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Computer Vision

Introduction

Filippo Bergamasco (filippo.bergamasco@unive.it)
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DAIS, Ca' Foscari University of Venice
Academic year 2018/2019

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About the teacher

Filippo Bergamasco

http://www.dais.unive.it/~bergamasco

- Fixed-term researcher (RTDA)
- KiiS research group. I work on 3D reconstruction, camera calibration, ego-motion estimation, photogrammetry etc.

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About the teacher

Filippo Bergamasco

http://www.dais.unive.it/~bergamasco

For any question regarding this course, please contact me via mail: filippo.bergamasco@unive.it

Or come visit me at my office Z.B08

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About this course

Official UNIVE course page:

http://www.unive.it/data/course/255294

Unofficial course page:

http://www.dais.unive.it/~bergamasco/computer_vision_2018_2019.html

- **48** hours frontal lessons (lab included)
- Timetable: Monday and Tuesday 12:15 - 1:45 pm
- Code: CM0193

Changelog…

- Computer Vision 2016 – 2017 [CM0193]
  - 30 hours
- Computer Vision 2017 – 2018 [CM0193]
  - 30 hours
- **Computer Vision 2018 – 2019 [CM0193]**
  - 48 hours
- Geometric and 3D Computer Vision 2019-2020 [CM0526]
  - 48 hours

This year I'll introduce some of the concepts related to 3D reconstruction and stereo geometry

Most of the course still focused on low/mid level vision

Check your study plan!

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- Did you enroll before a.y. 2017?
  - Good, you can follow this course now
- Did you enroll in a.y. 2017-2018?
  - Good, you can follow this course now
- Did you enroll in a.y. 2018-2019?
  - You should have “Geometric and 3D Computer Vision” in your plan. **You cannot give the exam this year**.
  - Why?
    - Course codes are not compatible
    - Syllabus will be subject to changes

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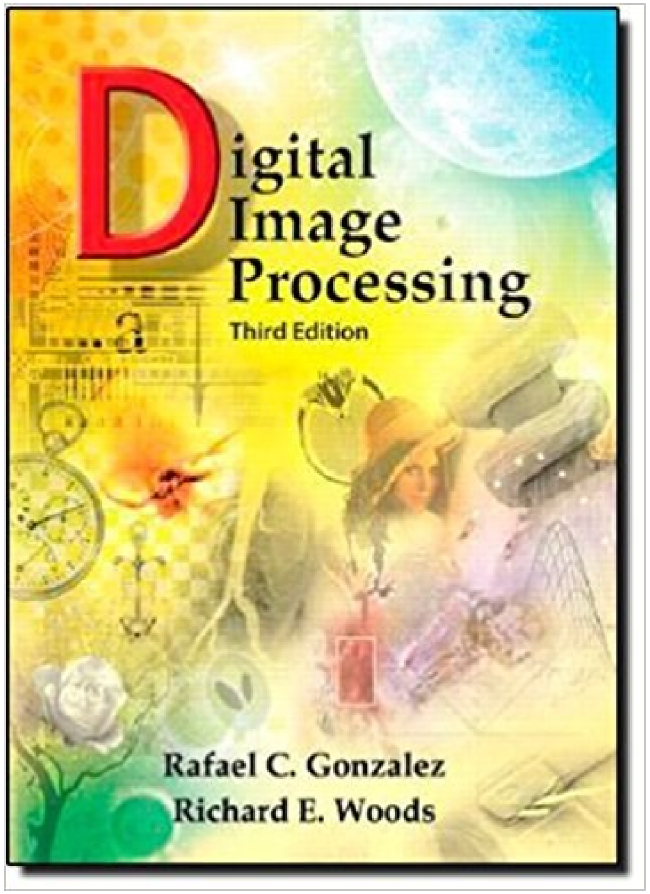
Referral Texts



R. C. Gonzalez e R.E. Woods. **Digital Image Processing** (3rd edition). Pretience Hall

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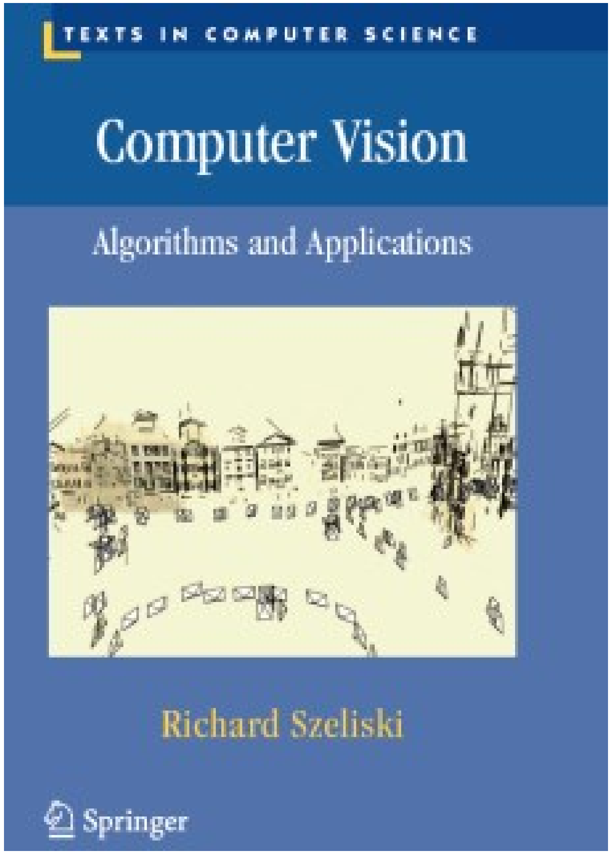
Referral Texts



R. Szeliski. **Computer Vision Algorithms and Applications**. Springer

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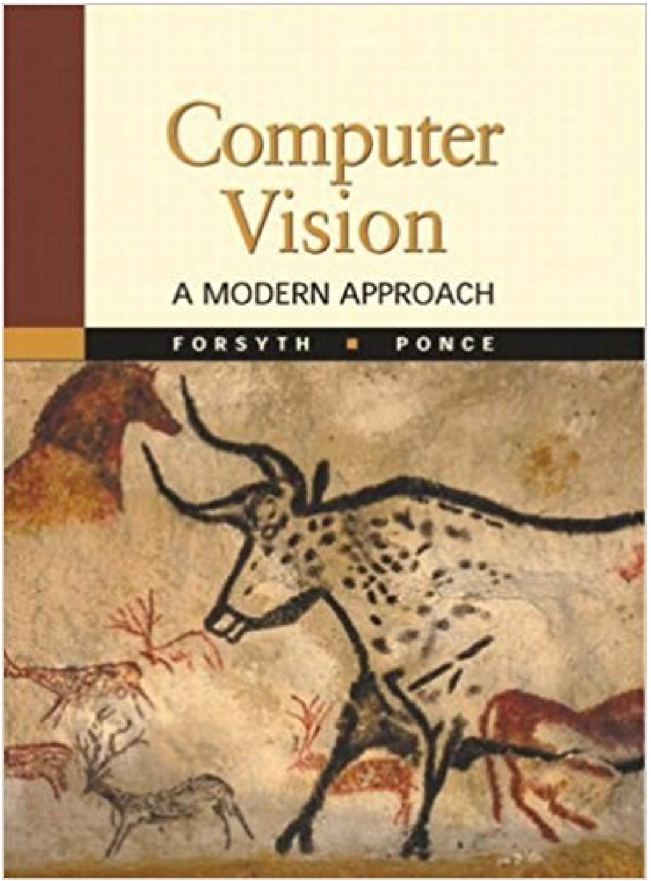
Referral Texts



D. Forsyth and J. Ponce. **Computer Vision. A Modern Approach**. Prentice-Hall, 2002

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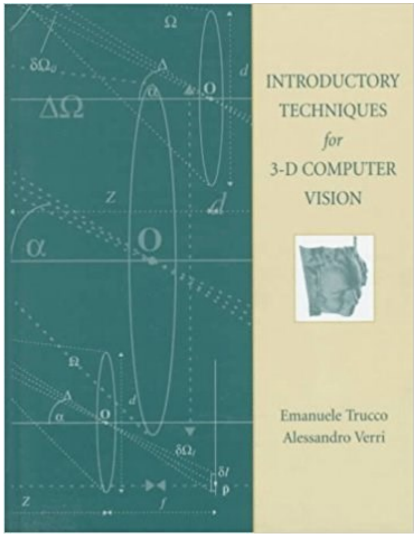
Additional reading

E. Trucco and A. Verri. Introductory Techniques for 3D Computer Vision. Prentice-Hall, 1998



About the exam...

Final exam consists in the development of a software project that must be performed individually.

Project submission information: (more will follow)

- Submit via moodle the full source-code and data at least 1 week before the exam
- During the exam, I'll ask you to show me your project and explain its details (algorithms, choice made, trade-offs, strengths and limitations)
- The goal is to evaluate your knowledge of the most common computer vision techniques and theories

About the lab

We will spend some hours in the lab so you can put your hands on some of the algorithms discussed during the course

After each lab session you will be asked to complete an assignment within few weeks (deadline is usually not strict)

Completing all the assignments is required (not sufficient) to obtain the full-marks (lode)

Are you interested in a challenging computer vision thesis?

WE WANT YOU!

A thesis activity can substitute the proposed project and assignments.

If interested, contact me as soon as possible so we can discuss the details together.

Get involved

digitalmetrix

Start-up & spin-off focused on the development of structured-light based 3D scanning solutions

digitalviews

Spin-off focused on the development of optical vision-based solutions for industrial quality inspection

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Our topics…

- Camera-projector and camera-camera calibration with non-pinhole camera models
- Stochastic phase-unwrapping for robust structured-light scanning of complex materials like metal, shiny plastic, etc
- Deep learning for the identification of aesthetic defects in production pipelines
- Automated 2D/3D assessment of serigraphic printings
- Industrial metrology
- Multi-spectral and polarimetric imaging

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Questions?

What is Computer Vision?

Computer vision is about building an automatic system that “sees”

- Difficult to give a concise definition since the area spans multiple different problems (we will see some examples in a minute…)

How we’ll consider cv in this course:

*“A set of **computational techniques** aiming at estimating or making explicit the **geometric** and **dynamic properties** of the **3D world** from **digital images**”*

Introductory techniques for 3D computer vision - E. Trucco, A.Verri

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What is Computer Vision?

Different levels of vision:

1. Low (Image processing)
   a. Image restoration
   b. Contrast enhancement
   c. Noise reduction

   Image → Image

1. Medium
   a. Segmentation
   b. Shape recognition

   Images → attributes/features

1. High
   a. Scene understanding

   Images → concepts

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What is Computer Vision?

The purpose of a machine vision system is to produce a symbolic description of what is being imaged

As human, we perceive the three-dimensional structure of the world around us with apparent ease

Easy to distinguish the flower in the foreground from the leaves in the background

From a signal point of view, there are just variations in color and brightness

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What is Computer Vision?

What we see

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

A difficult business

Despite the remarkable advances in the last decades...

