

Replacing radar by an optical sensor in automotive applications

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Intro



- Individual motor car traffic is fun, comfort and necessity
- Automotive industry is an essential part of our industrial society
- Toll of the road: 600.000 road casualties in Germany since 1945
- Applied safety systems (deformable zone, seat belt, airbag) reduce the impact of accidents
- New strategy under development: Avoiding accidents by automatic attention

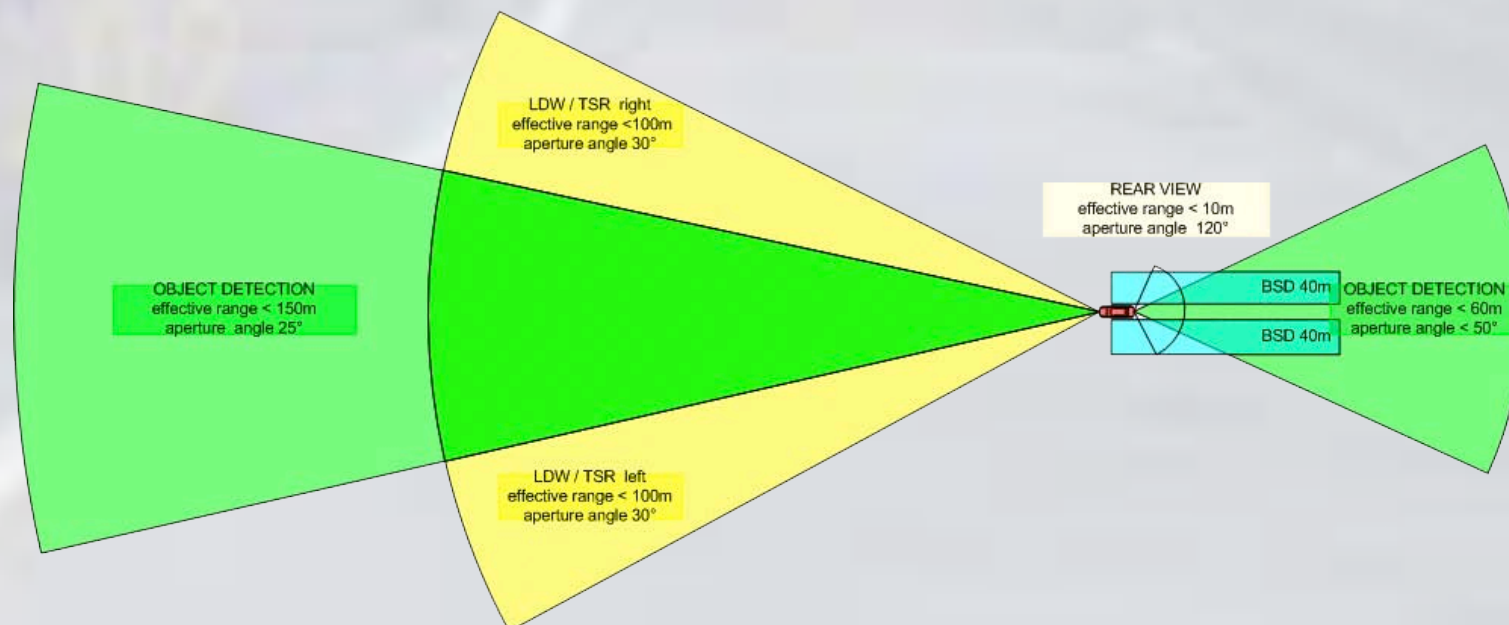
Surroundings perception



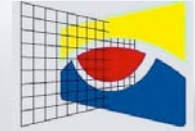
Driver assistant systems

- provide informations
- call attention to occuring threats
- could assume control

Systemaufbau und Bereichdefinition (maximale Werte) von mehrfach genutzten optischen Systemen



Possible Threads



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- Obstacles
- Traffic participants
- Pedestrians
- Information overload
- Driver's fatigue
- Animals
- ...



Supposable Assistants



Safety

- Emergency Brake
- Pre-crash warning system
- Collision mitigation
- Lane departure warning
- Driver's concentration monitor
- Blind spot detection
- ...

