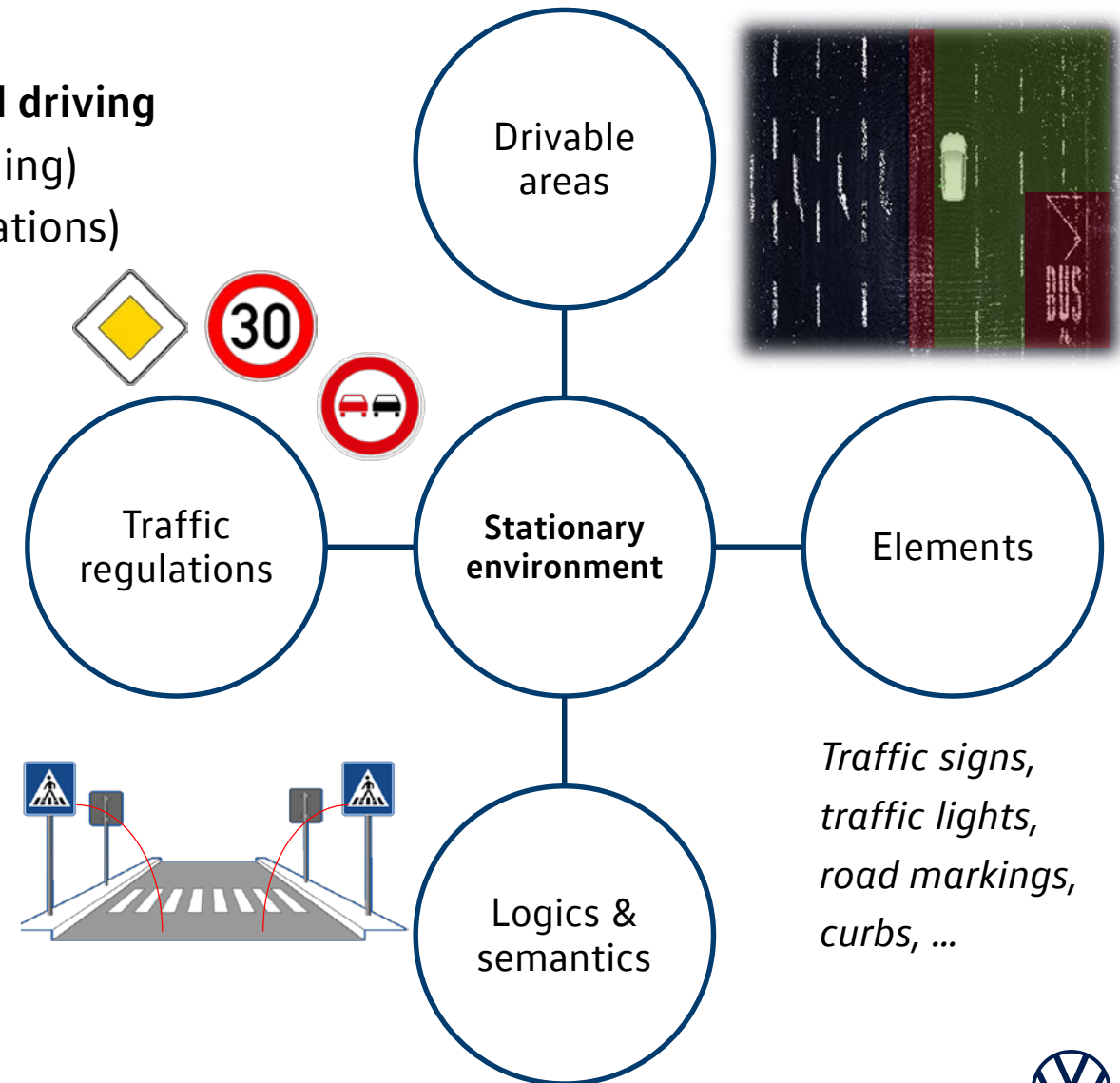# Towards Knowledge-based Road Modeling for Automated Vehicles: Analysis and Concept for Incorporating Prior Knowledge

Jenny Fricke[1], Christopher Plachetka[1], Bernd Rech[1]