"the dream of having a computer interpret an image at the same level as a two-year old (for example, counting all of the animals in a picture) remains elusive"

Humans and animals can interpret images so effortlessly while computer vision algorithms are still error prone:

- **Perceptual** components of artificial intelligence (such as vision) is probably as difficult as **cognitive** ones (logic proving, planning)

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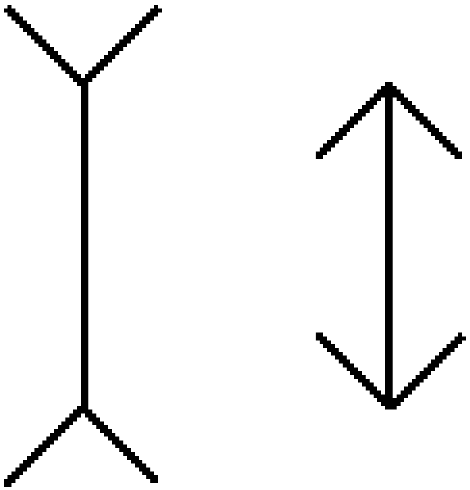
Human vision

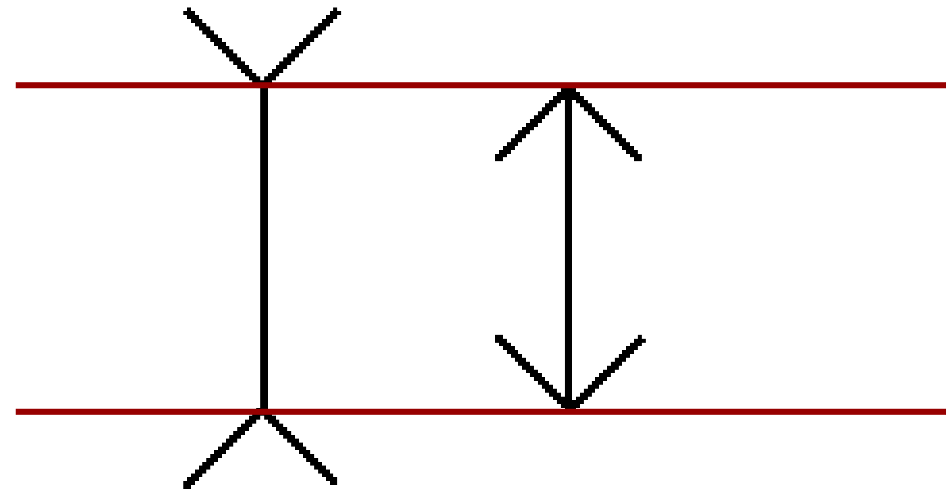
Optical illusions give us interesting clues of how the human visual system works (and the inherent assumptions made by our brain)



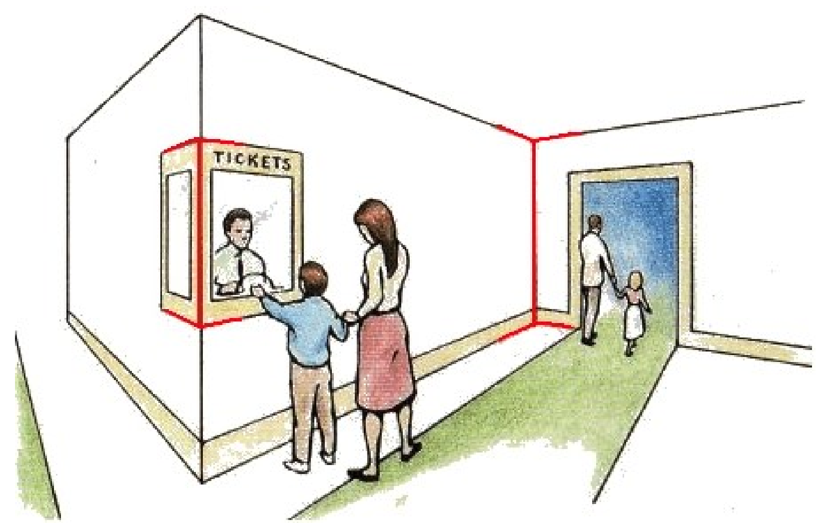
Which one is longer?

Müller-Lyer Illusion

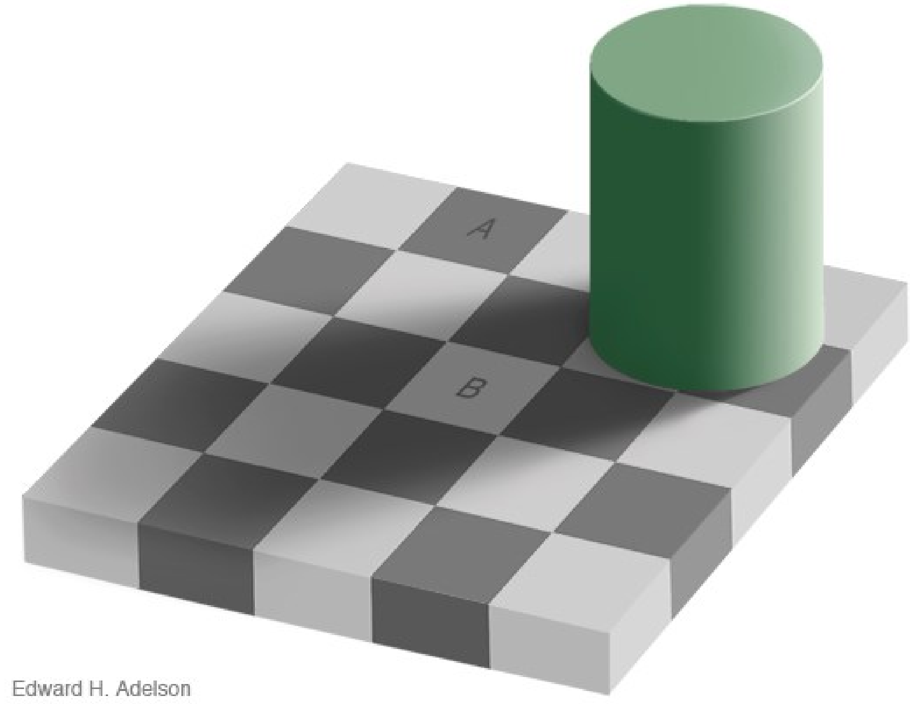
Human vision



The Müller-Lyer illusion occurs because the visual system processes that judge depth and distance assume in general that the "angles in" configuration corresponds to an object which is closer, and the "angles out" configuration corresponds to an object which is far away.



Human vision



Which one is brighter?

The percept is due to brightness constancy, the visual system's attempt to discount illumination when interpreting colors

Human vision

Rotating mask illusion

When determining the shape of an object only from shading (with no stereo vision), the brain assumes a convex shape (especially for faces)

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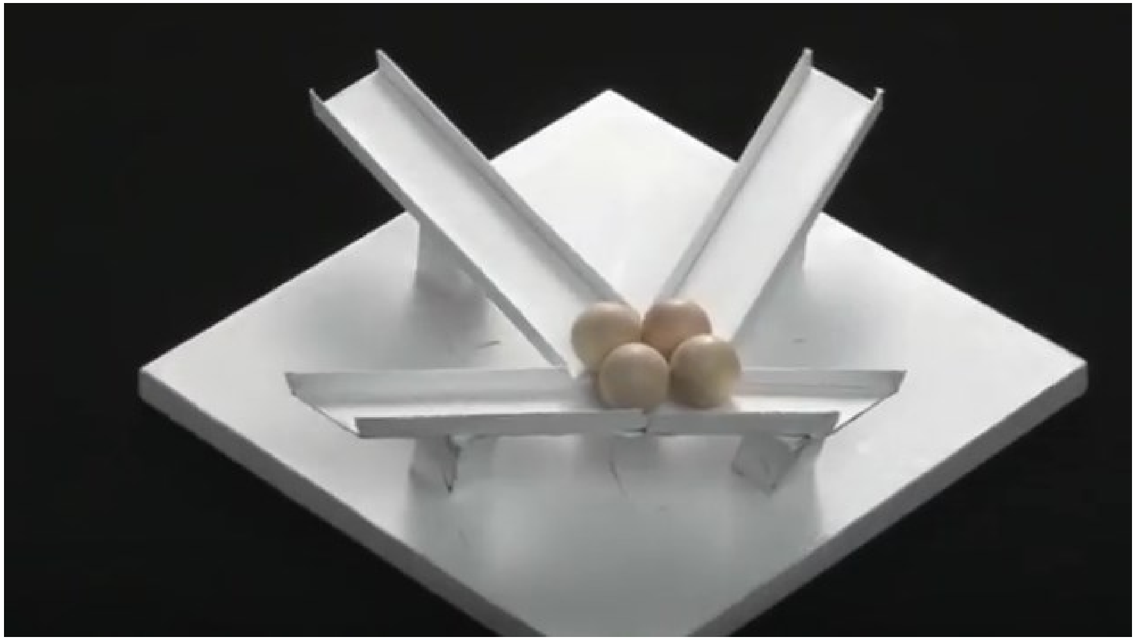
Human vision

Optical Perception



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Why is difficult?

Giving a symbolic description of the contents of an image is difficult because is intrinsically an **inverse problem:**

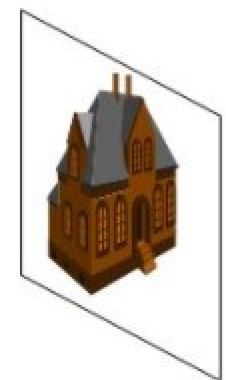
- We want to recover some unknowns given insufficient information to fully specify the solution

- We must resort to physic-based and/or probabilistic-based models to **disambiguate potential solutions**

Computer Vision vs. Graphics

Computer graphics

3d to 2d implies information loss



Computer Vision

Need for models

Raster image

- A house
- Some polygons
- Lines, edges

Computer Vision vs. Graphics

The **models** we use in computer vision are usually developed by:

- Physics: radiometry, optics, etc.
- Computer graphics

And describe how:

- Objects move or animate
- Light reflects from object surfaces
- Shapes get projected to the sensor image plane
- etc.

Computer Vision vs. Graphics

In limited contexts, computer graphics nowadays is so advanced that the illusion of reality is almost perfect

Computer Vision applications

So, what are the most common applications in which computer vision is used today?

