Using eHorizon to enhance camera-based environmental perception for ADAS and AD

Dr. Hongjun Pu

Continental Automotive GmbH, Wetzlar, Germany

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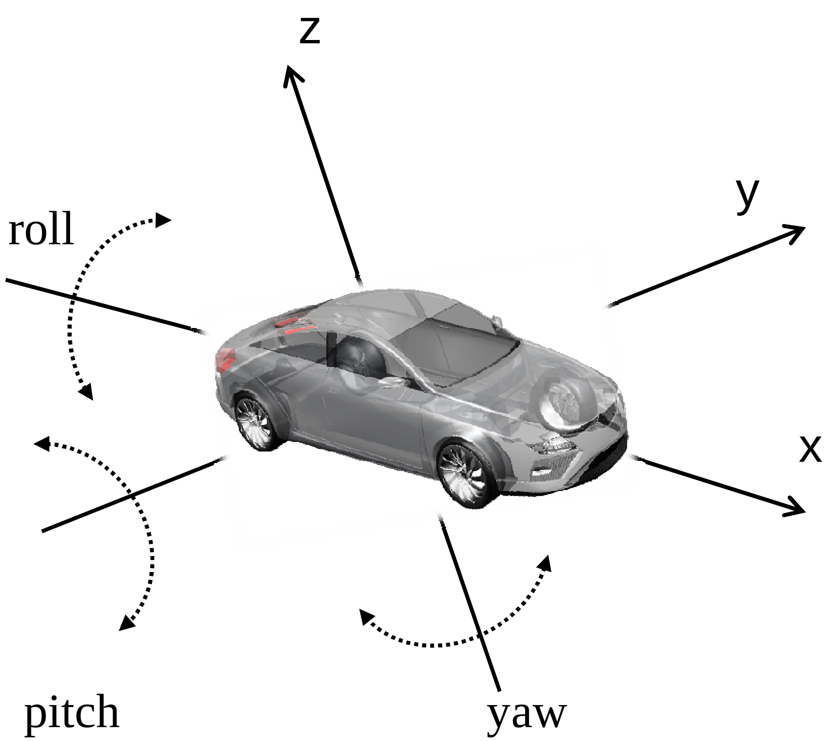
Visual Perception and Automated Driving (AD)

- Currently high expectations within the field of road traffic automation is forcing R&D activities towards technologies enabling AD.
- The traditional tasks of automation are to control certain variables of a system or process; based on direct or in-direct measurements as a feedback.
- Due to the situation of today's road traffic, the environment and traffic are subject to highly dynamical changes. Therefore, the driving control of an autonomous vehicle must be adaptive and self-learning.
- Accordingly, the most challenging tasks for AD are the perception of the environment and the recognition of the situation, whilst the control of the vehicle motion itself is a solvable task in the most cases.
- For the environmental perception, an autonomous vehicle must possess a similar capability of sense as that of the human driver; in particular the sense of sight. So camera and camera-based sensing technologies are indispensable for AD.
- It differs from "assisted driving", whereby the driver is directly involved. An autonomous vehicle has to do everything by itself, including mapping the camera pictures to the real world.

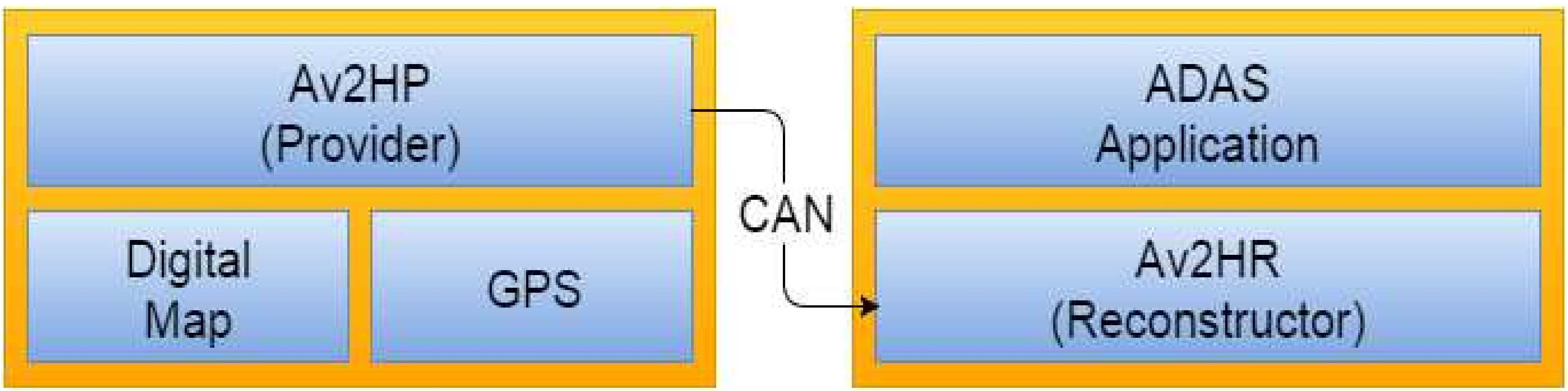
Mapping Camera Pictures to the Real World