[1]Volkswagen AG, Commercial Vehicles, Self-Driving System Development

- **Representing the stationary environment for automated driving**
  - Necessary for all subsystems (e.g., scene understanding)
  - Onboard perception not sufficient (e.g., sensor limitations)



Drivable areas

Traffic regulations

**Stationary environment**

Elements

*Traffic signs, traffic lights, road markings, curbs, ...*

Logics & semantics

- **Representing the stationary environment for automated driving**
  - Necessary for all subsystems (e.g., scene understanding)
  - Onboard perception not sufficient (e.g., sensor limitations)

- **Common approach: reliance on High Definition (HD) maps**
  - Information about element's positions and connections (e.g., association of signs to lanes)

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- **Common approach: reliance on High Definition (HD) maps**
  - Information about element's positions and connections (e.g., association of signs to lanes)

- **Problem: driving functions relying on HD maps are prone to failures**
  - Deviations between real world and map data
  - ➤ Can cause false predictions, false vehicle behavior

- **Objective: concept allowing for a continued operation of the driving function despite map deviations**

- **Need for system ensuring map dependability:**
  - Onboard detection of deviations ahead
  - Onboard corrections of deviations
  - Map updates within short cycles
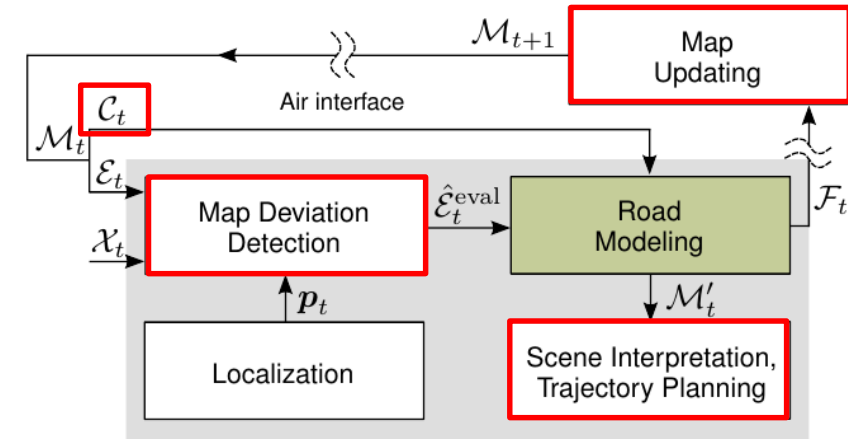
- **Road modeling tasks**
  - Evaluation of undetected physical elements
  - Evaluation and establishment of connections and semantical elements
  - Plausibility checks by resolving inconsistencies
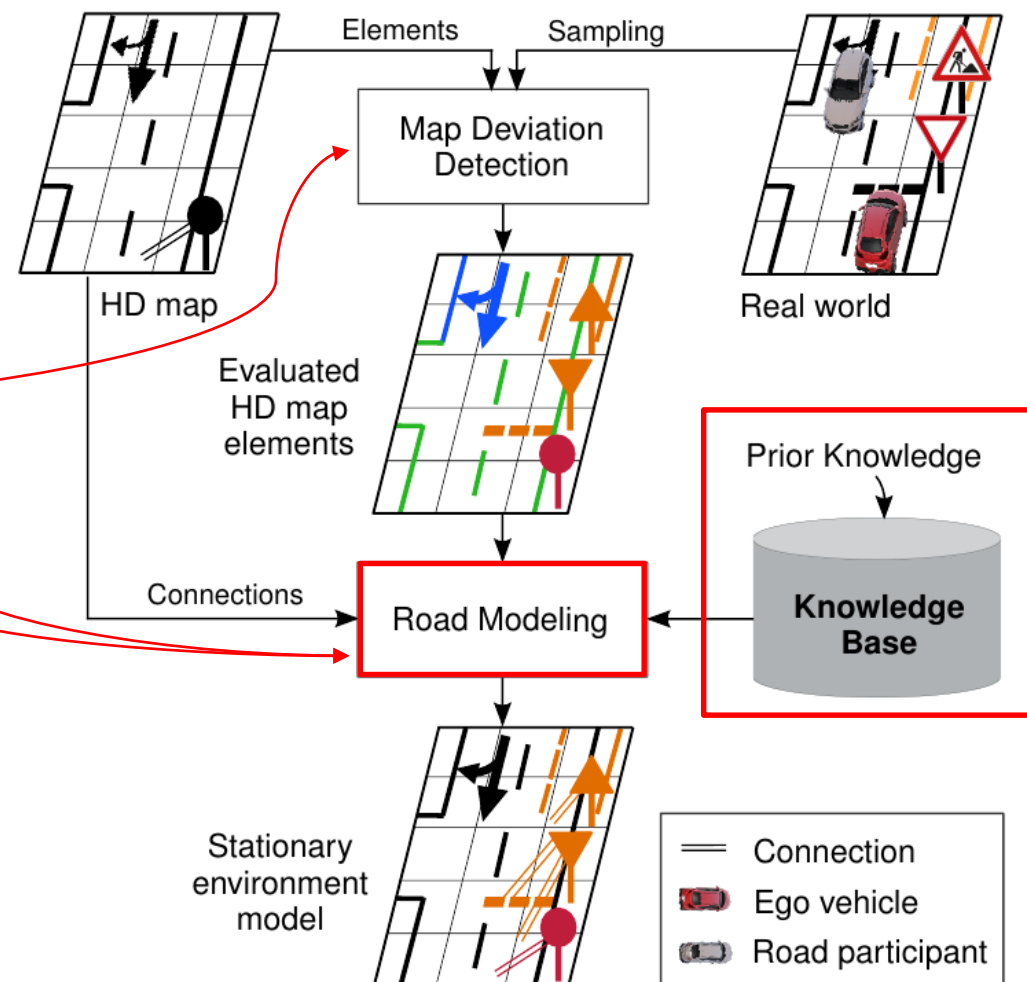
- Work on environment modeling with knowledge **focuses on offline map generation**, hardly on online map validation

