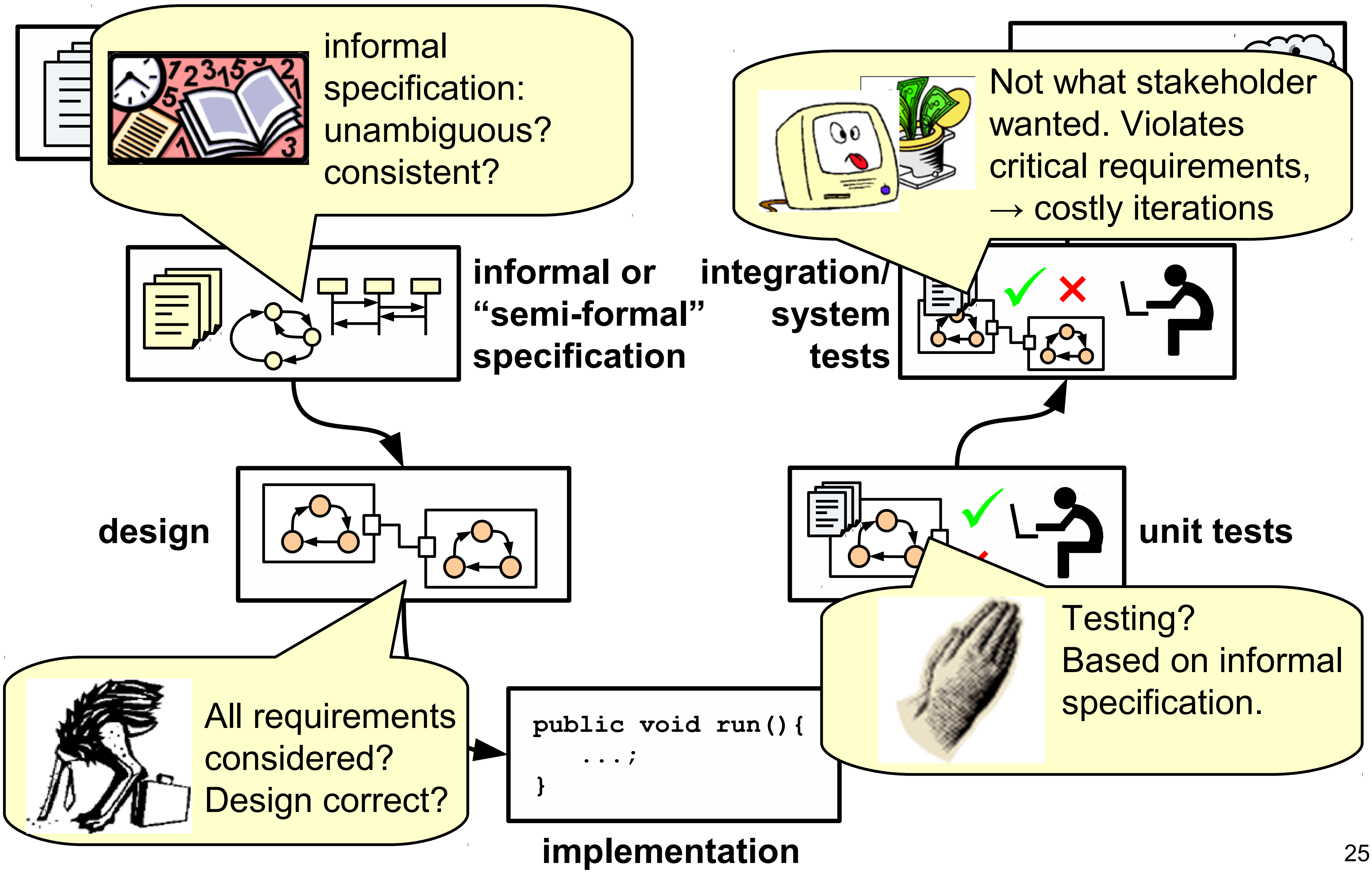
