Autonomous
Inspection and
Intervention
Robots

Abstract

The purpose of the project is to develop procedures to allow a land based robot to navigate, find objects and servo in onto objects to move or manipulate.

The project contains a study of several mechanisms for robots to work in complex environments, while a demonstrator has been developed for industrial AGV/LGV docking systems. The repeatability can be within a few millimeters.

For more information and results from this and related projects, look at:

`http://www.isy.liu.se/cvl/Projects/AIIR`

`http://idefix.ikp.liu.se/rames/LIDAR.htm`

`http://www.ndc.se`

The demonstrator system is a robot designed to identify the position of a pallet, and move up to it such that it can lift the pallet to move it. The problem consists of two parts:

- Identification of the pallet of interest and estimation of its approximative position.

- Successive improvement of position estimate of the pallet, as the robot moves towards it, as well as taking a particular path towards the pallet.

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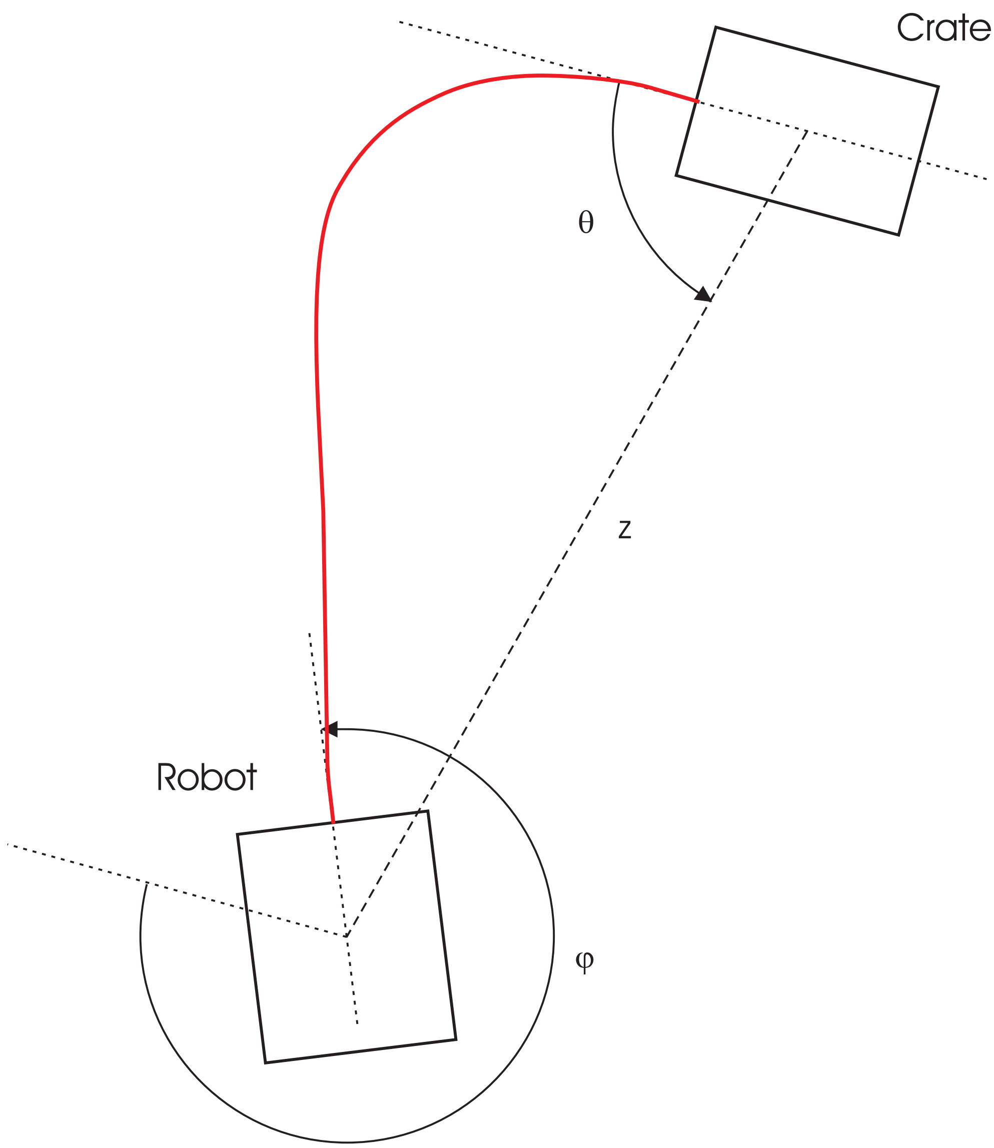


Research

In addition to the procedures implemented in the demonstrator, a number of procedures for more flexible operation of a robot have been developed.

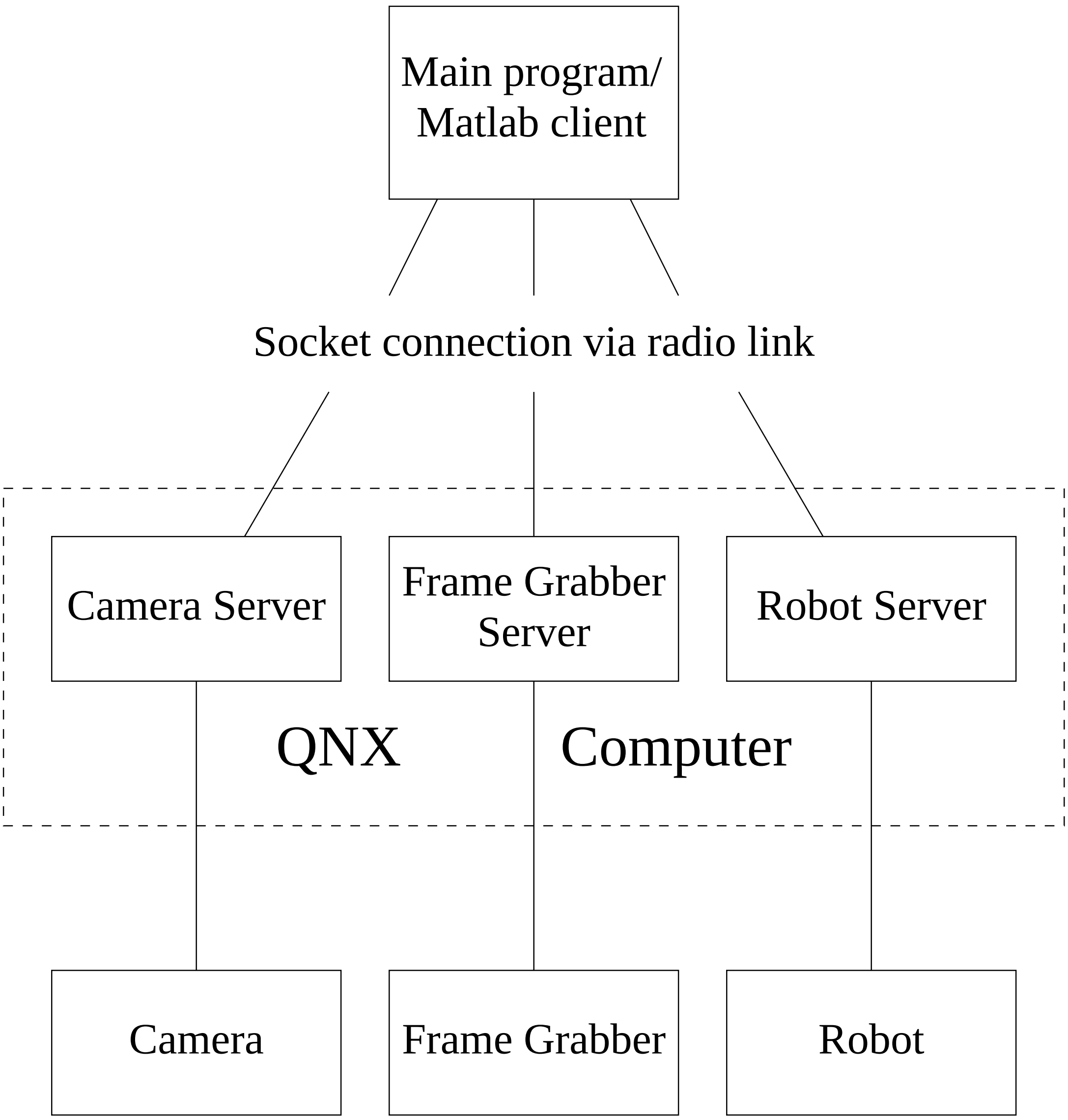
- Shape, object and scene description
- From sensor data to CAD models
- Smooth-pursuit tracking
- Infrared image analysis
- Robust motion estimation
- Robot navigation (localization, path planning and positioning)

An important part of the demonstrator is to implement fusion between the information from two sources:

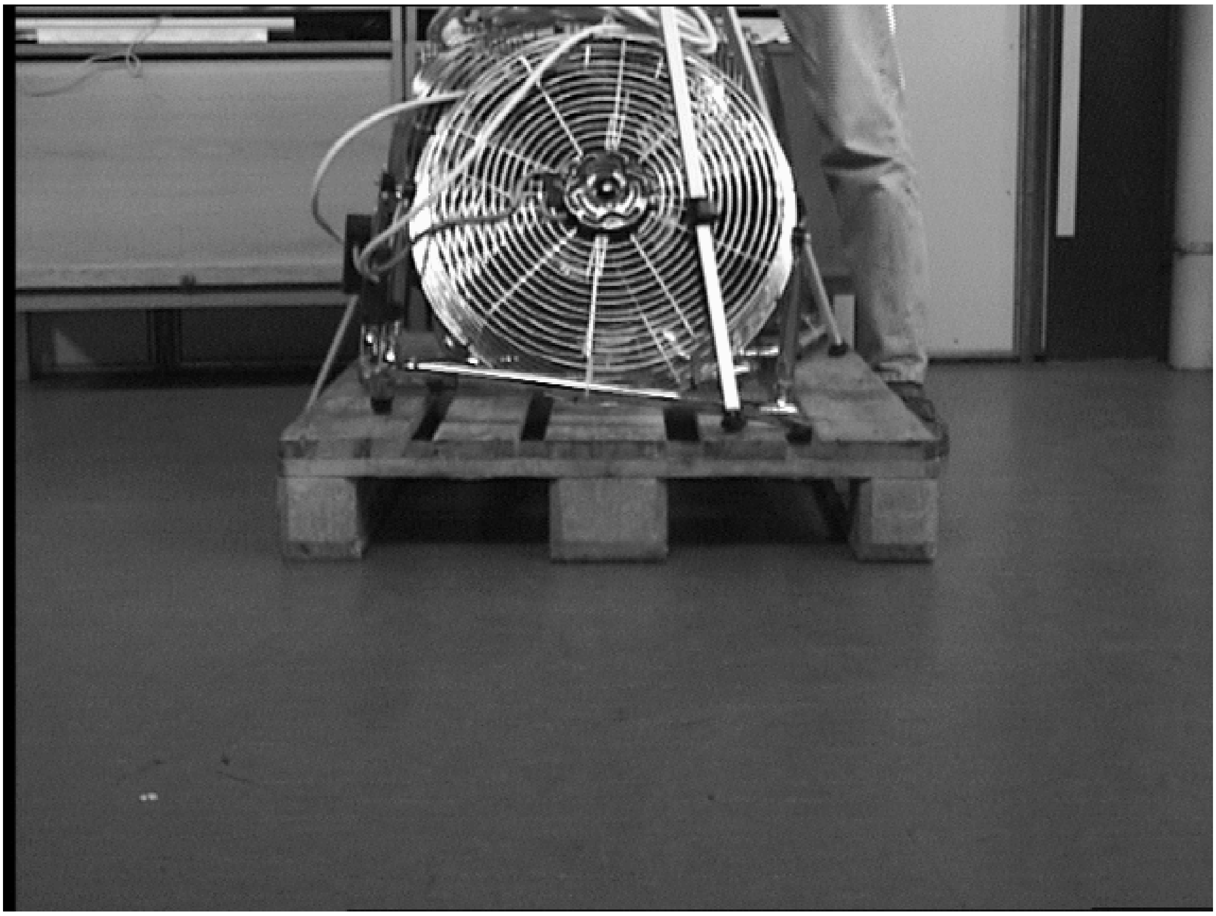
- Computer Vision
- Laser Ranging

The same camera sensor is used for both modes of sensing which gives a more compact system but some challenges for system integration.

Three separate communication channels have been implemented in a way which allows distributed processing and control; a feature which is valuable in telerobotics.



Original frame



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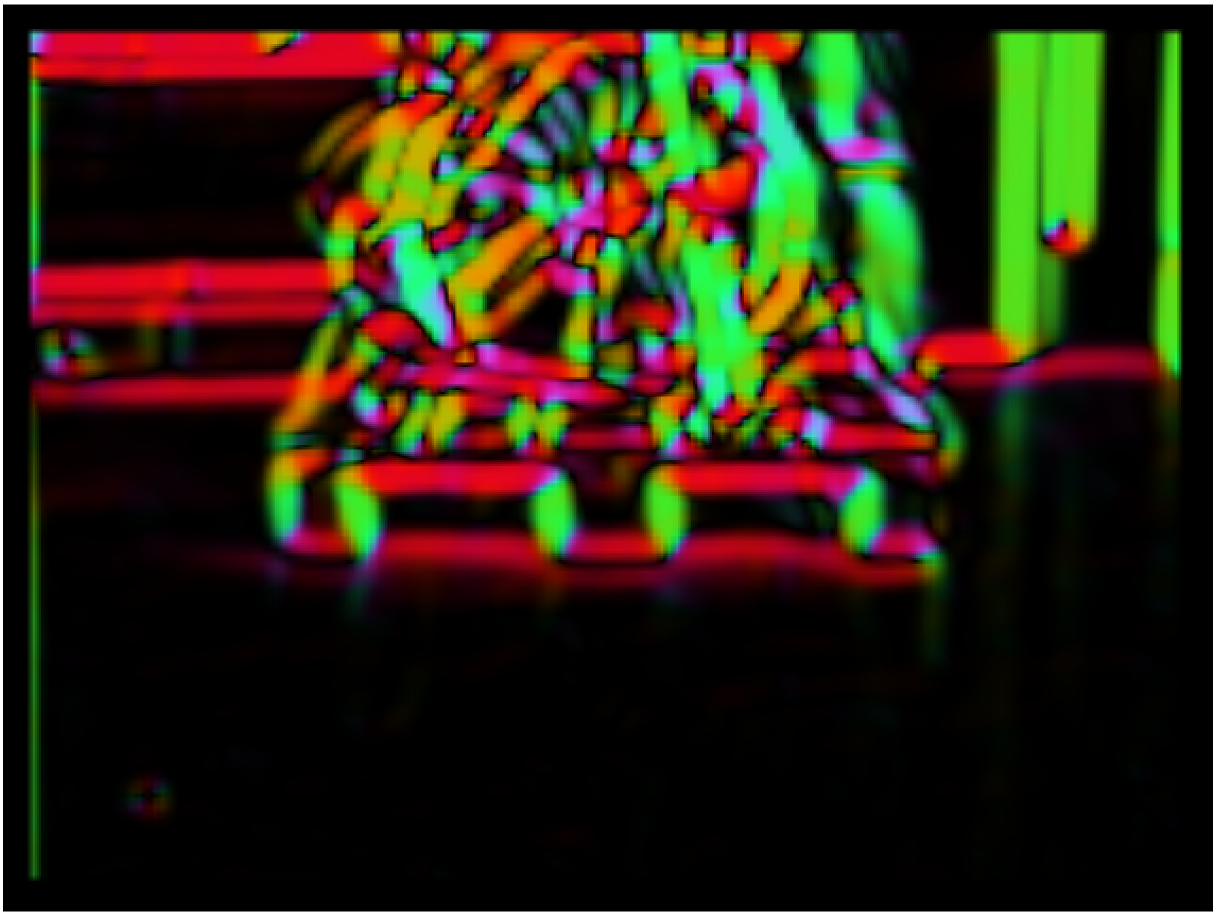
Orientation operation