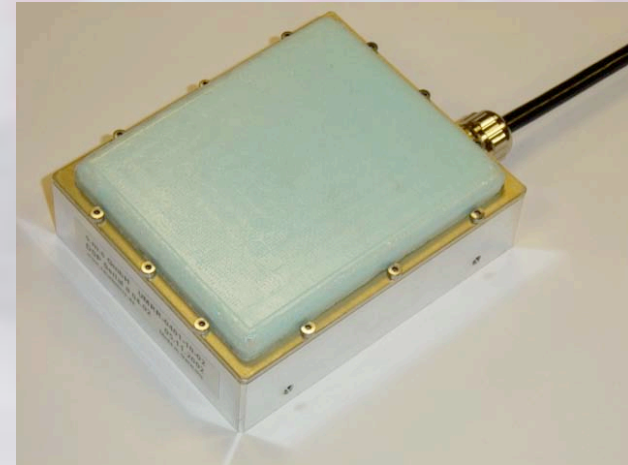
Comfort

- Adaptive cruise control / Stop&Go
- Traffic sign recognition
- High beam assistant
- Electronic drawbar
- ...

Required Sensor Technology



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(SMS)

Alternatives

- Radar
- Laser
- Ultrasonic
- Video

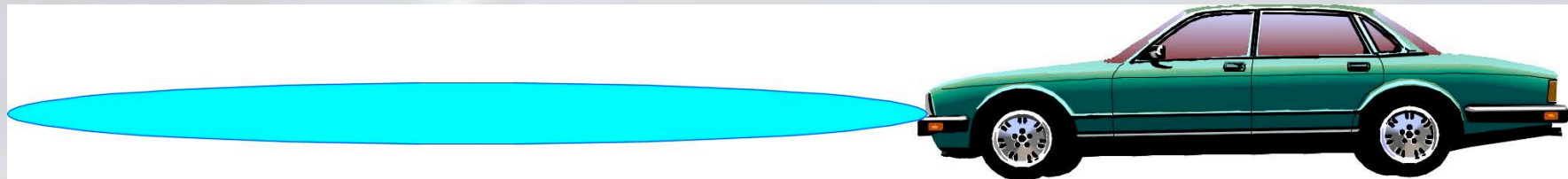


(Ibeo)

Radar



- Covering distance: ~150m
- Vertikal aperture angle: ~5°
- Horizontal aperture angle: ~5° x number of sensors
- Lateral resolution: number of sensors (e.g. 5) x 1
- Distance resolution: < 10cm
- Additional feature: Speed measurement



Radar's Appreciation



Benefits

- Availability
- Robustness
- Insensitiveness regarding dirt and weather conditions
- Distance resolution and accuracy

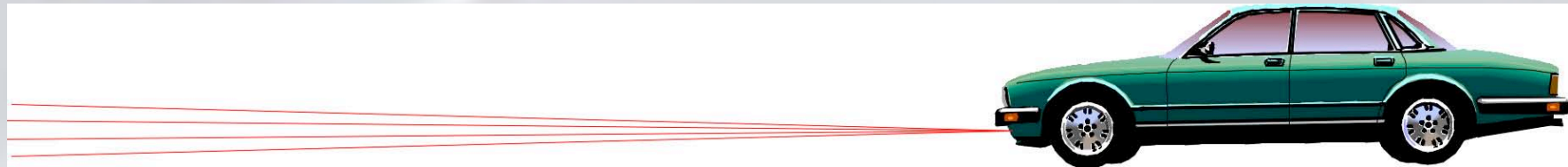
Malefits

- Poor lateral resolution
- Narrow vertical aperture
-> Problems in mountainous regions
- Few (~5) samples requiring several calibrated sensors
- No information about the course – additional sensors necessary to estimate any thread potential

Laser



- Covering distance: ~200m
- Vertical aperture angle: ~3.5°
- Horizontal aperture angle: ~240°
- Lateral resolution: 100 x 4
- Distance resolution: < 10cm



Laser's Appreciation



Benefits

- Insensitiveness regarding weather conditions
- Distance resolution and accuracy