- Focus on **special areas** (e.g., intersections) <u>or</u> **features** (e.g., geometry or traffic regulations)

- Lack of **precise argumentation** why specific knowledge is needed in the first place

➢ Presented work for road modeling covers
  - **Framework proposal** to solve road modeling tasks
  - **Holistic view** (not restricted to subparts or features)
  - **Derivation** of required **knowledge**
  - **Description** and **representation** of **derived knowledge**
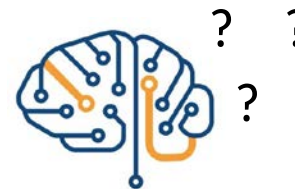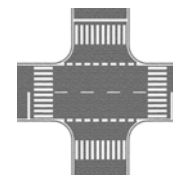
- **Framework** should take conditions into account:

  - **Input** from two sources
    * Map deviation detection component
      (**evaluated elements**, e.g. as an object list)
    * HD map (**connections**)

  - **Output** for two purposes
    * Subsystems (**alternative map hypothesis**)
    * Updates (**deviating elements** and **connections**)

- **Framework** should take conditions into account:

  – **Input** from two sources
    * Map deviation detection component
      (**evaluated elements**, e.g. as an object list)
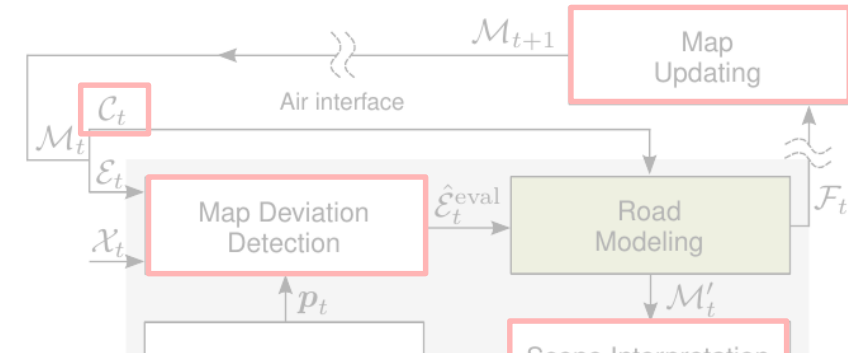