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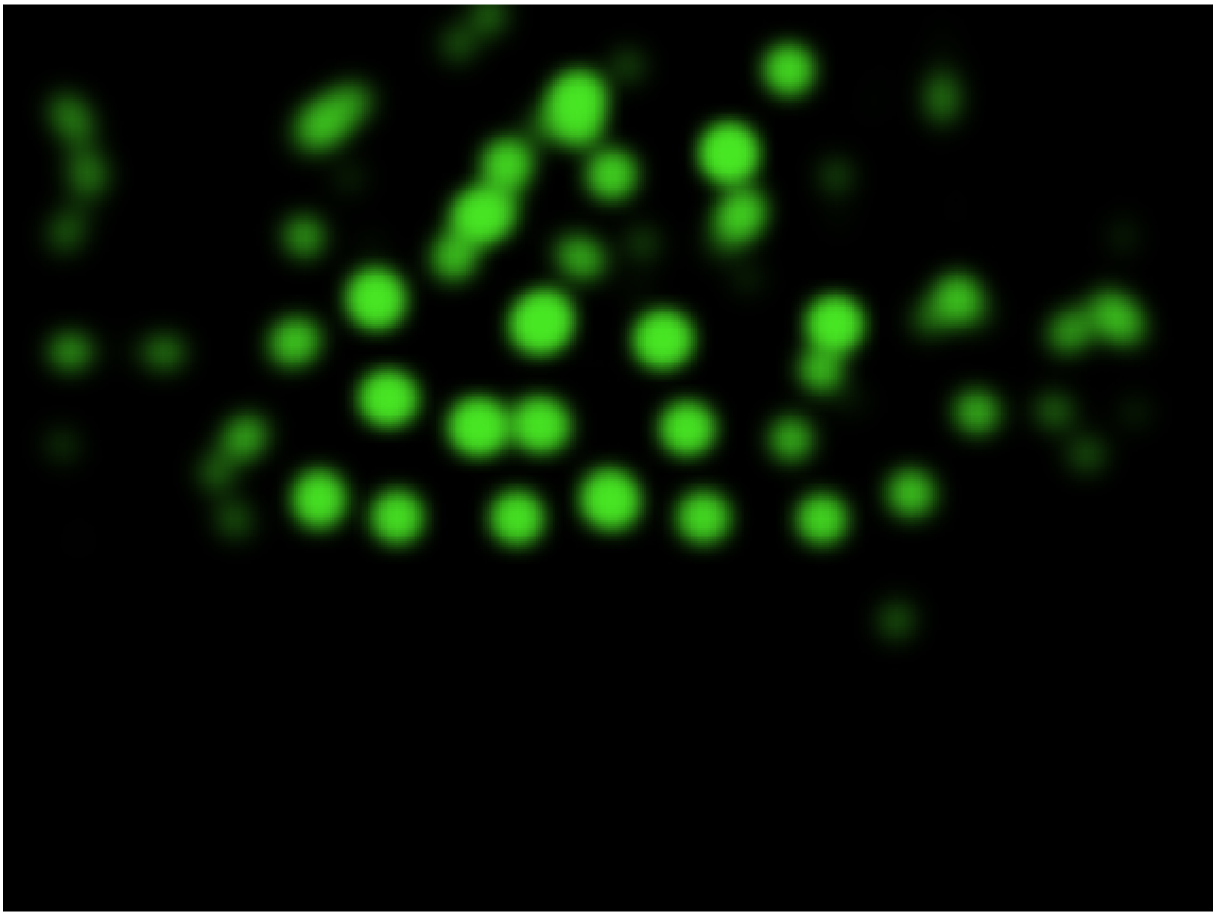
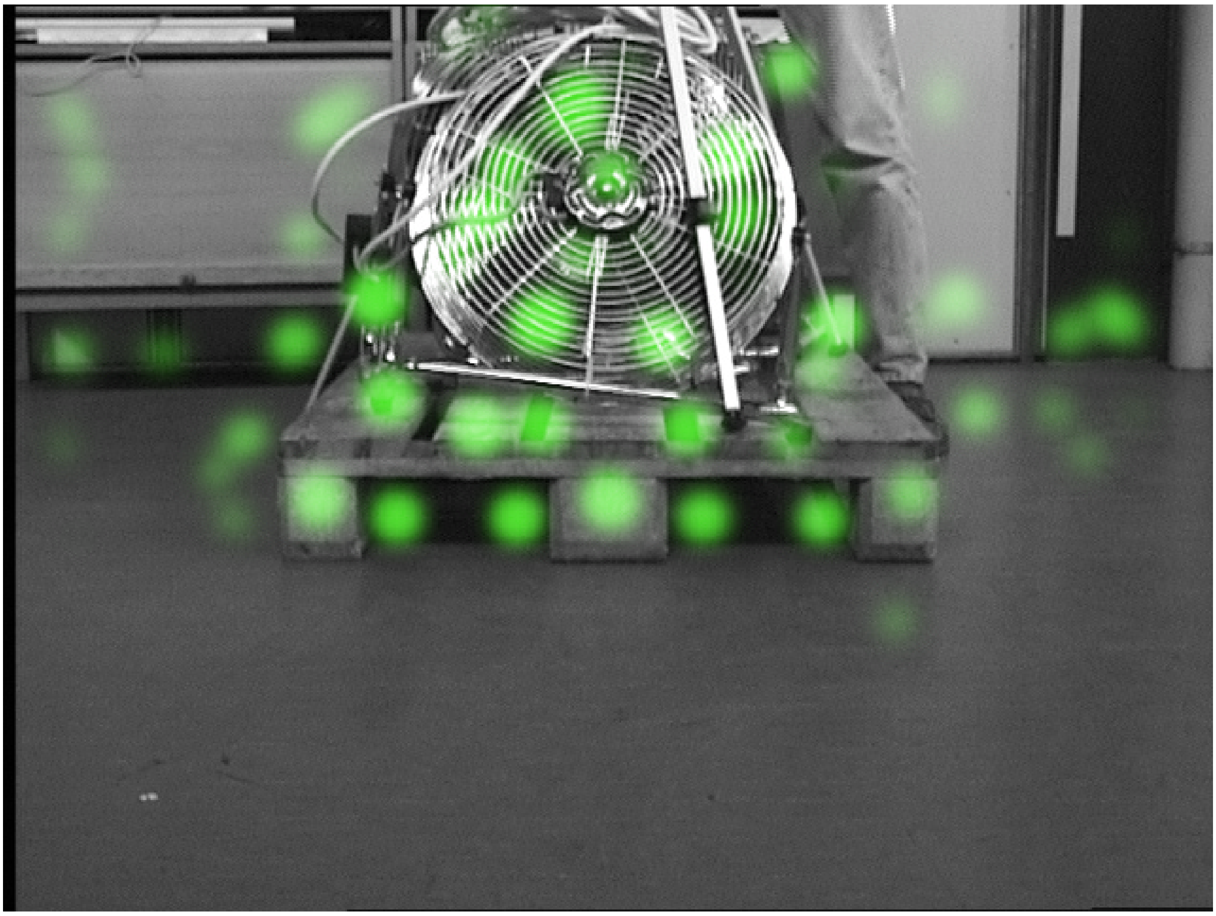
Rotational symmetry operation



Rotational symmetry on original



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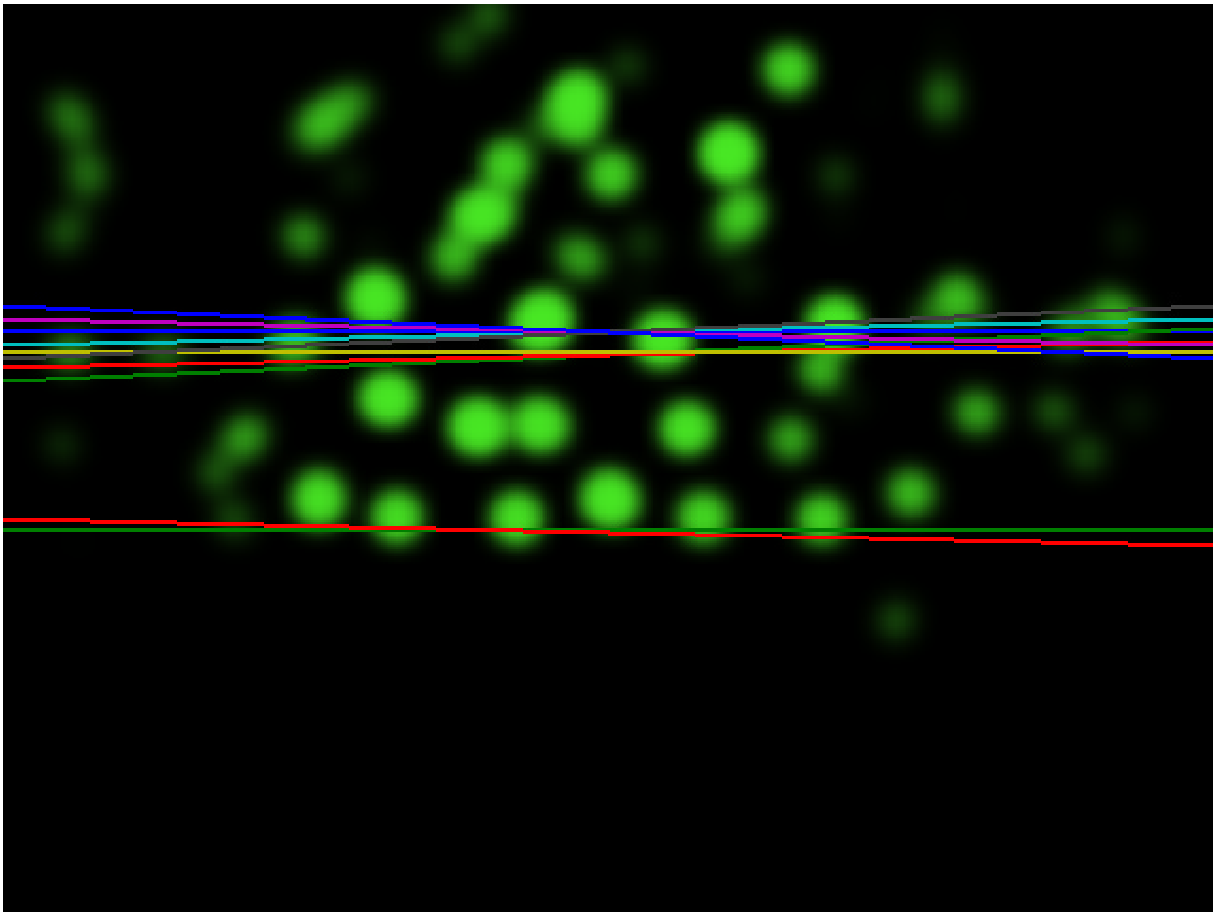
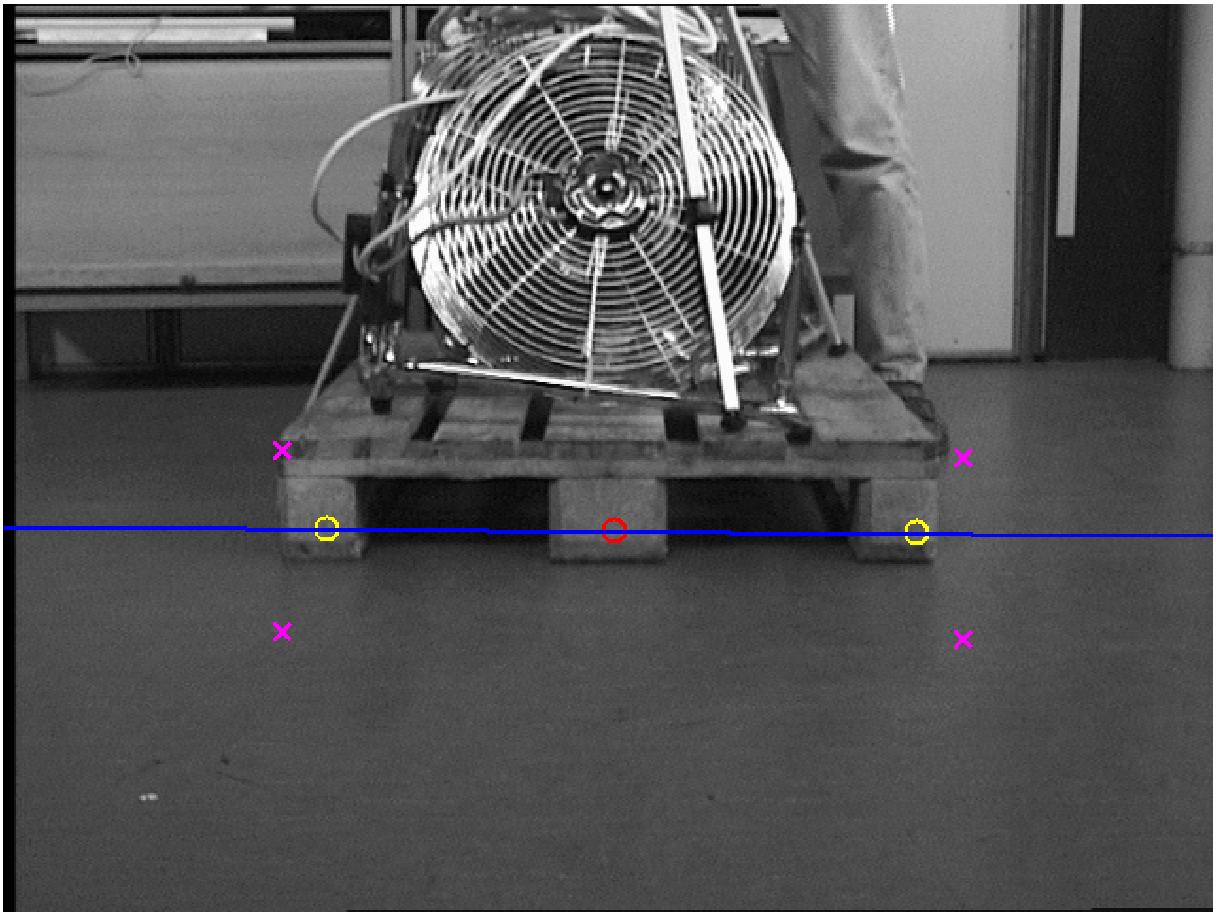
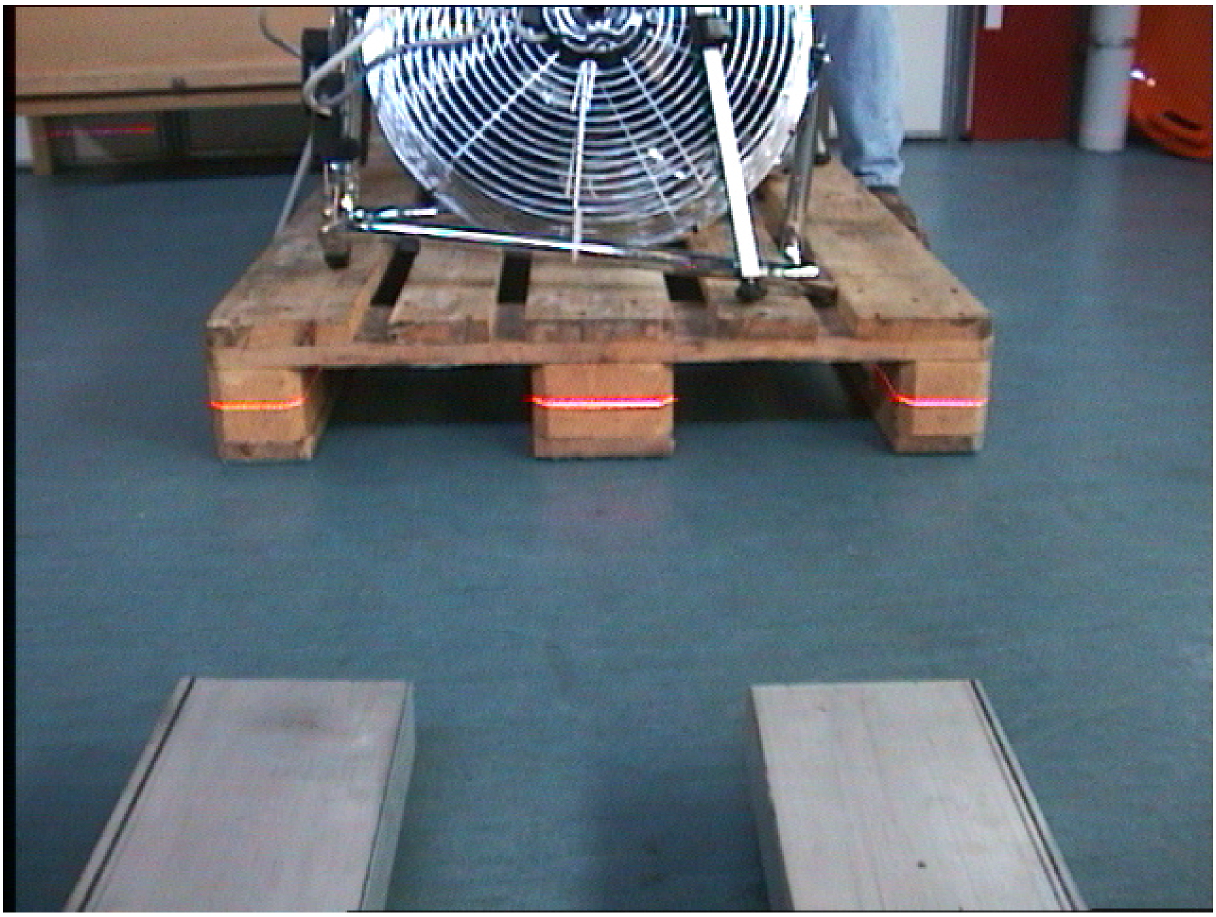
Hough lines to locate the pallet and define its orientation