■ Malefits

- Mechanically moving components
- Just up to 4 divergent scan lines
- Narrow aperture

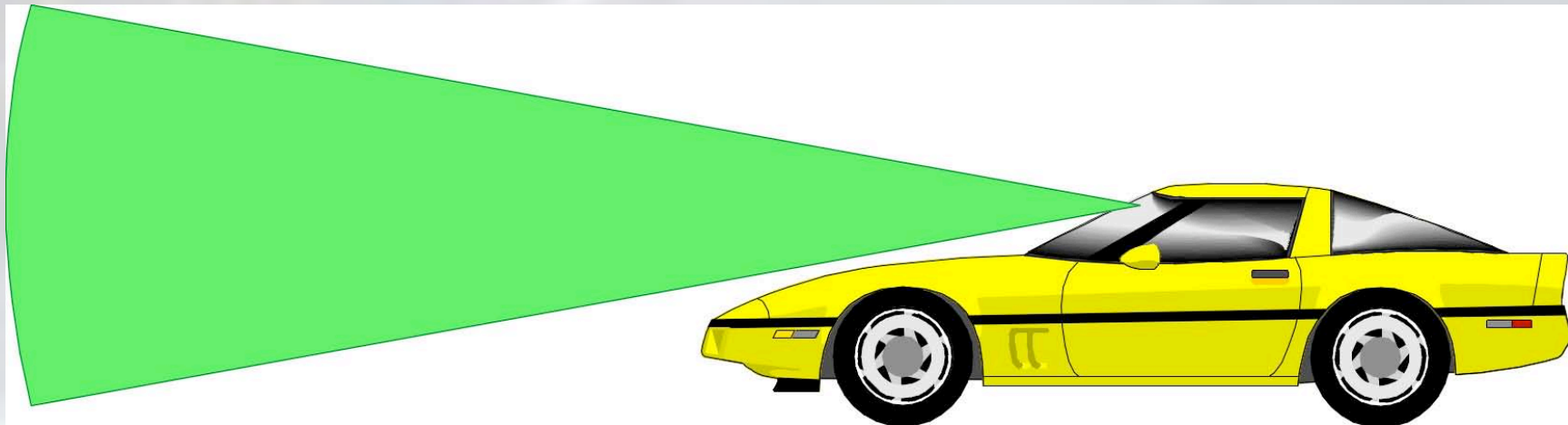
-> 2D cut view

-> Likely missing objects in mountainous regions

Stereo camera



- Covering distance: >400m
- Vertical aperture angle: 18°
- Horizontal aperture angle: 30°
- Lateral resolution: 800 x 480
- Distance resolution: 0.7m@50m; 10m@200m single shot



Stereo camera's appreciation



Benefits

- Insensitiveness regarding dirt and weather conditions (mounted behind windscreen and wiper)
- Lateral resolution
- Multiple analysis, various assistants possible (not only object detection)
- **Passive system -> no radiation!**
- Easily adaptable by parameter adaption (aperture/resolution vs. covering distance)

Malefits:

- **Sensitiveness regarding calibration parameters**
- High demand of processing power
- Mounted inside the passenger compartment
-> installation size is critical

Overcoming the difficulties: Installation

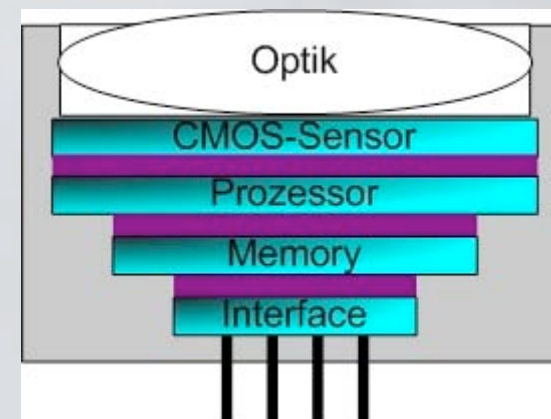
- Choose an applicable mounting location

-> behind the central rear mirror



- Minimizing the installation size

-> Project KISS: **1cm³ - camera**



Overcoming the difficulties: Processing Power



- Development of memory-saving algorithms
- Using the advantages of DSP-Architecture
- Interleaved development process