**Findings:**
- Framework for knowledge-based road modeling should adress three tasks
  i. **Stationary environment completion**
     (evaluation of occluded elements)
  ii. **Stationary environment interpretation**
      (composing semantical elements, evaluation of connections)
  iii. **Stationary environment plausibility**
       (resolving inconsistencies)

- Semantical elements are required for the evaluation of physical elements and vice versa

- Prior knowledge needed for evaluation
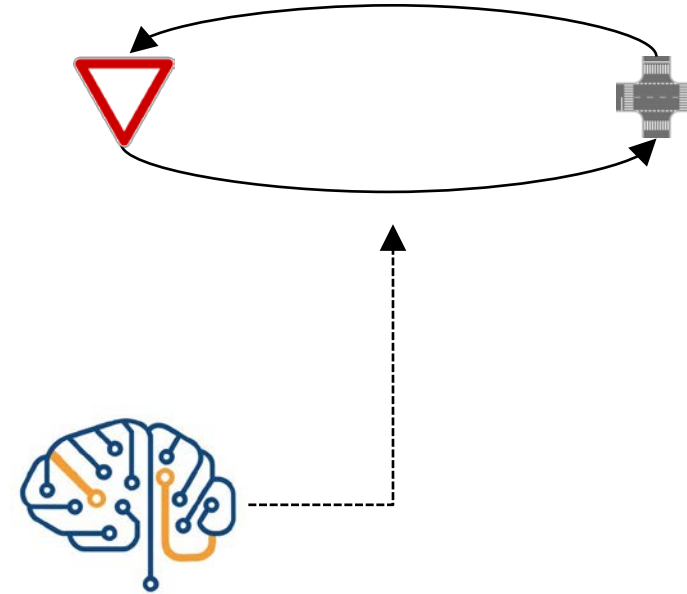
*‚Presence of right-of-way signs is mandatory for each lane entering an intersection'*

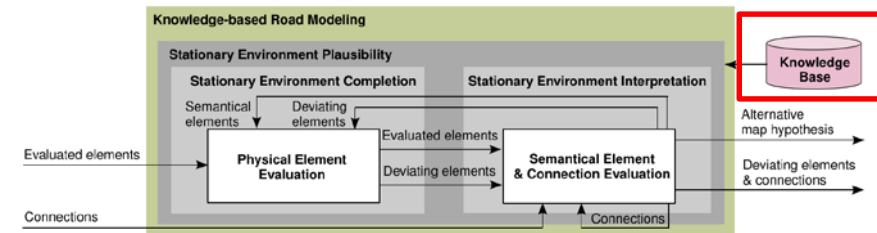- Semantical elements are required for the evaluation of physical elements and vice versa

