Research Initiative Ko-FAS

Kooperative Fahrerassistenz und Aktive Sicherheit

HAVEit Fusion Workshop, 2011-02-22, Brussels

Ko-PER – Cooperative Perception
to Promote
Driver Assistance and Preventive Safety

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Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

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Who participates in Ko-PER: Project Partners

BMW Group
Forschung und Technik

hochschule aschaffenburg
university of applied sciences

DAIMLER

ITE

Continental

IZVW

DELPHI

UNIVERSITÄT PASSAU

SICK
Sensor Intelligence.

ulm university universität ulm

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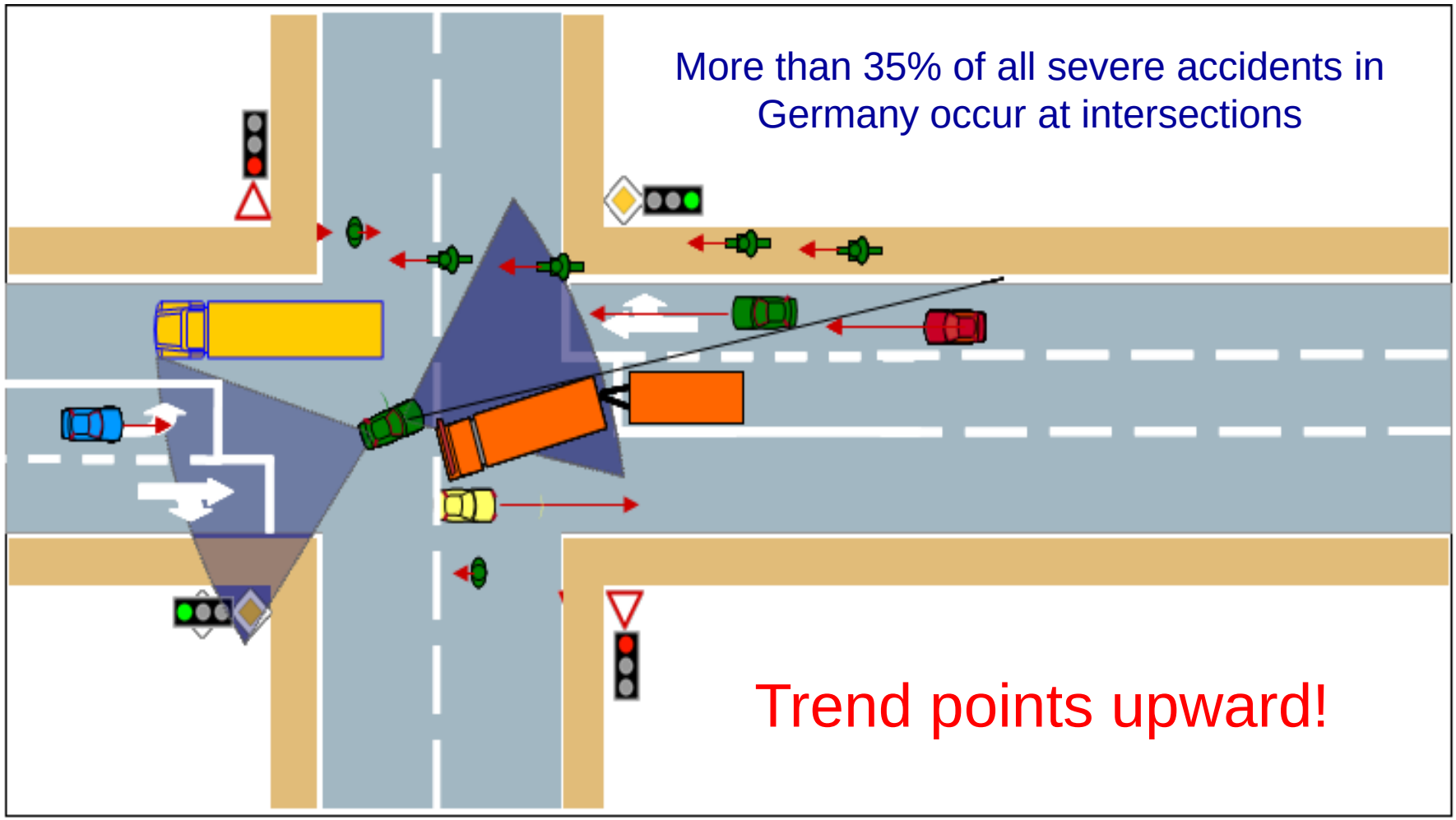
What is Ko-PER? – Basic Ideas

- Combine the results of intra-vehicle environment perception and inter-vehicle communication (*i.e.* sim^{TD}):
  → *Cooperative Perception Messages (CPM)*
- Simultaneously utilise the electronic perception of a multitude of vehicles (cooperative perception) + self-localisation in space and time
- Optionally: Equip neuralgic intersections with sensor networks to contribute to the inter-vehicle surveillance (intersection perception)
- Communicate the various perception results via broadcast:
  CPM intersection; (integration of sim^{TD}-CAM into the CPM messages
  → market introduction scenarios)
- Evaluate the Ko-PER added value by means of selected vehicle functions and applications

What is Ko-PER?



Paradigm Change

Potentially complete environment perception allows:

- Cancellation of occlusions
- Overcoming of quasi-deterministic models
- Step-by-step adoption of rule-based and cognitive approaches (Scene interpretation, scene recognition), hence:
- Machine-based early recognition / disentanglement of conflict situations / design of real-time conflict resolution strategies

- Generic perception (surveillance of the vehicle surroundings)
- Generic HMI (multitude of functions)

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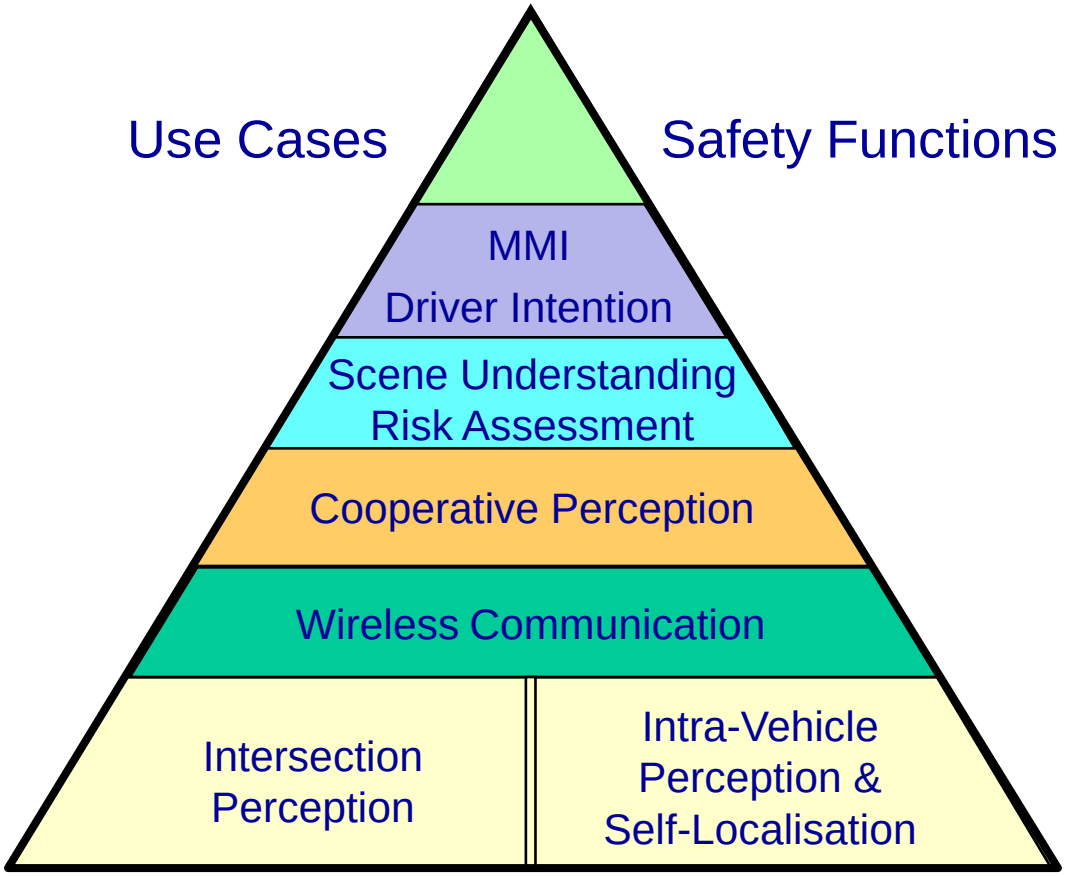
The Ko-PER Pyramid



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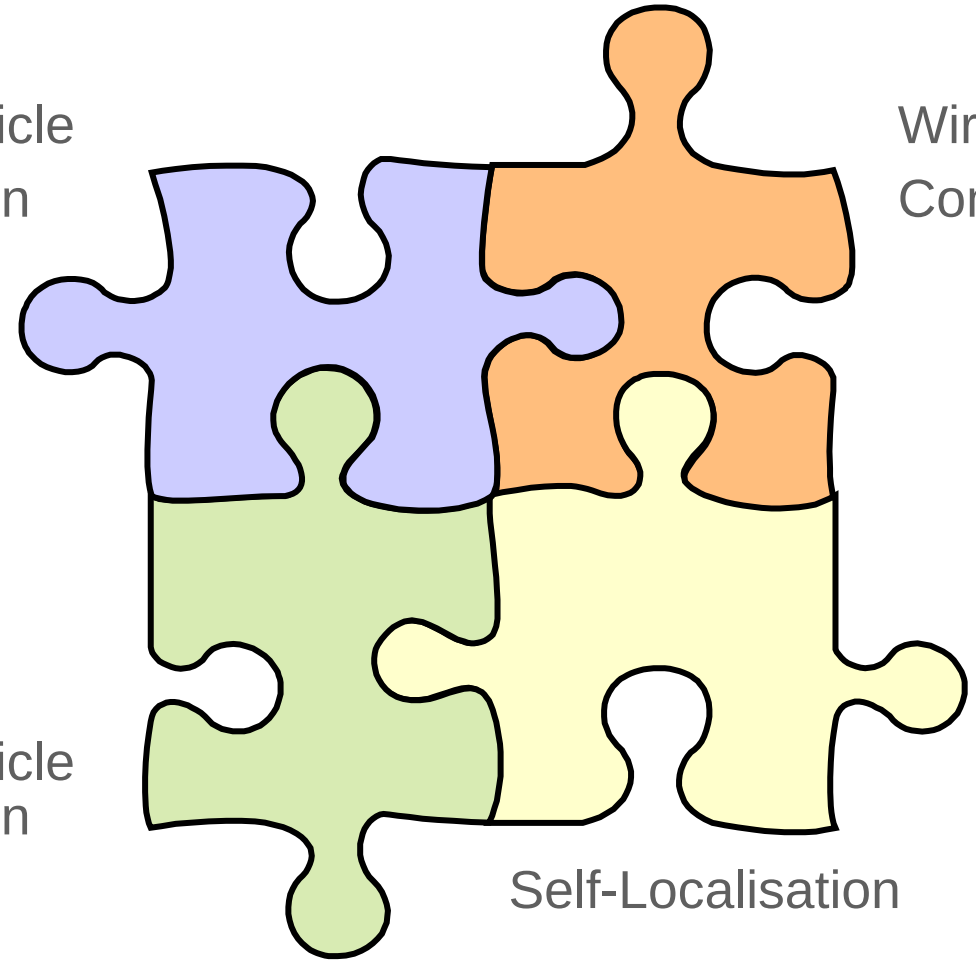
Building Blocks Towards Cooperative Perception



