Object Recognition and Real-Time Tracking in Microscopy Imaging

Jan Wedekind

30th Aug – 1st Sep 2006

MMVL	`http://www.shu.ac.uk/research/meri/mmvl/`
MiCRoN	`http://wwwipr.ira.uka.de/~micron/`
Mimas	`http://sourceforge.net/projects/mimas/`
MediaWiki	`http://vision.eng.shu.ac.uk/mediawiki/`

People: J. Wedekind, M. Boissenin, B.P. Amavasai, F. Caparrelli, J. Travis

MATERIALS AND ENGINEERING
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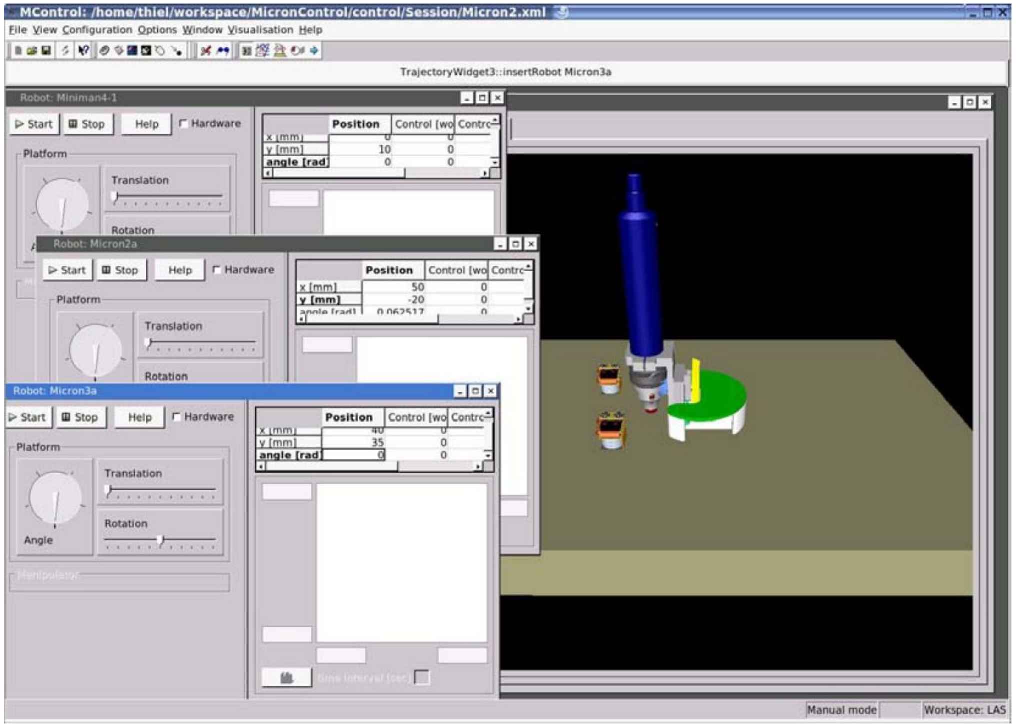
MiCRoN
European Union IST project

Uppsala, Lausanne, St. Ingbert, Athens, Pisa, Barcelona, Karlsruhe

Control & GUI



Universität Karlsruhe (Germany)

`http://wwwipr.ira.uka.de/~micron/`

`http://www.cordis.lu/ist/`

Motivation

- prototype soldering/assembly
- cell manipulation
- manipulations inside vacuum chamber

Project Goals

- Manipulate μm-sized objects
- Closed-loop control of robot
- 3D object recognition and tracking

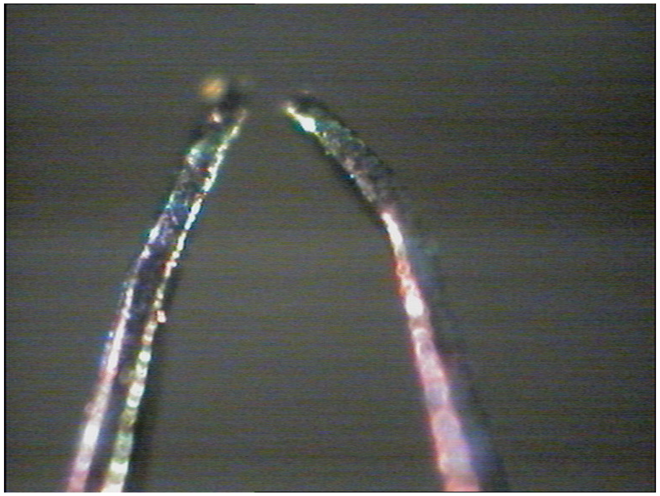
Sheffield Hallam University

Motivation
MiCRoN robot (i)

Locomotion Platform

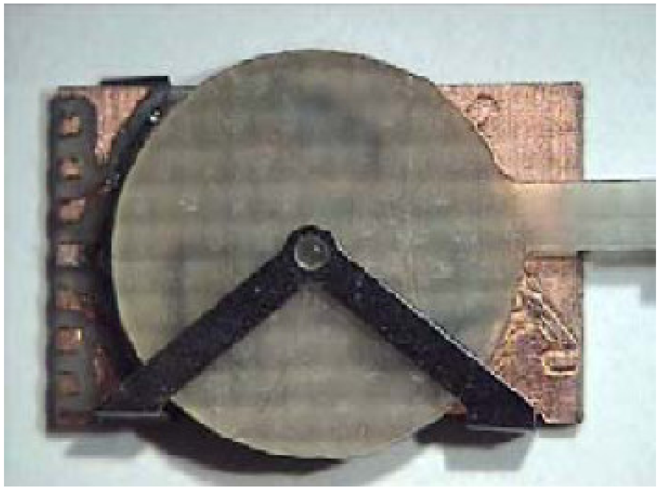
Ecole Polytechnique Fédérale de Lausanne (Switzerland)

Gripper



Scuola Superiore, Sant'Anna (Italy)

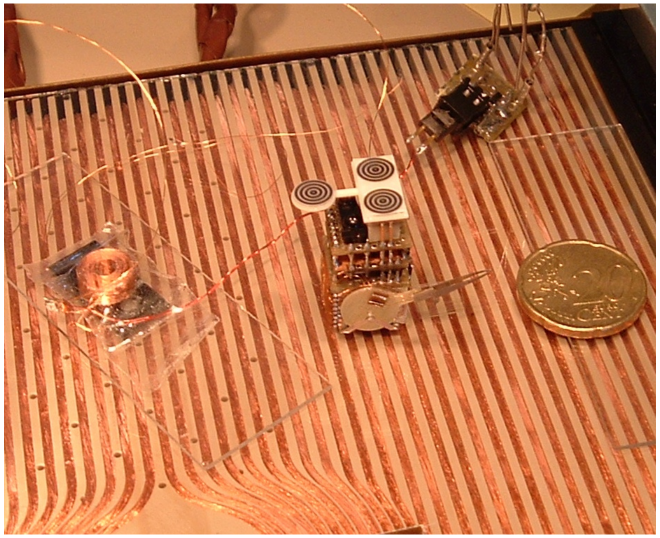
Rotor

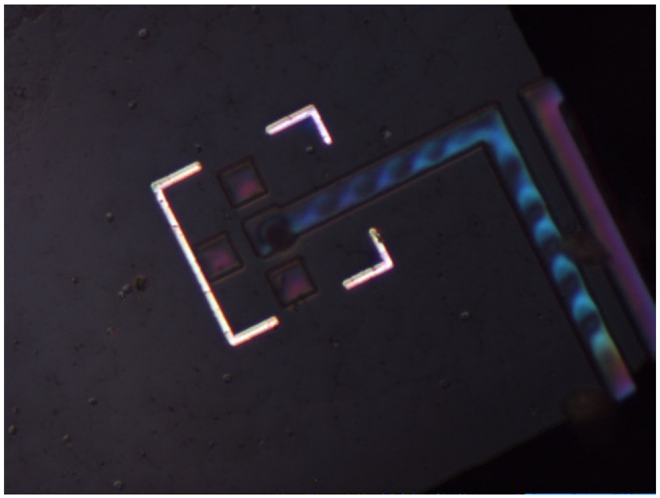


Uppsala University (Sweden)

Motivation
MiCRoN robot (ii)

