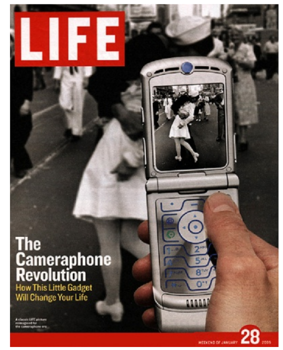
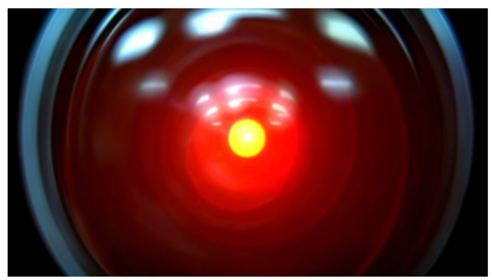
Computer Vision





Basic Info

- Instructor: Paolo Favaro (paolo.favaro@inf.unibe.ch)
- Teaching Assistants:
  Adam Bielski (adam.bielski@inf.unibe.ch)
  Adrian Wälchli (adrian.waelchli@inf.unibe.ch)
  Xiaochen Wang (xiaochen.wang@inf.unibe.ch)

- Course webpage: http://cvg.unibe.ch/teaching
- Course material acknowledgements:
  - Svetlana Lazebnik – University of Illinois
  - Steve Seitz – University of Washington
  - Jan Koenderink – University of Leuven
  - Kristen Grauman – University of Texas at Austin
  - Andrea Vedaldi – University of Oxford
  - Srinivas Narasimhan – Carnegie Mellon University

To Do List

- On behalf of the Branch Committee for Computer Science, I would like to inform you about the **student's ToDo list for every semester**. The details can be found on our web site at http://mcs.unibnf.ch/organization.

- **JMCS students** please pay attention to these dates

1. Each student must **register for the teaching units** that they want to take during that semester until the registration deadline (see below) in Academia.

2. Each student must **register for the exams** until the registration deadline (see below) in Academia.

3. Each student must **register for the BeNeFri network** if he/she follows a teaching unit at a partner university until

- Autumn semester: September 30th
- Spring semester: February 28th

The procedure is dependent on the student's situation

- Bern: http://www.selfservice.studis.unibe.ch
- Neuchâtel:
  - JMCS student: nothing to do
  - Hosted JMCS student: https://am-institute.ch/benefri/assets/files/BeNeFri-inscript_automne%202015.pdf
- Fribourg: http://www.unifr.ch/mydata

Travel expenses are reimbursed by the student's home university and must be claimed until

- Autumn semester: January 31st
- Spring semester: June 30th

Use therefore the travel regulation (BeNeFri forms).

Hosted JMCS students

- **Hosted JMCS students**, e.g.: bachelor students in Computer Science (major, minor, optional studies) or master students in Mathematics or Information Management have exactly to do the same tasks as JMCS students. Additionally, **every semester** they have to:
- Complete a request form for Academia access (http://mcs.unibnf.ch/node/535) at the beginning of every semester

Hosted JMCS students

Hosted JMCS students are all students other than JMCS students who follow a teaching unit of the Joint Master in Computer Science, e.g.:

- bachelor students in Computer Science (major, minor, optional studies)
- master students in Mathematics or Information Management

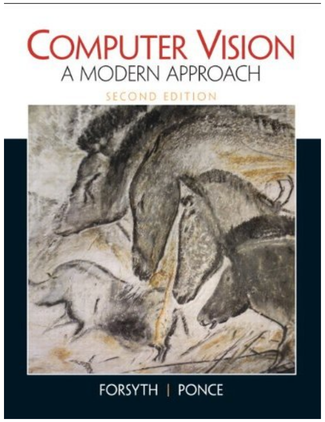
They have exactly to do the same three tasks as mentioned above for JMCS students and they must additionally do **every semester** the following task:

4. Each student must **complete a Request for Academia Access form** at the beginning of every semester until

- Autumn semester: September 30^{th}
- Spring semester: February 28^{th}

The student will be informed when he/she is able to login into Academia.

Textbooks



- Forsyth & Ponce, *Computer Vision: A Modern Approach*
- Kristen Grauman and Bastian Leibe, *Visual Object Recognition (pdf available online)*
- Christopher Bishop, *Pattern Recognition and Machine Learning*
- Yi Ma, Stefano Soatto, Jana Kosecka, S. Shankar Sastry, *An invitation to 3-D vision: From images to geometric models*
- Richard Szeliski, *Computer Vision: Algorithms and Applications*
- Simon J.D. Prince, Computer Vision: Models, Learning, and Inference (available online: http://computervisionmodels.com)

Course requirements

- 2 Assignments
  - Deadlines specified in the next slide
  - Each assignment has a maximum score of 100 and a pass is 60
  - To register for the exam one needs at least a pass on <u>each</u> assignment
  - Each assignment to be made available in ILIAS
  - Assignments will require use of PYTHON (tutorial material will be provided)
- Tutorials
  - Weekly
  - Aim is exam preparation
- Exam
  - There will be a written final exam (duration 120 mins)
- Final Mark
  - 70% Exam and 30% Assignments

Assignments

- First assignment: Image inpainting and blending
  - Available on October 15
  - Due on November 12

- Second assignment: 3D reconstruction
  - Available on November 12
  - Due on December 10