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Intra-Vehicle (On-Board) Perception

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2
3

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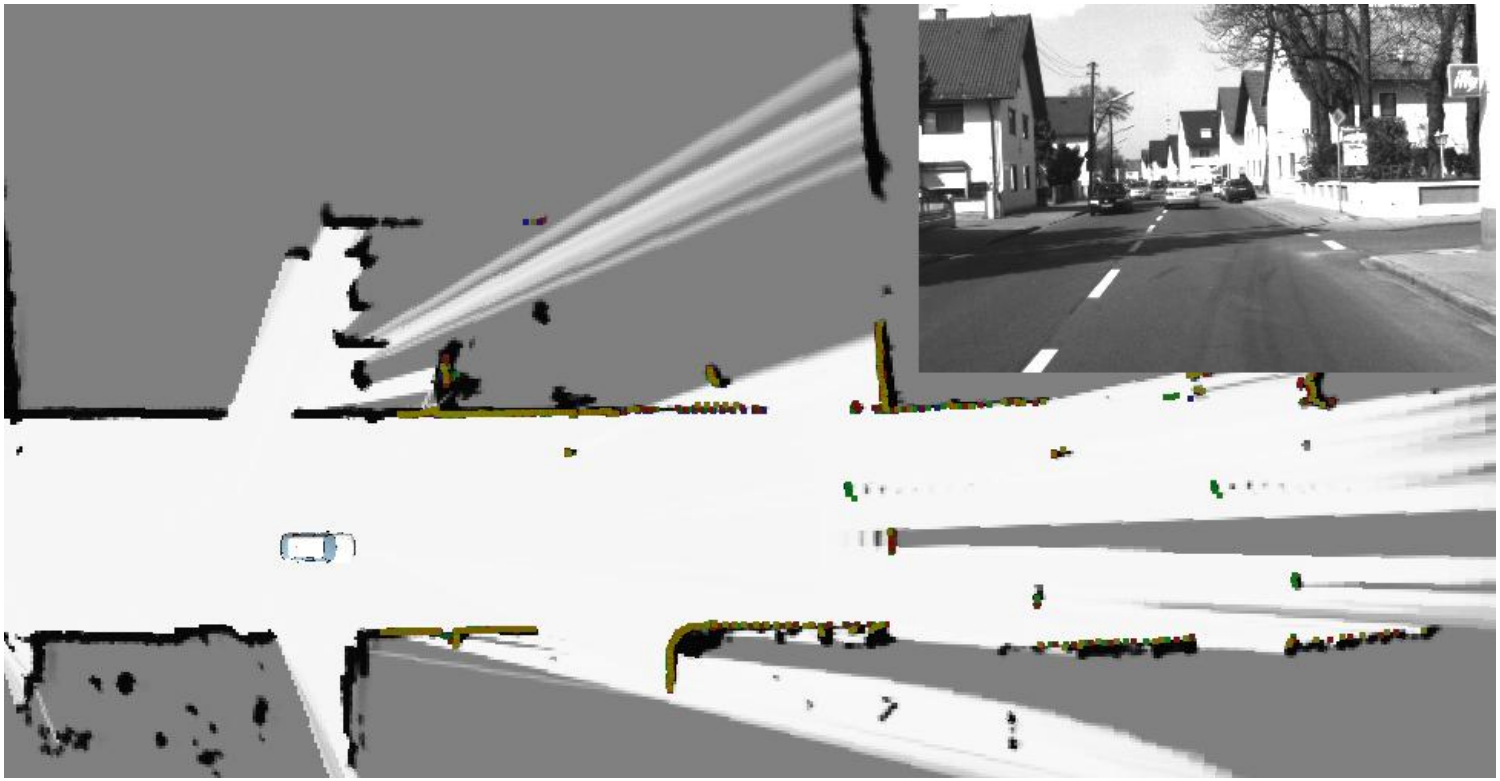
Intra-Vehicle (On-Board) Perception: Real-Time Map

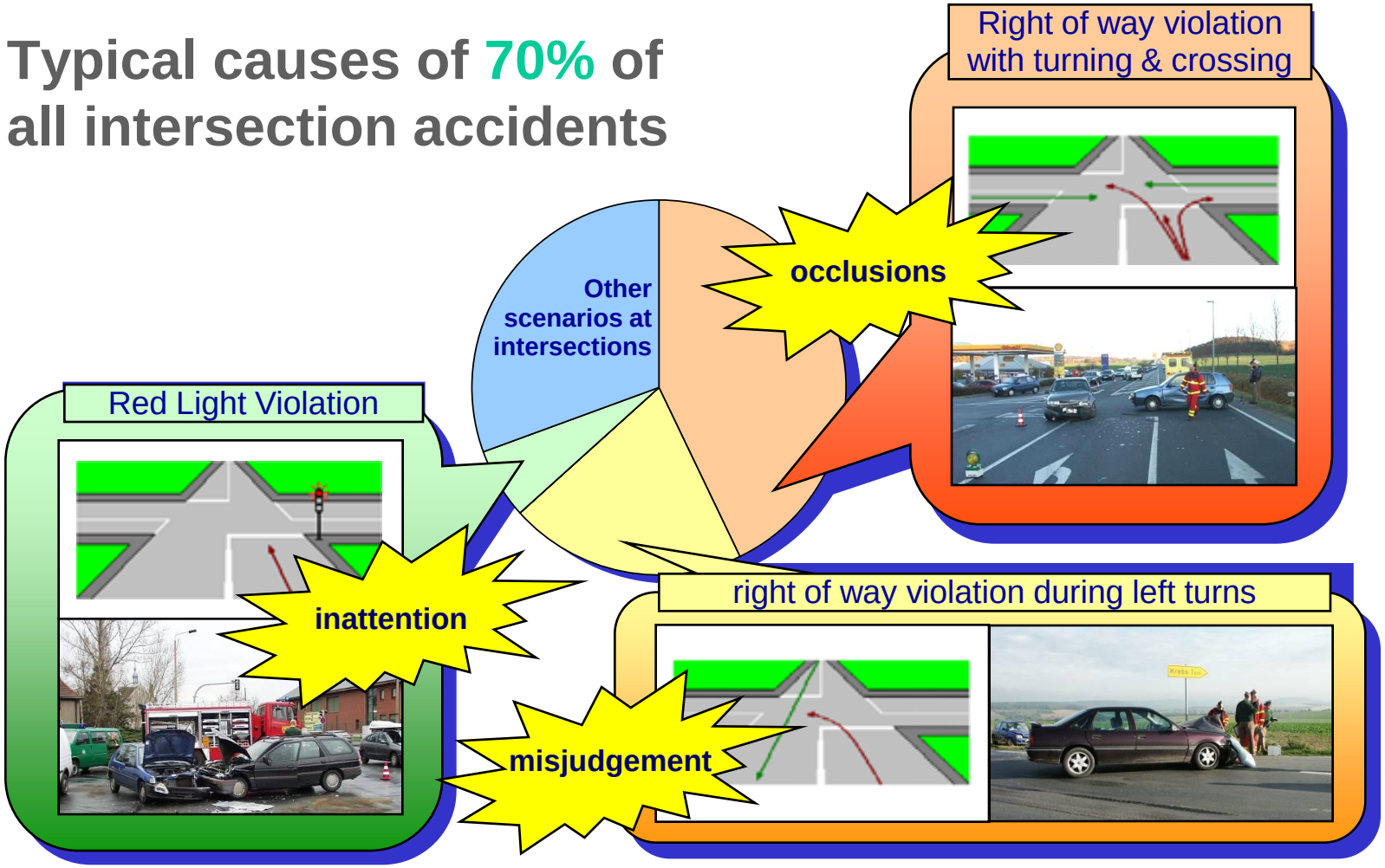


Video

Video

Causes of Intersection Accidents

Typical causes of 70% of all intersection accidents



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Private, Semi-Private und Public Test Intersections

Intersection Ulm (Daimler Campus)

Test Intersection Alzenau

Public Intersection Aschaffenburg

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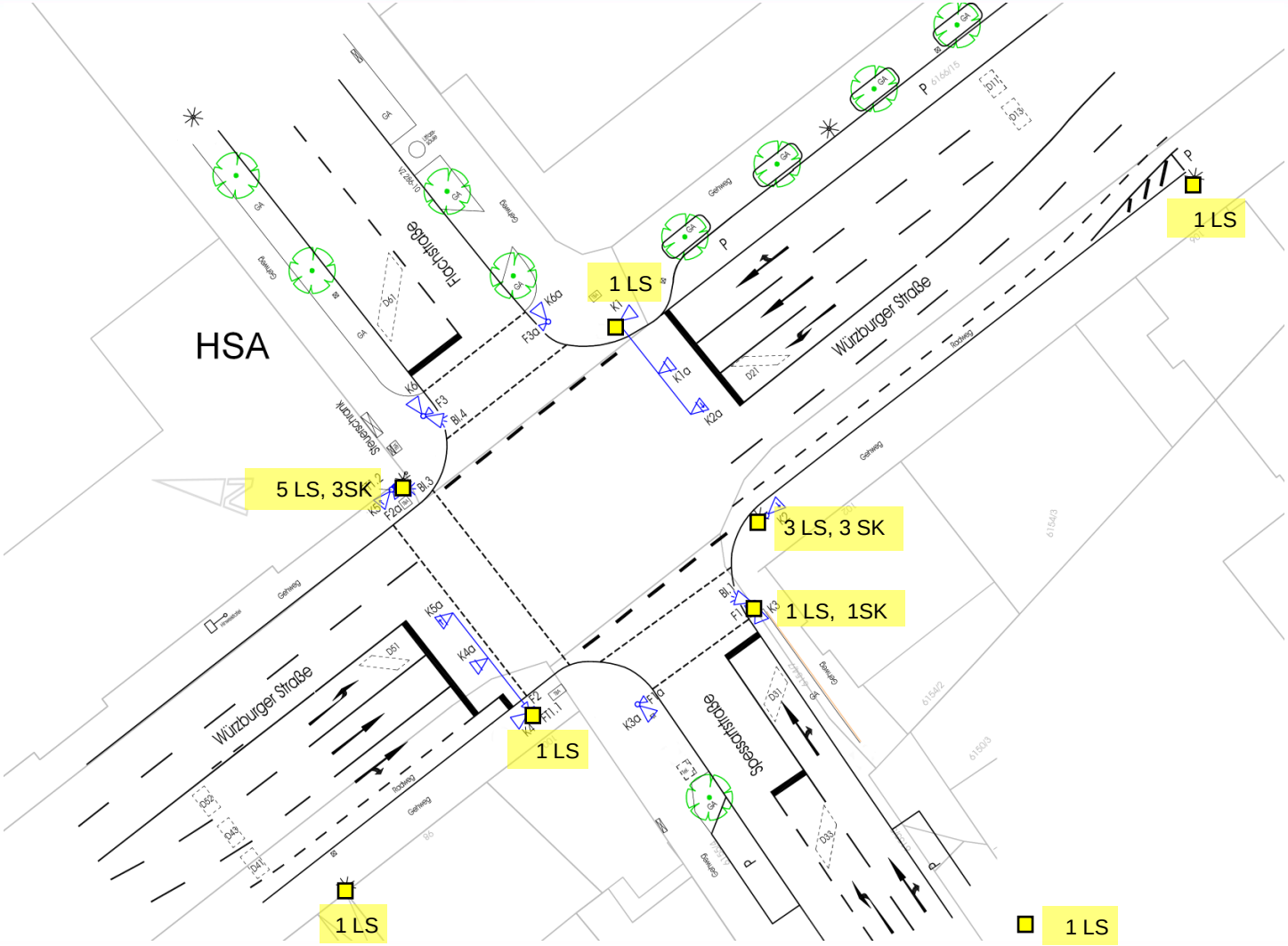
Public Intersection AB: Sensor Arrangement



