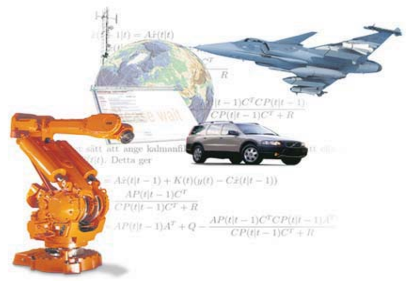
Welcome to the graduate course on Dynamic Vision!



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Camera – A device that provides 2D projections of the 3D world

Course Contents

Motion, dynamics and vision

- Rigid body motion
- Camera models
- Camera calibration
- Feature extraction
  - No details, but explain the idea and how it can be used
- Epipolar geometry
- Sensor fusion using cameras
  - State estimation (bonus for those interested)
- Examples of industrial use of cameras

We view vision as a sensor to be used in order to compute the motion.

Goals

- Show that the camera is a powerful sensor.
- Understand how we can pose and solve various estimation problems based on camera images.
- Show examples of how cameras can be used together with other sensors.
- Let you **experience** the possibilities and challenges of working with camera images.
- **Have fun and learn new things!!!**

Why are we Interested in Cameras as Sensors Now?

- Until just over 10 years ago there was no commercial hardware available to transfer images at frame rate (30 Hz) into the memory.
- Even if the above would have been possible, there were no computers available for processing the images. We now have powerful computer able to process images in real-time.
- It is only during the past 10 years that the geometry of vision has been thoroughly understood and systematically explained.
- Finally, as with many other areas, it is driven by applications. These applications are now emerging fast.

A Few Examples

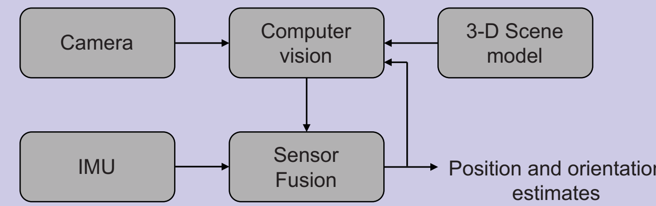
Inertial sensors **Camera** Barometer (altitude)	Inertial sensors **Camera** Radar Wheel speed sensors Steering wheel angle sensors	Inertial sensors Radar Barometer (altitude) Terrain elevation DB **Soon: Vision sensors**	Inertial sensors **Camera**

Introductory Example – Fusing Inertial Sensors and Camera

Objective:

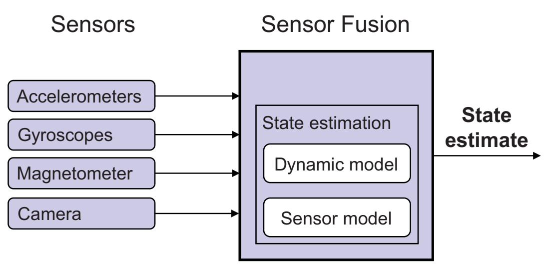
Produce high quality **estimates** of the position and orientation (**pose**) of a camera in real-time using measurements from **inertial** sensors and a **camera.**

Schematic overview of the solution:



The work was conducted within a 6th framework EU project (MATRIS).

Introductory Example – Sensor Unit



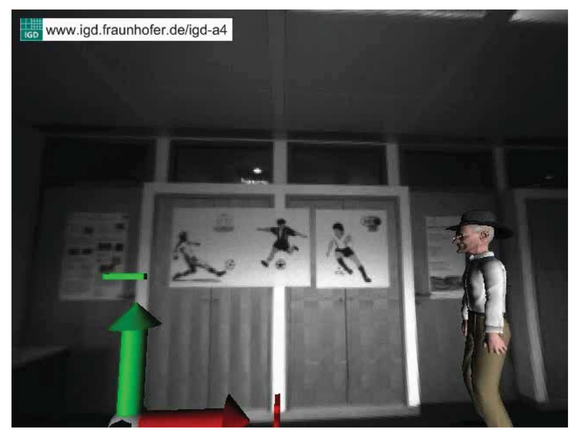
Sensor unit developed within the project

$$x = \begin{pmatrix} b \\ \dot{b} \\ \ddot{b} \\ q \\ \omega \\ \delta_\omega \\ \delta_a \end{pmatrix}$$