Image inpainting and blending

A combination of 2 problems with 3 optimization methods

inpainting

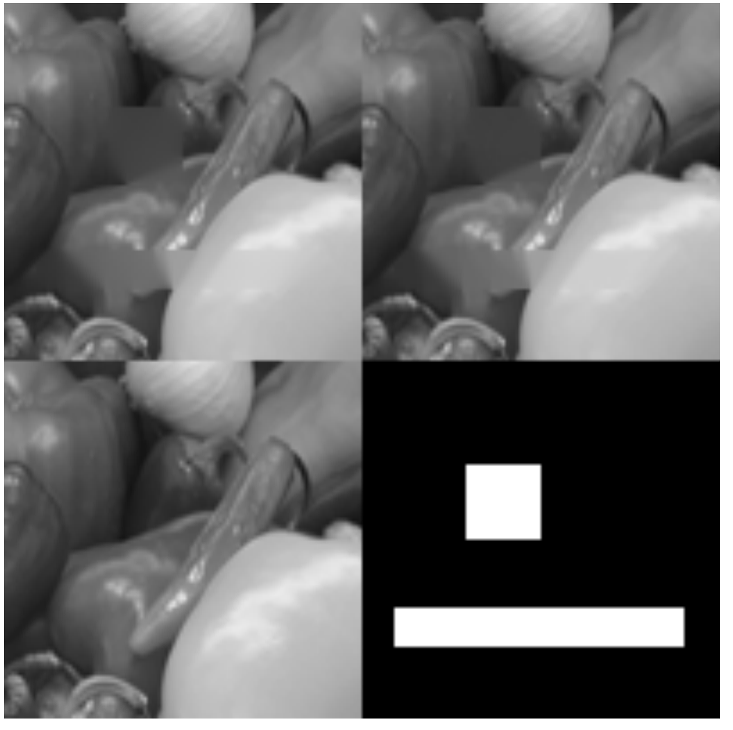
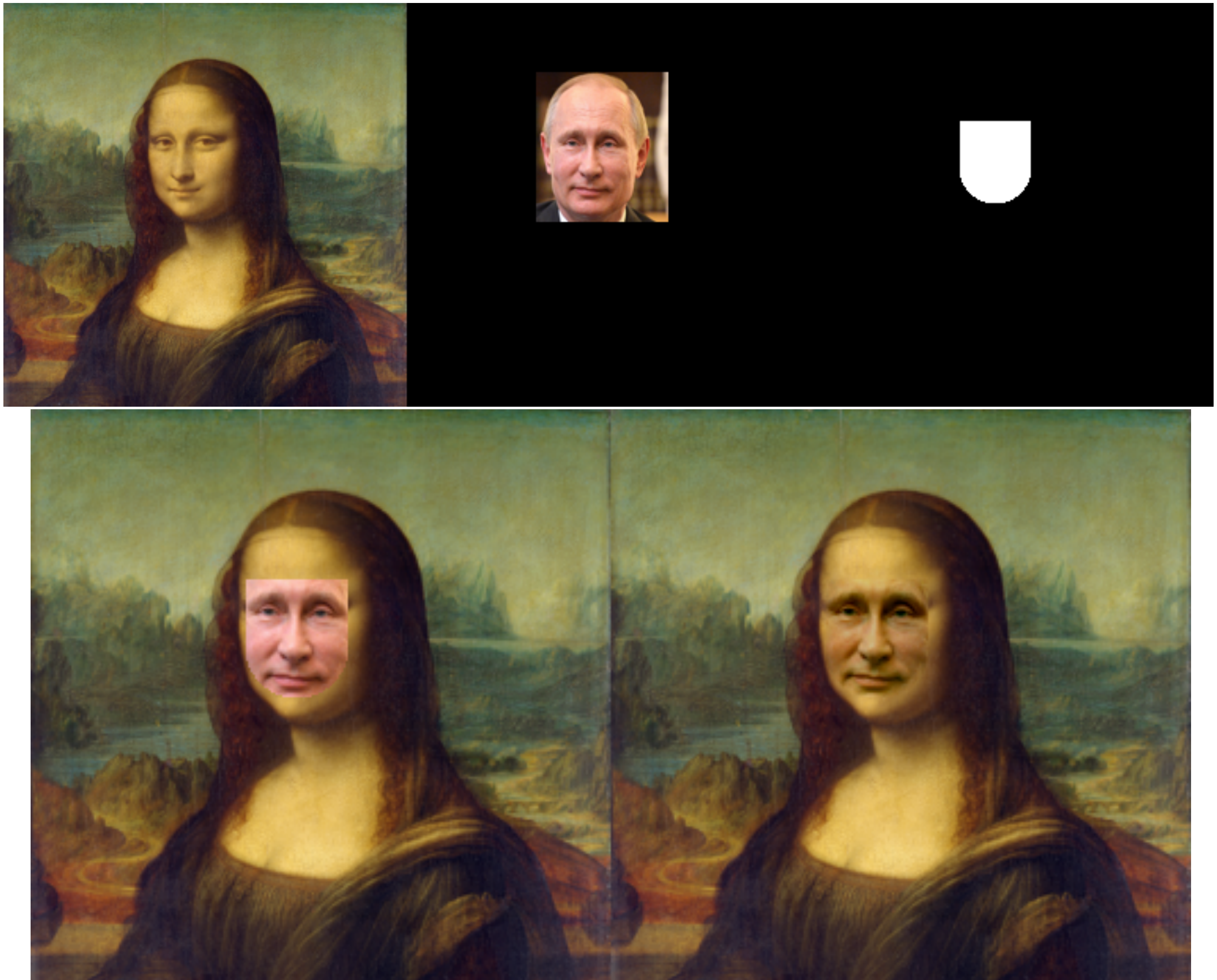