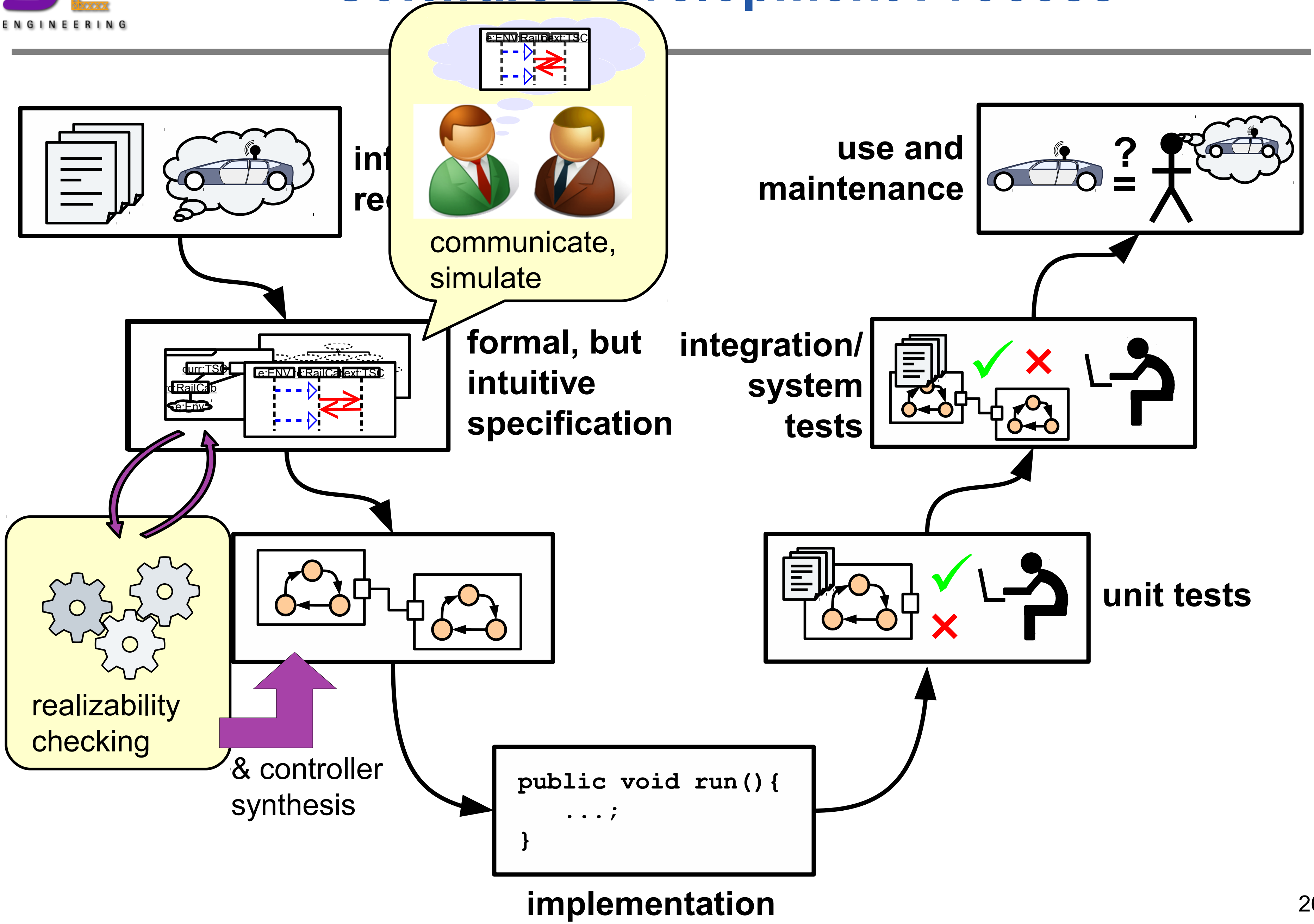


