



8th October

EMO 2015
STELLA POLARE
CONVENTION CENTER

FIERA MILANO RHO
Sagittarius conference hall - h. 9.30

Workshop

FUTURE TRENDS IN MACHINE TOOLS AND MANUFACTURING

**Computer Vision and Machine Learning
for Manufacturing**

Rita Cucchiara

Imagelab, <http://www.Imagelab.ing.unimore.it>

DIPARTIMENTO DI INGEGNERIA «Enzo Ferrari» Università di Modena e Reggio Emilia, Italia

Direttore SOFTECH-ICT

Research Center in ICT for Enterprise Tecnoplo di Modena

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Attivazione master di II livello - MUMET: Master in "Visual Computing and Multimedia technologies"



Al via il nuovo Master MUMET. Il master vuole creare nuove figure professionali (MULTIMEDIA DATA SCIENTIST), con competenze avanzate sulle tecnologie informatiche multimediali e sul visual computing, competenze attualmente molto rare ed assai richieste per i sistemi, servizi ed applicazioni nelle smartcities and communities.

Presentazione del Master

Sito web del Master in "Visual Computing and Multimedia technologies"

International Workshop on Wearable and Ego-vision Systems for Augmented Experience (WEsAX)



ImageLab is organising the first International Workshop on Wearable and Ego-vision Systems for Augmented Experience (WEsAX) that will be held on the July 3, 2015, in conjunction with the IEEE International Conference on Multimedia and Expo (ICME), Turin, Italy. The goal of the first International Workshop on Wearable and Ego-vision Systems for Augmented Experience (WEsAX) is to give an overview of the recent technologies and system solutions, create a forum to exchange ideas and address challenges emerging in this field.

Seminario Nvidia

Lunedì 17 Novembre 2014 dalle 14.00 alle 16.15 presso l'Aula PO 4 (ex FA-DC) - dipartimento DIFE - si terrà un seminario sulle architetture parallele



softex-ict
 Centro Interdipartimentale di Ricerca
Softech: ICT per le Imprese



ImageLab is a research laboratory at the Dipartimento di Ingegneria "Enzo Ferrari", University of Modena and Reggio Emilia, Italy. ImageLab is also part of the Centro di Ricerca Interdipartimentale in ICT Softtech-ICT of the Modena Technopole.

Research at ImageLab covers topics of Computer Vision, Pattern Recognition & Machine Learning, and Multimedia, applied to optical images and videos as well as data from different sensors.

In addition, ImageLab is currently involved in research activities on vision-based human-computer interaction. In particular, the main research activities concern:

- video surveillance, machine vision and robot vision,
- medical imaging, human-centered multimedia, content-based retrieval, people detection and tracking, human behaviour understanding, Egocentric vision and embedded sensors.

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www.imagelab.unimore.it

IMAGELAB
 DIFE UNIMORE Lab
 4 staff people
 15 phd students and post doc
 1 spin-off
 >300 scientific publications



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News ed Eventi

Pubblicazione Brevetto - progetto Fiorimage
 WO 2014/1106 A1

Protocollo di Intesa
 "Osservatorio su Media Digital"

Invited speech @ ICCBE2015: "Human Behavior understanding in video"
 Prof. Caccubeni is presenting a talk on "Human Behavior understanding in video" at the International Conference on Computer Science and Engineering.

INAUGURAZIONE TECNOPOLIO DI MODENA
 Sabato 13 dicembre ore 10.00 - 13.00 via Vivarelli 2 - Modena

Softech-ICT è un Centro Interdipartimentale di Ricerca in ICT per le imprese promosso dal Dipartimento di Ingegneria "Enzo Ferrari" e dal Dipartimento di Economia "Marco Biagi" di UNIMORE.

Softech-ICT è un laboratorio accreditato dalla Rete Atti Tecnologie della Regione Emilia-Romagna, cofinanziato dall'EU FESR2007-2013, e al tempo stesso uno dei laboratori portanti del Tecnopolo di Modena. Softech-ICT svolge un ruolo di primo piano nell'ambito della Piattaforma Tecnologica "ICT e Design" della Regione.

Softech-ICT promuove, coordina e svolge attività di ricerca applicata, industriale e di trasferimento tecnologico nel settore ICT, con competenze in Informatica, Telecomunicazioni, Automatica ed Elettronica e nei relativi modelli economici, organizzativi e di business.



ASTER
 Area Alta Tecnologia

INTRANET

- Intranet Softech-ICT

Link

- Aster piattaforma ICT e Design
- Regione Emilia-Romagna
- Dipartimento di Ingegneria Enzo Ferrari
- Dipartimento di Economia Marco Biagi

www.softex-unimore.it

SOFTECH-ICT
 EU FESR2007- lab
 UNIMORE Technopole of Modena
 Emilia Romagna High technology network
 Interdipartimental center of research in ICT

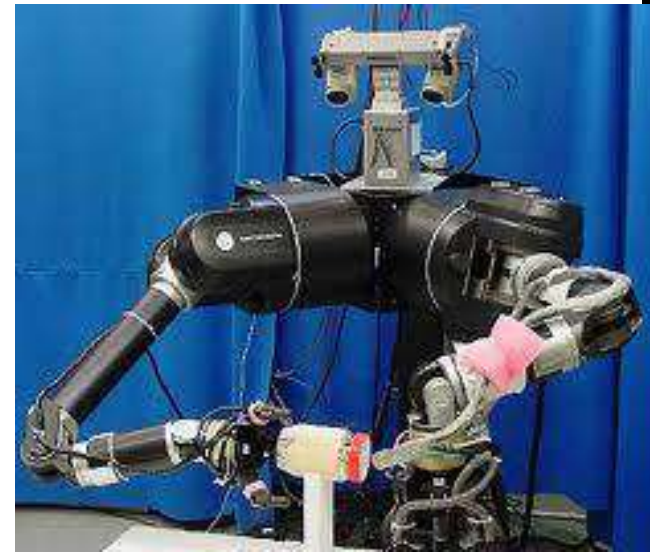
>50 people
 Ict for enterprise

3 QUESTIONS:

Why computer vision is so fashionable?

*Why machine learning
and pattern recognition
are so strategic ?*

*What can we do for
manufacturing?*



Computer Vision

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

Pattern Recognition

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

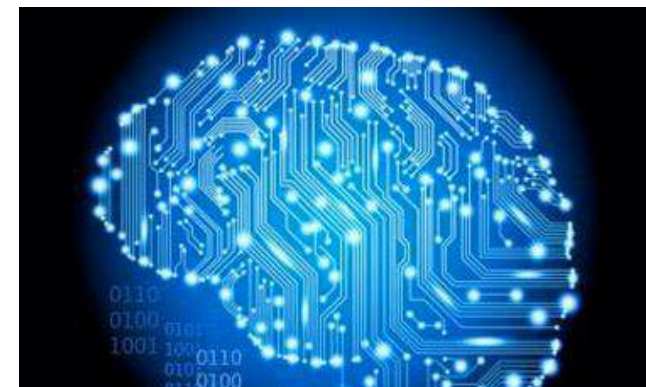
Machine Learning

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

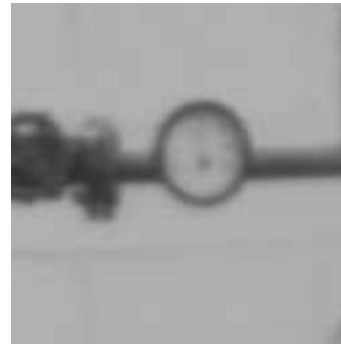
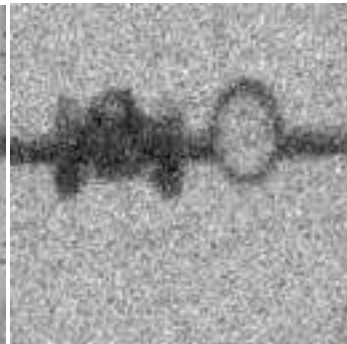
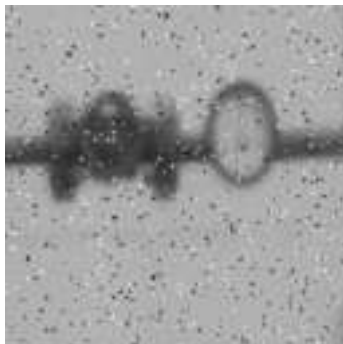
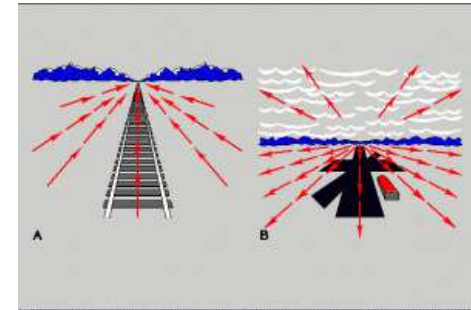
Probabilistic theory

'80

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

Syntactic and
Structural PR
Neural Networks

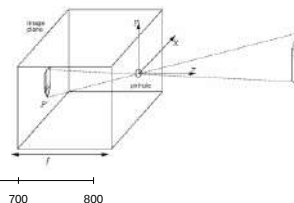
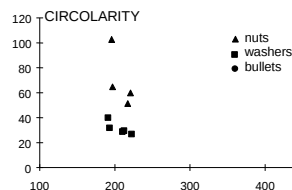
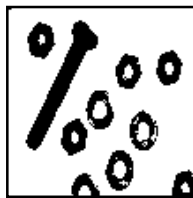
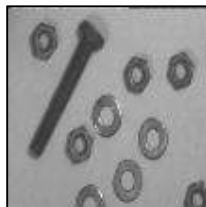
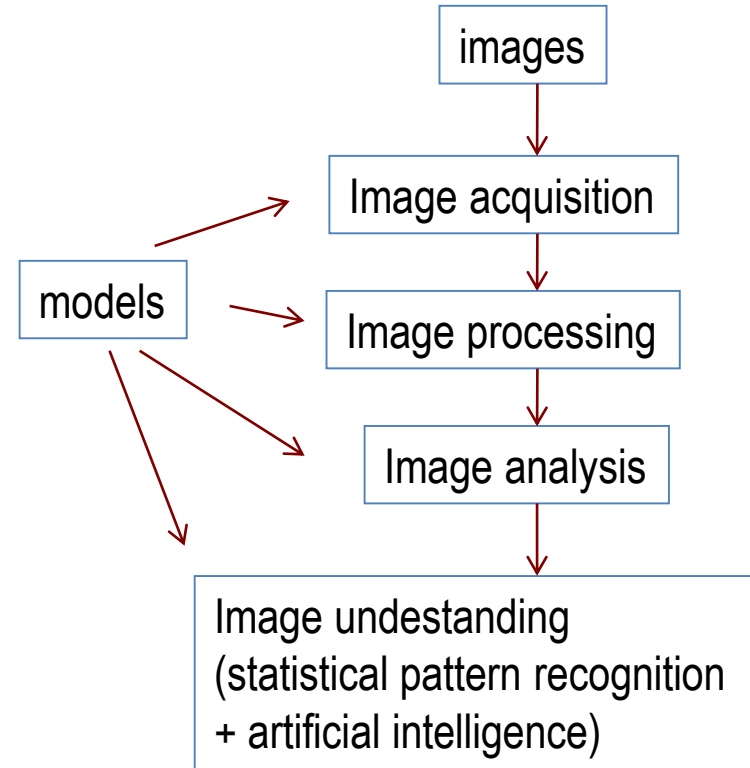
Pattern Recognition and Machine learning



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

'90

Statistical PR
Clustering
Bayesian nets
Hidden Markov Models
Supervised Classification



Object #8

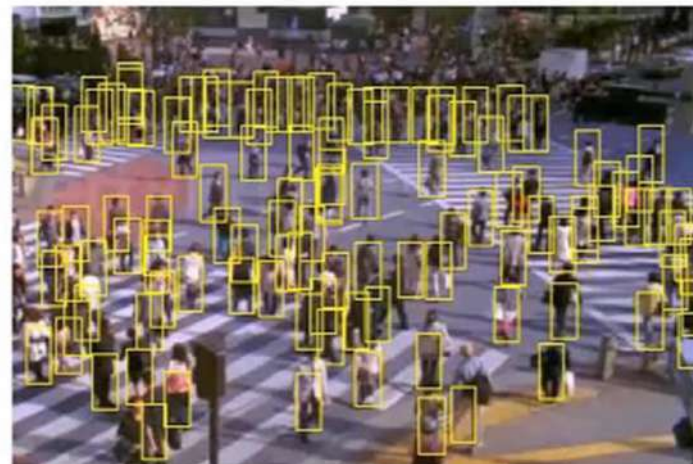
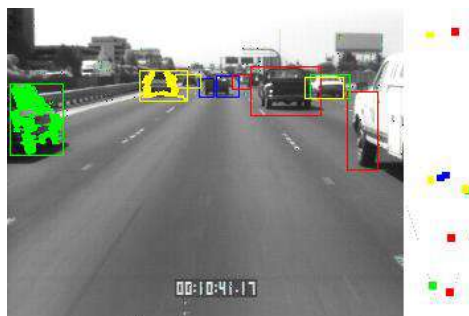
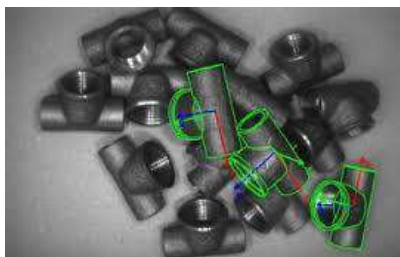
Diameter: 22.3 mm
Position: (47,38) mm