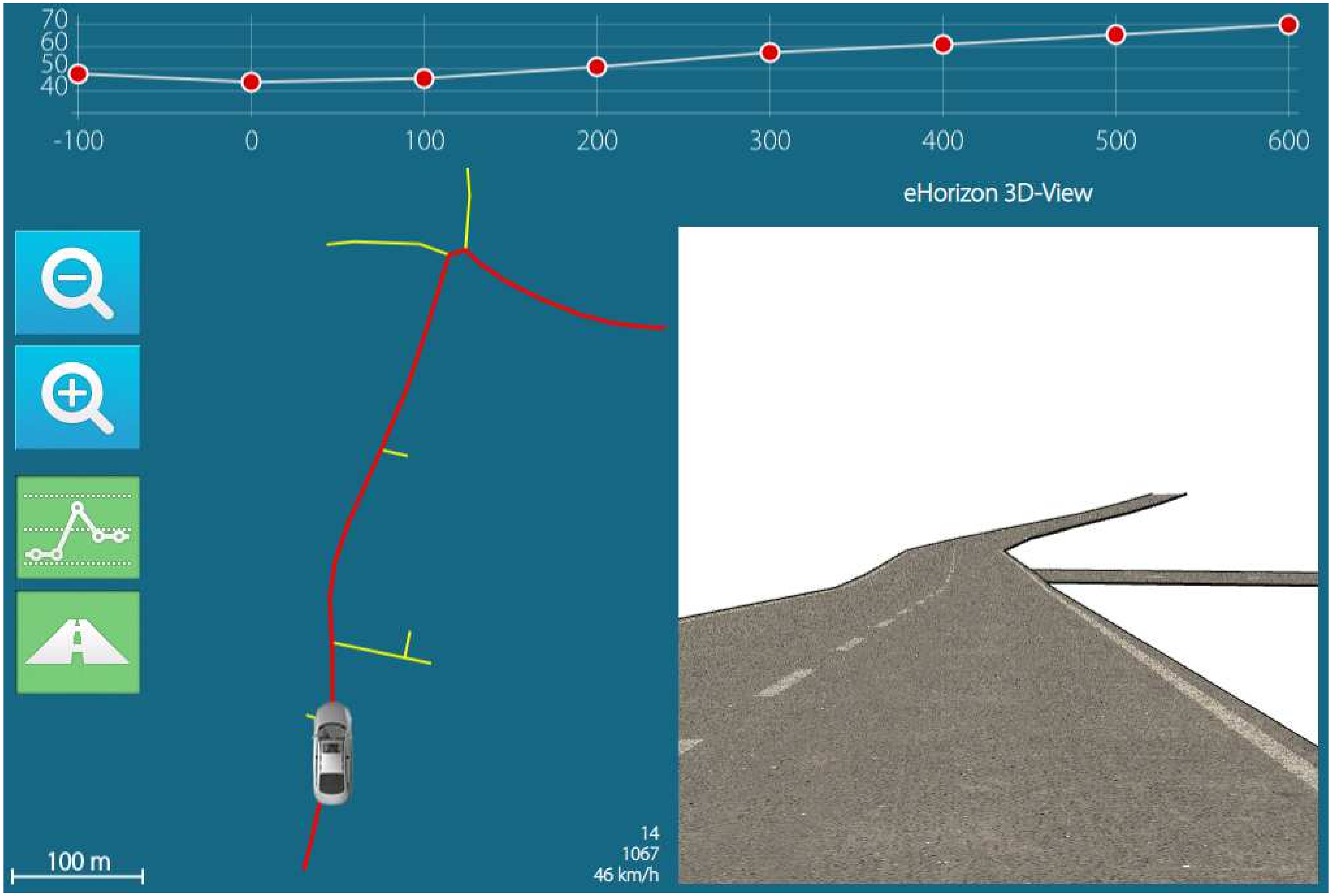
- Using a coordinates system fixed on the vehicle and with known mounting parameters of the camera, one can calculate the optics within the vehicle coordinates system.
- Given the position and orientation of the vehicle in the world frame, one can also transfer everything from the vehicle coordinates system into the real world.
- In order to interpret the camera picture according to the real objects and events on the road, one needs to further know the road topology.
- The Continental electronic Horizon can provide the road topology in a practical way.