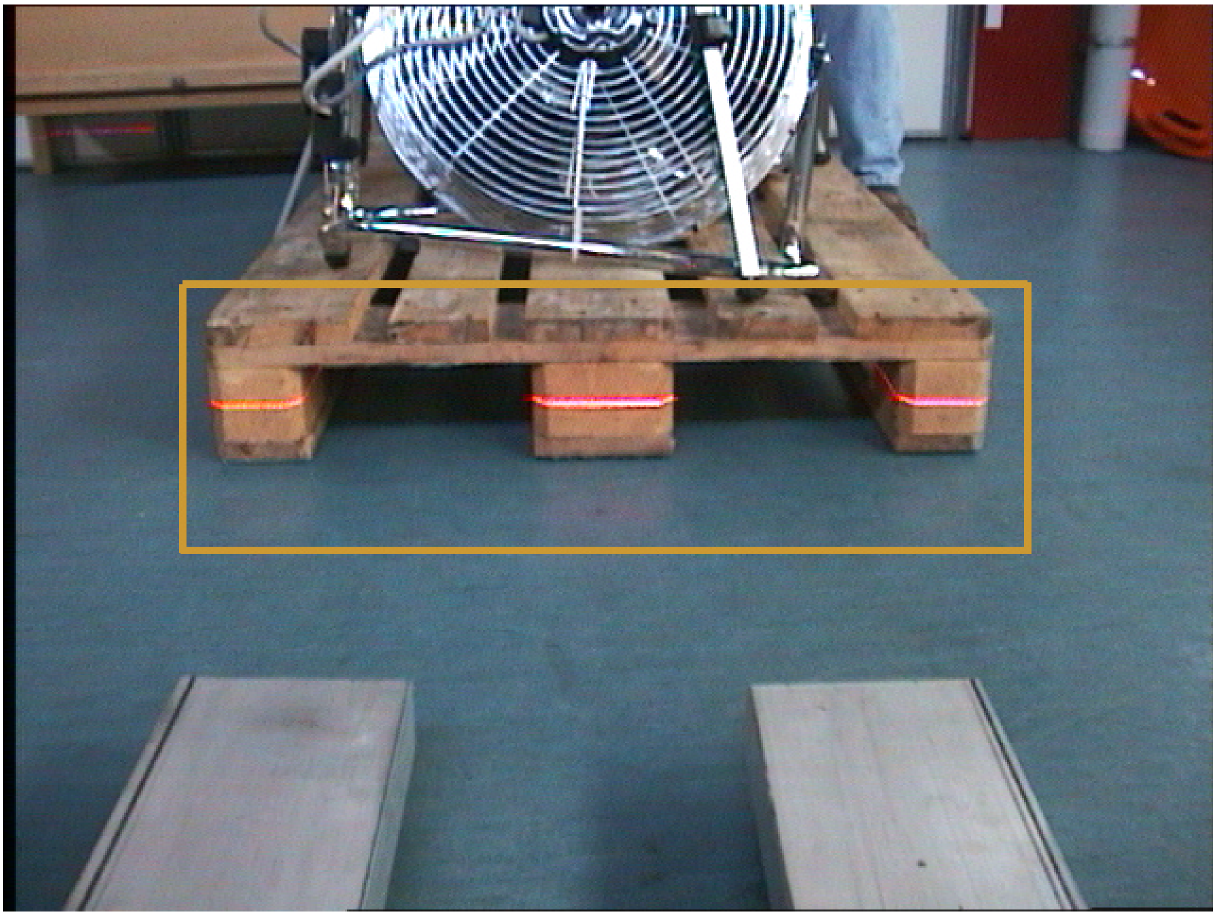
Pallet position found



Laser plane



Region of interest



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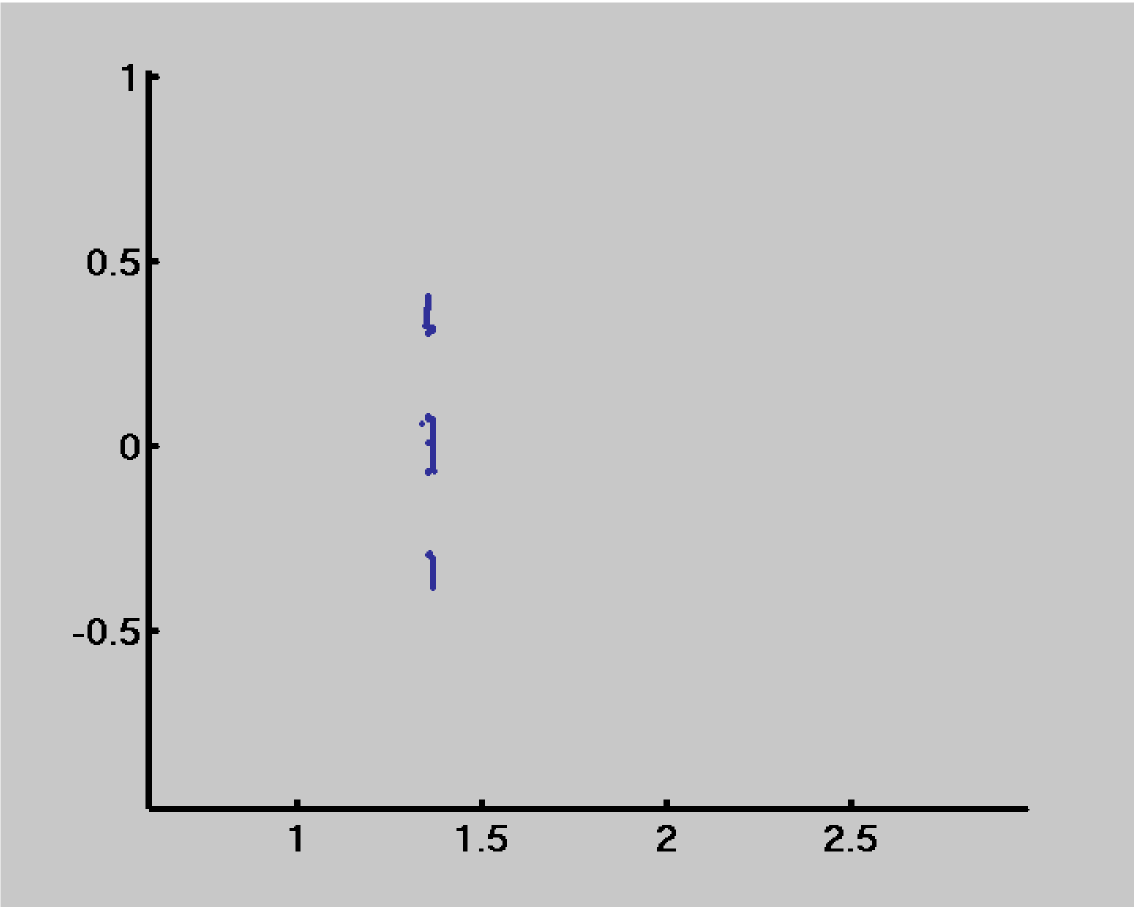
Distance measures



