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Description Logics for Vision-Based Urban Intersection Understanding

Definition "Intersection Understanding"

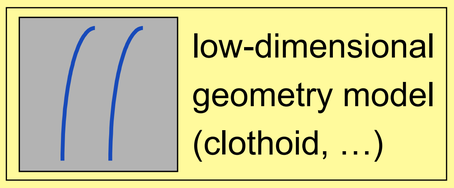
:= **Image Understanding** for road intersection images, (at least) for

- Autonomous navigation through intersection, obeying traffic rules
- Generation of a human-readable, qualitative scene description

How?

Common Approach to Lane Recognition

1. project



2. compare with image cues (edges, markings, texture, ...)

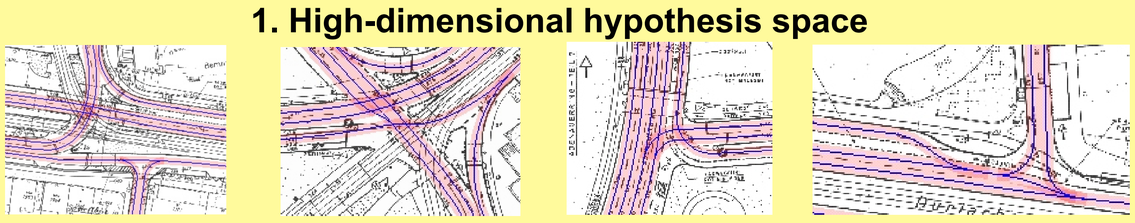
3. update model parameters

➔ Cannot be generalized to more complex environments!

Why?

Challenges in Intersection Understanding

1. High-dimensional hypothesis space



2. Few measurements

Limited field of view

Heavy occlusions

Lacking features

3. Noise

Unmodelled objects

Bad feature quality

➔ Problem becomes ill-posed!

What can we do?

Prerequisites for Intersection Understanding

1. Hardware: active / omnidirectional cameras
2. Large nr of complementary feature detectors

   Example Crossroad: crossing vehicle, stop sign, traffic light, pedestrian crossing, arrow marking, lateral marking, exit lane right,...

3. **Knowledge representation**

   Develop high-dimensional geometry model

   Narrow down hypothesis space

   Specify domain knowledge on a conceptual level

   Explicate all assumptions

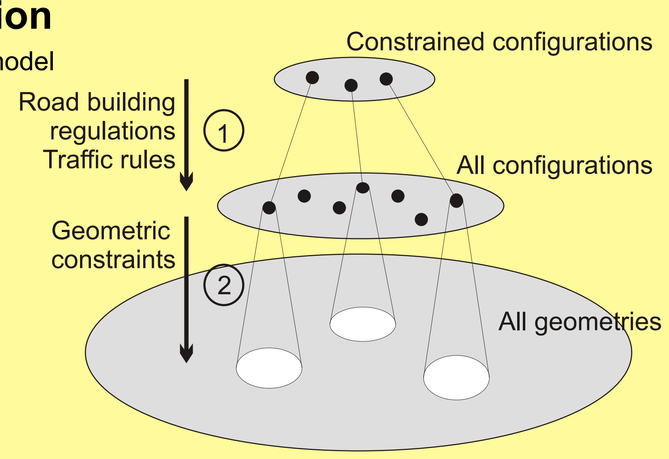
   → Maintainable KR

   → Extendable KR

   Use a highly formalized language

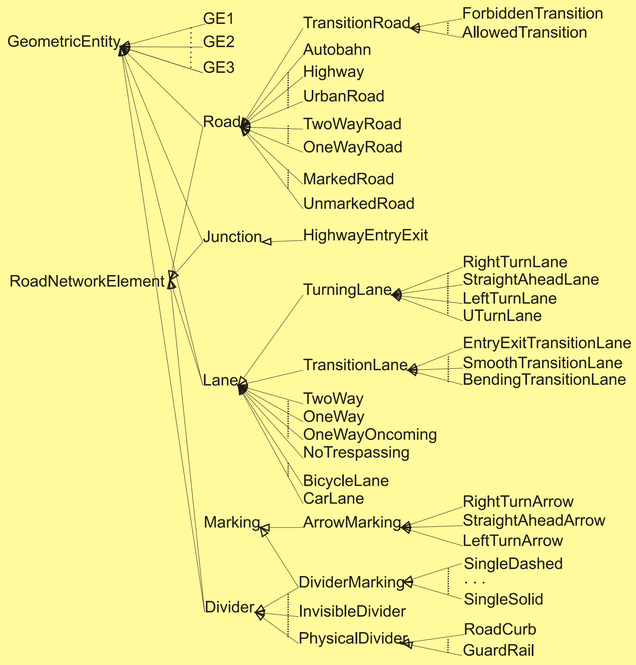
   → Allows for reasoning

   → Avoids semantic ambiguities

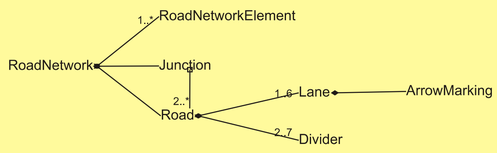


Knowledge Representation for Roads and Intersections with the Description Logic $\mathcal{ALCQHI}_{\mathcal{R}+}(\mathcal{D}^-)$

Taxonomy



Partonomy



Road Building Regulations

// Only right turn lanes can be right of right turn lanes
RightTurnLane ⊑ ∀ hasRightNeighbor.RightTurnLane

// All autobahns and highways are one way roads
Autobahn ⊔ Highway ⊑ OneWayRoad

// A one way road is defined as a road
//which has only one way lanes
OneWayRoad ≡ Road ⊓ (∀ PLane.OneWay
⊔∀ PLane.OneWayOncoming)

// A one way road does not have a uturn lane
OneWayRoad ⊑ ∀ PLane.¬UTurnLane

// There is no more lane after a guardrail or road curb
GuardRail ⊔ RoadCurb ⊑ ¬(∃hasLeftNeighbor.Lane)

...