Software Development Process



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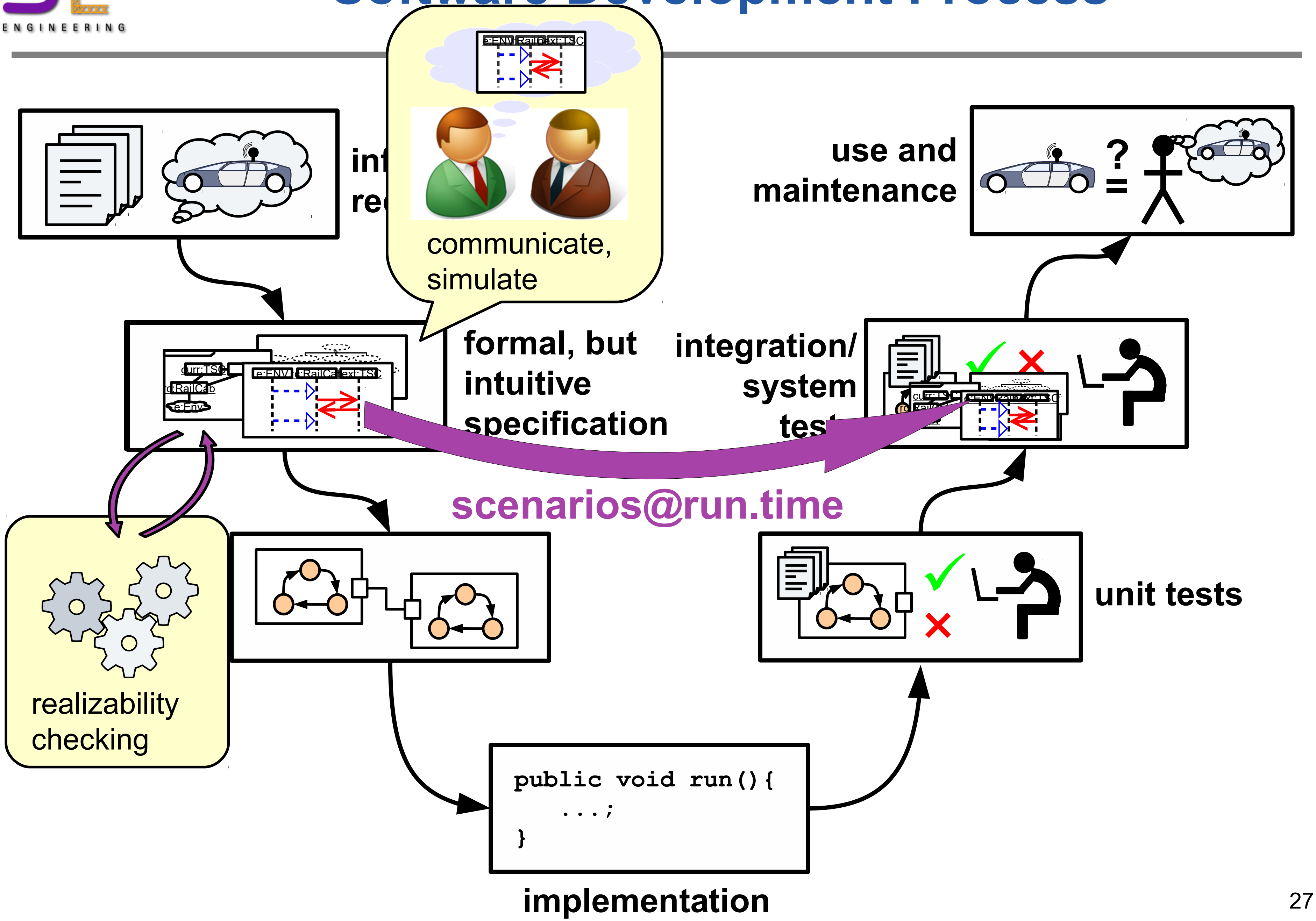


Scenario Design Language (SDL)

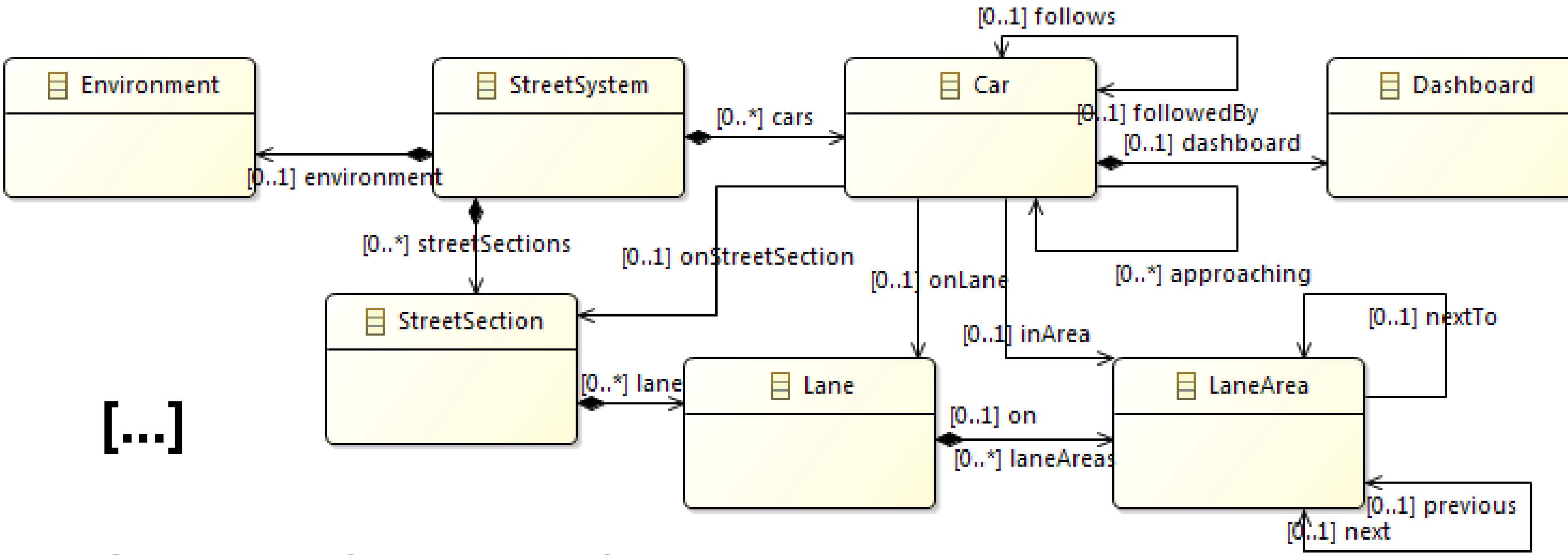
- Textual language based on **Live Sequence Charts (LSCs)**
- **Collaborations** describe, by a set of roles, a structure of objects that collaborate to fulfill a certain functionality

```
collaboration ApproachingObstacleOnBlockedLane{
        dynamic role Environment env
        dynamic role Car car
        dynamic role Dashboard dashboard
        ...
```