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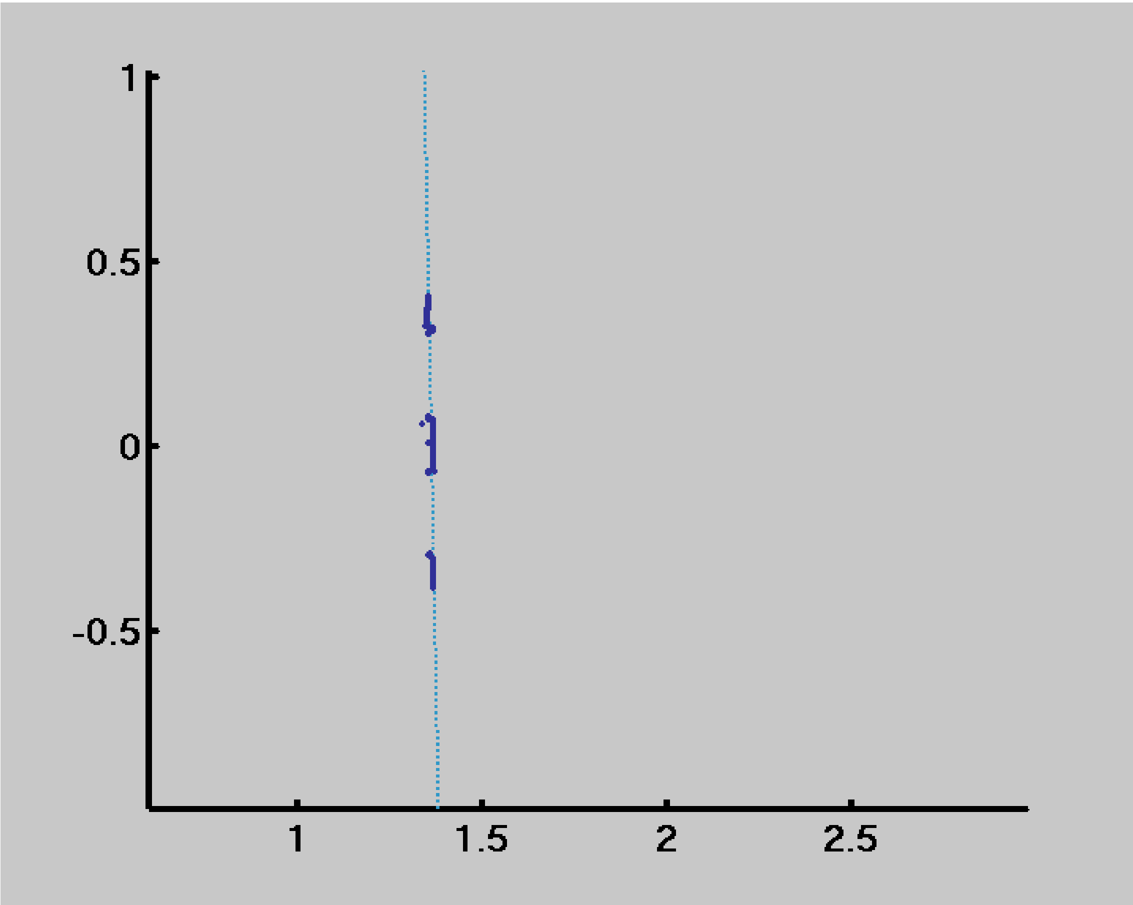
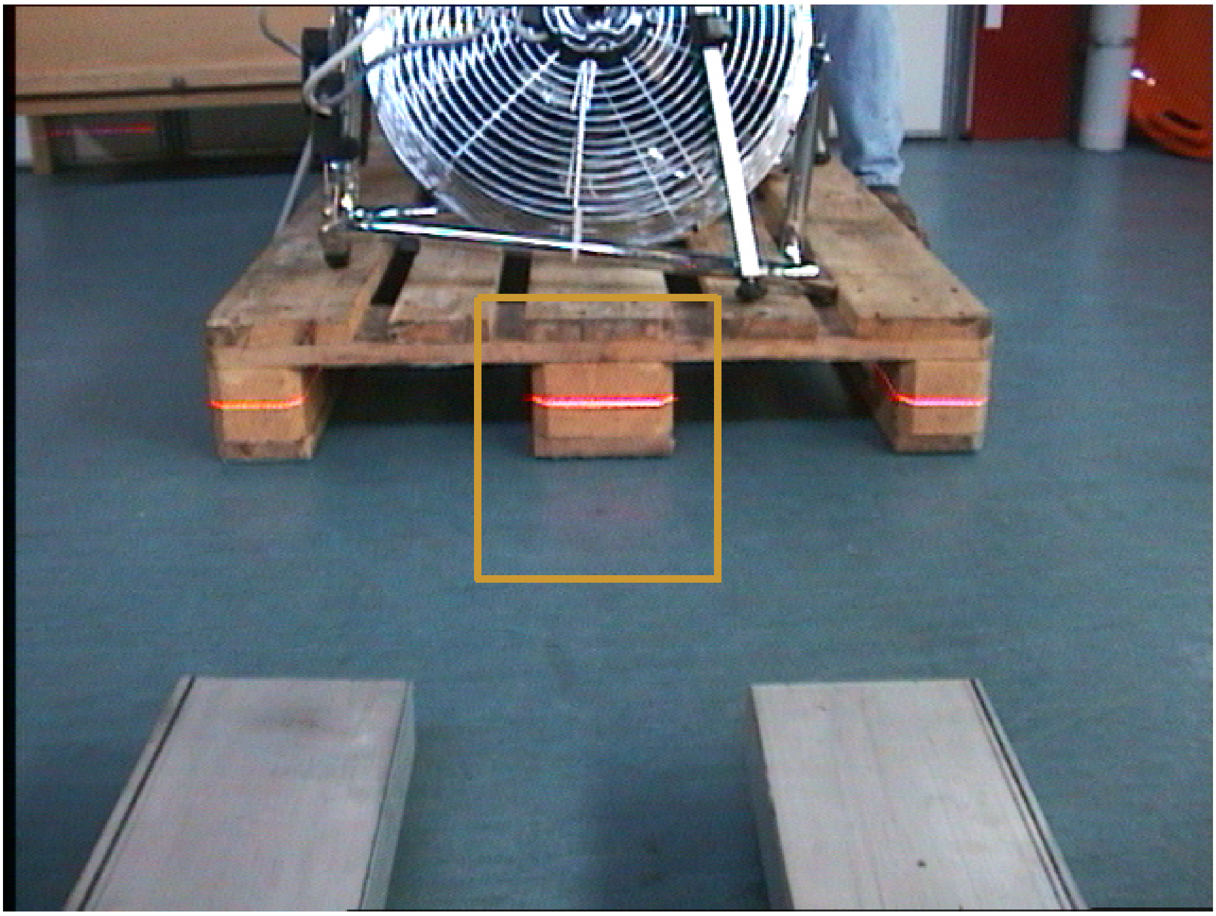
Line fitted to detected laser