I see an object circular
that is a «nut»

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

'00

Support Vector Machine
Graph analysis
Clustering, Boosting
Bag of words

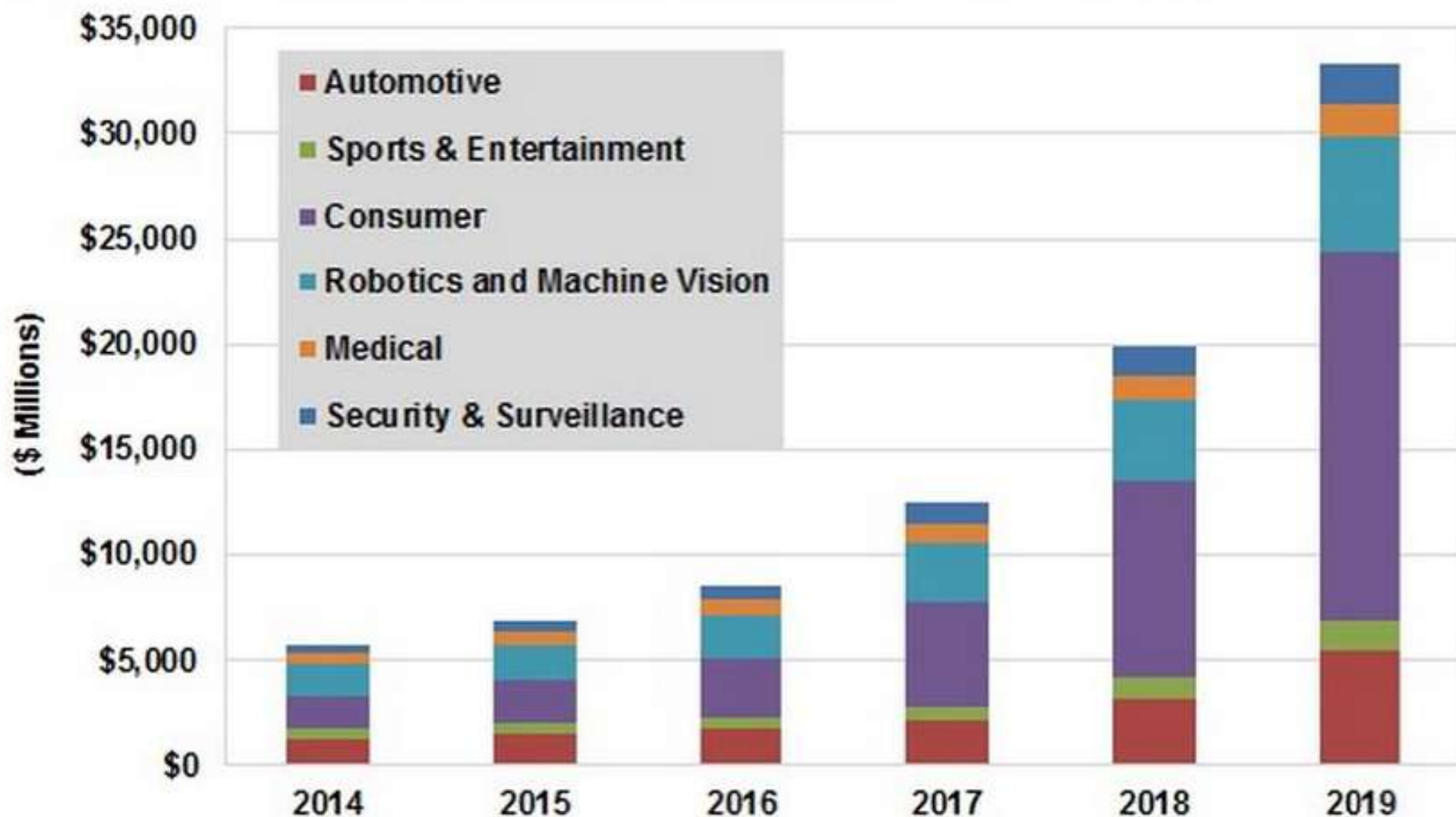


Concept, event
Action detection
Gesture HCI..

'10

Deep Learning

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



WHY VISION AND LEARNING IN MANUFACTURING?

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..)

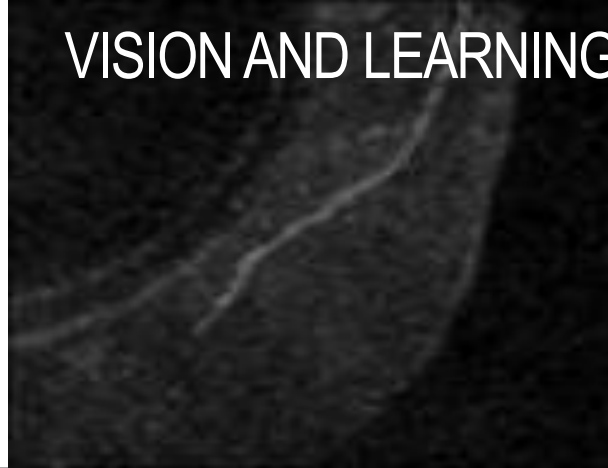
3D reconstruction and augmented reality

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

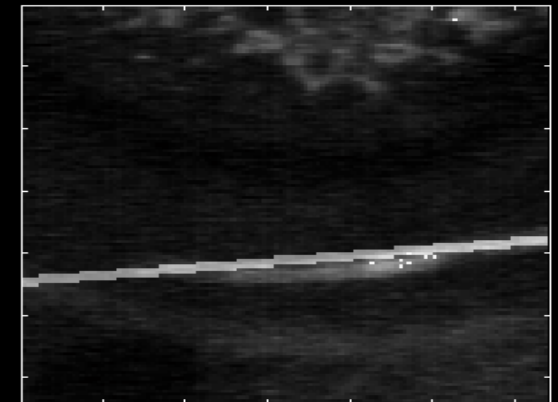
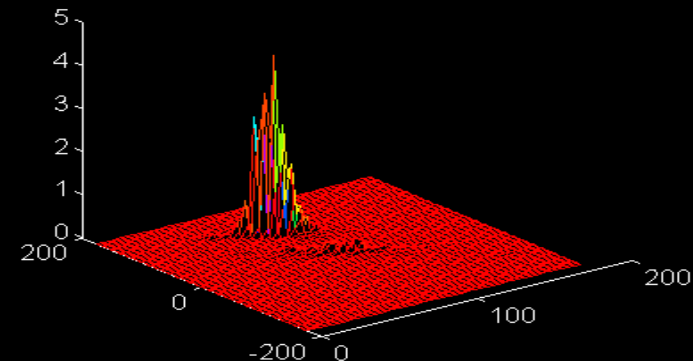
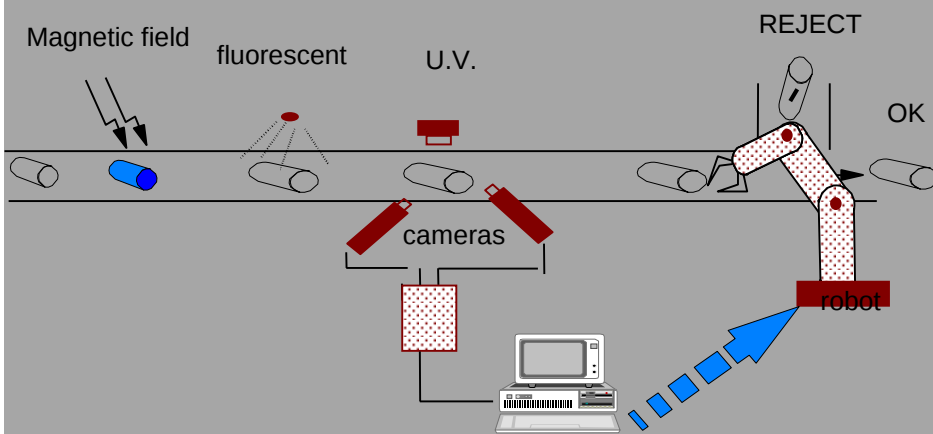
QUALITY INSPECTION



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.