Development <-> Porting



Overcoming the difficulties: Calibration



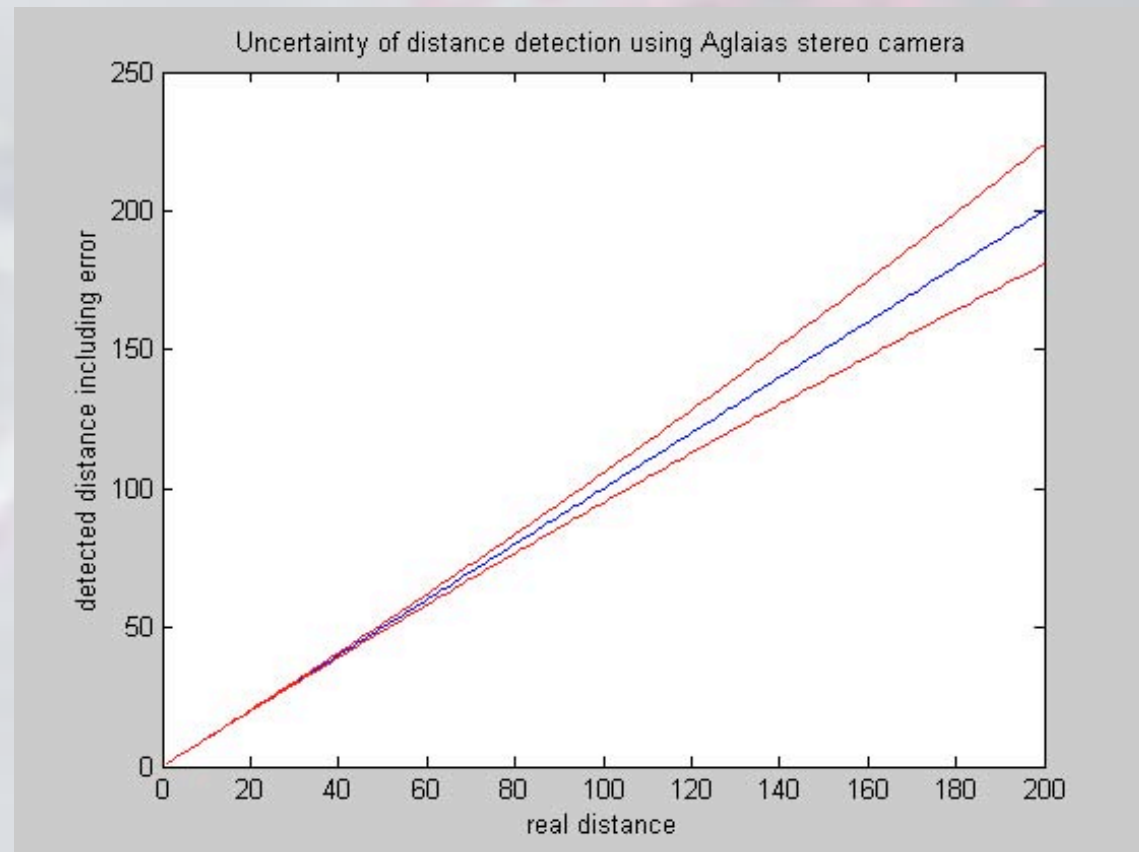
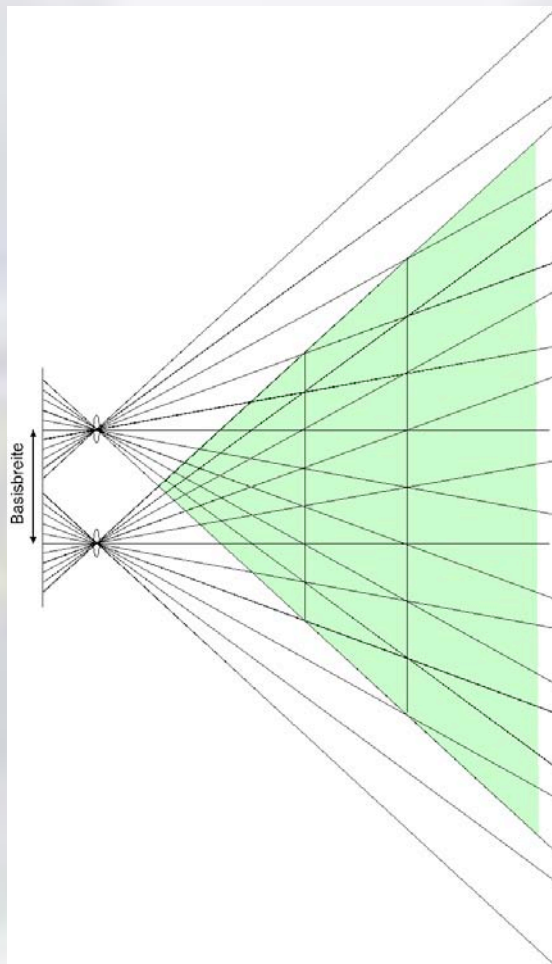
Rock-solid assembly vs.
automatic calibration