Region to search for center block



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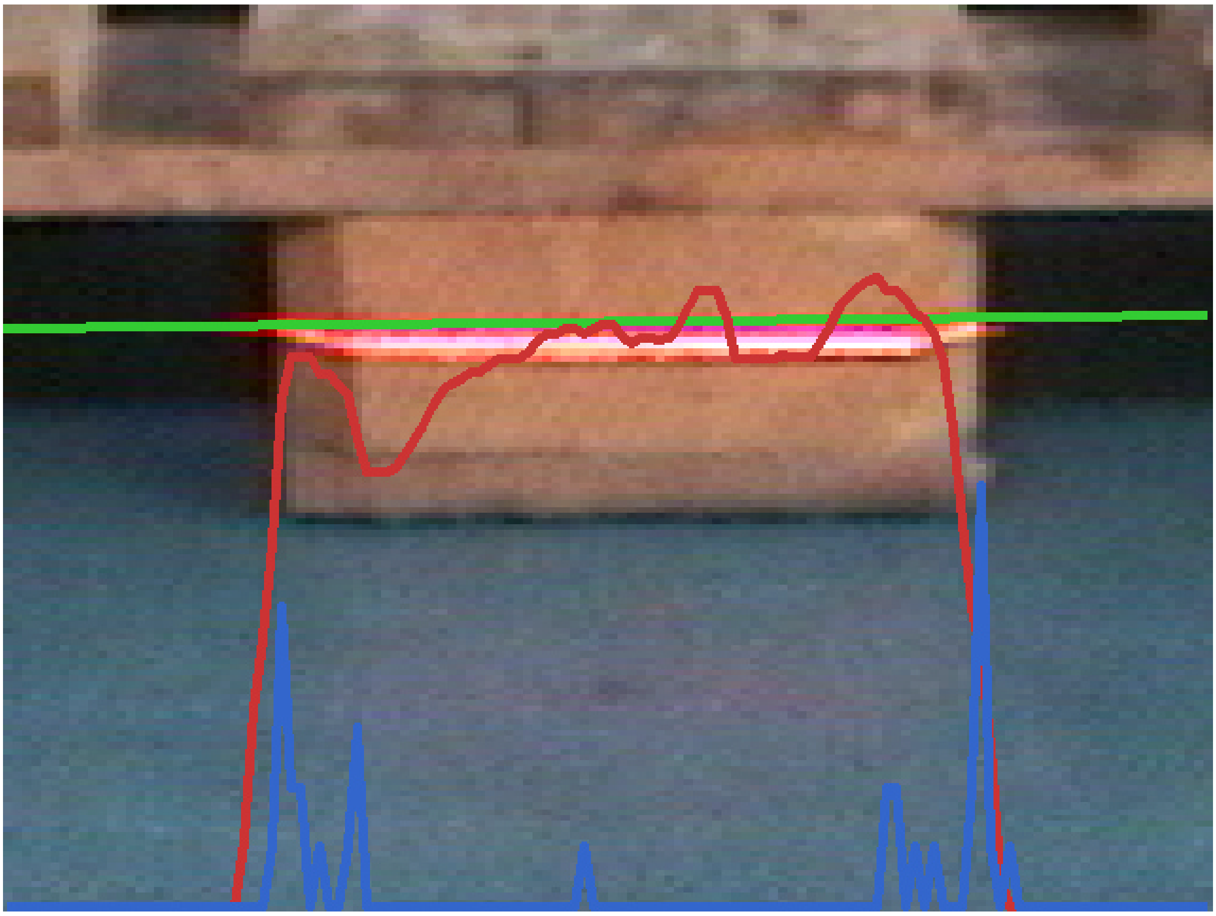
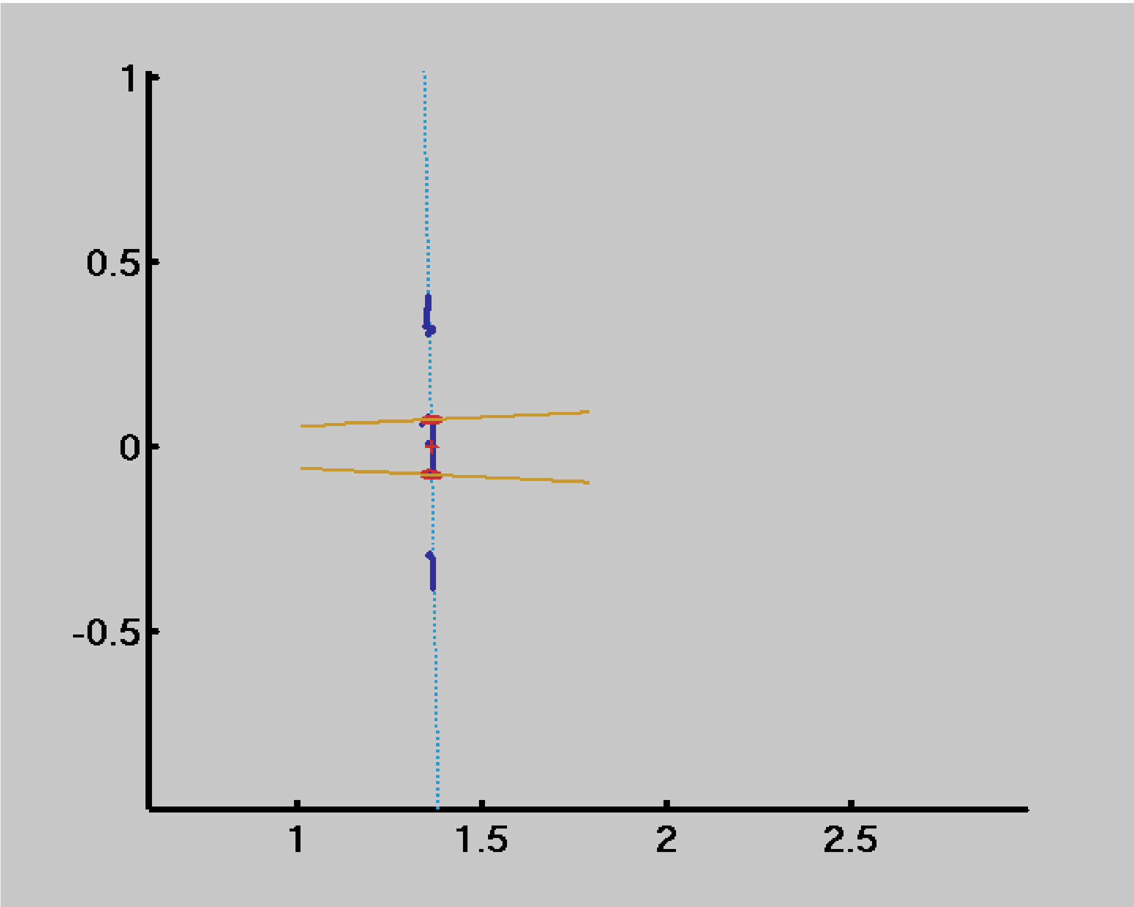
Finding edges using laser and image gradients



Estimated position of center block



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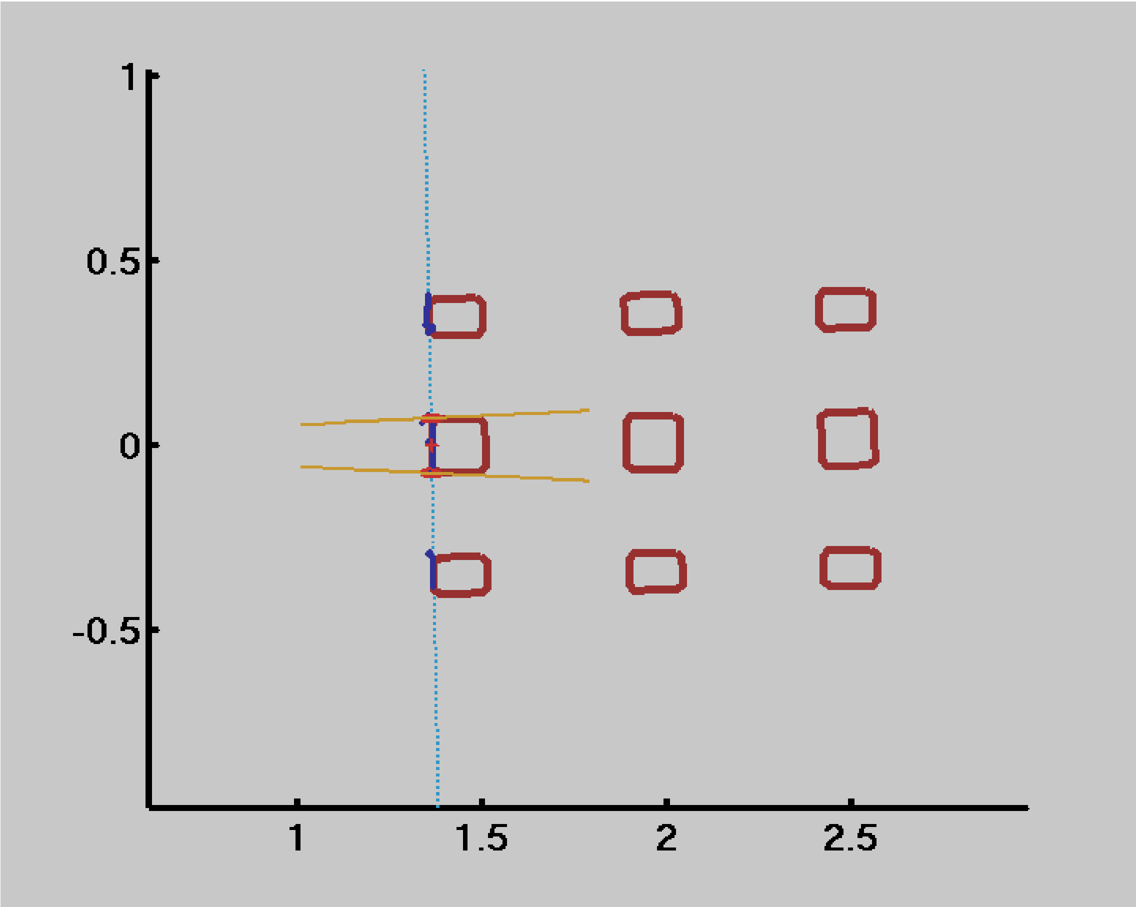
Estimated pallet position and orientation



Position error: < 2.5 mm

Orientation error: < 1 mrad

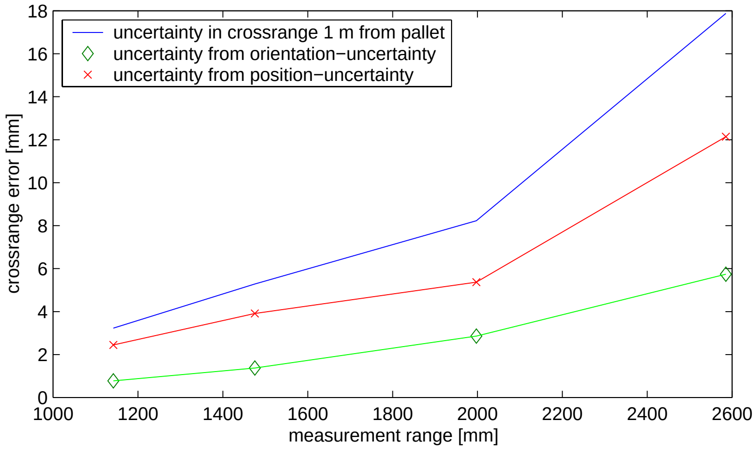
Radon transform

- The area selected by the gate is color filtered to enhance the laser.