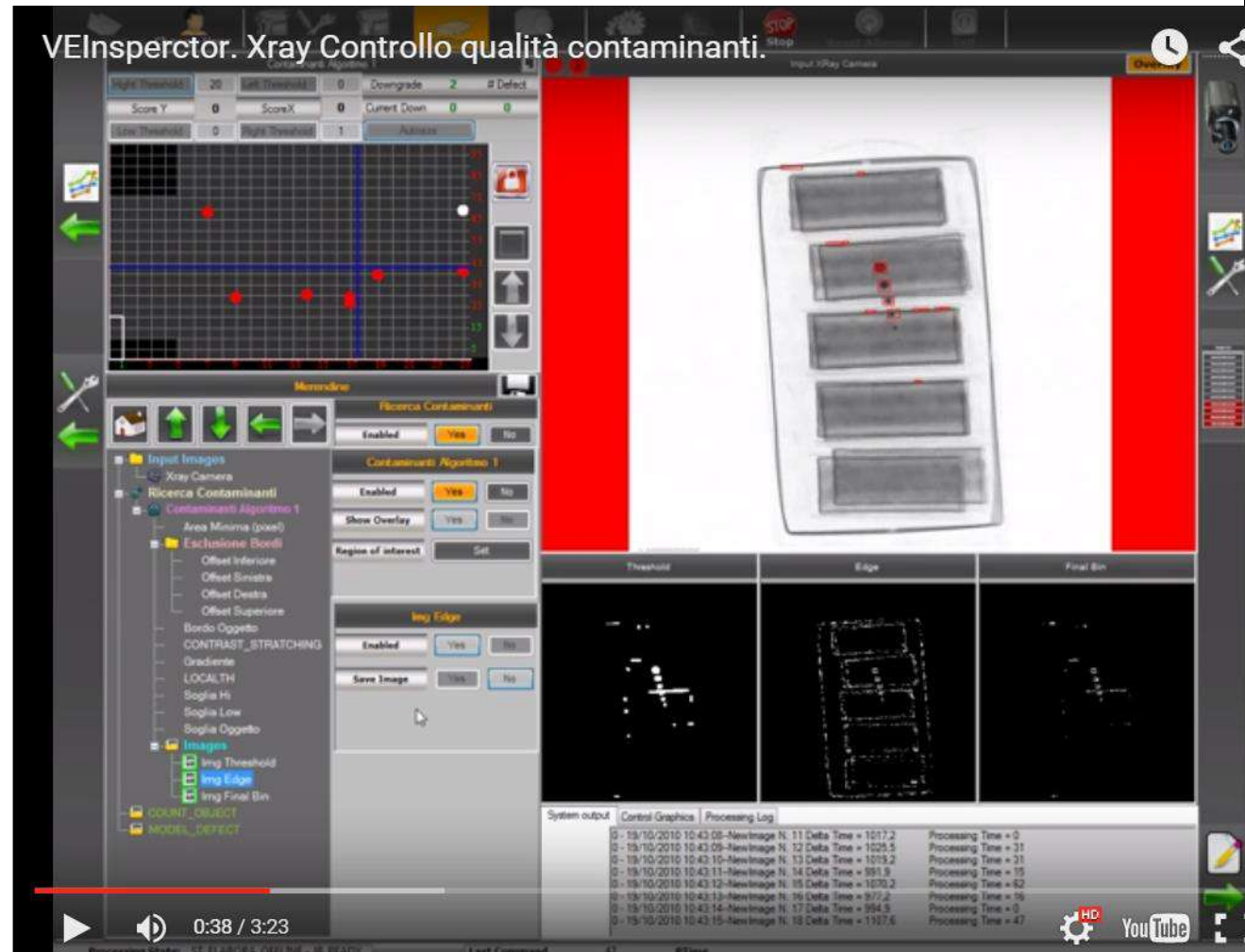
Table 1. Average accuracies

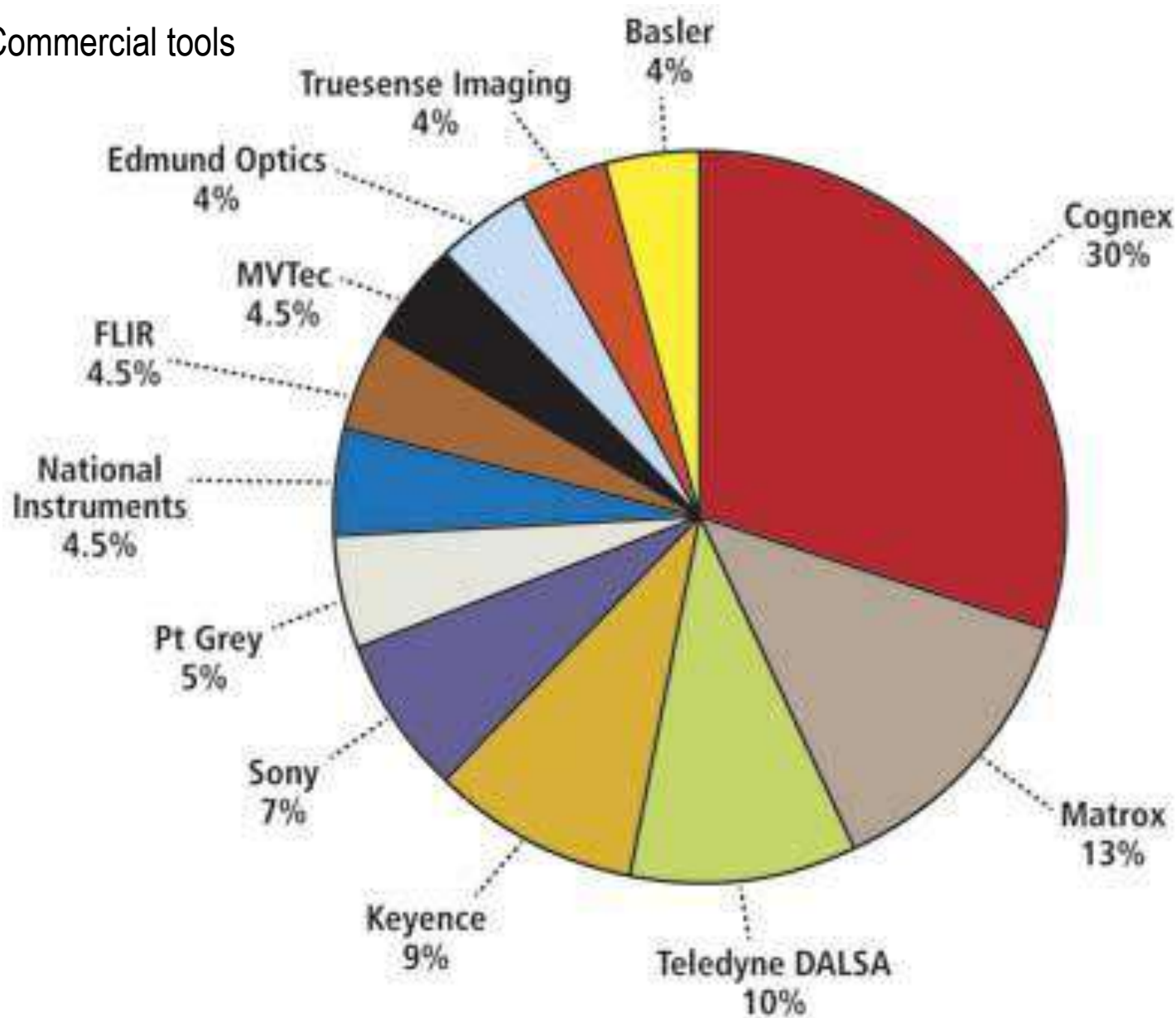
	Discrim	Logdisc	Quadisc	NN	Predict	c4.5 tree	c4.5 rules
CH	0.853	0.857	0.853	0.885	0.873	0.959	0.959
H1 H2	0.855	0.928	0.316	0.845	0.864	0.933	0.933

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

NOW commercial tools.

Thanks to VISION-E srl
UNIMORE spin-off





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

(by vision-system.com)

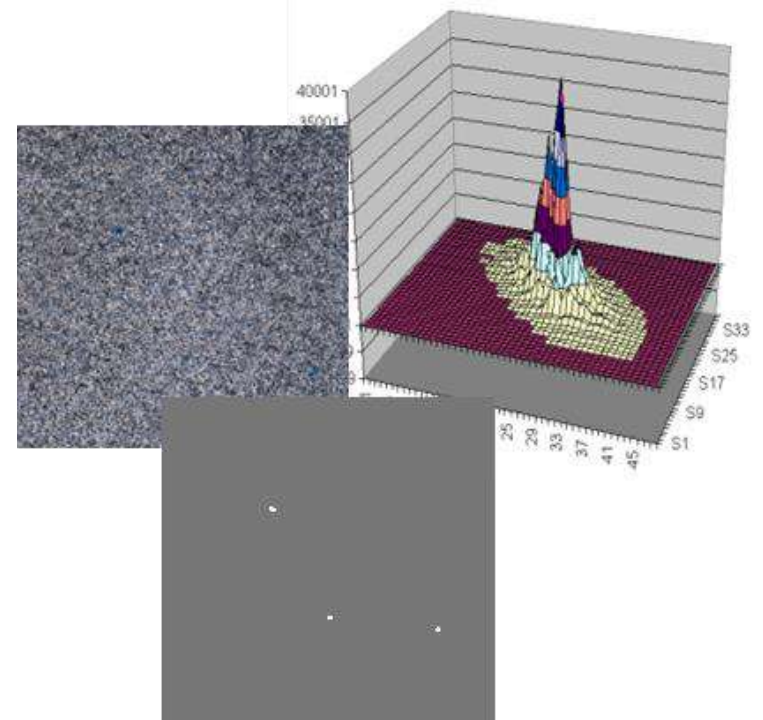
For open-source sw OpenCv, PointCloudLib, ... → CVonline/SWEnvironments.html

Special solutions for special problems....

FLAW Detection 2006 -

Italvision-Imagelab

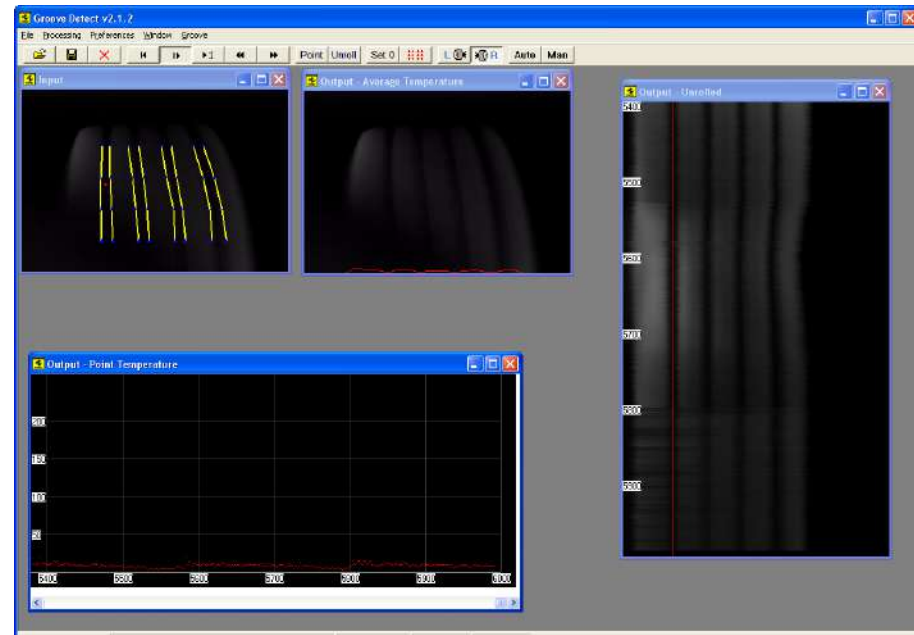
Texture and k-means clustering



Dynamic weels' grooves analysis 2005-

Ferrari-Imagelab

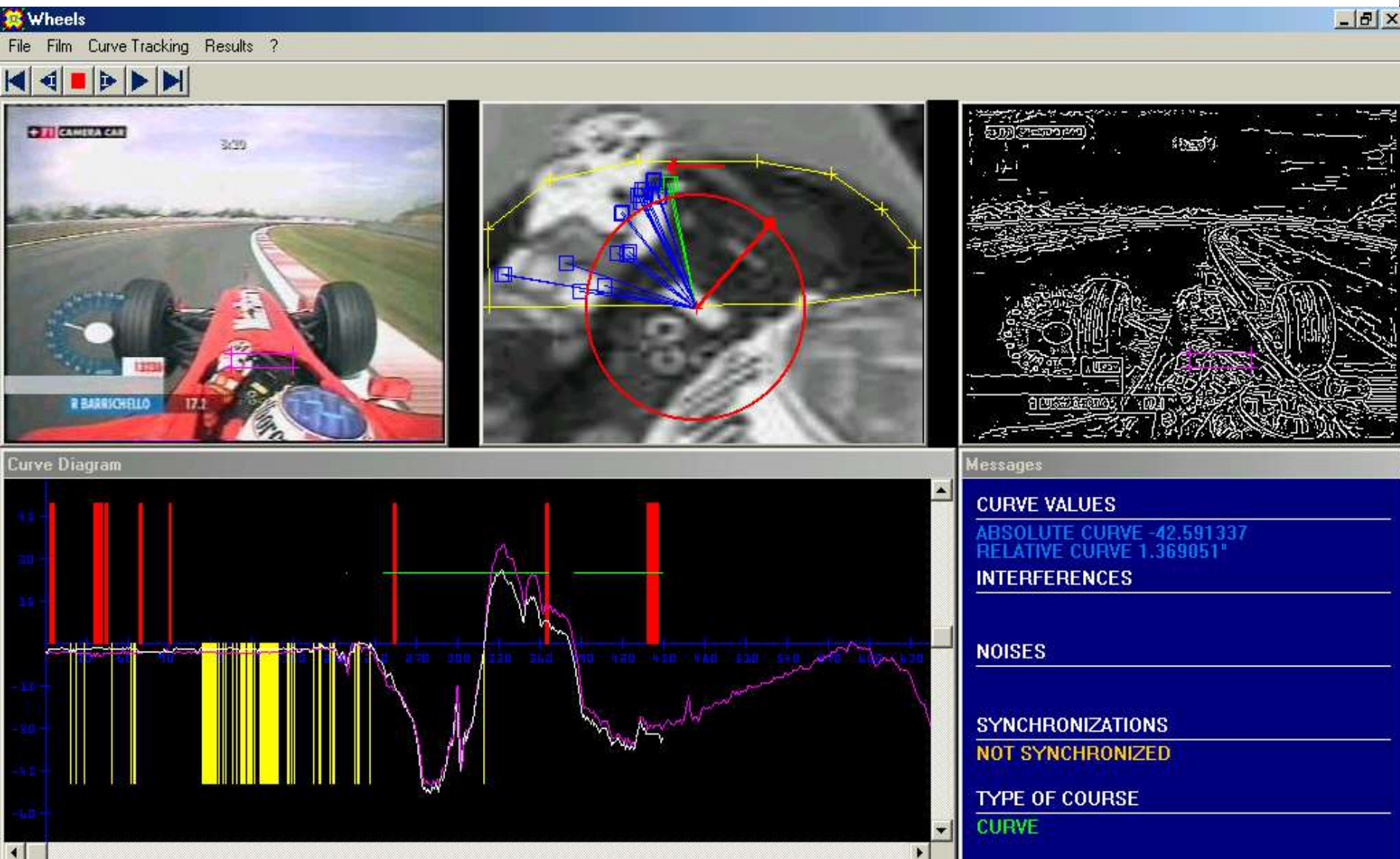
Active contour models (Snakes)



MOTION INSPECTION

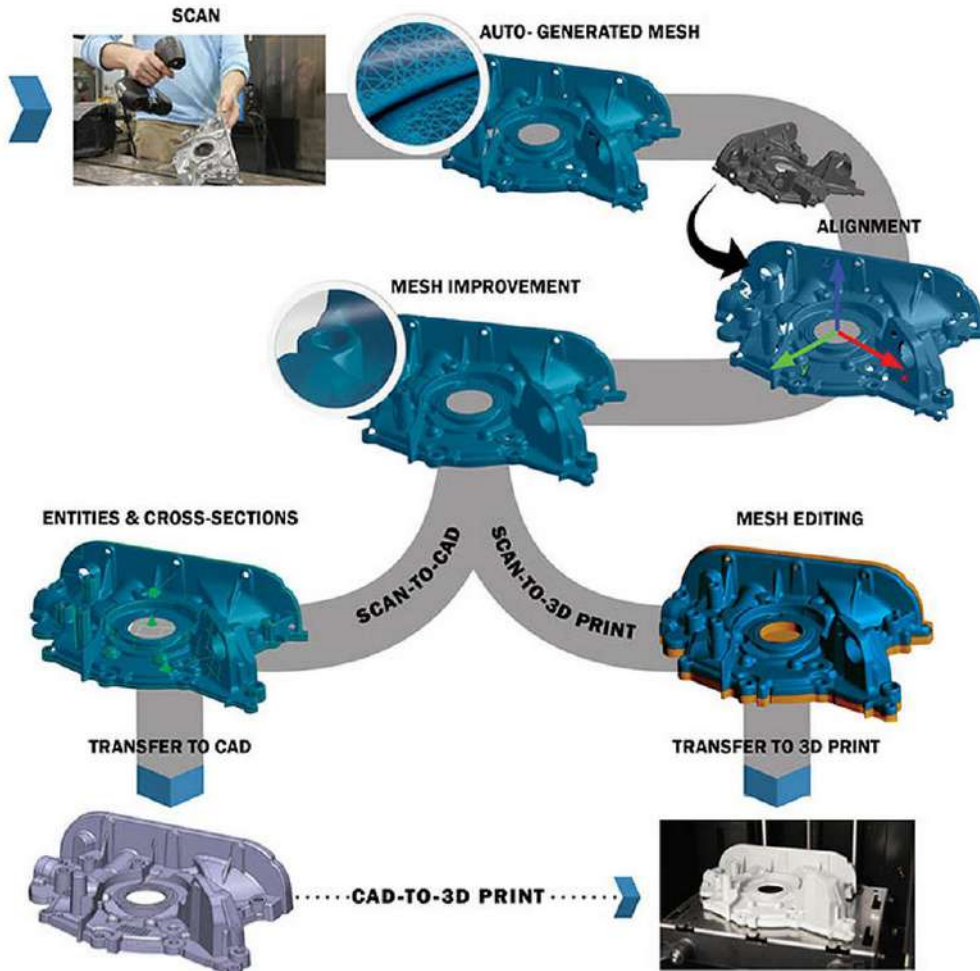
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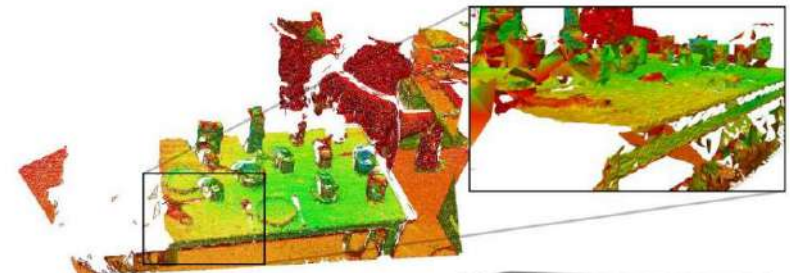
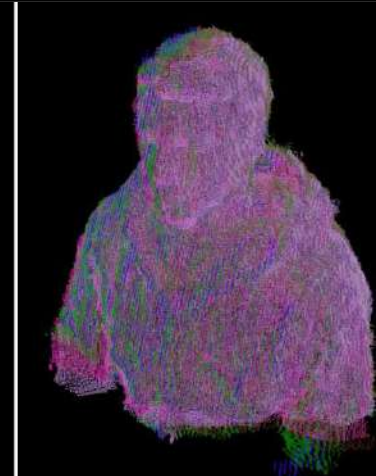
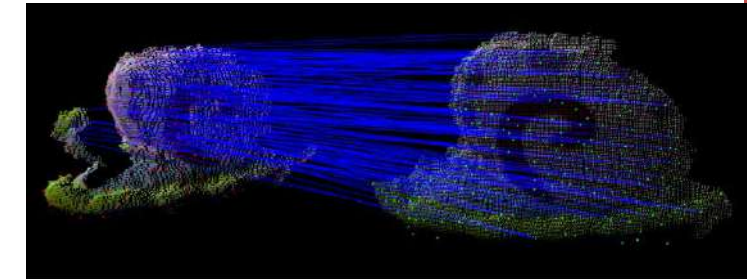