The Continental electronic Horizon

- The electronic Horizon (eHorizon) is an emerging technology providing road information to ADAS applications for the purpose of fuel/energy optimization and safety enhancement.
- The eHorizon provider extracts road attributes from a geo-database (digital map) and provides them over a well specified CAN-interface to the ECUs possessing an eHorizon reconstructor.

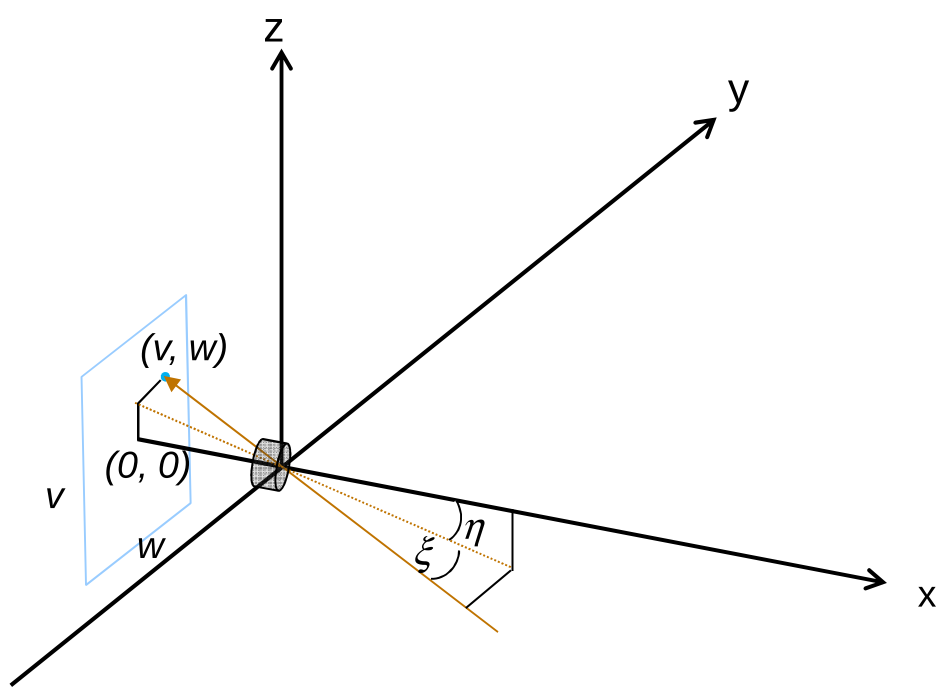


Road Reconstruction based on attributes provided by eHorizon



Mapping between the picture and the real world: the “Light-Ray”

› Given the optical and montage parameter of the camera, one can determine for an arbitrary image pixel (v, w) of the camera picture the entering angle (η, ξ) of the light-ray that creates this image pixel.



Mapping of the picture and the real world: the “Inverse Light-Ray”

- If one just inverts the light-ray and lets it go from the camera focus point to the real world, then any point on the inverse light-ray can be expressed as:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = k\vec{r}_0 = k\begin{pmatrix} \cos(\xi)\cos(\eta) \\ \sin(\xi)\cos(\eta) \\ \sin(\eta) \end{pmatrix}$$

for $0 \le k \le \infty$, where

$\vec{r}_0(v, w)$ is a unit vector with the pitch of η and yaw of ξ:

- With increasing *k*, the inverse light-ray will somewhere reach the original object, which is depicted at the image pixel (*v*, *w*).
- Suppose that the depicted object lies on the road, then one needs just to obtain the point where the inverse light-ray crosses with the road surface.