- **Scenarios** describe properties that must be satisfied by all message-based interactions of objects

```
specification scenario DashboardOfCarApproachingOn
                                    -BlockedLaneShowsStopOrGo{
        message env->car.approachingObstacleOnBlockedLane()
        ...
}
```

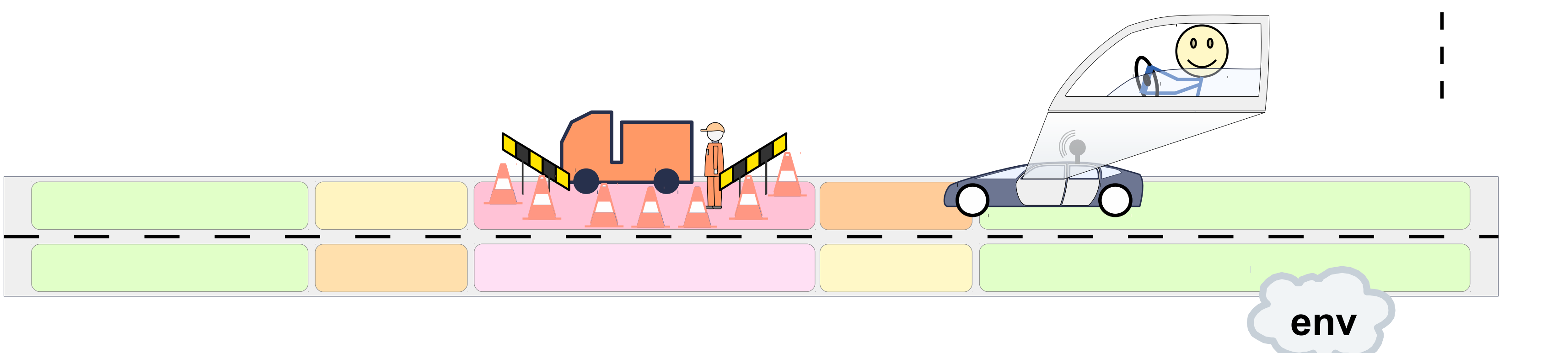
The Object System



[...]

- SDL specifications refer to systems of objects (instances of a class model)