3D INSPECTION

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

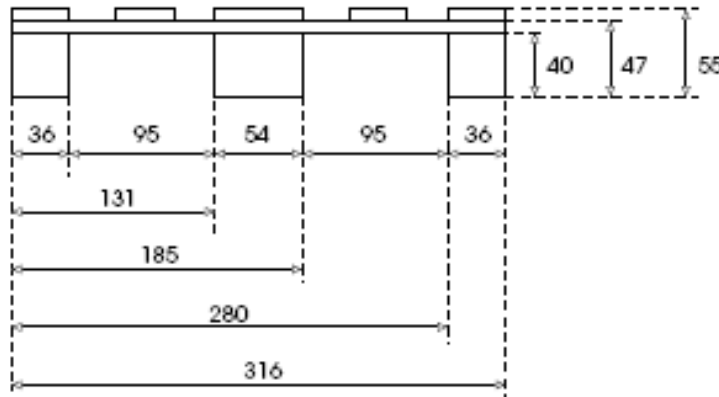
*Kelly, A., Nagy, B., Stager, D., Unnikrishnan, R., "An Infrastructure-Free Automated Guided Vehicle Based on Computer Vision", IEEE Robotics and Automation Magazine. 2007.



AUTONOMOUS GUIDANCE: TARGET DETECTION BY VISION

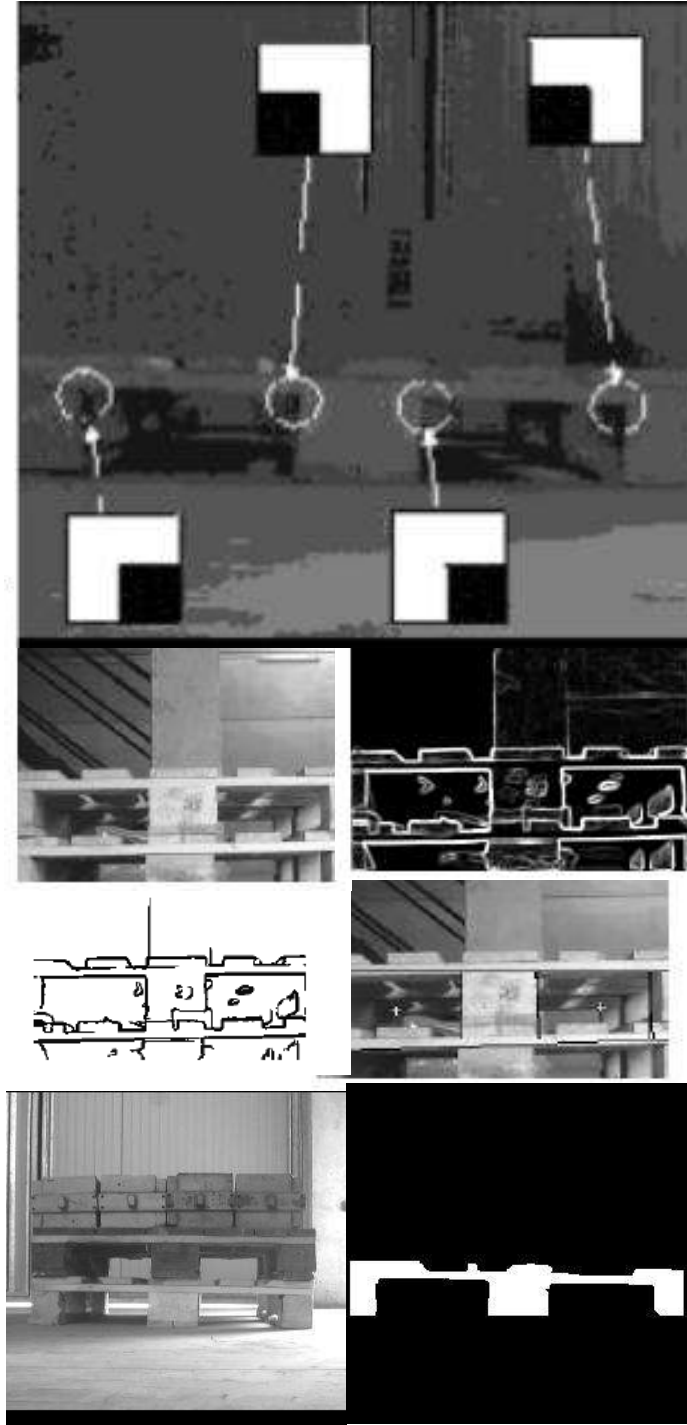
Pallet recognition in un-constrained environment

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



R. Cucchiara, M. Piccardi, A. Prati, "Focus based feature extraction for pallet recognition"

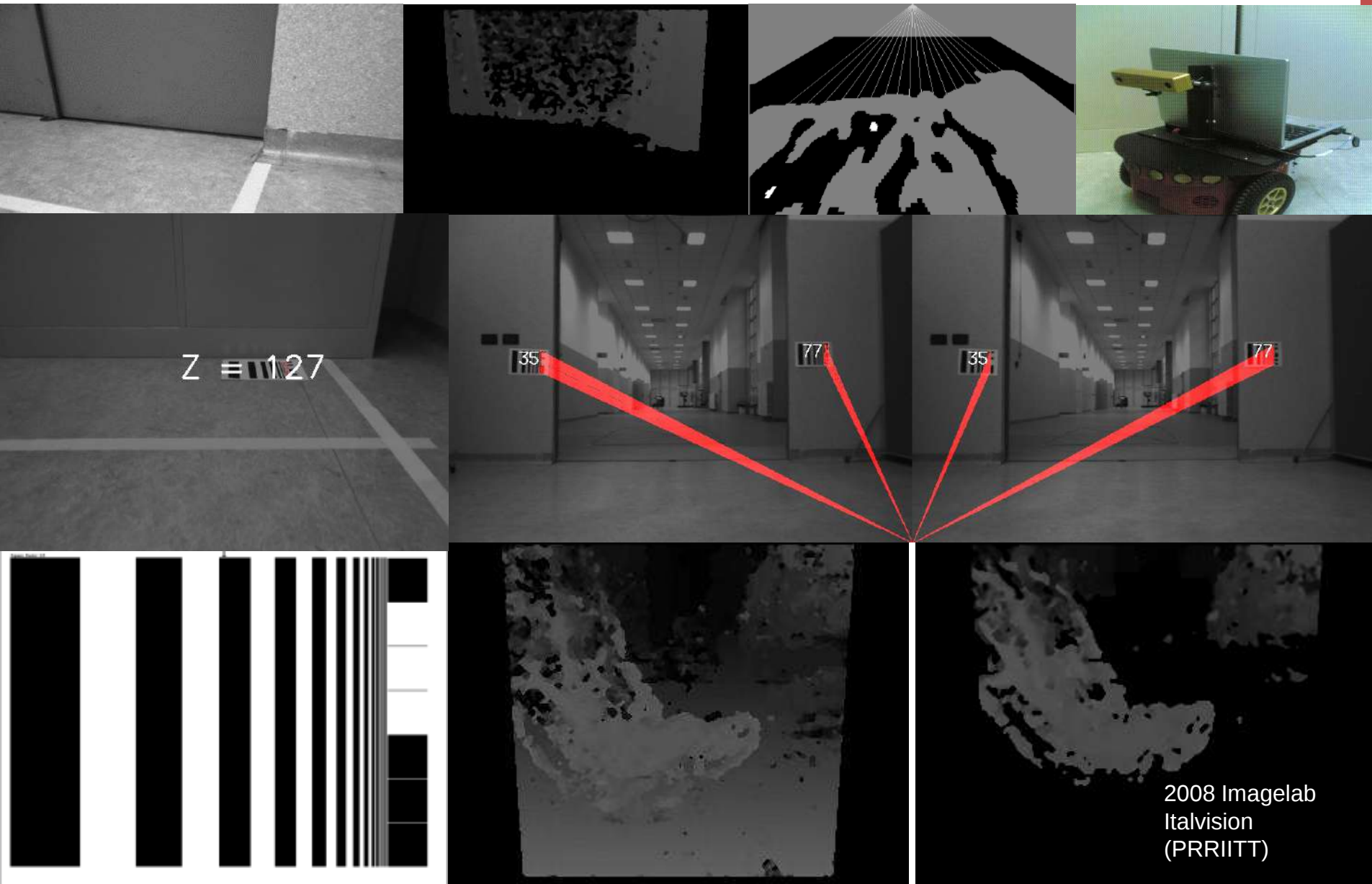
in *Proceedings of the 11th British Machine Vision Conference (BMVC 2000)*, Bristol, UK, pp. 695-704, 2000



AUTONOMOUS GUIDANCE: LOCALIZATION BY STEREO VISION

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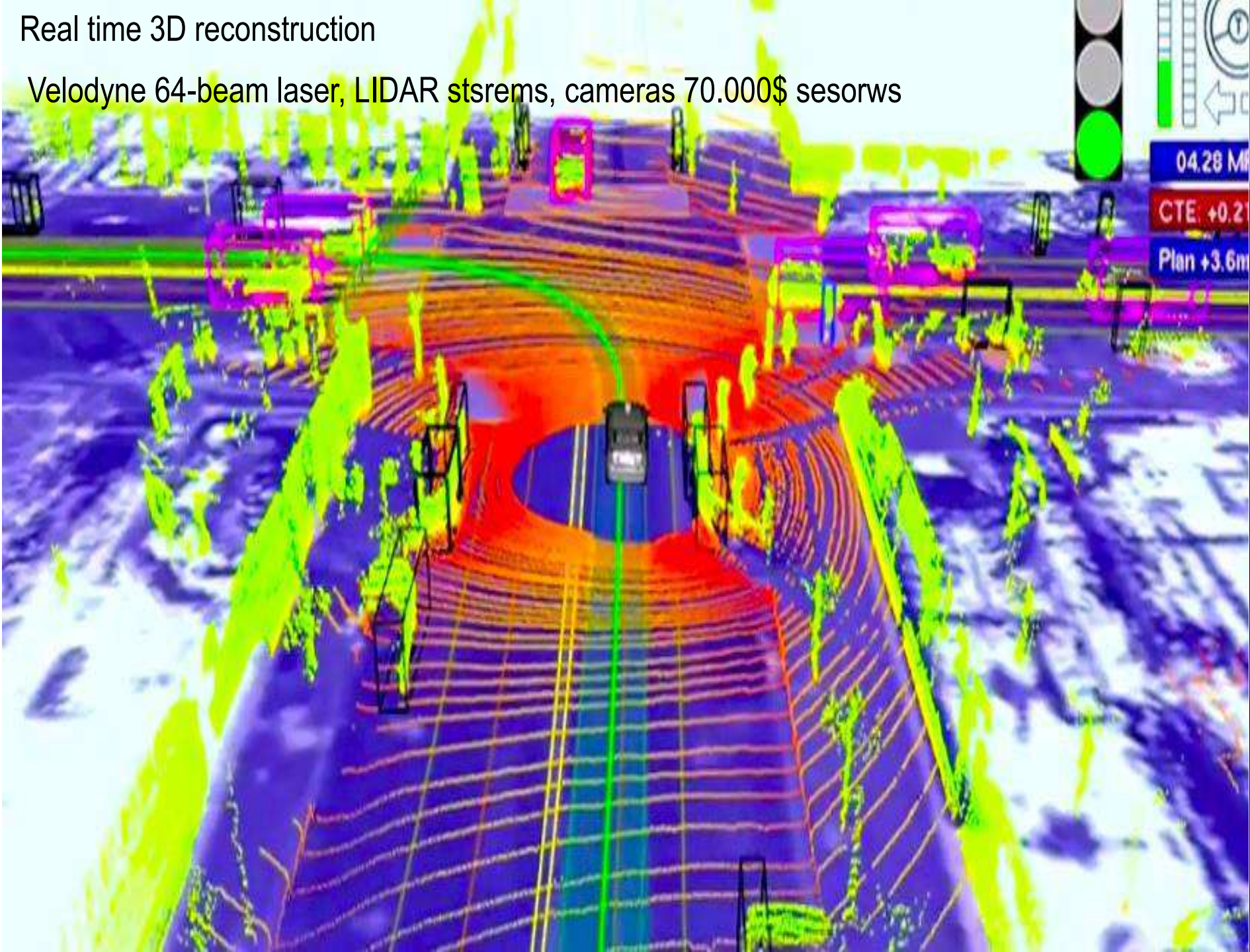


