Computer Vision for Road Safety

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New Zealand

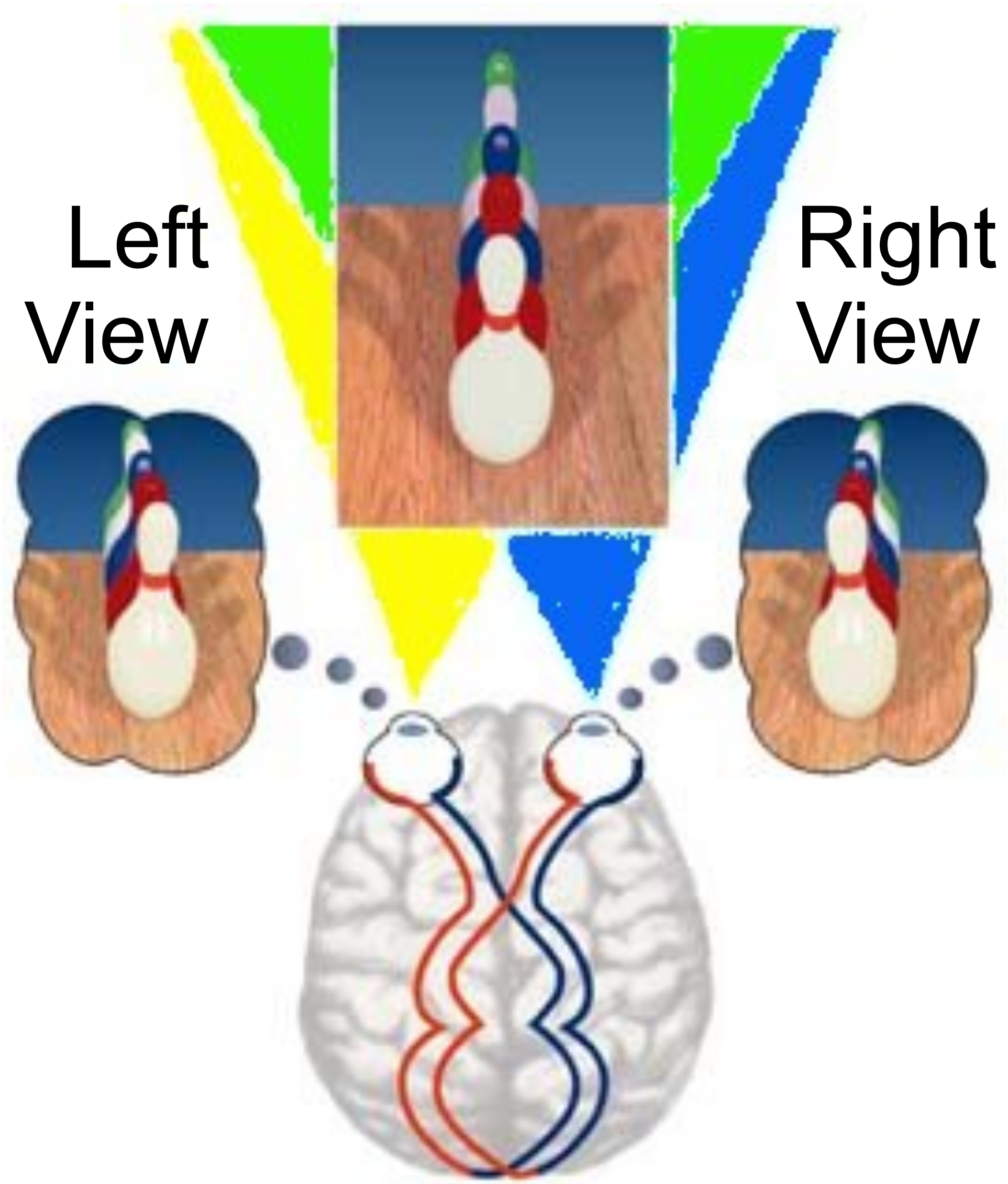
Auckland (1.5 million people) - New Zealand (4.5 million people)

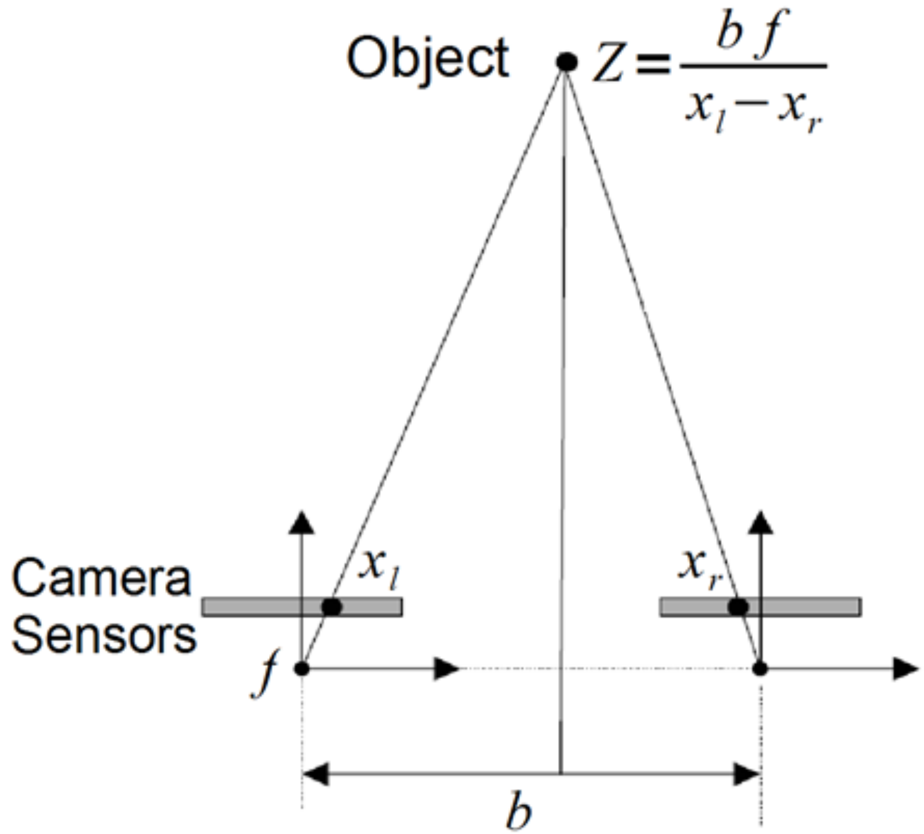
15% of population of NZ is Asian; many Chinese students

Hon. Dr. **Wan Gang**, Minister of Science and Technology of PRC, at The University of Auckland on March 28, 2011

Computer Vision
Example: Stereo Vision

Binocular Stereo





Z = distance

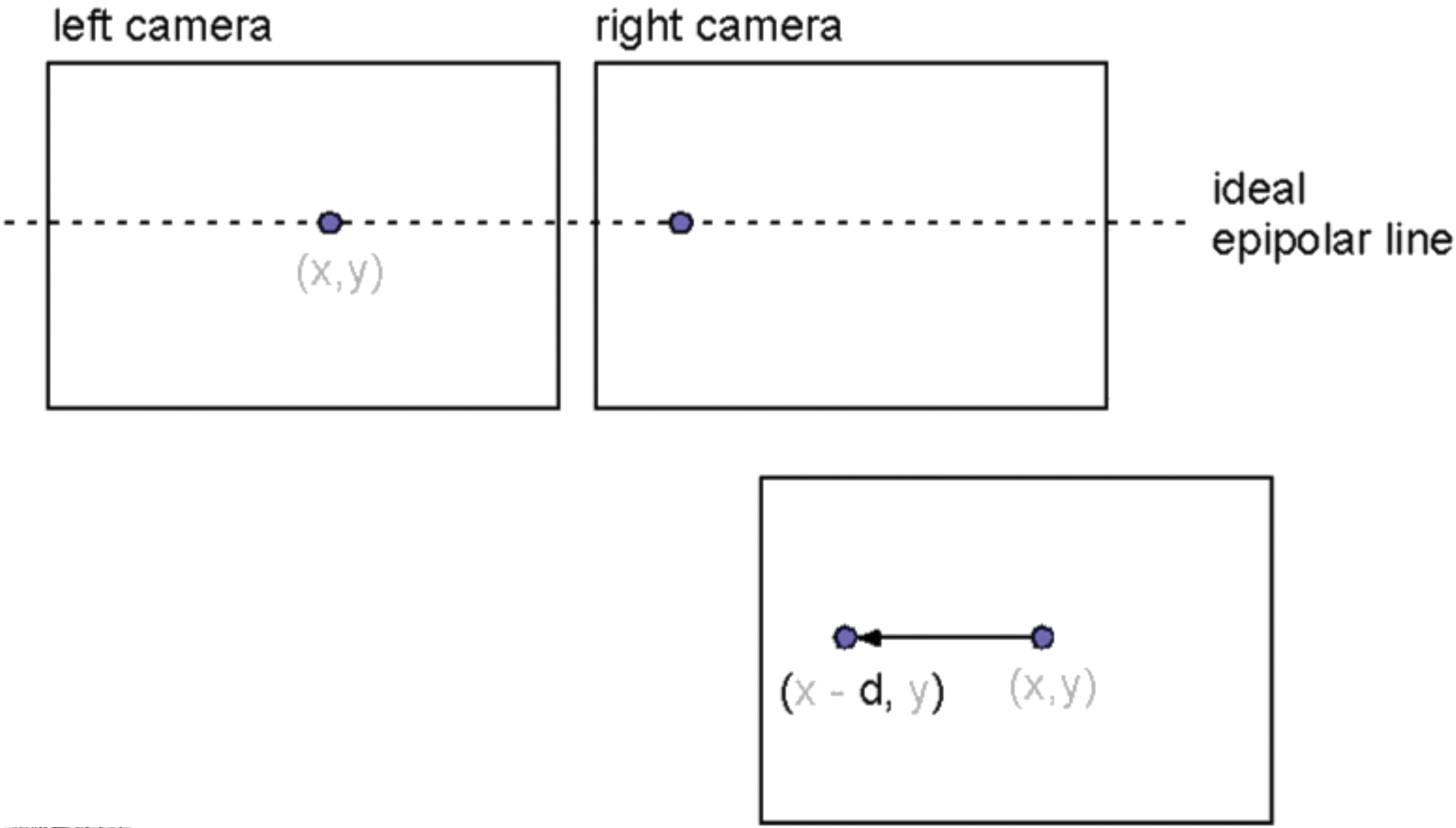
b = baseline

f = focal length

x_l = left cam. pixel dist.