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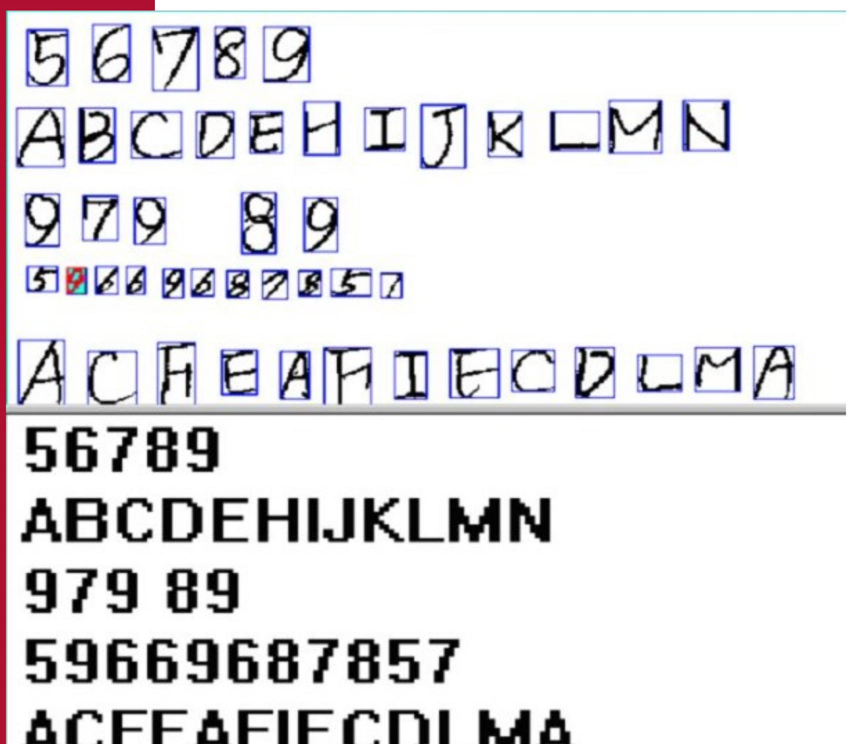
Computer Vision applications

Optical Character Recognition (OCR)



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Computer Vision applications

Optical Character Recognition (OCR)

Computer Vision applications

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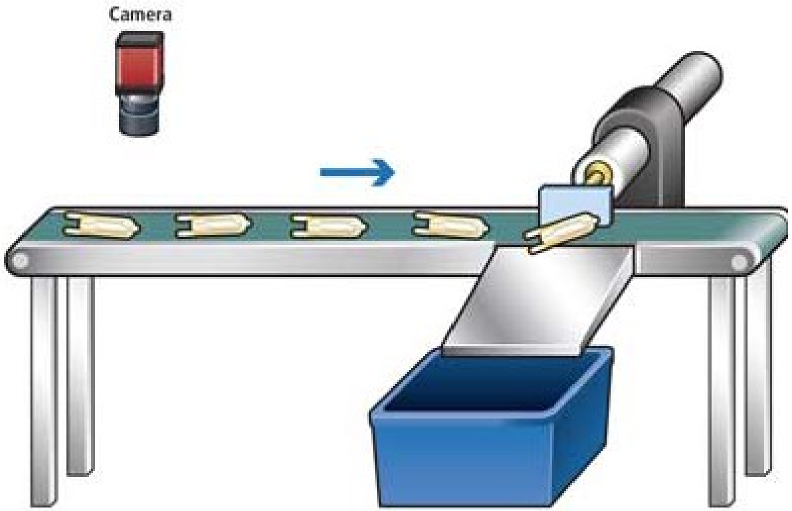
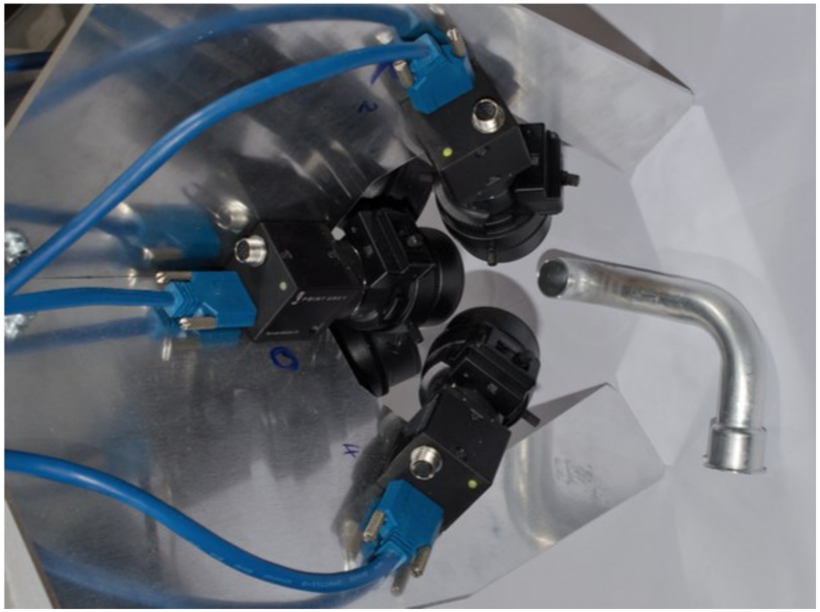
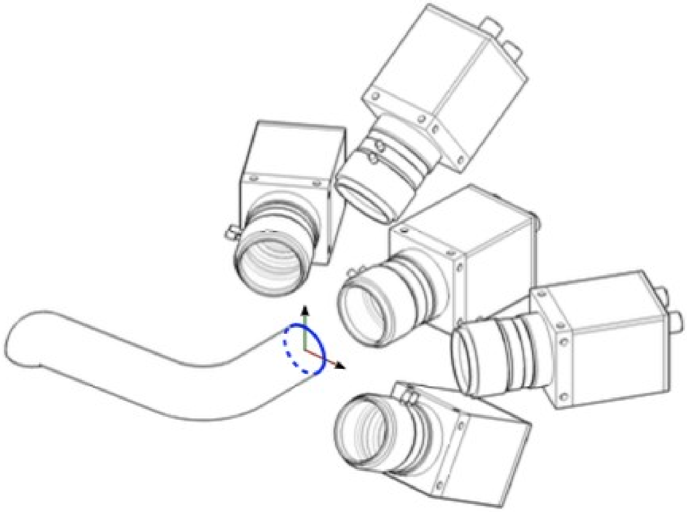
Machine inspection



Computer Vision applications

Machine inspection





Pipe inspection device developed in our lab

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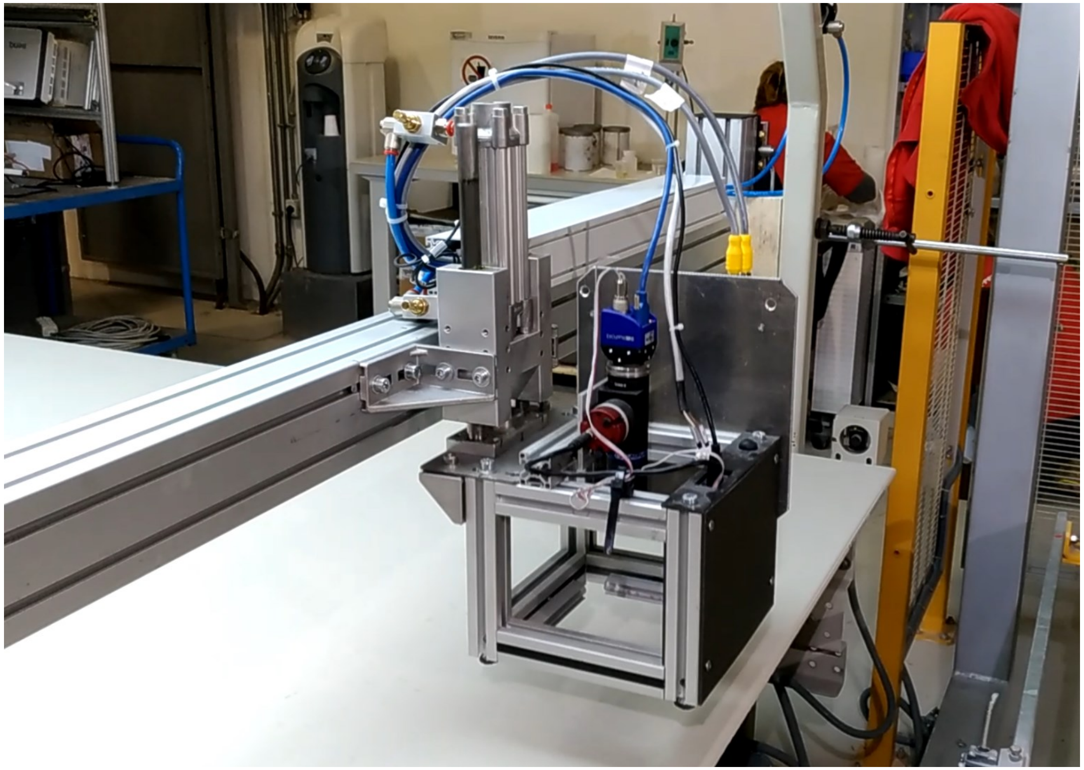
Computer Vision applications

Machine inspection



Kitchen countertops inspection device developed in our lab

digitalmetrix

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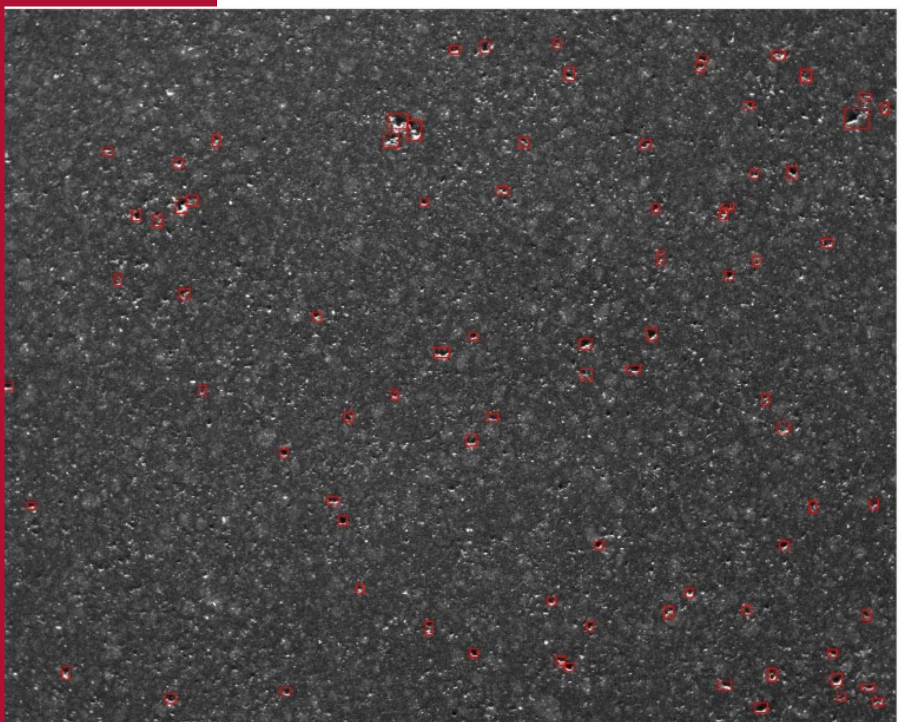
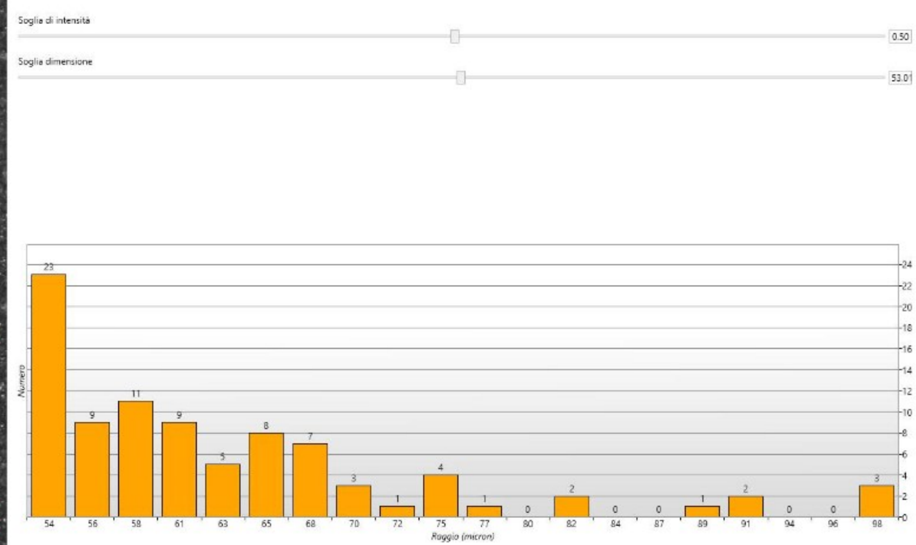
Computer Vision applications