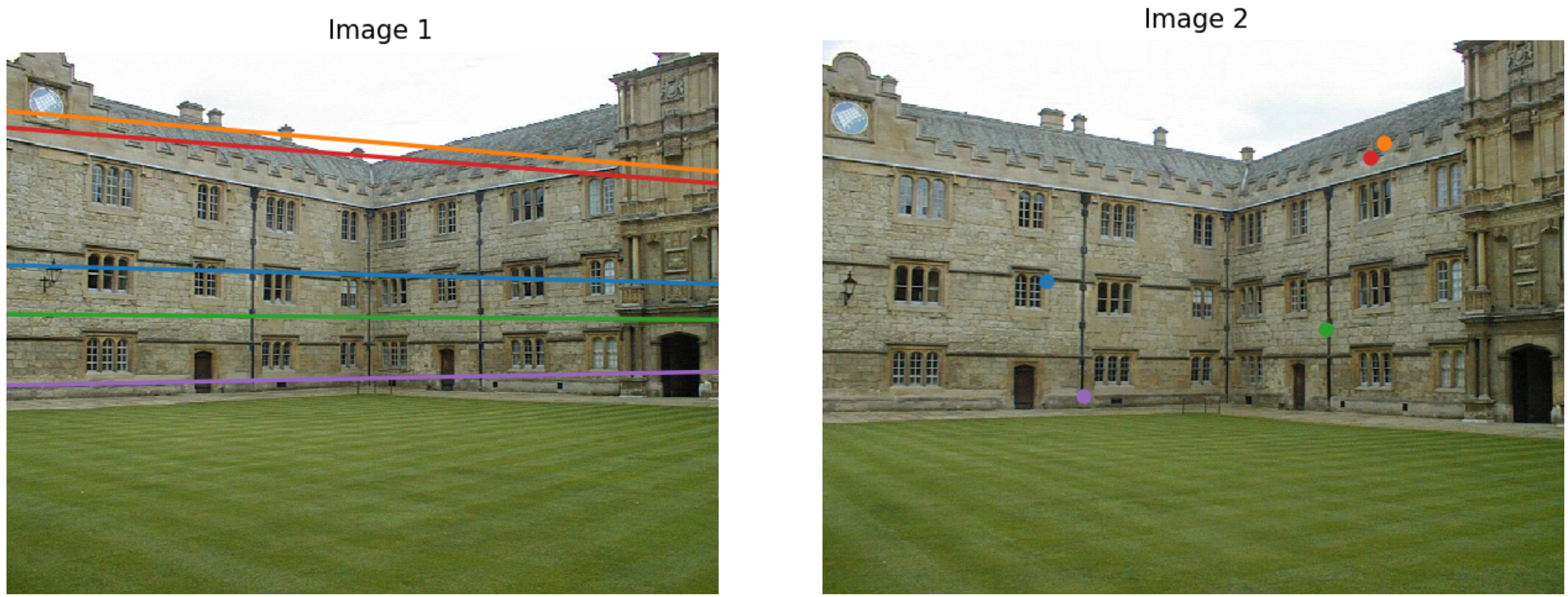
Image inpainting and blending



3D Reconstruction

1.

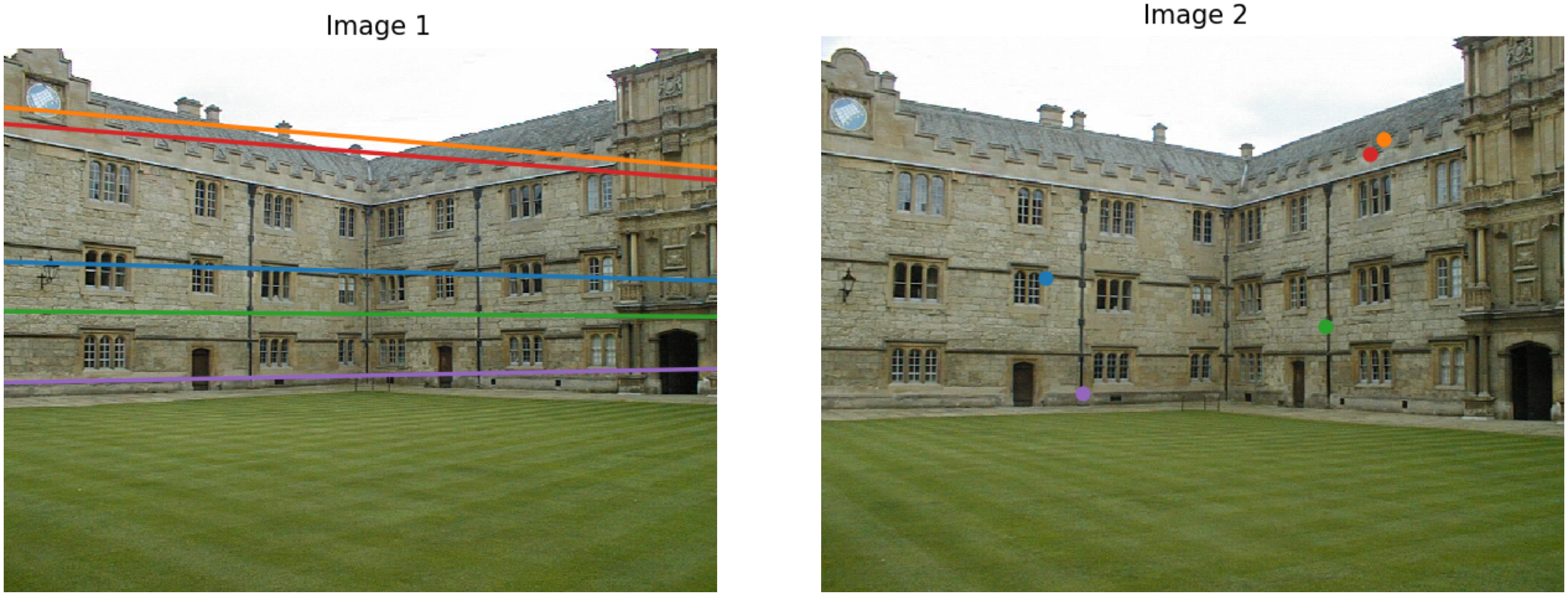
Given high-res pictures of the same scene from different viewpoints



3D Reconstruction

2.

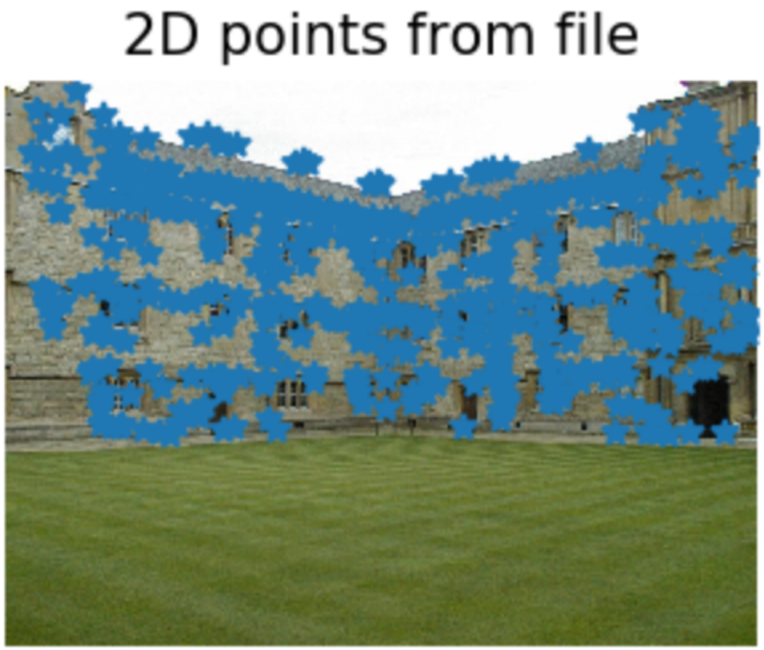
Select points and apply computer vision methods (epipolar geometry) to find correspondences in the other image