<<instanceof>>



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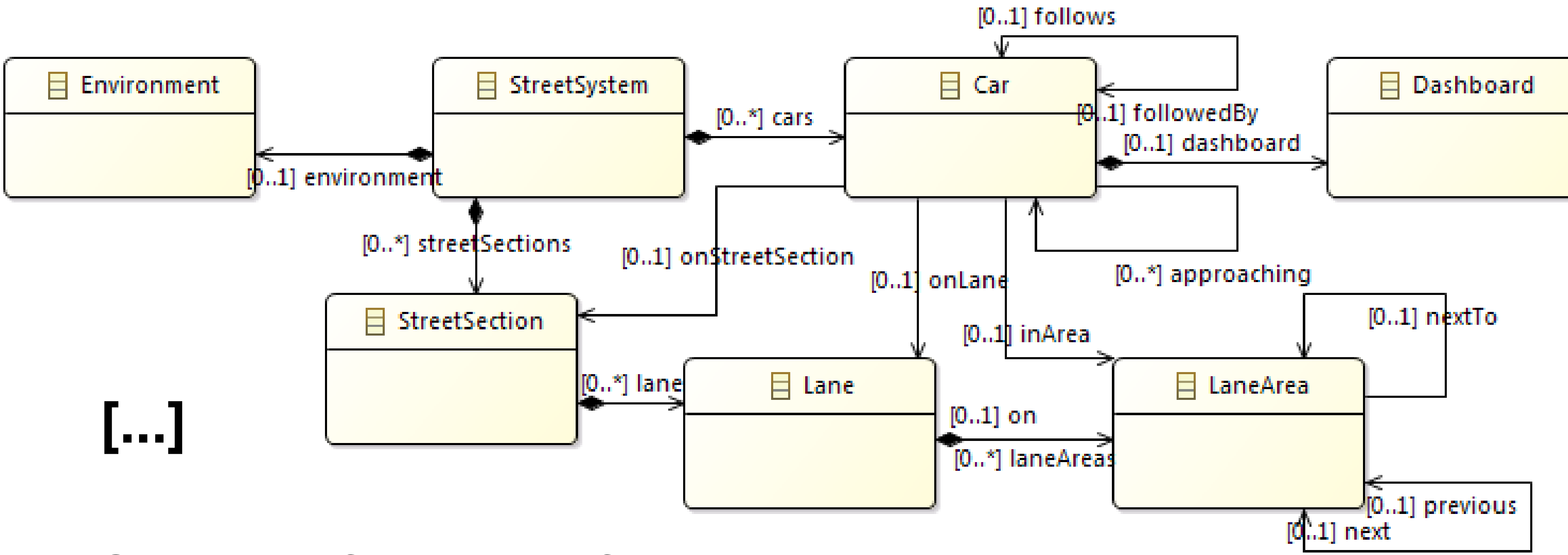
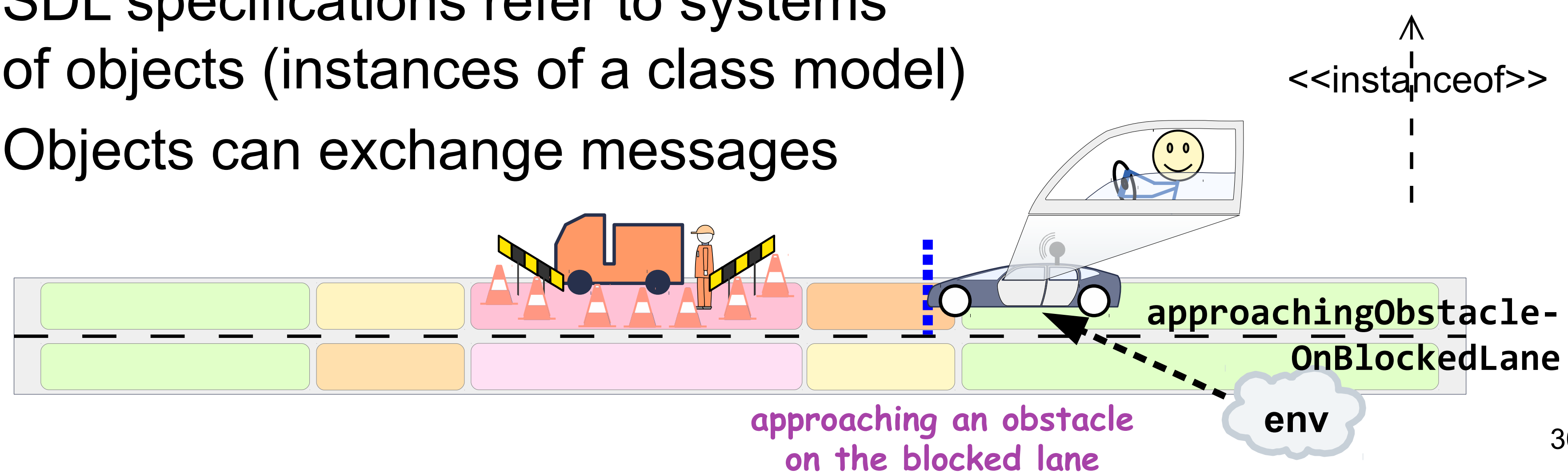


- SDL specifications refer to systems of objects (instances of a class model)
- Objects can exchange messages



Scenario Design Language

- Formalizing our first scenario:

```
specification scenario DashboardOfCarApproachingOn
                             -BlockedLaneShowsStopOrGo
with dynamic bindings [
   bind dashboard to car.dashboard
]{
   message env->car.approachingObstacleOnBlockedLane()
   alternative{
      message strict requested car->dashboard.showGo()
   } or {
      message strict requested car->dashboard.showStop()
   }
   message env->car.obstacleReached()
}
```

- With the modalities **strict** and **requested**, we can express what may, must, and must not happen