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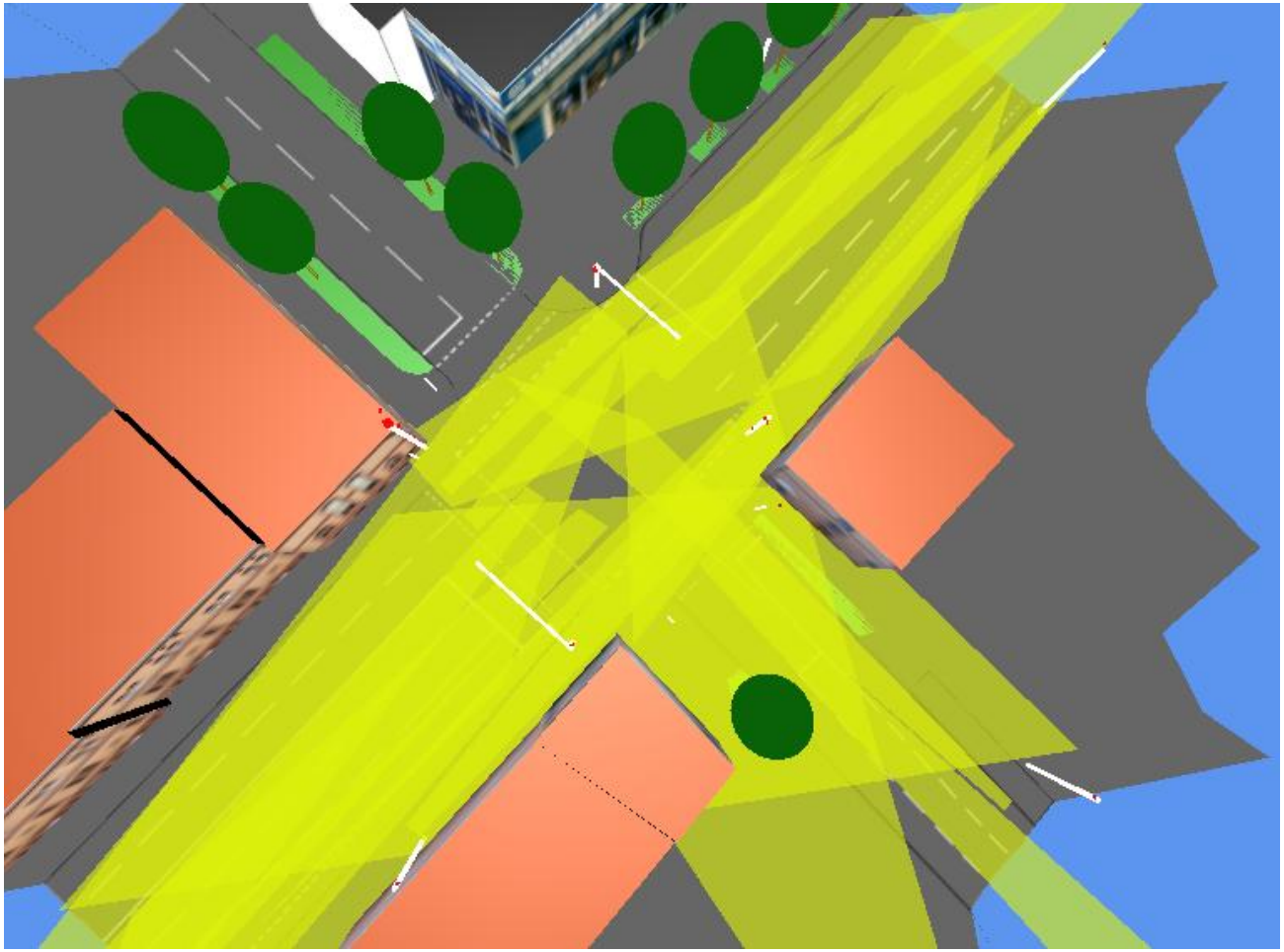
Sensor Arrangement/ Coverage: Laser Scanners



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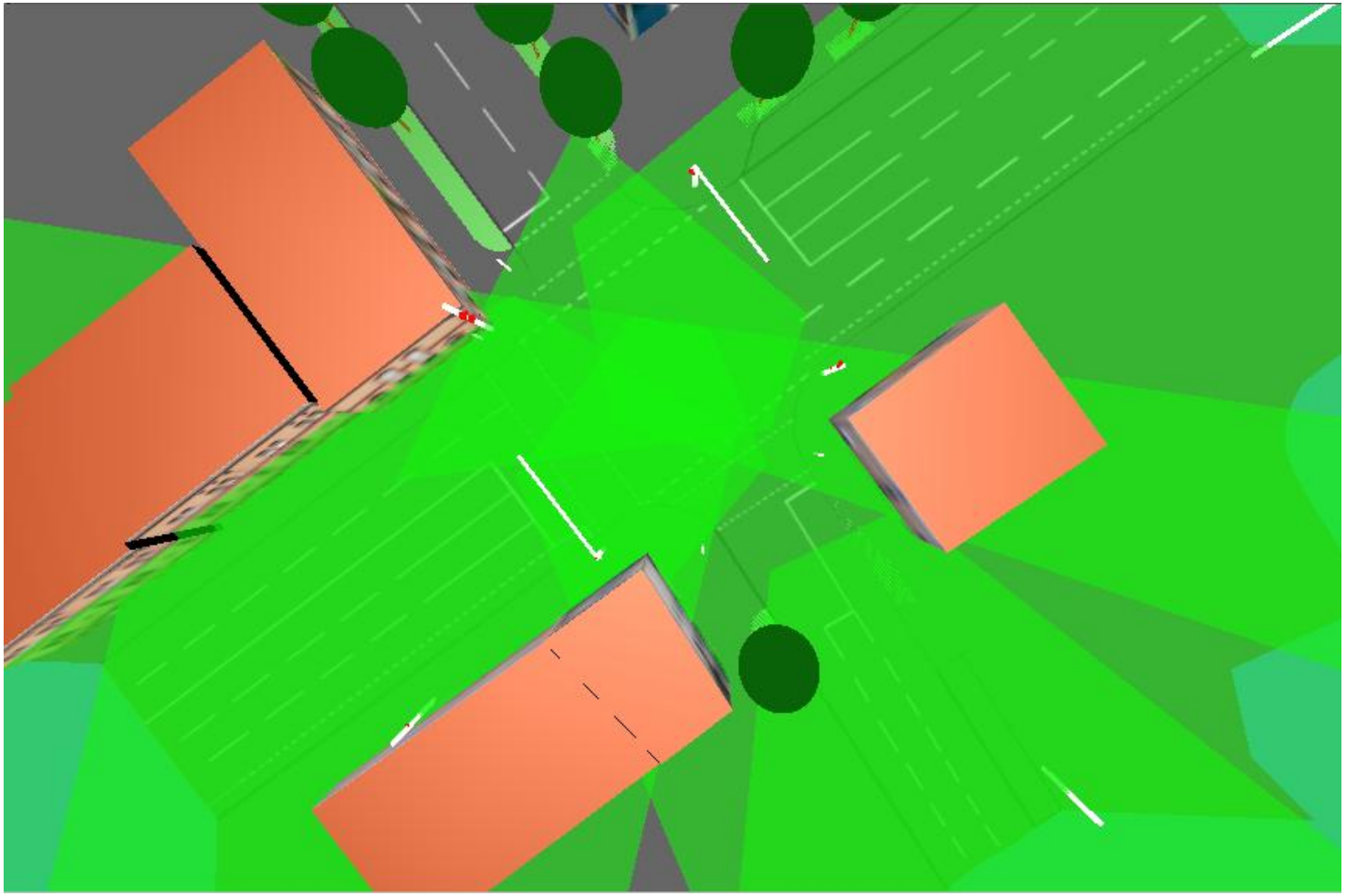
Sensor Arrangement / Coverage: ‘VGA’ Cameras



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Public Intersection AB / IZVW Driving Simulator

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Approaches Aiming at Self-Localisation

The following approaches will be investigated:

- Land-mark detection in combination with map matching
  (laser scanner, image sequence und high-precision digital road map)
- Utilisation of Ko-TAG antenna / transponder (cooperative sensors)
- Tightly Coupled GPS / INS
- Cooperative GNSS
- Result data fusion of several (or all four) approaches

Self-Localisation Utilising Land-Marks

Map requirements

- High-precision land-marks (video)
- Point land-marks (posts, traffic signs)
- Challenge: successive land-marks representing the course of the road
  - Lane markings
  - Directional arrows

Application requirements w.r.t. perception purposes

- Lane attribution of the host-vehicle and of detected objects
- Curvature information
- Road and lane width / boundaries, conflict-free area

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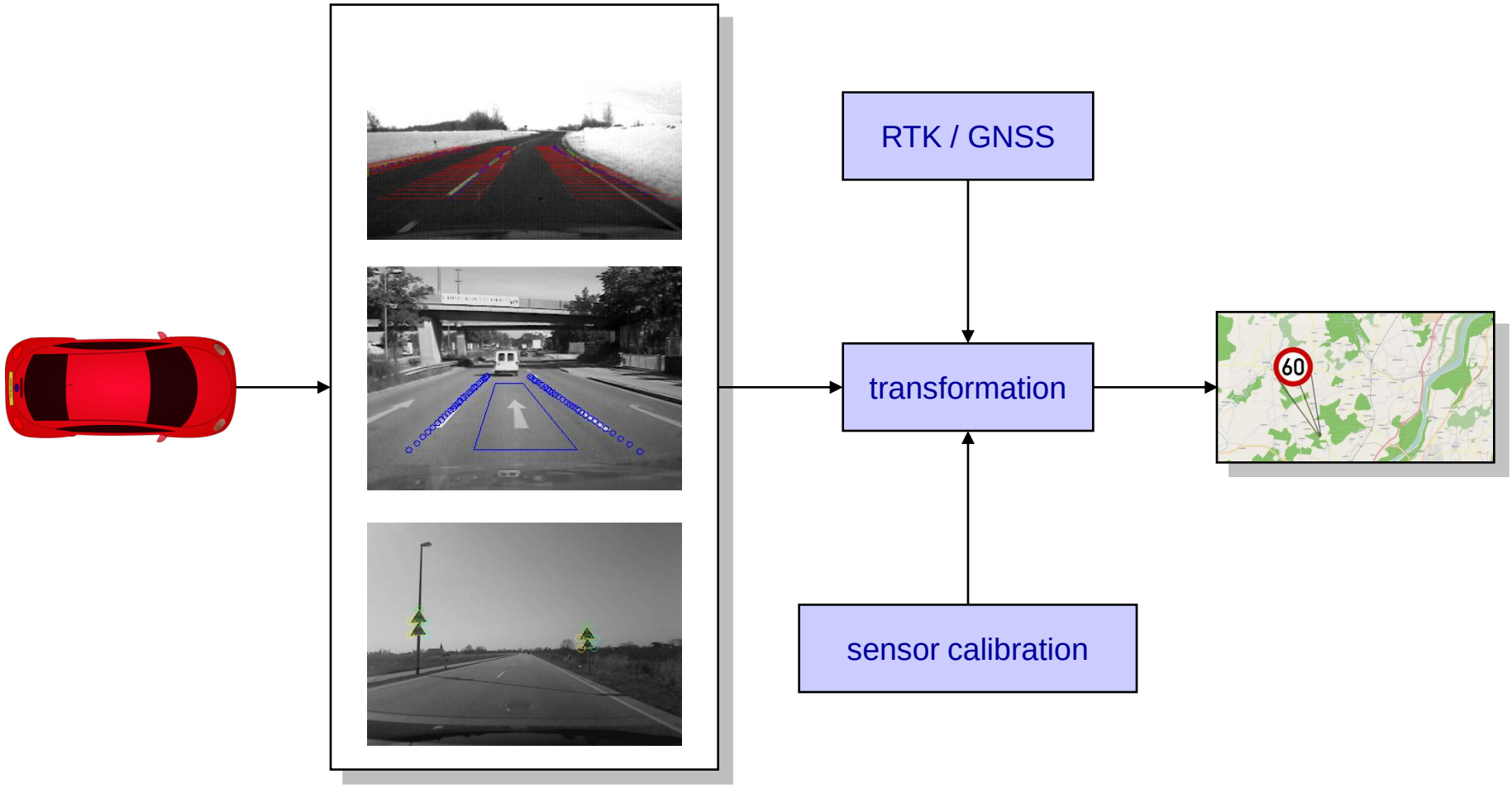
Important Aspect: Cartography (Courtesy FORWISS)