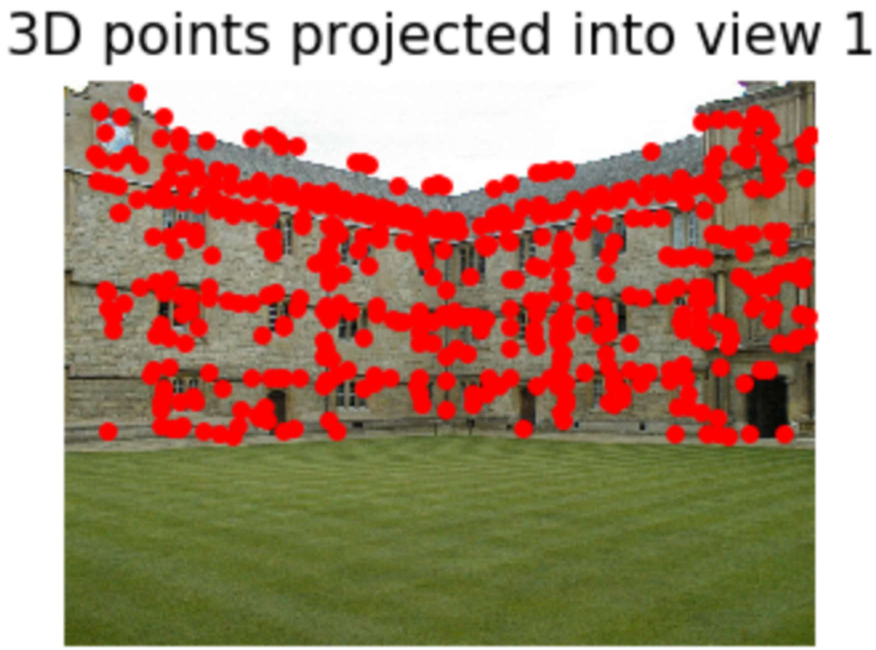


3D Reconstruction

3.

Find reliable point correspondences from one image to the other

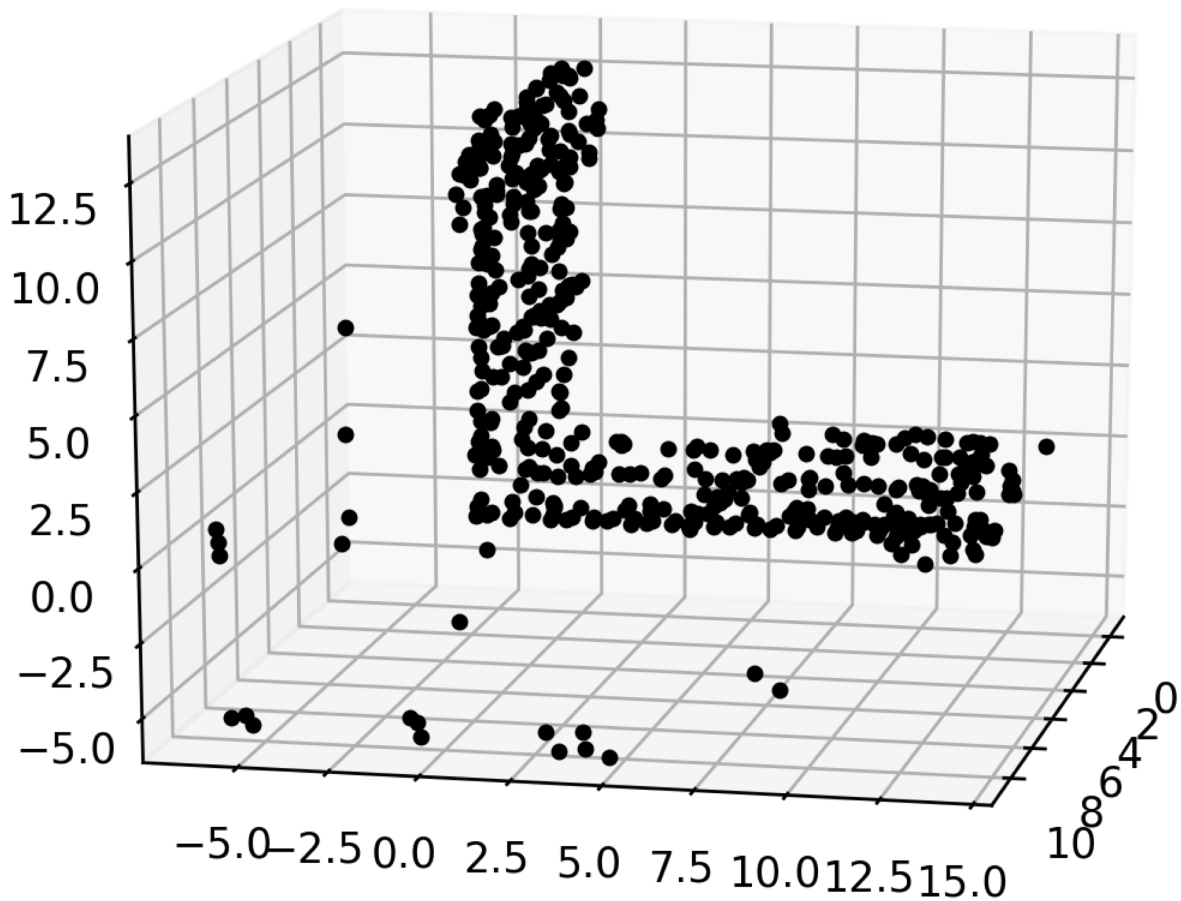




3D Reconstruction

4.

Compute the 3D reconstruction of the detected points



Academic integrity policy

- Feel free to discuss assignments with each other, but **coding must be done individually**

- Feel free to incorporate code or tips you find on the Web, provided this doesn't make the assignment trivial and you **explicitly acknowledge your sources**

