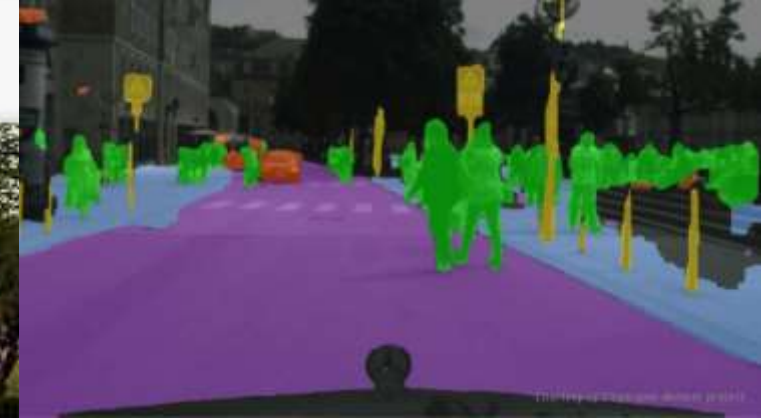
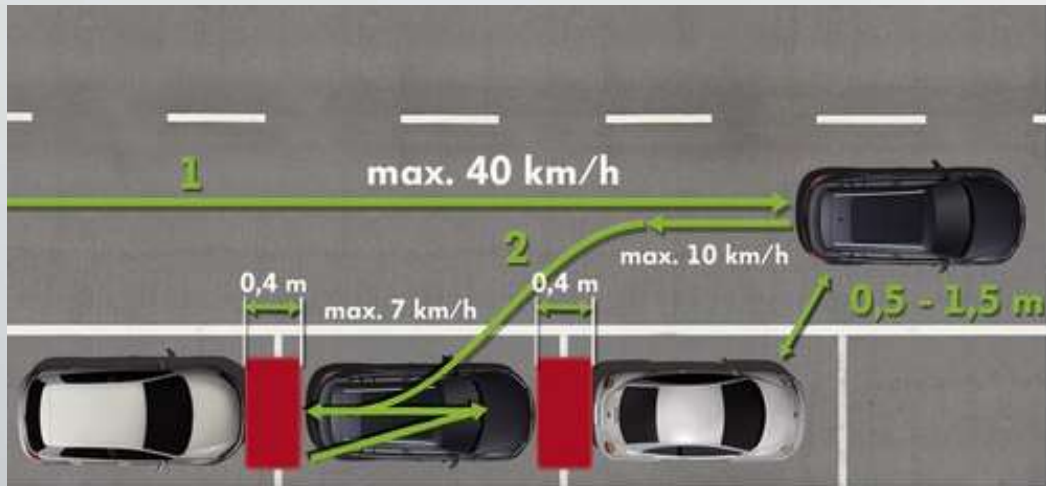
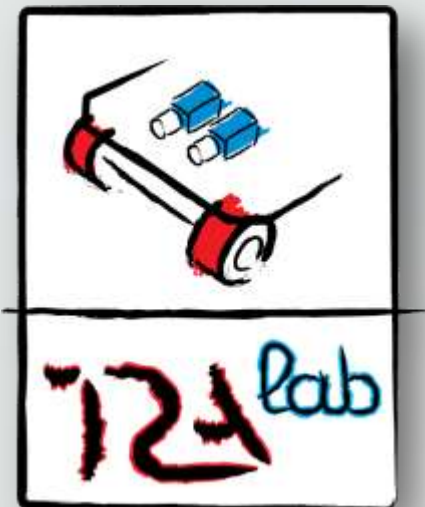


A few sensor failure modes





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Dip. Informatica, Sistemistica e Comunicazione

Università degli Studi di Milano - Bicocca

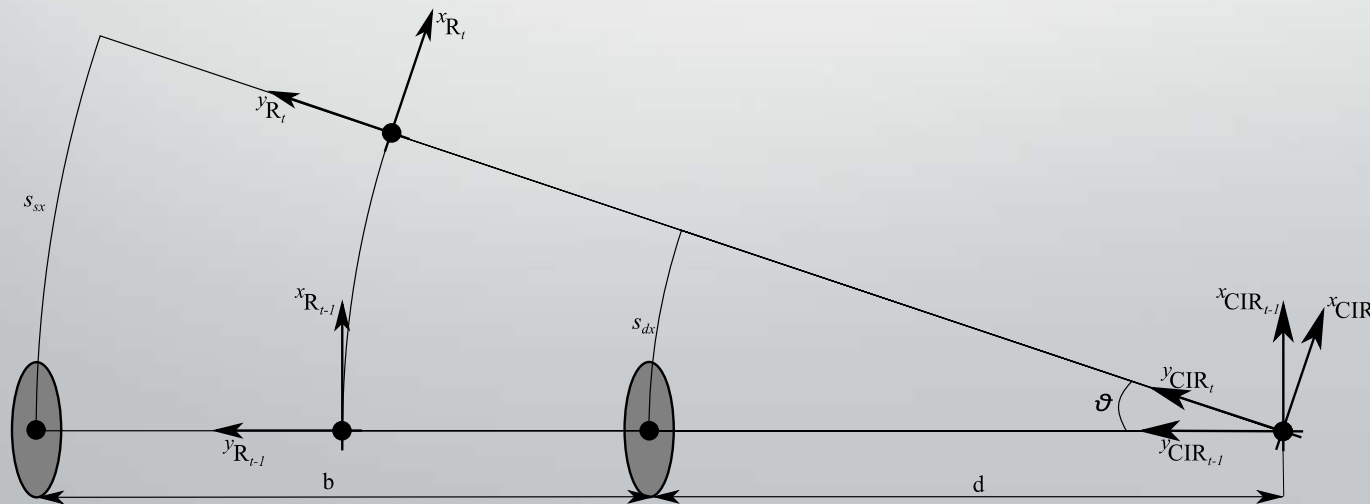
A short review of failure modes of sensors used in ADAS and autonomous driving