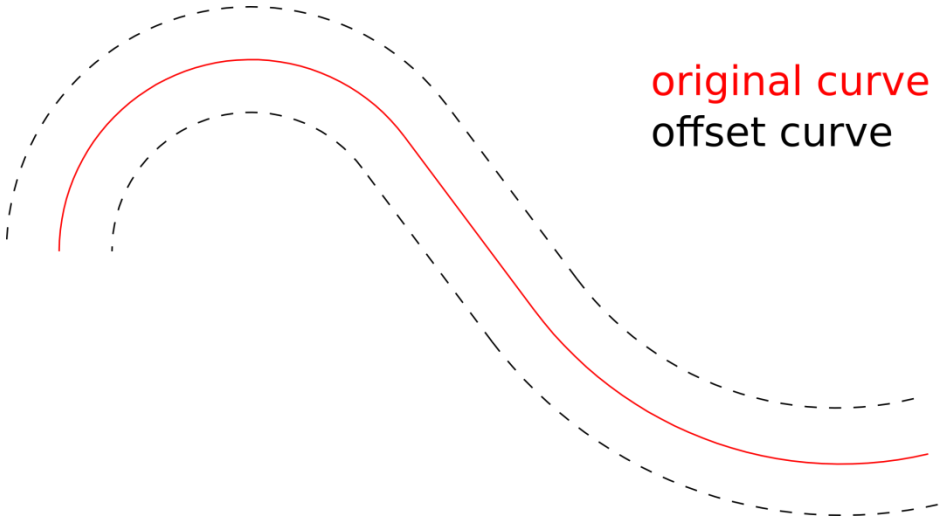
Extension of digital maps with high-accuracy land-marks



Self-Localisation with Video-Extracted Land-marks

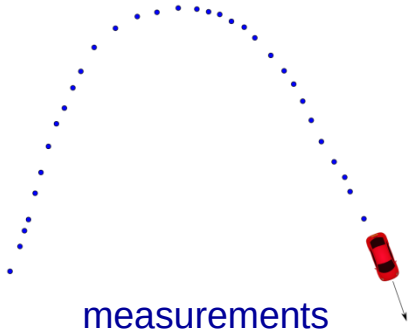
Resulting technical requirements for land-mark representation

- Accuracy
- Error estimation and error control
- Fast computability of the relevant curves
- Distance computation point-to-curve
- Curvature estimation
- Offset curves
- Data volume

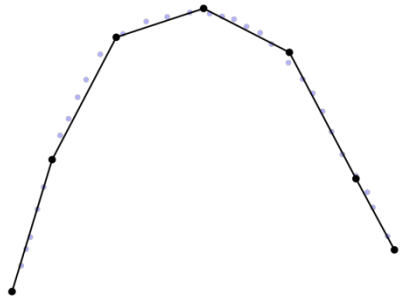


Representations of the Road and Lane Geometry

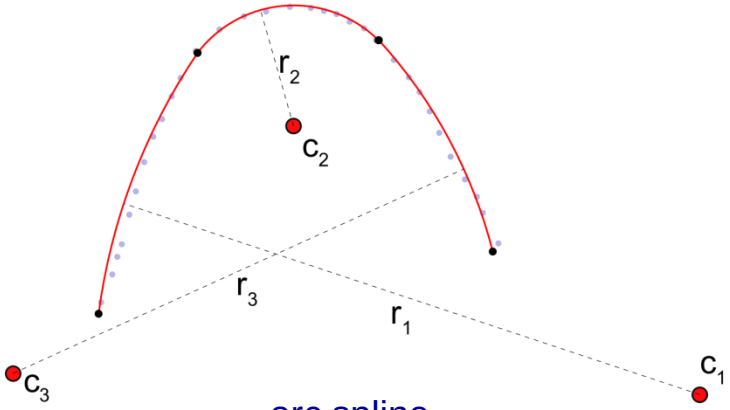
Choice of representations of lane-marks in a digital map



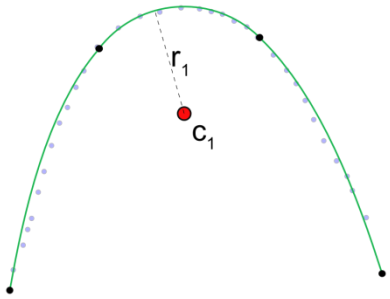
measurements



polygonal curve



arc spline



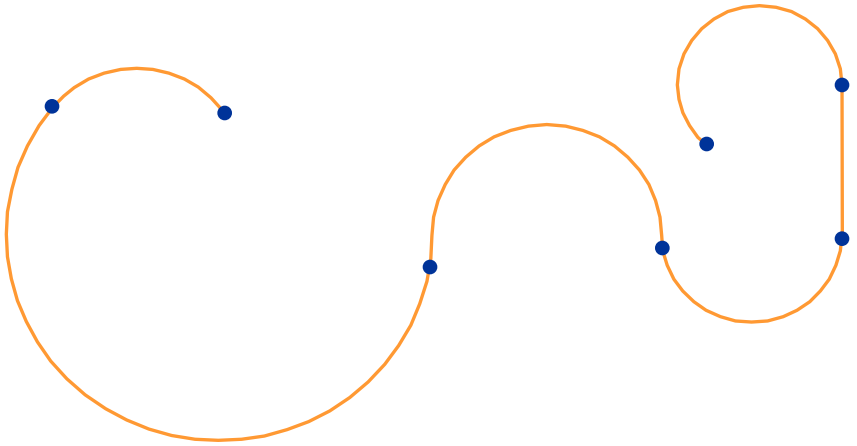
clothoids + arcs

Models investigated:

- **polygonal curves**
- **circular arc splines**
- **clothoids**
- **cubic splines**
- **discrete clothoids**

Circular Arc Splines: Definition

- A (circular) arc spline is an injectively parametrisable planar curve, the image of which consists of a sequence of arcs and straight lines
- An arc spline is called smooth if the tangent vectors at either side of a breakpoint are equal



Circular Arc Splines: Properties

- The curvature of an arc spline is a step function (*i.e.* constant in between a finite number of breakpoints)
- Distance computation in closed form is possible
- Invariant with respect to rotation, translation and scaling
- Offset curves can be represented with arc splines again
- Parameter-free representation is possible
- Compatible with common geometry- and CAD-systems

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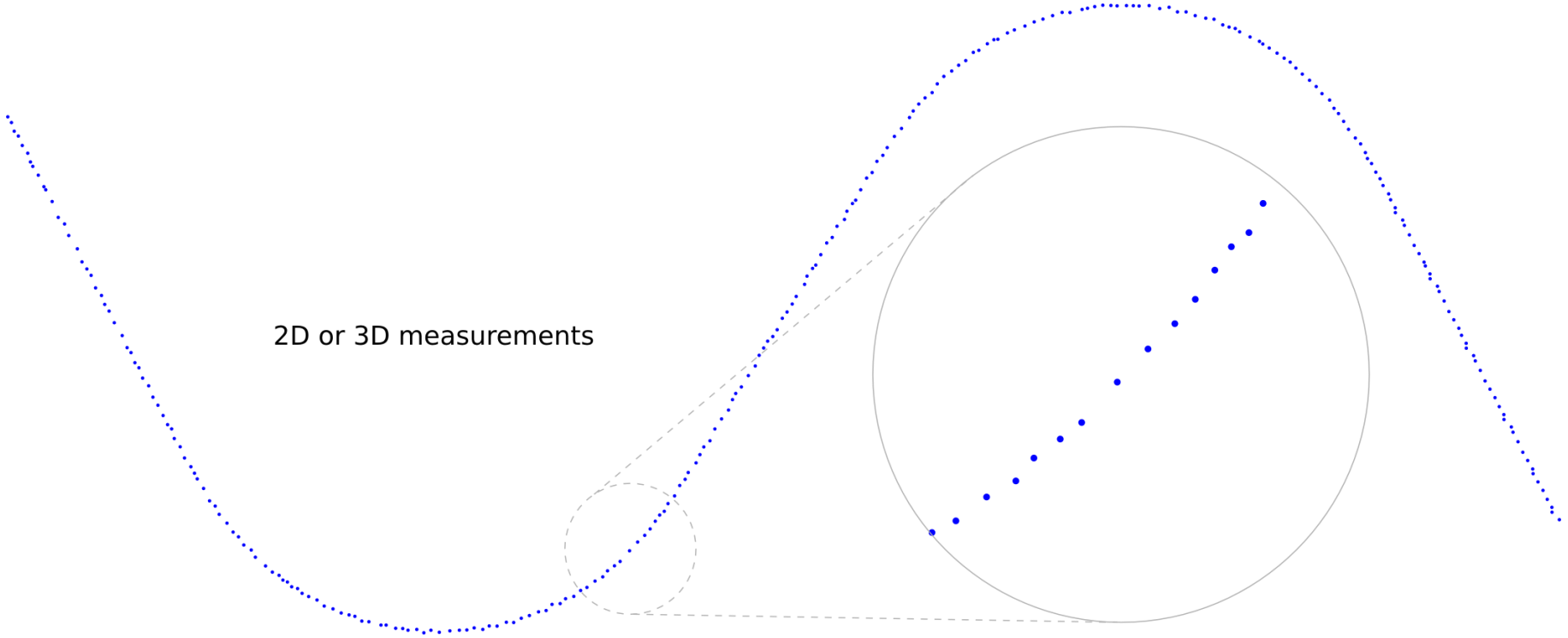
ARC Splines: Example Set of Given Points



