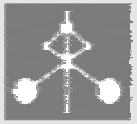
University Cooperation with Industry: Formats and Results
or
The ISIS Competence Center

Lennart Ljung

Linköping University

The Swedish Competence Centra

- Initiative by VINNOVA, a Swedish government funding agency
- Cooperation between industry and academia
- Long term commitment -10 years
- Jointly funded by VINNOVA, the companies and the university
- Flow of ideas and people in both directions
- 28 centra exist in Sweden
- International interest in the format



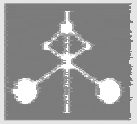
ISIS: A VINNOVA Competence Center

- ISIS: Integrat rial Control and Super

A coalition between 6 research groups and 10 companies. Sponsored by VINNOVA.

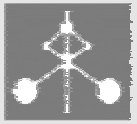
The University Teams: EE + CS

- Automatic Control (EE)
- Communication Systems (EE)
- Vehicular Systems (EE)
- Theoretical Computer Science Lab (CS)
- Embedded Systems Lab (CS)
- Engineering Data Bases Lab (CS)



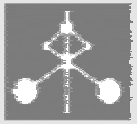
ISIS Industrial Partners

ABB Automation Systems	ABB Automation Products	ABB Corporate Research
ABB Robotic Products	Ericsson Radio	
SAAB Automobile	Mecel	Nira Dynamics
SAAB Aircraft	SAAB Bofors Dynamics	



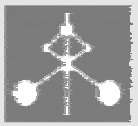
Some More Facts

- Cash Contribution from VINNOVA, Industry and University: 1 MEuro/year
- Work Contribution from industry: Another 0.8 MEuro
- Non-Cash support from University: another 0.5 MEuro
- Most cash spent on PhD student salaries
- A Governing Board from the industrial partners
- A Director from University



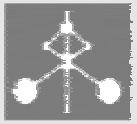
The Goals of ISIS (1)

- Be a center for systems for control and supervision, by providing the different competences for this, integrated under one roof.
- Provide cross-disciplinary research and integration between Control Engineering and Computer Science
  - Workshops, Seminars, Discussion groups (TKG)
- Run projects with big impact on industrial products and system development, at the same time as they are of indisputable scientific quality (Handle the tricky balance between keeping the companies happy and producing good research.)
  - Products, Patents, Papers, PhD's



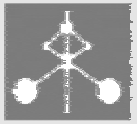
The Goals of ISIS (2)

- Provide both technology transfer to industry and application transfer to university. Help industry find competence of mutual interest.
  - Significant flow of people in both directions. Advanced techniques in products (ILC, UML, Bayes). More applied work in Control and CS groups.
- Educate people with a broad understanding of the whole ISIS competence area.
  - 10 PhD's, 15 Techn. Lic's, "many" MSc's. A related gradute school (ECSEL) and two undergraduate study profiles in the EE and CS programs.



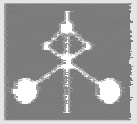
Technical Activities

- 11 Projects (typically involving 1-2 PhD students each)
- Focus areas
  - Sensor fusion
  - Detection/Diagnosis/Supervision
  - Control applications
- Non-competing companies with common technical interests/problems
- Example: Sensor Fusion … (Fredrik Gustafsson)



Sensor Fusion

- Bring together measurements of different kinds for better basis of decisions
- Example: An automobile – The rotational speeds of each of the four wheels and a road map. Estimate the position of the car.
- Basically a non-linear filtering problem

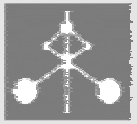


Filtering Formulation

$$\frac{d}{dt}x(t) = f(x(t), u(t), w(t))$$
$$y(t) = h(x(t), u(t), e(t))$$

y and u measured, w and e are noises, x to be estimated

u: wheelspeeds, f: kinematics, x: car position
y: on/off road, h: the map



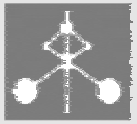
Solving the Filtering Problem

$$\frac{d}{dt}x(t) = f(x(t), u(t), w(t))$$
$$y(t) = h(x(t), u(t), e(t))$$

y and u measured, w and e noises, x to be estimated

A classical difficult problem unless f and h are linear and e and w Gaussian processes.