Determination of the Crossing Point using eHorizon

The inverse light-ray algorithm delivers an approximate mapping from an image-pixel to the original object in real world:

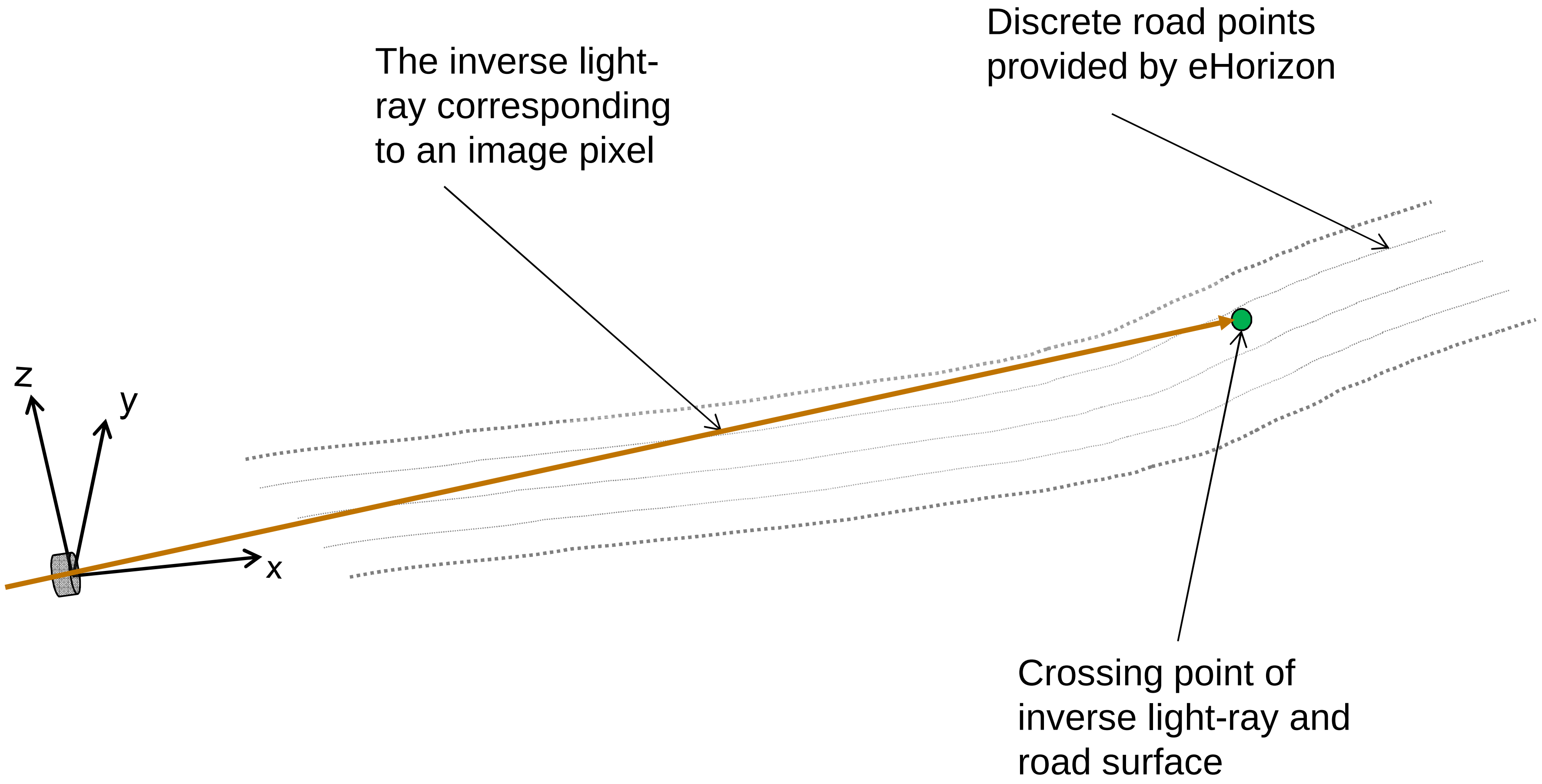
1) The road topology data will be extracted from the eHorizon for a few meters to a few hundred meters ahead of the ego-vehicle.
2) Using the road topology data, one or more poly-line(s) are defined in the vehicle coordinates system to represent the road or the lanes of the road.
3) Suppose that there are totally *p* discrete road points contained in the poly-line(s), then the crossing point is approximately the point (x, y, z) on the inverse light–ray that has the minimal distance to one of the *p* road points.

If the depicted object, e.g. standard traffic sign, is expected to be *q* mm over the road surface, all road points are translated in z-axis for *q* mm.