Computer Vision

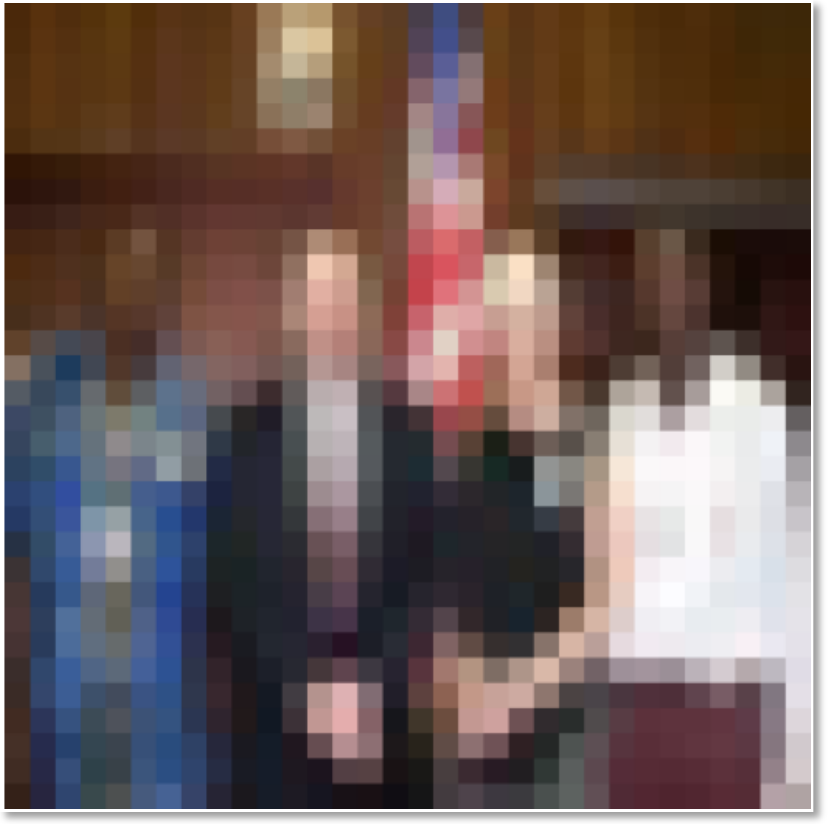
The goal of computer vision

- To extract “meaning” from pixels

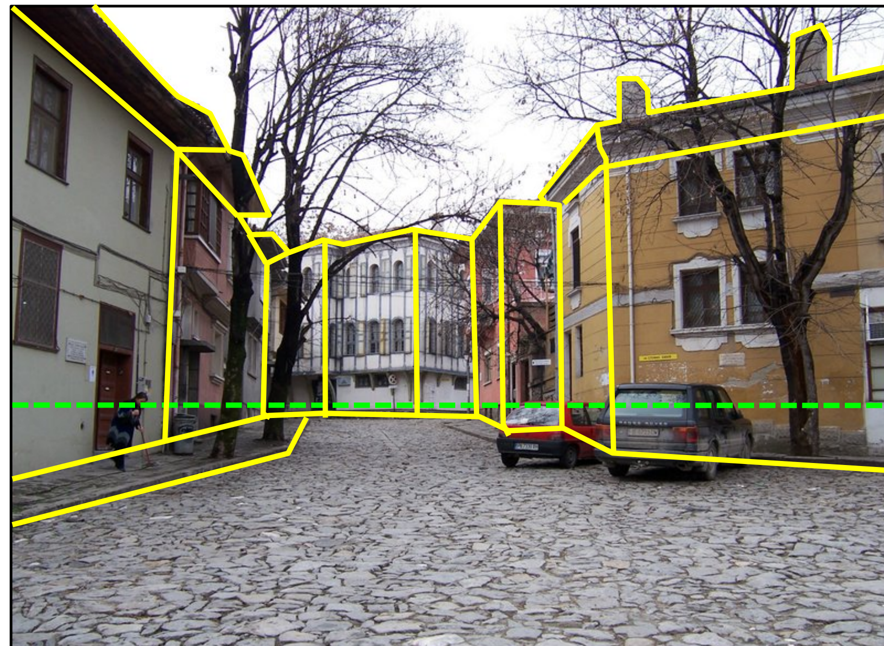
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

The goal of computer vision

- To extract “meaning” from pixels



What kind of information can be extracted from an image?



Semantic information

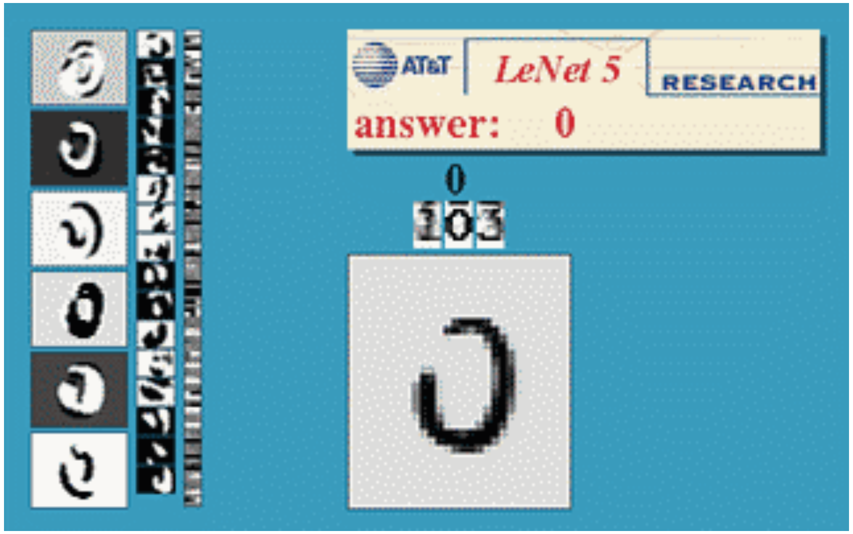
Geometric information

Why study computer vision?

- Vision is useful
- Vision is interesting
- Beware: Human vision is easy, but computer vision is difficult
  - Half of primate cerebral cortex is devoted to visual processing
  - Achieving human-level visual perception is probably “AI-complete”

Successes of computer vision to date

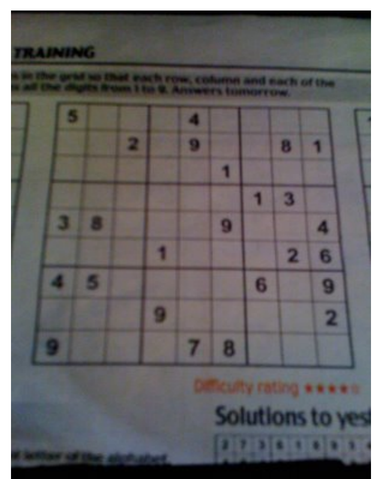
Optical character recognition (OCR)



Digit recognition
yann.lecun.com

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Automatic check processing



Sudoku grabber

http://sudokugrab.blogspot.com/

Source: S. Seitz, N. Snavely

Biometrics

Fingerprint scanners on
many new laptops,
other devices

Face recognition systems now
beginning to appear more widely
http://www.sensiblevision.com/