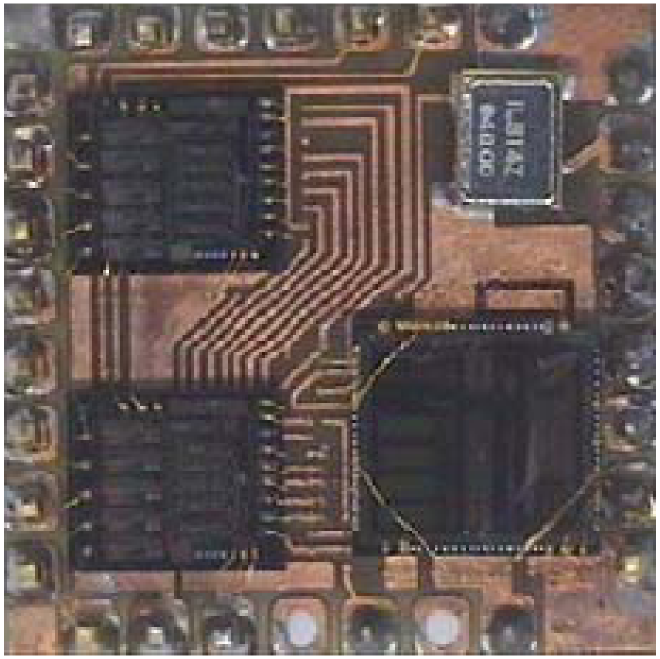
Power Floor, Syringe





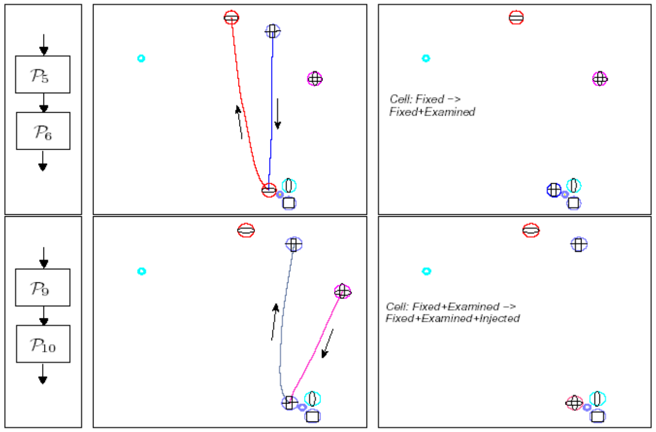
Fraunhofer Institute, St. Ingbert (Germany)

PCB



University of Barcelona (Spain)

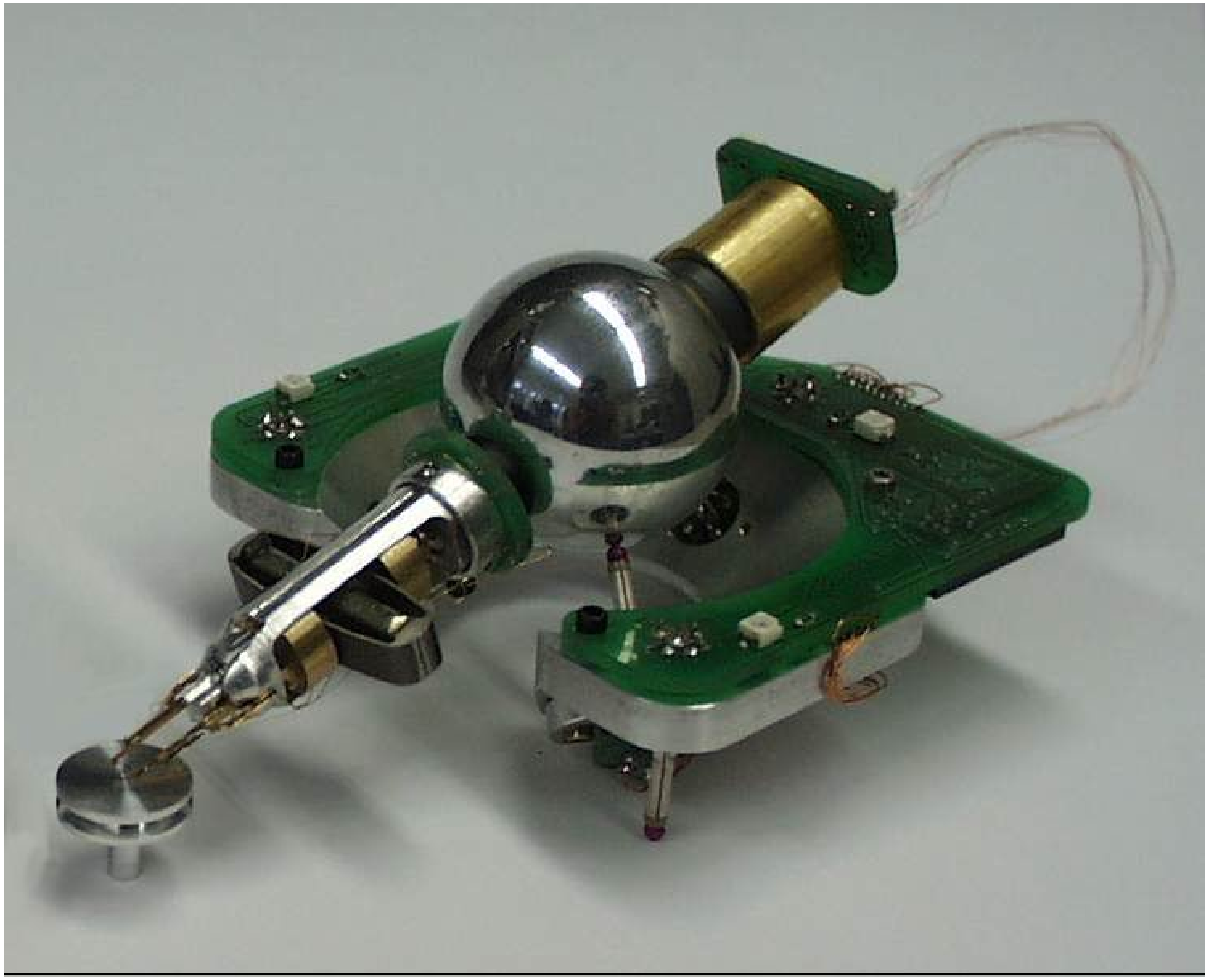
Task Planning



National Technical University of Athens (Greece)

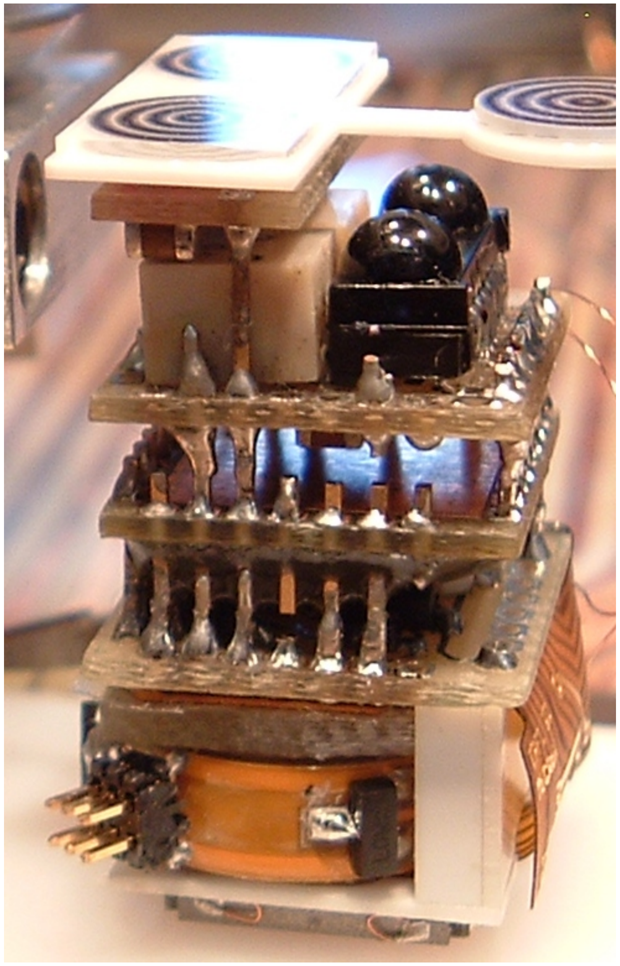
Motivation
MINIMAN vs. MiCRoN robot

MINIMAN III-2 (5 d.o.f.)



centre of sphere - end effector = 6.2 cm

MiCRoN (4 d.o.f.)



fits on a 20 cent coin

Geometric Hashing
1988, Lamdan & Wolfson

Geometric Hashing : A General and Efficient Model-Based Recognition Scheme

Yehezkel Lamdan and Haim J.Wolfson

Robotics Research Laboratory
Courant Inst. of Math., NYU
715 Broadway, 12'th floor,
New York, N.Y. 10003.