Scenario Design Language

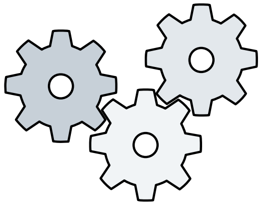
- Formalizing our second scenario:

```
specification scenario ControlStationChecksForCarOnBlockedLane
with dynamic bindings [...]{
   message env->car.approachingObstacleOnBlockedLane()
   message strict requested car->obstacleControl.register()
   alternative if [
        obstacleControl.carsOnNarrowPassageLaneApproaching.isEmpty()
   ] {
      message strict requested obstacleControl->car.enteringAllowed()
      message strict requested car->dashboard.showGo()
   } or if[
      !obstacleControl.carsOnNarrowPassageLaneApproaching.isEmpty()
   ] {
      message strict requested obstacleControl->car.enteringDisallowed()
      message strict requested car->dashboard.showStop()
   }
}
```

Simulation via Play-Out

- An SDL specification can be executed via p**lay-out**
  – an executable interpretation of the scenarios

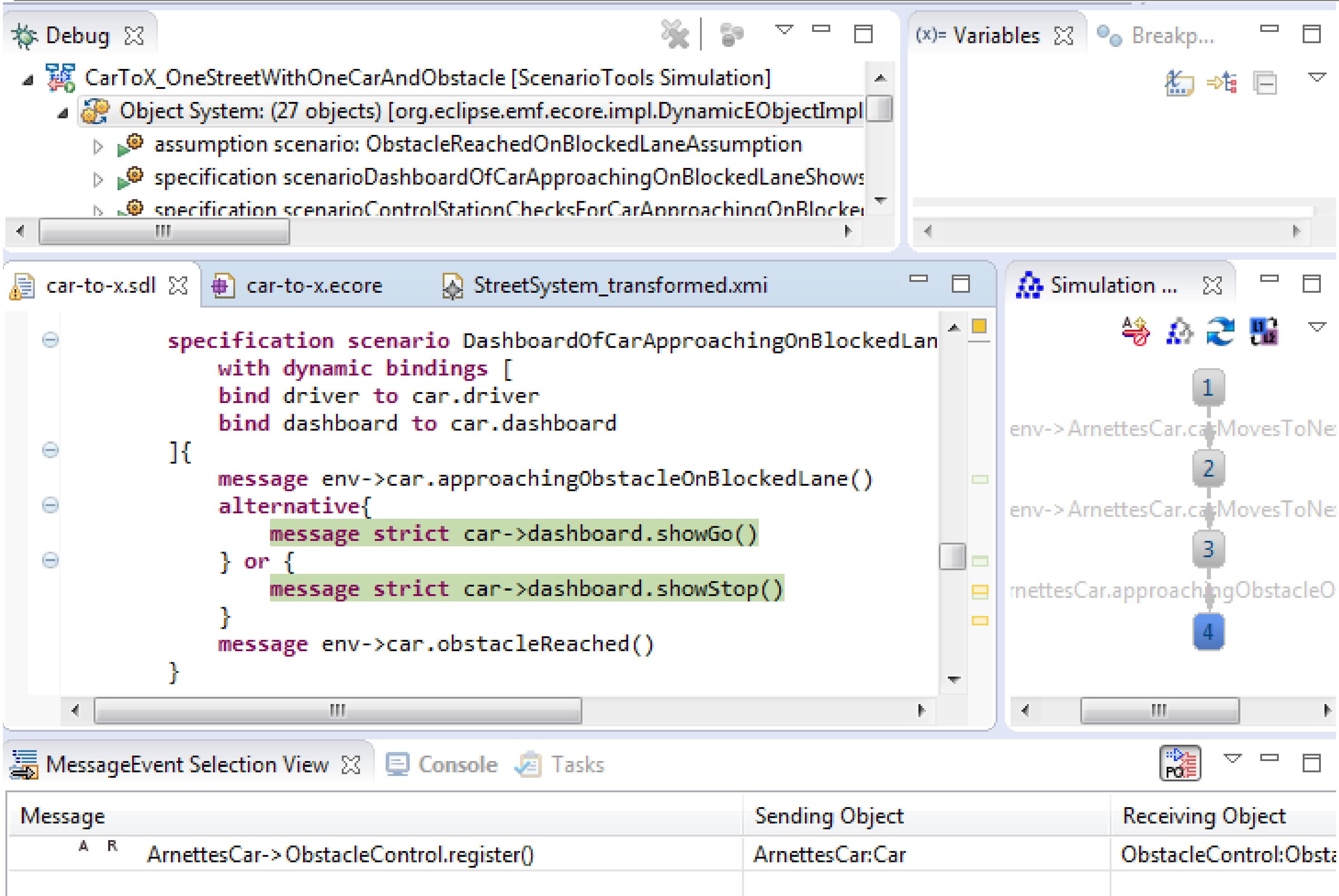
- This can be used for **simulation**
  – to **analyze** and **understand** the **interplay of the scenarios**