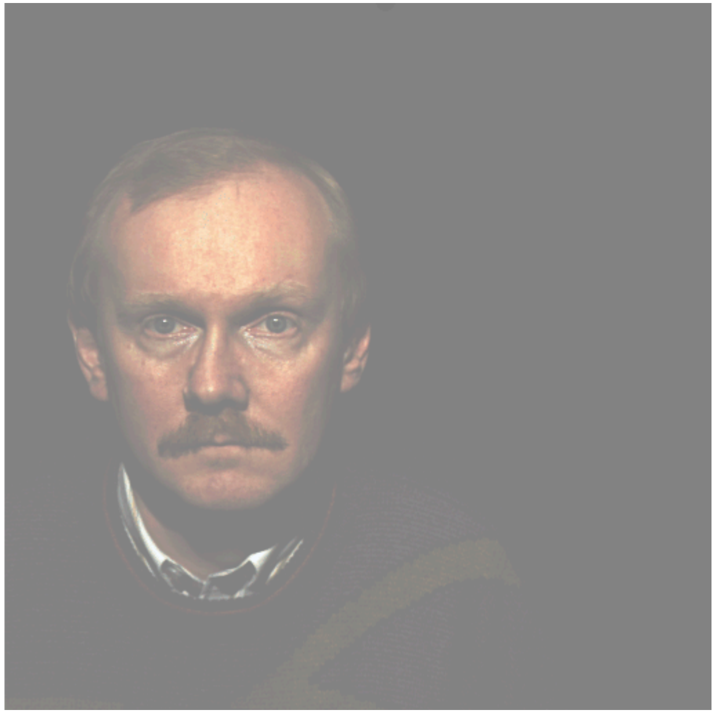
x_r = right cam. pixel dist.

Stereo Disparity – 1D Search



disparity *d* at *(x,y)* in left image

Stereo vision in my group at TU Berlin, 1993



disparity: the visual shift left to right between corresponding pixels

Stereo vision in my group at TU Berlin, 1993

disparity: the visual shift left to right between corresponding pixels

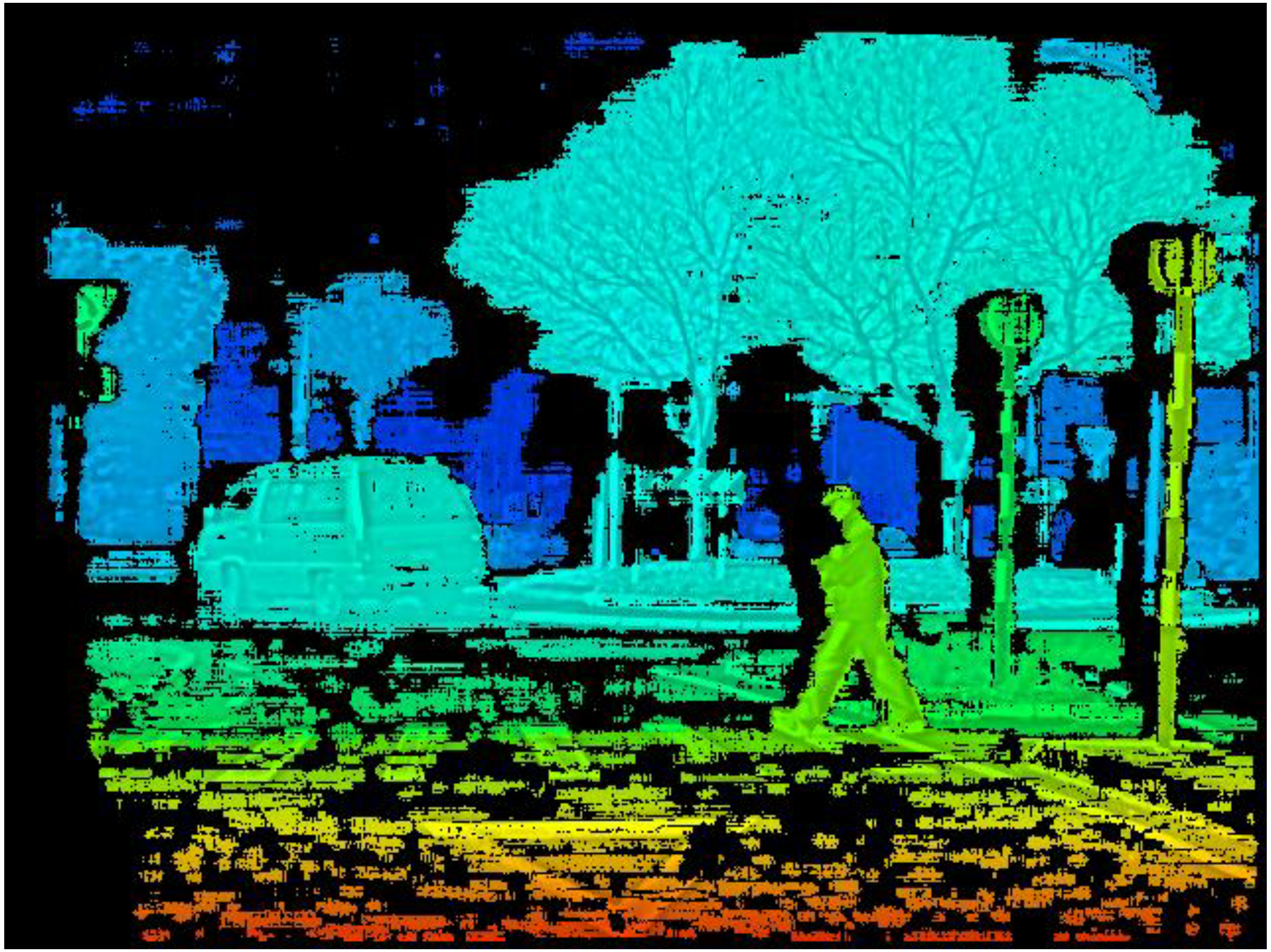
Stereo matching 1993

using a correlation-based hierarchical stereo matcher

Disparity map:

Grey values represent disparity (i.e. distance)

.enpeda.. solution for: Stereo analysis 2011



disparity map: use of a color key for showing disparities

.enpeda.. solution for: 3D visualization of stereo analysis result

The *.enpeda..* Project at UoA

Since 2007: The *.enpeda..* project at Tamaki Innovation Campus

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Main partners: **Daimler AG** **German Aerospace Center**

DAIMLER

DLR

Road Safety

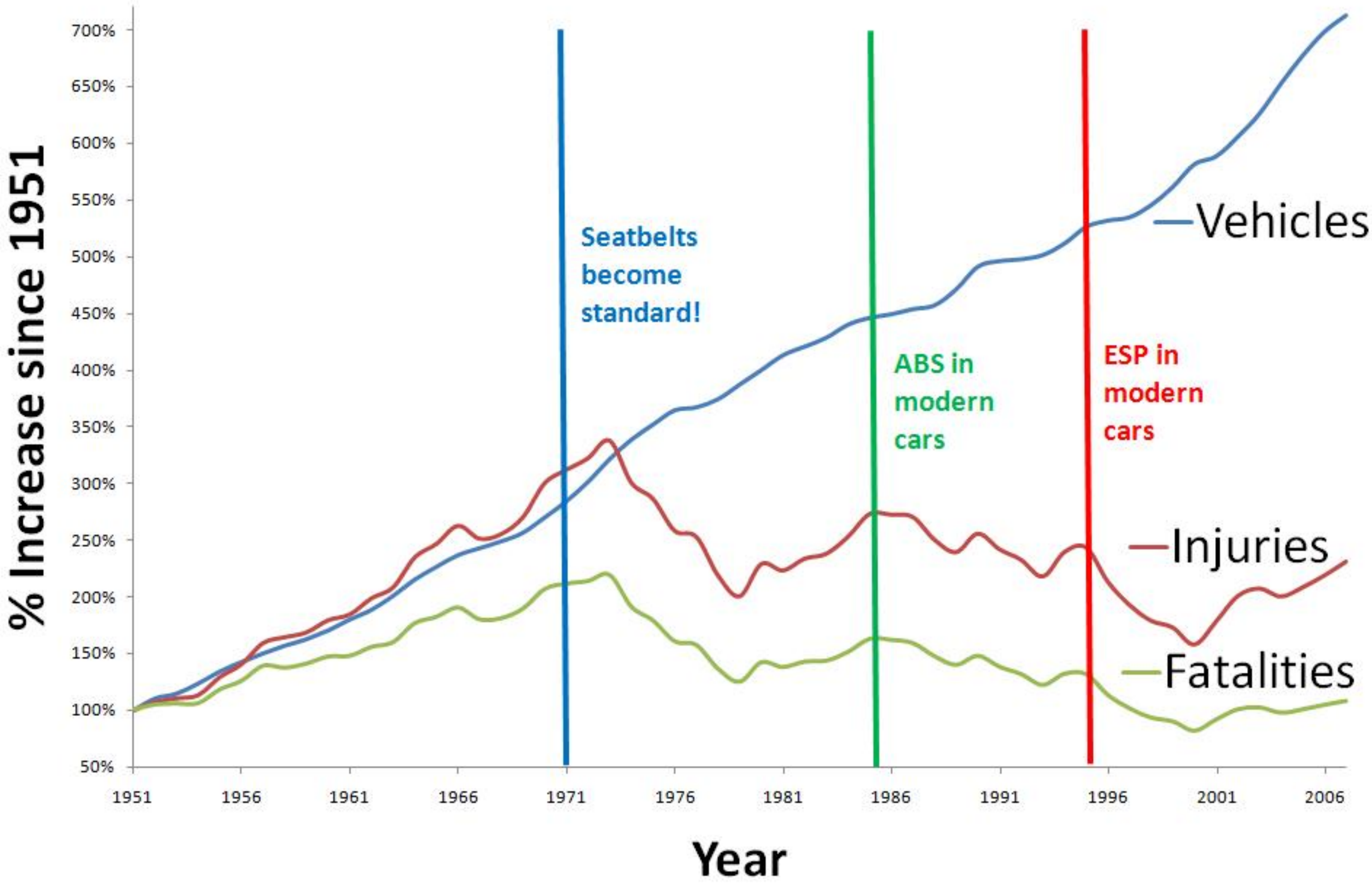
Annual **road accident toll** worldwide:

deaths:	1.3 million people (260,000 children)
injuries:	50 million people
social costs:	US$ 518 billion