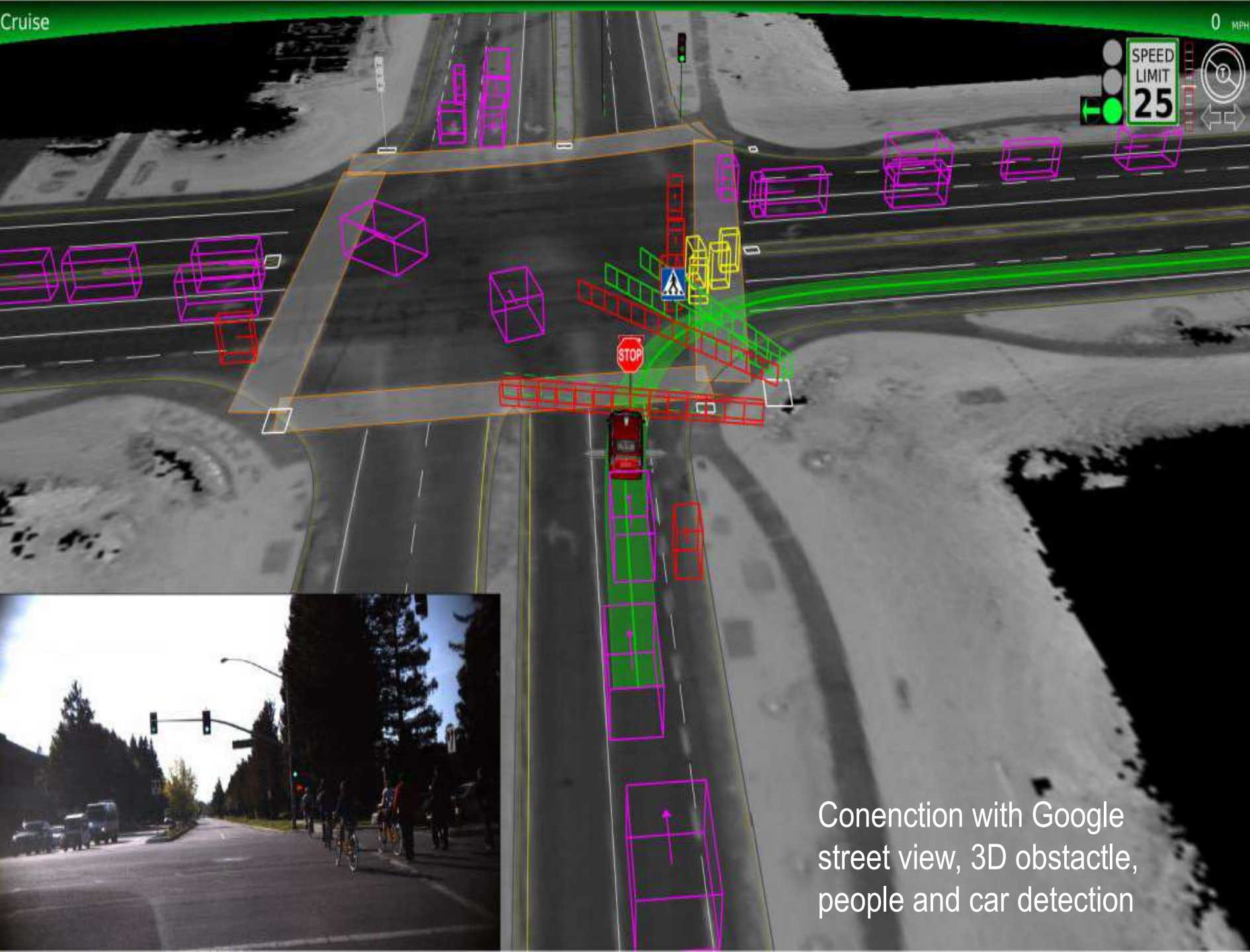
NOW VISION, LEARNING AND BIG DATA



Real time 3D reconstruction

Velodyne 64-beam laser, LIDAR streams, cameras 70.000\$ sesorws



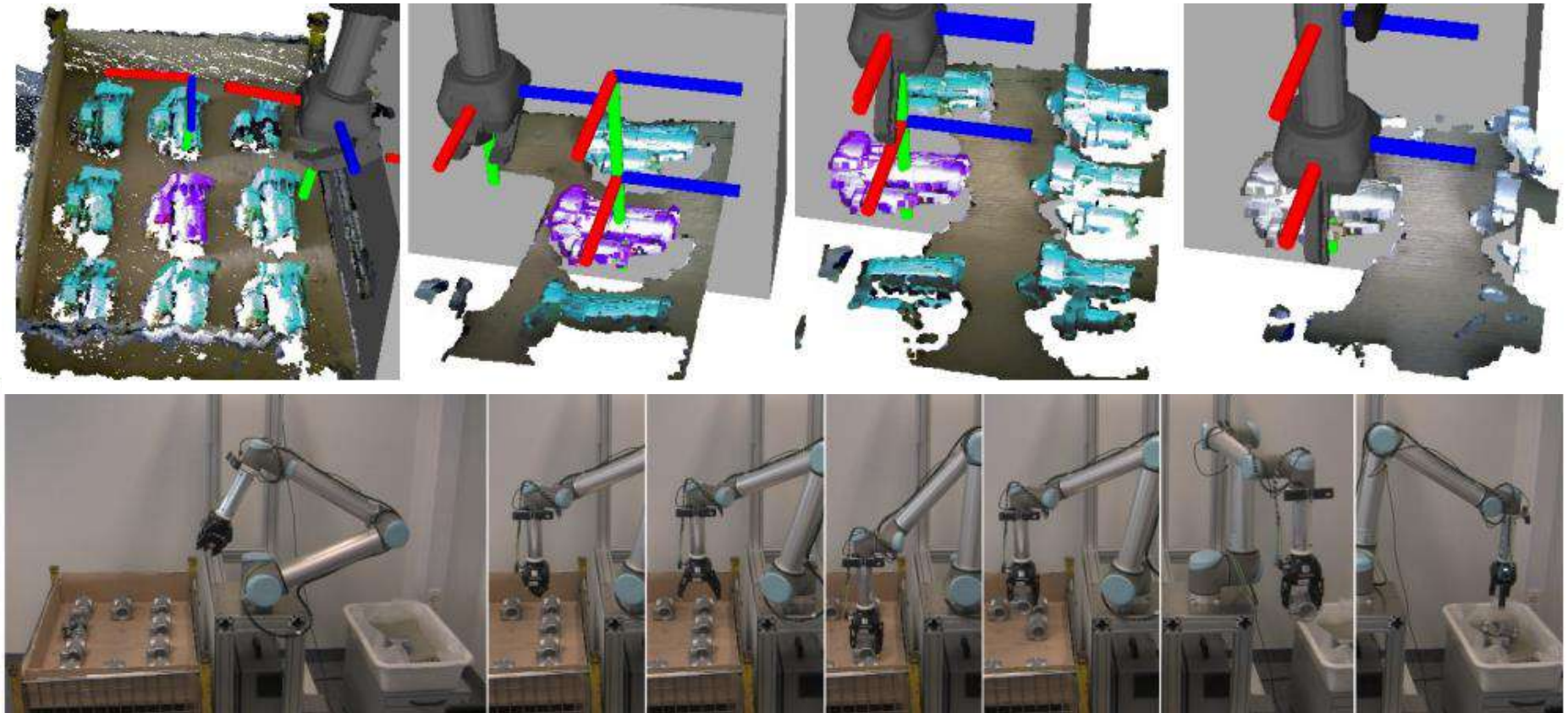


Conenction with Google
street view, 3D obstactle,
people and car detection

OBJECT DETECTION

Since '80 **model-based vision***

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

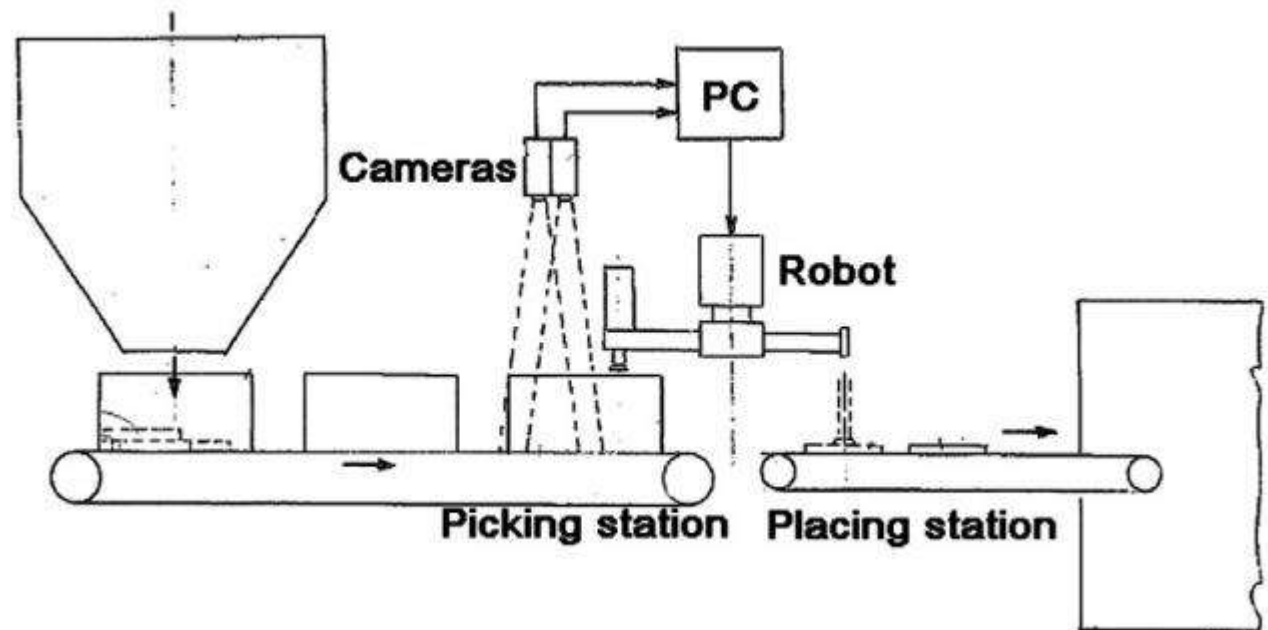


*R.Chin, C. Dyer «Model based Recognition in Robot Vision» ACM Computing survey 1986

**Dirk Holz, Angeliki Topalidou-Kyniazopoulou, Jorg Stuckler, 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, eccentricity..) 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