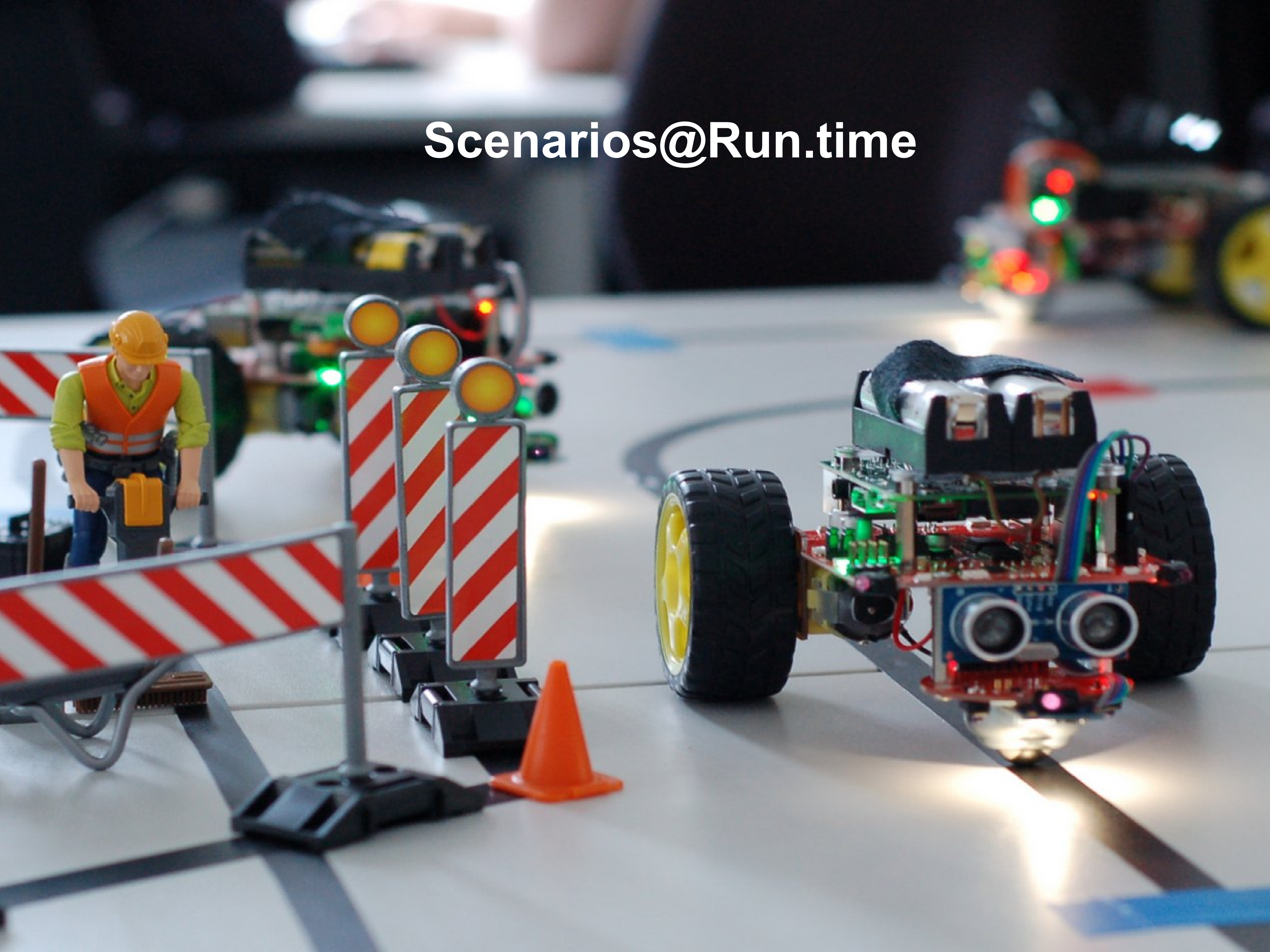


- The **play-out** algorithm In a nutshell:
  1) environment events occur and activate scenarios
  2) the scenarios prescribe events that the system must execute
  3) play-out executes these events while trying to avoid violations
  4) when all system reactions are executed, wait for the next environment event (goto Step 1)