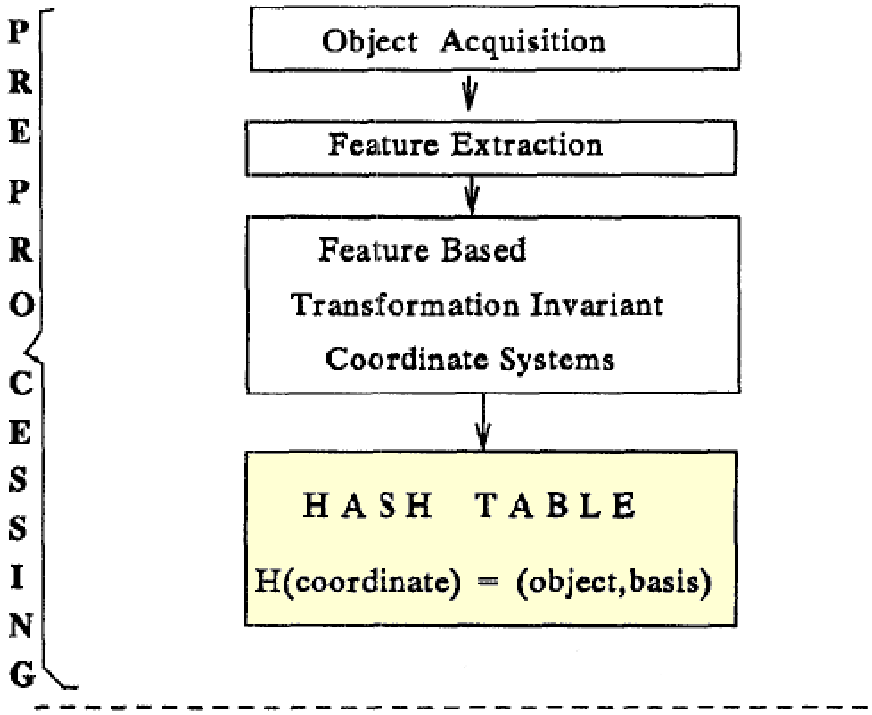
Abstract: A general method for model-based object recognition in occluded scenes is presented. It is based on *geometric hashing*. The method stands out for its efficiency. We describe the general framework of the method and illustrate its applications for various recognition problems both in 3-D and 2-D. Special attention is given to the recognition of 3-D objects in occluded scenes from 2-D gray scale images. New experimental results are included for this important case.

1. Introduction.

We present a unified approach to the *representation* and *matching* problems which applies to object recognition under various geometric transformations both in 2-D and 3-D. The objects are represented as sets of geometric features, such as points or lines, and their geometric relations are encoded using minimal sets of such features under the allowed object transformations. This is achieved by standard methods of *Analytic Geometry* invoking *coordinate frames* based on a minimal number of features, and representing other features by their coordinates in the appropriate frame. Our

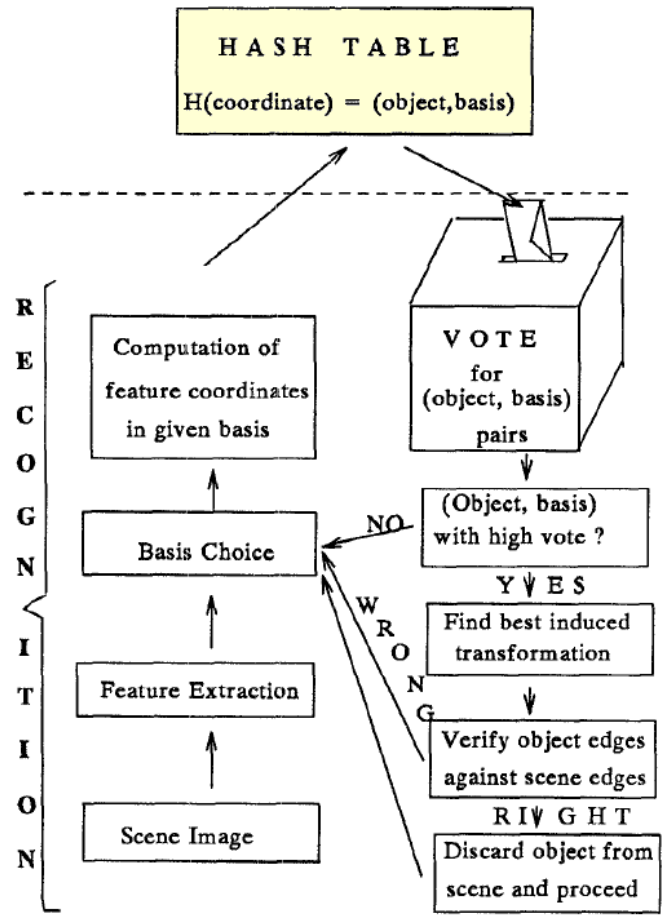
Geometric Hashing
Preprocessing & Recognition

Preprocessing



1988, Lamdan & Wolfson

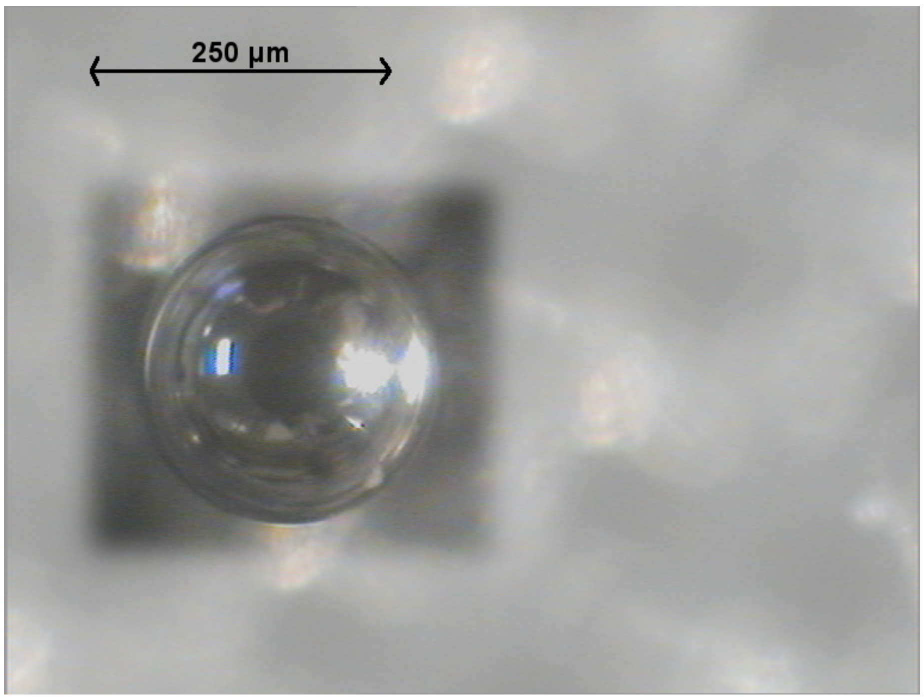
Recognition

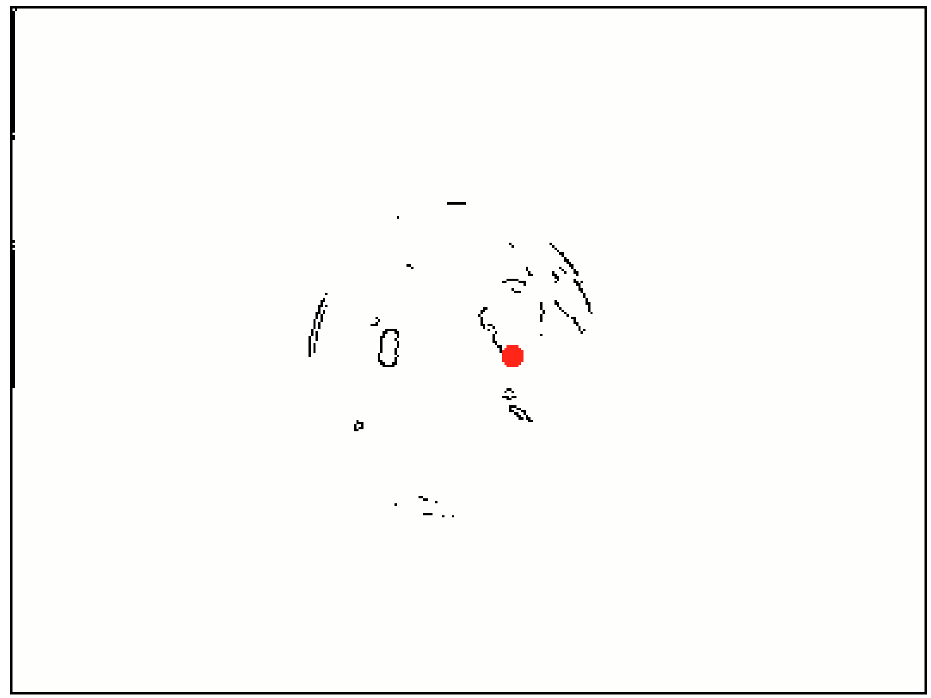


Geometric Hashing
2 Degrees-Of-Freedom (i)