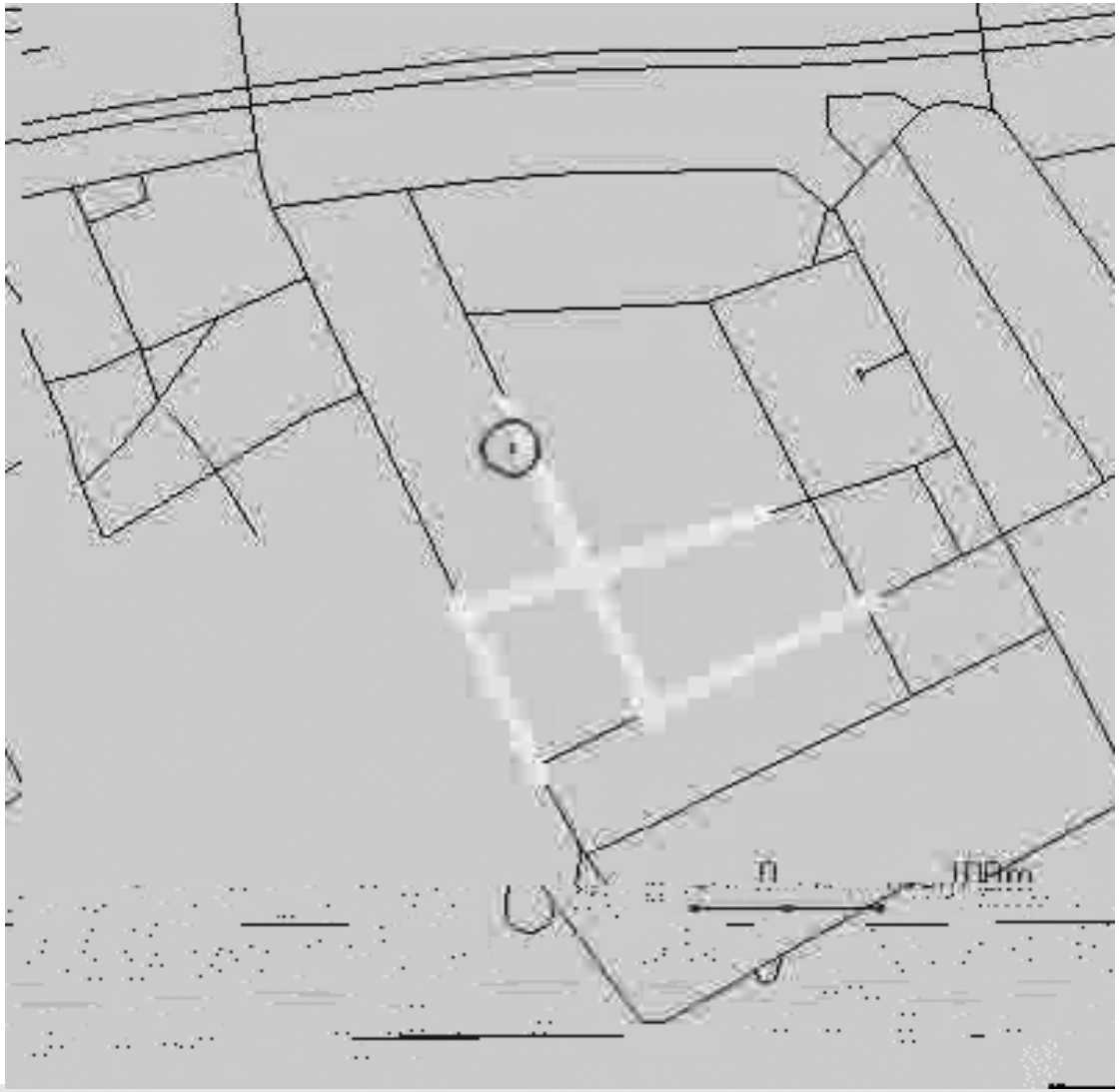
New simulation based techniques:
MCMC -- Particle Filters



Car Navigation: A Particle Filter

- Red: True
- White: particles
- Blue: estimate (after convergence)
- Black lines: the map

- (Thanks to Fredrik Gustafsson)

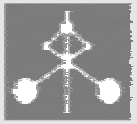


Car positioning

- An ISIS project with NIRA Dynamics
- Complete navigator with voice guidance!
- Integer implementation of the particle filter
- PF in simulation mode off-road
- # particles up to 15000 (without GPS) or as small as 50 (with GPS)
- On-going R&D work at NIRA Dynamics AB and ISIS