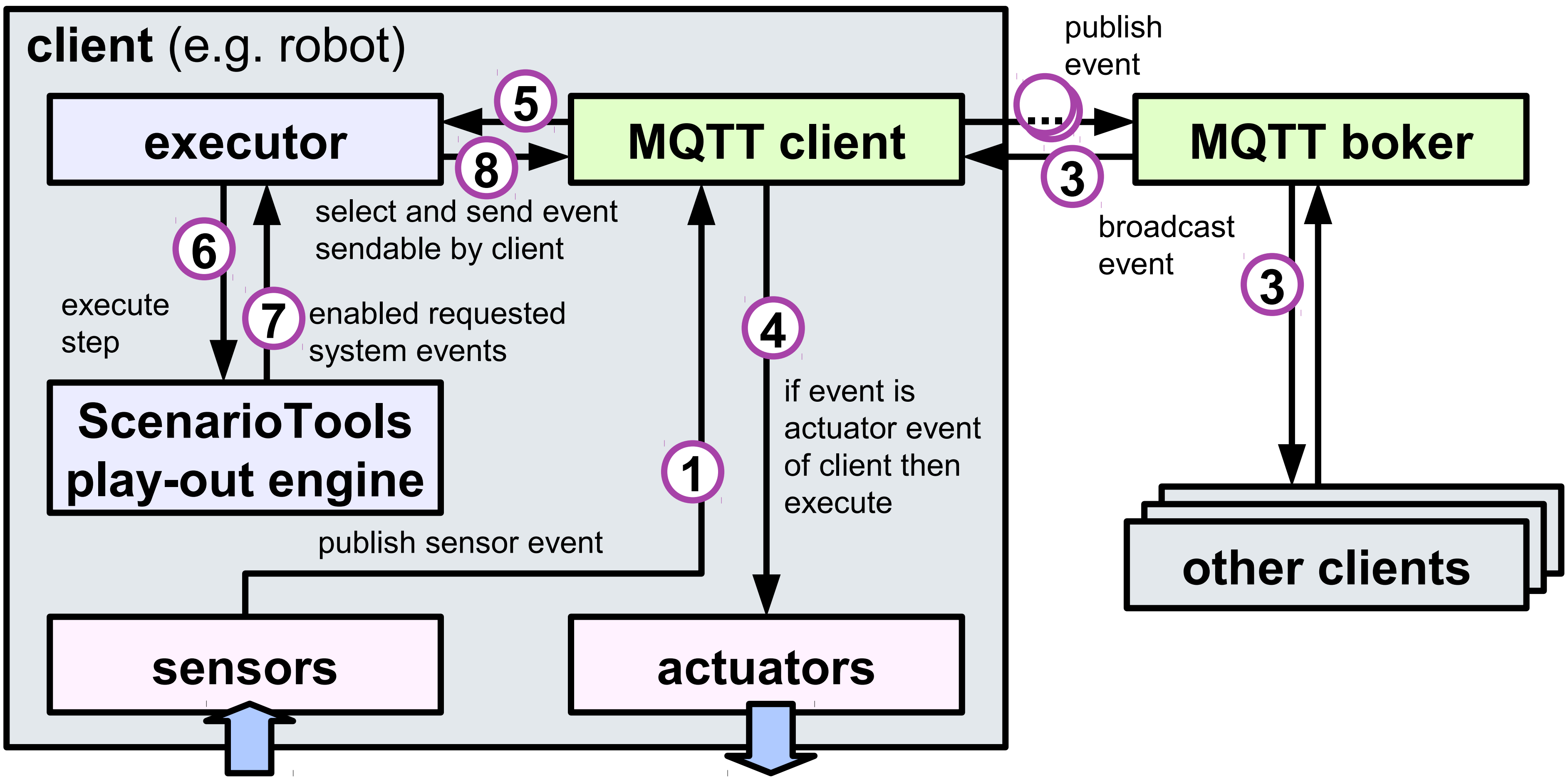
Simulation via Play-Out in ScenarioTools

ScenarioTools.org




Scenarios@Run.time

Steps in the Scenarios@Run.time Framework



Summary & Perspective

- Execute scenario specifications on **distributed** systems
- **New**:
  - **dynamic structures**: interpretation of dynamic role bindings
  - also execute **environment assumptions**
    - **run-time monitoring** if environment behaves as assumed

- Relies on full synchronization of all components on all events
  - this overhead must be reduced:
    - only synchronize objects in certain parts of the system
    - analyze **at run-time** minimal set of components to synchronize

- Future work:
  - safe run-time updates of specification changes
  - dependability: how to recover from run-time failures