Solder Sphere

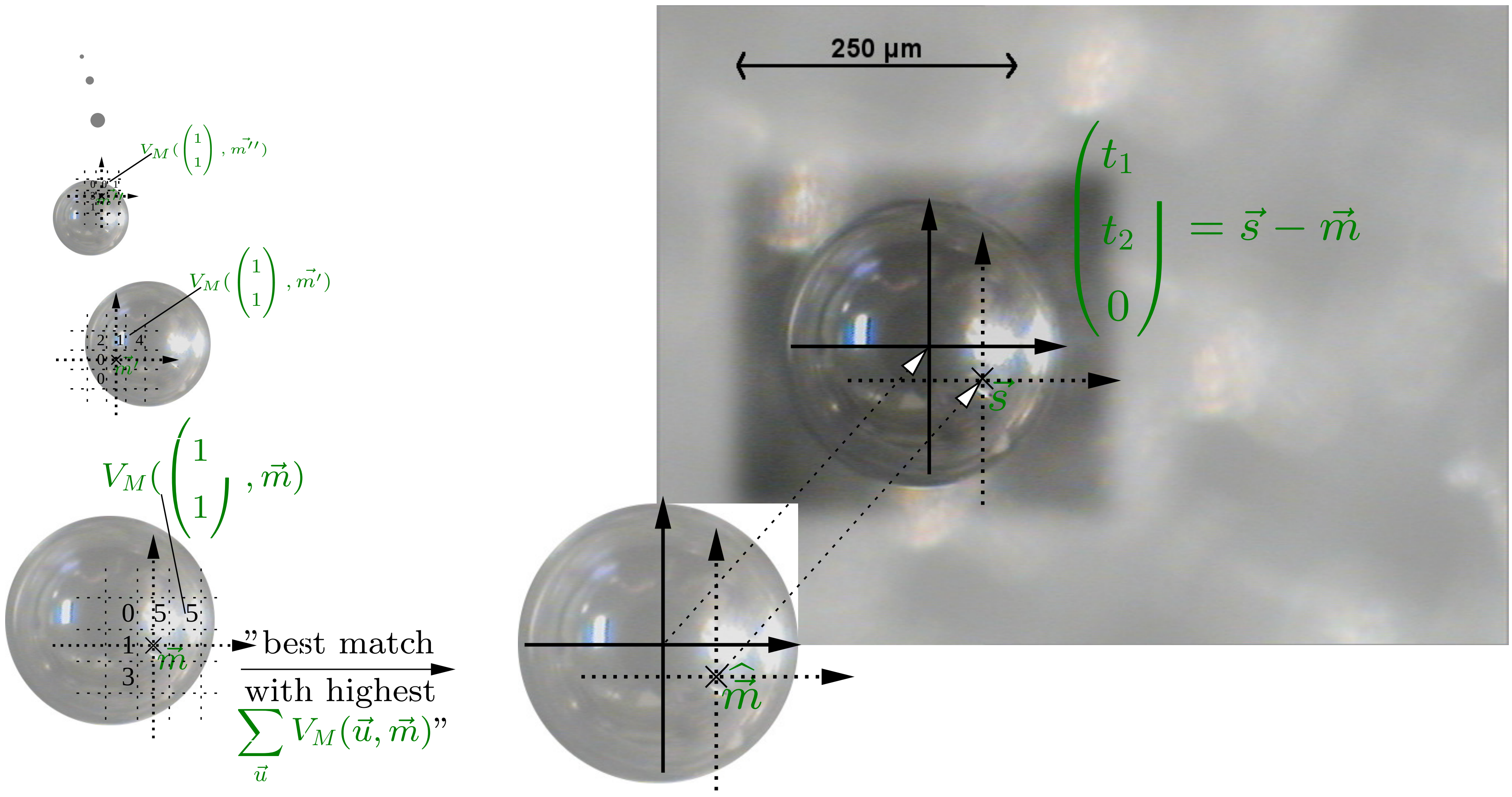
- Extract Sobel edges
- Randomly select a feature location





Geometric Hashing
2 Degrees-Of-Freedom (ii)

Solder Sphere

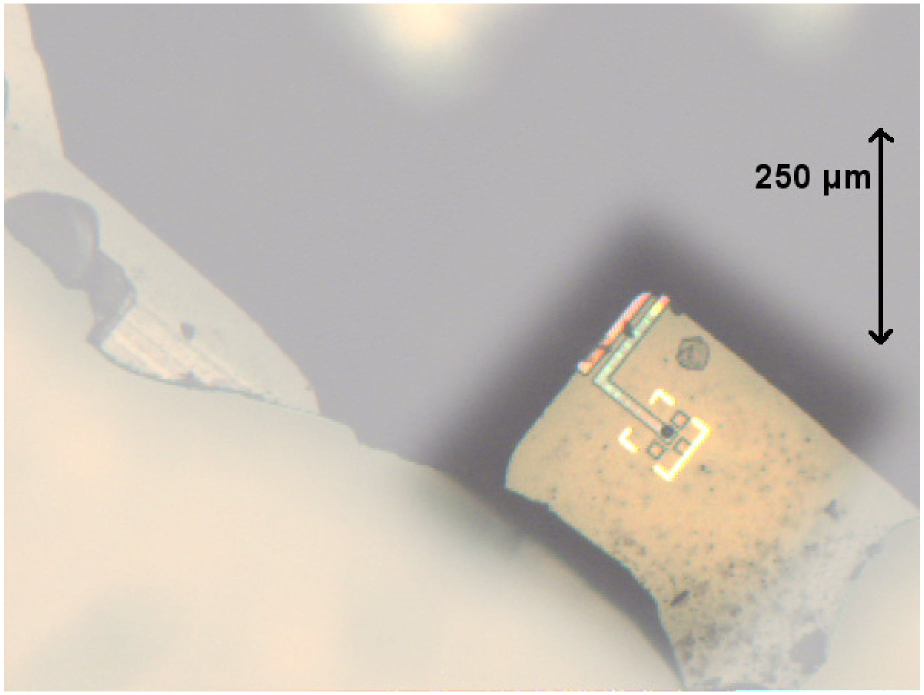


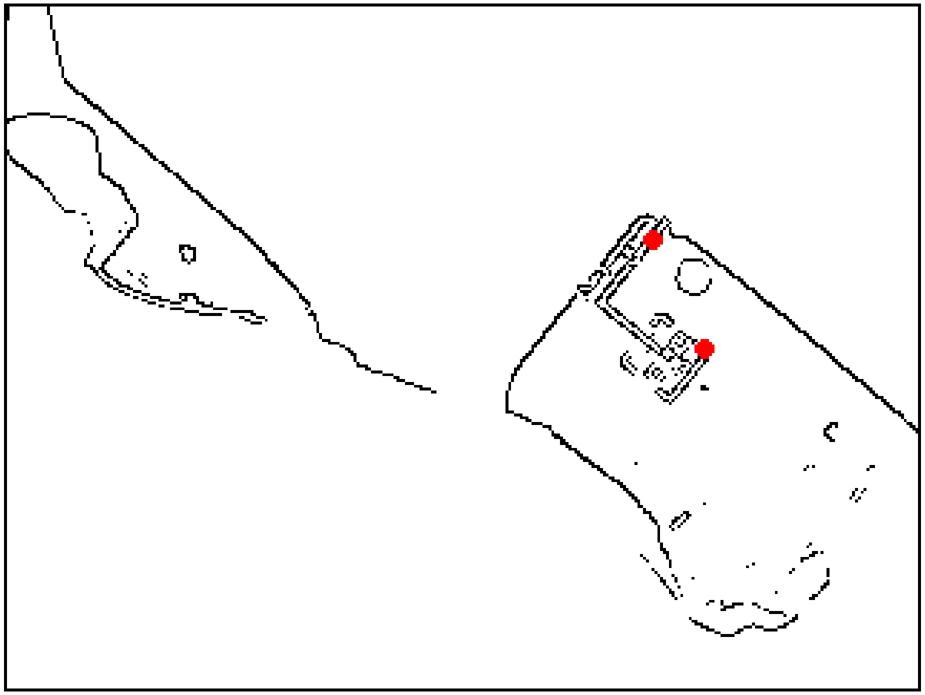
a single feature-correspondence reveals the object's pose

Geometric Hashing
3 Degrees-Of-Freedom (i)