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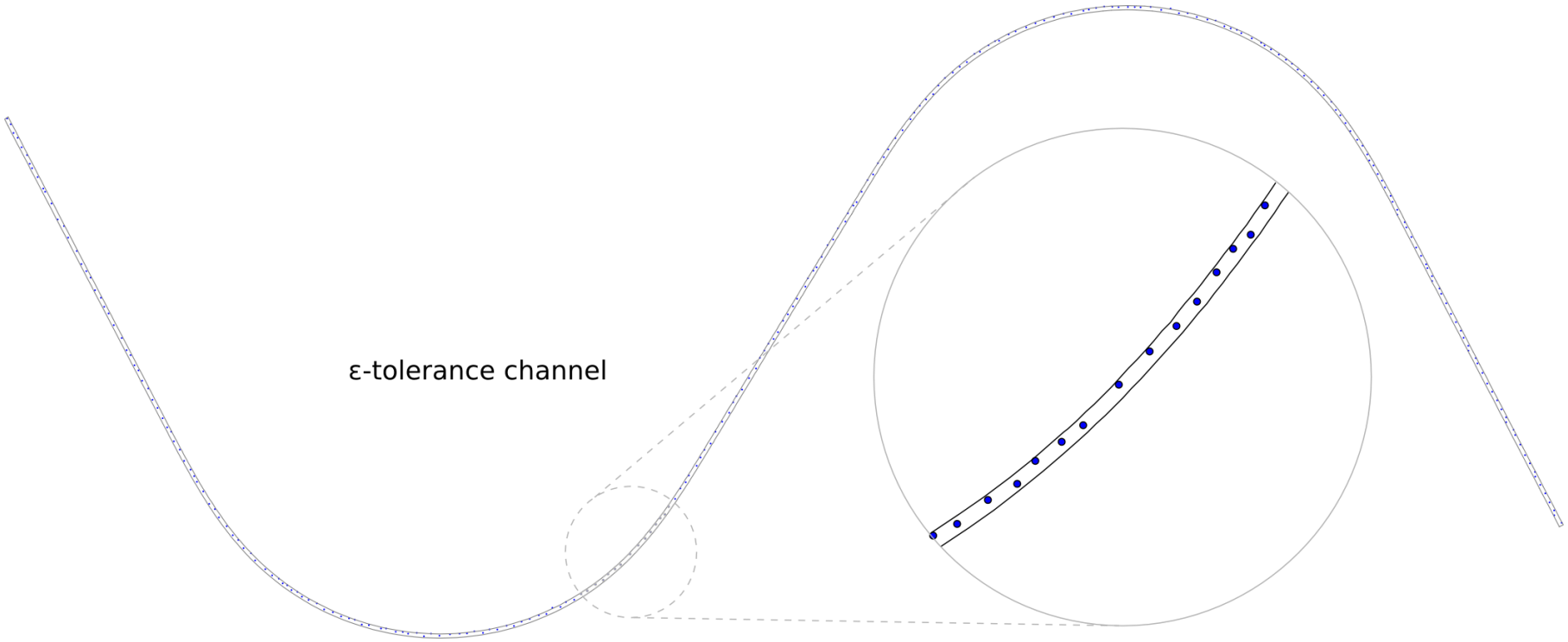
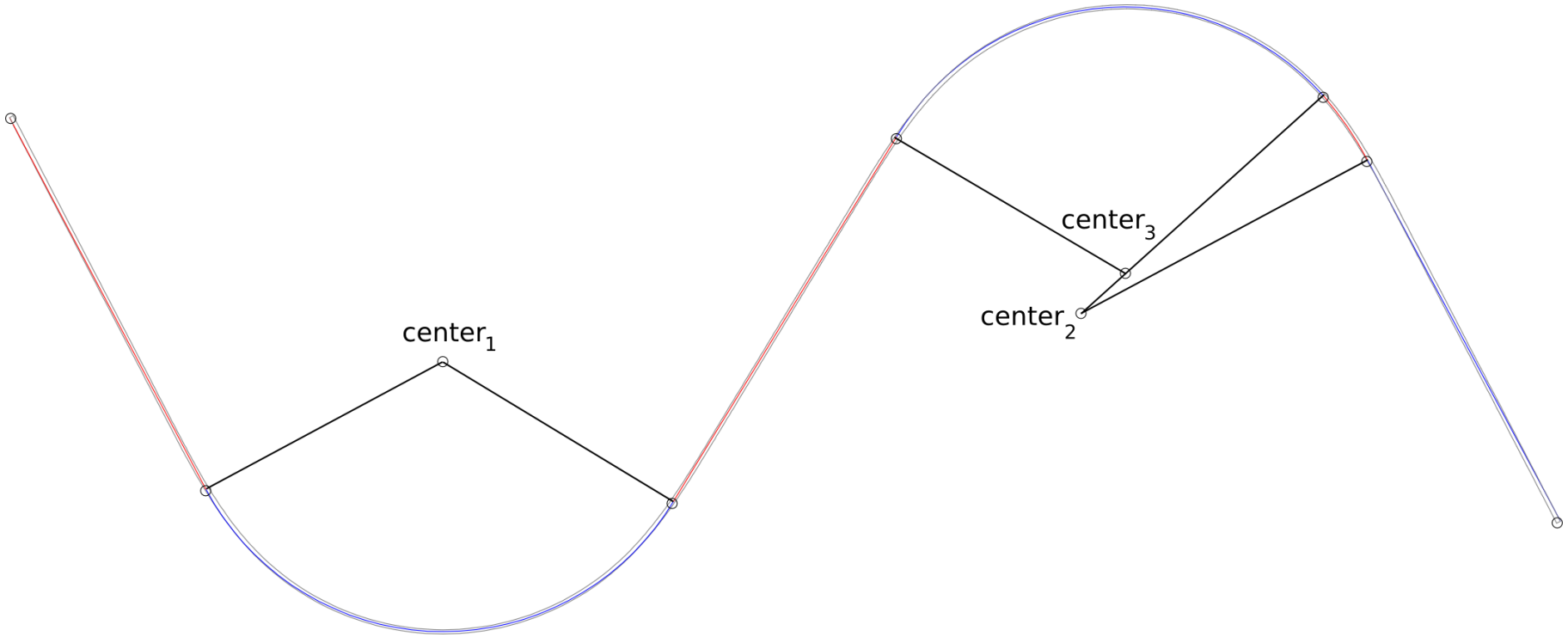
Arc Splines: Tolerance Channel Along Initial Curve

Distance with respect to the maximum norm



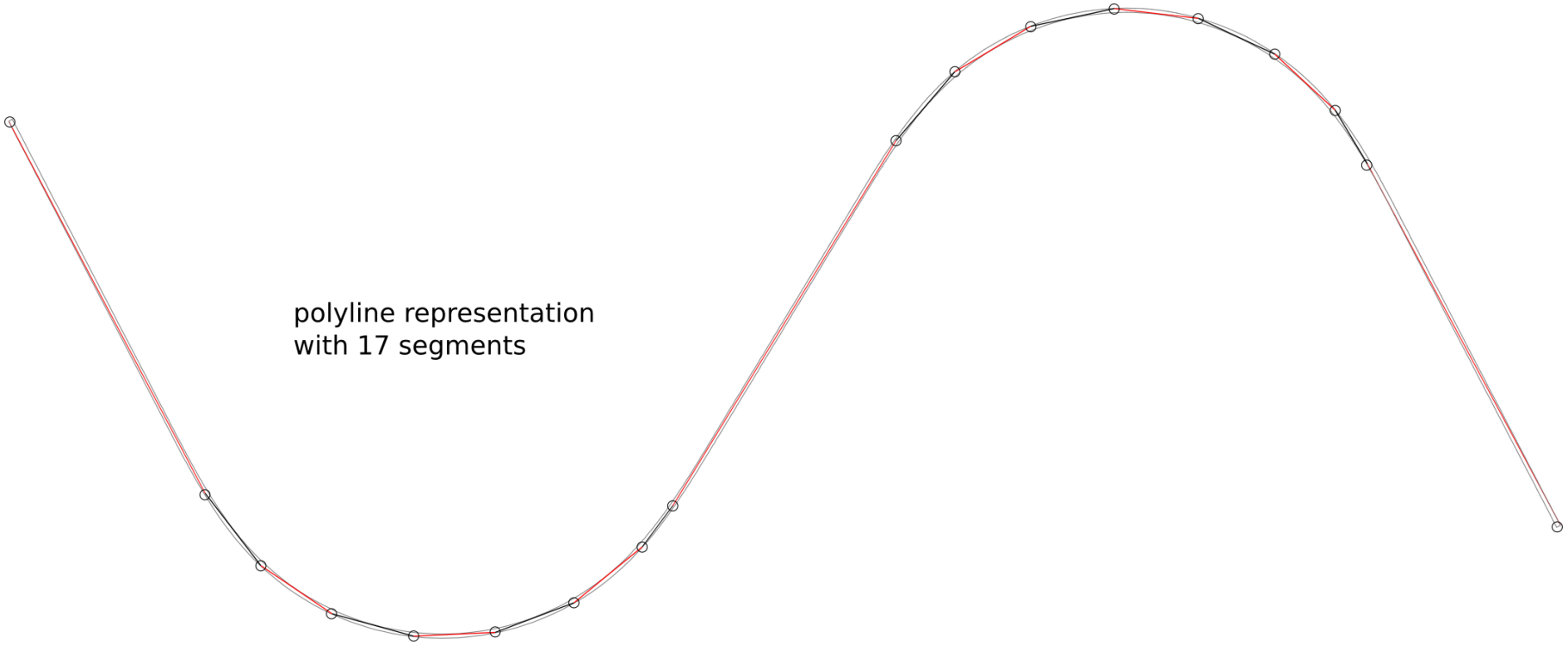
Arc Splines: Existence of Minimum Arc Path

Algorithm for smooth arc path computation
featuring the minimum number of segments



Polyline Representation *vs.* Arc Splines

17 polyline segments versus 6 arc spline segments



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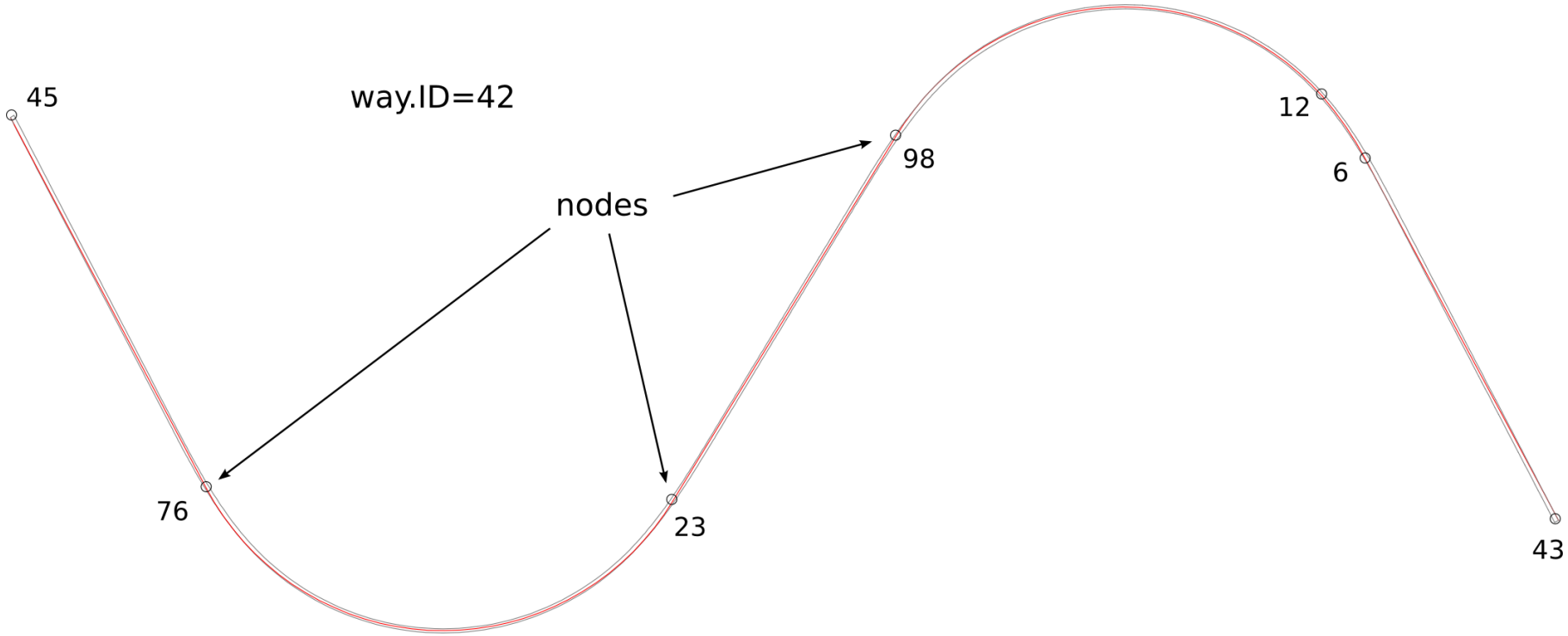
Arc Splines: OpenStreetMap Representation