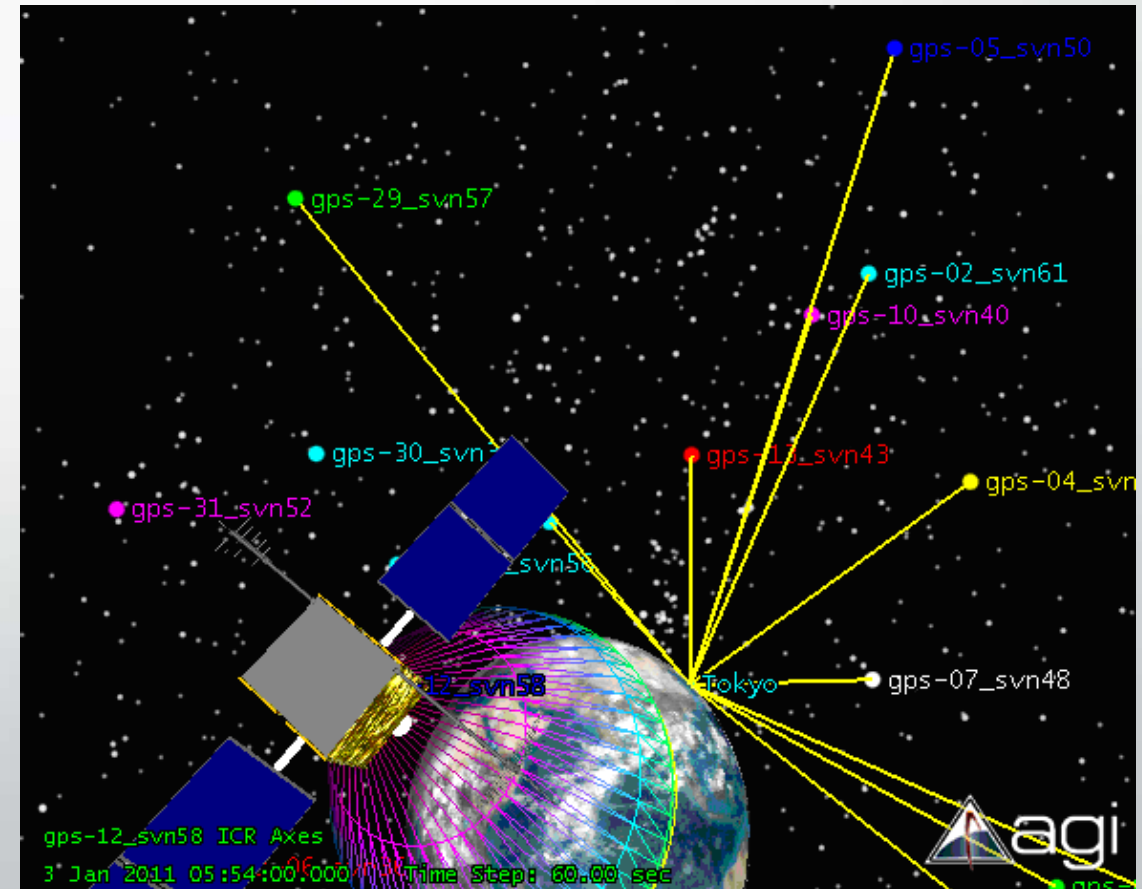
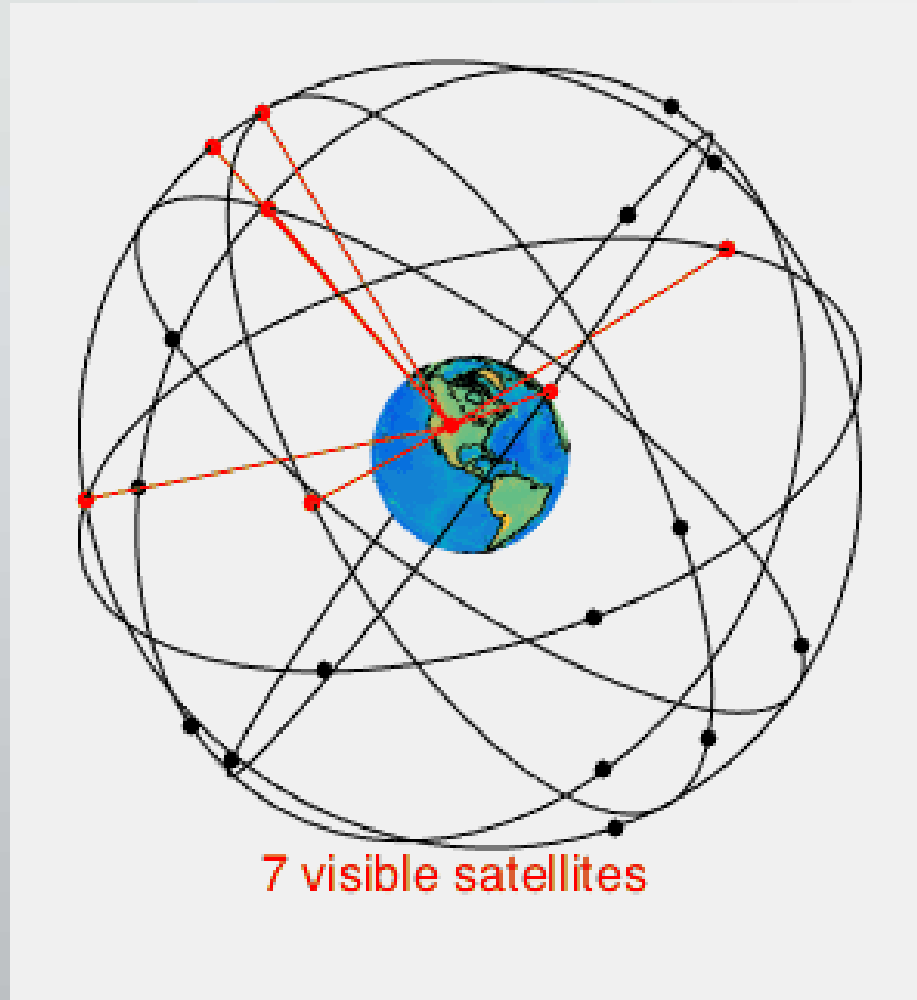
Index

- Simplest idea: proprioception.
- Position estimation based on proprioception is not enough.
- Global localization.
- Global localization is not enough.
- Sensors for observing the world outside the robot (car), for localization and world modeling.

