Computer Vision and Machine Learning for Manufacturing

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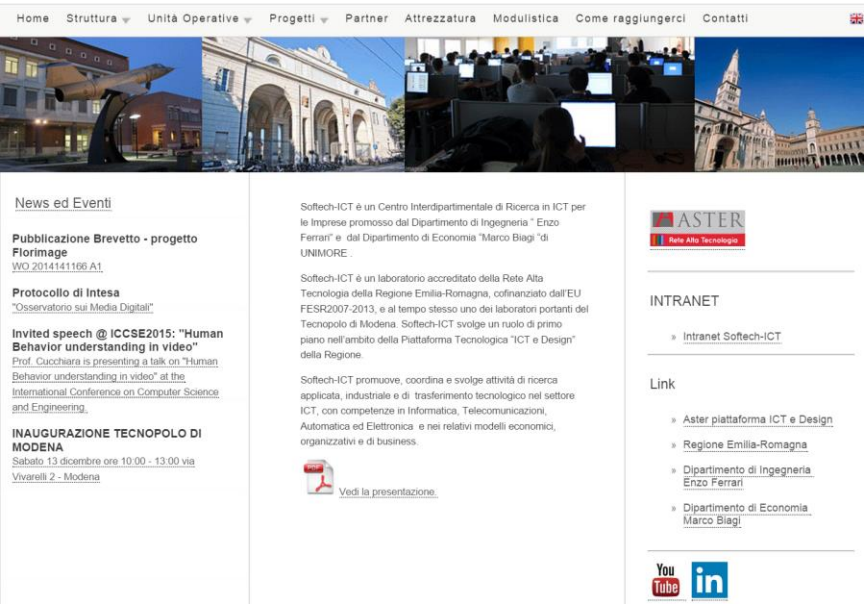
COSTRUIAMO INSIEME IL FUTURO



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IMAGELAB

DIEF UNIMORE Lab
4 staff people
15 phd students and post doc
1 spin-off
>300 scientific pubblications

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SOFTECH_ICT

EU FESR2007- lab
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Emilia Romagna High technology network
Interdipartimental center of research in ICT

>50 people
Ict for enterprise

3 QUESTIONS:

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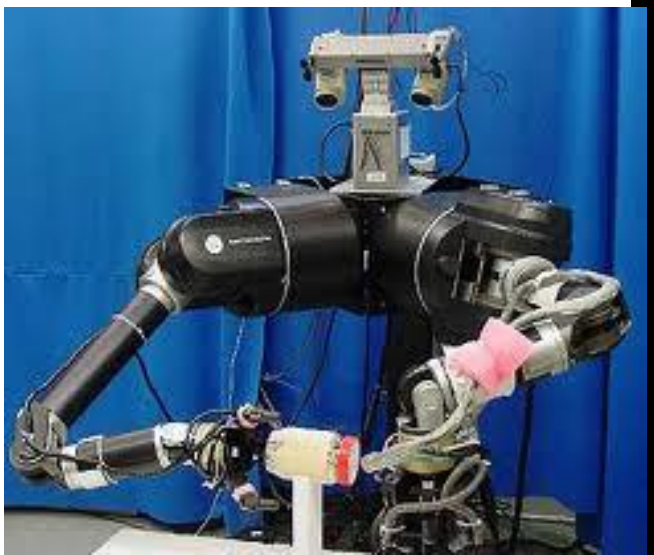
Why computer vision is so fashionable?

Why machine learning and pattern recognition are so strategic ?

What can we do for manufacturing?



Pattern Recognition

the scientific discipline studying **how to classify or recognize patterns** and observed data **using a priori knowledge or statistical information**

Computer Vision

the scientific discipline studying **how to perceive and understand the world through visual data by computers.**

Machine Learning

the scientific discipline studying **how to construct algorithms that can learn from and make predictions on data**.

Artificial Intelligence

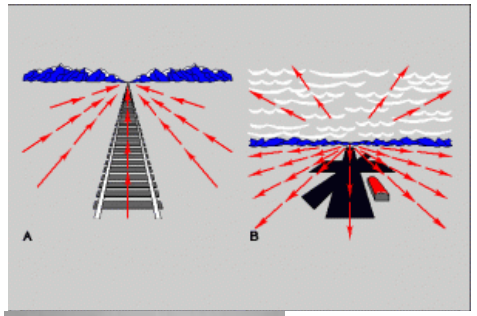
the scientific discipline studying **how to create computers and computer software** that are capable of **intelligent behavior**.

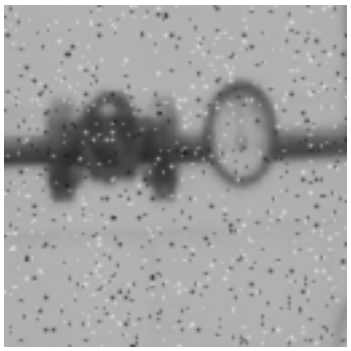
Then… **Machine Vision,** Medical Imaging, Video surveillance, Biometry……

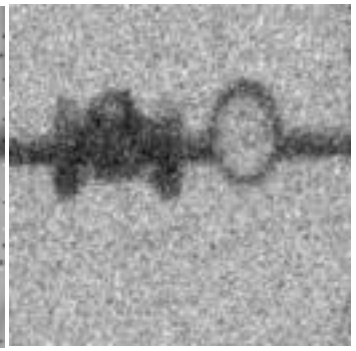
'70
Experiments of image processing
Optical flow, MIT studies
Probabilistic theory

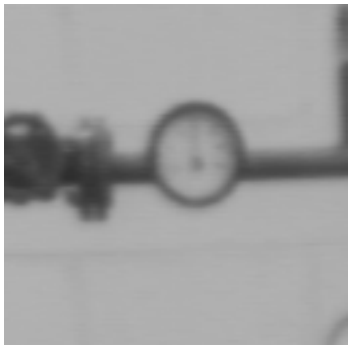
'80
1980 D. Marr «Vision»
Computational Vision
Noise analysis
Edge detection
Binarization

Syntactic and
Structural PR
Neural Networks





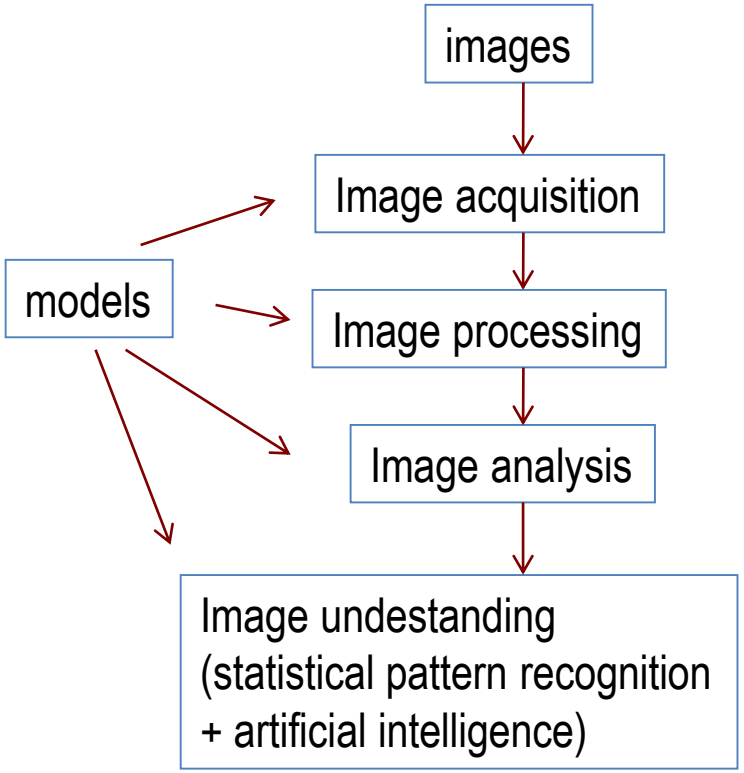


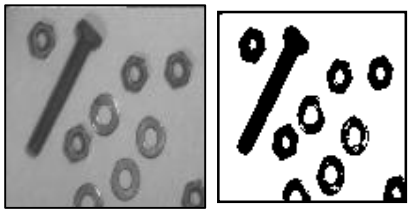


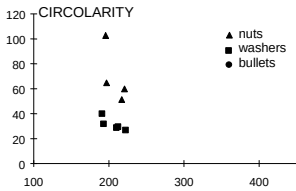
'90

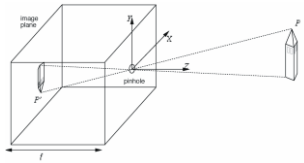
Edges, Shapes, Color
'KLT tracker
3D geometry, segmentation

Statistical PR
Clustering
Bayesian nets
Hidden Markov Models
Supervised Classification









Object #8
Diameter: 22.3 mm
Position: (47,38) mm

I see an object circular
that is a «nut»

Computer Vision and Machine Vision..

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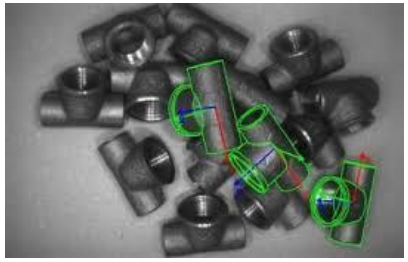
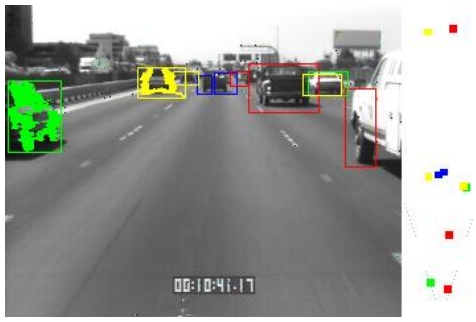
SIFT , Keypoints Detectors,
Tracking by detection,
Superpixel, Voxels

'00

Support Vector Machine
Graph analysis
Clustering, Boosting
Bag of words





'10

Deep Learning

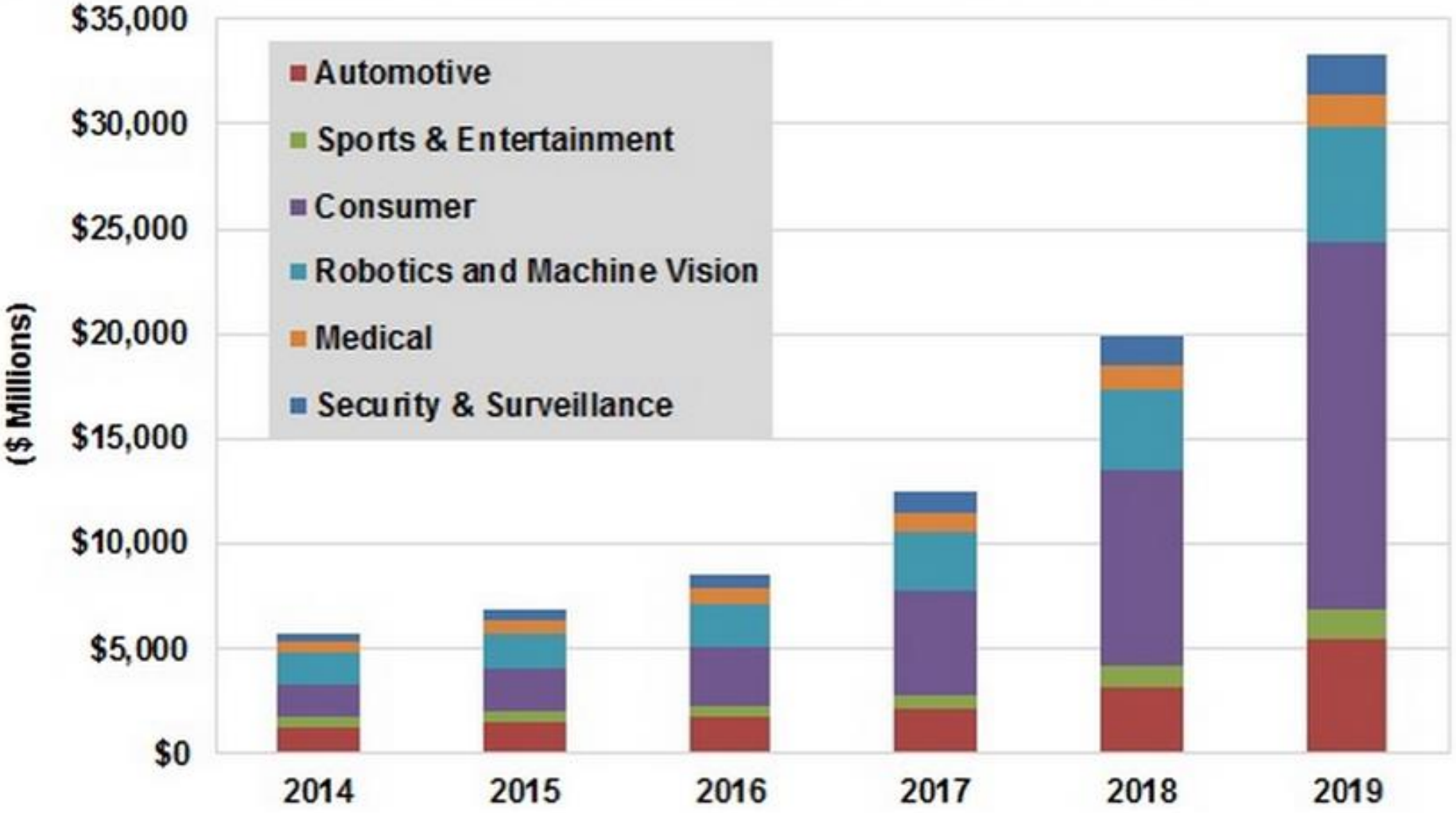
Concept, event
Action detection
Gesture HCI..