Machine inspection





Kitchen countertops inspection device developed in our lab

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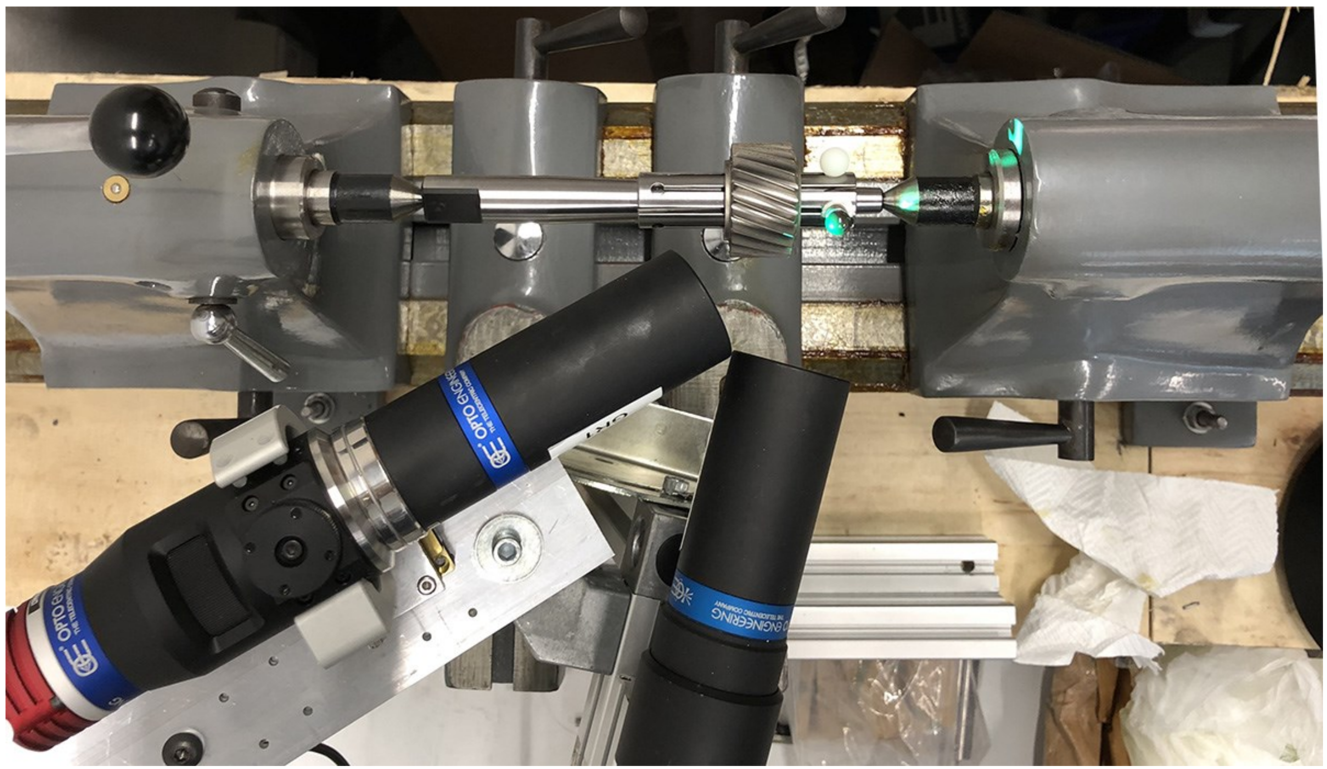
Computer Vision applications

Vision-based industrial metrology

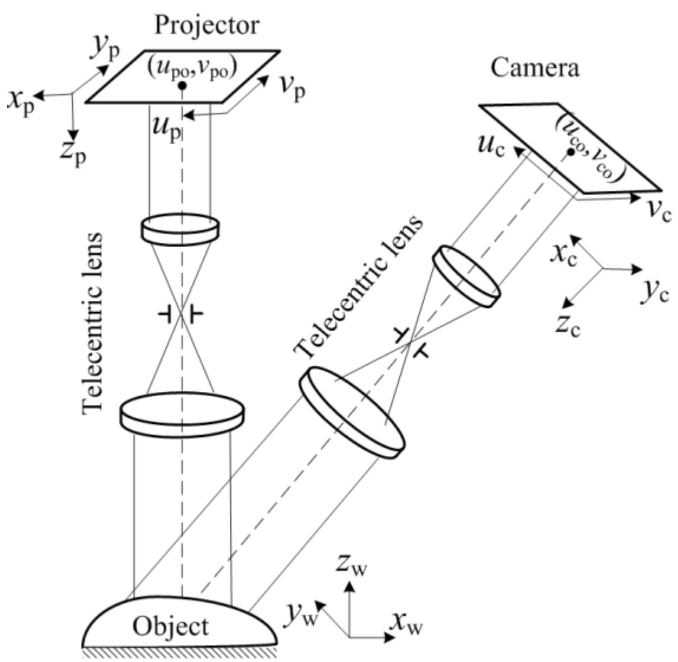


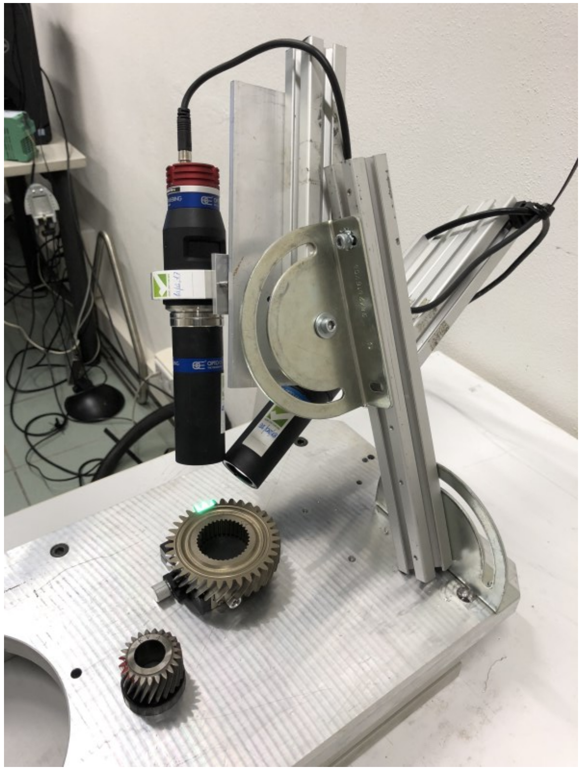
Gear' surface reconstruction device developed in our lab

digitalmetrix

Computer Vision applications

Vision-based industrial metrology





Gear' surface reconstruction device developed in our lab

Computer Vision applications

Surveillance and tracking

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Computer Vision applications

Surveillance and tracking

Boat tracking device developed in our lab

digitalmetrix

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Computer Vision applications

Surveillance and tracking

Boat tracking device developed in our lab

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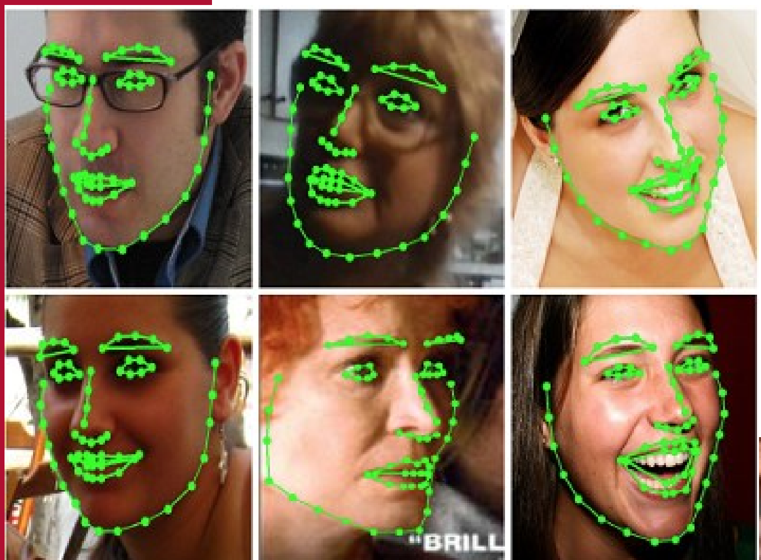
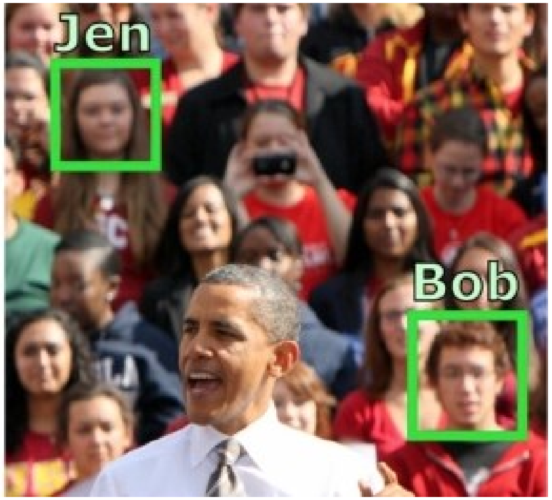
Computer Vision applications