The Story of Sensor Fusion in ISIS Projects

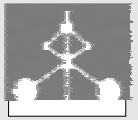
- Actually, it first started with terrain navigation with SAAB Bofors Dynamics (missiles). An altitude data base was used in conjunction with radar altitude measurements.
- This was done in at the same time as the particle filter theory was understood and developed (Cramer-Rao bounds, marginalization …)
- The application to car navigation with Nira Dynamics was deleloved in parallel with navigation and landing systems for the Gripen Aircraft (coming up …)



Lennart Ljung
The ISIS Competence Center

Delft
June 8, 2004

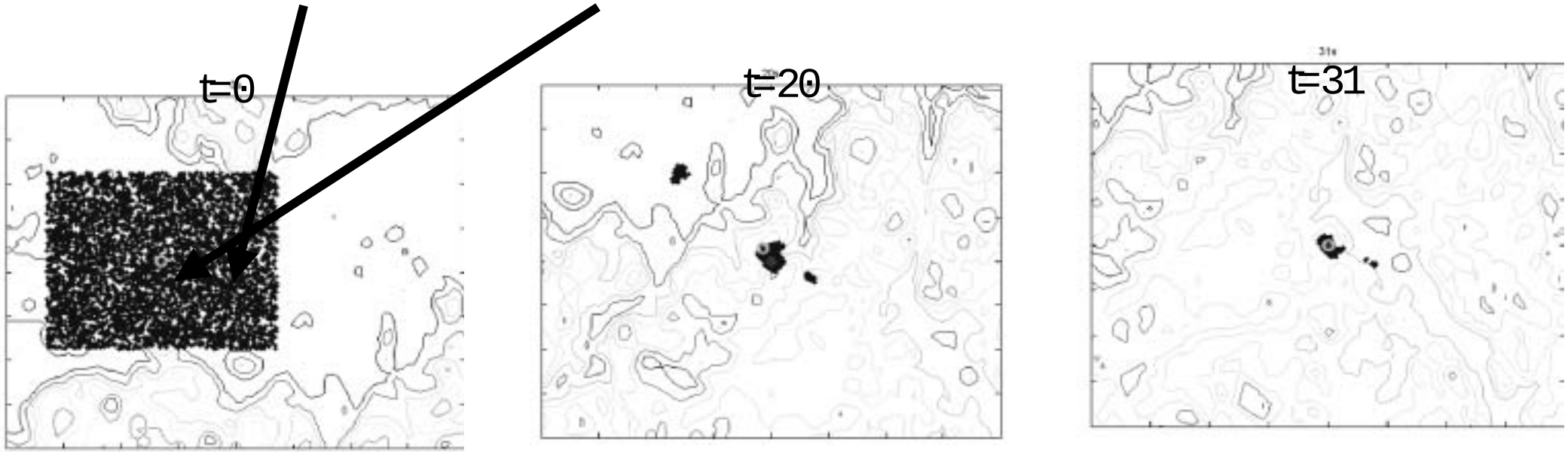
AUTOMATIC CONTROL
COMMUNICATION SYSTEMS
LINKÖPINGS UNIVERSITET



Terrain-aided navigation II

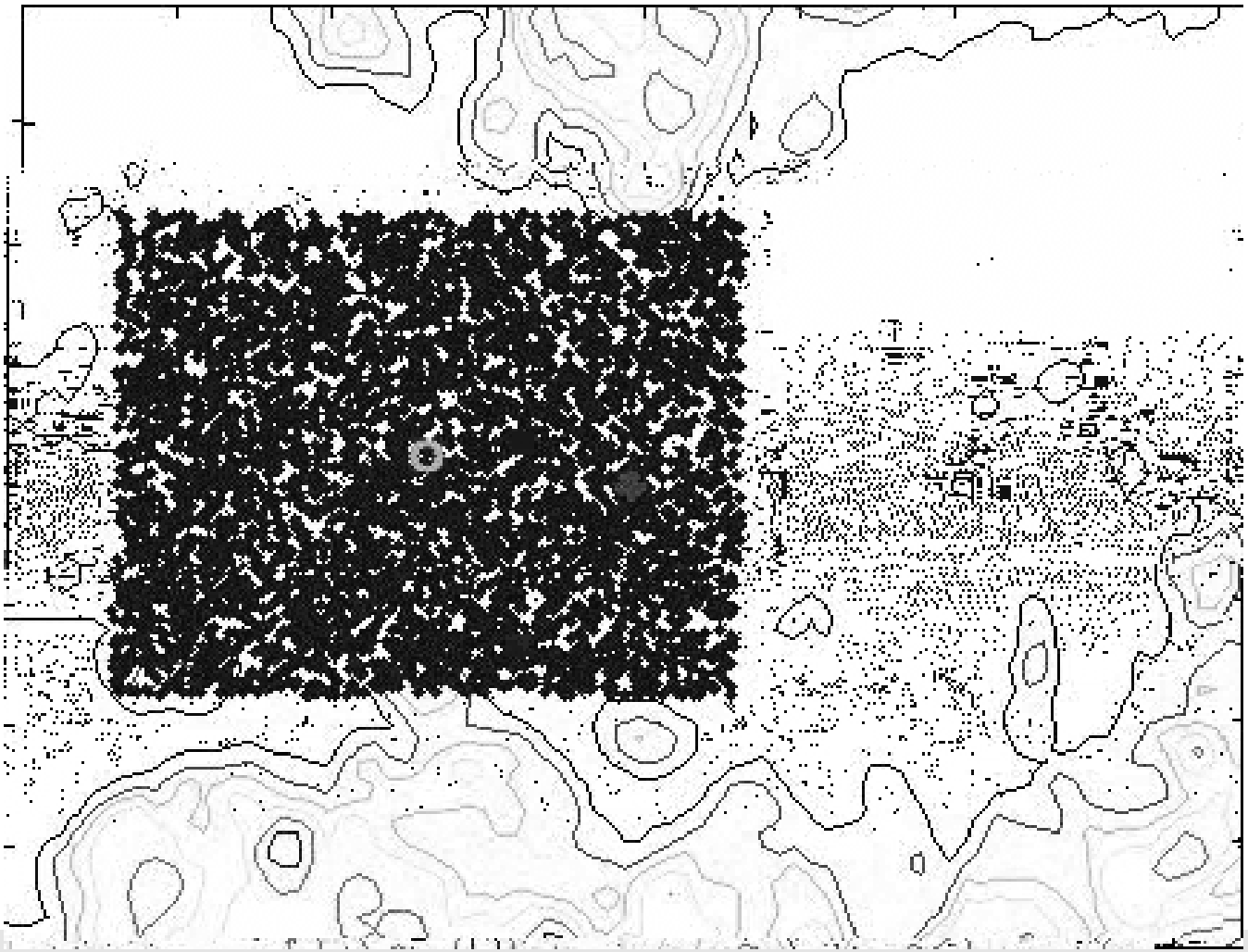
2D Example

- Simulated flight trajectory on GIS
- Snapshots at t=0, 20 and 31 seconds
- Red: true Green: estimate



Terrain-aided navigation III

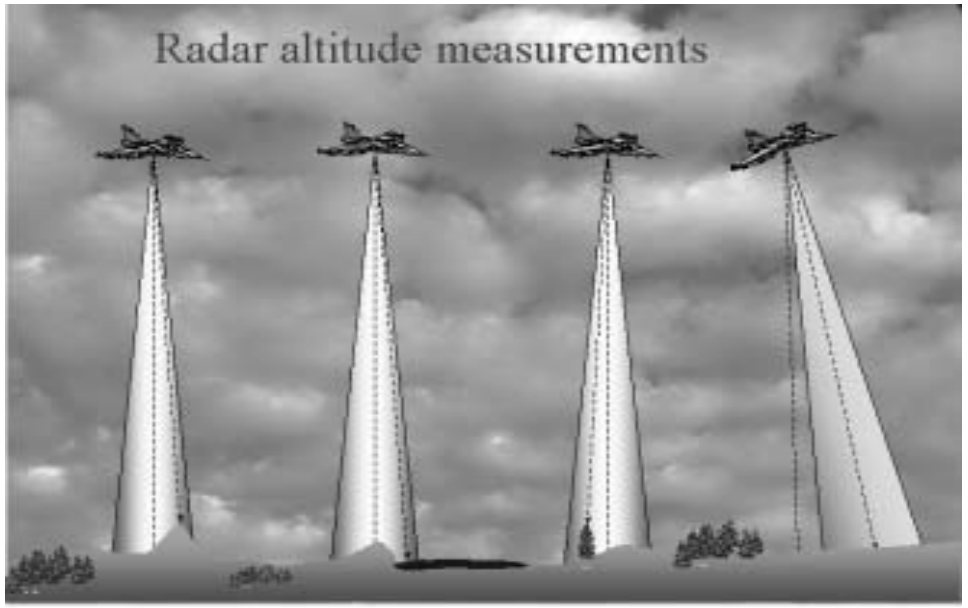
Animation of terrain navigation in 2D using realGIS