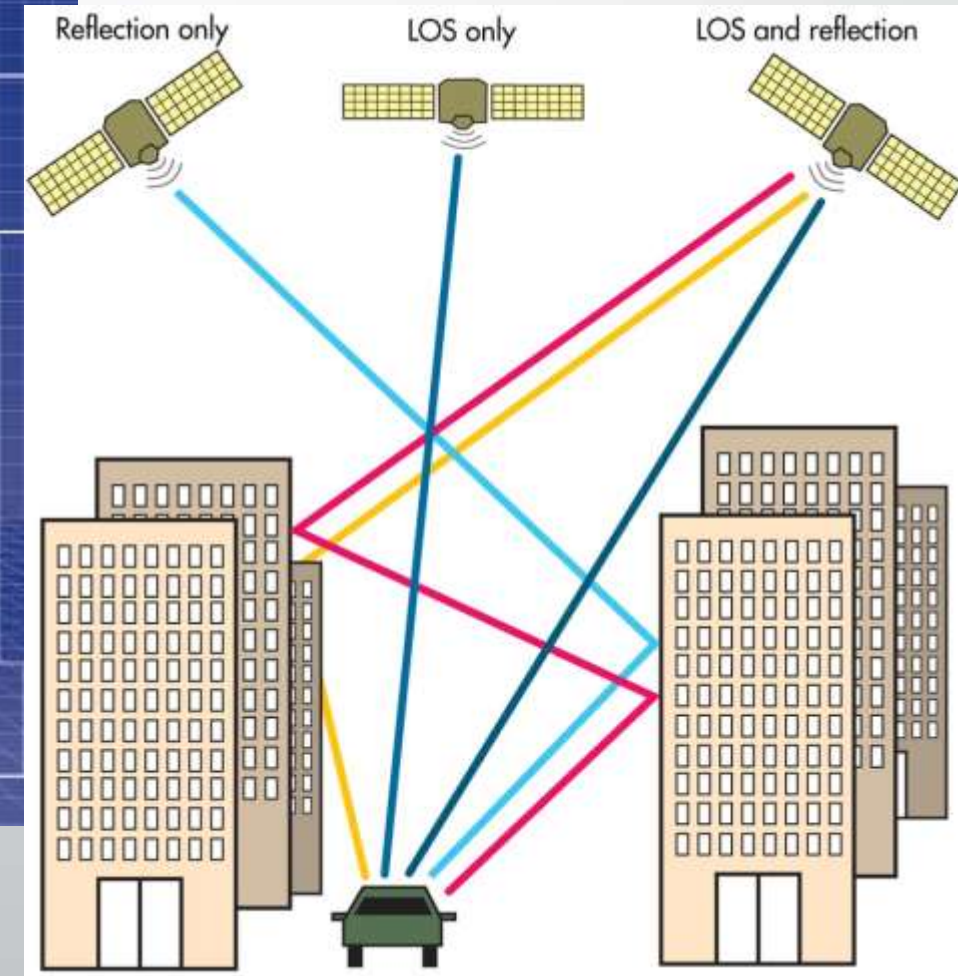
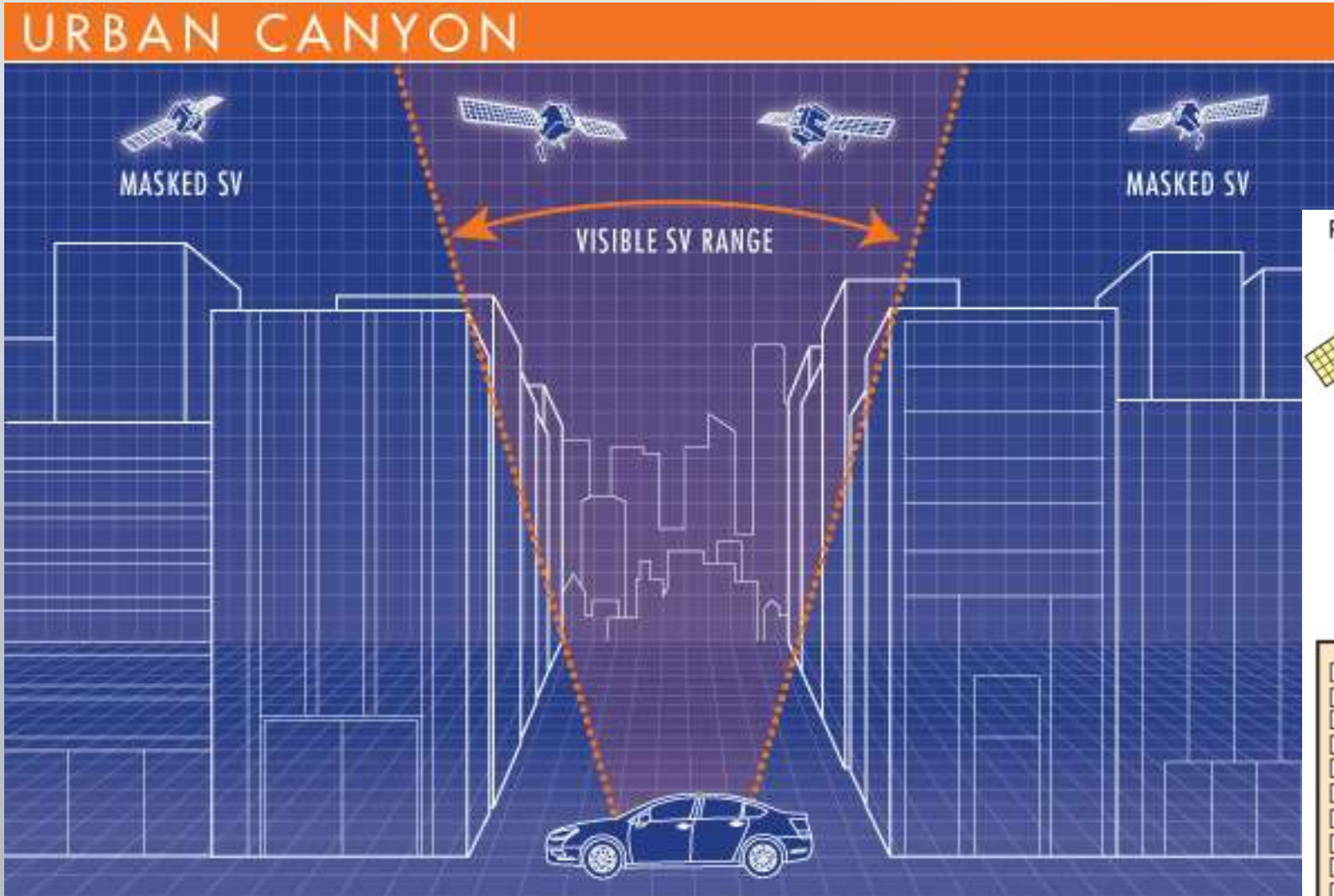
Proprioperception of motion