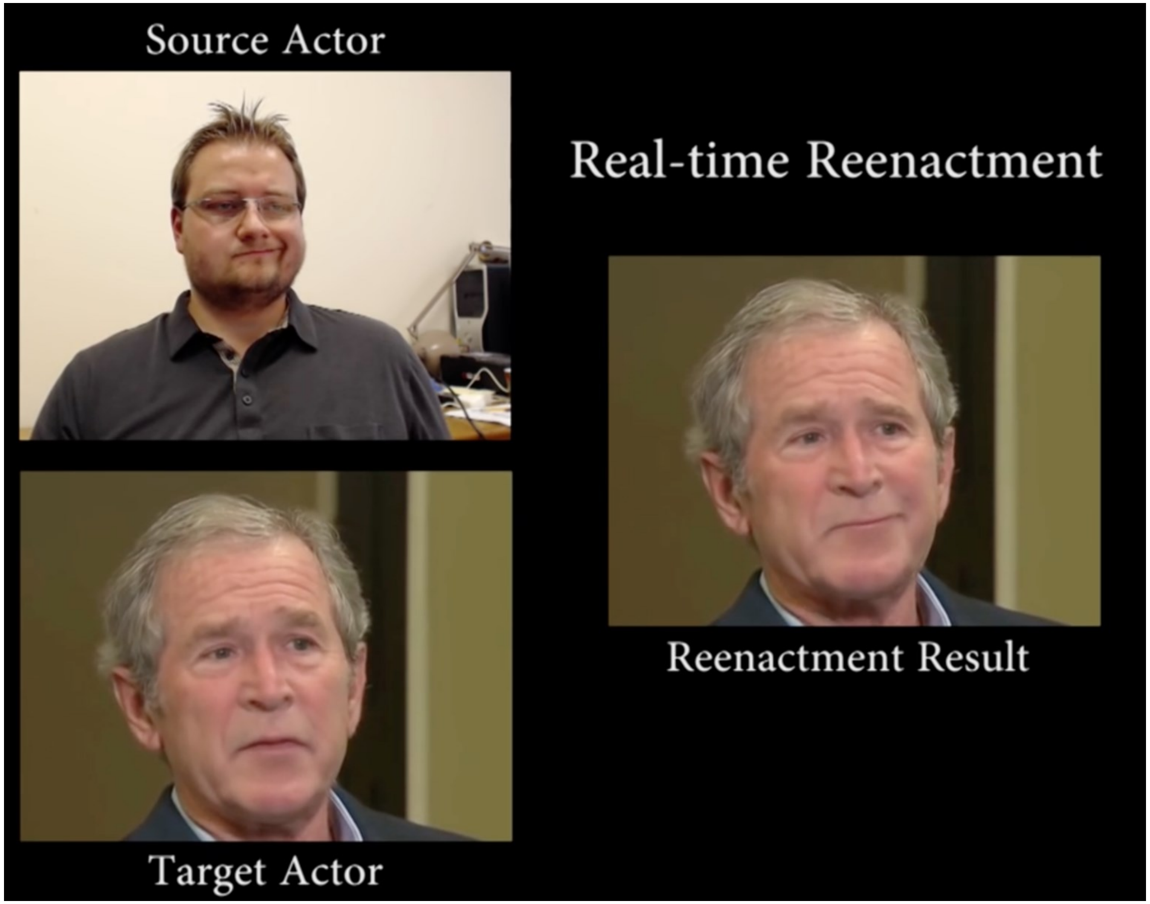
Face detection and recognition





Computer Vision applications

Face capture and reenactment



Computer Vision applications

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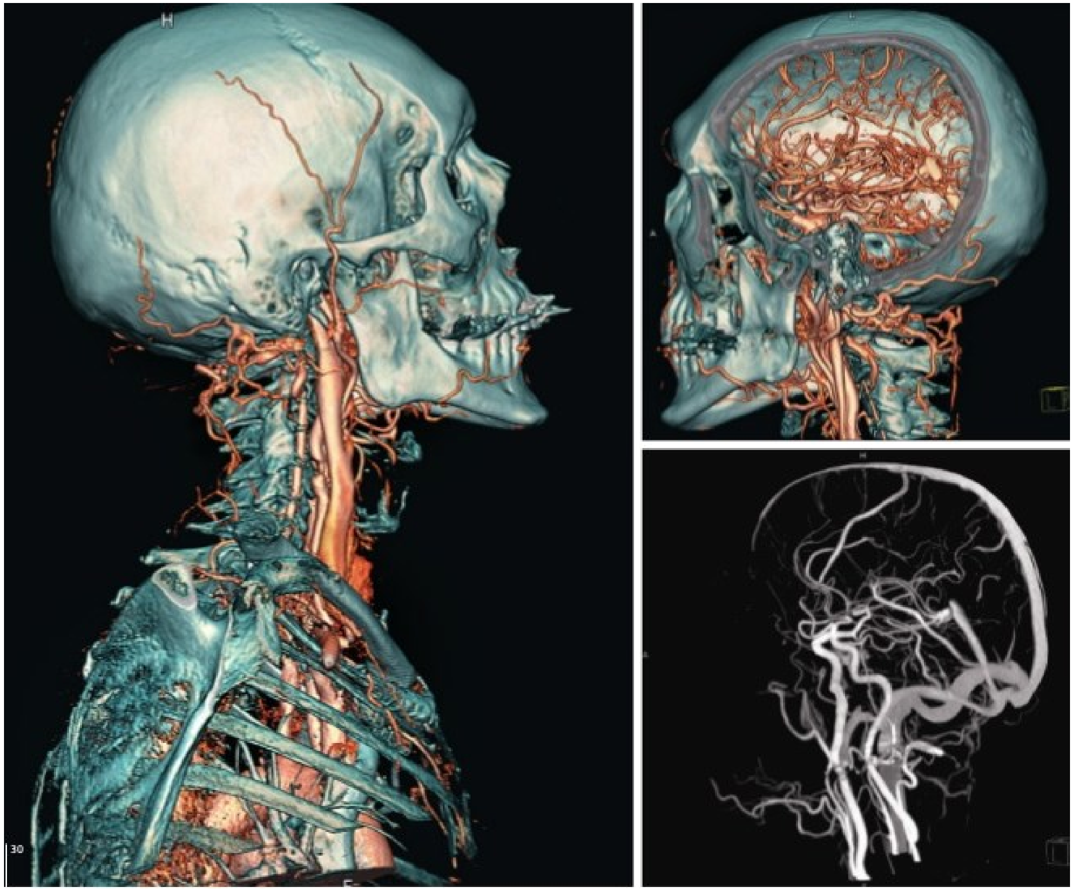
Medical image analysis



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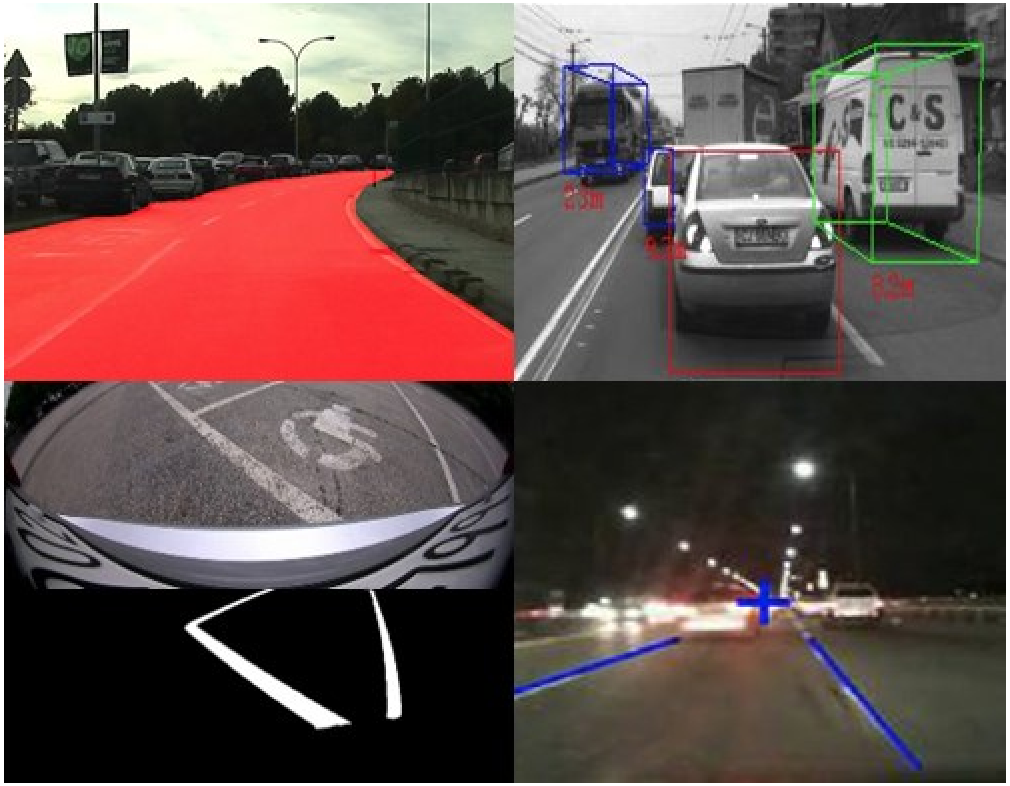
Computer Vision applications

Driving assistance



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Computer Vision applications

Driving autopilot (autonomous vehicles)

Computer Vision applications

Smart advertising

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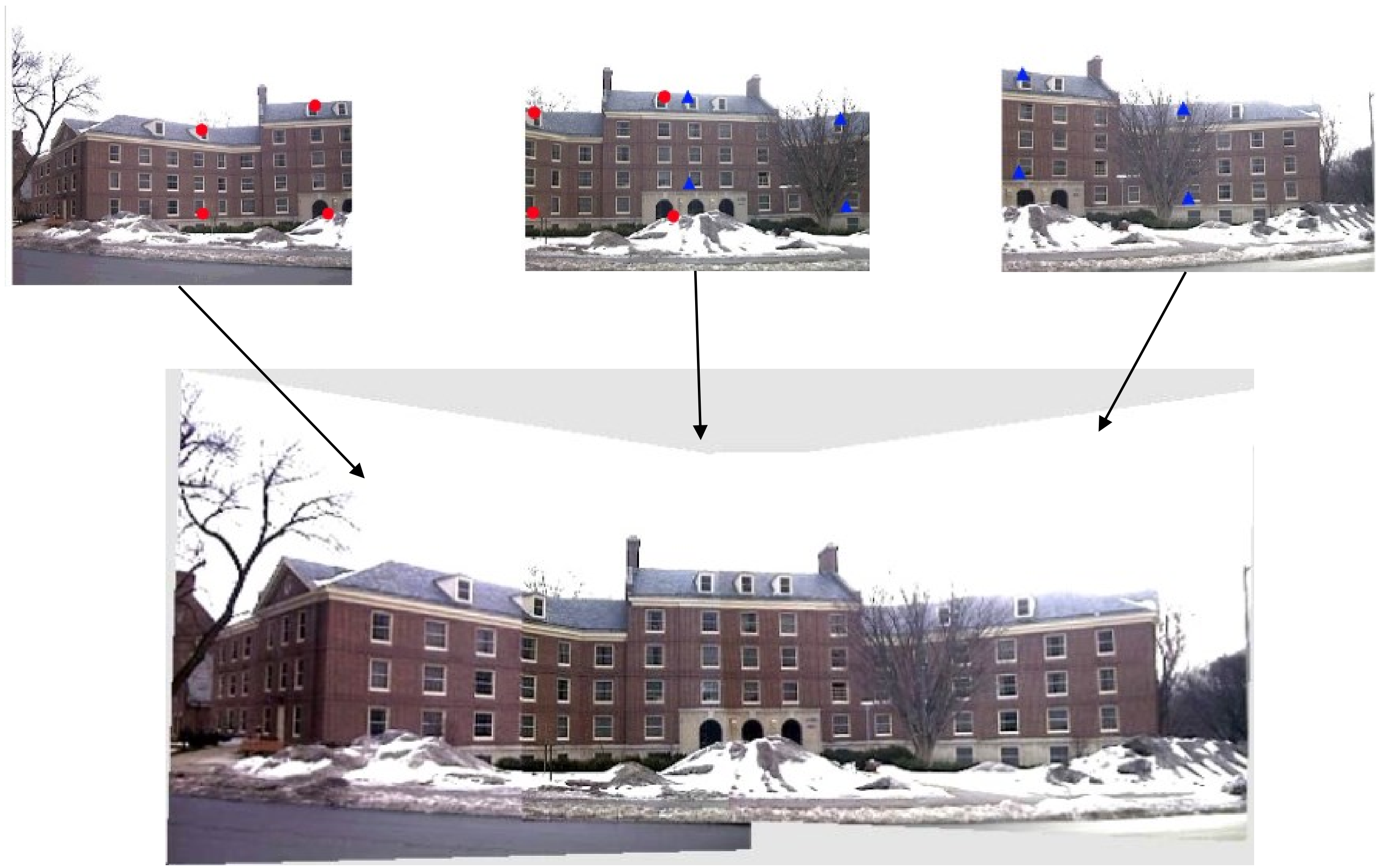
Computer Vision applications