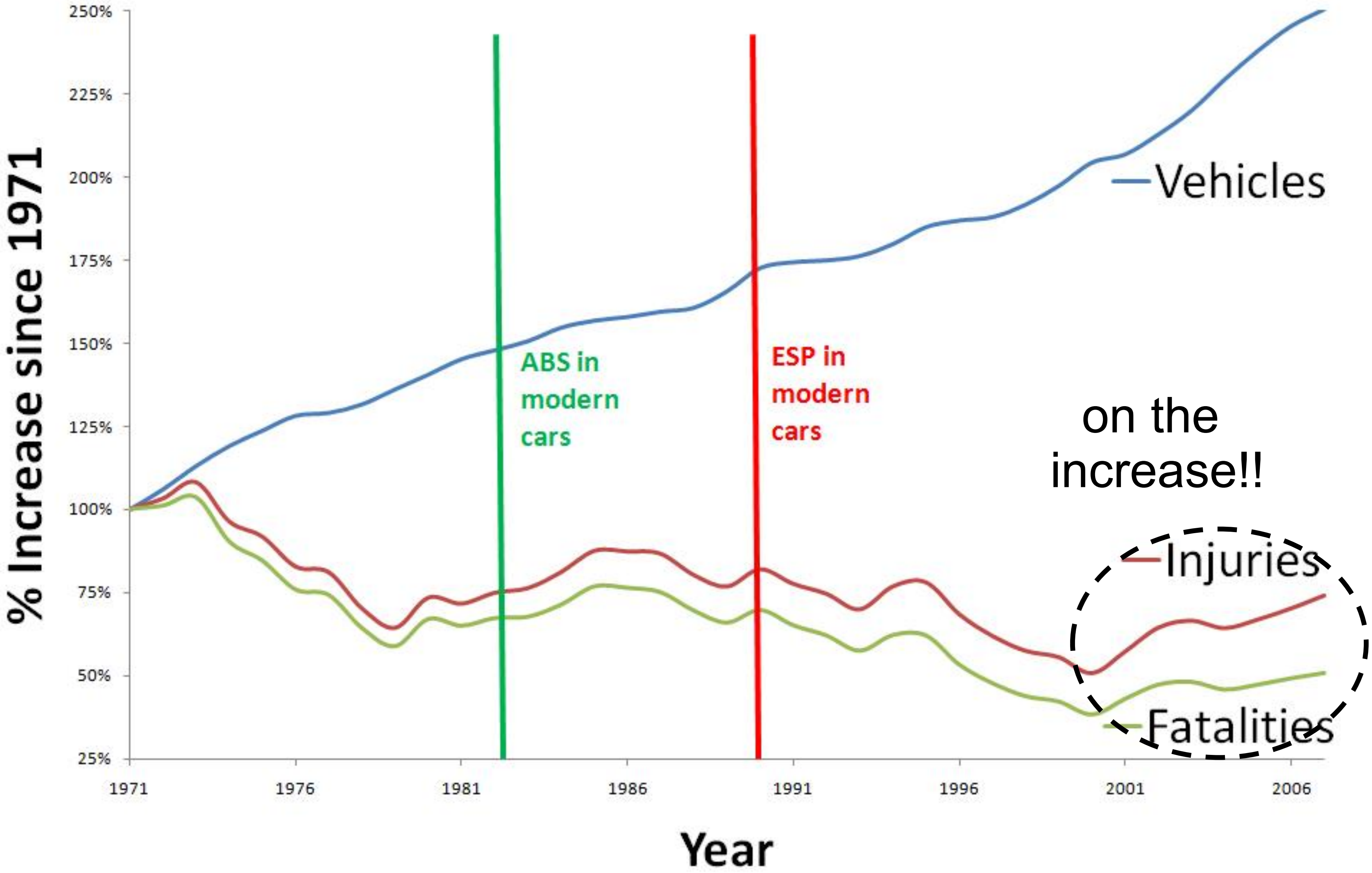
(numbers from 2009, and steady at about that level)

(CHINA OUT) Rescuers work at the traffic accident site on April 1, 2011 in Xi'an, Shaanxi province of China. A truck collided with a bus at a cross on Friday morning. As the truck headed for the sidewalk, it collided into a pedestrian and 6 vehicles which were stopped nearby. As a result 16 people were injuried, one currently has severe injuries.
(March 31, 2011 - Photo by Getty Images AsiaPac)

Accident Statistics for New Zealand



Statistics since Seatbelt



According to the World Health Organization, the 10 leading causes of death worldwide in 2009:

1. 12.6% Ischaemic heart disease
2. 9.7% Cerebrovascular disease
3. 6.8% Lower respiratory infections
4. 4.9% HIV/AIDS
5. 4.8% Chronic obstructive pulmonary disease
6. 3.2% Diarrhoeal diseases
7. 2.7% Tuberculosis
8. 2.2% Trachea/bronchus/lung cancers
9. 2.2% Malaria
10. 2.1% Road traffic accidents

Computer Vision and Road Safety

Options for used sensors:

Radar: Very good longitudinal distance/speed
Poor lateral distance/speed.

Ultrasound: Only accurate at low speed.

Laser / LIDAR: Very good for distance,
not for motion estimation.

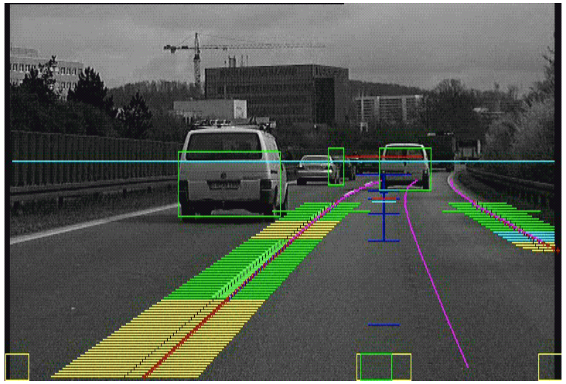
Cameras: Can do it all!
Vision-based DAS is developing quickly.

Mature Systems

Speed Limit Assistance

Self Parking (2008)

Backing-Up Aid



Lane Recognition

NightView (2005)

Blind spot supervision

DAS in the Market

- Anti-Lock-Brakes(1982), Electronic Stability Programs (1995) (inertial sensors)

- Mitsubishi Diamante (1995-1996): Camera for lane recognition and Radar for ACC
- Mercedes Truck (since 2000): Lane Departure Warner
- Subaru Legacy (1998-2004): Stereo-based ACC
- Cadillac (2001-2004): FIR Night Vision System
- Toyota (since 2004): Night Vision System, Parking Guide, Lane Monitoring
- Nissan (since 2004): Lane Keeping System
- Honda (since 2004): Lane Keeping System, Collision Mitigation System (Radar)
- Since 2005 every major car manufacturer offers camera-based driver assistance

Cameras and computer vision contribute since mid 1990s to the design and implementation of active safety systems that perceive the environment around a car and act accordingly. Those systems may also use other sensors (e.g., GPS, LIDAR, radar, ultrasound, or IMU).

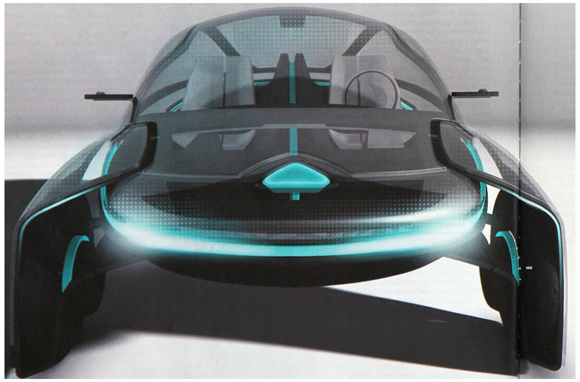
Passive safety systems (seat belt, air bag, ABS, ESP) are designed to minimize the consequences when a vehicle is already involved in a dangerous situation.

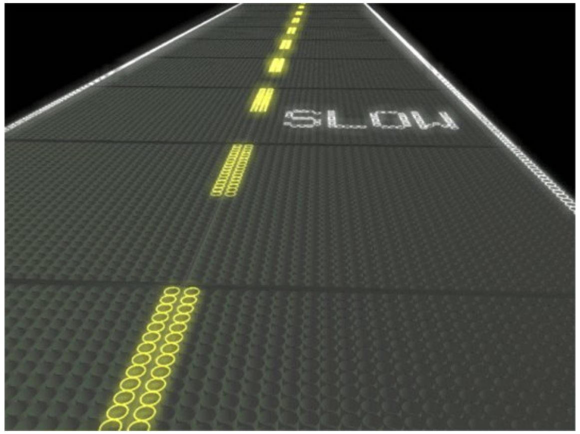
Safe, environmental-friendly, economic, efficient
future transportation will use

active safety systems with computer vision integrated for

- "intelligent vehicles"
- "intelligent roads"

  guidance, energy transmission, ... , energy collectors (whole road a solar panel?)





- Will there also be "intelligent drivers" ?

Three Roadmaps to Future Traffic

DAS

Driver Assistance Systems

lane departure

safe distance

blind spot

speed signs

stop signs

free space

sleepiness

AH

Automated Highways

debris detection

safe distance

free space

driver readiness

DLV

Driverless Vehicles

multi-sensor

MILITARY

ground manifold

…

CIVIL APPL.