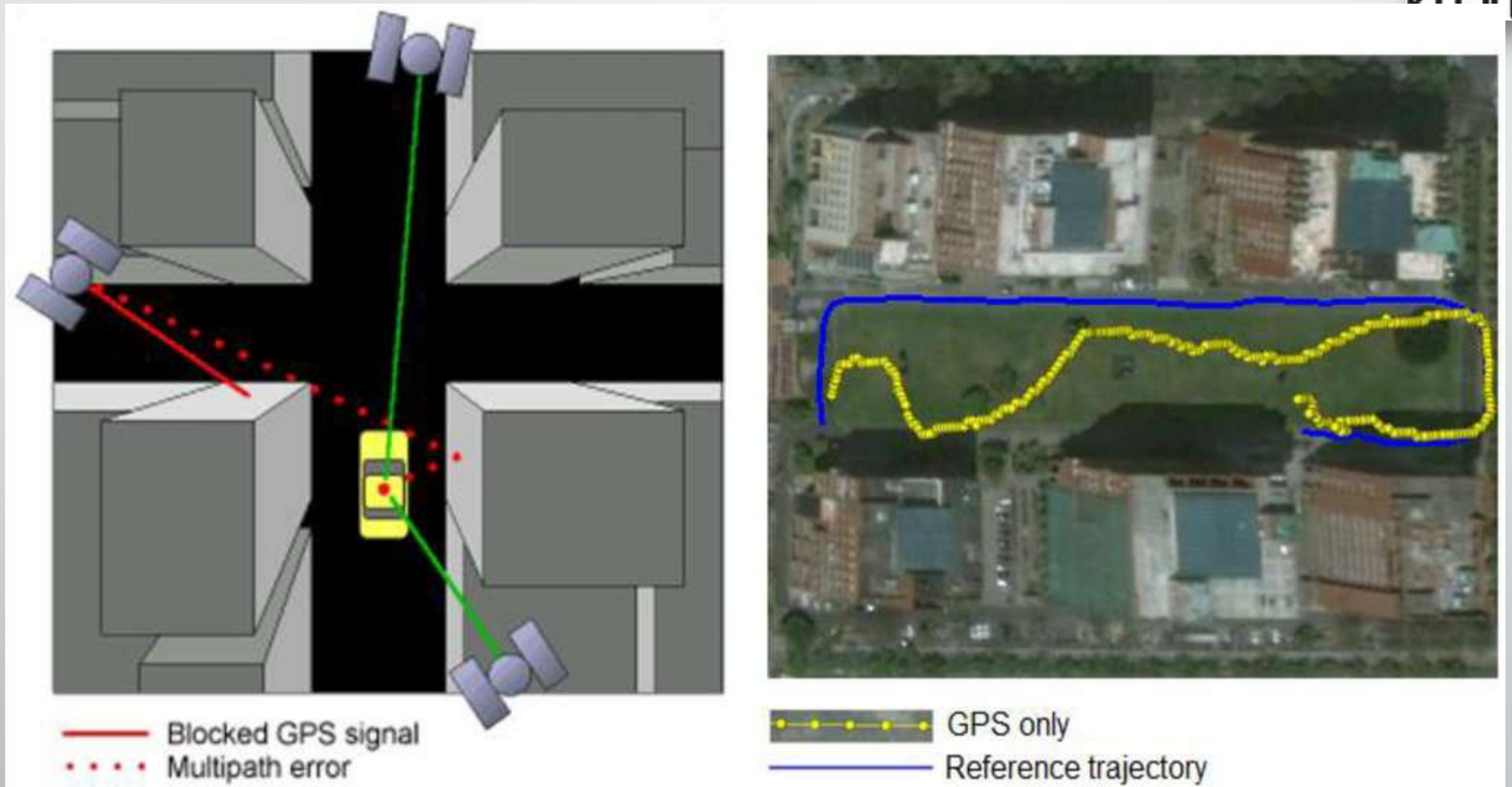
GNSS: GPS, Galileo, Glonass, Beidu



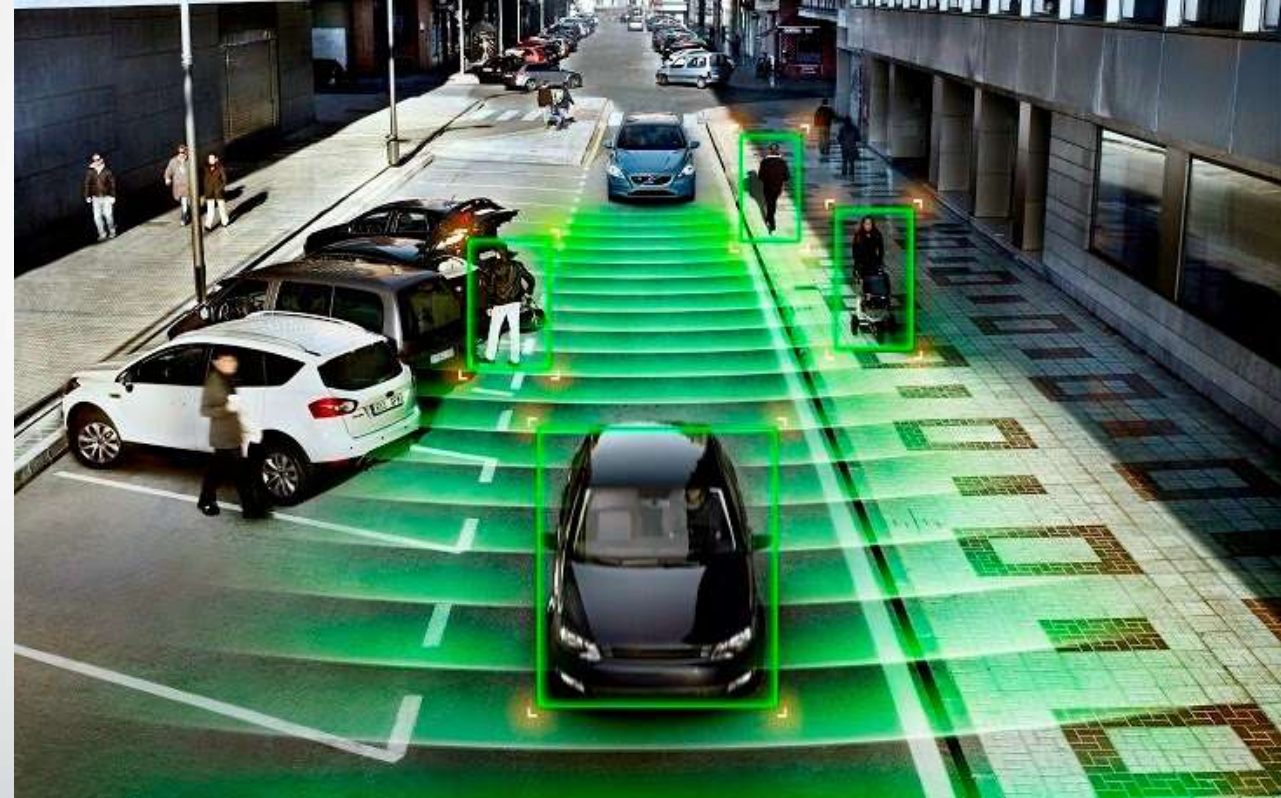
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GNSS: GPS, Galileo, Glonass, Beidu



Necessari sensori a bordo robot



Sensors

- In ADAS and in autonomous driving the robotcar builds a model of the world.
- This means the car perceives the world around it by means of its sensors and processing the data from the sensors.



Sensors

- Sensors are the union of sensor hardware, electronic signal conditioning, conversion in computer treatable format, software processing and settings for the software parameters



Sensors

- Perception is never 100% perfect.



plant
car
boat
water
river
house
building



Sensors

- Failures
 - HW limits
 - Processing errors



Most used sensors

Under the bonnet

How a self-driving car works

Signals from **GPS (global positioning system)** satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone

Lidar (light detection and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads

Video cameras detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road

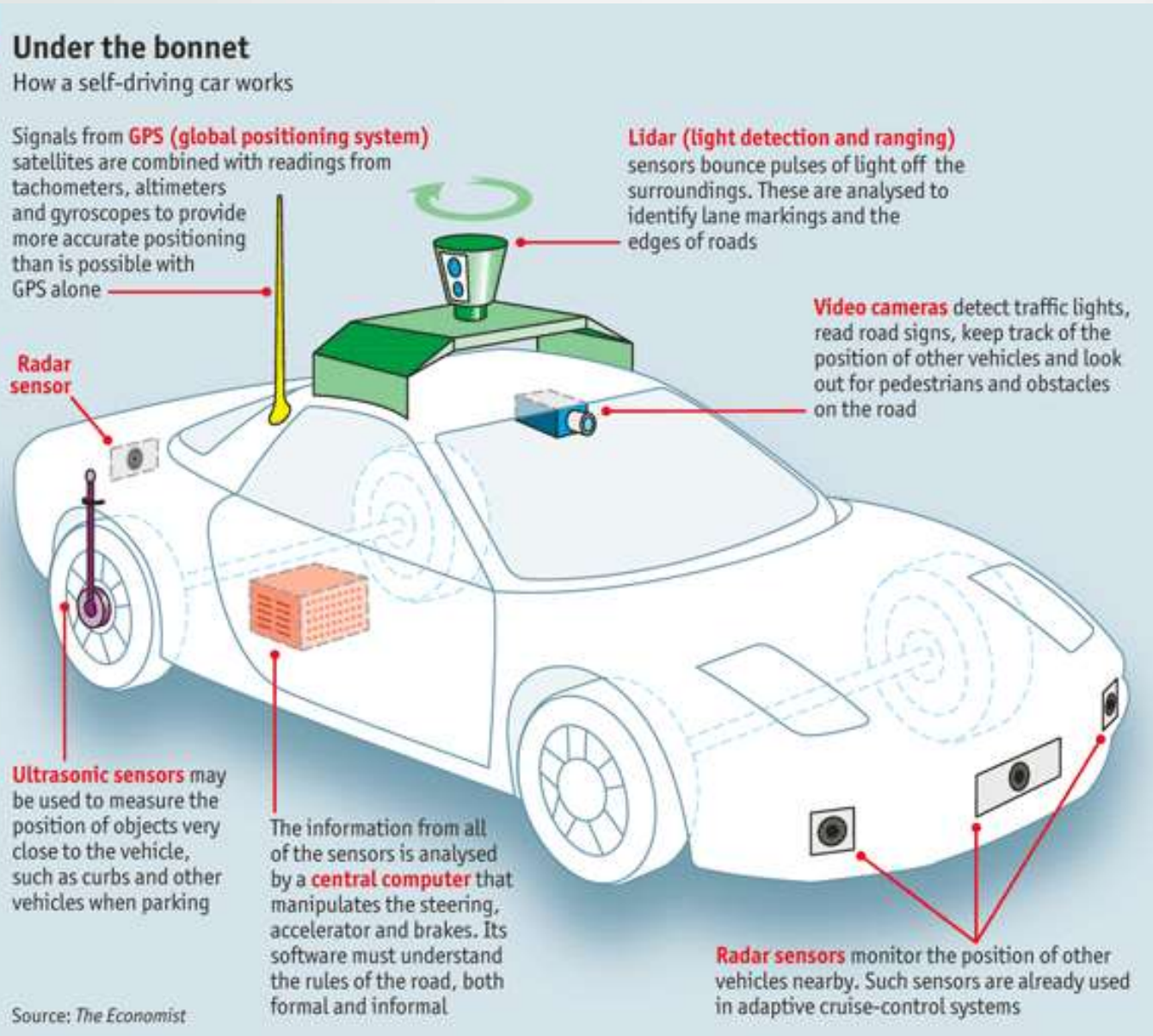
Radar sensor

Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as curbs and other vehicles when parking