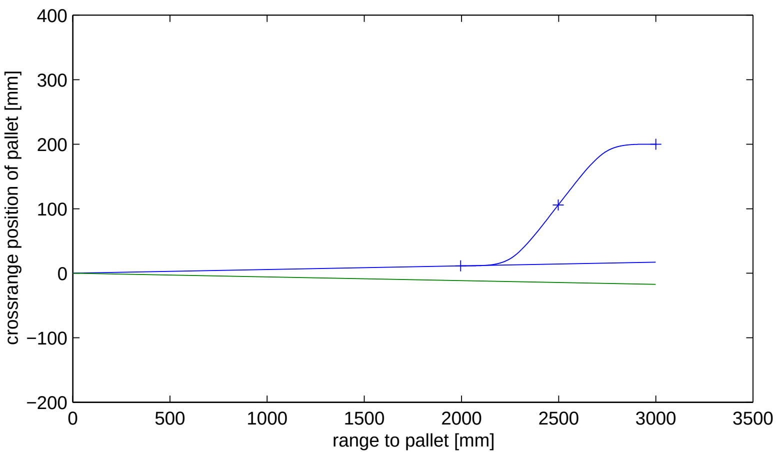
- On the laser image the Radon / Hough transform is used with a coarse resolution in angle to find the main direction of the front of the pallet.

- The laser line is extracted as the maximal intensity in a small area around the Hough-line.

The error in crossrange decreases as the distance decreases.



To reduce overshoots the next point is selected on the 3σ-uncertainty limit.



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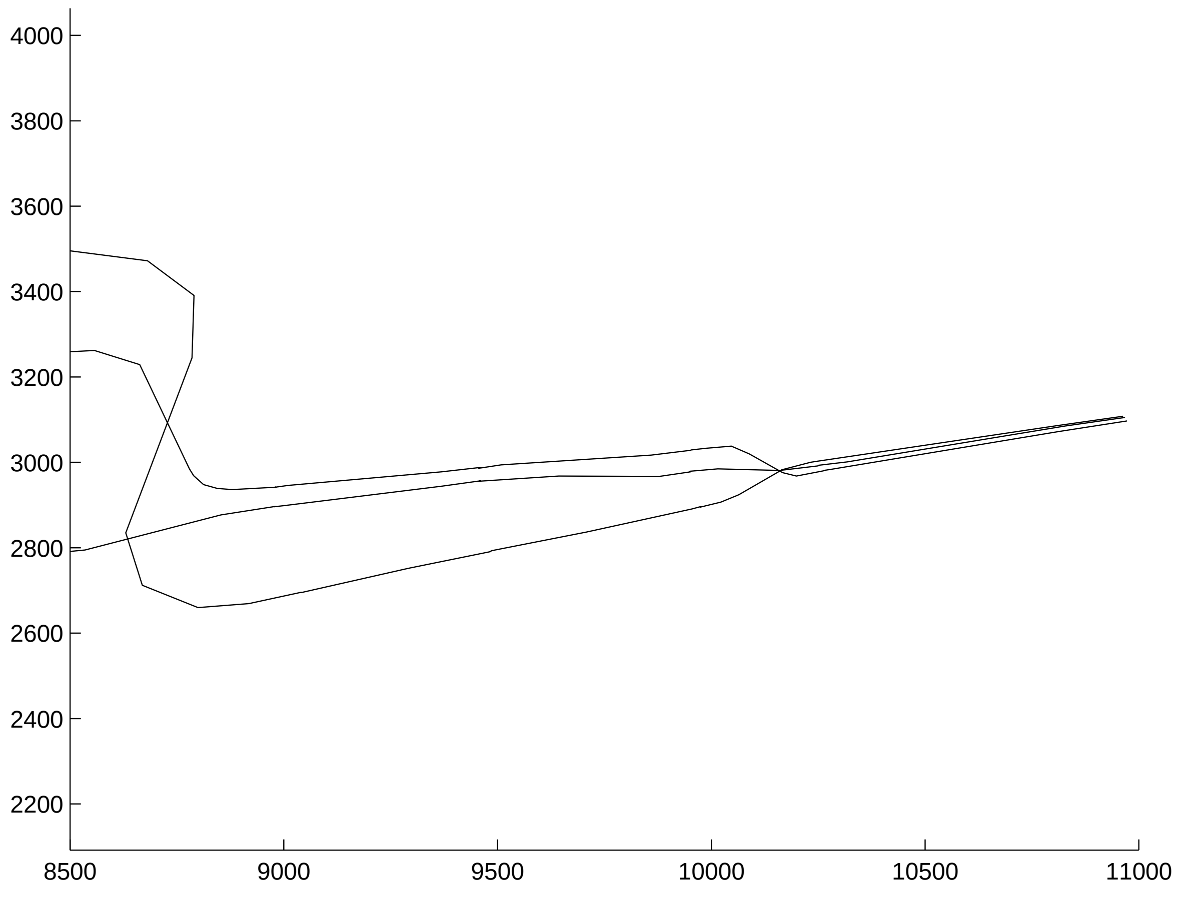
Trajectories from three docking experiments (one extreme) .

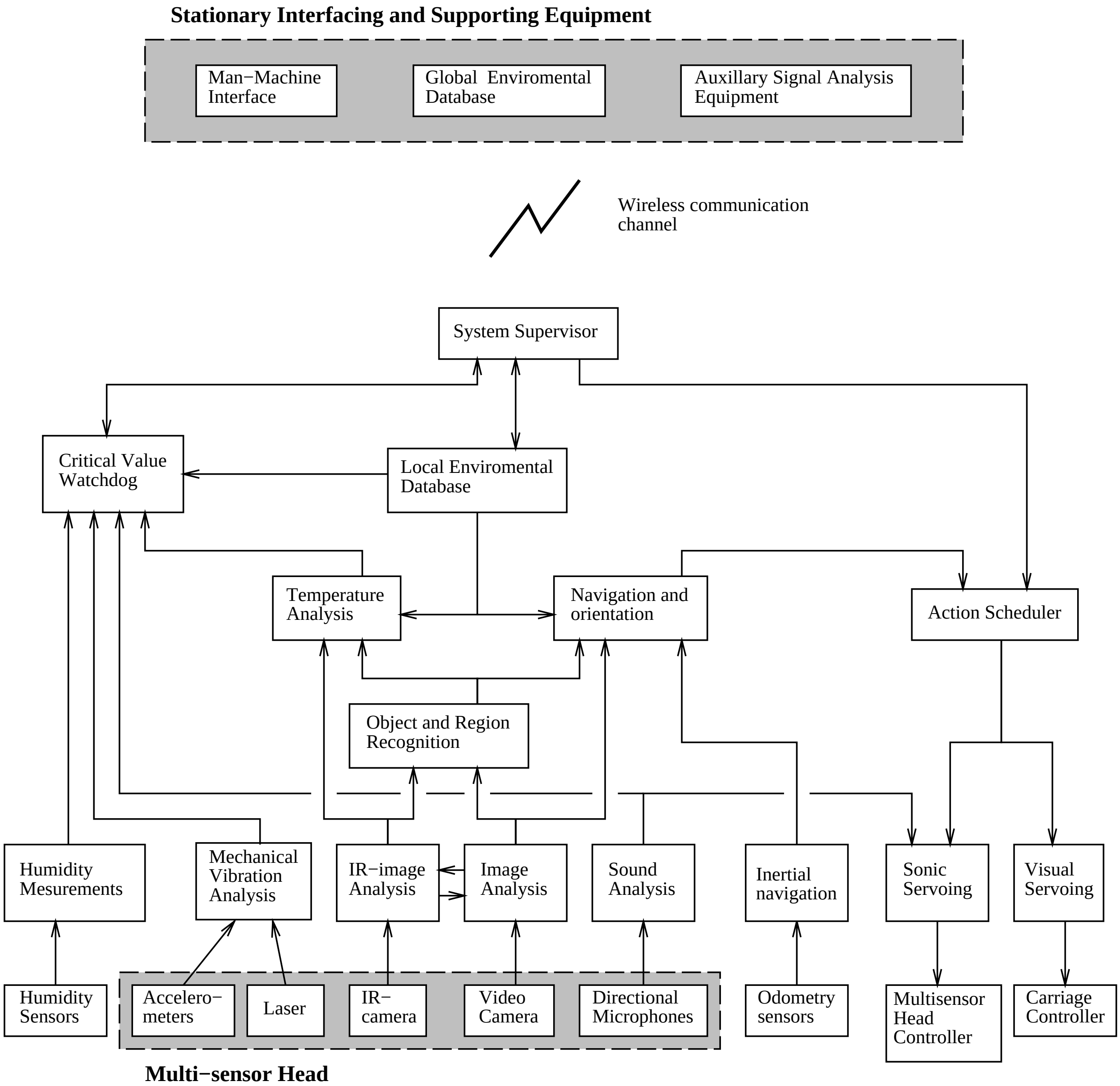


Academic results

The AIIR project has partly financed:

- Seven PhD dissertations.
- A number of Lic. thesis.
- A number of papers in journals and conferences.