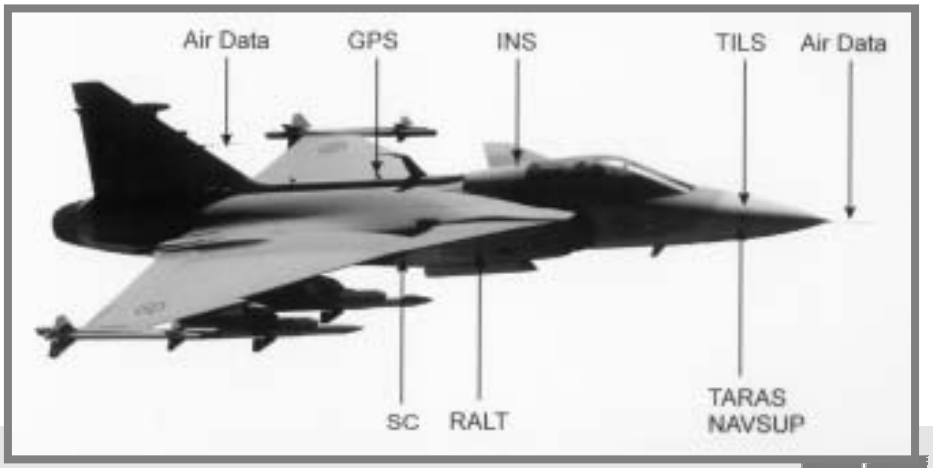


Aircraft navigation

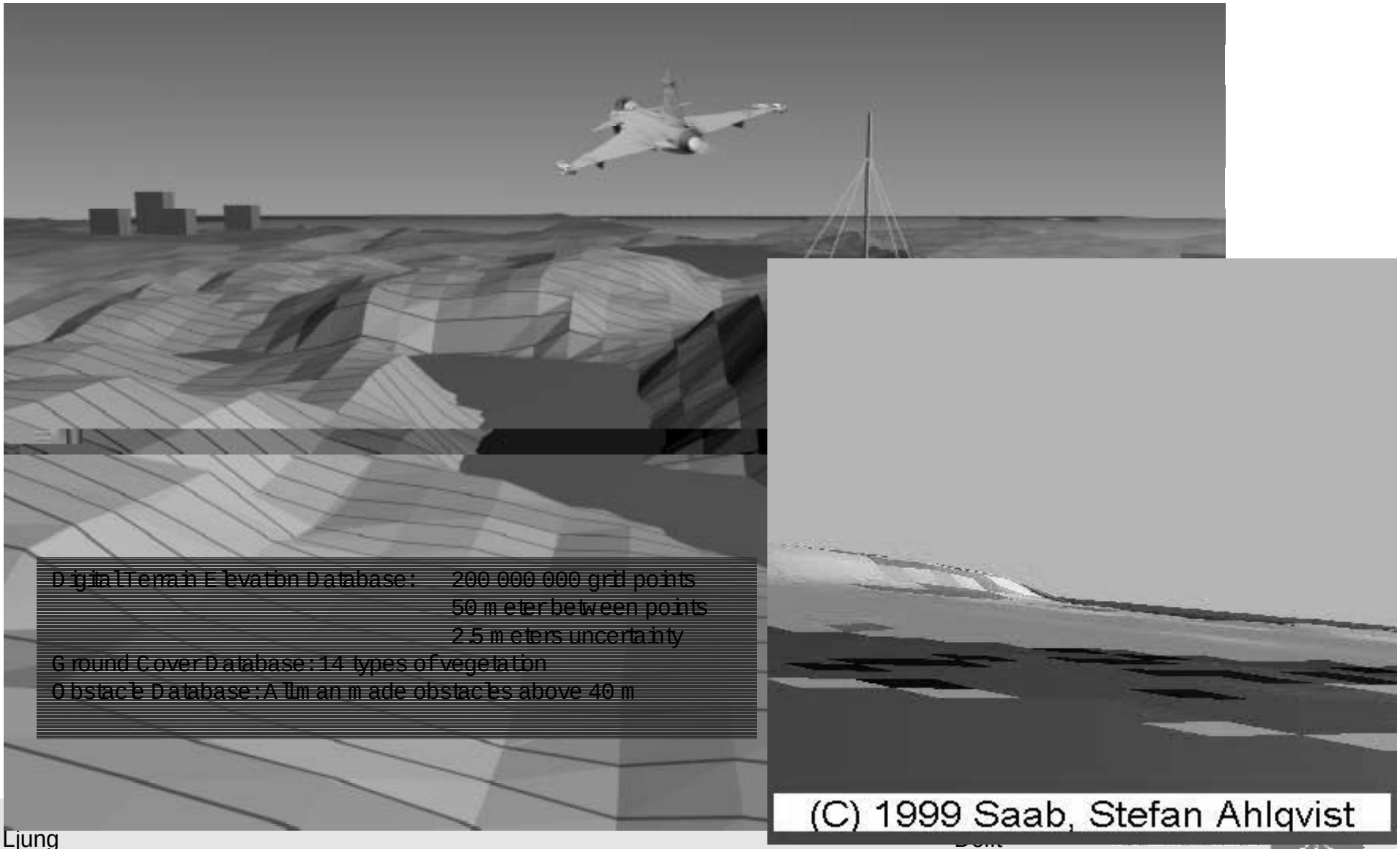
New (2G) integrated navigation and landing system for Gripen is based on particle filter for terrain navigation