The information from all of the sensors is analysed by a **central computer** that manipulates the steering, accelerator and brakes. Its software must understand the rules of the road, both formal and informal

Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems

Source: *The Economist*



- RADARs
- LIDARs
- Cameras

Most used sensors

Under the bonnet

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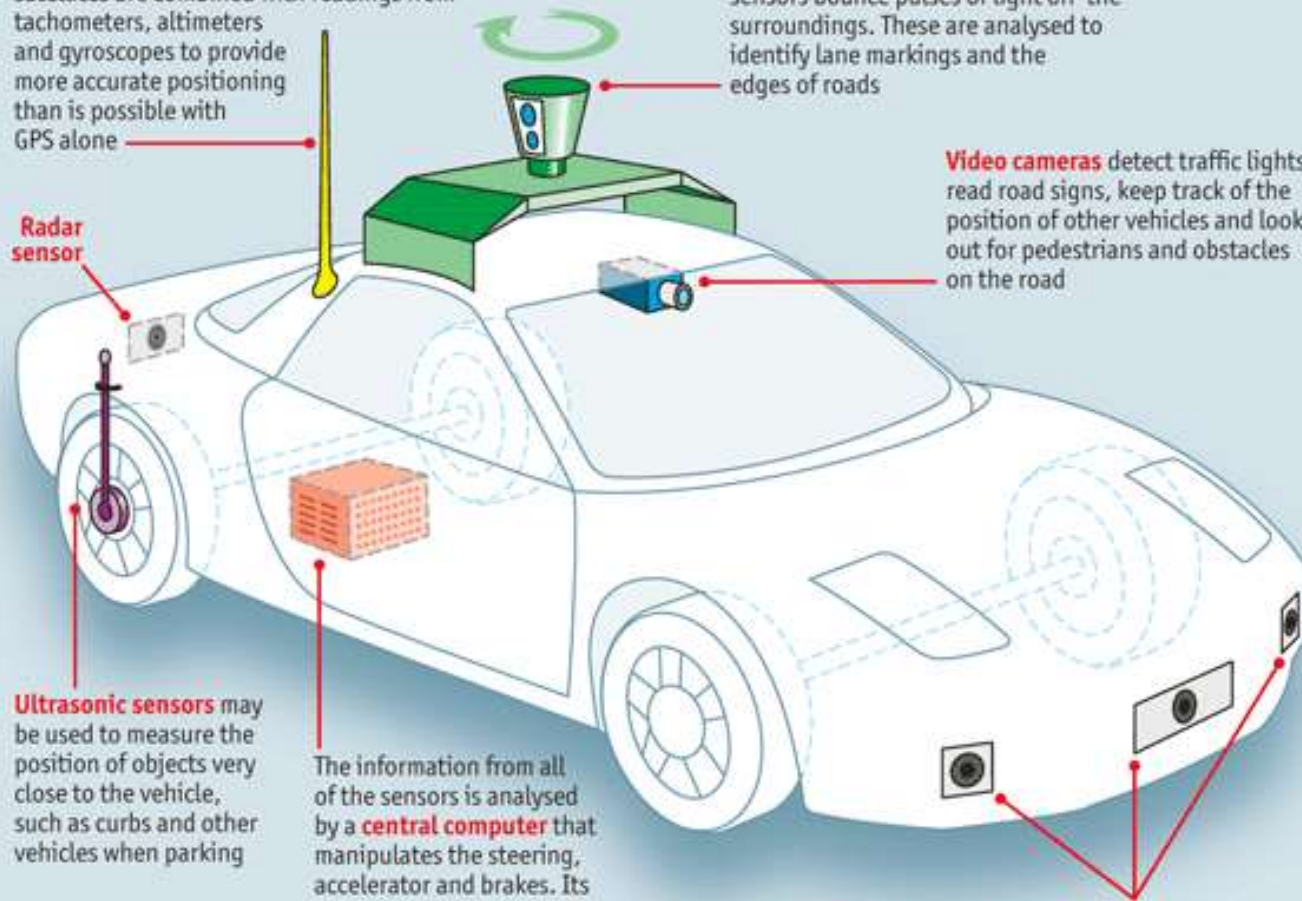
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Source: *The Economist*



• RADARs

• LIDARs

• Cameras

Physics of cameras and LIDARS

- Electromagnetic waves

- Visible
- NIR
- Visible + NIR
- FIR
- Multi-spectral
- etc.

- Cameras all bands

- LIDAR quite often NIR

- LIDAR: active

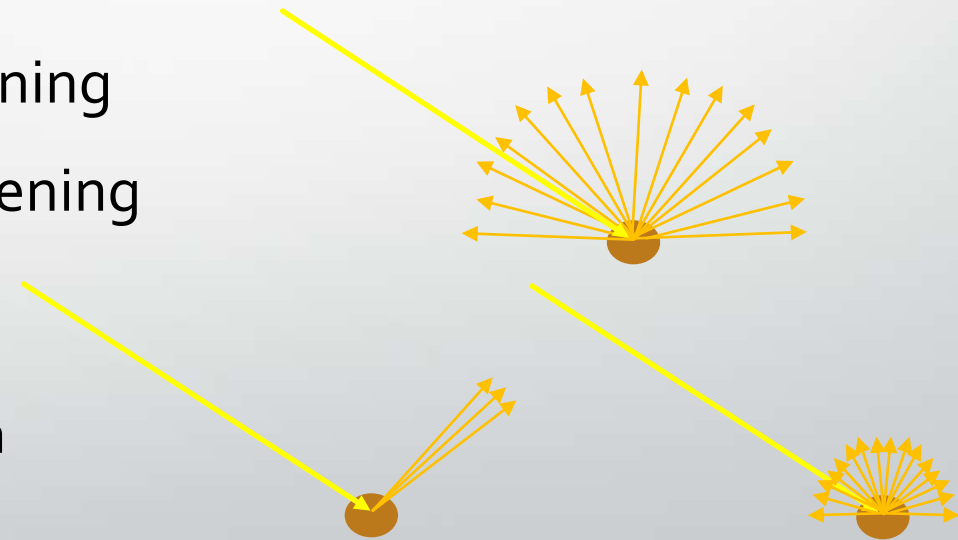
- Camera systems: quite often passive

- Active lightening

- Passive lightening

- Absorption
- Re-emission
- Reflection
- Refraction

Electromagnetic waves



Camera defects

- Sensor
 - Smearing
 - Not enough dynamic range
 - Defective pixels
 - Etc.
- Lenses
 - Chromatic aberrations
 - Geometric distortions
 - Vignetting
 - Etc.