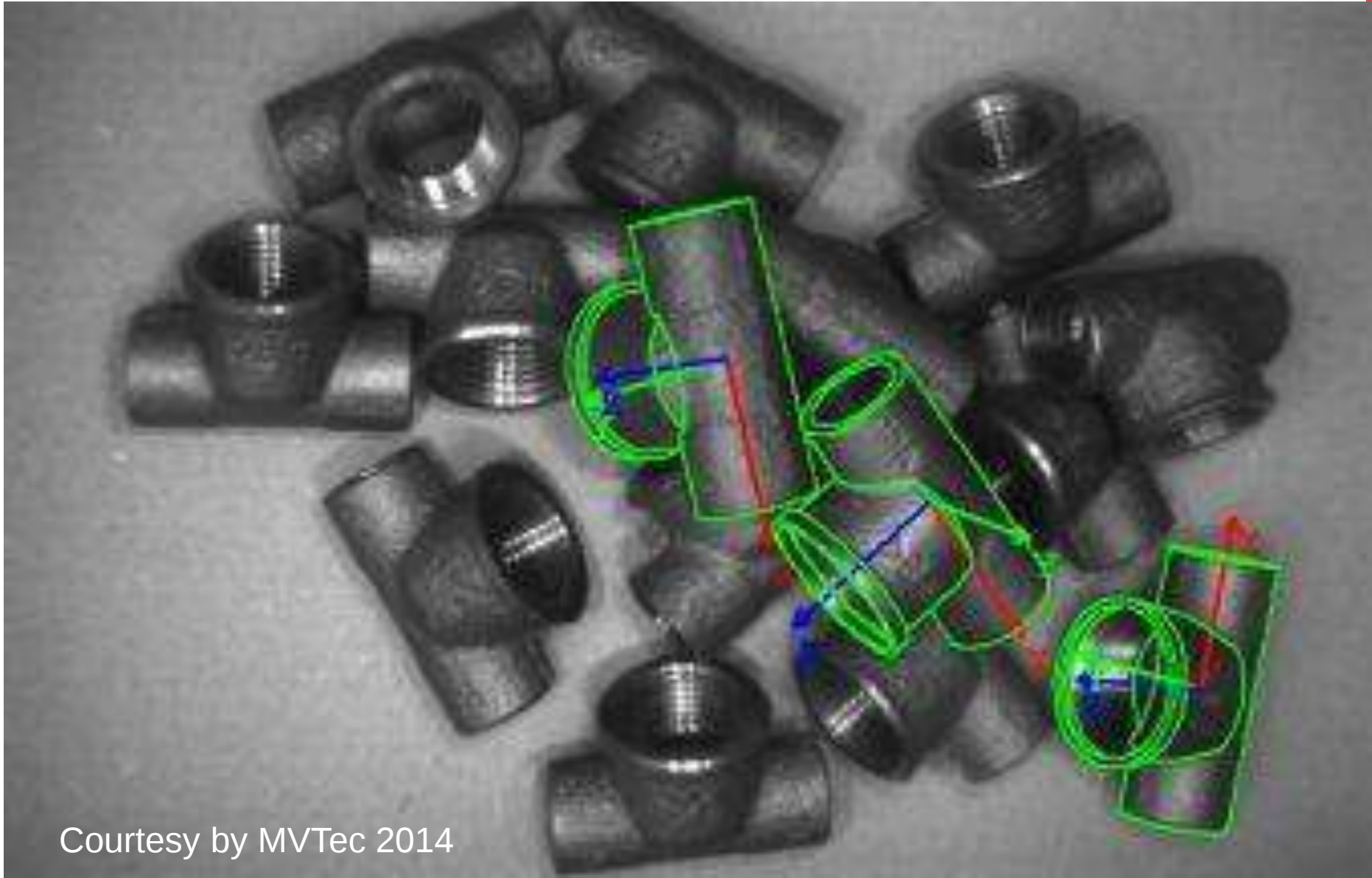


Now... Many commercial products

based on template matching, with CAD-based view

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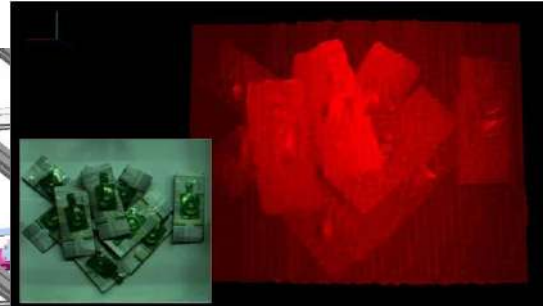
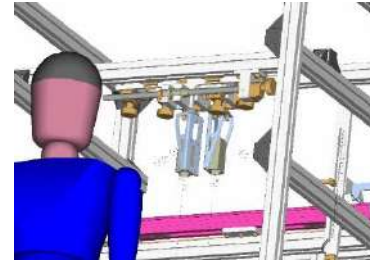
Courtesy by MVTec 2014

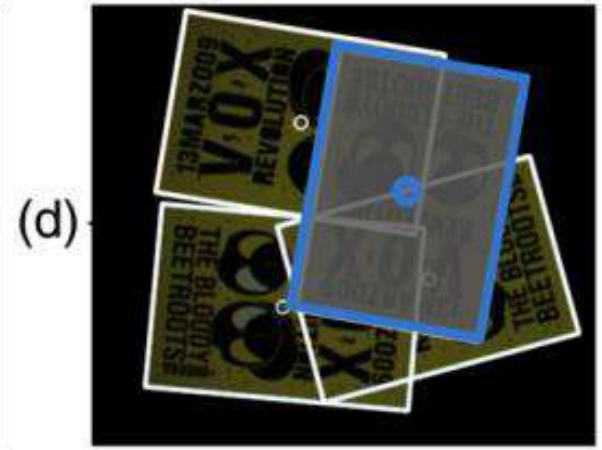
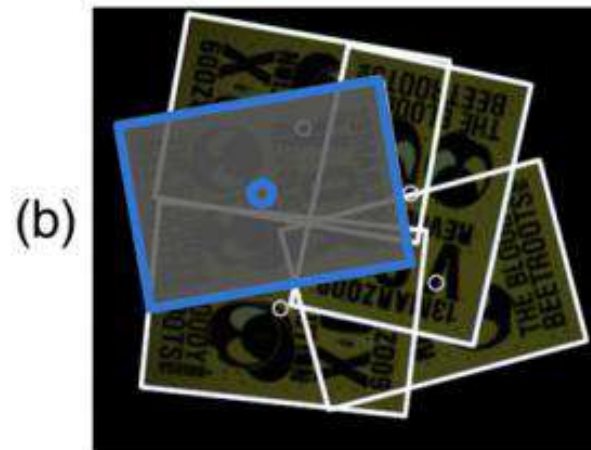
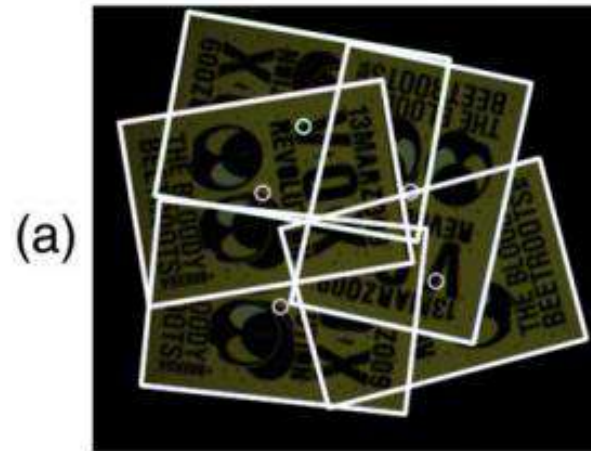
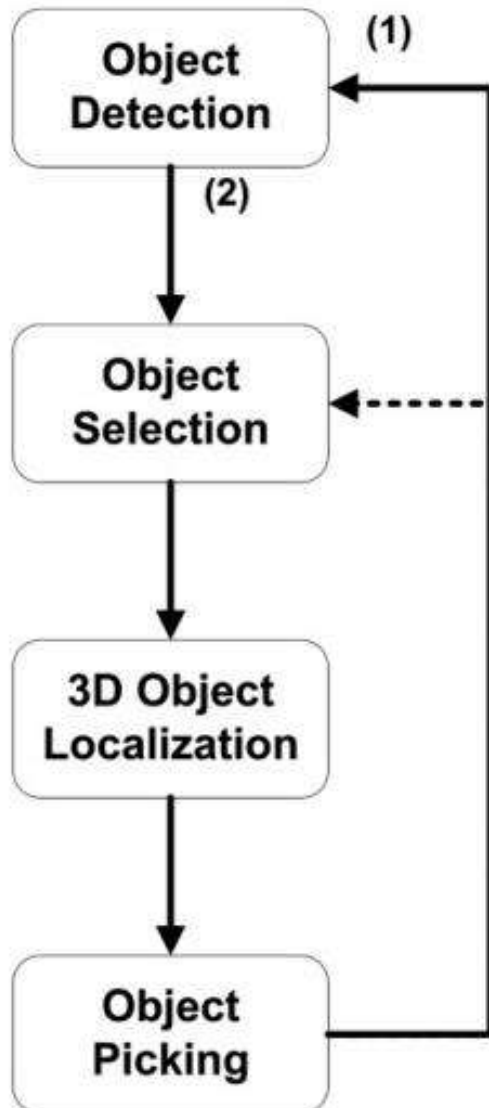
VISION AND LEARNING FOR PICK-AND-PLACE

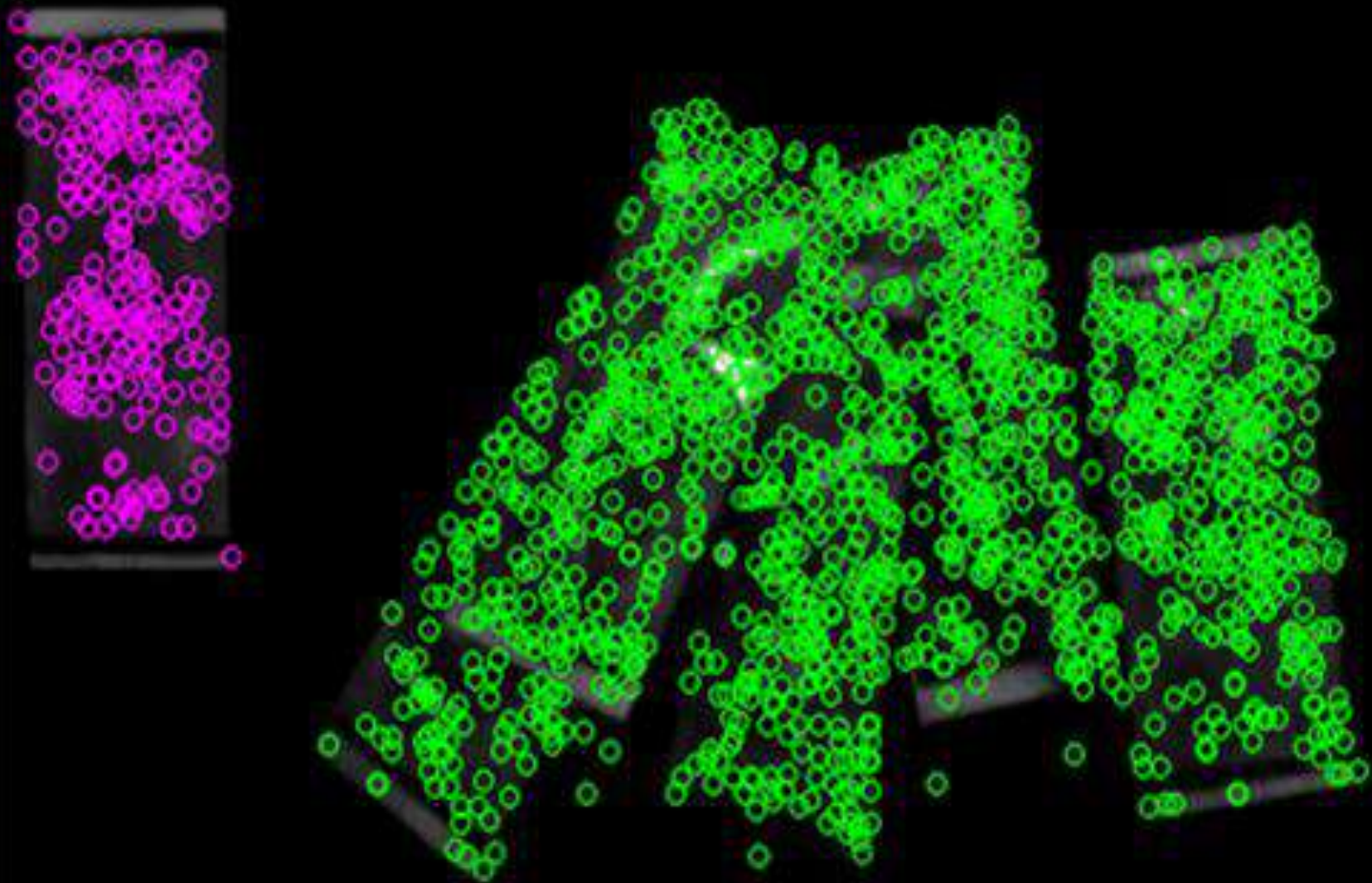
With Marchesini spa, Bologna Patent . BO2009A 000278.

Paolo Piccinini PhD

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







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

Object localization by a registration transform

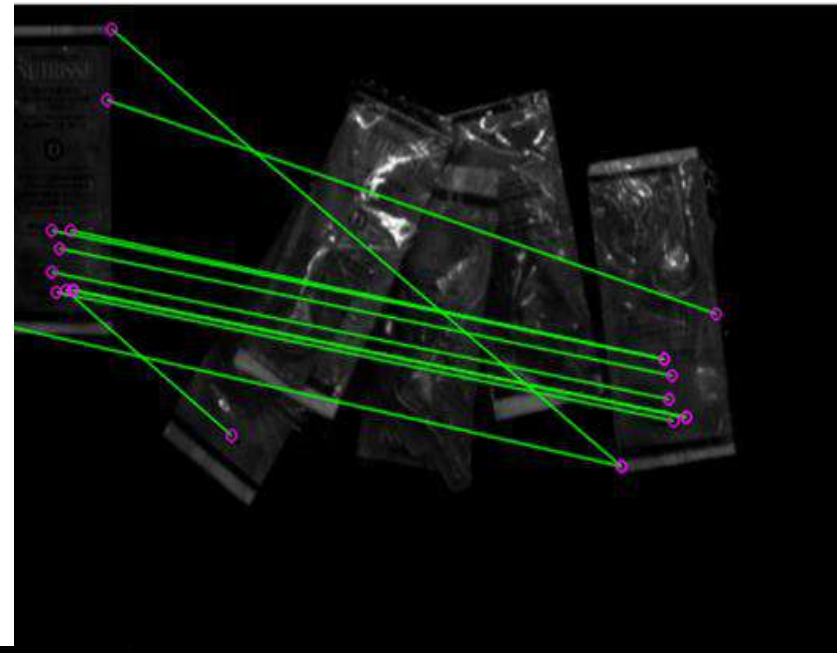
$K = \{k_i \equiv (x_i, y_i, D_i, \vartheta_i)\}_{i=1..n}$ features in the model M