...

Geometric Constraints

Road ⊓ $\exists_{=2}$PP.Lane ⊓	// A two lane road
$\exists_{=3}$directlyFollowedBy. Lane	// directly followed by // a three lane road
⊑ ∃PP.(Lane ⊓ GE2)	// must contain some lane // of the form GE2

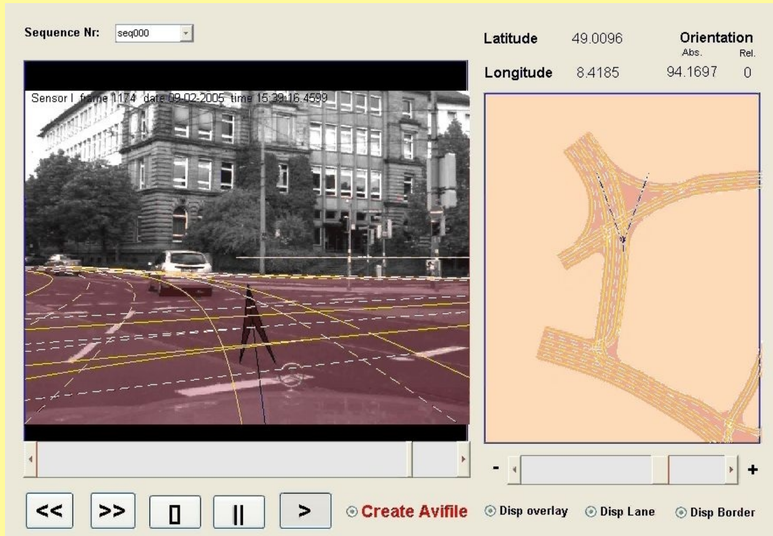
...

DL Inference

- **Satisfiability** Does the knowledge base make sense?
- **Consistency** Does the sensor data make sense?
- **Entailment** Determines the most specialized individual description that deductively follows from the KB

  $\mathcal{KB} \models \text{lane}_i : (\text{OneWayLane} \sqcap \text{RightTurnLane})$
- **Query answering** Retrieves individuals; similar to database query

yields



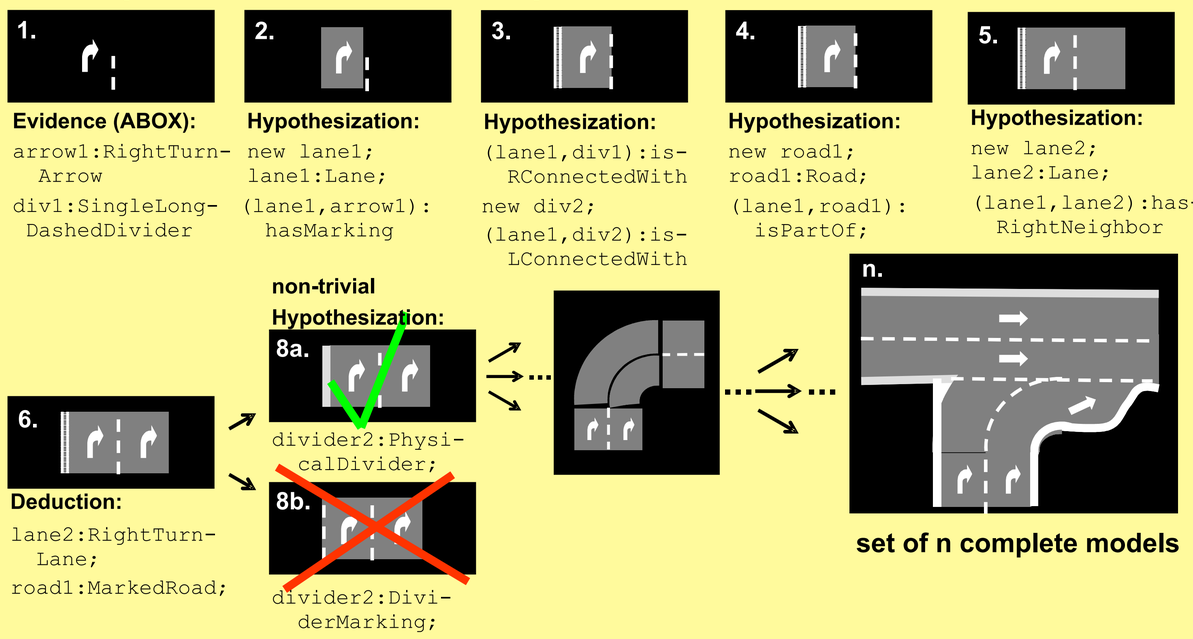
Model of intersection geometry and configuration

Problem:

Deductive Inference requires **monotonicity!**
Therefore, a **complete low-level segmentation** must be provided.
But Computer Vision has shown: **Data-driven segmentation not feasible.**

Outlook

(Non-monotonic) Model Construction



Logic for Artificial Intelligence (ACAI)
August 20-28, 2007
Leuven, Belgium

[1] Baader, F., Calvanese, D., McGuinness, D., et al. (2003). The Description Logic Handbook. Cambridge University Press.
[2] Haarslev, V., Möller, R. (2003). RACER: A Core Inference Engine for the Semantic Web. Proceedings of the 2nd International Workshop on Evaluation of Ontology-based Tools.
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[4] Neumann, B., Möller, R. (2006). On Scene Interpretation with Description Logics. In Christensen, H., Nagel H.-H.: Cognitive Vision Systems: Sampling the Spectrum of Approaches, Springer.