Source: S. Seitz

Face detection

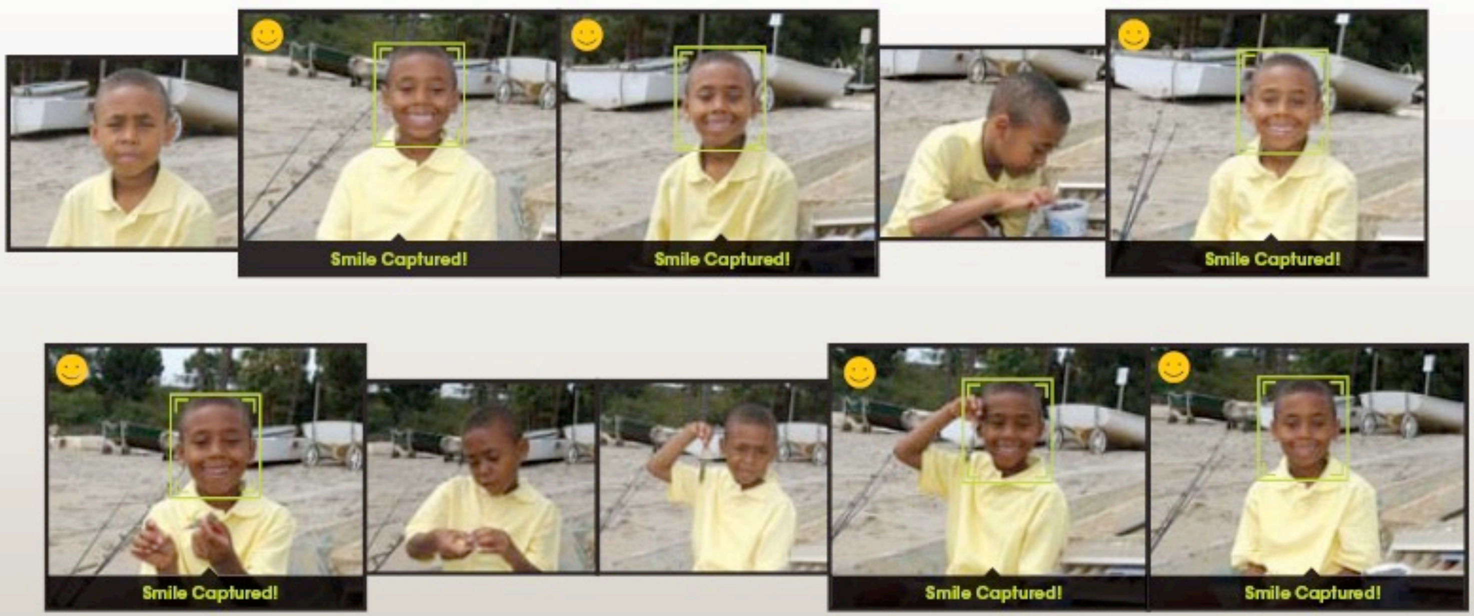
Many consumer digital cameras now detect faces

Source: S. Seitz

Smile detection

The Smile Shutter flow

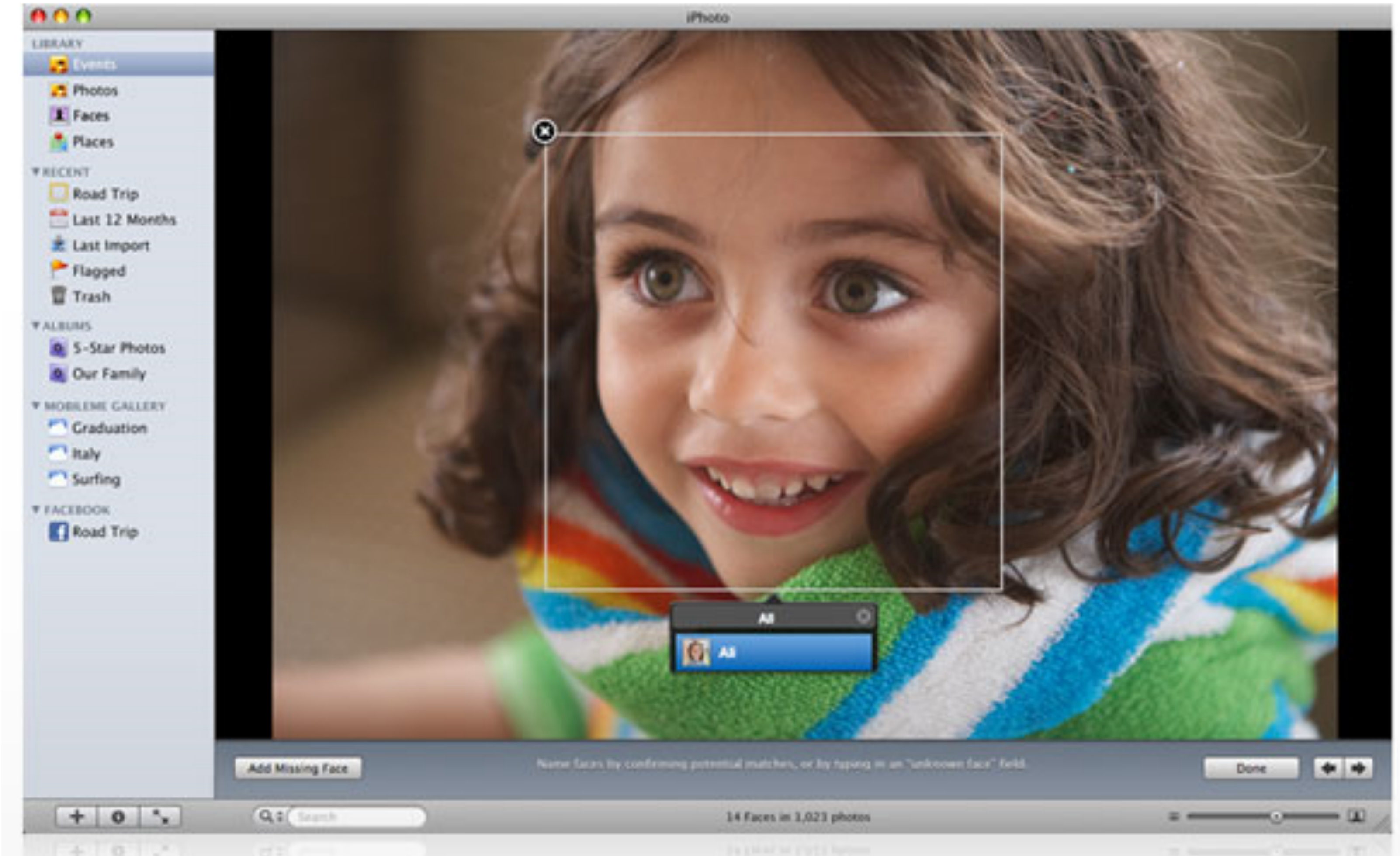
Imagine a camera smart enough to catch every smile! In Smile Shutter Mode, your Cyber-shot® camera can automatically trip the shutter at just the right instant to catch the perfect expression.