Pattern Recognition and Machine learning

Tractica

Now.. It's works!

Computer Vision Revenue by Vertical Market, World Markets: 2014-2019



Source: Tractica

WHY VISION AND LEARNING IN MANUFACTURING?

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Quality inspection
(integrity, quality levels,
defect detection, process optimization..)

Object Recognition
(picking and placing, handling,
robot control, selection...)

Autonomous guidance
(obstacle detection, trajectory following, environment exploration..)

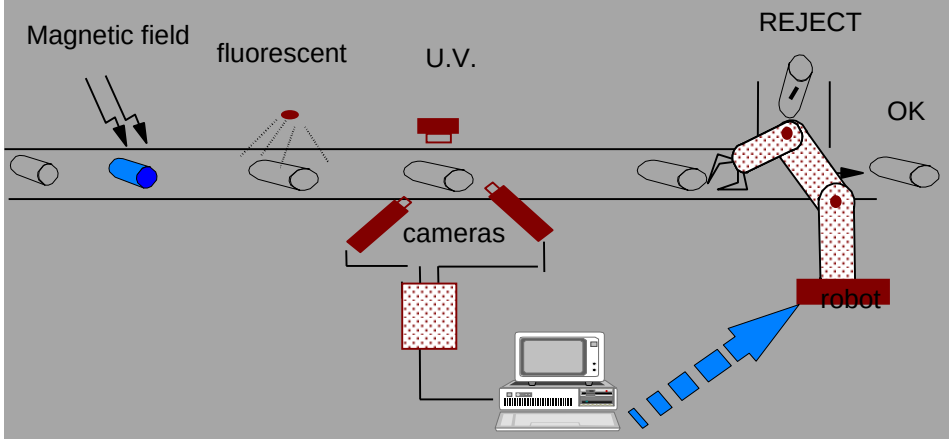
Human-Robot, Human-machine interaction
(worker safety, wearble, interfaces,
action recognition..)

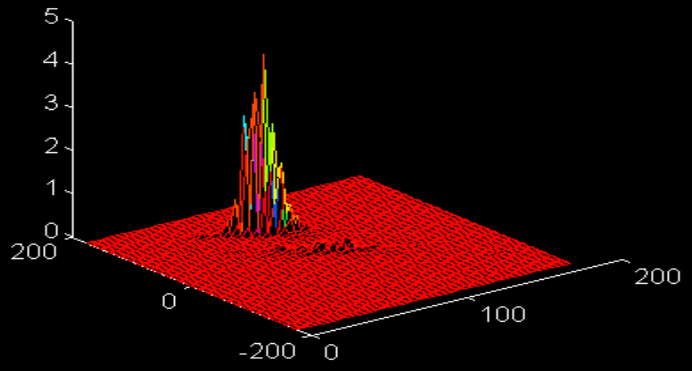
3D reconstruction and augmented reality
(point cloud, 3D analysis,
Physical-augmented-virtual world..)

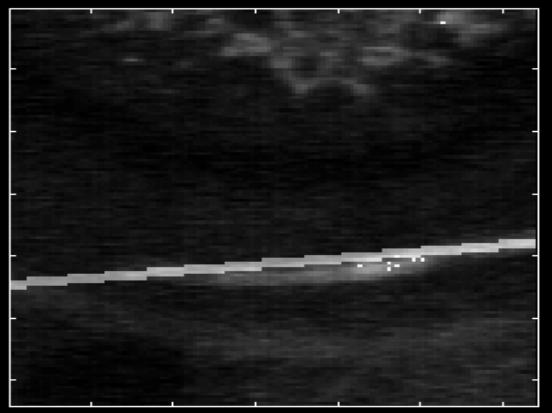
QUALITY INSPECTION

VISION AND LEARNING IN QUALITY INSPECTION

A very old story……. Berco –UNIFE 1995*







*R. Cucchiara, F. Filicori, R. Andreetta,"Detecting micro cracks in ferromagnetic material with automatic visual inspection"in Proceedings of the Intern Conf. Quality Control by Artificial Vision QCAV' France 1995,
R. Cucchiara, F. Filicori,"The Vector-Gradient Hough Transform« IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 20, n. 7, pp. 746-751, 1998

VISION AND LEARNING IN QUALITY INSPECTION

defective and non-defective industrial workpieces

six different learning algorithms: (in ’98*)

- ✓ Artificial Intelligence: an attribute-value learner, C4.5,
- ✓ Pattern Recognition: a backpropagation neural network, NeuralWorks Predict,
- ✓ Pattern Recognition: a k-nearest neighbour algorithm,
- ✓ Statistical analysis: 3 techniques, linear, logistic and quadratic discriminant.

Table 1. Average accuracies

	Discrim	Logdisc	Quadisc	NN	Predict	c4.5 tree	c4.5 rules
CH	0.853	0.857	0.853	0.885	0.873	0.959	0.959
H1 H2	0.855	0.928	0.316	0.845	0.864	0.933	0.933

**R. Cucchiara, P. Mello, M. Piccardi, F. Riguzzi* «An Application of Machine Learning and Statistics to Defect Detection “*Journal of Intelligent Data Analysis 1998*

- ✓ Machine vision in constrained scenario
- ✓ Structured light,
- ✓ Mainly model-based
- ✓ Image processing and measurement tools
- ✓ 2D and 3D geometry

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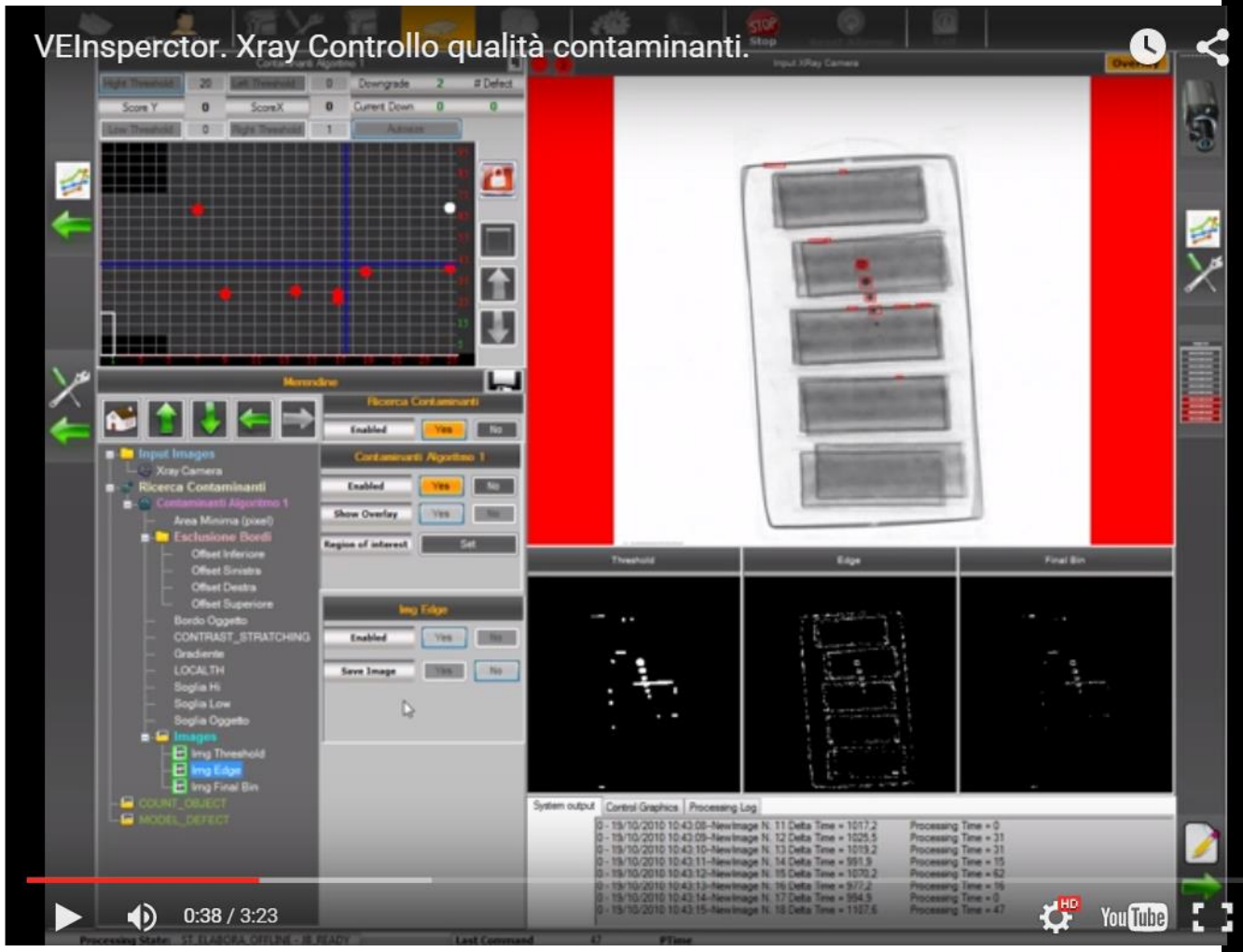
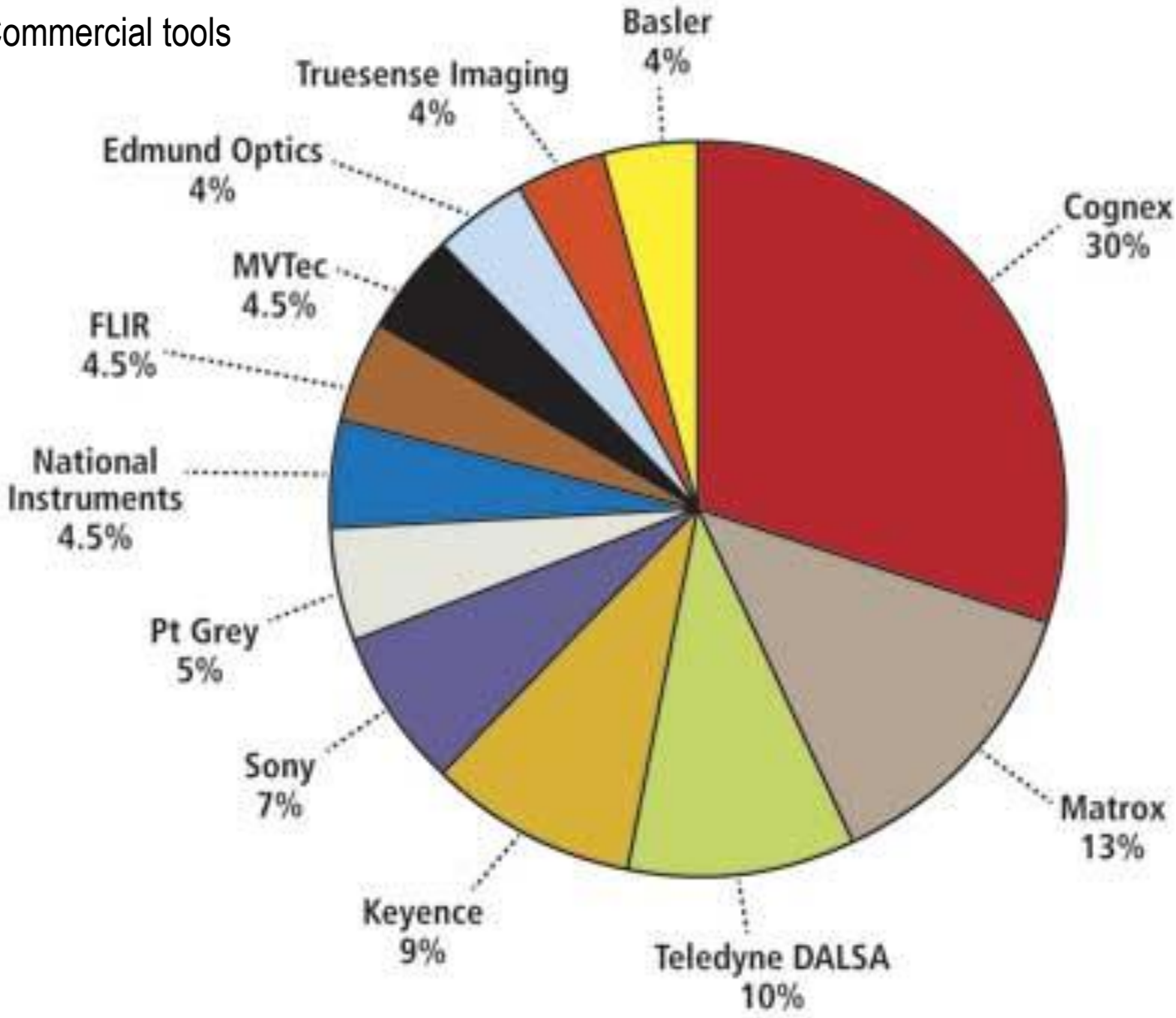
NOW commercial tools.



Thanks to VISION-E srl

UNIMORE spin-off

Commercial tools

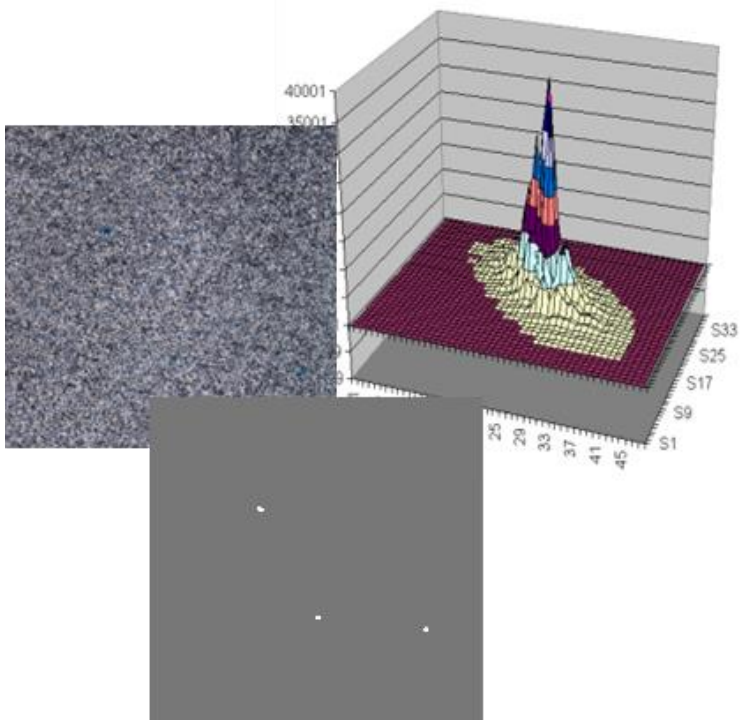


which companies had made the greatest impact on the machine vision over the past twenty years ?