- b: Position
- $\dot{b}$: Velocity
- $\ddot{b}$: Acceleration
- q: Unit quaternion describing the orientation
- ω: Angular velocity
- δ_ω: Bias term (gyroscopes)
- δ_a: Bias term (accelerometer)

$$y = \begin{pmatrix} y_{\text{acc}} \\ y_{\text{gyr}} \\ y_{\text{cam}} \end{pmatrix}$$

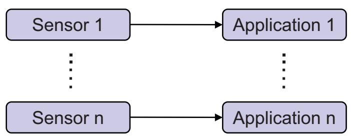
Introductory Example – Fusing Inertial Sensors and Camera



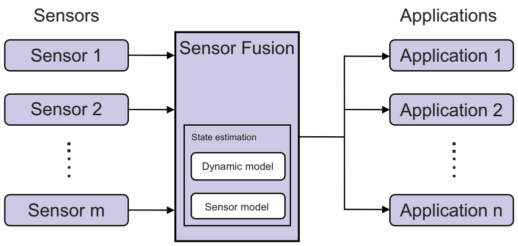
Applications in augmented reality, e.g., sports broadcasting.

Automotive Sensor Fusion

Common situation, to be changed



New situation, is coming



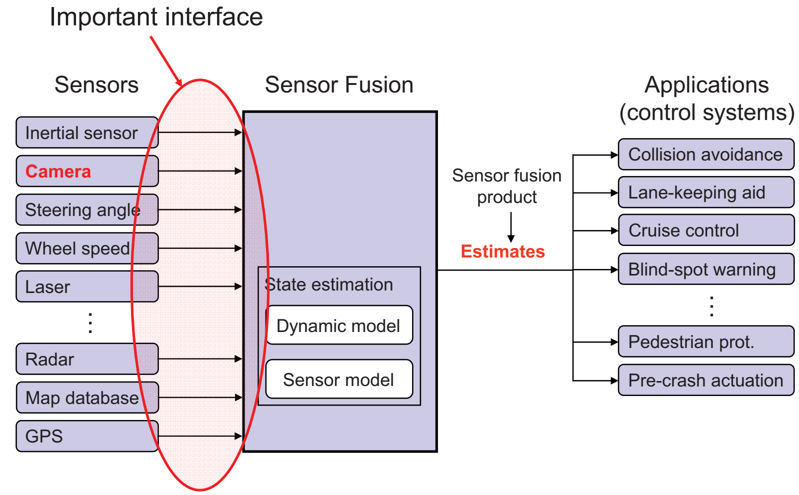
Dickmanns and co-workers 1994

Dickmanns, E. D. **Dynamic Vision for Perception and Control of Motion**, Springer, 2007.

Application example, lane keeping aid system

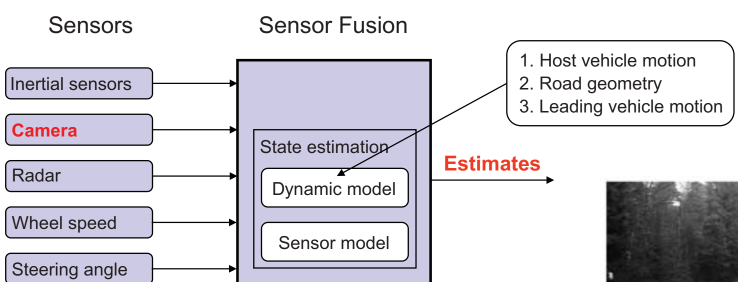
Lecture 1

Automotive Sensor Fusion



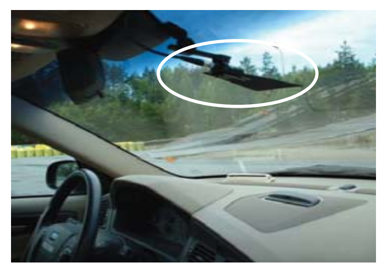
Lecture 1

Automotive Sensor Fusion



Lecture 1

Exterior Sensors – A Classic Example (Radar and Vision)