Panorama stitching



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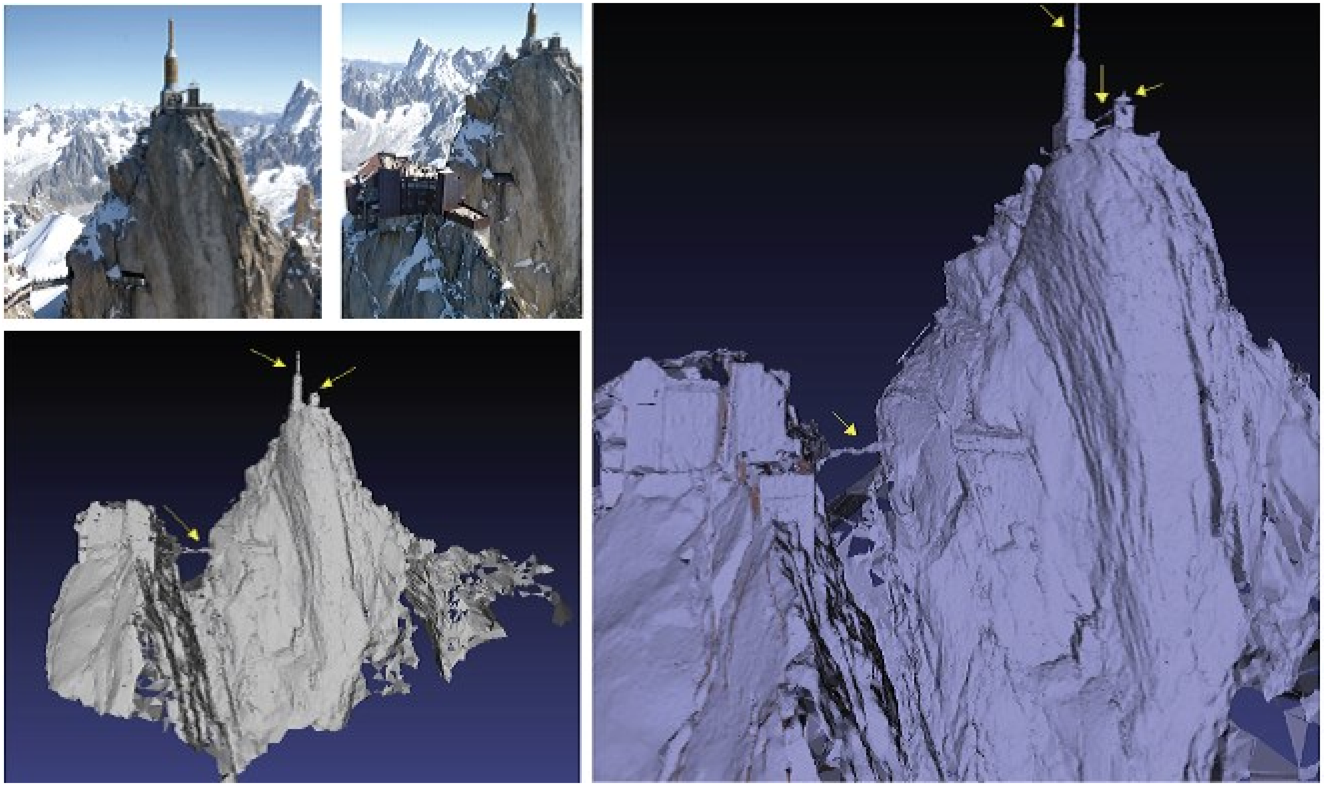
Computer Vision applications

Stereo 3D reconstruction



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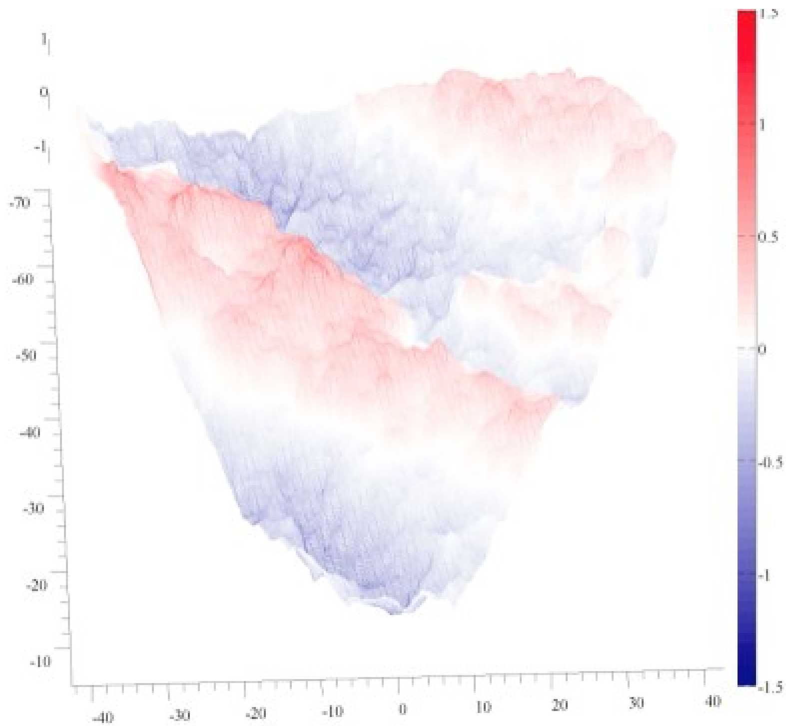
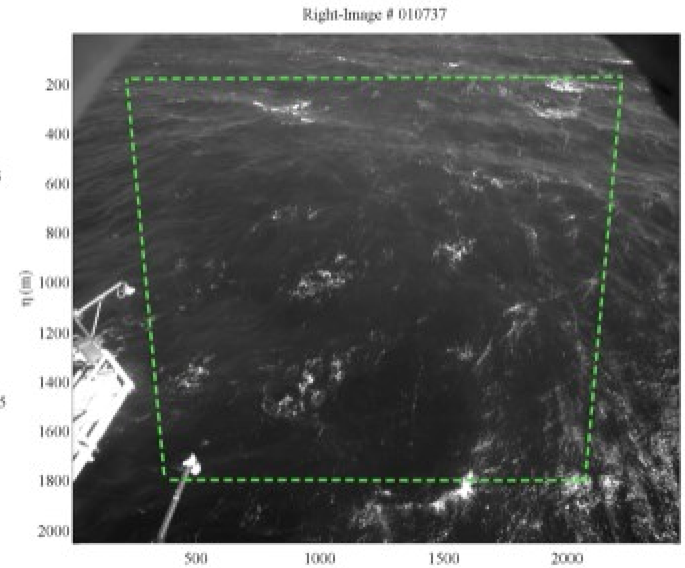
Computer Vision applications

Stereo 3D reconstruction

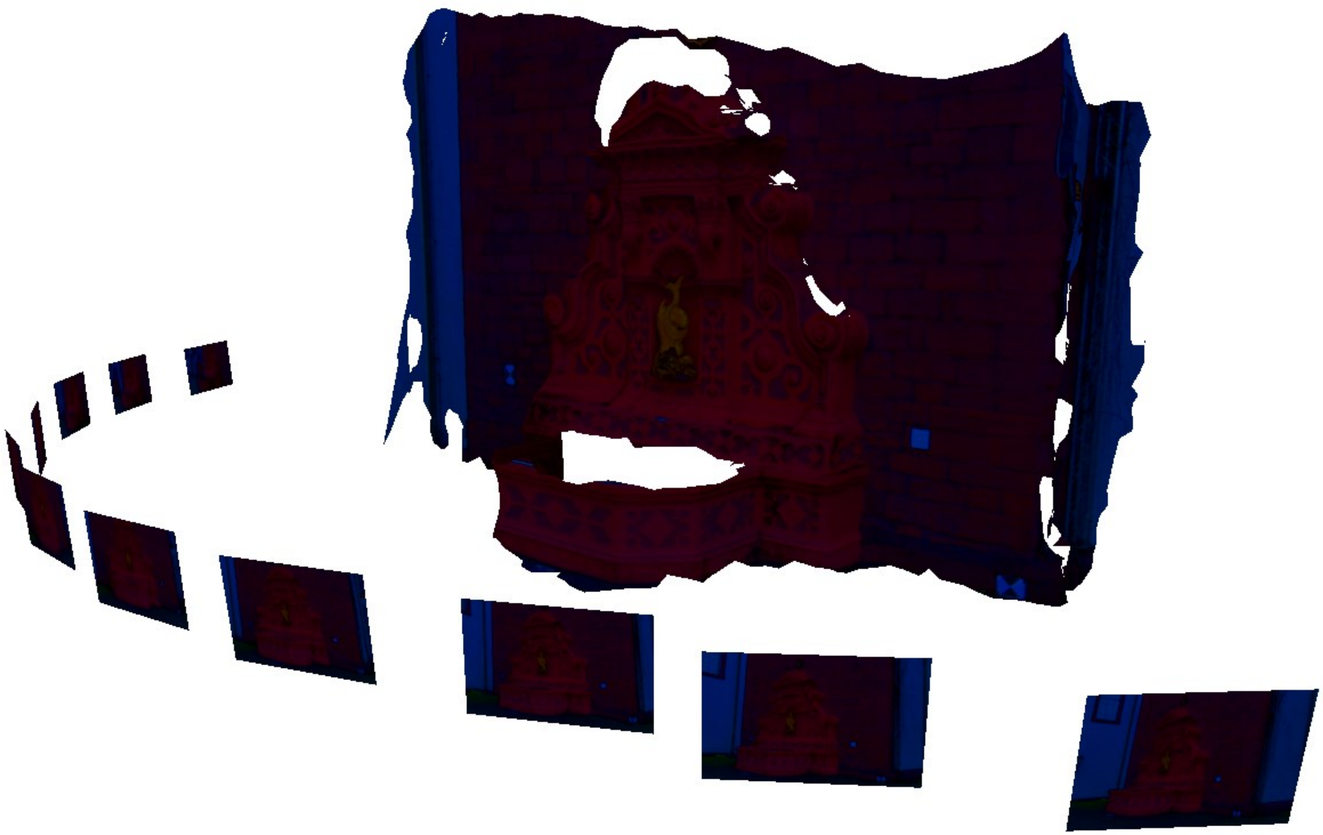




Sea waves 3D reconstruction pipeline
http://www.dais.unive.it/wass

Computer Vision applications

3D reconstruction (structure from motion)



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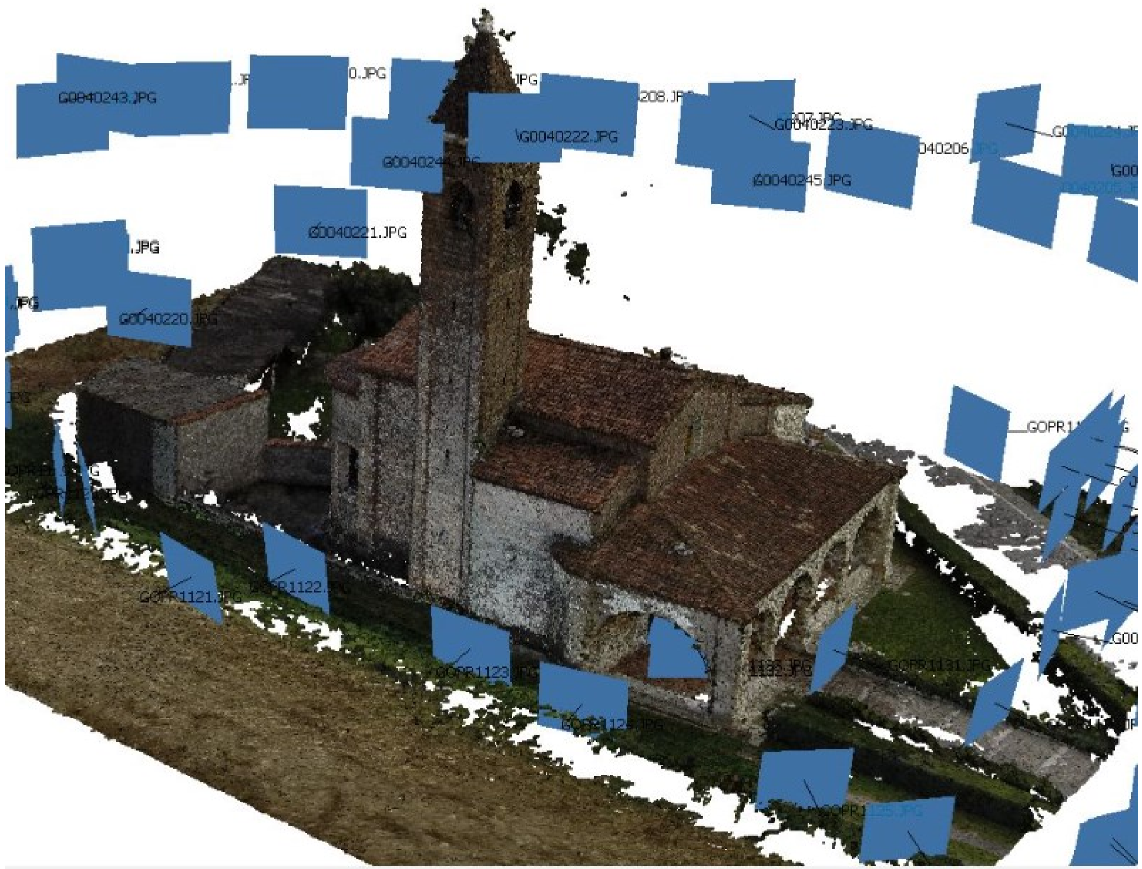
Computer Vision applications