(by vision-system.com)

For open-source sw OpenCv,PointCloudLib, ...→CVonline/SWEnvironments.html

Special solutions for special problems….



FLAW Detection 2006 -

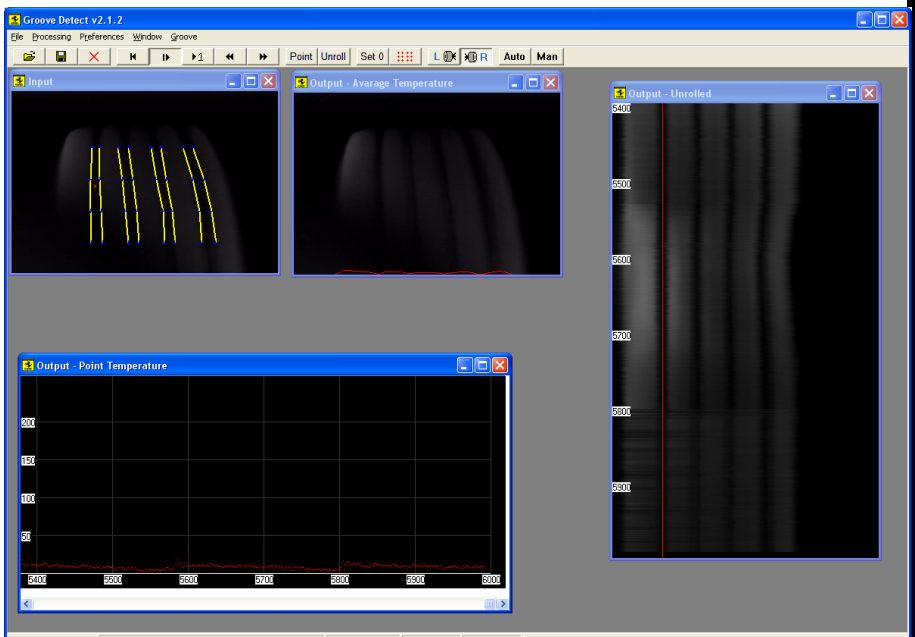
Italvision-Imagelab

Texture and k-means clustering

Dynamic weels' grooves analysis 2005-

Ferrari-Imagelab

Active contourn models (Snakes)



MOTION INSPECTION

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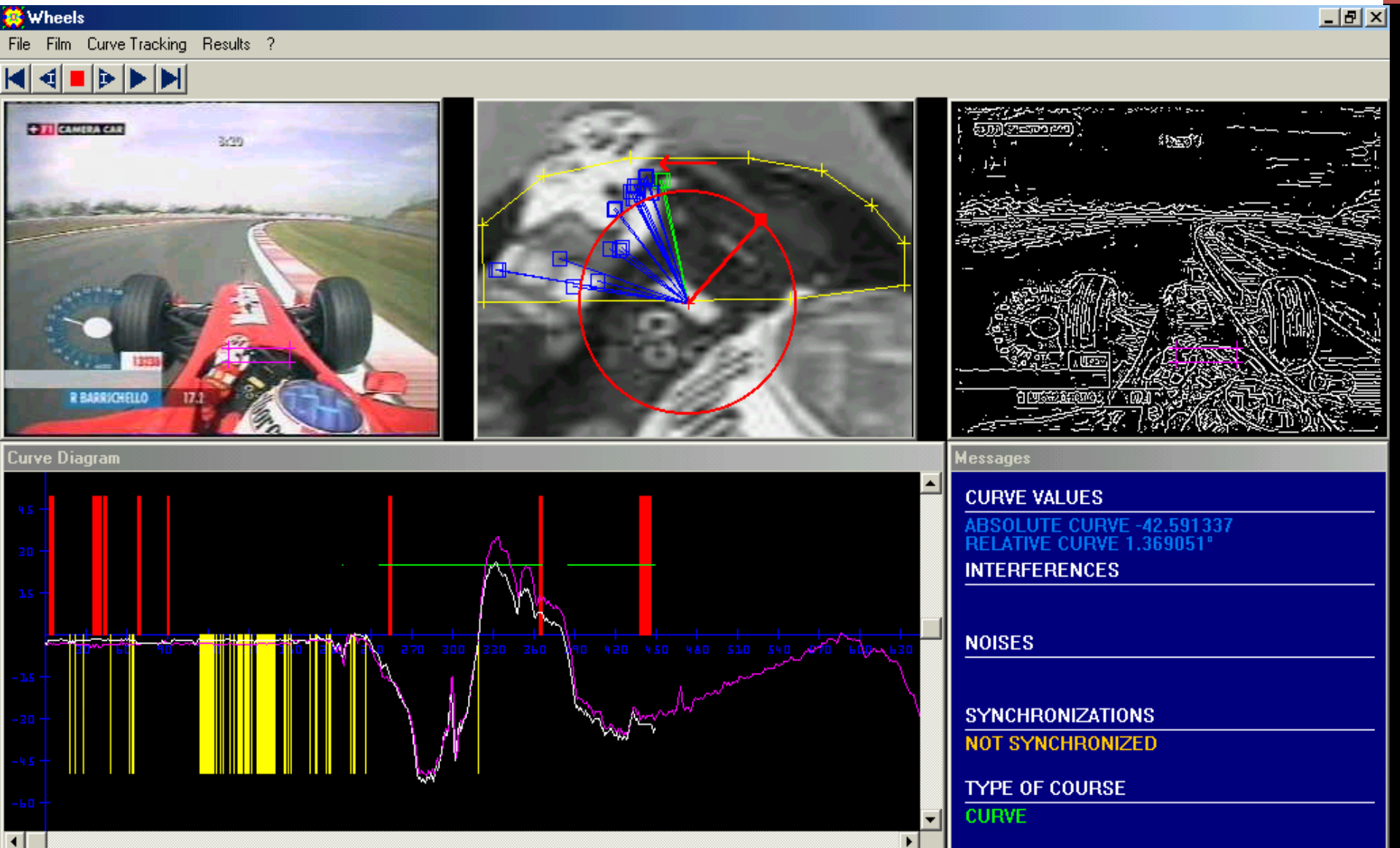

3D INSPECTION

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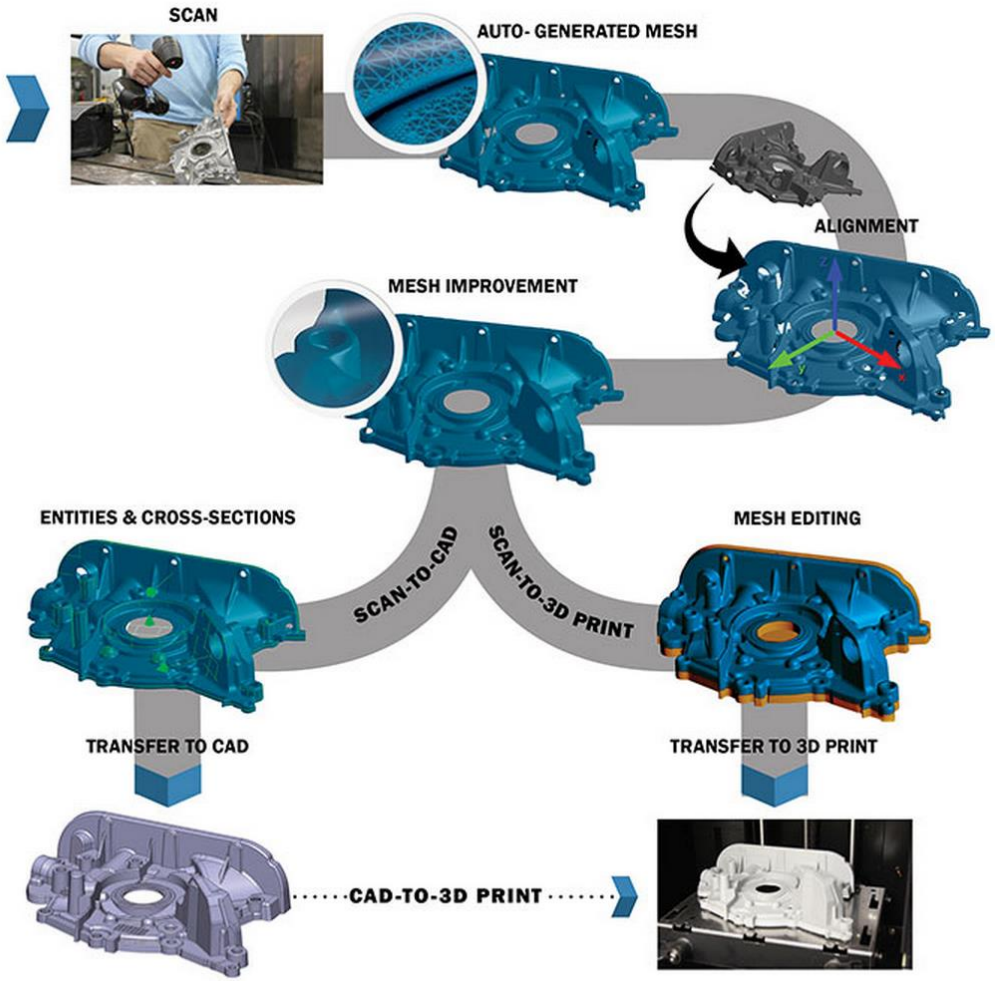
Now many sensors and tools



Creaform 3D scanner

Th Bortolotti 2014

AUTONOMOUS GUIDANCE

Autonomous guidance is more complex:

- ✓ 3D world reconstruction
- ✓ Unconstrained scenario
- ✓ Human presence

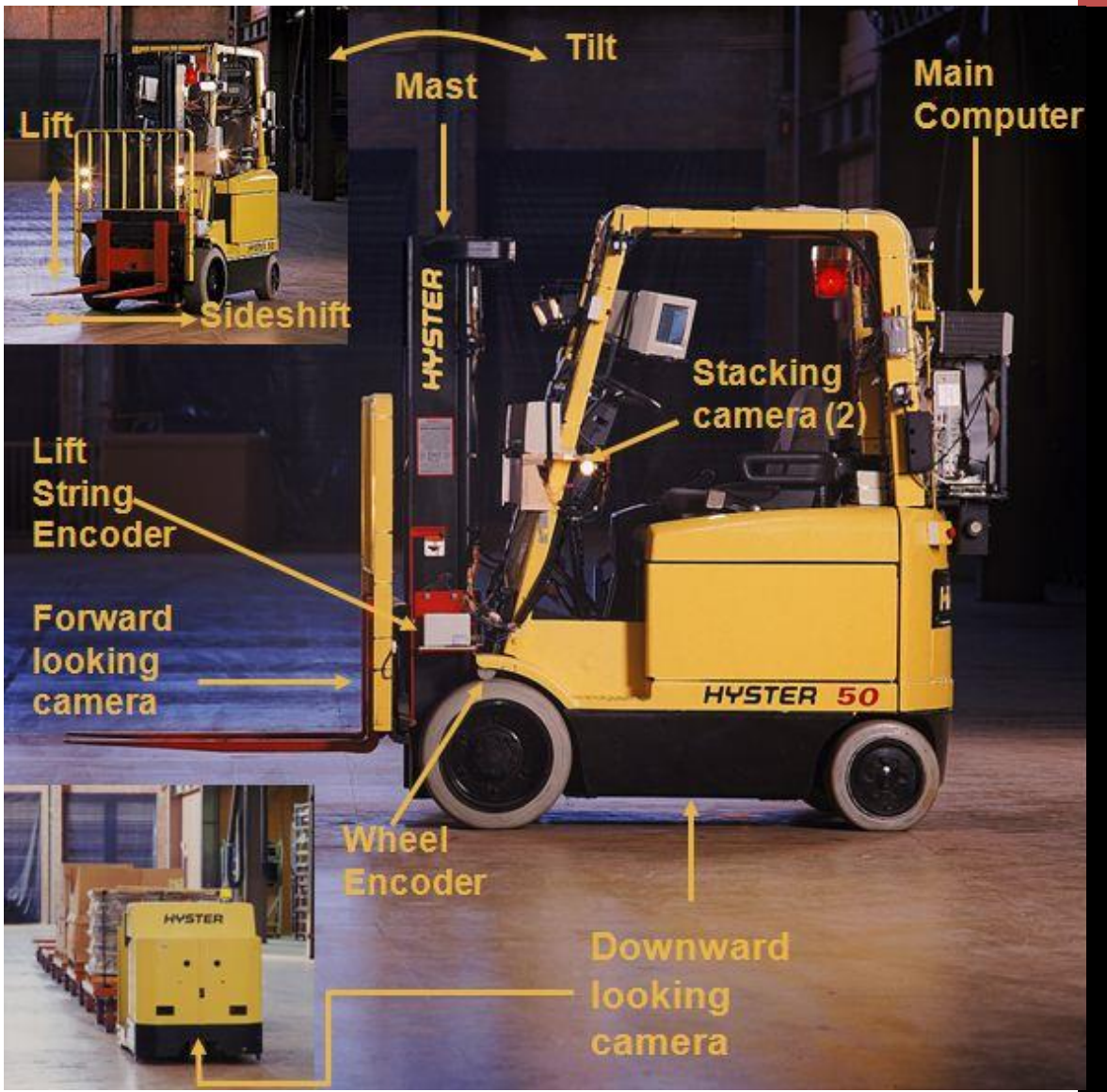
Now:

Vision and other sensors (GPS, Laser..)*

Markers in the environment

Big Data collection

A large impact of computer vision and machine learning

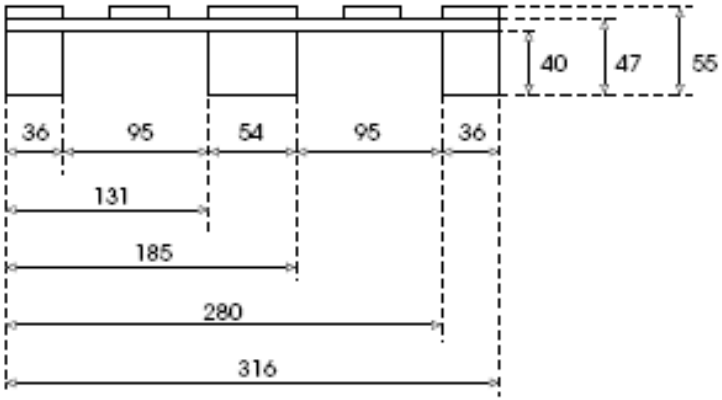


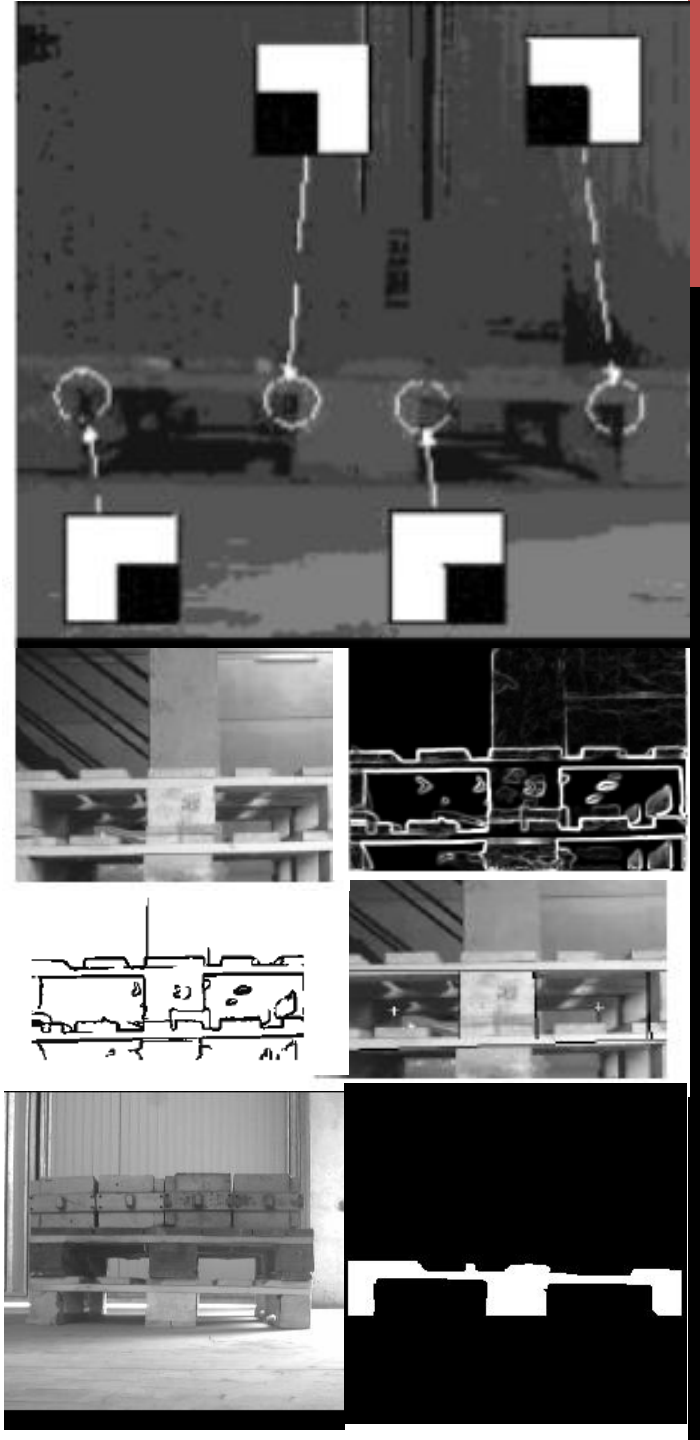
*Kelly, A.,Nagy, B. ,Stager, D., Unnikrishnan, R., "An Infrastructure-Free Automated Guided Vehicle Based on Computer Vision", IEEE Robotics and Automation Magazine. 2007.

AUTONOMOUS GUIDANCE: TARGET DETECTION BY VISION

Pallet recognition in un-constrained environment

- ✓ Image processing
- ✓ Hough Transform
- ✓ Harris Corner Detection
- ✓ Constraint grah analysis
- ✓ Decision Trees





R. Cucchiara, M. Piccardi, A. Prati,**"Focus based feature extraction for pallet recognition"**
in *Proceedings of the 11th British Machine Vision Conference (BMVC 2000)*, Bristol, UK, pp. 695-704, 2000

AUTONOMOUS GUIDANCE: LOCALIZATION BY STEREO VISION

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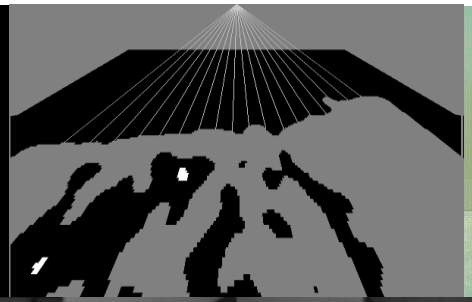