[Sony Cyber-shot® T70 Digital Still Camera](#)

Source: S. Seitz

Face recognition: Apple iPhoto software

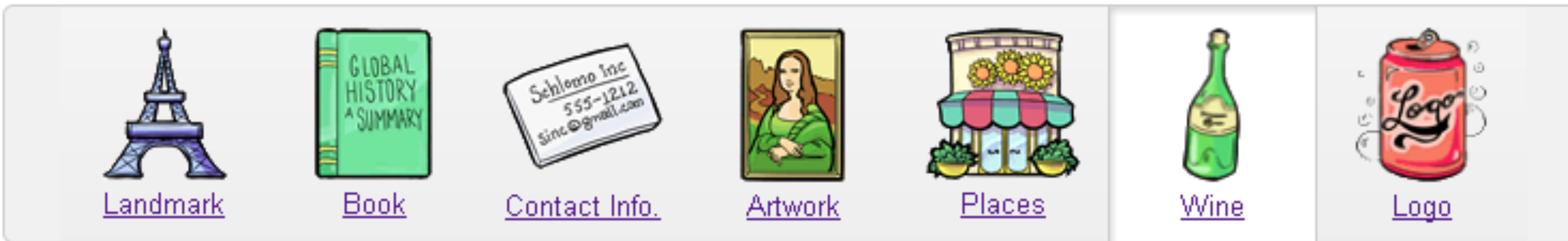


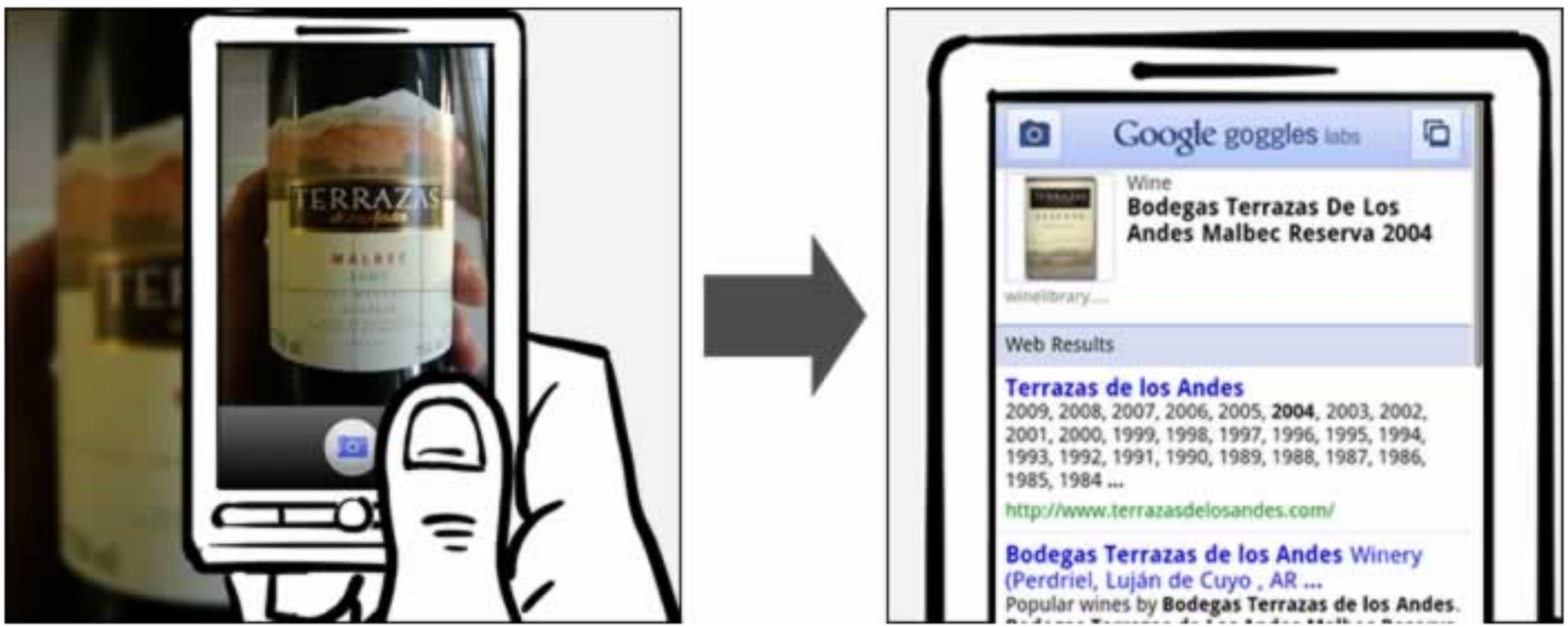
http://www.apple.com/ilife/iphoto/

Mobile visual search: Google Goggles

Google Goggles in Action

Click the icons below to see the different ways Google Goggles can be used.