Block diagram of an extended system

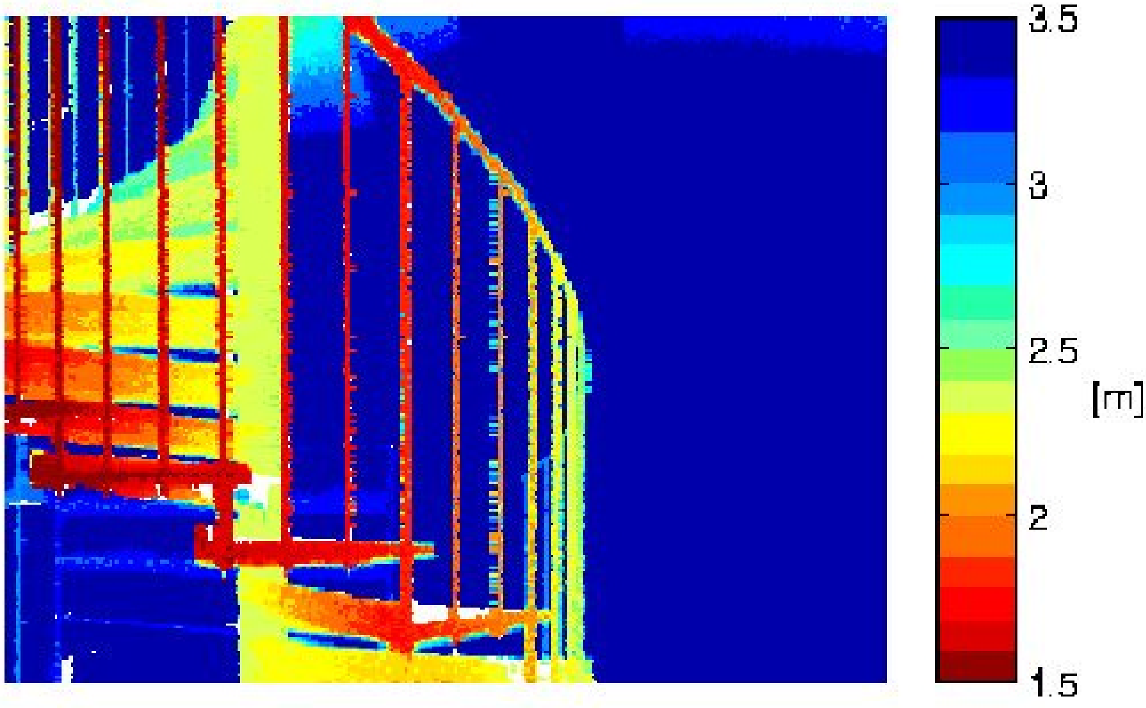


Shape, object and scene description

A new structure for an object recognition system has been proposed. The system resembles the structure of a view-based multi-layer system. An advantage with view-based systems is that they do not require any explicit 3D geometric object descriptors.

From sensor data to CAD models

Experiments are in progress for extracting geometric primitives from 3D range sensors. Parameters of primitives ⇒ CAD models.



Smooth-pursuit tracking

A new tensor based tracker using fast sequential filtering in combination with the local structure tensor concept, has been implemented.

The algorithm admits general camera motion by estimating affine transformations of the object and background motion fields.

Infrared image analysis

Algorithms for detection of abnormal variations in heat distribution, both spatially and temporally, has been implemented by spatio-temporal filtering of infrared image sequences.

This can be used to warn an operator about heat leaks or other unnormal temperature conditions in the scene.

Robust motion estimation

New algorithms for optical flow computation that are robust and produce accurate results have been implemented.

Having estimated the optical flow it is possible to compute other qualities like Focus-of-expansion (the camera translation direction), Time-to-collision for any object in the scene, and Depth (distance to any object in the scene).

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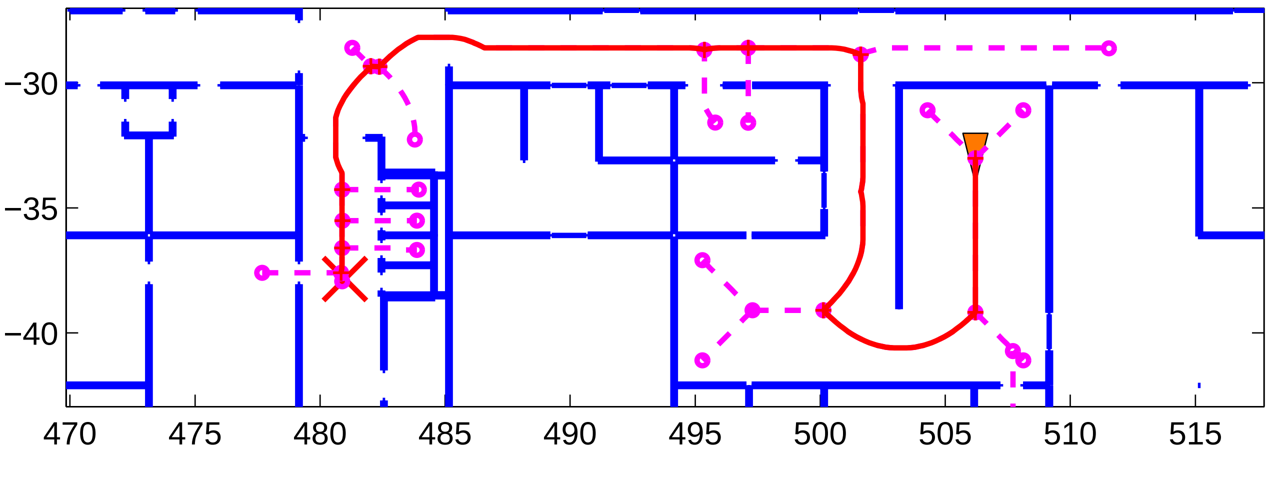
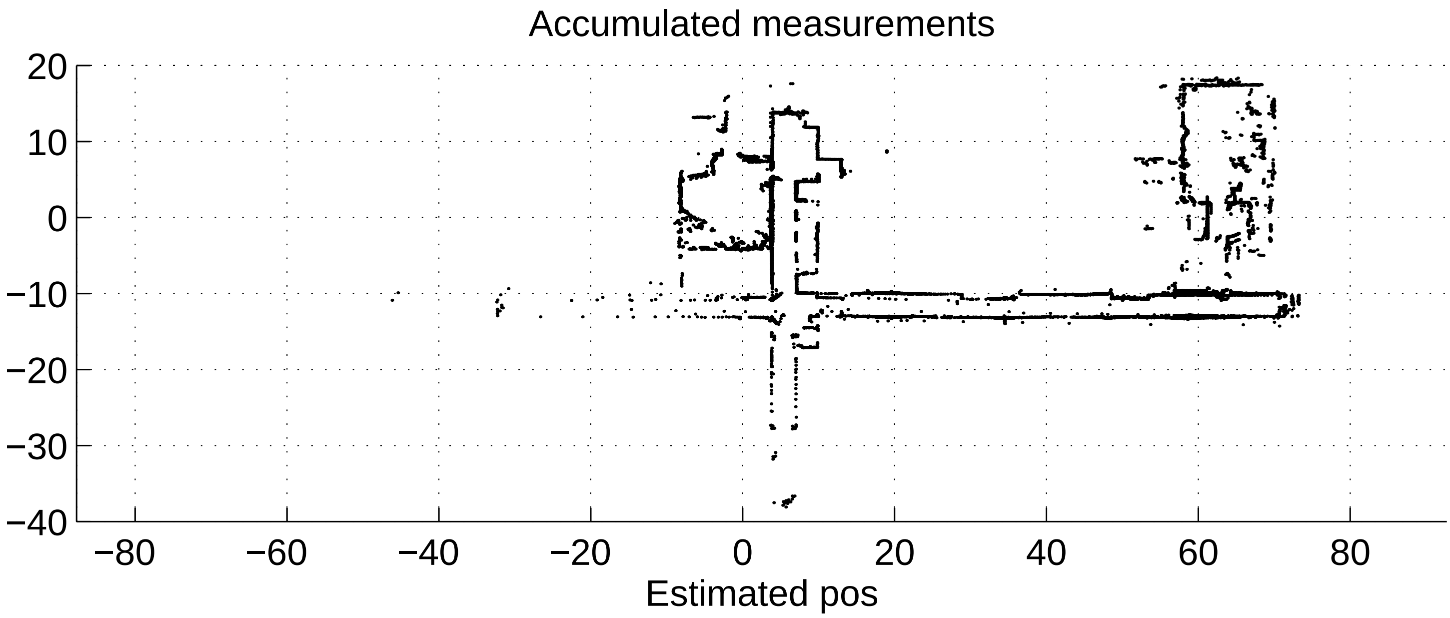
Navigation

A robust system using AutoCAD building construction plans has been designed. This algorithm does not accumulate errors which is a common problem when no à priori maps is used.



Map generation

Also when no à priori map is available a robust localization and map generation system was possible to design for mobile robots with 2D laser scanners.



Automatic probe placing

Algorithms for automatic probe placing in front of an object using a range camera have been developed and tested experimentally.

These algorithms have been extended to also include docking of a mobile robot to an object and gripping of objects using a manipulator.

Inspection robot instrumentation

The needed instrumentation for an inspection robot was initially specified by ABB Atom:

Vibration	amplitude	±40 mm
	resolution	0.01 mm
	max. dist.	10 m
	frequency	0-100 Hz
Sound-level	frequency	20-20.000 Hz
	level	90 dB
Humidity	range	0-100% Rh
Temperature	object	290° C (max)
	air	55° C (max)
	resolution	±5° C

Instrumentation proposal

The following proposal is based on the instrumentation that is discussed above and fits the needs specified up to now.

Measured quantity	Instrument	Approx. price (nov 95)
Vibration	OMETRON VS-100 or Polytec OFV-2600	232.000 SEK 191.000 SEK
Sound-level	GRAS 40AF microphone GRAS 26AB amplifier GRAS 12AA power supply	6.500 SEK 7.000 SEK 10.200 SEK
Humidity	Testostor 171-3 computer interface	7.300 SEK 1.800 SEK
Temp.	Thermopoint-5000	14.000 SEK