Syringe Chip

- Extract Sobel edges
- Randomly select two feature locations



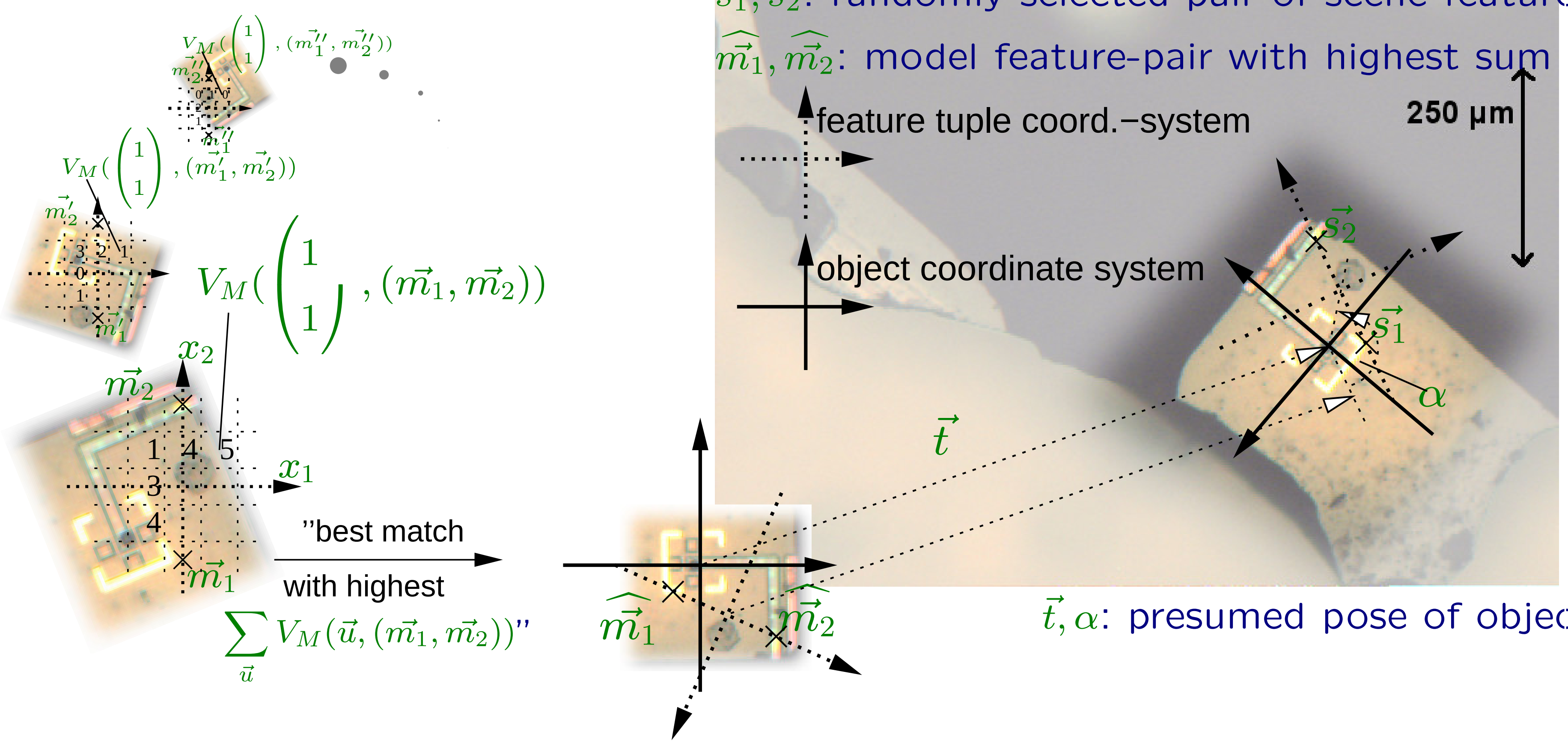


Geometric Hashing
3 Degrees-Of-Freedom (ii)

Syringe Chip

$\vec{s_1}, \vec{s_2}$: randomly selected pair of scene features

$\widehat{\vec{m_1}}, \widehat{\vec{m_2}}$: model feature-pair with highest sum of votes



$\vec{t}, \alpha$: presumed pose of object

two feature-correspondences are revealing the object's pose

Bounded Hough Transform 2001/2004, Greenspan, Shang & Jasiobedzki

Efficient Tracking with the Bounded Hough Transform

Michael Greenspan[1,2,4] Limin Shang[1] Piotr Jasiobedzki[3]

[1]Dept. of Electrical & Computer Engineering, [2]School of Computing, Queen's University, Canada
[3]MDRobotics, 9445 Airport Rd., Brampton, Ontario, Canada
[4]corresponding author: michael.greenspan@ece.queensu.ca

Abstract

The Bounded Hough Transform is introduced to track objects in a sequence of sparse range images. The method is based upon a variation of the General Hough Transform that exploits the coherence across image frames that results from the relationship between known bounds on the object's velocity and the sensor frame rate. It is extremely efficient, running in $O(N)$ for N range data points, and effectively trades off localization precision for runtime efficiency.

The method has been implemented and tested on a variety of objects, including freeform surfaces, using both simulated and real data from Lidar and stereovision sensors.

ing variants of the Iterative Closest Point Algorithm (ICP) [1]. This is primarily because range data is more expensive to collect, and so the images tend to be sparse, which makes it difficult to extract meaningful features. Examples of ICP-based tracking are [2, 3] and recently [4], which simultaneously reconstructs while tracking.

The Hough Transform is a well known and effective method of feature extraction and pose determination that has been explored thoroughly in the literature [5]. Many variations of the Hough Transform have been proposed [6], some of which are specifically tailored to tracking. The Velocity Hough Transform (*VHT*) [7] included a specific ve-

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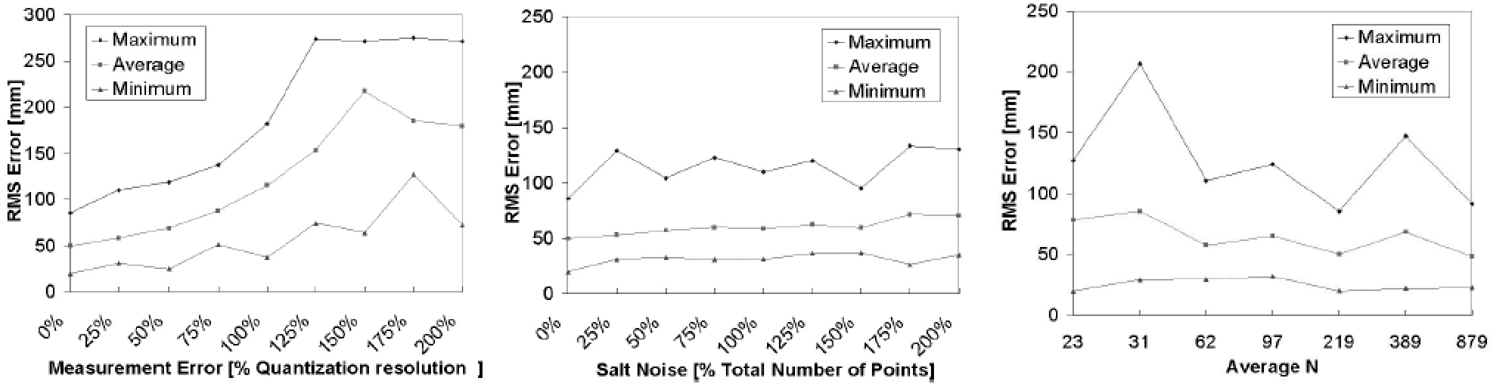
Bounded Hough Transform 6 d.o.f. satellite tracking 2001/2004, Greenspan, S. & J.



a) measurement error b) outliers c) sparse data

Figure 6: Effects of Data Degradation

Figure 7: Robot Mounted Satellite Model

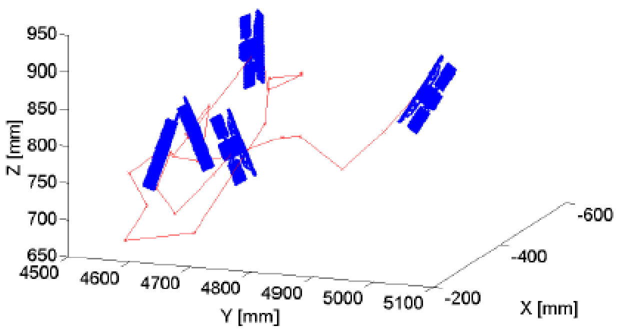


Figure 8: Satellite Trajectory, Lidar Data

of a Radarsat satellite was mounted on a 6 dof articulated

majority of which fell on the surface of the robot and the background and were therefore outliers. To demonstrate the effectiveness of the method at tracking in sparse as well as

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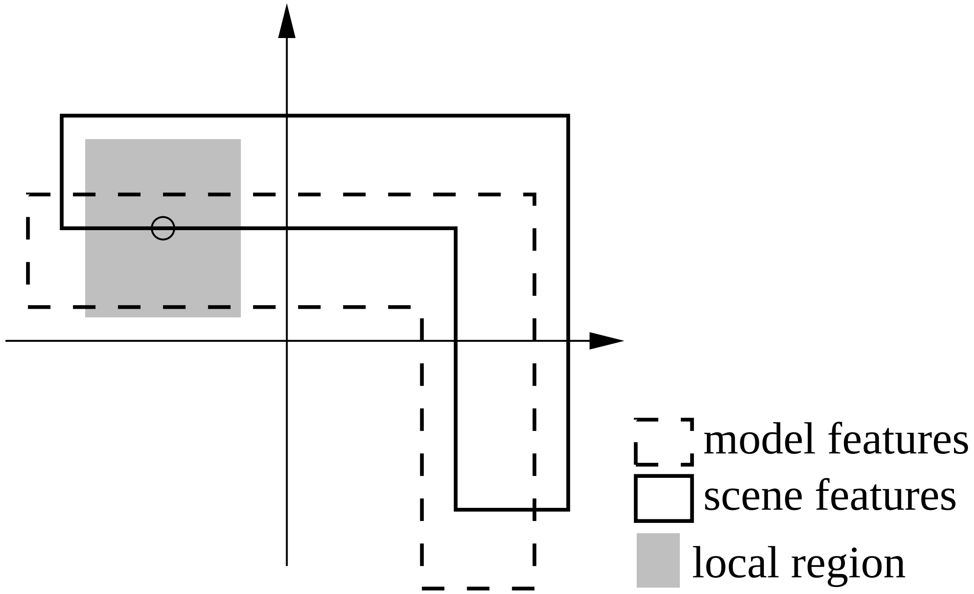
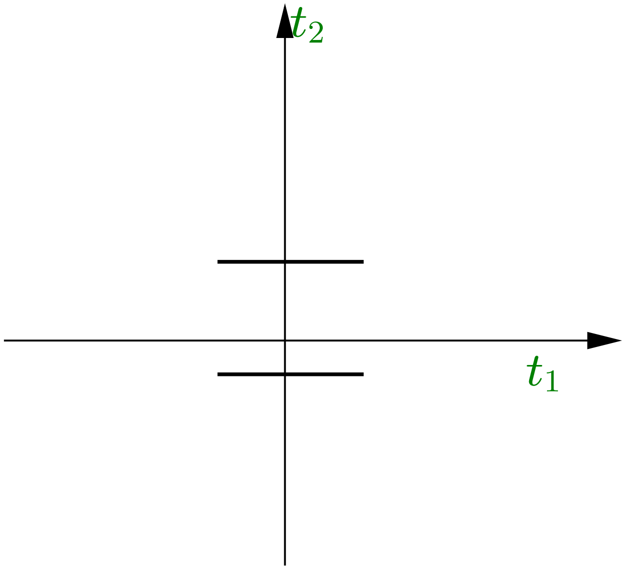
Bounded Hough Transform
2 Degrees-Of-Freedom