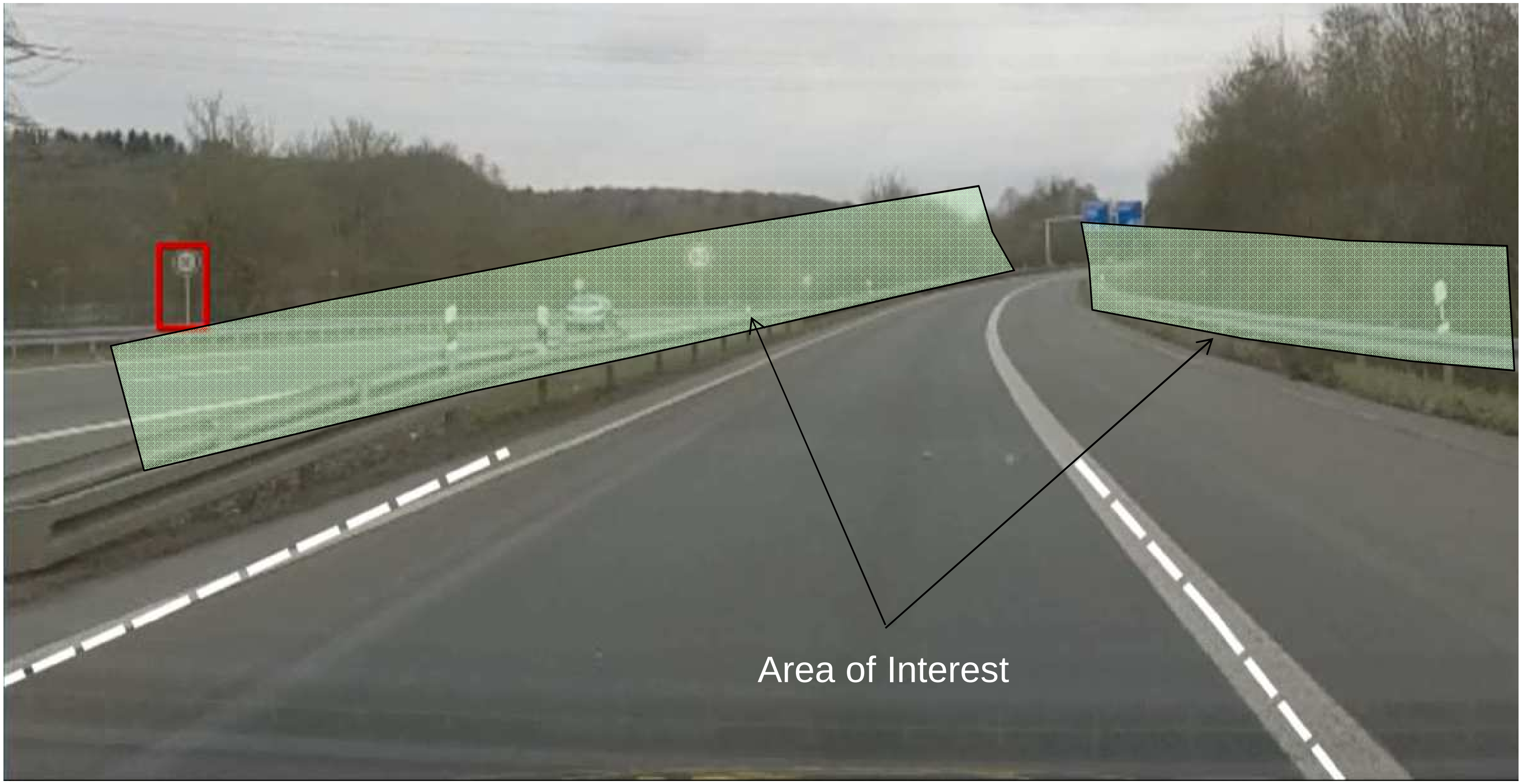
The above Inverse Light-Ray Algorithm (ILA) has the following properties

- The accuracy of ILA increases, if the resolution of the eHorizon increases.
- The execution of ILA has always determined computing steps by given accuracy demand and eHorizon resolution.
- An inverse mapping, i.e. to calculate the light-ray from real world to the picture, is always possible using the same equations presented in the paper.

Determine the Crossing Point using eHorizon: Illustration



Example: Traffic Sign Recognition



Thanks a lot for your attention !