Vision

Detects

- other vehicles + classification
- lane markings
- pedestrians

Azimuth angle: high accuracy
Range: low accuracy
Wide field of view
Sensitive to bad visibility

Radar

Detects

- other vehicles

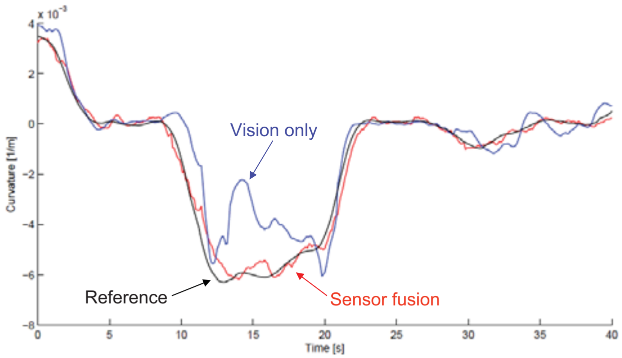
Azimuth angle: medium accuracy
Range: very high accuracy
Range rate: very high accuracy
Narrow field of view
Less sensitive to weather conditions

Lecture 1

Automotive Sensor Fusion

Results in a nonlinear state-space model.

State estimation problem solved using the extended Kalman filter.



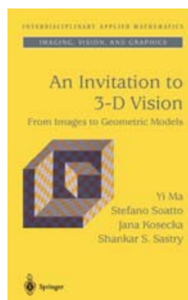
Practical Issues

- The course gives 3hp (an additional 3hp via project)
- Lecturer and organizer: Thomas Schön
- 5 lectures (theory and examples)
- 1 invited lecture from the industry (C3 Technologies)
- 1 bonus lecture on nonlinear state estimation (particle and Kalman filters)
- 3 home work assignments (for the PhD students who want credits)
    - Will be posted on the course web site

Course Litterature

Course book:

Ma, Y., Soatto, S., Kosecka, J. and Sastry, S.S. **An invitation to 3-D vision – from images to geometric models**, Springer, 2006.



Recommended side reading:

Hartley, R. and Zisserman, A. **Multiple view geometry in computer vision**, Cambridge university press, 2003.

Trucco, E. and Verri, A. **Introductory techniques for 3-D computer vision**. Prentice Hall, 1998.

Faugeras, O. **Three-dimensional computer vision - a geometric viewpoint**. MIT Press, 1993.

Marr, D. **Vision**, Freeman, 1982.

Schedule – Lectures

Nr	Date	Contents
1	Wed. 12/11	Introduction and rigid body motion (Chapter 1-2)
2	Wed. 19/11	Camera models and calibration (Chapter 3, 6)
3	Wed. 3/12	Feature extraction and tracking (Chapter 4, 11)
Bonus	Dec. 11/12	Nonlinear state estimation (hand out)
4	Wed. 14/1	Epipolar geometry and reconstruction (Chapter 5)
5	Wed. 28/1	Sensor fusion using camera images
Industry	Fri. 30/1	C3 Technologies

Several research articles will also be handed out during the course

Schedule – Home Work Assignments

The home work assignments should be solved individually. However, it is allowed to discuss the solutions with other students.

Nr	Contents	Due date	Discussion
1	Rigid body motion, image formation, camera models and camera calibration	Dec. 10	Dec. 12
2	Feature extraction and feature tracking	Jan. 14	Jan. 16
3	Sensor fusion using images	Feb. 11	Feb. 13

- The home work assignments will be posted on the web site.
- Due at 23.59 per Email to schon@isy.liu.se
- You may have 3 late days in total.

Projects – 3 hp

- Check web site for ideas or even better, make up your own!!
- Form teams (2 - 4 students/project)
- Time line,

Date	Action
< Jan. 14	Initiate project, collect data, etc.
Jan. 14	Project proposals are due
Mar. 23	Reports are due
Mar. 27	Project presentation and discussion

Projects – 3 hp

A few project ideas:

- Robot motion estimation using camera(s).
- Estimate bicycle motion using sensor fusion of cameras, inertial sensors and GPS. (inspired by Karl Johan Åström's lecture yesterday)
- Build a SLAM system able to work in an office environment
- Automotive target tracking using forward looking cameras
- **Own ideas!!!** Search youtube.com for ideas
- ….