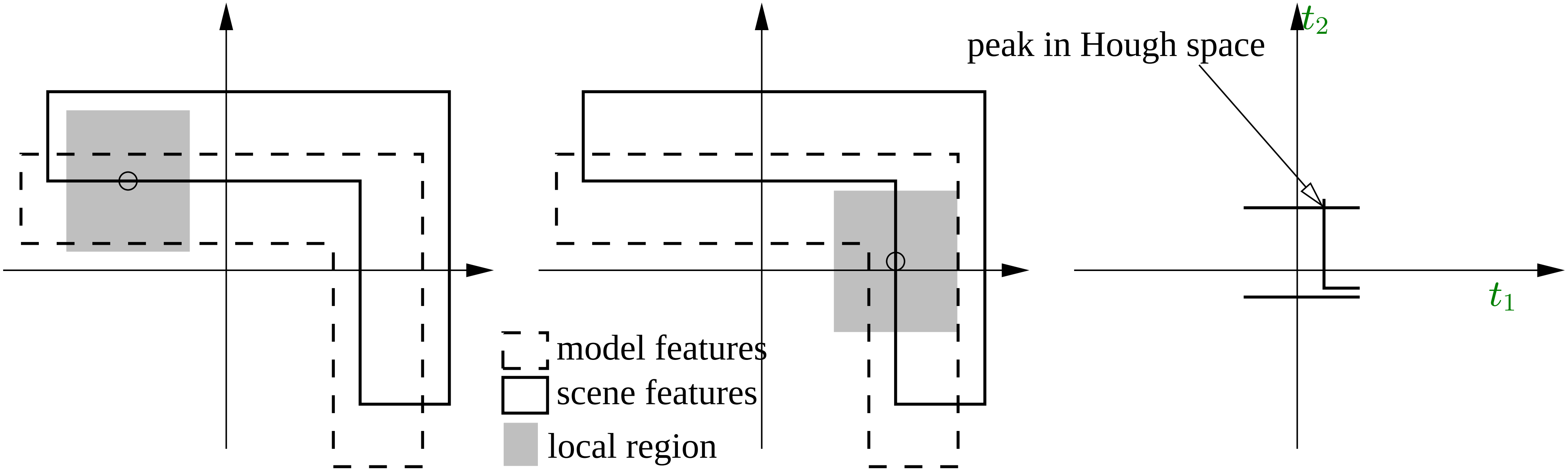
Accumulate Votes



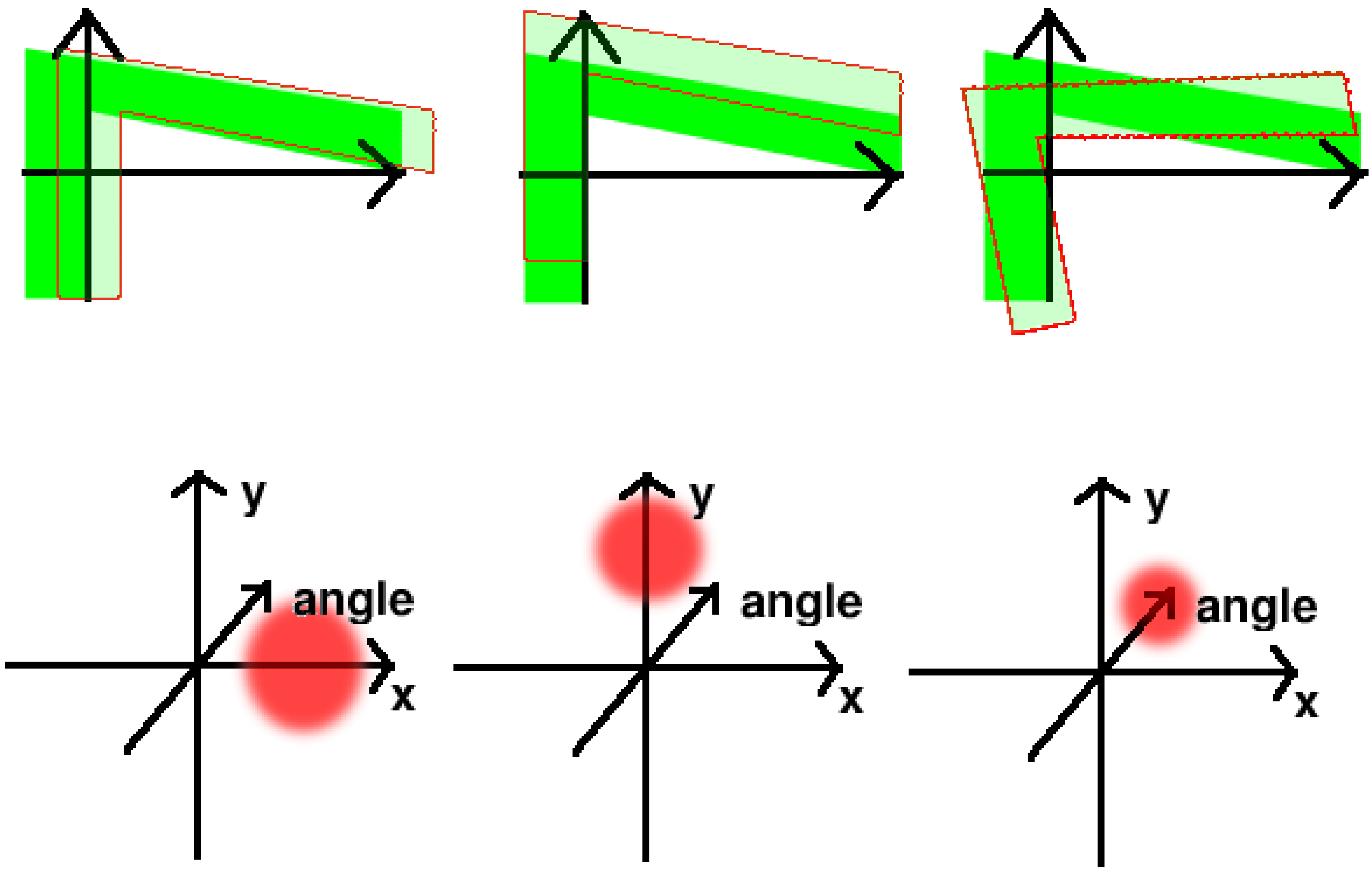


Bounded Hough Transform 2 Degrees-Of-Freedom

Accumulate Votes

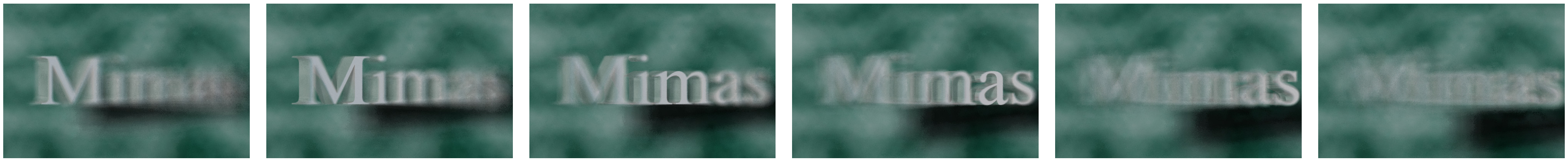


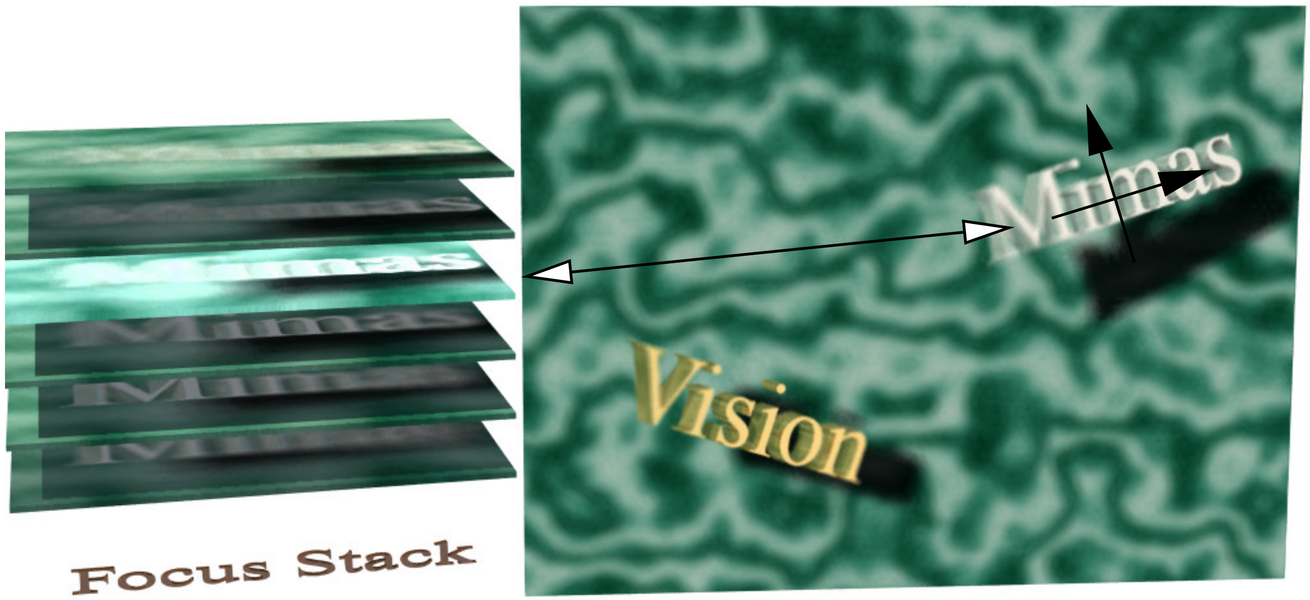
Bounded Hough Transform
3 Degrees-Of-Freedom