**Findings:**
- Processing steps are performed **iteratively** due to mutually dependence
- Evaluation regarding three states: **verified existing, deviating, remaining unknown**
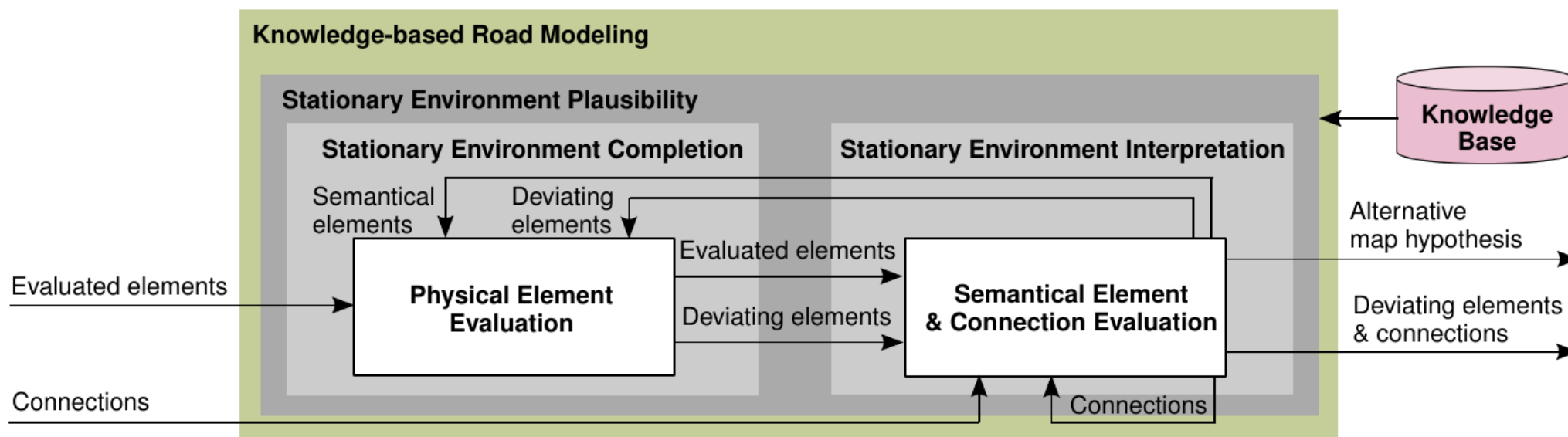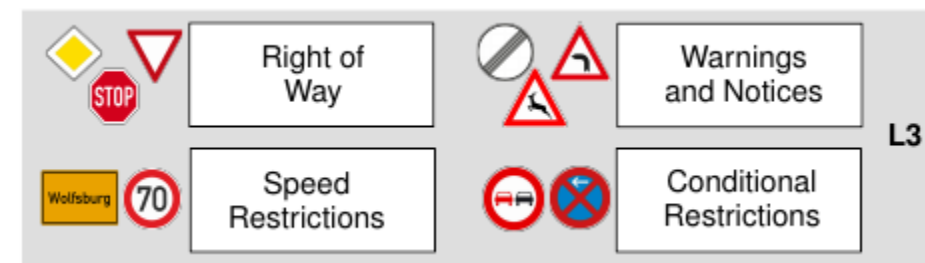
➤ **Which kind of knowledge is required?**
   – Introduction of layered model for traffic regulations

**L3 Restrictions on driving and parking behavior**
   – Regulations to be observed for driving on permitted lanes



**L2 Topology of the road network**
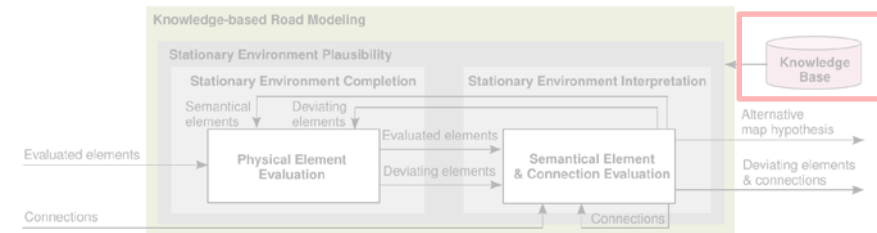   – Permissible lanes, directions, linking of lanes



**L1 General topographical information**
   – Description of all drivable lanes

➢ **Which kind of knowledge is required?**
  – Introduction of layered model for traffic regulations

**Findings:**
- Derived **prior knowledge** is subsumed under **three categories**
  i. **Types and meanings of elements**
     - e.g., driving direction, speed, right of way
  ii. **Road building regulations**
     - e.g., allowed designs (dimensions) and connections
  iii. **Traffic rules**
     - e.g., order of priorities

**L1 General topographical information**
  – Description of all drivable lanes
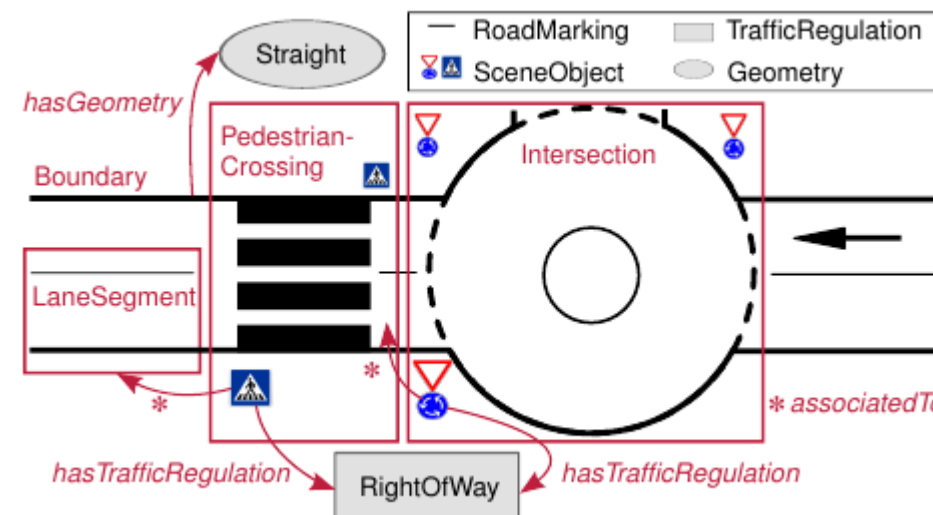
➢ **How to describe the derived knowledge?**