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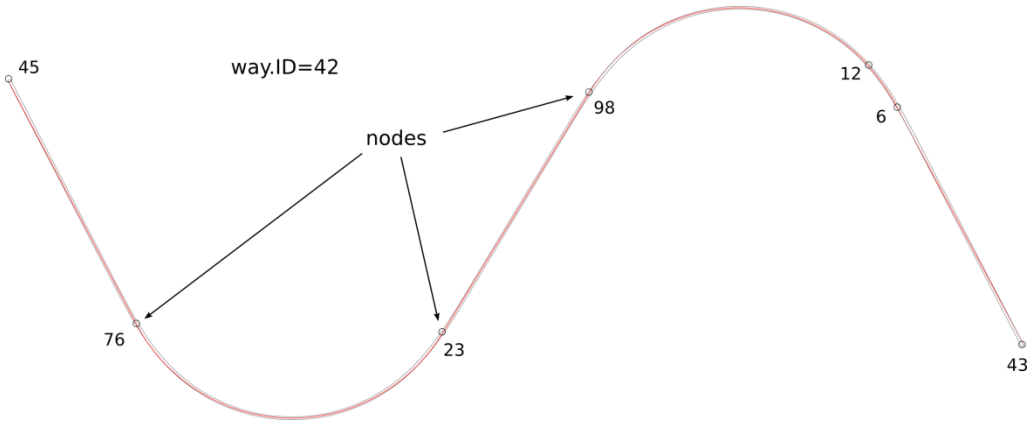
Arc Splines: OpenStreetMap Parametrisation

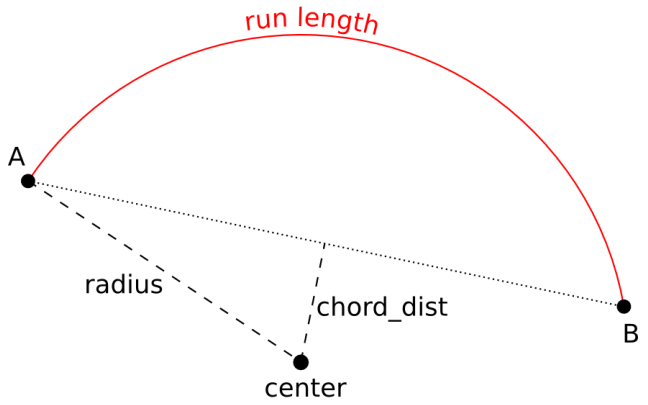
ID	x	y	highway	run_length	radius	chord_dist
45	0.0	0.0	lane	0.0	-	-
76	35.4	18.7	lane	40.0	25.6	-12.6
23	36.6	63.2	lane	94.0	-	-
98	1.8	84.5	lane	134.8	-25.3	15.0
12	-2.1	125.2	lane	182.3	-33.6	33.4
6	4.0	129.3	lane	189.7	-	-
43	38.5	147.7	lane	228.8	-	-

nodes and node-tags

way	num	node
42	1	45
42	2	76
42	3	23
42	4	98
42	5	12
42	6	6
42	7	43

way-nodes





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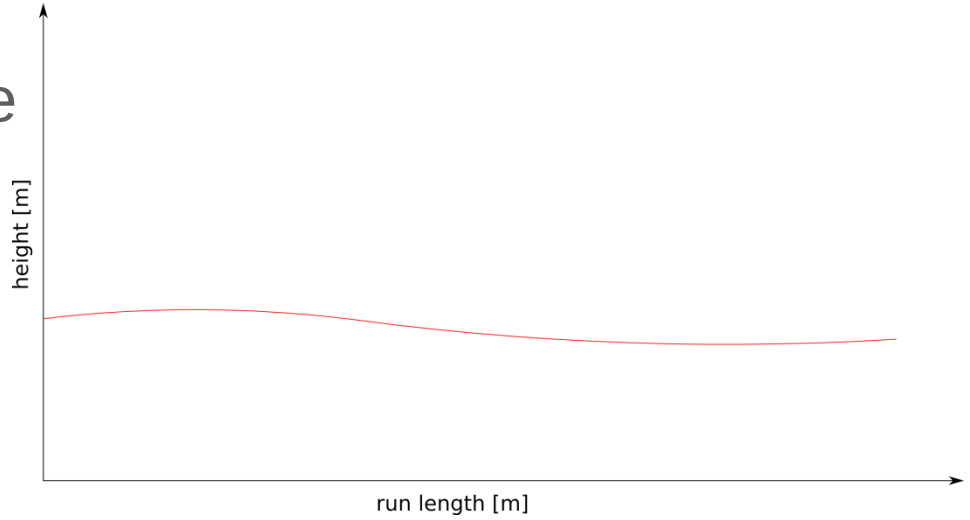
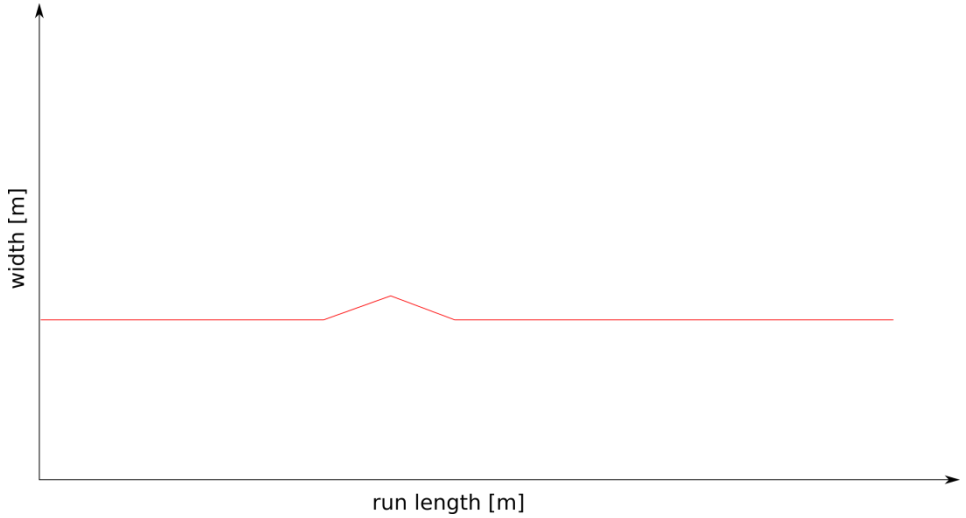
Arc Splines: Representation of Height and Width

- Height and lane width can be (and will be) represented as arc splines, too.
- parametrisation utilises arc length of the planar spline



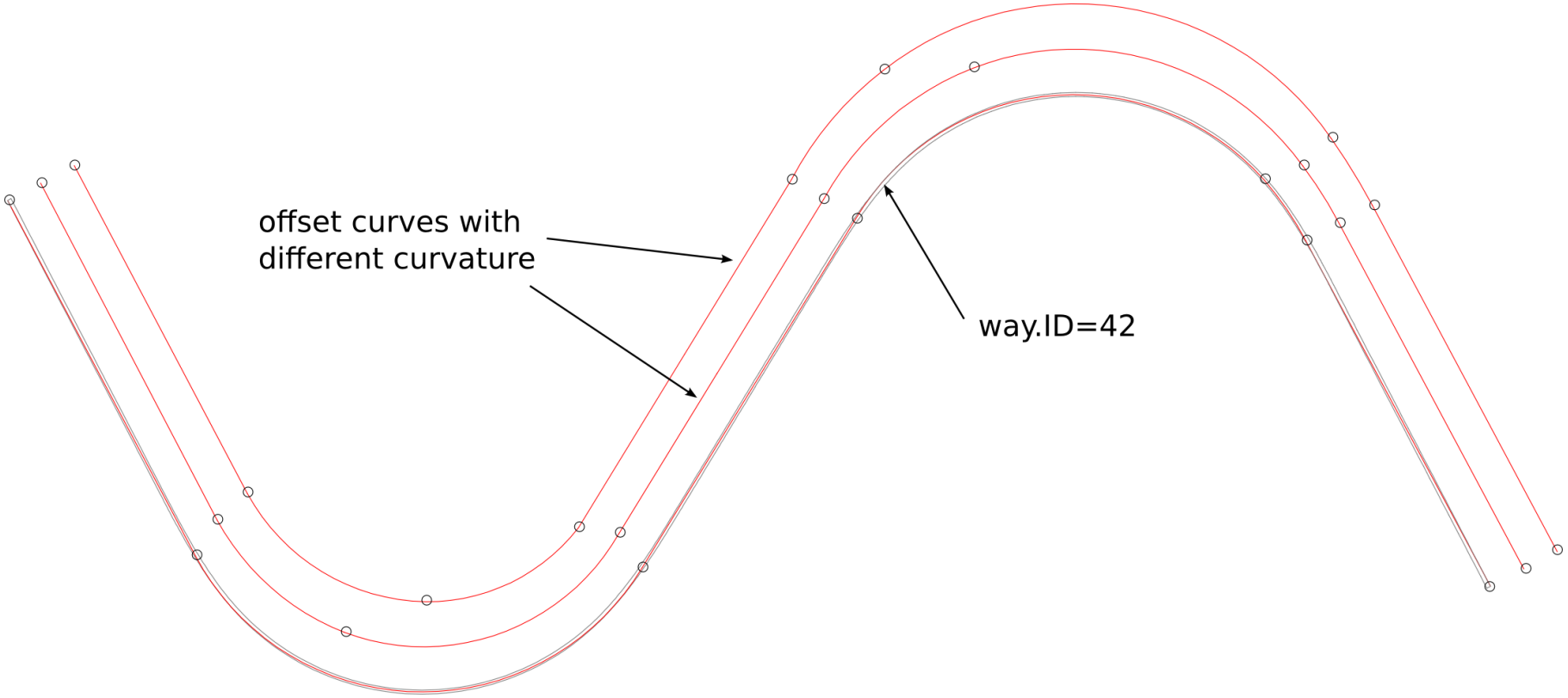


ID	highway	width	curve_type	h_id	w_id
42	lane	3.75	planar_curve	12	67
12	-	-	height_curve	-	-
67	-	-	width_curve	-	-

ways

Arc Splines: Representation of Lanes (Variable Width)

Representation of varying lane widths



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Self-Localisation (SL) via Land-marks: Summary

Arc spline representation of roads and lanes ensures

- Approximation with arbitrary accuracy
- Flexible modelling of lanes
- Distance computation in closed form
- Generation of offset curves
- Curvature information
- Efficient data representation
- Simple and detailed height representation
- Simple and detailed road and lane boundary representation
- Compatibility with common CAD-systems
- Fast computation of the information required in applications