4 Degrees-Of-Freedom

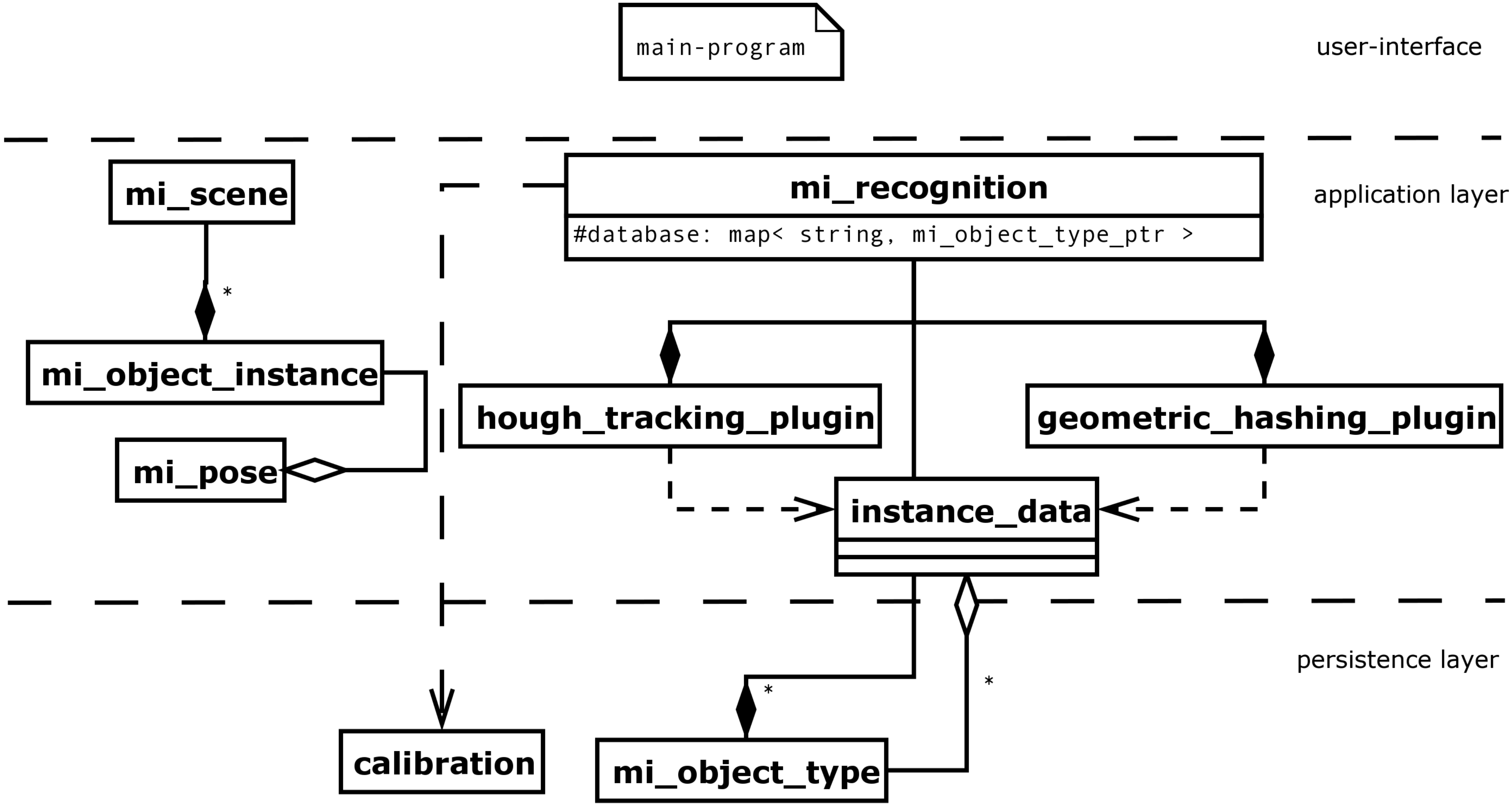
Artificial Scene



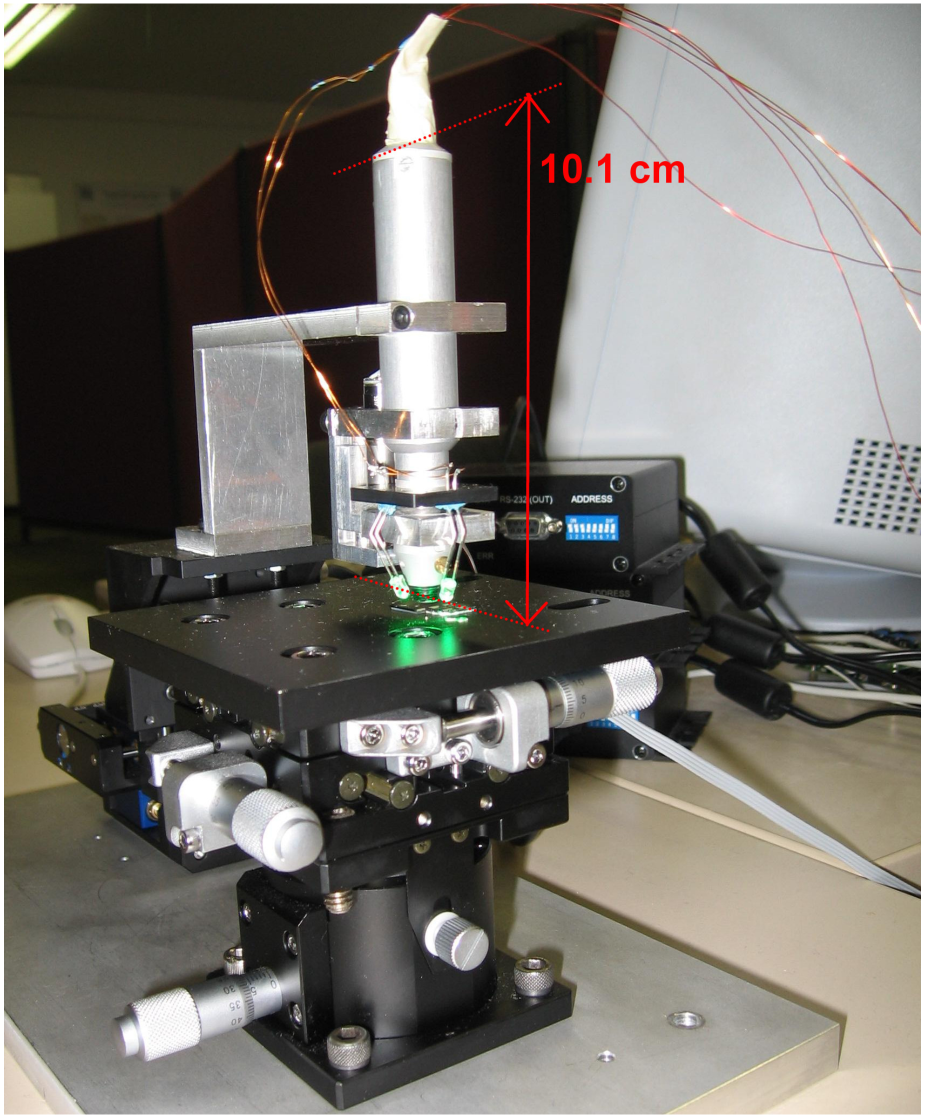


Implementation
Software Architecture

Application Layers

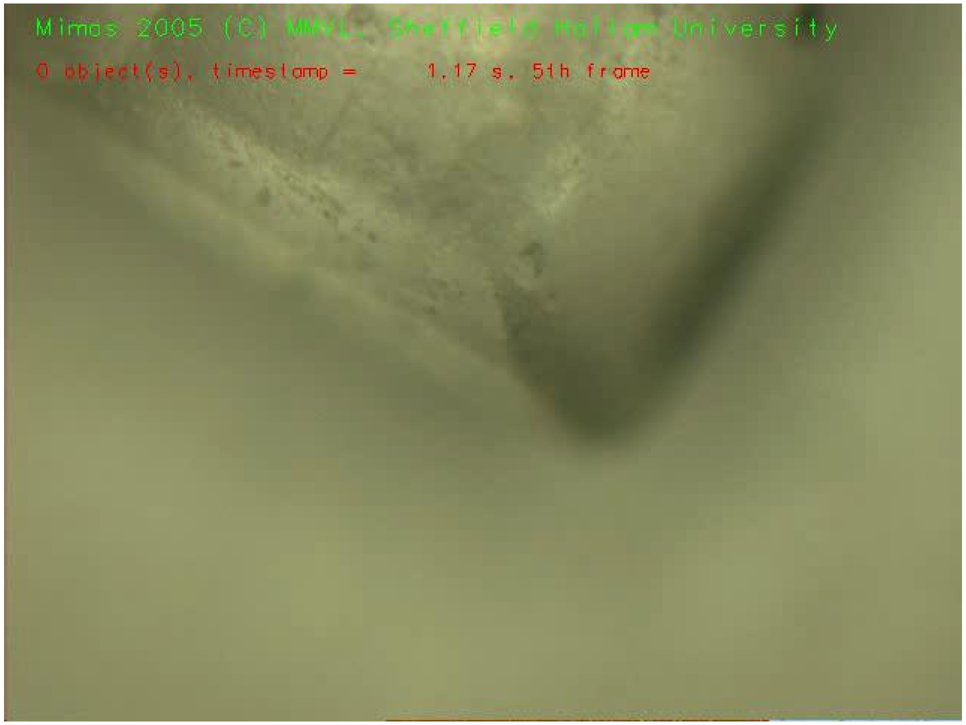


Implementation
Microstage with Custom-build Camera

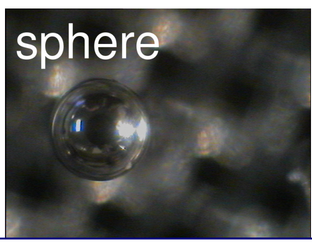
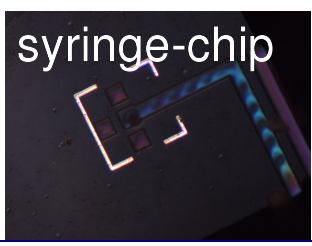


Implementation
Graphical User Interface

Pushing Sugar



Results (i)

video	resolution (down-sampled)	time per frame (recognition)	stack size	degrees-of-freedom	recognition-rate	time per frame (tracking)
dry run (load frames only)	384×288	0.0081 s	-	-	-	-
	384×288	0.20 s	7	(x, y, z)	88%	0.020 s
	160×120	0.042 s	10	(x, y, z, θ)	87%	0.016 s

Results (ii)

video	resolution (down-sampled)	time per frame (recognition)	stack size	degrees-of-freedom	recognition-rate	time per frame (tracking)
	384×288	0.27 s	16	(x,y,z,θ)	88%	0.025 s
	384×288	0.072 s	14	(x,y,z,θ)	88%	0.018 s
	192×144	0.32 s	9 1	(x,y,z,θ) (x,y,θ)	35% 45%	0.022 s

Conclusion

- Depth estimation based on a single image is possible
- Real-time was achieved
  - Real-time recognition possible with low recognition-rate