Next generation may be based on marginalized particle filter for sensor fusion (27 state EKF today)



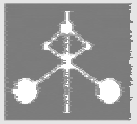


Positioning: GIS as a sensor



And more sensor fusion …

- ABB Robotics realized that similar techniques could be applied to precise estimation of the gripper’s position. This is now under investigation.
- In a separate project with Volvo (outside ISIS) on collision avoidance, the same ideas on particle filters have been used to analyse complex scenes.



On the robot

- Accelerometer mounted at the tool
- Model with state vector

$$x_t = \begin{pmatrix} q_t & \dot{q}_t & \ddot{q}_t \end{pmatrix}^T,$$

and

$$x_{t+1} = Ax_t + B_w w_t,$$

$$y_t = h(x_t) + e_t$$

where

$$h(x_t) = \begin{pmatrix} q_{m,t} \\ \ddot{\rho}_t \end{pmatrix},$$

- Goal: Estimate arm angles for ILC

Volvo Application: Forward collision avoidance

- Warning - braking - steering
- Path prediction and tracking central
- Detection of critical situation or unavoidable crash
- (Thanks to Jonas Jansson, Volvo)

Volvo demonstrator

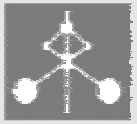
ISIS as a center

What are the benefits of ”running the projects within a center”?

- A new meeting place
- A stable relationship
- Inspiration for new approaches in undergraduate and graduate education
- More visibility

Industrial Involvement and commitment:

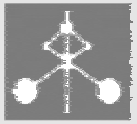
- Strategy documents
- Regular meetings of various kinds
- New projects
- Flow of people in both directions



Flow of Resources

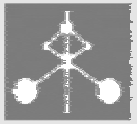
No micromanagement!

- A project is one or two graduate students (80% each)
- Each project has a given amount of resources depending on the number of PhD students
- This sum shall cover the student's salary and all overhead, including supervision
- The managment of this resource is up to the division, not the center



Strategy for Balance

- The participating university labs have reasonable resources for ”idea- and curiosity based” research outside the center.
- The projects must be in line with central, long-term activities in the companies:
  - SAAB: Navigation and sensor fusion
  - ABB robotics; robot accuracy and intelligent error message handling
  - …
- Acceptance from the companies that the projects should lead to dissertations
- Mutual egoism in the choice of projects



Summary

- Challenge
  - Keep the companies happy, while producing good research
- Difficulties
  - Balance industrial need with personnel resources
- Advantages
  - A stable relationship
  - Much increased interaction: Cross contacts between ”unrelated” companies
  - Much less red tape