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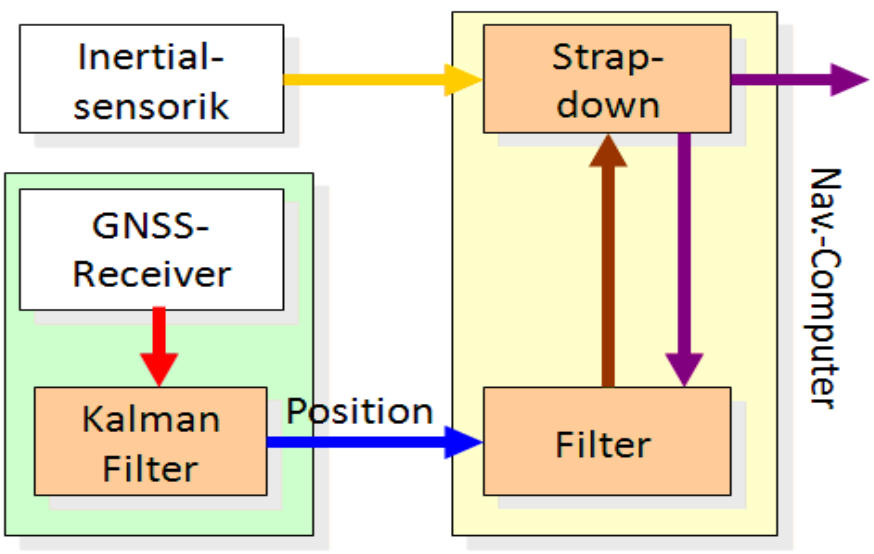
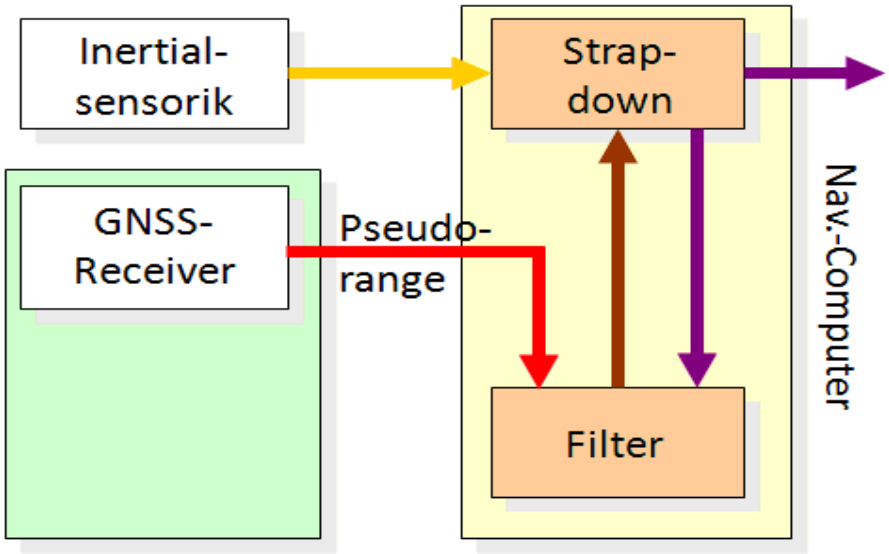
SL via Coupled GPS / INS (Courtesy ITE@KIT)





Measurement of acceleration and angular rates via inertial sensors

- Late fusion of GNSS localisation results and INS integrated data
- Cascaded filtering
- No GNSS stabilisation if less than 4 satellites are visible

- Early fusion of GNSS raw data and inertial measurements
- GNSS stabilisation even with less than 4 visible satellites

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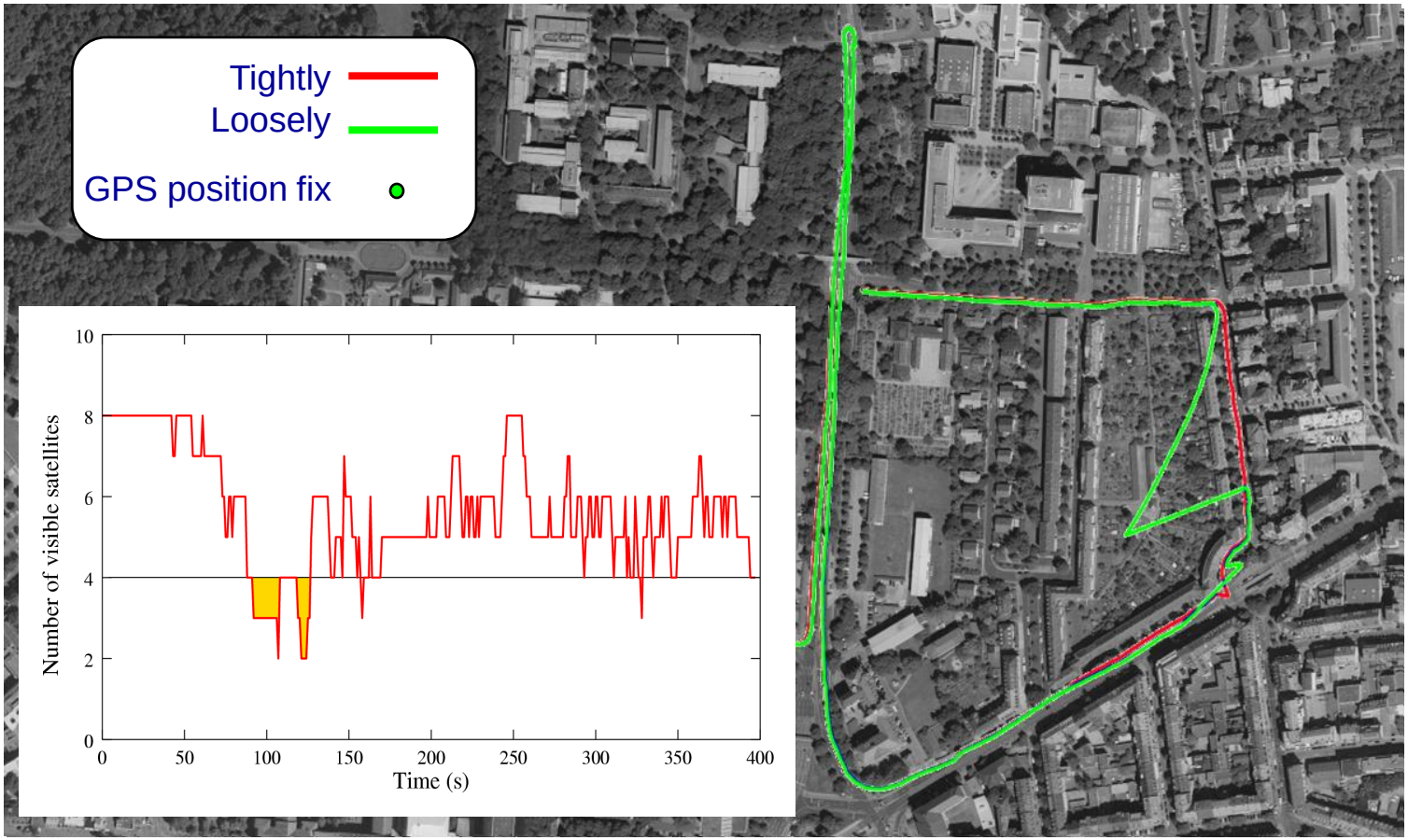
Primal Capability Estimates (Courtesy ITE@KIT)



Source: Institut für Theoretische Elektrotechnik und Systemoptimierung of KIT

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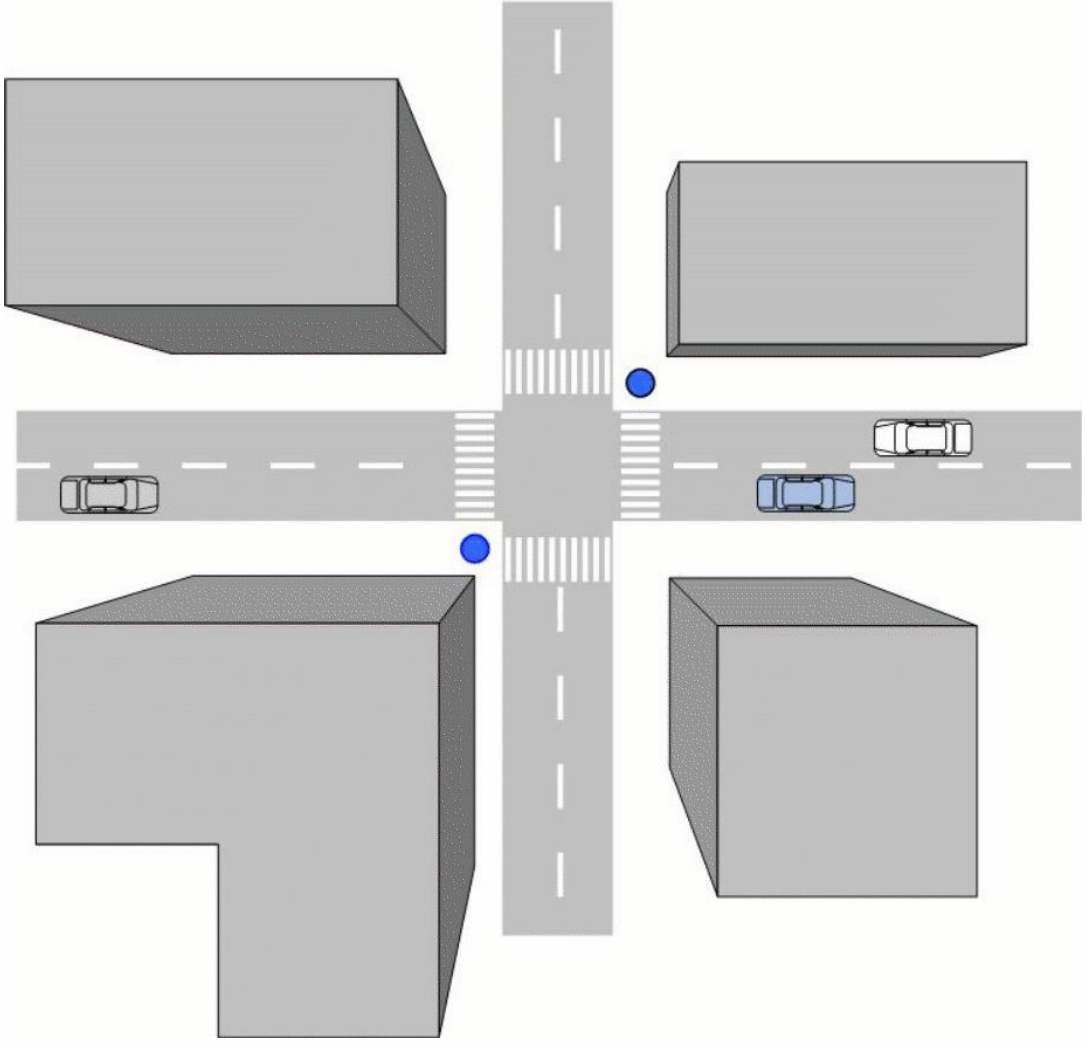
Localisation via Ko-TAG Antenna / Transponders



Direction-sensitive distance attribution: vehicle antenna array two (or more) transponders at intersection

(Courtesy:

The Ko-TAG Project)