  - Low recognition-rate much more tolerable than low frame-rate
  - Real-time tracking solves problem of low recognition-rate
- Focus stack must not be self-similar
- Rough surfaces are rich in features

Future Work

Problems and Possible Solutions

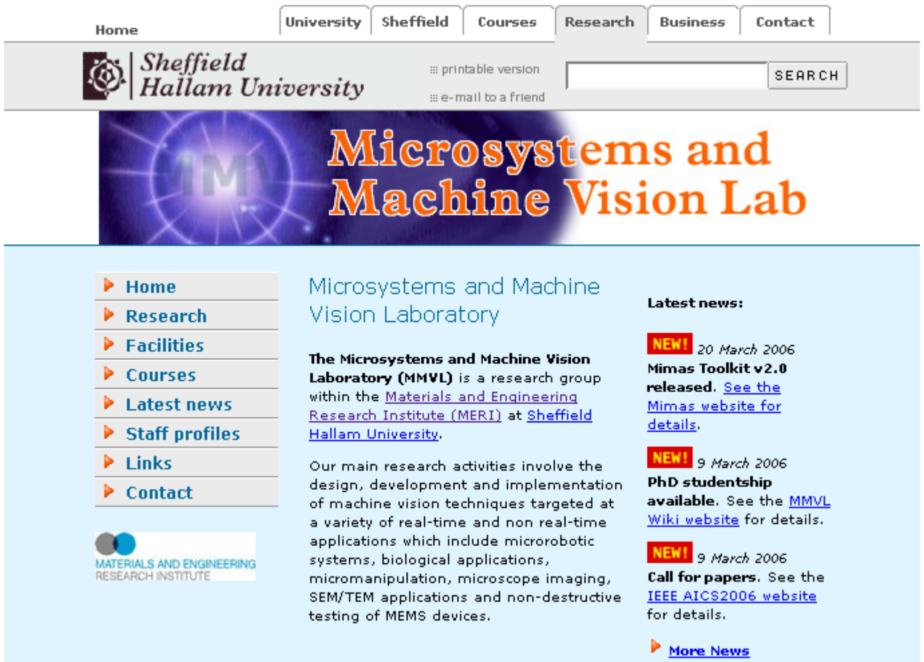
Problem	Solution
Geometric Hashing scales badly with number of objects	Use RANSAC with Linear Model Hashing
High memory requirements, parametrisation for more than 2 objects is difficult	Use local feature context, use less features, use only salient features
Sub-sampling decreases accuracy	Implement non-uniform partitioning of Hough-space (adaptive accuracy)

Research Topics

- more than 4 degrees-of-freedom
- develop micro-assembly for industrial application
- develop semi-automated supporting microscope tool for biological application

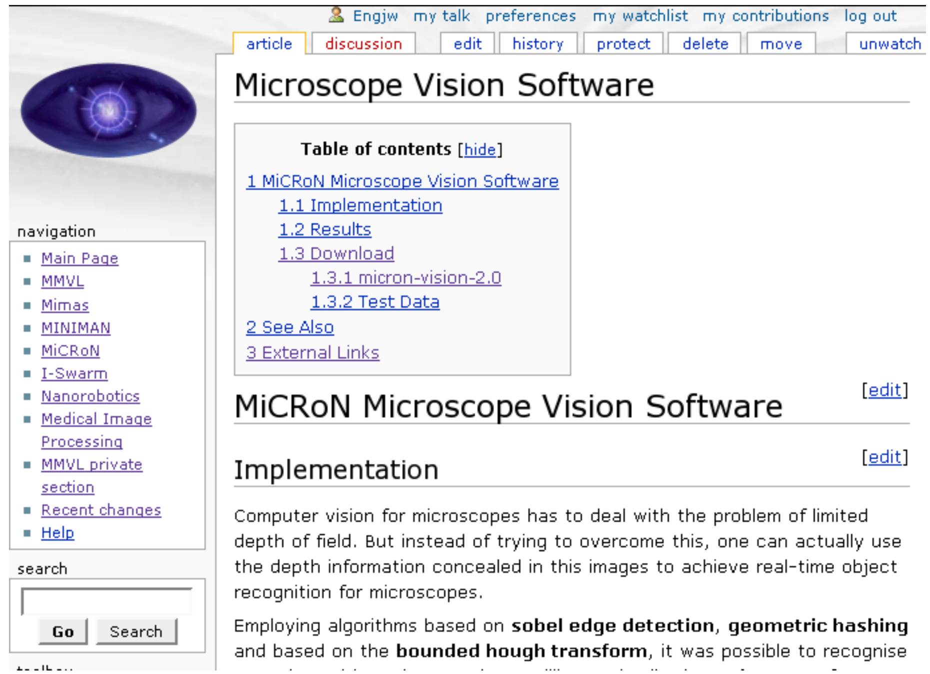
Homepage

MMVL official website

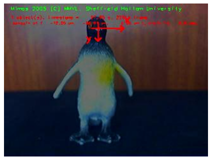


www.shu.ac.uk/research/meri/mmvl/

MMVL MediaWiki



vision.eng.shu.ac.uk/mediawiki/



Open source MiCRoN vision software + test data

Open source Mimas real-time computer vision library