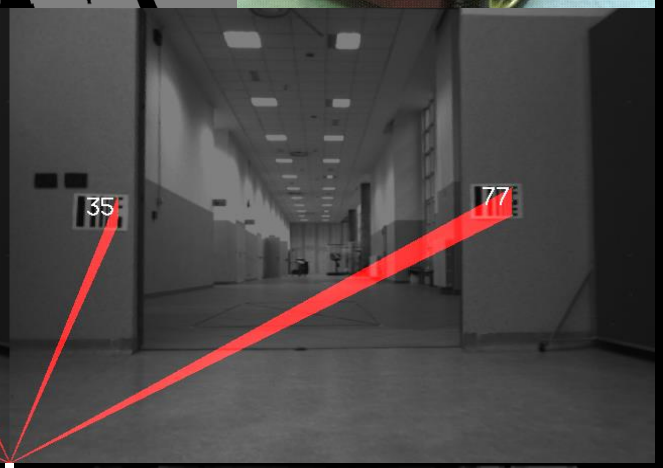

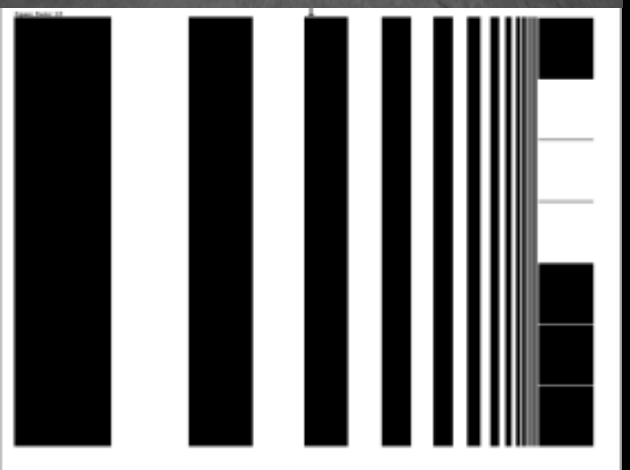

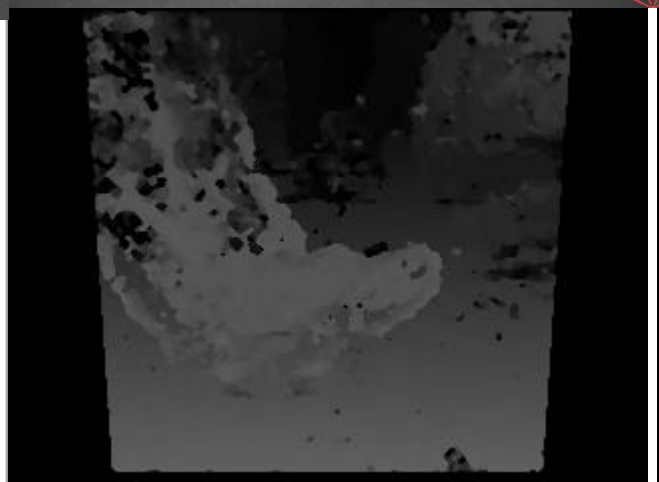

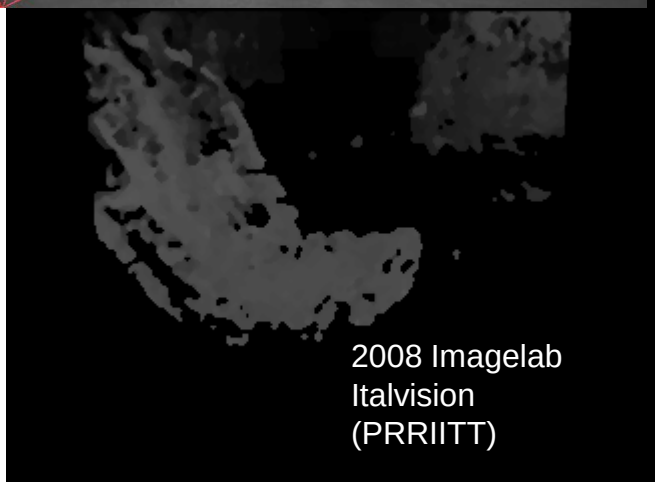

2008 Imagelab
Italvision
(PRRIITT)

NOW VISION, LEARNING AND BIG DATA

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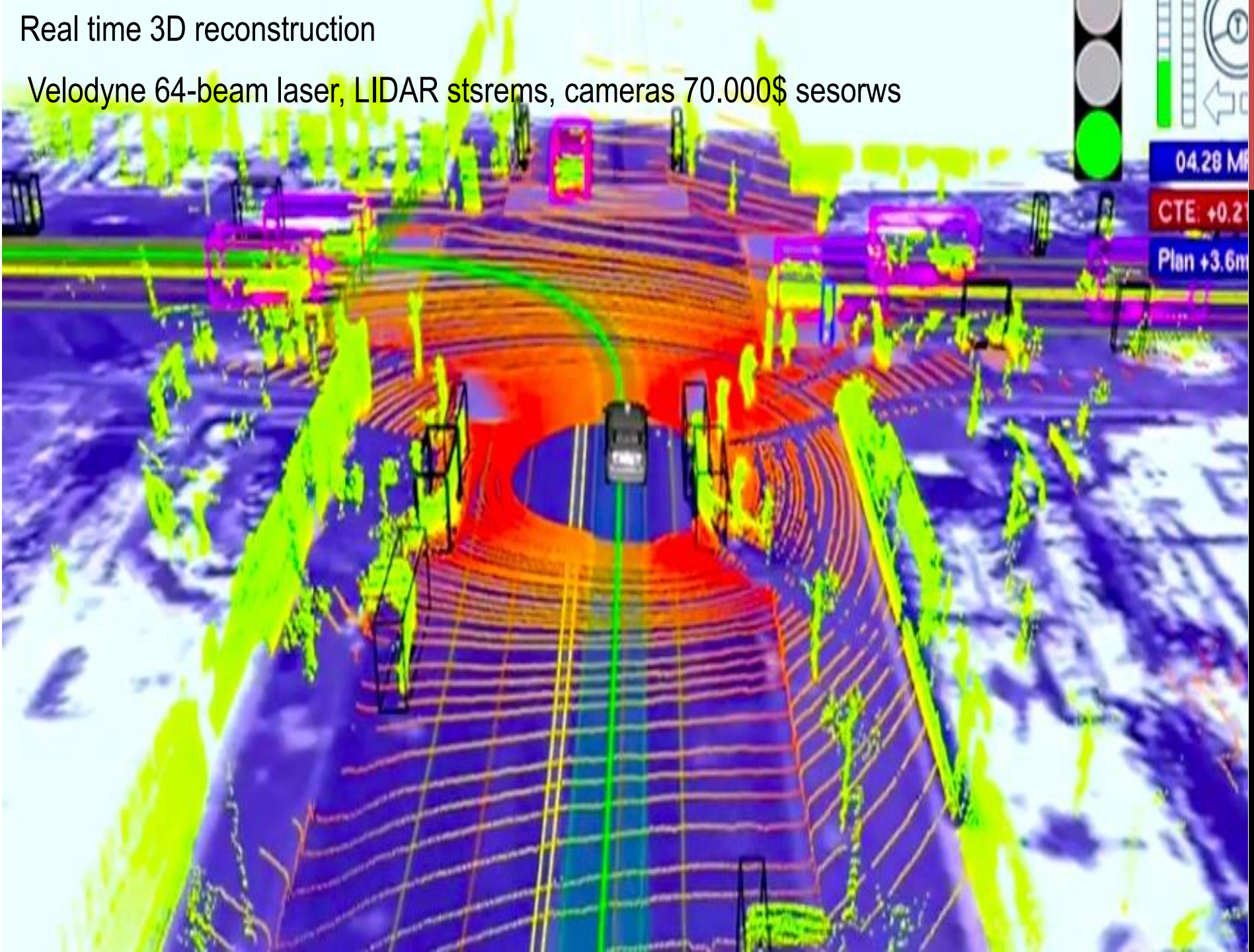
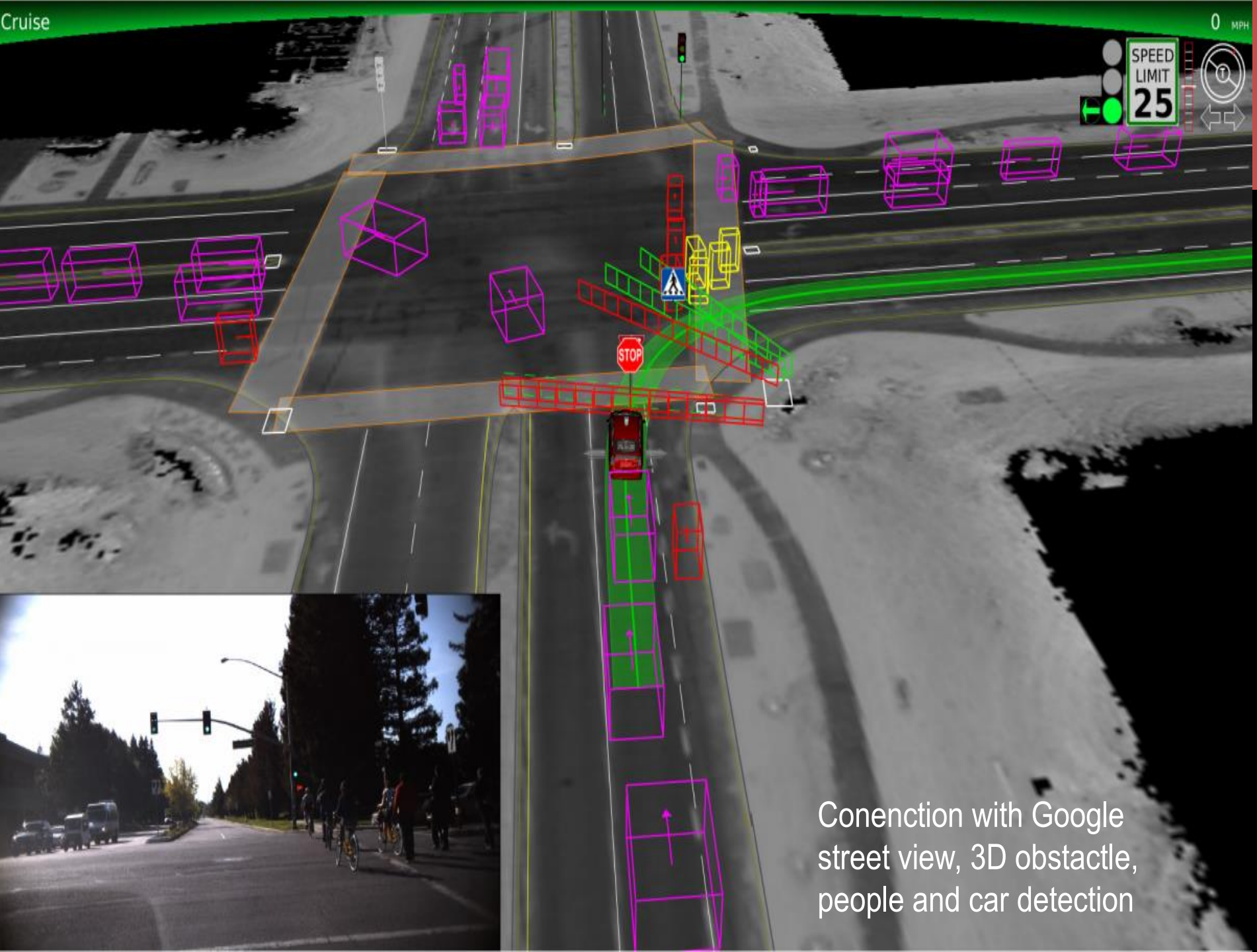
Sebastian Thrun Stanford

Real time 3D reconstruction

Velodyne 64-beam laser, LIDAR stsrems, cameras 70.000$ sesorws




Cruise
0 MPH
SPEED LIMIT 25
STOP
Conenction with Google street view, 3D obstactle, people and car detection

OBJECT DETECTION

Since ’80 **model-based vision***

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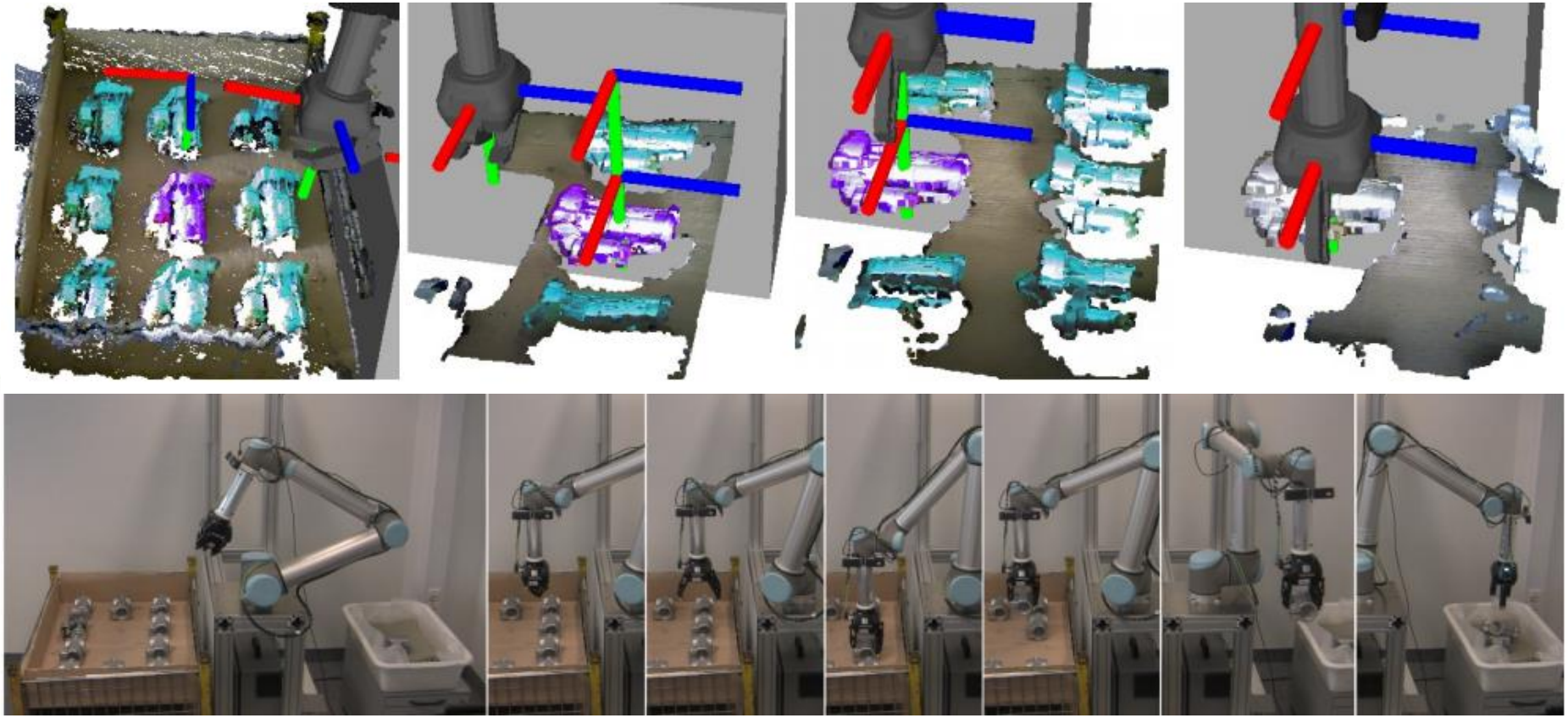
- Recognition of objects and parts in a small datatset (1-50)
- Ad-hoc recognition **

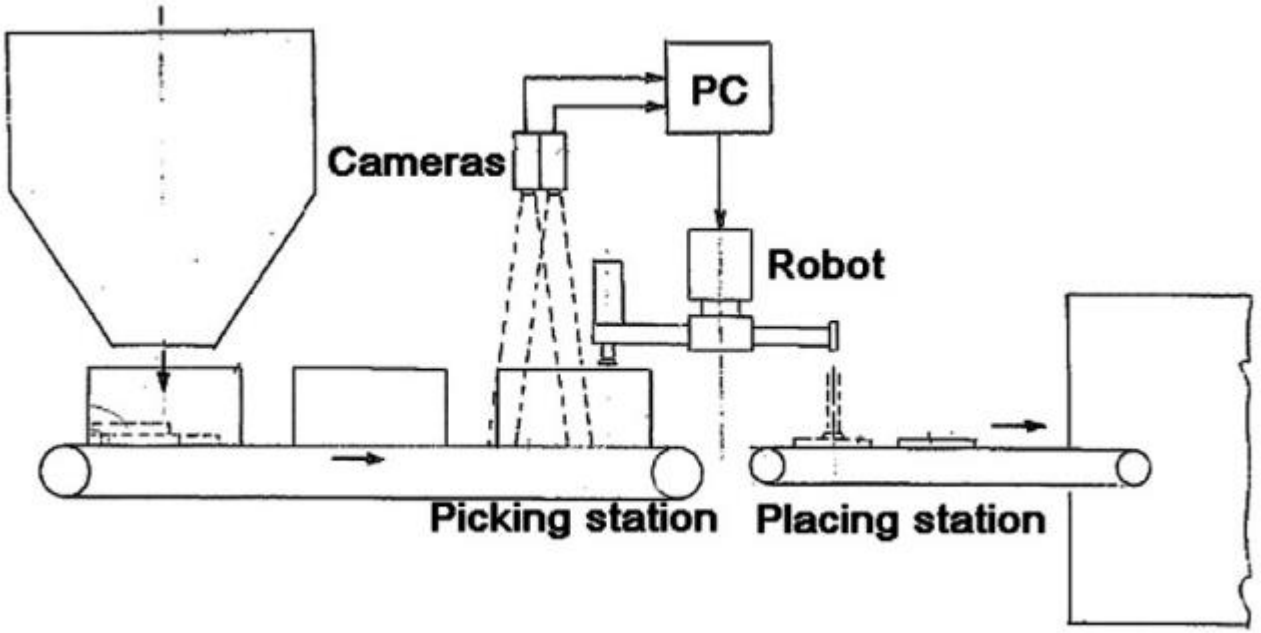


*R.Chin, C. Dyer «Model based Recognition in Robot Vision» ACM Computing survey 1986

**Dirk Holz, Angeliki Topalidou-Kyniazopoulou, Jorg St ¨ uckler, and Sven Behnke «Real-Time Object Detection, Localization and Verification for Fast Robotic Depalletizing « IROS 2015

Typical approaches:

- ✓ Thresholdings and **object based features** (edges, color, moments, area, eccentricty..) for localization
- ✓ **Detection-by-feature** approaches (localization of specific details, e.g holes, corners, not generalizable)
- ✓ **CAD-based models**: Visual features and matching 3D models
- ✓ Simple PR discriminant classification



Now... Many commercial products

based on template matching, with CAD-based view

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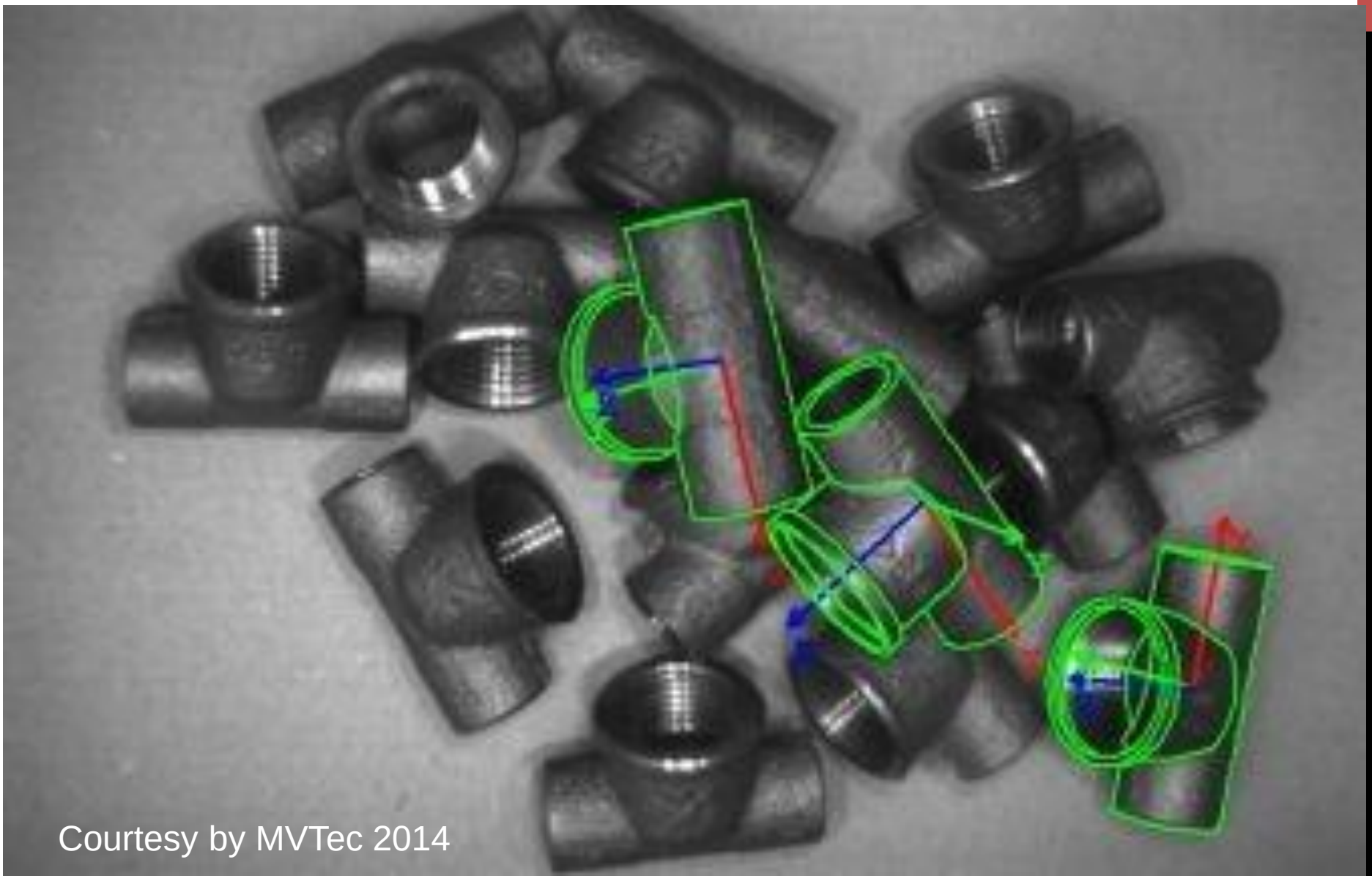