▪ Semantical description of stationary environment information

▪ Describability of information based on established map frameworks

> **How to describe the derived knowledge?**

- Semantical description of stationary environment information

- Describability of information based on established map frameworks

**Findings:**

- Road model consisting of five primitives
    i.   **Road markings**
    ii.  **Scene objects**
    iii. **Geometries**
    iv.  **Traffic regulations**
    v.   **Semantical elements**

➢ **How to represent the derived prior knowledge?**

- **Concepts**: collections of hierarchical classes representing the stationary environment domain

- **Relations**: description of properties of concepts itself and between them

- **Restrictions**: imposing constraints on the validity of relations and concepts

- **Rules**: specific combinations of concepts and relations to derive new knowledge
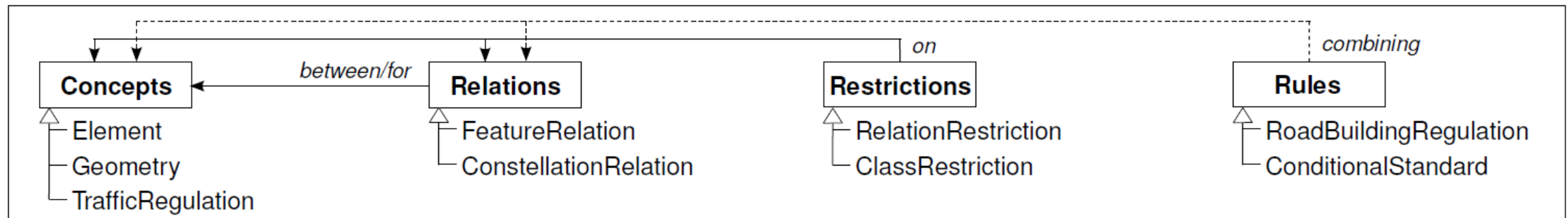
- Knowledge-based Road Modeling

- Stationary environment **completion**

   „Traffic sign *pedestrian crossing* is required to be part of a pedestrian crossing to be evaluated as valid"

- Stationary environment **interpretation**

   Distances of markings, grouping of elements

- Stationary environment **plausibility**

   Conflicting signs and markings
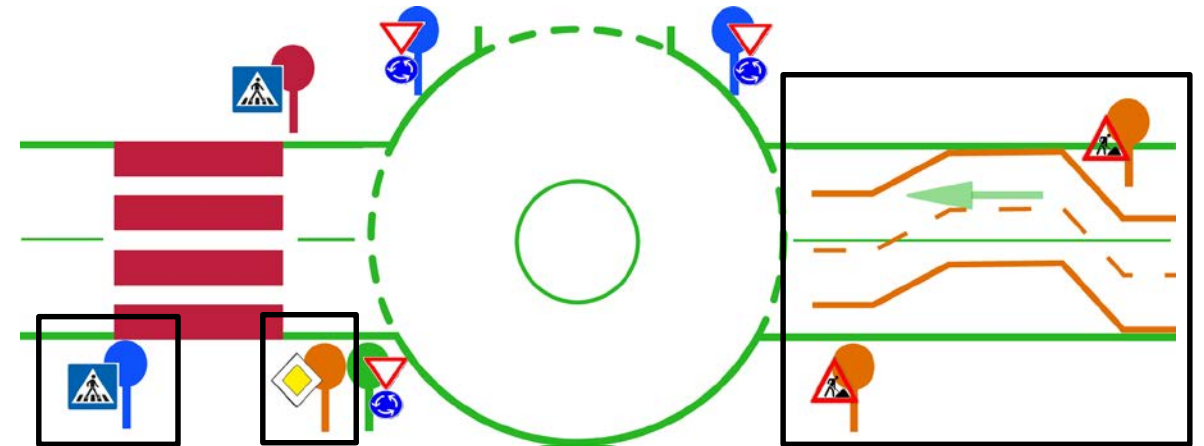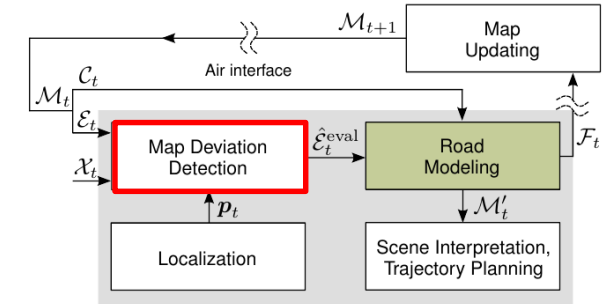