3D reconstruction (structure from motion)



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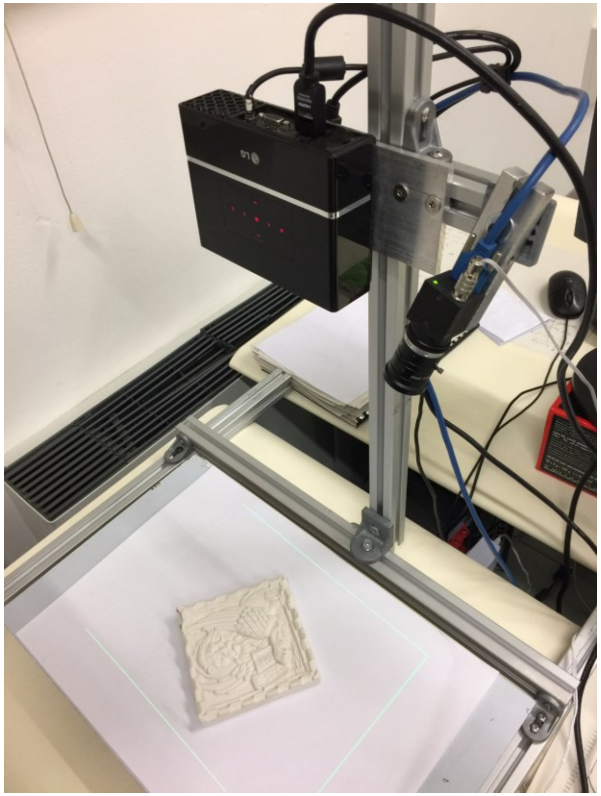
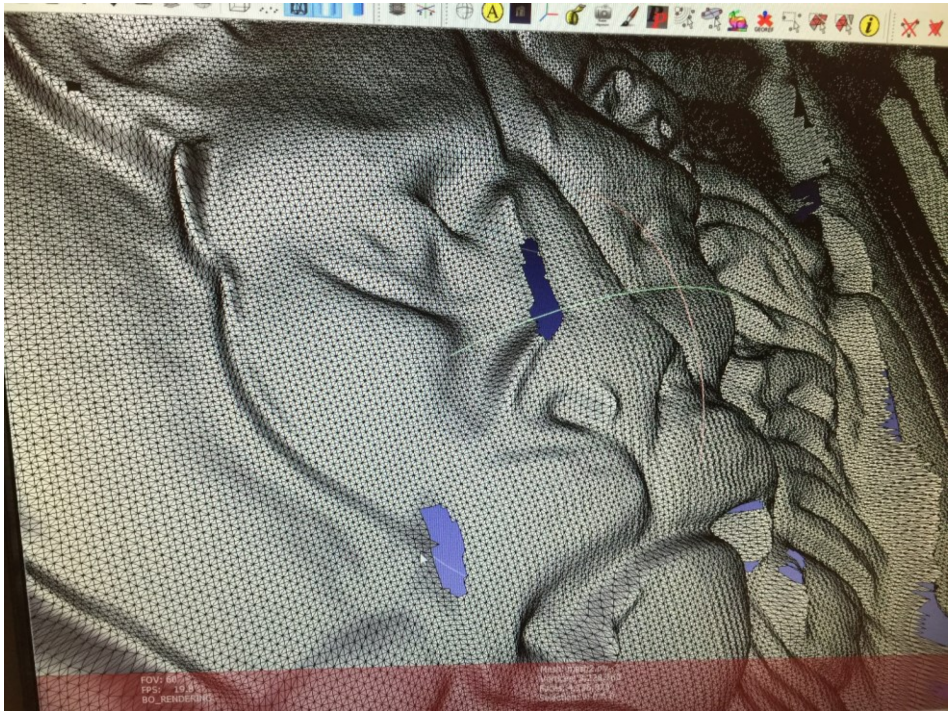
Computer Vision applications

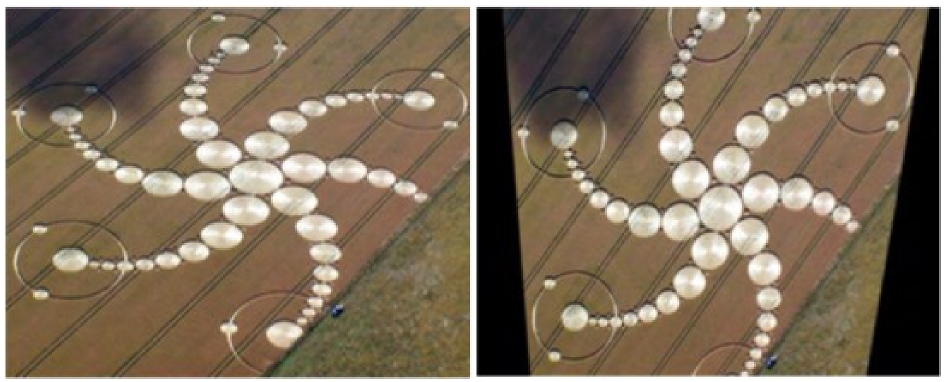
Structured-light scanning

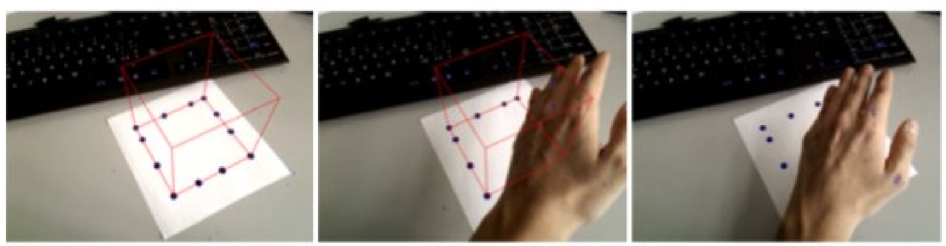


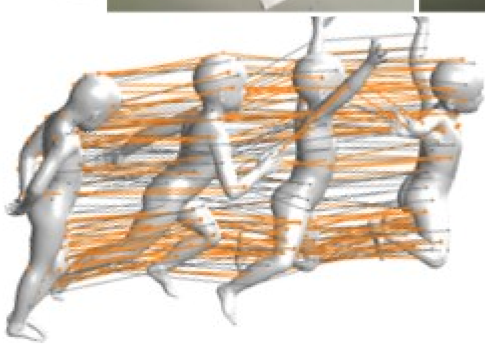


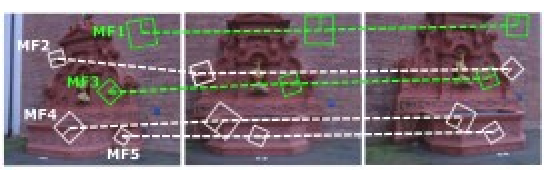
Computer Vision applications

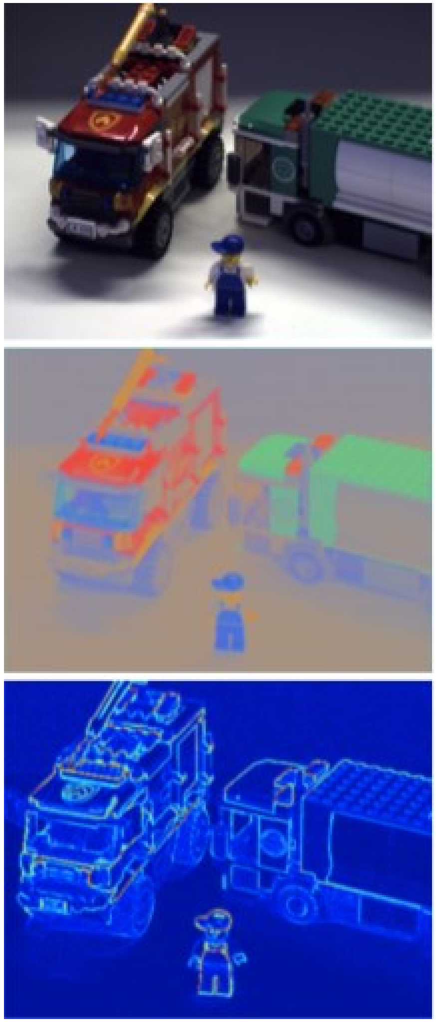
And much, much more...