ROBOTICS

tracking

…

Cameras and computer vision contribute

for **DAS**, **AH**, and **DLV**

to components that

- **control the vehicle**
- **perceive the environment and**
- **monitor the driver (if in manual mode)**

Typically integrated with other sensors:

GPS, LIDAR, radar, ultrasound, or IMU

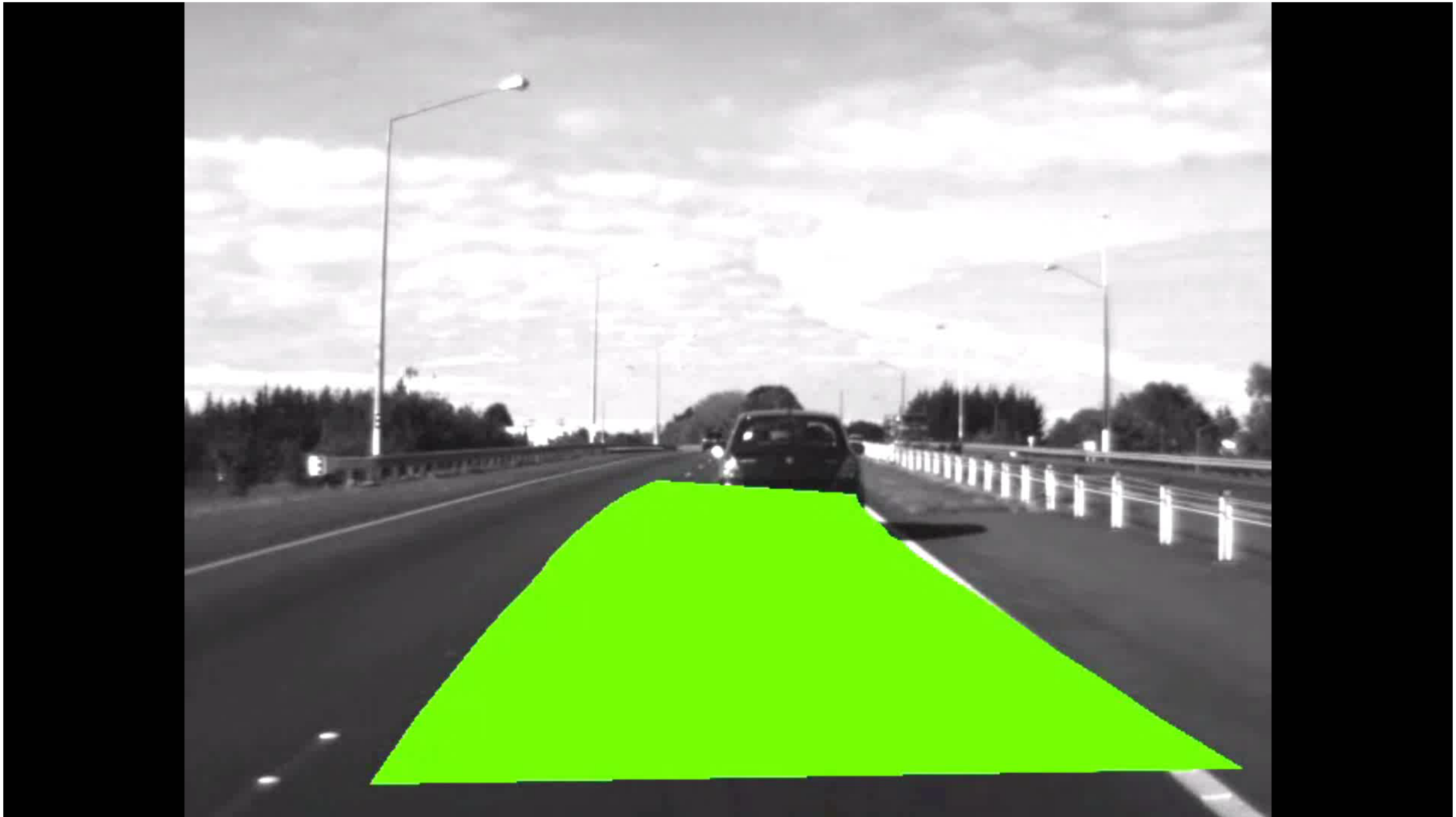
Active **DAS** are developed to

(i) predict traffic situations

(ii) adapt driving and car to the situation

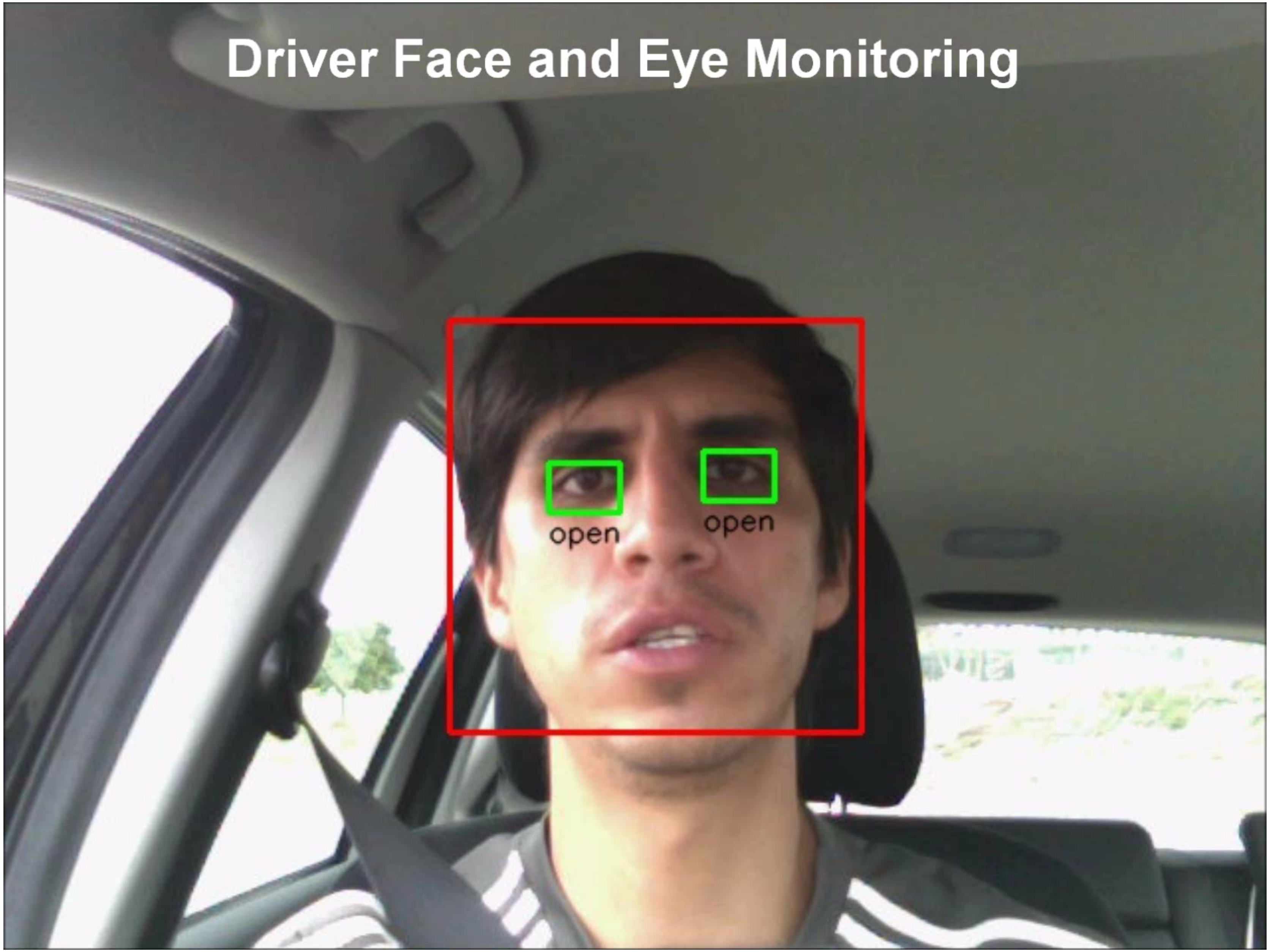
(iii) optimize for safety

.*enpeda*.. solution for: Predict the area the car is driving in



Driver Monitoring

.*enpeda*.. solution for: **Driver monitoring**



Five cases with response between: fine ... attention ... alarm

OK distracted blinking/falling asleep

Hon. Dr. **Wan Gang**, Minister of Science and Technology of China, March 28, 2011, at The University of Auckland when talking to me:

" Every truck or long-distance bus in China should be equipped with such a driver monitoring system."

We plan to collaborate on this with Jinan University and SINOTRUK and welcome further partners.

DAS on a Mobile Phone

.enpeda.. solution for: Lane detection

GPS with lane detection on the mobile phone

Feixiang Ren and Jinsheng Huang, **SkyEye Technologies Ltd.**

.enpeda.. solution for: **Lane departure warning**

Feixiang Ren and Jinsheng Huang are former MSc students of *.enpeda..* , their startup company **SkyEye Technologies Ltd.** collaborates with **Mail-Bit,** Israel, and develops DAS for iPhone , Android , and Windows mobile .

Test Vehicle of .*enpeda*..

Research Vehicle **HAKA1** at Tamaki campus

2 x 2MP 10 bit gray-value (fish-eye) cameras (Basler)

five VGA 10 bit gray-value cameras (PointGray)

Default recording mode:

two gray-value (10 bit) PointGray cameras, 640 x 480 resolution

High Awareness Kinematic Automobile No. 1

HAKA1

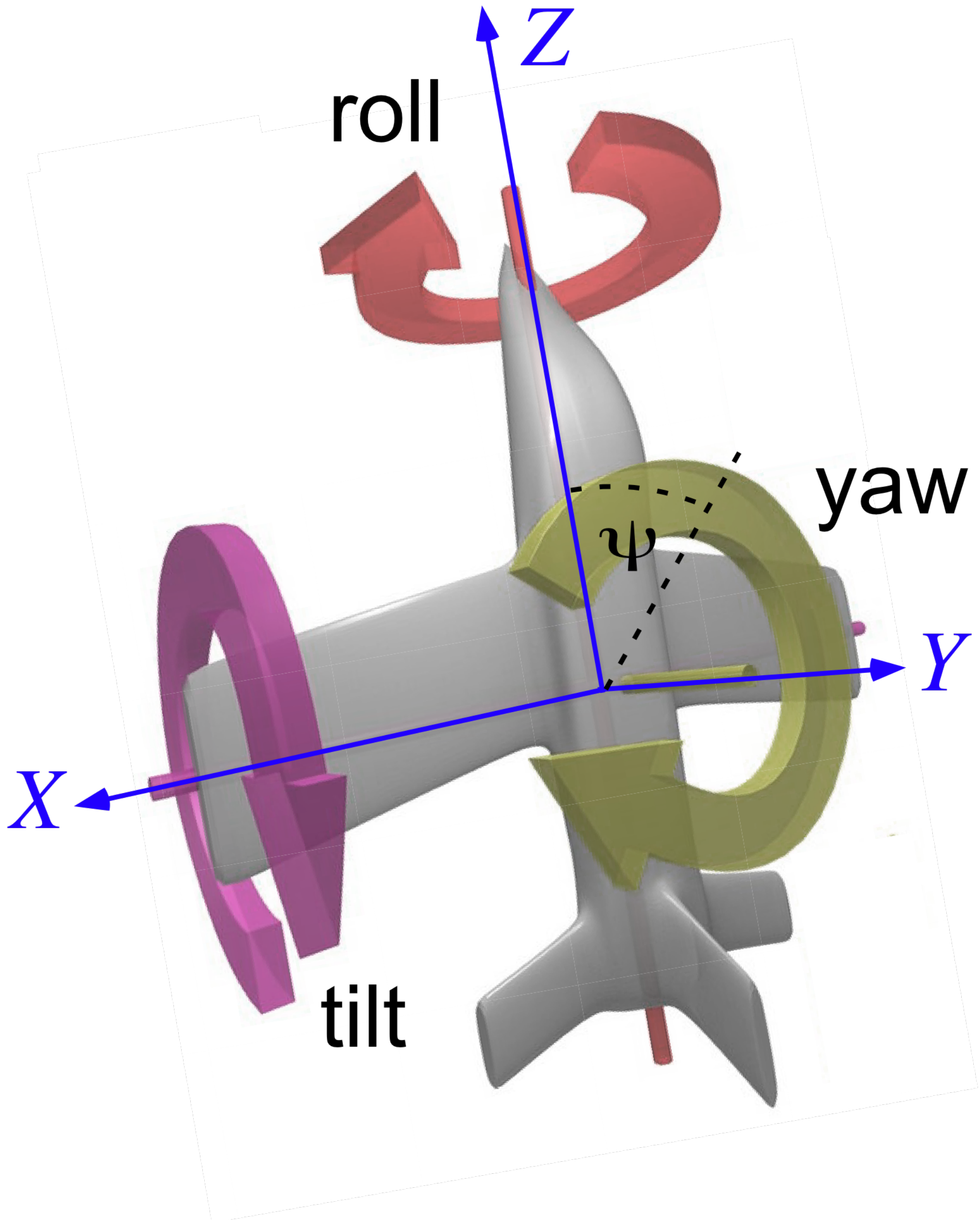
High Awareness Kinematic Automobile no. 1
test vehicle in the *.enpeda..* project

Yaw ψ

steering angle

Tilt and roll

often `disturbing' ego-motion components



Ego-vehicle

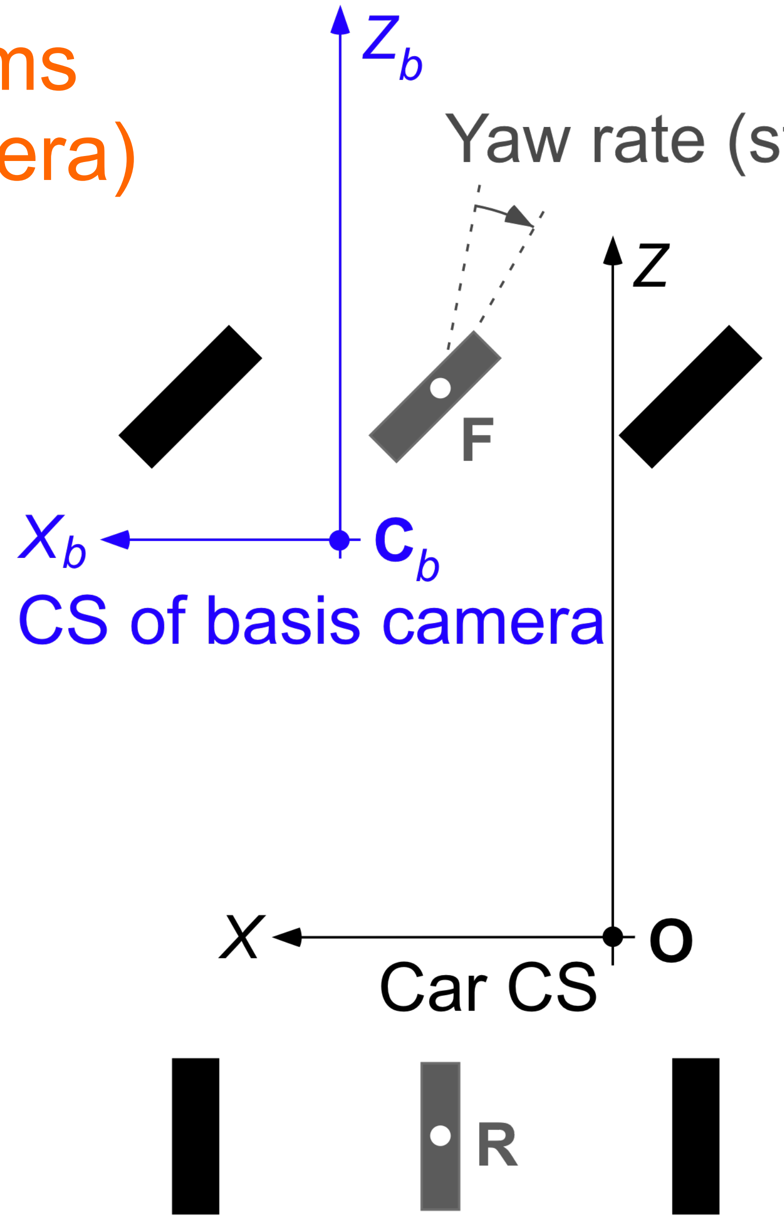
the car where the system is operating in

Ego-motion

changes in yaw, tilt, roll and velocity

(on ground manifold)

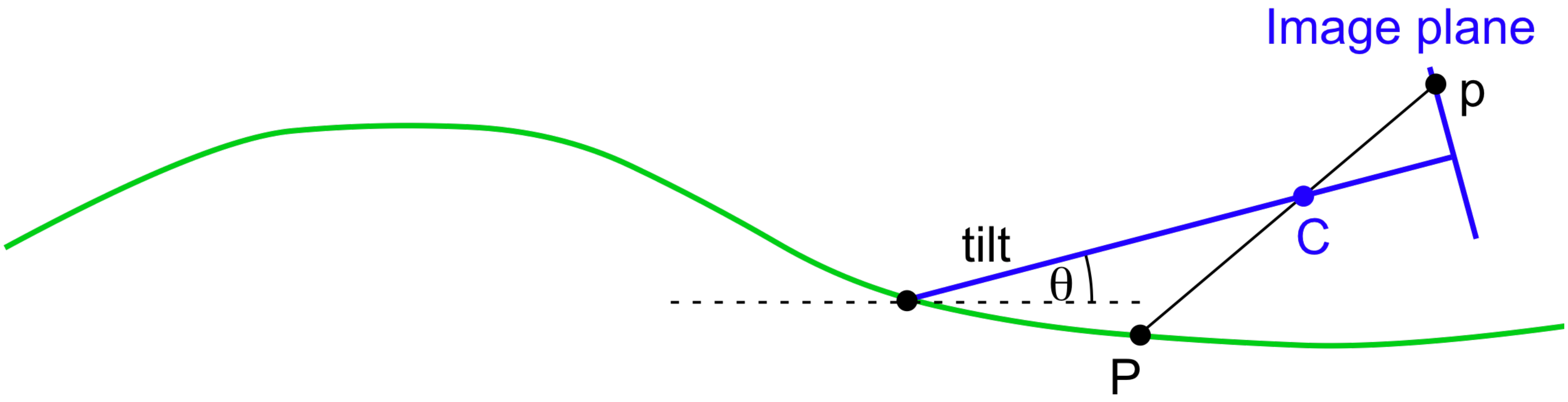
Coordinate systems (car and one camera)



F and **R** define the *bicycle model* of the car

The ego-vehicle on the road

Visual odometry, ground manifold estimation, free space calculation, lane detection, corridor detection, ...



Our Input Data

two gray-value cameras, that means ...

Imagine a driver with allochromasia, tunnel vision (limited peripheral viewing), and myopia (distance blur), but stereo vision:

Did you see the bird flying through?

At what distance to the car?

Stereo Frames, Auckland to Hamilton

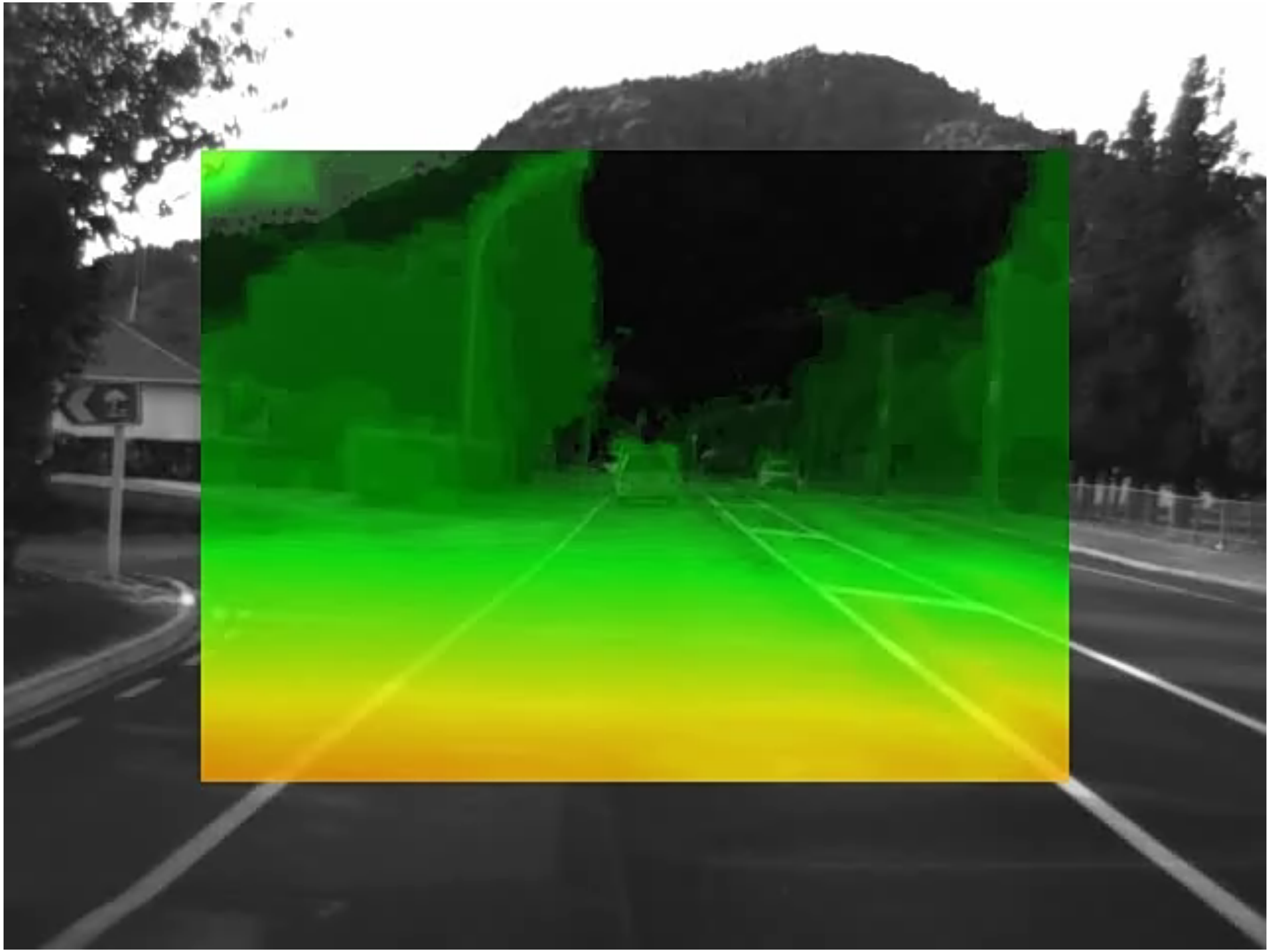
Left Camera

Right Camera

Distance Information

close ..... far

The Key



Traffic scenes are a challenge for vision:

Dense night traffic, but not yet rain, snow, or fog

Performance Evaluation

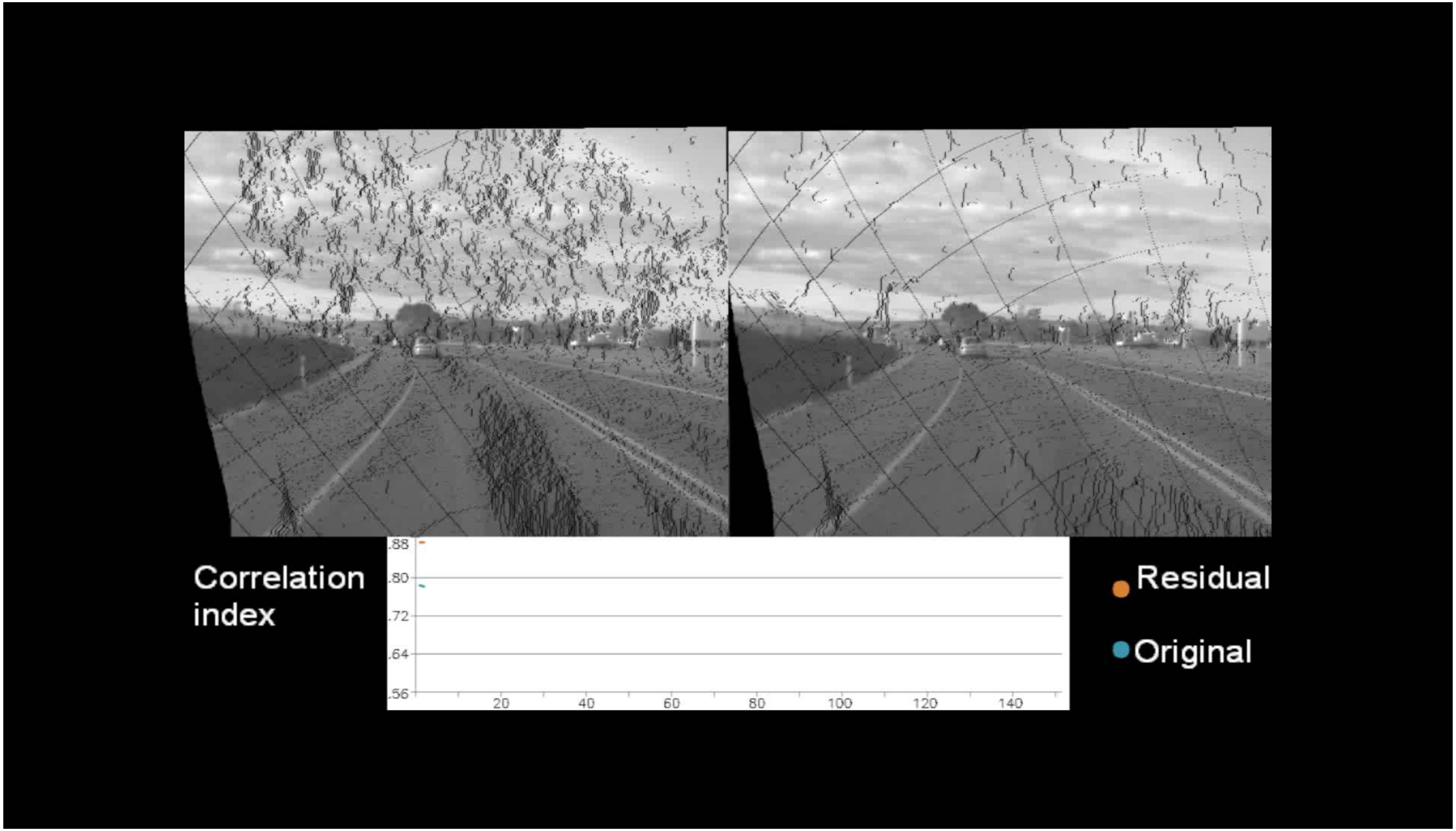
.*enpeda*.. solution for: **Performance Evaluation**

A third camera provides “ground truth”.

Distance data evaluated based on this ground truth.

Technology now used by Daimler A.G.

Our technology supports real-time confidence estimation



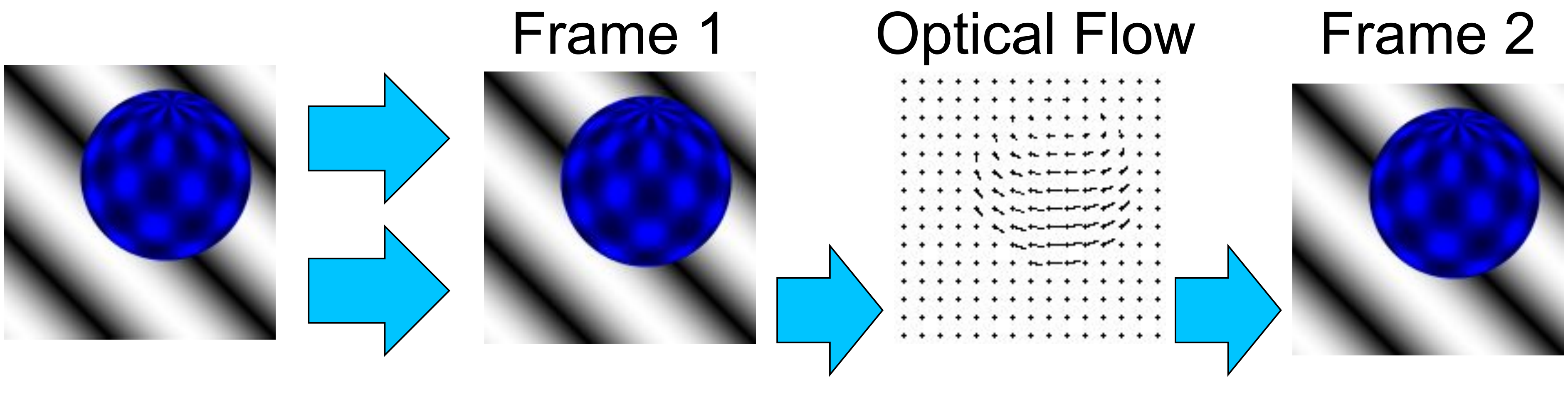
Motion Analysis

Motion Information (Optical Flow)

Compare sequential images over time

Use global matching algorithms to find the "flow" of the images

Only 2D motion obtained (image plane)