VISION AND LEARNING FOR PICK-AND-PLACE

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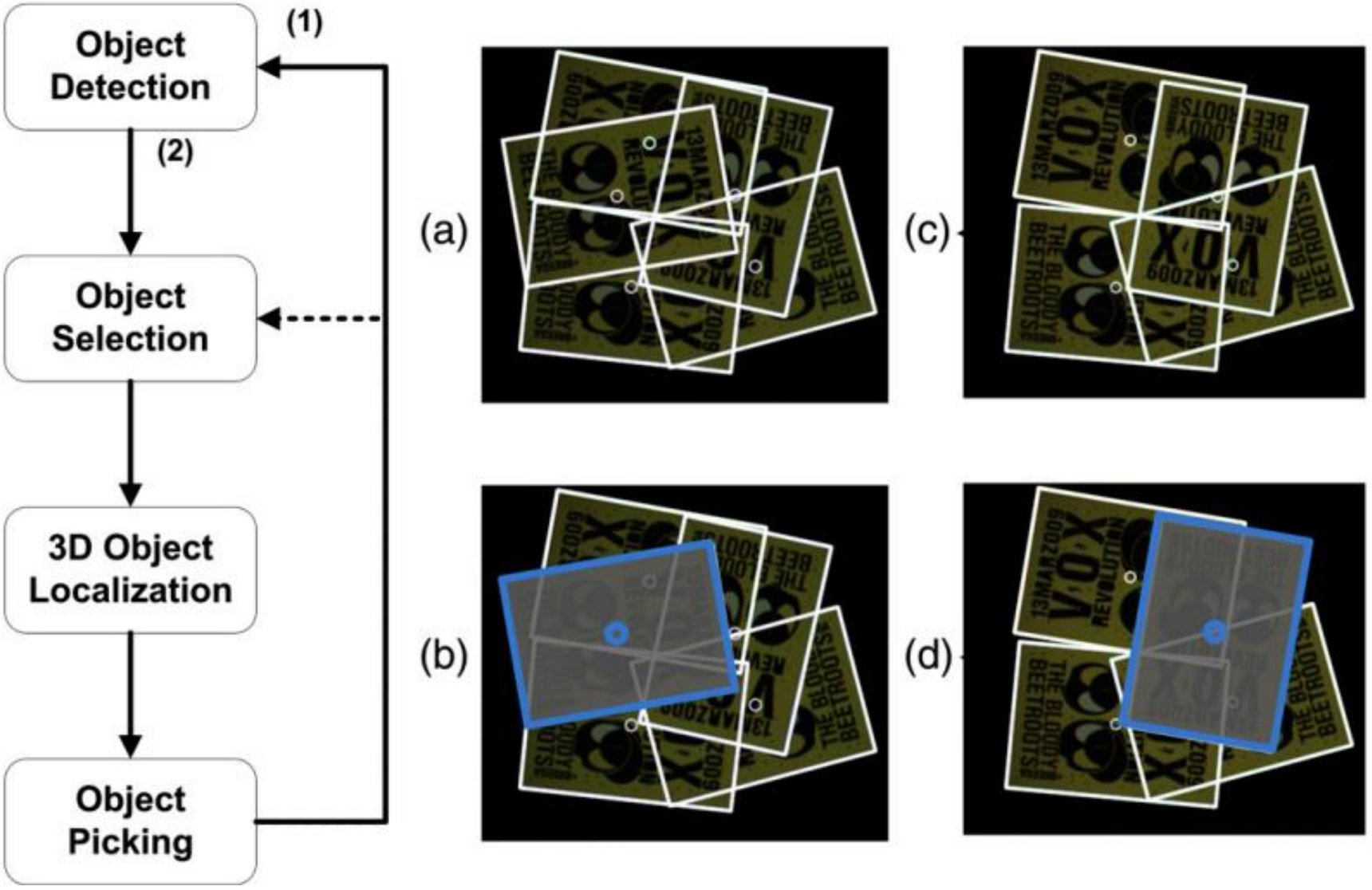
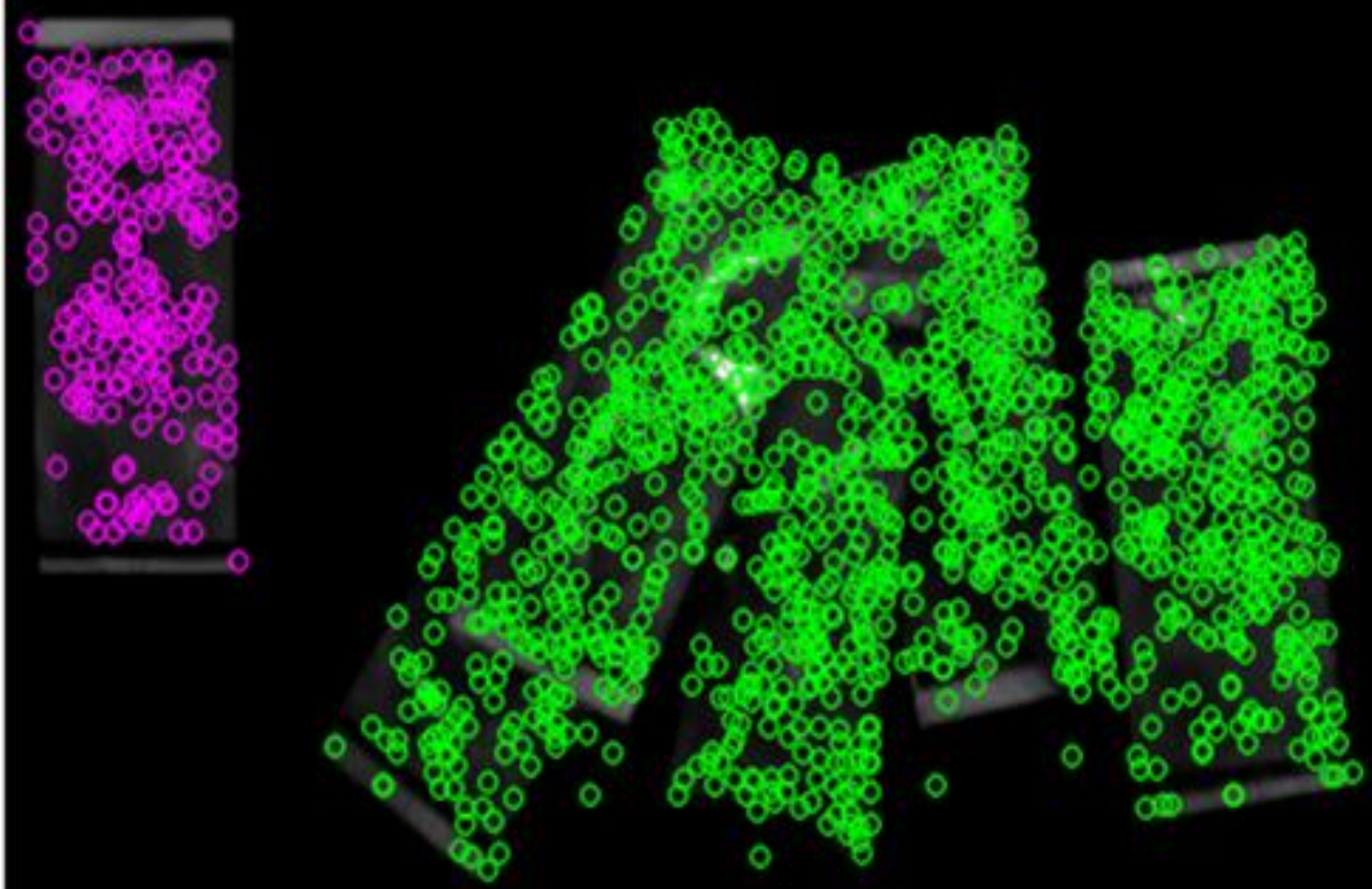
With Marchesini spa, Bologna Patent . BO2009A 000278.

Paolo Piccinini PhD

- Different objects types and distractors
- No CAD Models
- Learning by few examples
- Random object disposal
- Multiple instances and distractors
- Heavely occluded objects
- High working speed (100obj/min)

P.Piccinini, A. Prati, R.Cucchiara Real-time object detection and localization with SIFT-based clustering 2012 Image and Video Computing 30 (2012)573-587


Object Detection
(1)
(2)
Object Selection
3D Object Localization
Object Picking
(a)
(b)
(c)
(d)



SIFT features [Lowe 2004] Invariant to scale, rotation translation and illumination

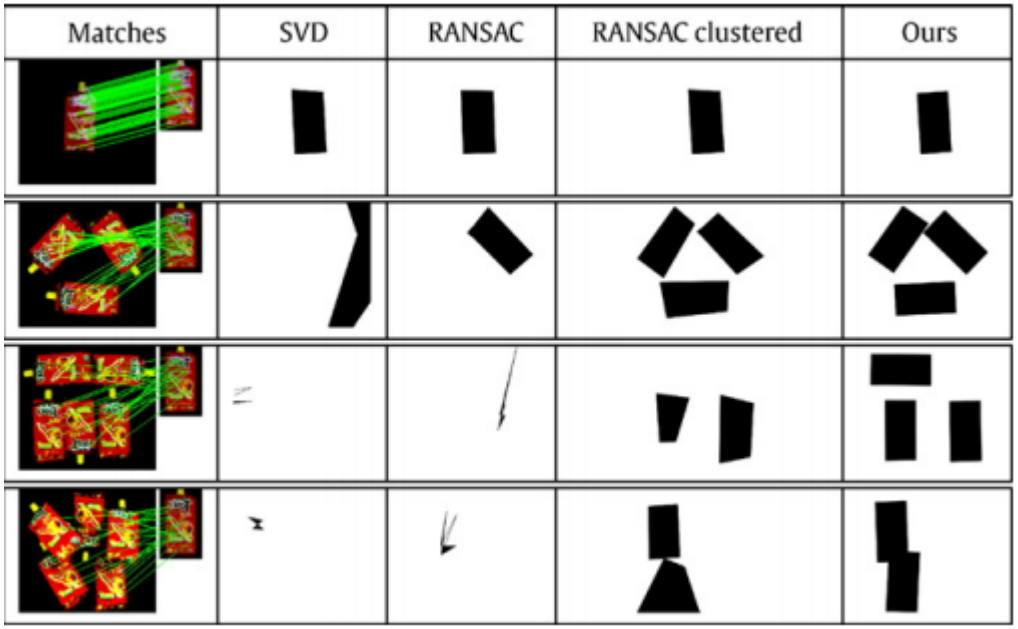
Object localization by a registration transform

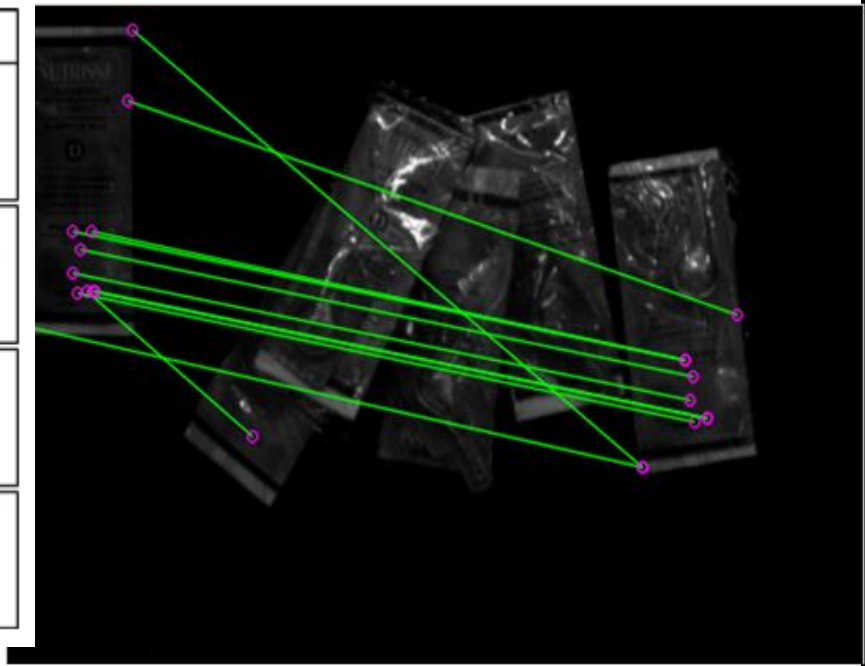
$K = \{k_i \equiv (x_i, y_j, D_i, \vartheta_i)\}$ i=1..n features in the model M