Smearing (blooming)

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.

- Lenses

- Chromatic aberrations
- Geometric distortions
- Vignetting
- Etc.



Dynamic range

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.



Defective pixels

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.

- Lenses

- Chromatic aberrations
- Geometric distortions
- Vignetting
- Etc.



Chromatic aberrations

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.

- Lenses

- Chromatic aberrations
- Geometric distortions
- Vignetting
- Etc.



Geometric distortions

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.

- Lenses

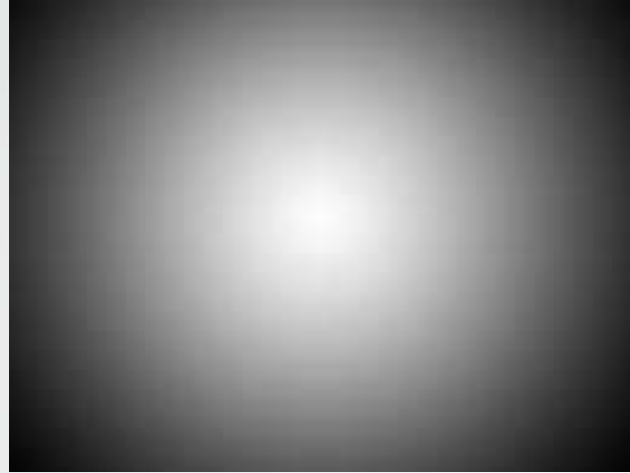
- Chromatic aberrations
- Geometric distortions
- Vignetting
- Etc.



Vignetting

- Sensor

- Smearing
- Not enough dynamic range
- Defective pixels
- Etc.



- Lenses

- Chromatic aberrations
- Geometric distortions
- Vignetting
- Etc.



Software and its parameters for cameras and LIDARS

- Thresholds
 - For edges / lines
 - For segmentation
 - Classification
 - etc.
- Algorithms



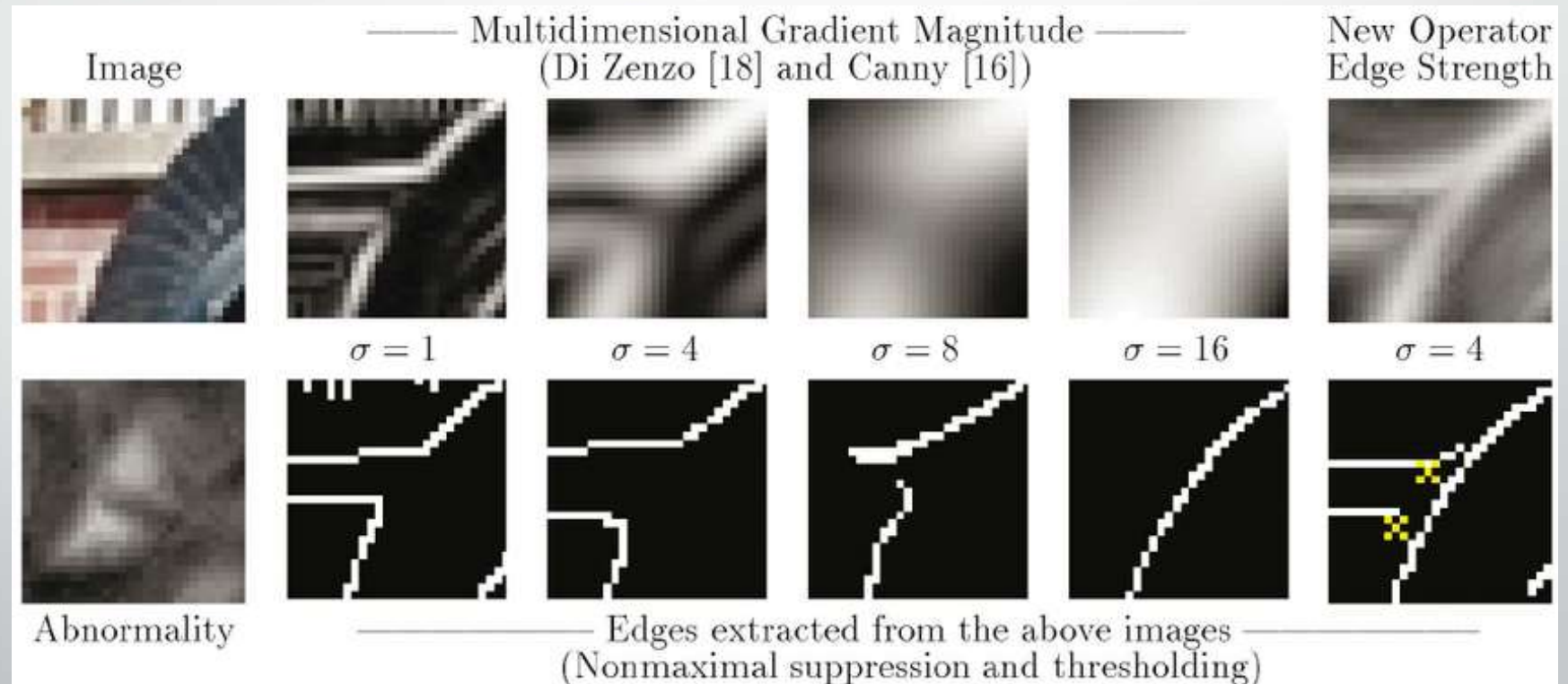
Software and its parameters for cameras and LIDARS

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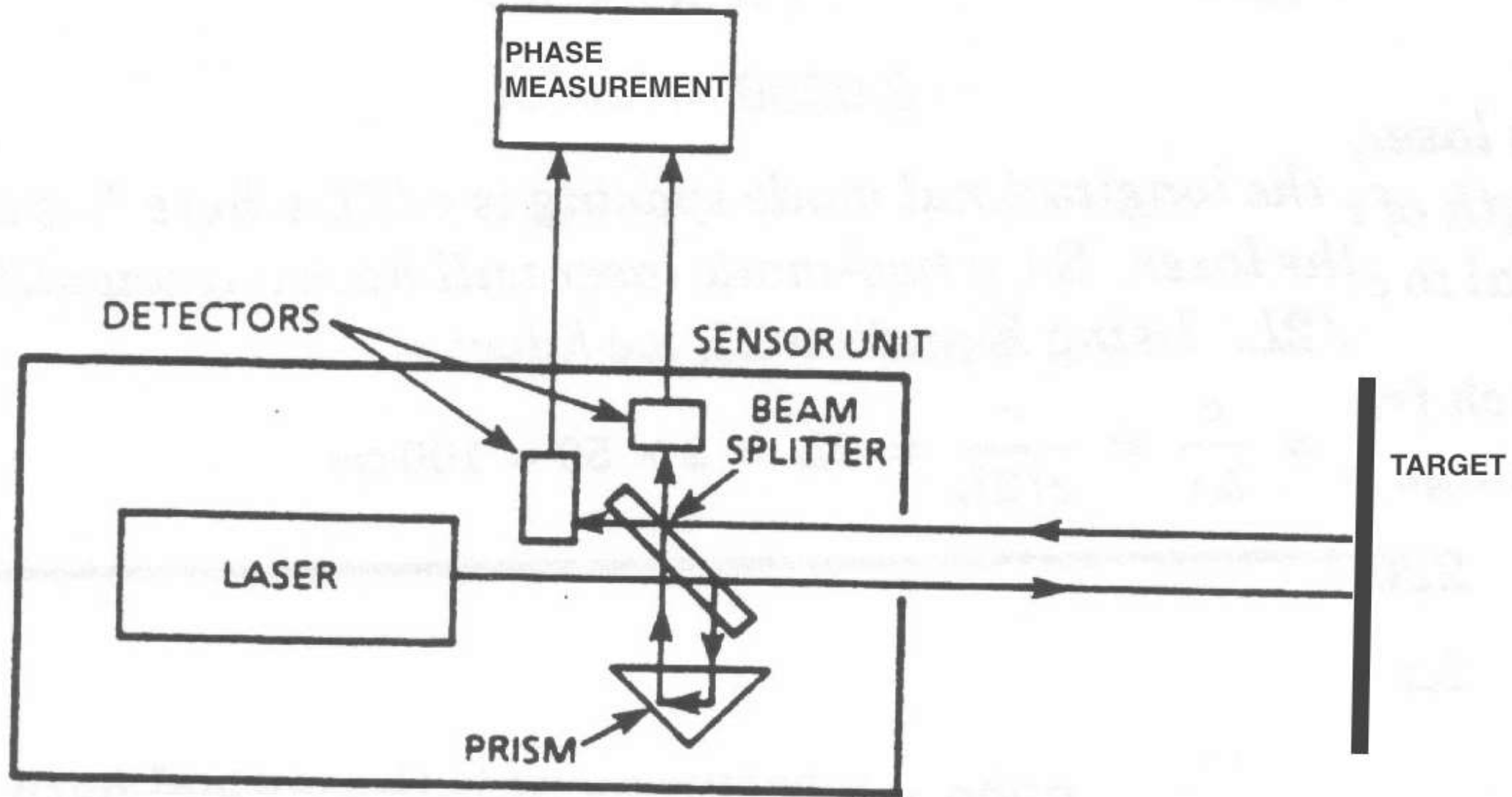