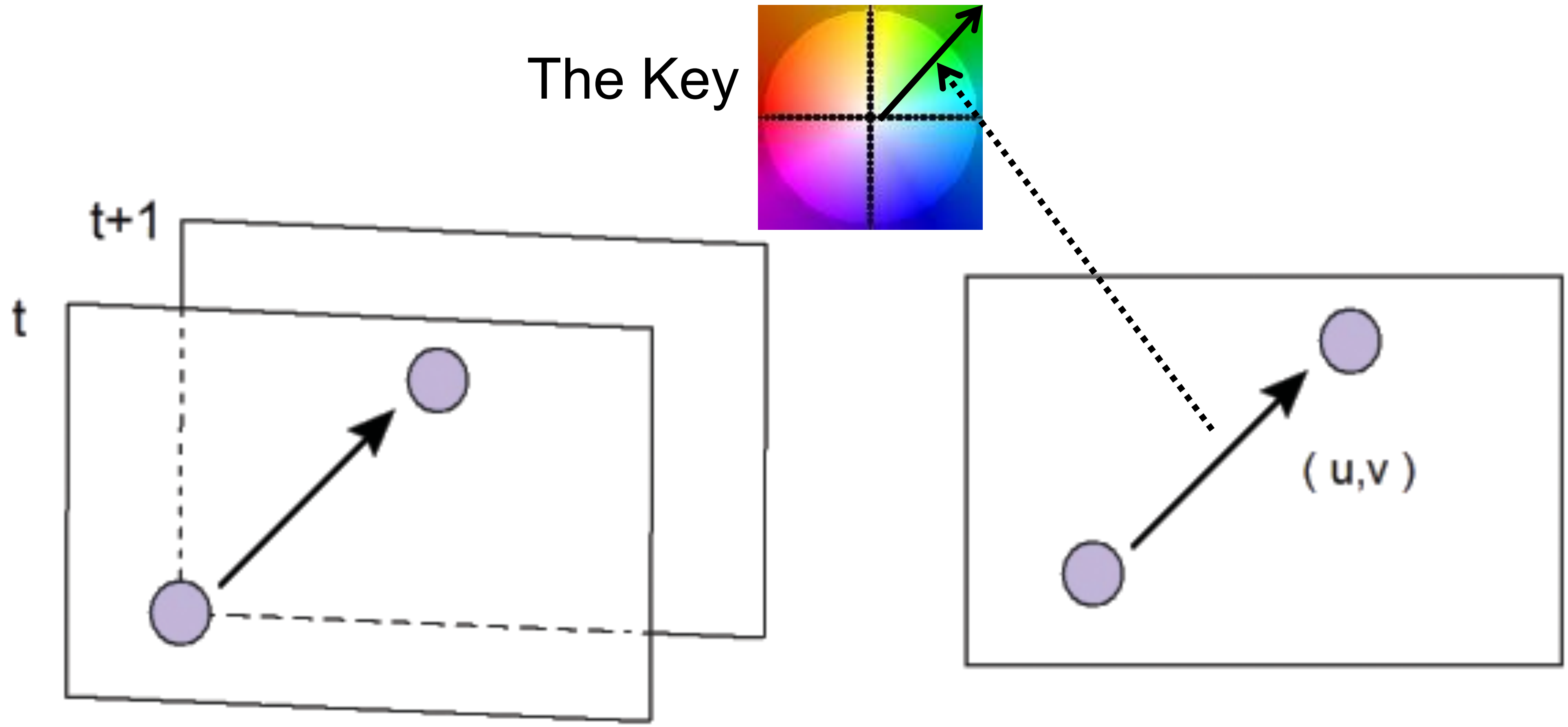


Optical Flow Example

Image 1

Image 2

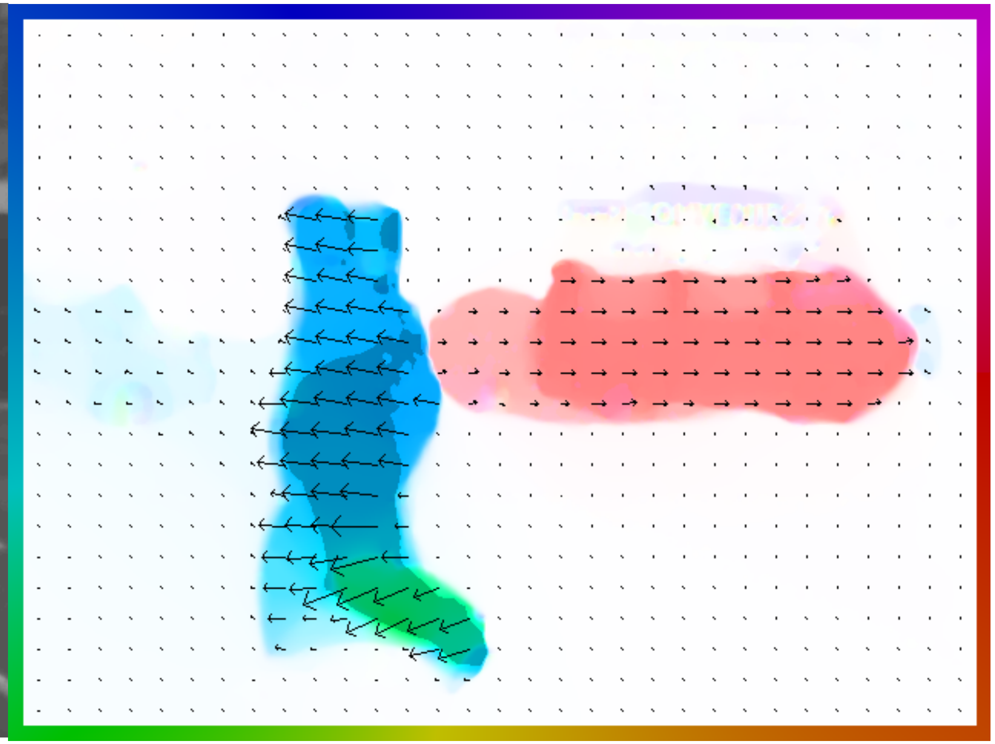
Optical Flow – 2D Search



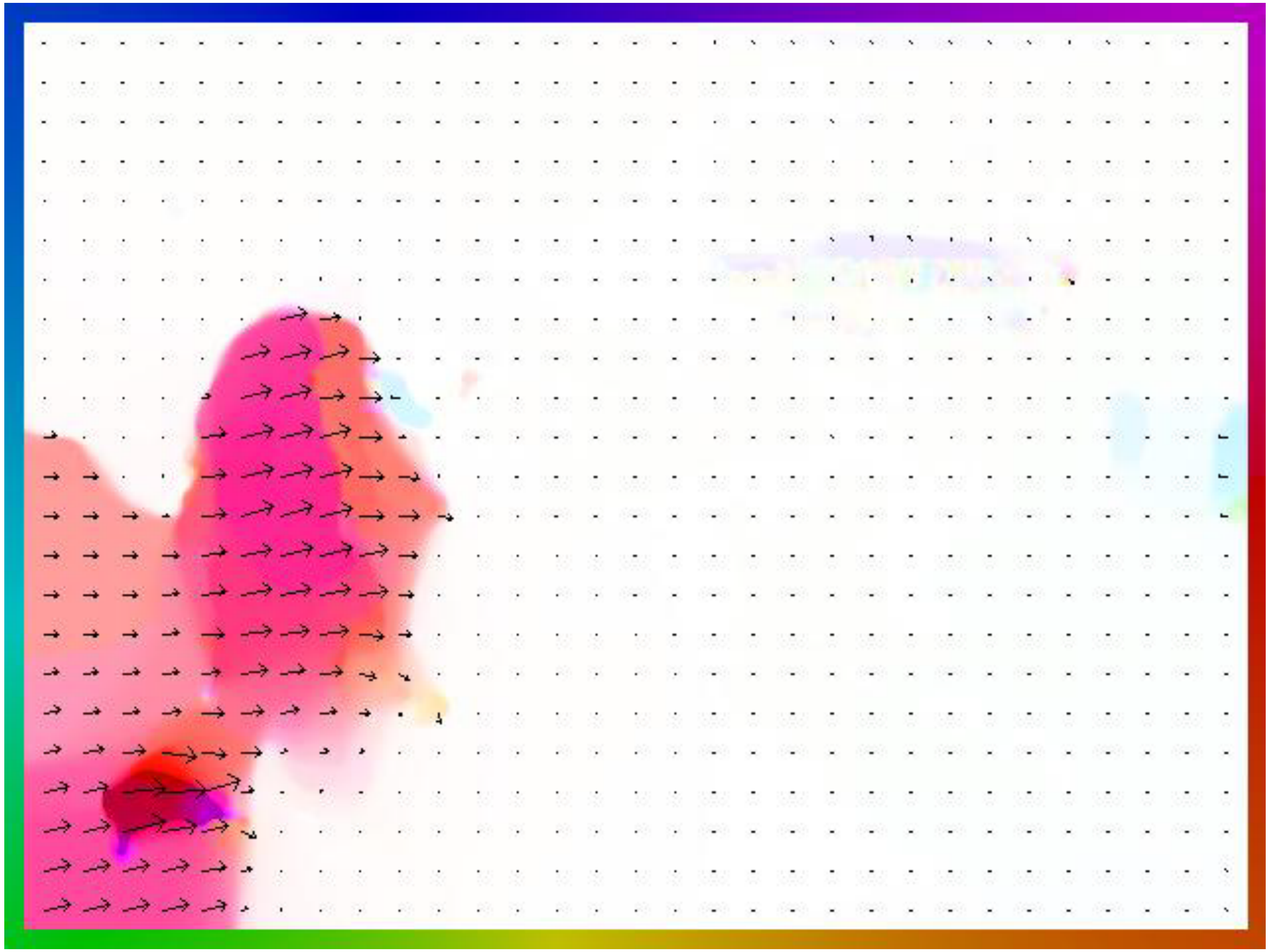
Original Frames

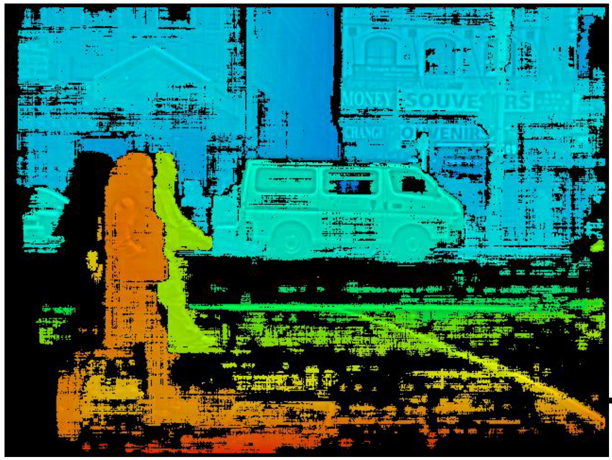
Optical flow

.enpeda.. solution for: **Dense motion analysis**



Used color key for showing motion





.enpeda.. solution for: Visualization of 3D stereo and motion

Combining stereo with motion

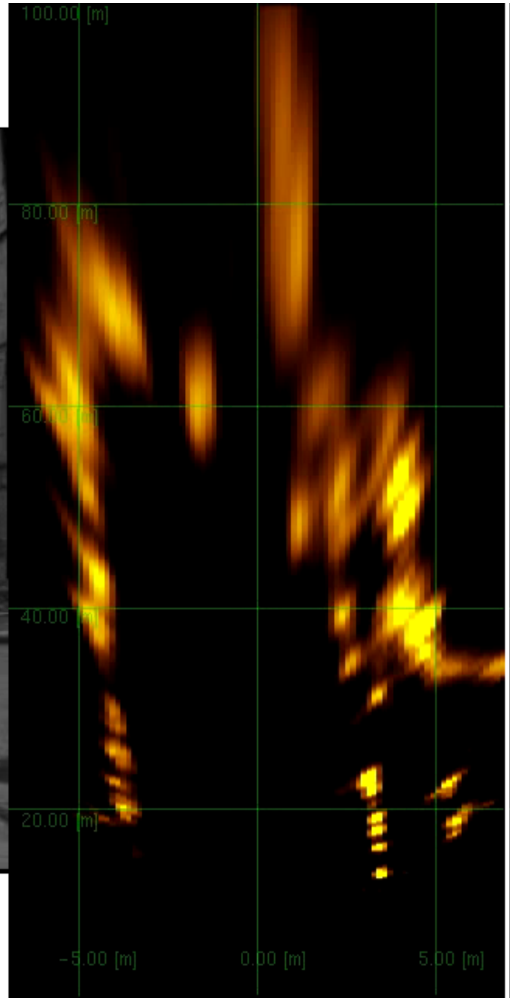
Scene Flow

In collaboration with Daimler A.G., Germany

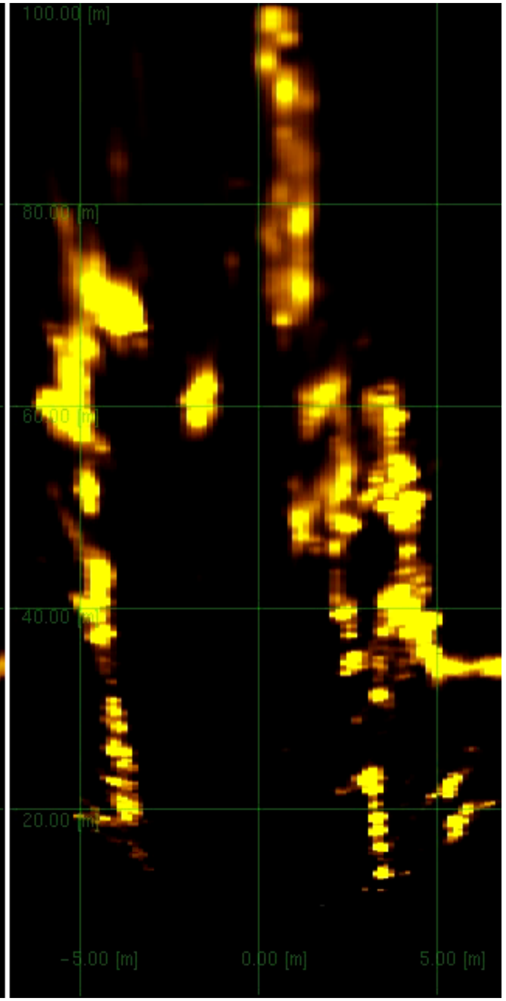
Distance to Obstacle

Integrating Stereo Over Time

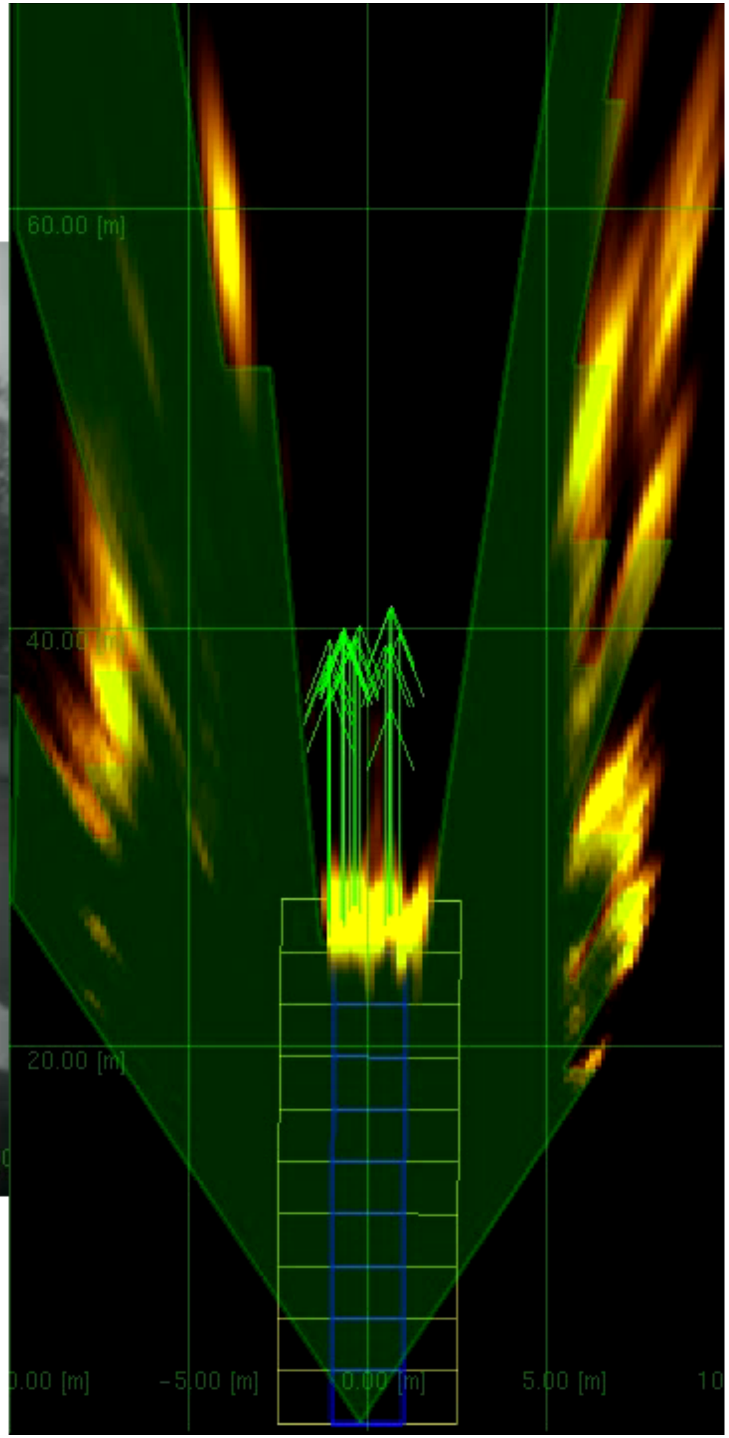
Original



Raw



Integrated



In collaboration with Daimler A.G., Germany

.*enpeda*.. solution for: Distance to "obstacles"

Summaries

DAS
Driver Assistance Systems

- **lane departure**
- **safe distance**
- **blind spot**
- **speed signs**
- **stop signs**
- **free space**
- **sleepiness**

AH
Automated Highways

- **debris detection**
- **safe distance**