$KI = \{k_{Ij} \equiv (x_{Ij}, y_{Ij}, D_{Ij}, \vartheta_{Ij})\}$ j=1..r features in the image I

Multiple matching with best-bin-first algorithm

Registration with planar homography with 5 support points

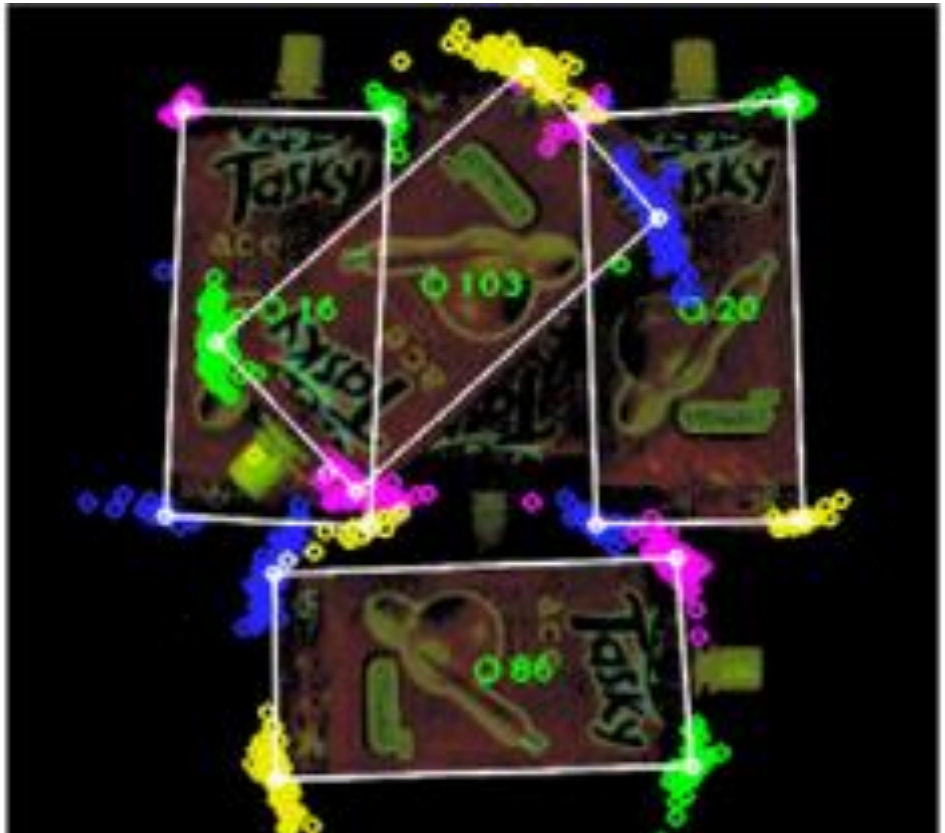


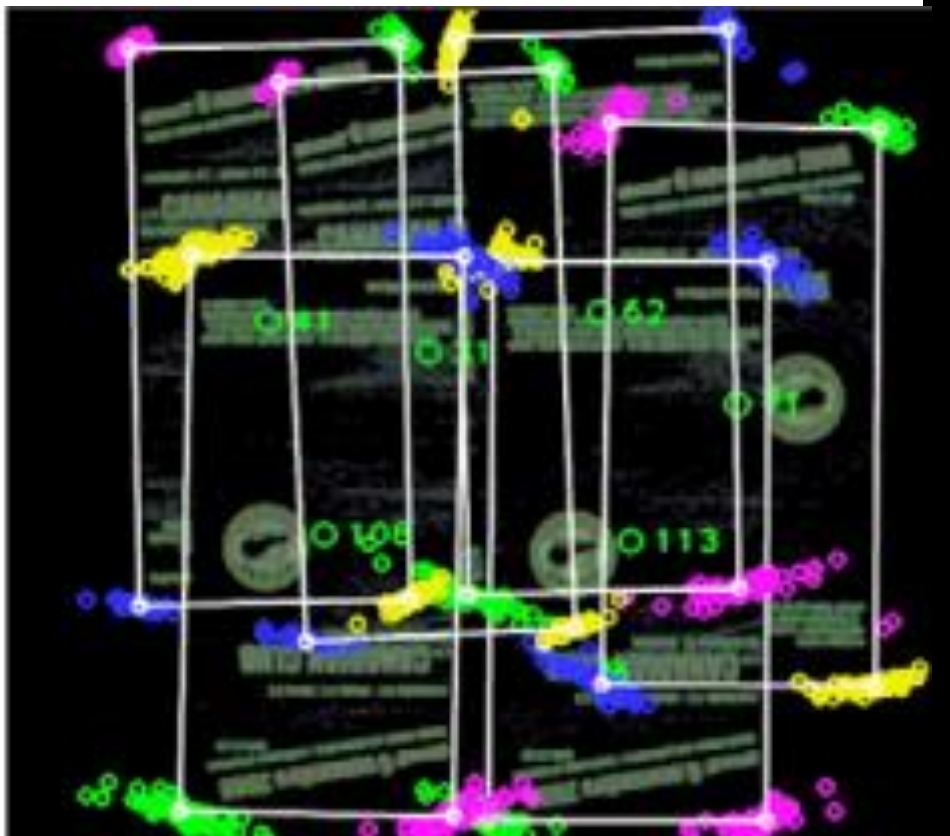


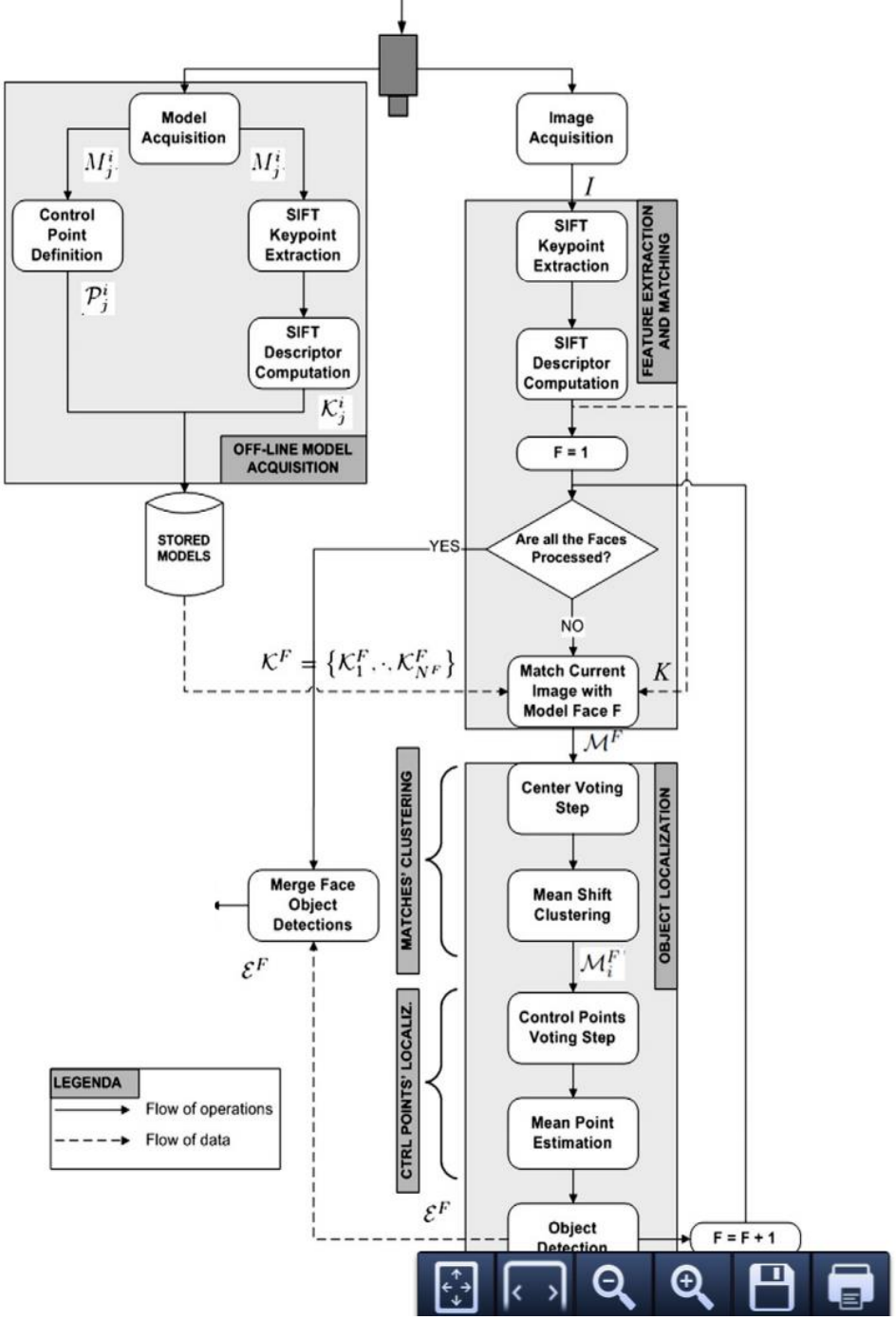
Clustering similar features,

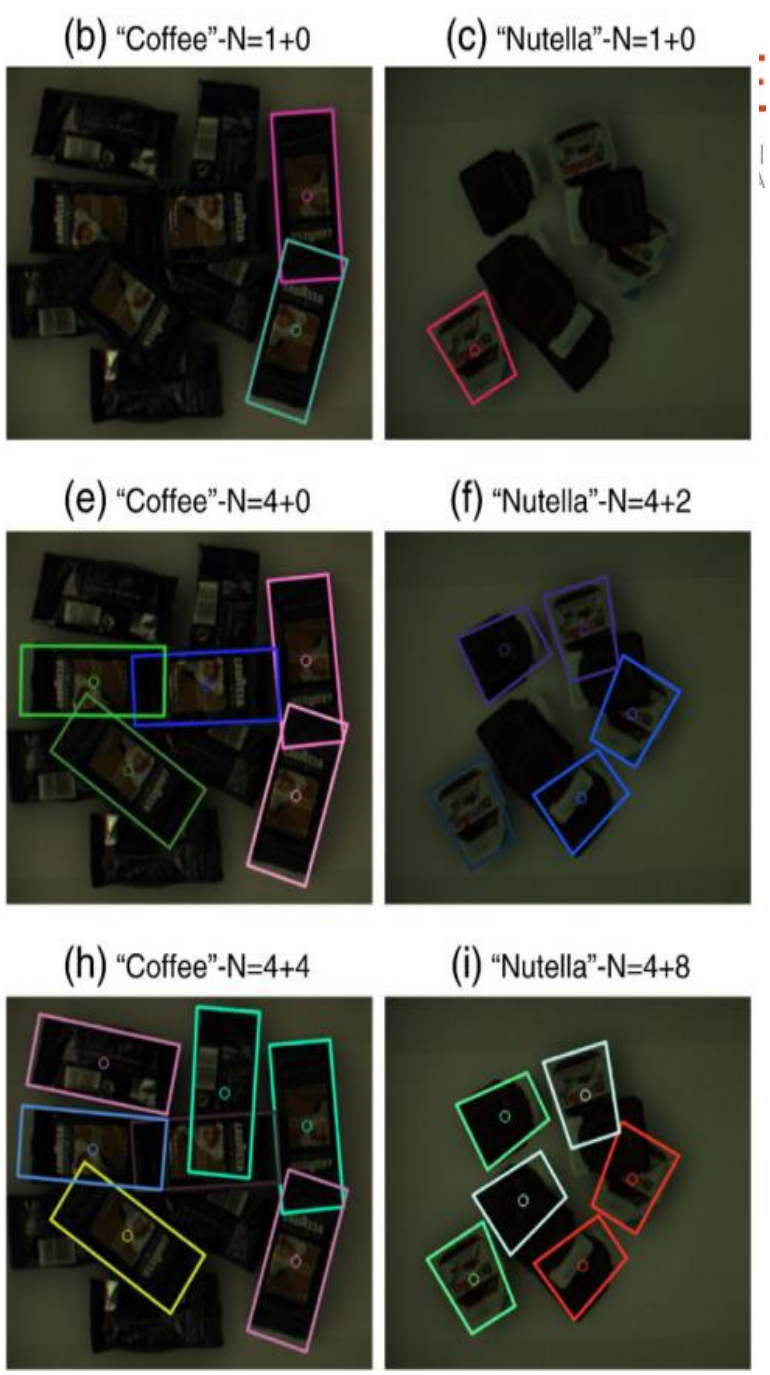
Mean-shift clustering for voting to single centers:

Estimations of center and control points by clustering






Model Acquisition
Image Acquisition
Control Point Definition
SIFT Keypoint Extraction
SIFT Descriptor Computation
OFF-LINE MODEL ACQUISITION
FEATURE EXTRACTION AND MATCHING
STORED MODELS
Are all the Faces Processed?
YES
NO
F = 1
Match Current Image with Model Face F
MATCHES' CLUSTERING
OBJECT LOCALIZATION
Center Voting Step
Mean Shift Clustering
Merge Face Object Detections
CTRL POINTS' LOCALIZ.
Control Points Voting Step
Mean Point Estimation
Object Detection
F = F + 1
LEGENDA
Flow of operations
Flow of data


(b) "Coffee"-N=1+0
(c) "Nutella"-N=1+0
(e) "Coffee"-N=4+0
(f) "Nutella"-N=4+2
(h) "Coffee"-N=4+4
(i) "Nutella"-N=4+8

Experimental results for single model approach.