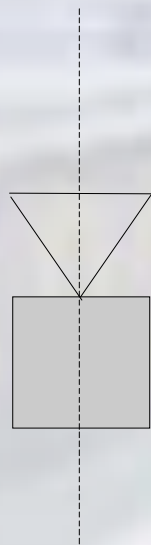
Uni Karlsruhe



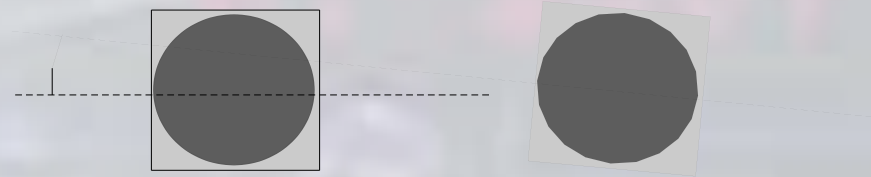
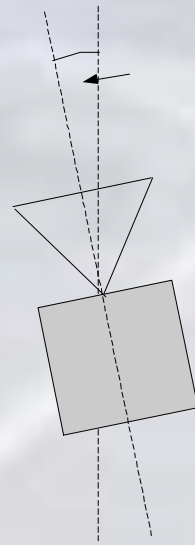
Principle of measurement



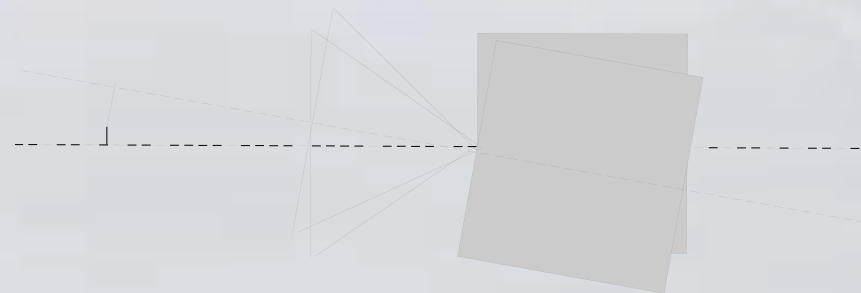
Calibration inaccuracies



Yaw



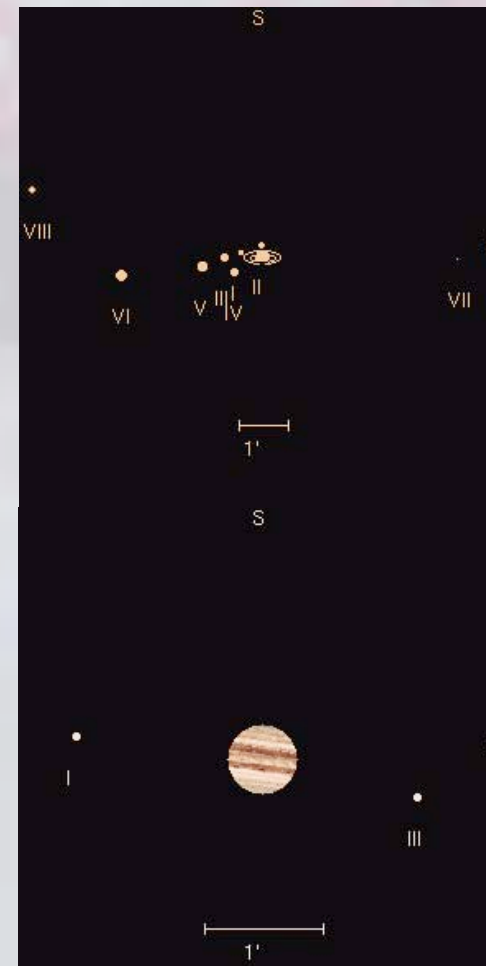
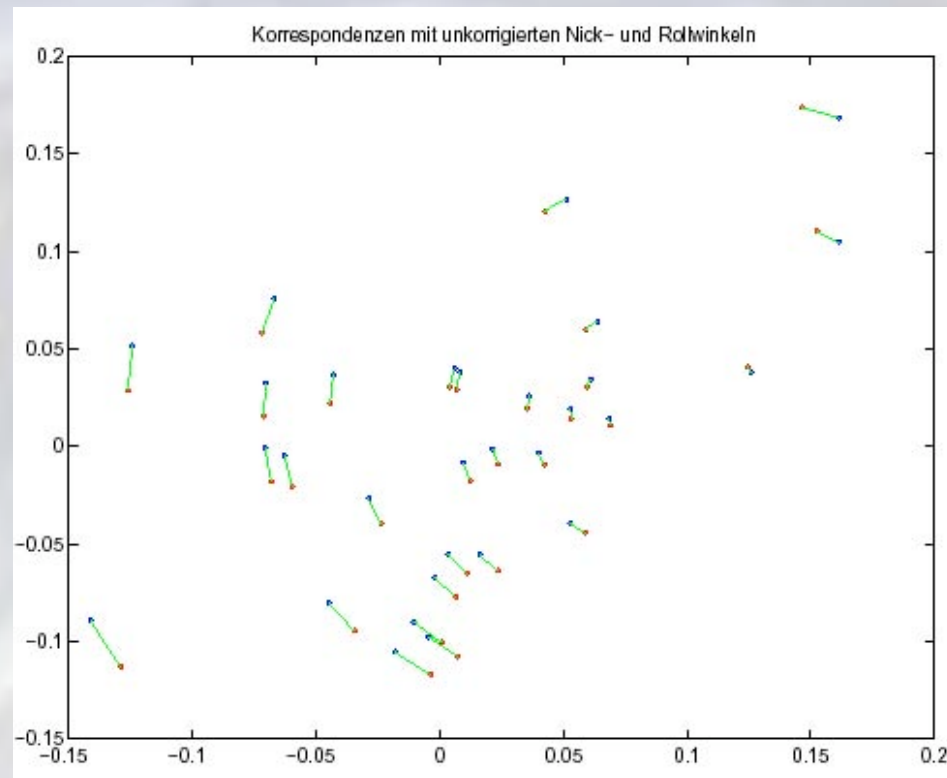
Roll