- **free space**
- **driver readiness**

DLV
Driverless Vehicles

multi-sensor

MILITARY
ground manifold
…

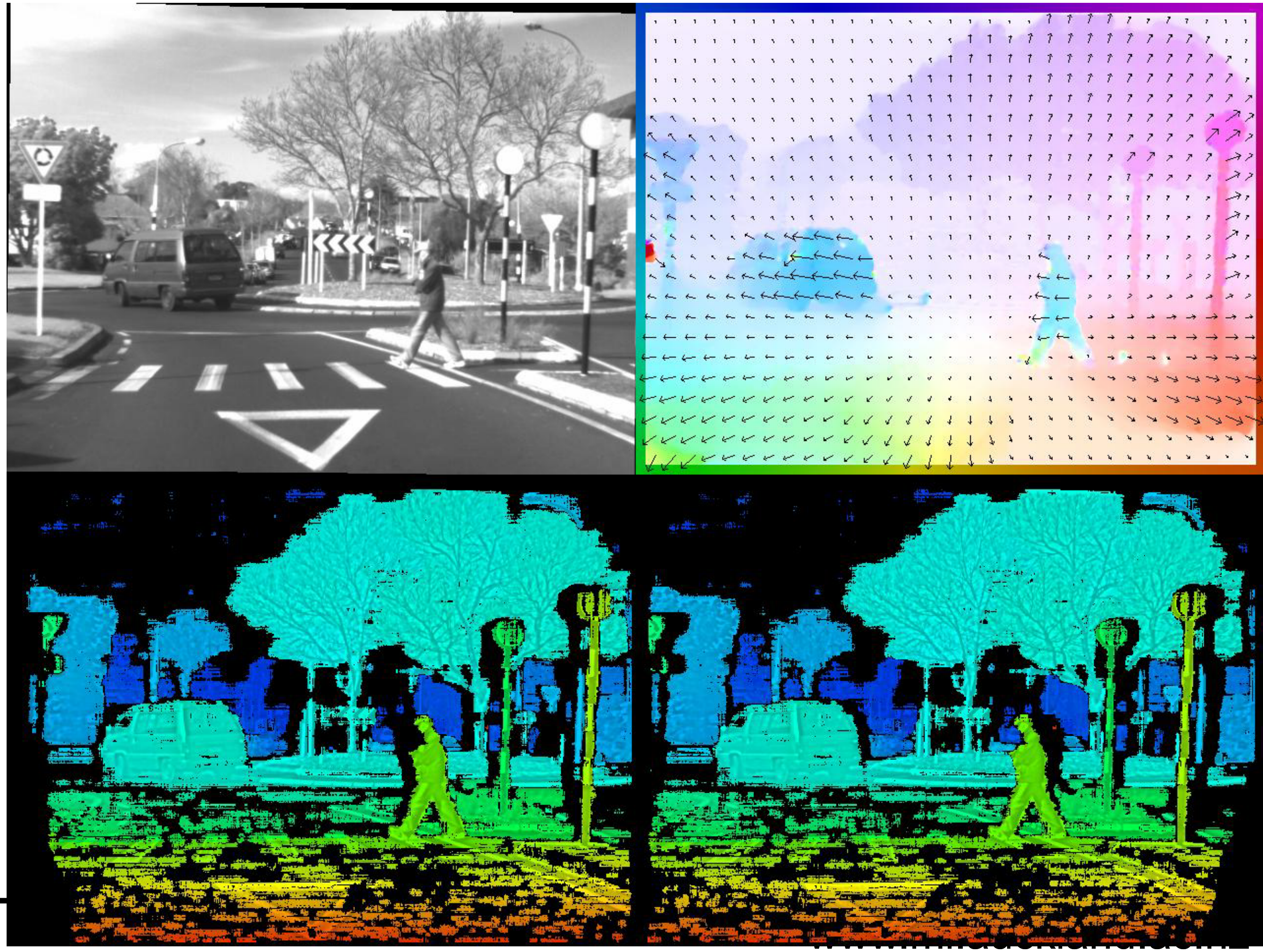
CIVIL APPL.
ROBOTICS
tracking
…

1993

Indoor, single stereo pair, slow, inaccurate

2011

Real-time video (FPGA, Bosch Germany, 2 Watt) stereo and motion at 30 Hz, sufficient accuracy



Conclusions

Vision-based DAS is the future (an expanding field of research; car industry needs it; road safety requires our attention): predict - adapt - optimize

Low-level vision is still not yet robust ... but progress is steady

Pedestrian detection and tracking, ..., understanding of complex traffic scenarios is still a challenge

We are ready to go to the next level.
Our technology applies to all types of cars.

Options: integration into

a large-scale **automated highway project**

or

a **collaboration with the car industry** in China (including our partners in China, e.g. Jinan Univ.)

or ...

Accident free driving is a realistic goal.

See “deaths, injuries, social costs” as above.