	Object-level		Pixel-level		Center dist.
	Precision	Recall	Precision	Recall	Mean (px)
Juice					
All RS	100.00%	25.00%	22.95%	23.66%	5.41
Clus RS	91.67%	82.50%	77.43%	79.93%	18.97
Ours	97.37%	92.50%	88.55%	87.64%	5.76
Nutella					
All RS	100.00%	15.38%	13.23%	14.46%	6.98
Clus RS	66.67%	33.85%	38.96%	35.82%	17.24
Ours	97.84%	86.78%	82.87%	83.13%	3.86
Flyer					
All RS	90.00%	16.36%	17.46%	15.72%	14.68
Clus RS	74.00%	64.91%	71.31%	68.46%	22.27
Ours	96.15%	90.91%	86.35%	89.39%	2.66

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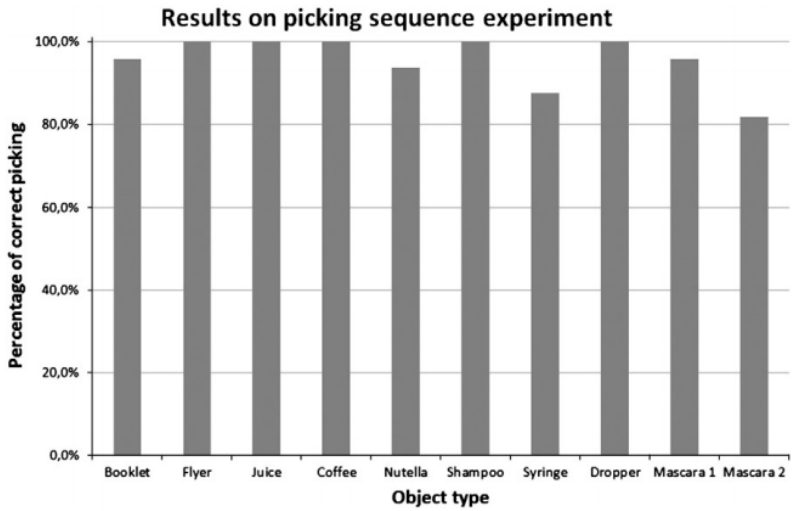
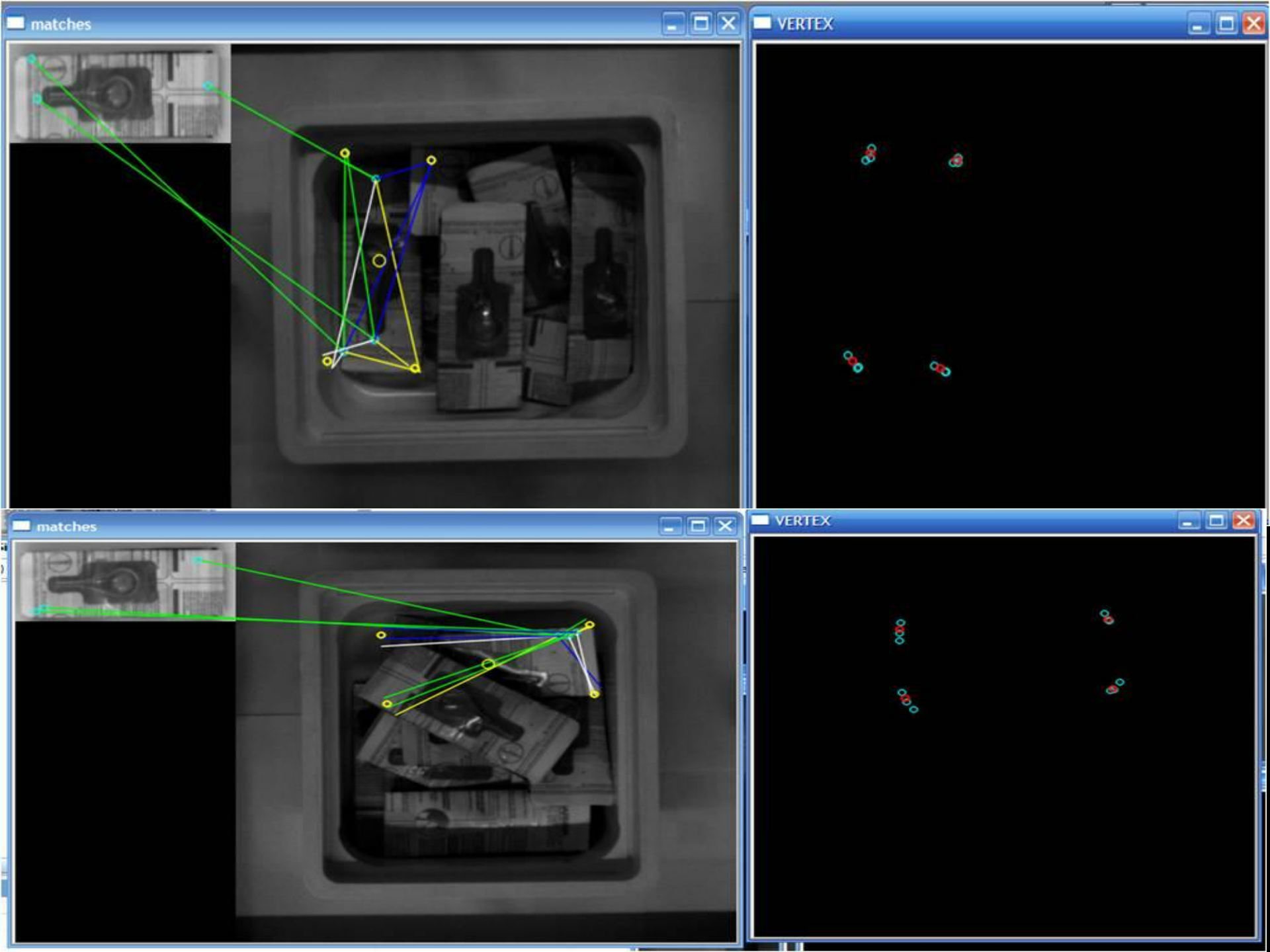
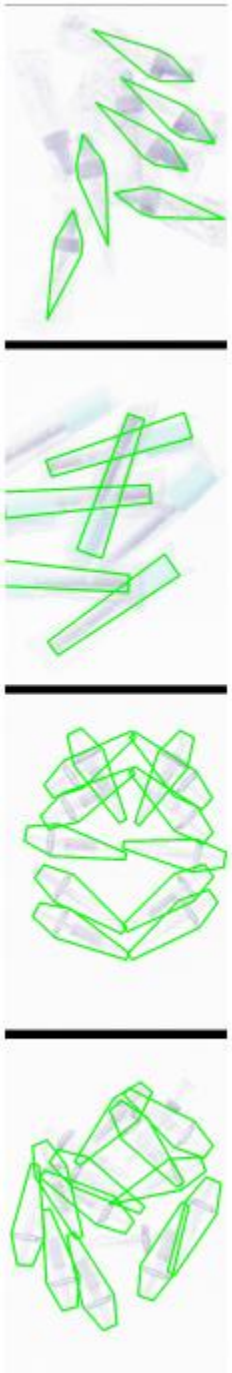
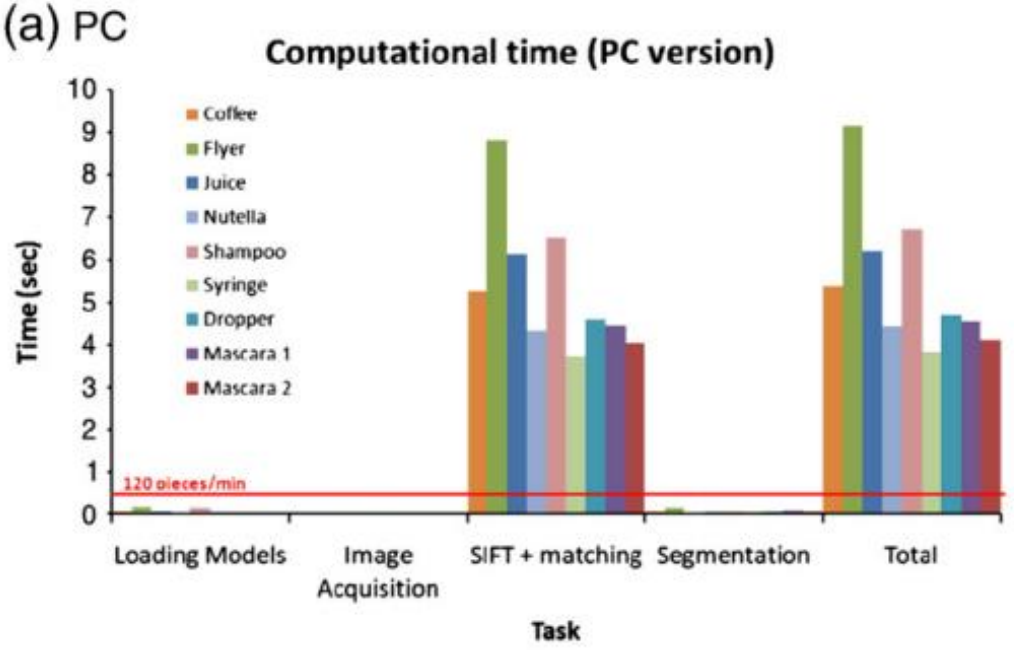
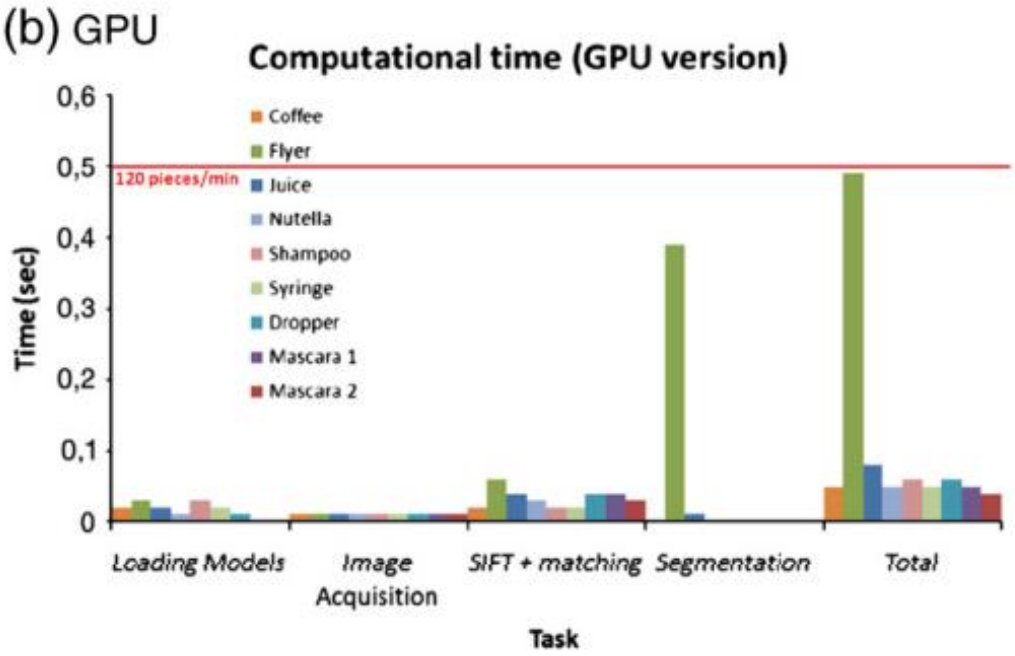



matches
VERTEX
matches
VERTEX

Real time processing only with GPU







NEXT STEPS?

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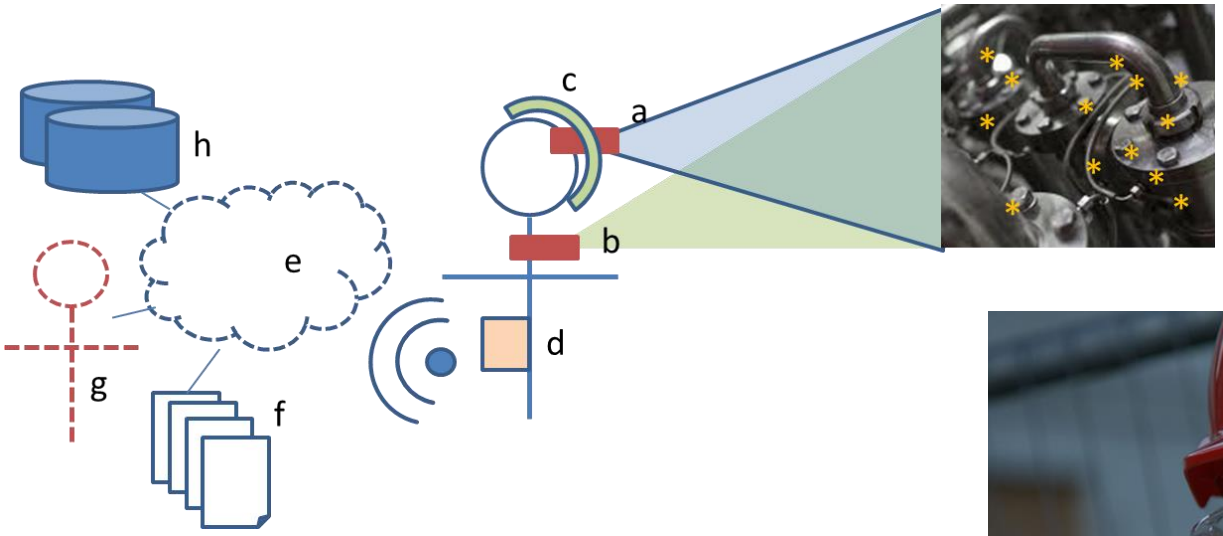
- Human in the loop: Augmented Vision for human-based inspection
- HAXIA Human Augmentation x Assistenza Industriale Softech-ICT 2014-2016
- R.Vezzani, Spin Automazione



- Classification with
- Keypoint matching
- Deep learning CNNs

THANKS

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RETE ALTA TECNOLOGIA EMILIA-ROMAGNA HIGH TECHNOLOGY NETWORK

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