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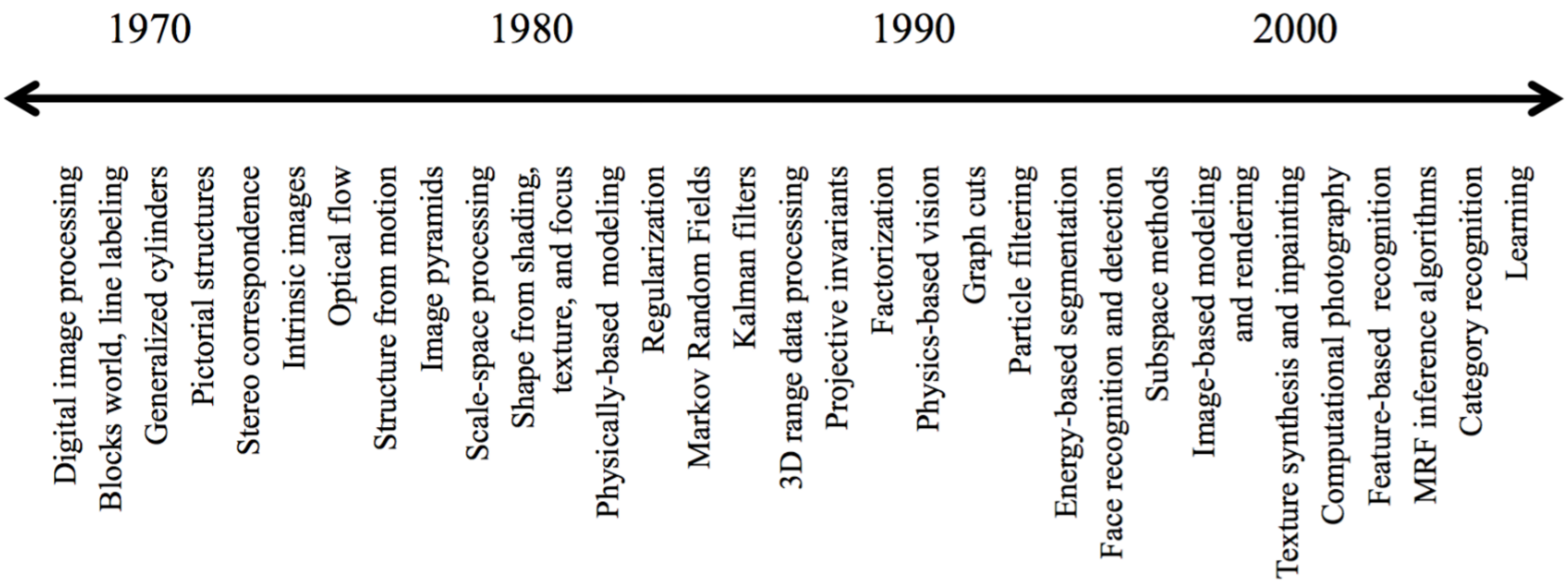
A Brief History



1970: What started distinguishing computer vision from image processing were early attempts to infer **3D structure from images**:

Lines extraction and labelling, stereo correspondences, optical flow, structure from motion

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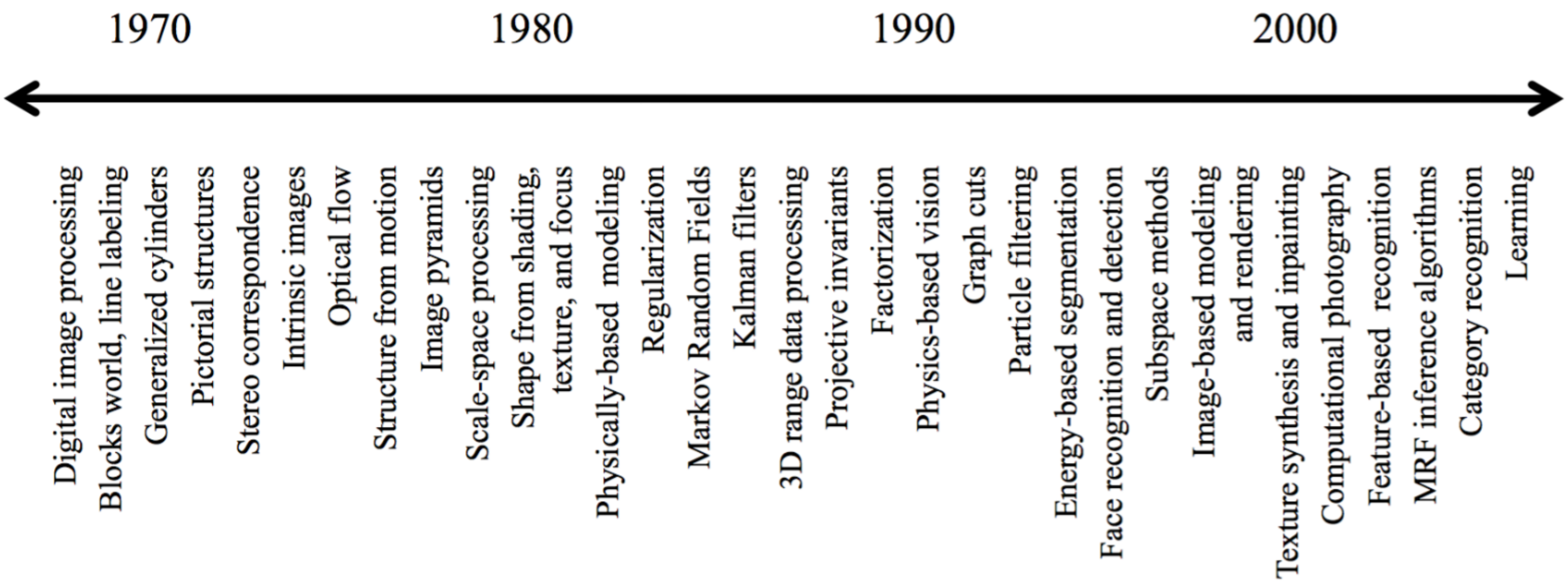
A Brief History



1980: attention was focused on more sophisticated mathematical techniques for performing quantitative image and scene analysis:

Variational optimization, MRFs, Image Pyramids, 3D scanning

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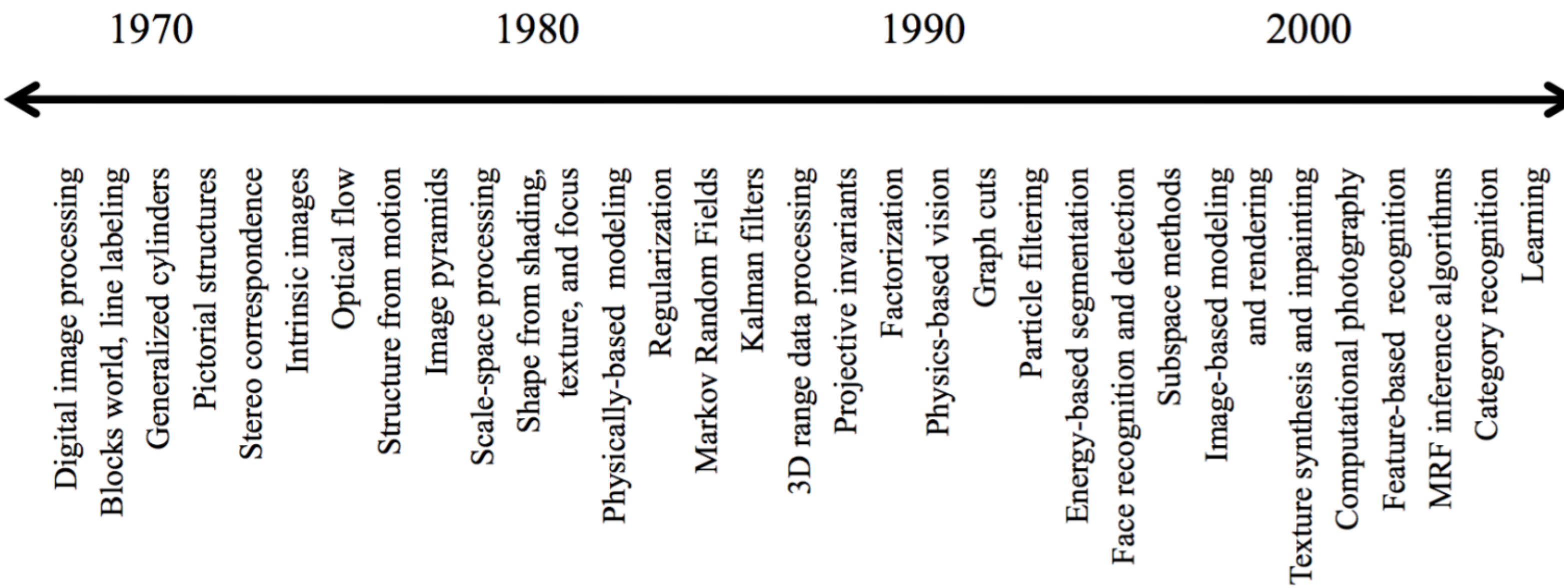
A Brief History



1990: While a lot of the previously mentioned topics continued to be explored, a few of them became significantly more active:

Sfm, bundle adjustment, projective invariants, multi-view stereo, image segmentation (GC)

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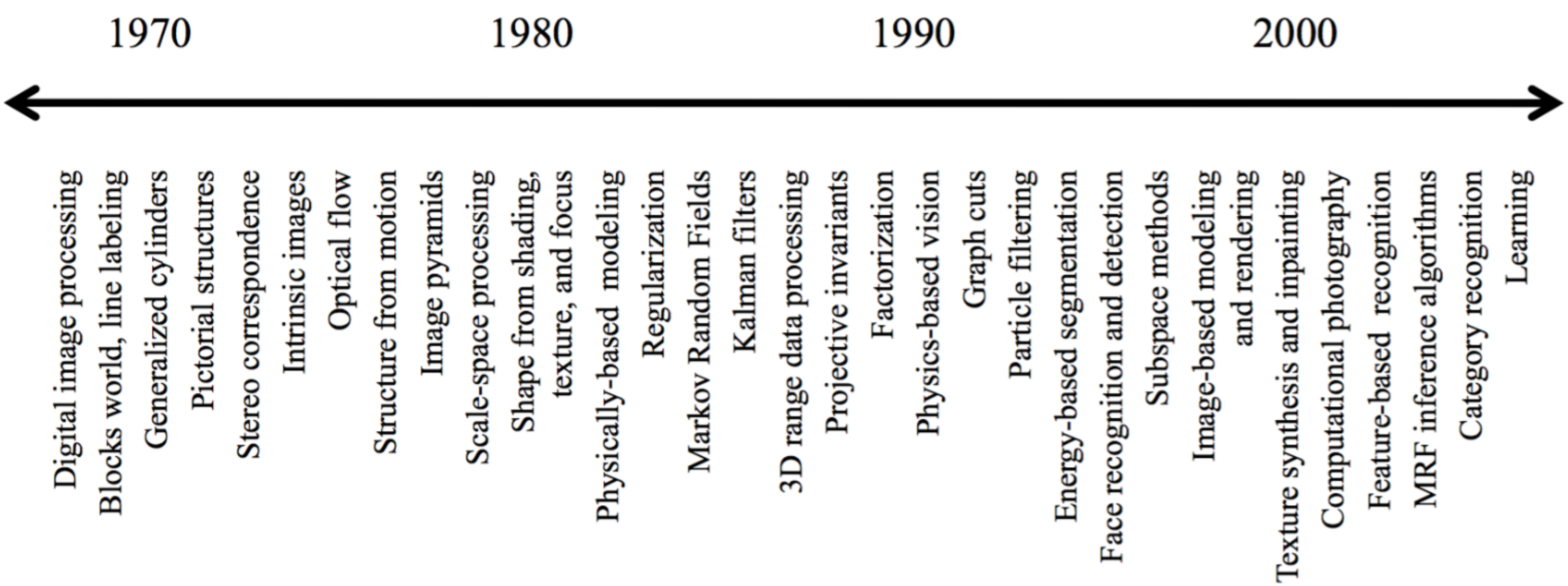
A Brief History



2000 - today: Continuous advances of all the previous topics:

SIFT features, texture synthesis, computational photography, learning

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A Brief History

1970 · 1980 · 1990 · 2000

- Digital image processing
- Blocks world, line labeling
- Generalized cylinders
- Pictorial structures
- Stereo correspondence
- Intrinsic images
- Optical flow
- Structure from motion
- Image pyramids
- Scale-space processing
- Shape from shading, texture, and focus
- Physically-based modeling
- Regularization
- Markov Random Fields
- Kalman filters
- 3D range data processing
- Projective invariants
- Factorization
- Physics-based vision
- Graph cuts
- Particle filtering
- Energy-based segmentation
- Face recognition and detection
- Subspace methods
- Image-based modeling and rendering
- Texture synthesis and inpainting
- Computational photography
- Feature-based recognition
- MRF inference algorithms
- Category recognition
- Learning

2012 - Today: Deep learning