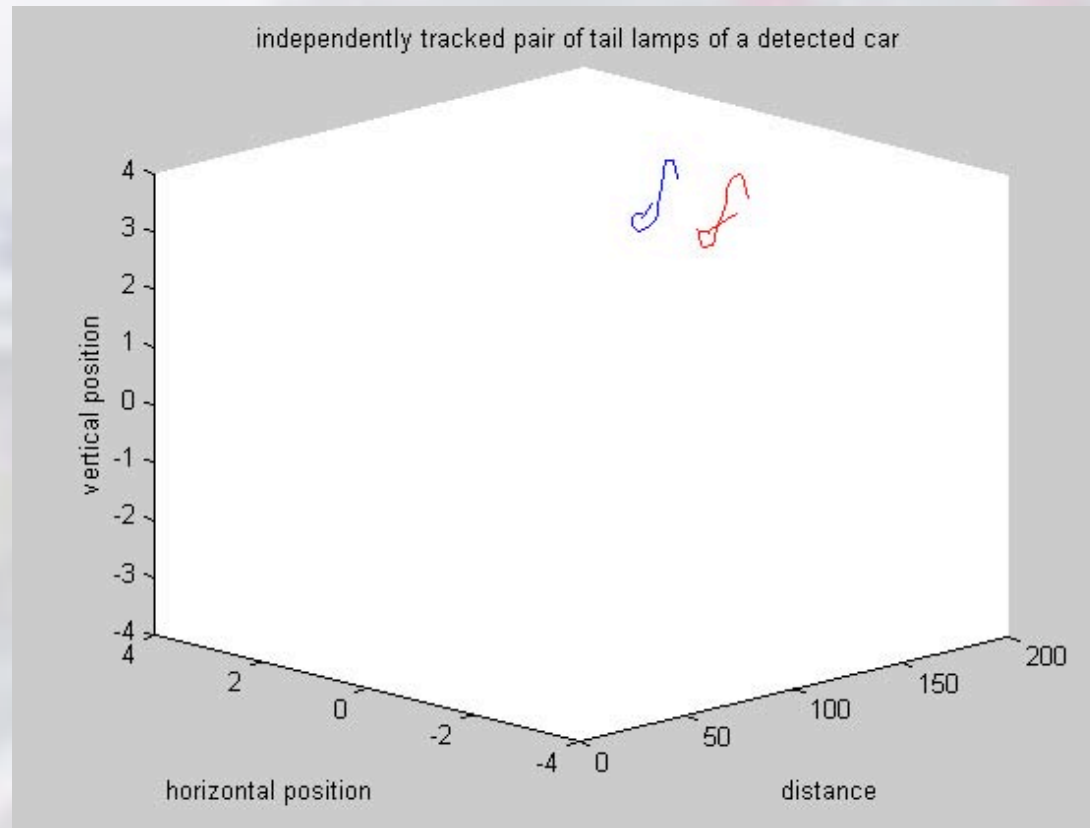
Pitch

Autocalibration

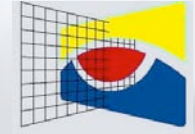
- Conformance of calibration data and camera adjustment
- Monitoring and adaption while processing
- Required accuracy: 1'



Results

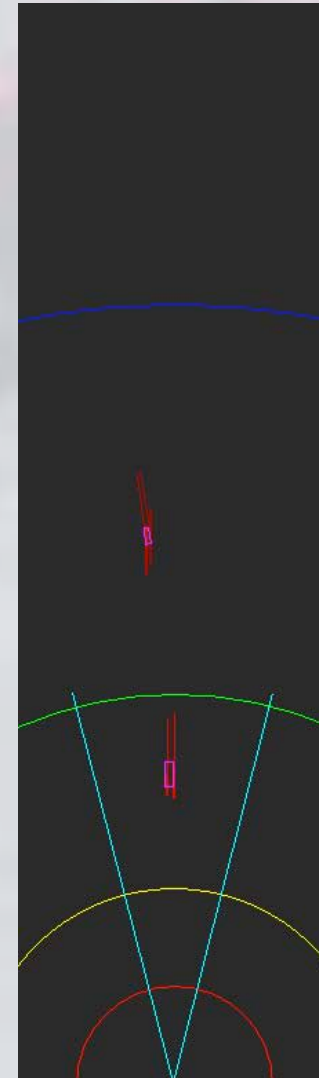


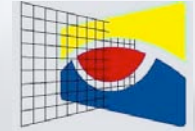
- Coherent movement of two rear lights of one car
- parallel motion and vertical shake caused by a pitch drive of the carrier vehicle



Results: Complex situation

- Three-leg interchange
- Following several cars
- Overtaking car
- Oncoming traffic
- Traffic on third leg





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Results: Distant approaching car

- Distance: approx. 800m
- Object position and speed are detected
- Correct classification: Approaching



Conclusion



- Stereo camera system is able to outperform all alternatives
- Various supposable assistants basing on the same input data
- Autocalibration and minimal installation size are essential
- All problems solved in principle
(Feature extraction, disparity determination, distance calculation, clustering, object tracking)
- Object detection (night) available, ported to DSP in mid '05
- Object detection (day) planned on PC in mid '05