Software and its parameters for cameras and LIDARS

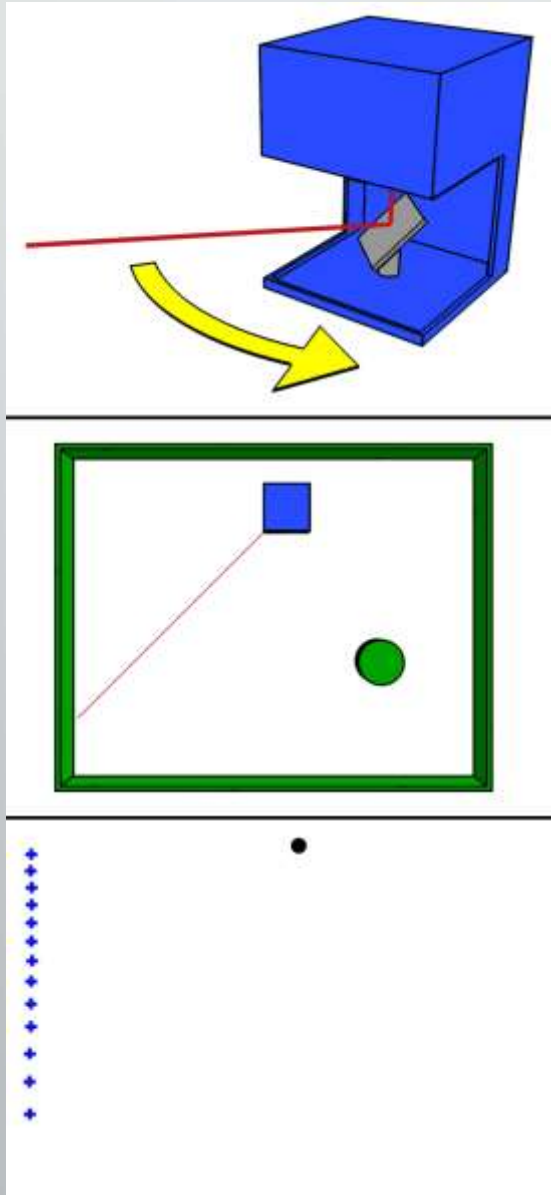
- Thresholds
 - For edges / lines
 - For segmentation
 - Classification
 - etc.
- Algorithms



Physics of LIDARS



Physics of LIDARS



- Beam steering
 - Solid state (phased array)
 - MEMS mirrors



LIDARS



How to deal with all these complications?

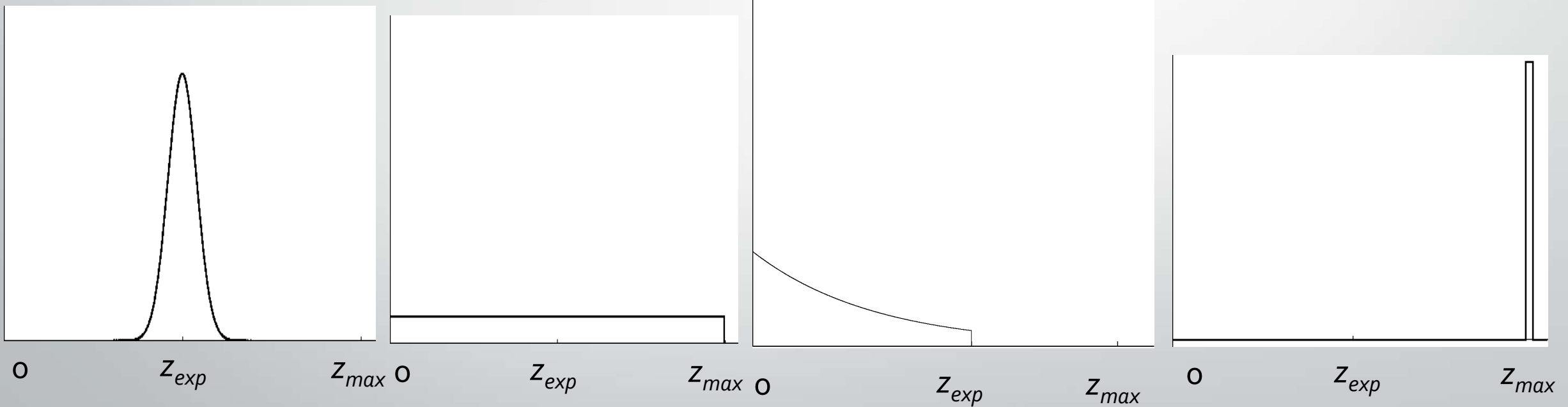
How to deal with all these complications?

Correct model of the probability of each error

How to deal with all these complications?