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

Multiple matching with best-bin-first algorithm

Registration with planar homography with 5 support points

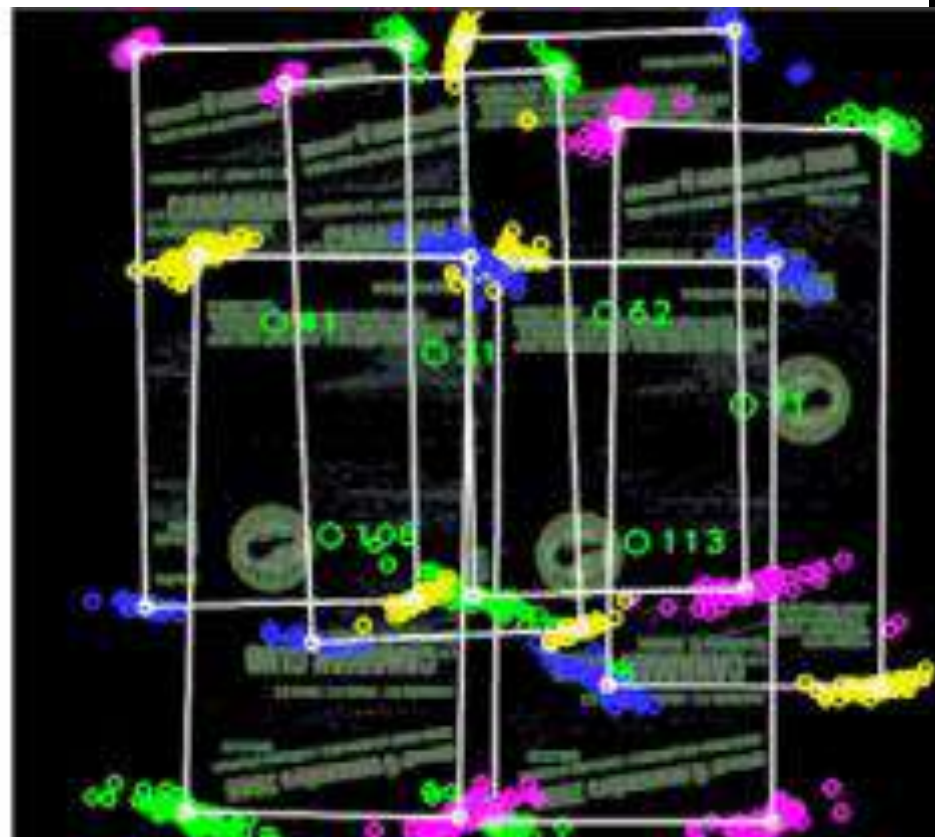
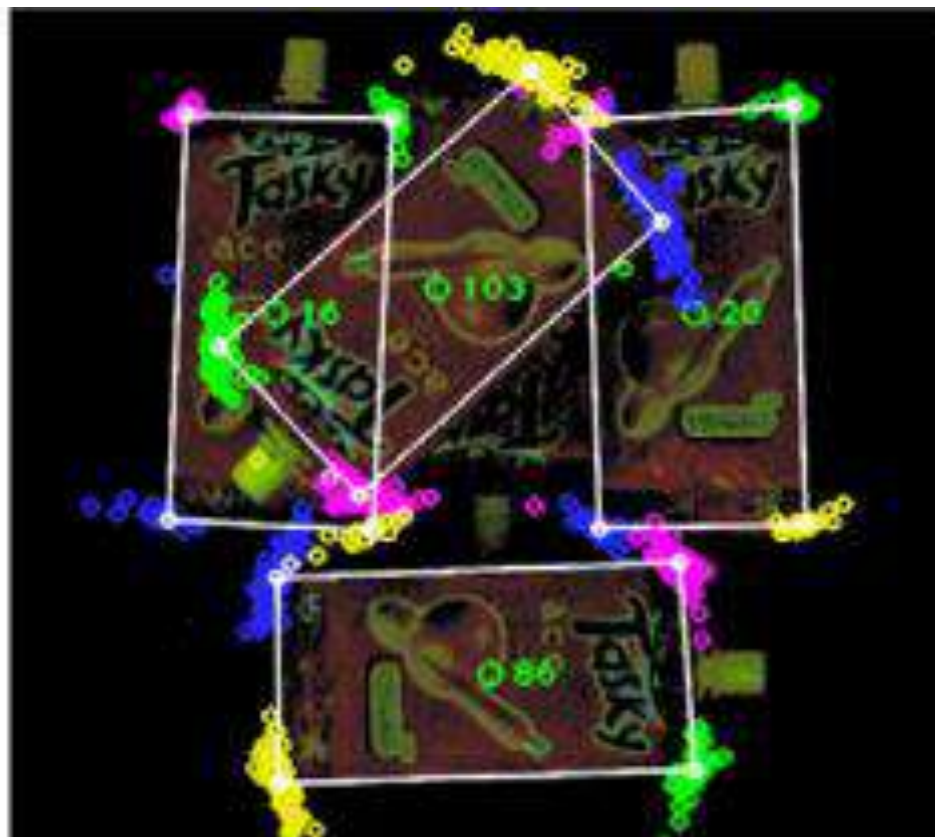
Matches	SVD	RANSAC	RANSAC clustered	Ours

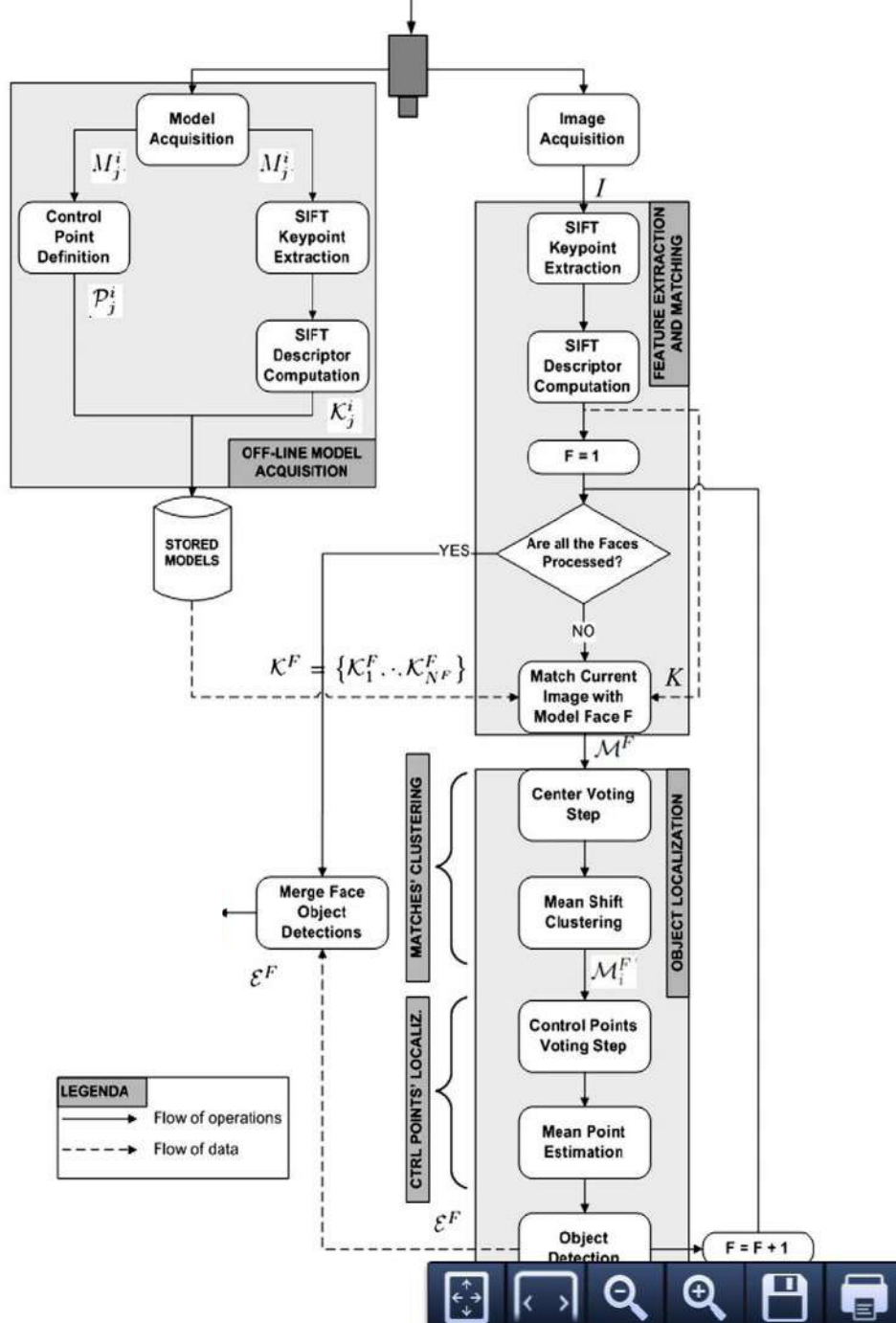


Clustering similar features,

Mean-shift clustering for voting to single centers:

Estimations of center and control points by clustering





(b) "Coffee"-N=1+0



(c) "Nutella"-N=1+0



(e) "Coffee"-N=4+0



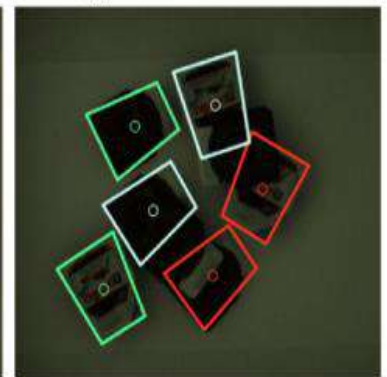
(f) "Nutella"-N=4+2



(h) "Coffee"-N=4+4



(i) "Nutella"-N=4+8

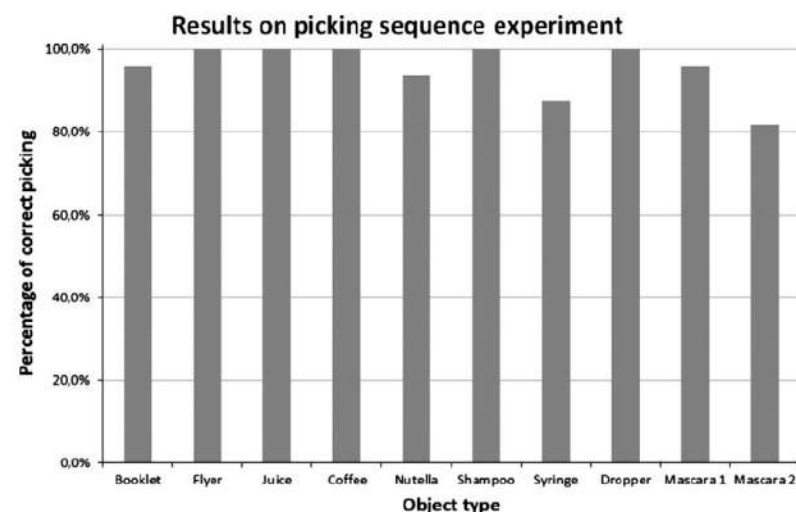


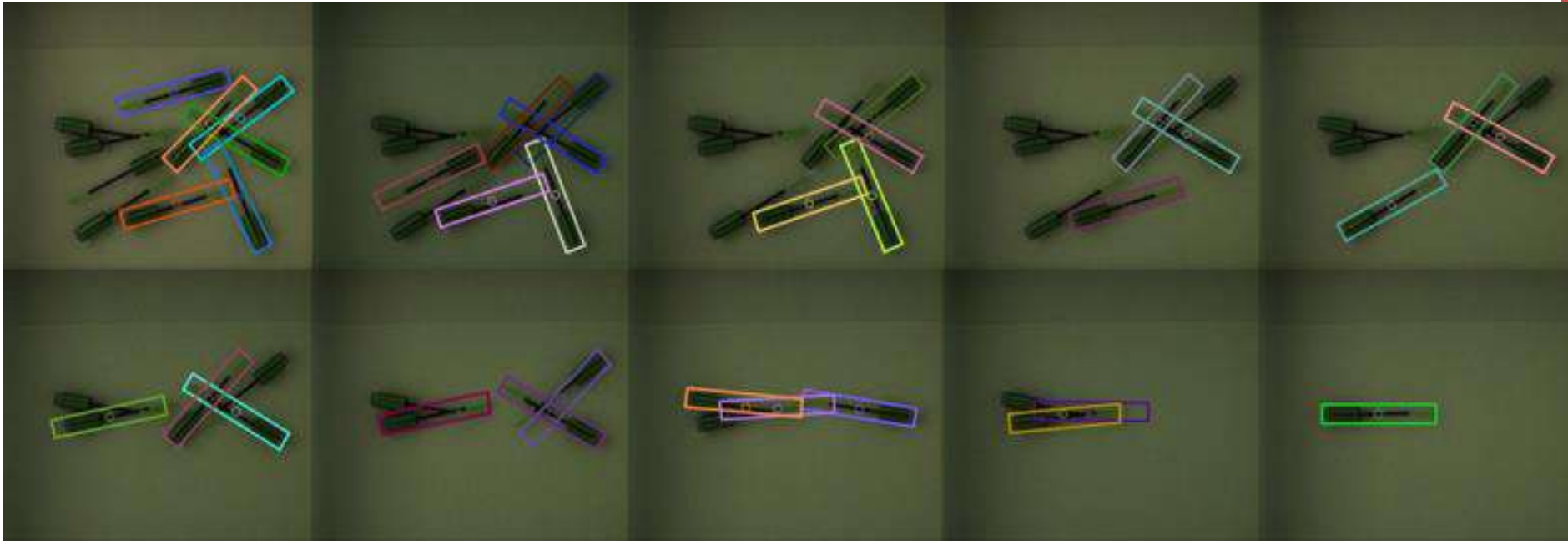
Experimental results for single model approach.