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Communication / Message Types

sim^{TD} +

- CAM: Cooperative Awareness Message (state info about sender)
- DEN: Decentralized Environmental Notification (danger warning)
  (Ko-PER will propose and utilize additional DEN types)
- TGM: intersection Topologie und Geometry Message
- SPaT: Signal Phase and Timing (signal state information)

Ko-PER ++

- iCPM: Cooperative Perception Message - infrastructure
  (Information about perceived objects: type, properties, dynamics)
- vCPM: Cooperative Perception Message - vehicles
  (information about static and dynamic objects)
- CLM: Cooperative Localization Message: GNSS / INS satellite-info

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Global (Mostly Track2Track) Data Fusion

Perception results of the ego-vehicle is integrated with those of other sensor networks (*i.e.* of intersections and other vehicles)

Such potentially complete environment surveillance allows:

- Cancellation of occlusions
- Overcoming of quasi-deterministic models
- Step-by-step adoption of rule-based and cognitive approaches (Scene interpretation, scene recognition), hence:
- Machine-based disentanglement of conflict situations / design of real-time conflict resolution strategies

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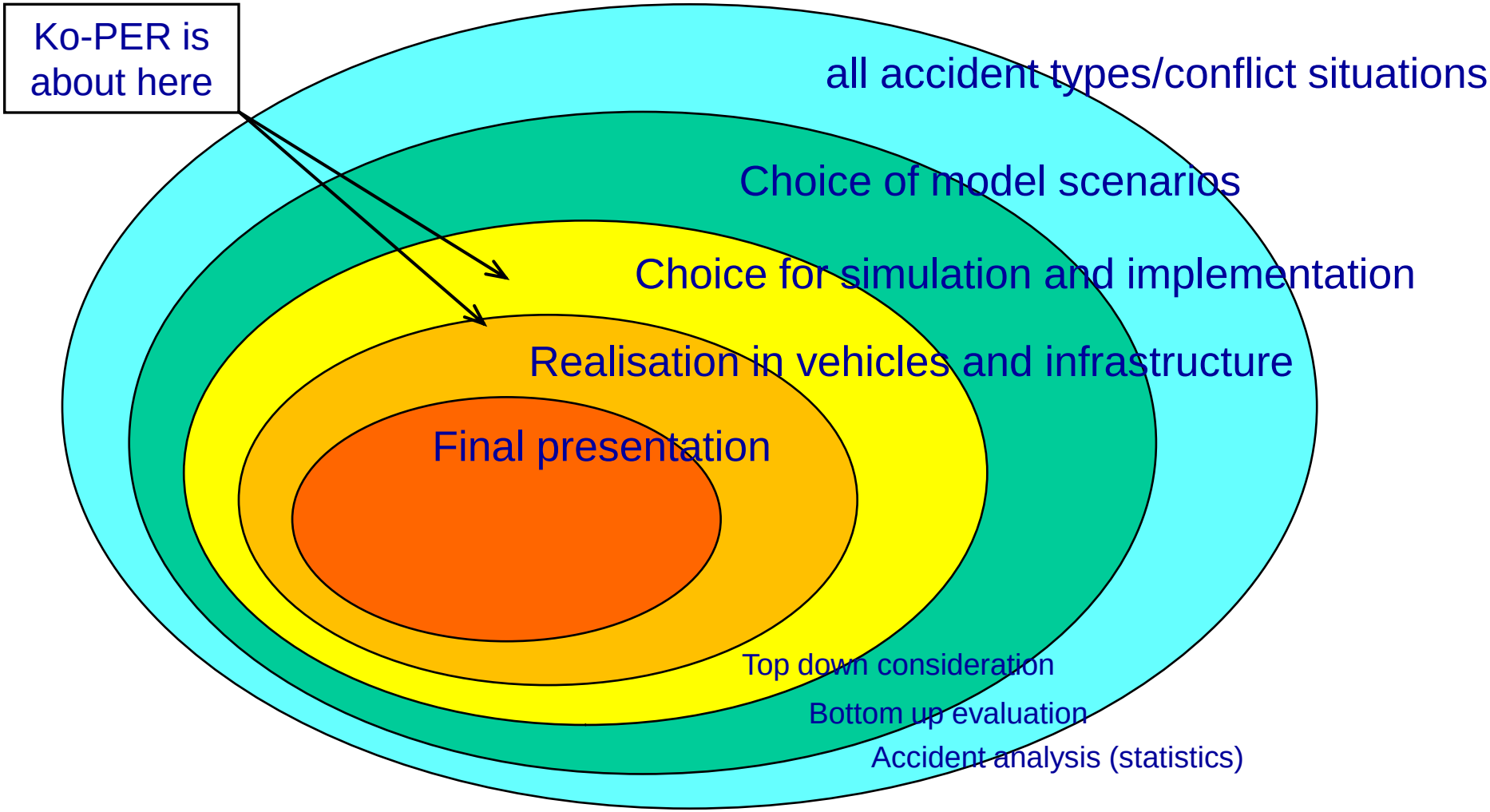
Traffic Scenarios, Use Cases, Functions



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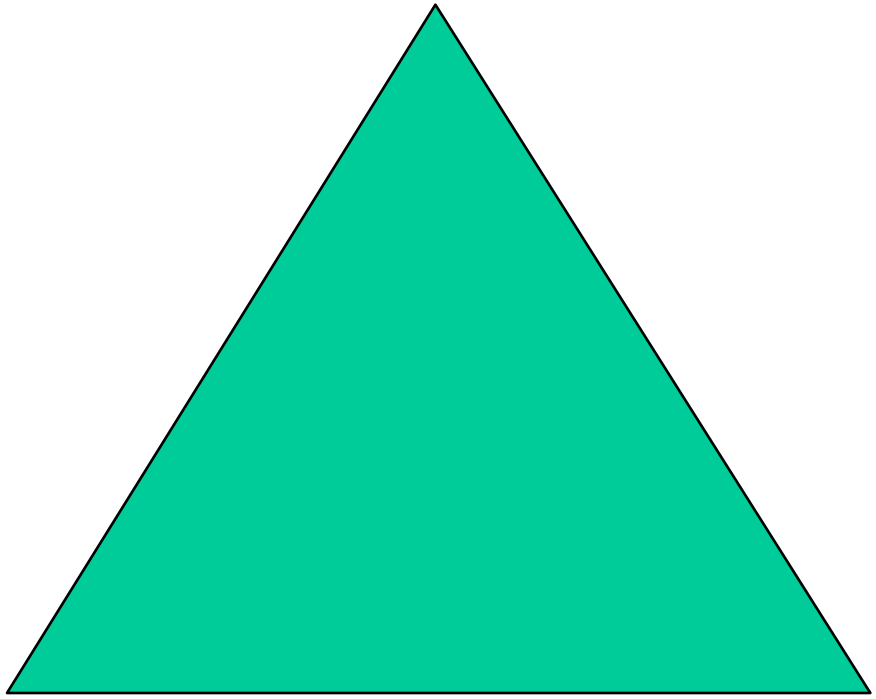
Selection of Scenarios, Use Cases, Functions

customer value
driver uneasiness / test subject feed-backs



Ko-PER selling points

relevance << accident statistics

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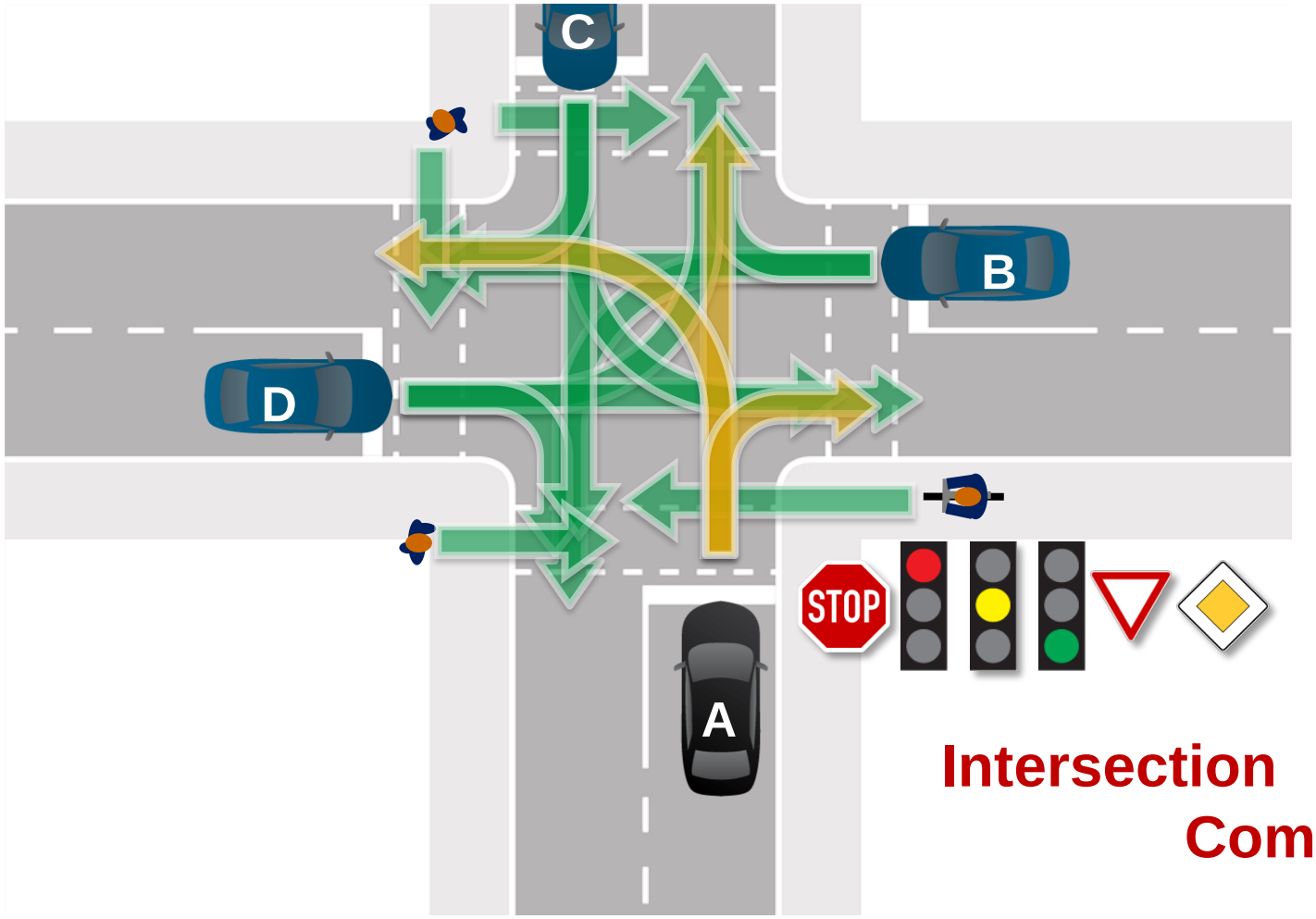
Selection of Scenarios / Use Cases / Functions



Intersection Combinatorics

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Conclusions and Future Prospects

- Roadmap for (communication-based) cooperative systems:
  - cooperative sensors systems and cooperative perception
  - host-vehicle cognition ► cooperative cognition
  - cooperative driver assistance complements and supports driver information & support; autonomous action as last resort

- Cooperative all-around view perception permits/enables situation awareness & risk comprehension: dependence on driver intension
- Unprecedented challenges concerning HMI concepts
- Supplement / complement of classical binary logic
- Comprehension of time as dimension of causal relations: courses of actions and their meaning rather than objects and their (dynamic) states are the crucial thing to be considered.

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Questions? Comments? Ideas?