Correct model of the probability of each error

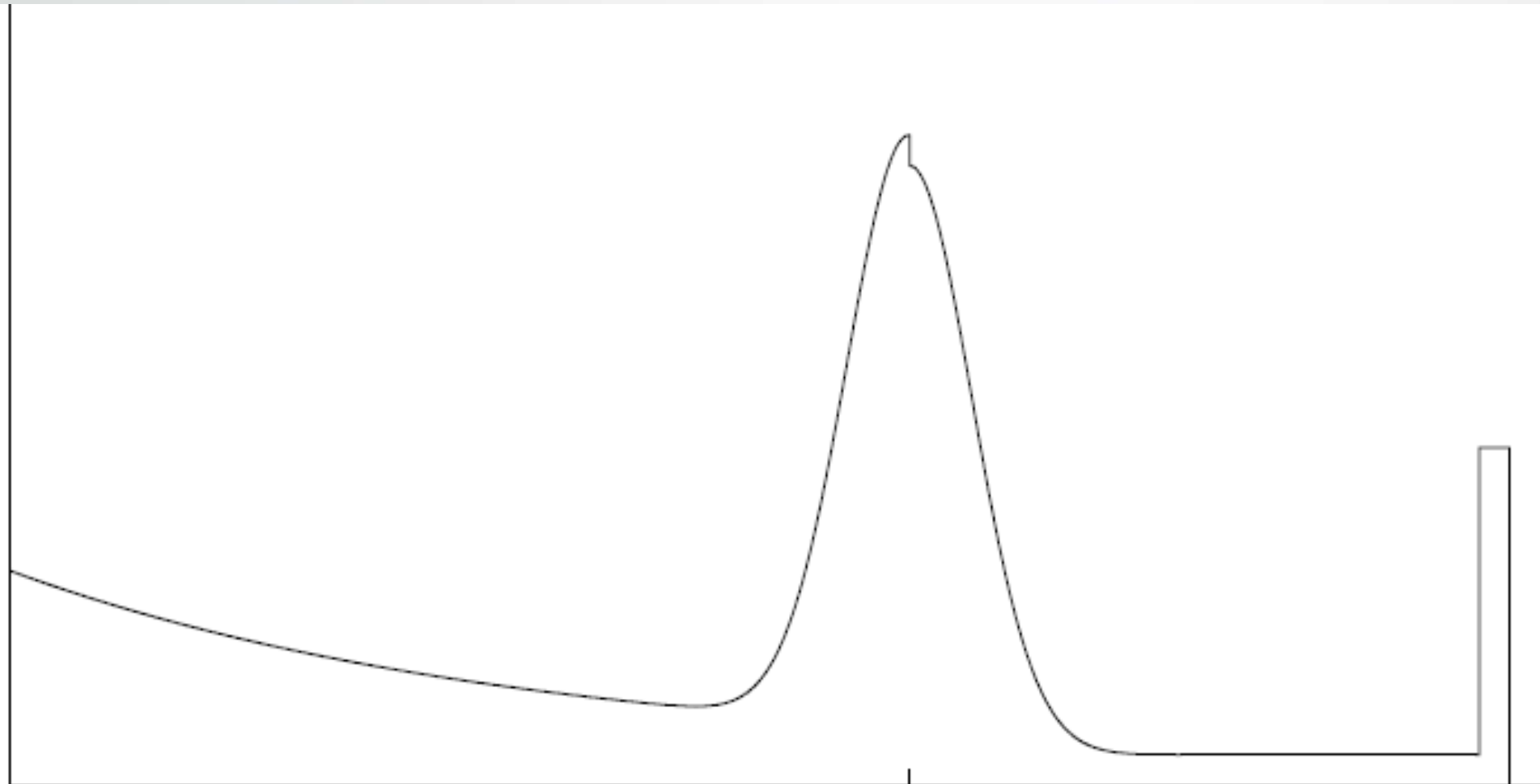
RANGE MEASUREMENTS



How to deal with all these complications?

Correct model of the probability of each error

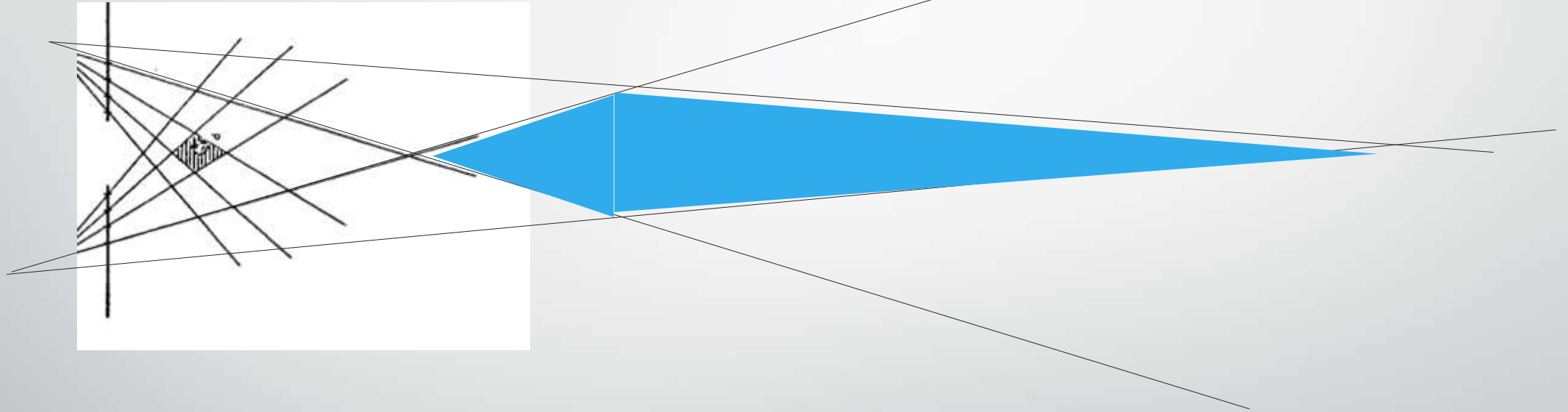
RANGE MEASUREMENTS: BEAM MODEL



How to deal with all these complications?

Correct model of the probability of each error

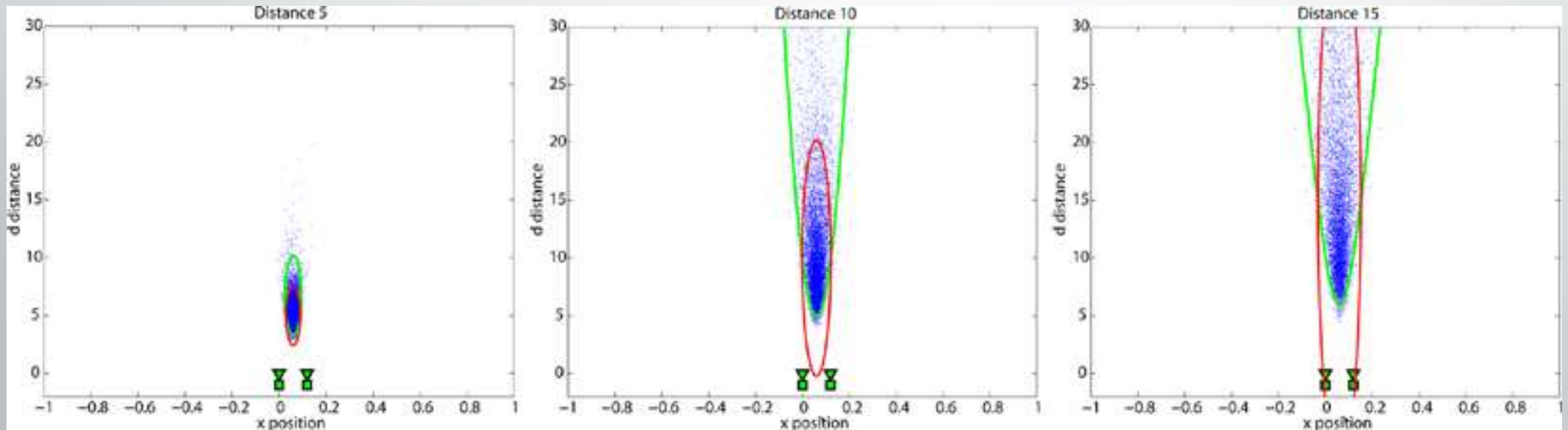
CAMERAS



How to deal with all these complications?

Correct model of the probability of each error

CAMERAS



THANKS FOR YOUR ATTENTION