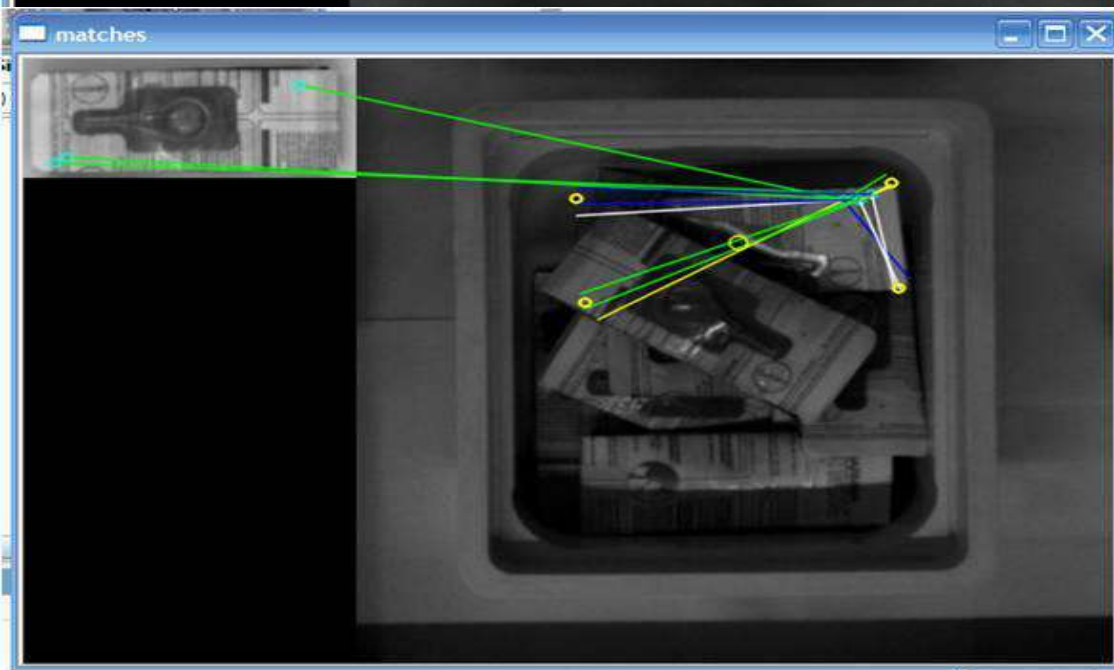
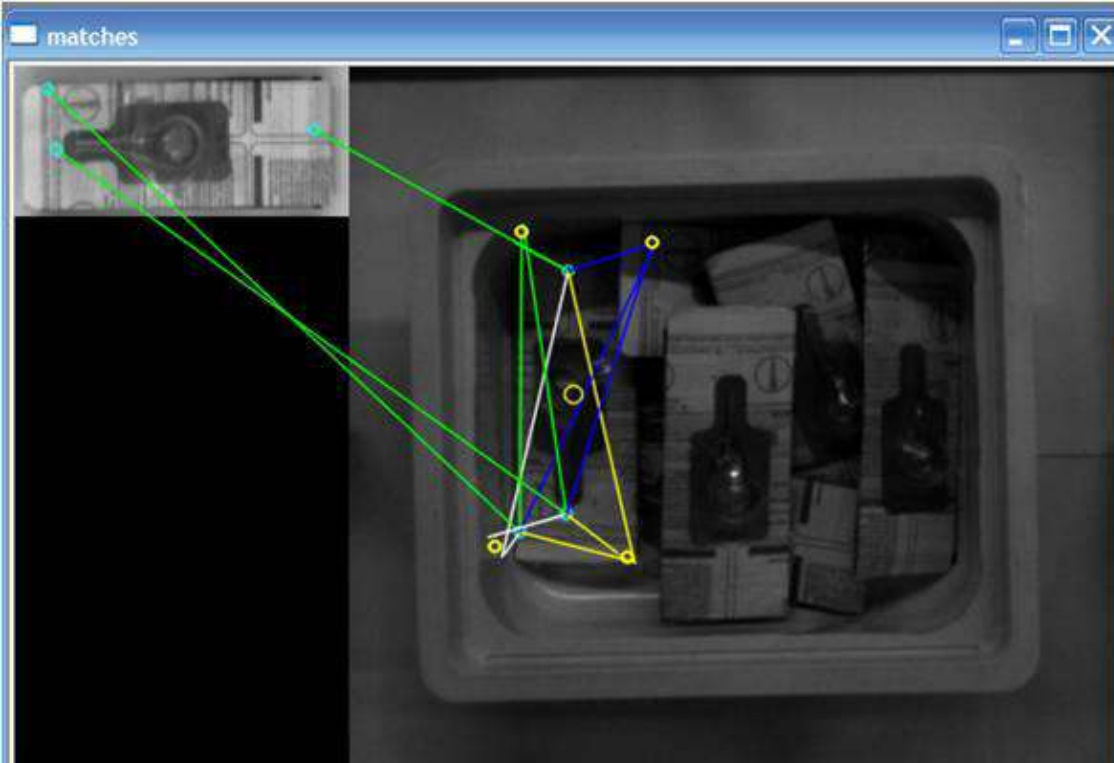
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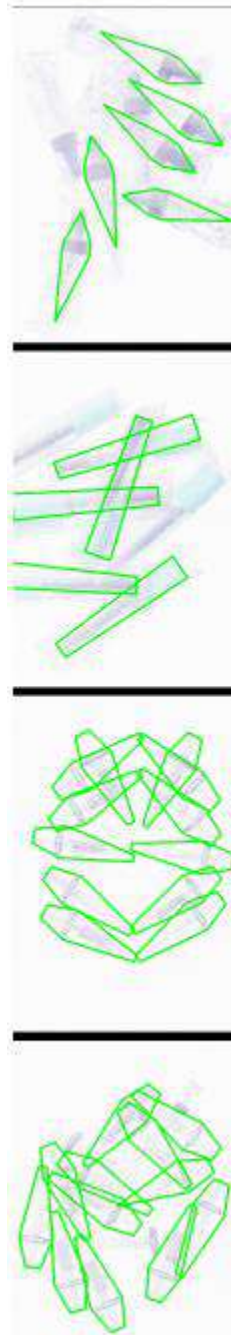
	Object-level		Pixel-level		Center dist.
	Precision	Recall	Precision	Recall	Mean (px)
<i>Juice</i>					
All RS	100.00%	25.00%	22.95%	23.66%	5.41
Clus RS	91.67%	82.50%	77.43%	79.93%	18.97
Ours	97.37%	92.50%	88.55%	87.64%	5.76
<i>Nutella</i>					
All RS	100.00%	15.38%	13.23%	14.46%	6.98
Clus RS	66.67%	33.85%	38.96%	35.82%	17.24
Ours	97.84%	86.78%	82.87%	83.13%	3.86
<i>Flyer</i>					
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



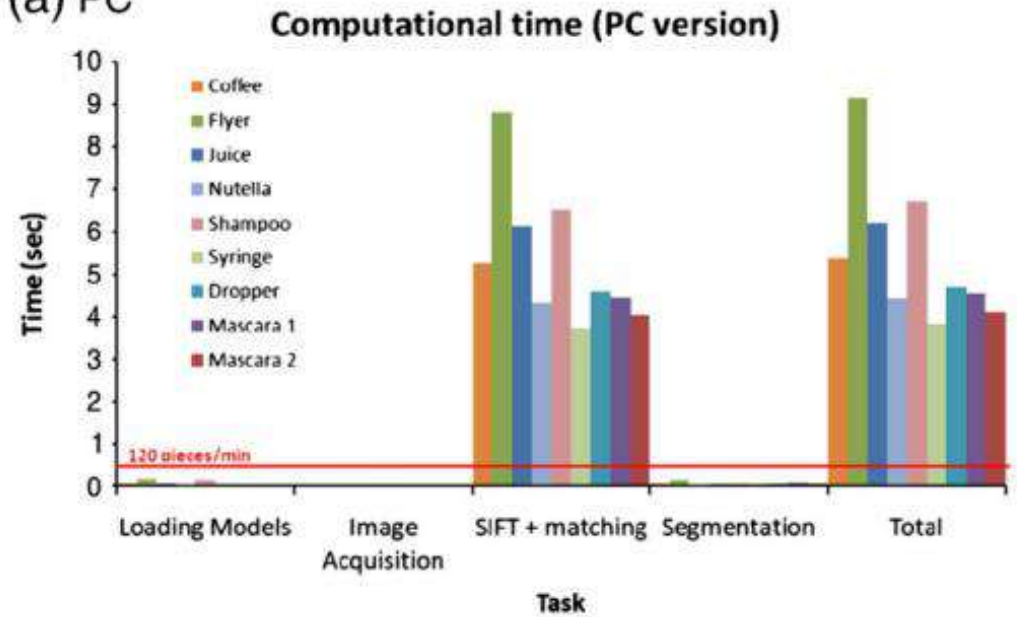




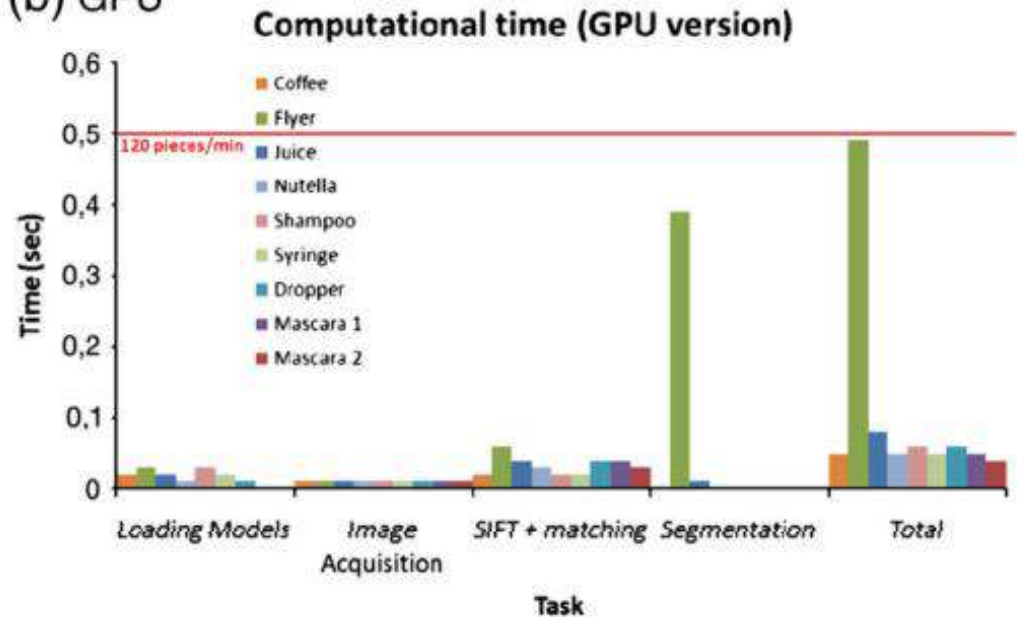
Real time processing
only with
GPU



(a) PC

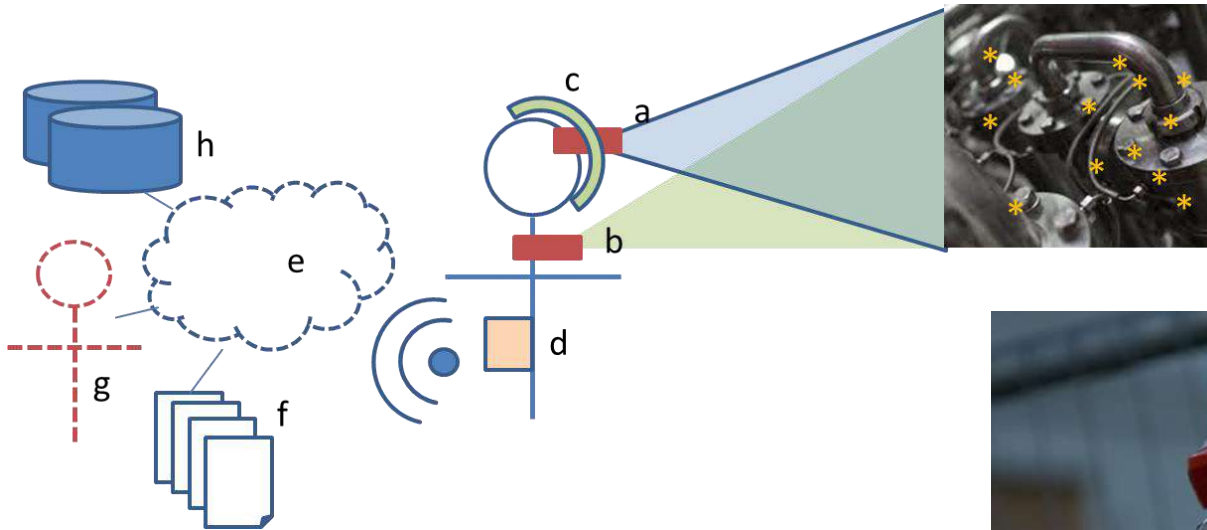


(b) GPU



NEXT STEPS?

- 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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