*Verified*

*Falsified*

*Unknown due to occlusion*

*Missing in HD map*

➢ **Summary**

    ✓ Definition of tasks to solve for knowledge-based road modeling

    ✓ Framework proposal

    ✓ Derivation of required prior knowledge categories

    ✓ Formal representation proposal of derived prior knowledge

➢ **Next steps**

    ▪ Knowlegde base will be published in upcoming paper

    ▪ Application of framework together with knowledge base on real data containing map deviations
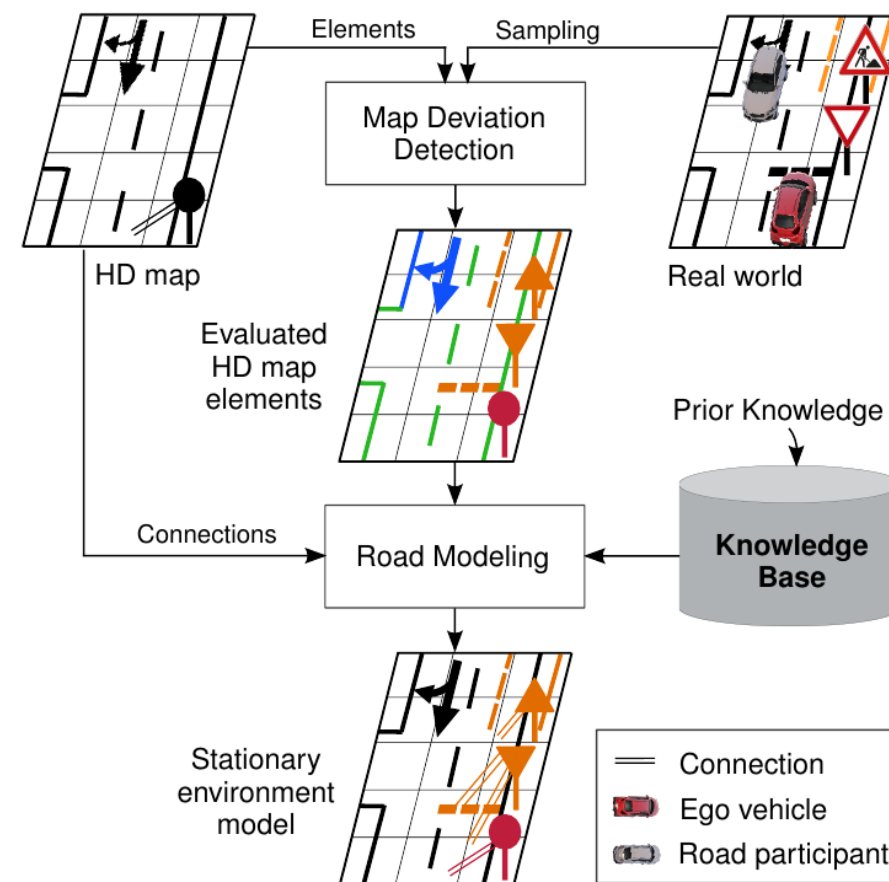
# Thank you.

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