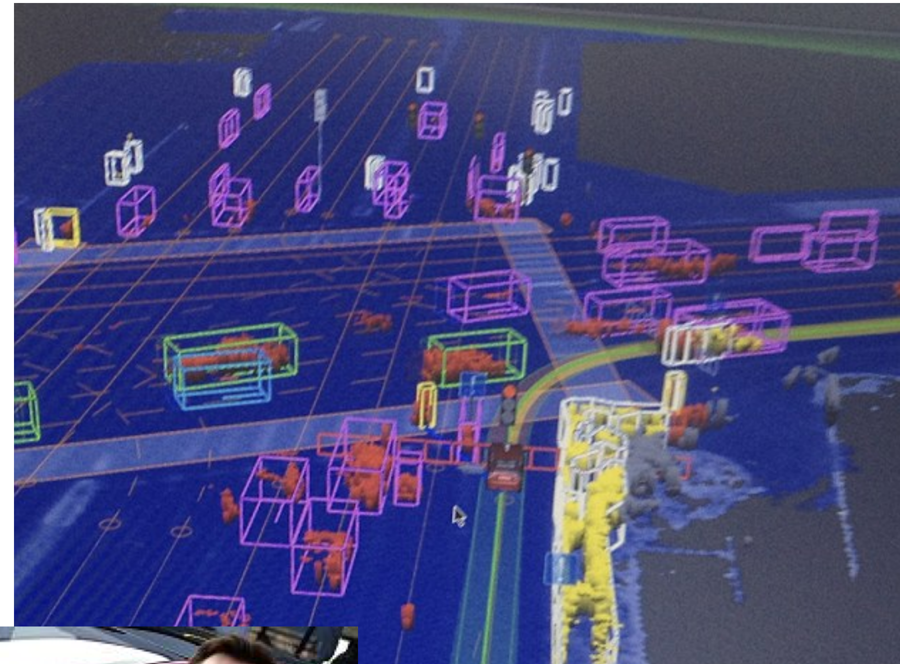
Automotive safety

[Mobileye](): Vision systems in high-end BMW, GM, Volvo models

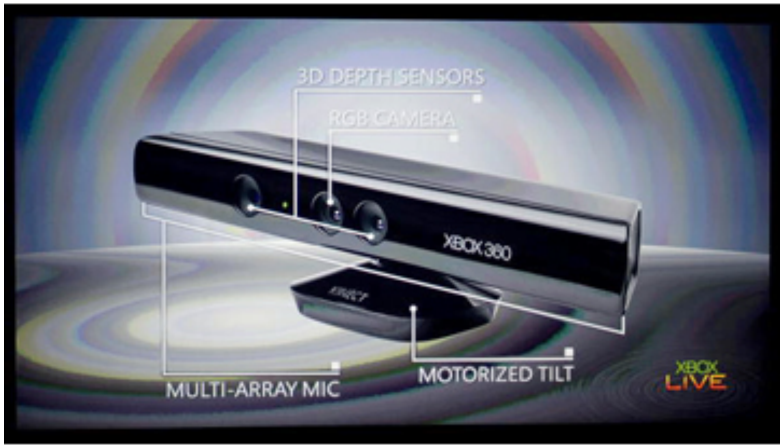
- Pedestrian collision warning
- Forward collision warning
- Lane departure warning
- Headway monitoring and warning

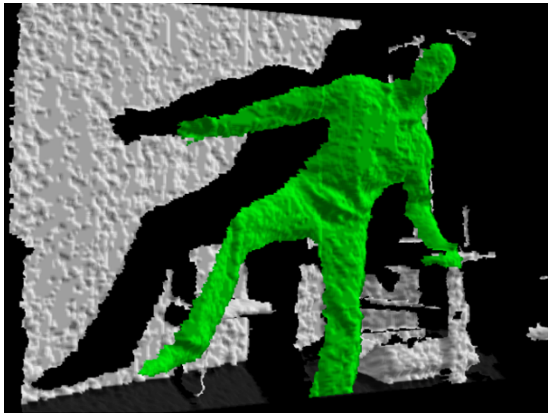
Source: A. Shashua, S. Seitz

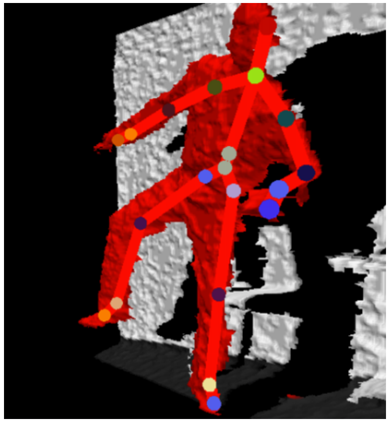
Google/Tesla self-driving cars



Vision-based interaction: Xbox Kinect







3D Reconstruction: Kinect Fusion

YouTube Video

3D Reconstruction: Multi-View Stereo

[YouTube Video]

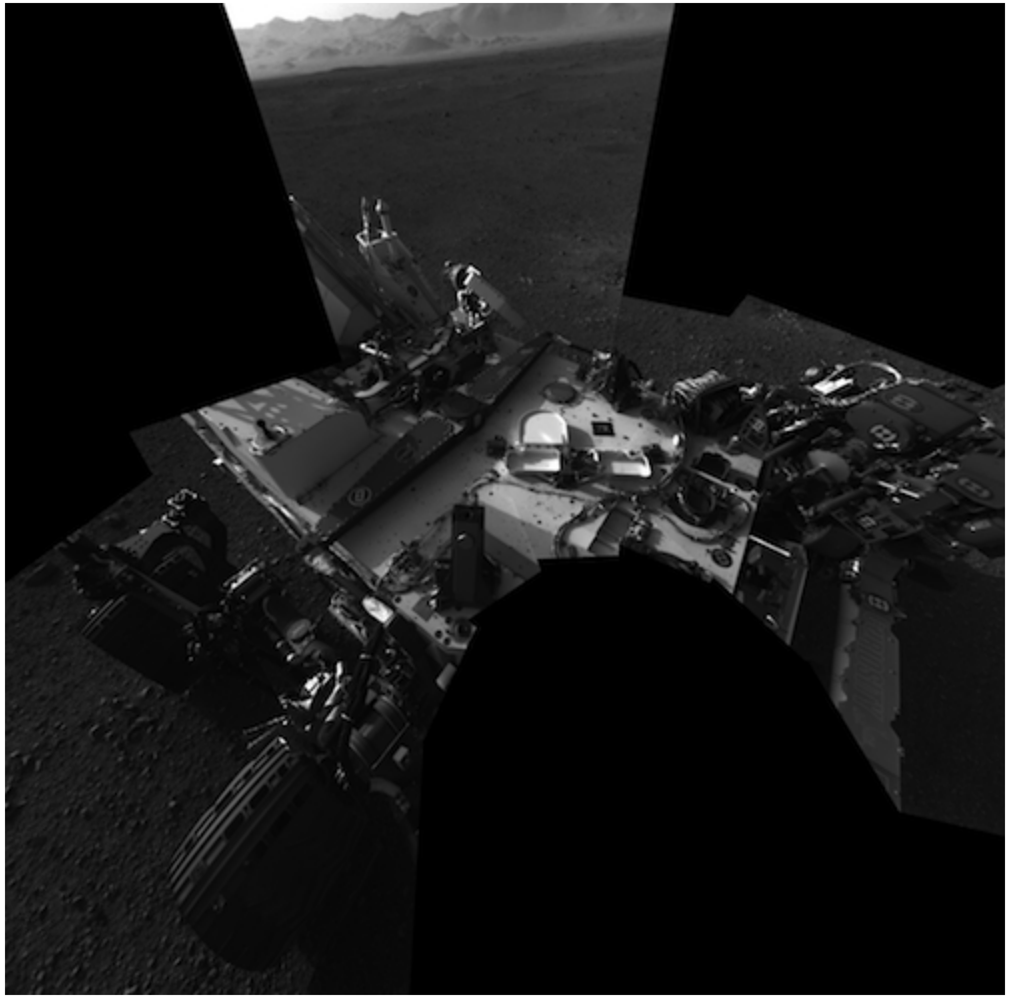
Google Maps Photo Tours

http://maps.google.com/phototours

Special effects: shape and motion capture

Source: S. Seitz

Vision for robotics, space exploration



[NASA'S Curiosity Rover has a system consisting of 17 cameras]

Why is computer vision difficult?

Challenges: viewpoint variation

Michelangelo 1475-1564

slide credit: Fei-Fei, Fergus & Torralba

Challenges: illumination

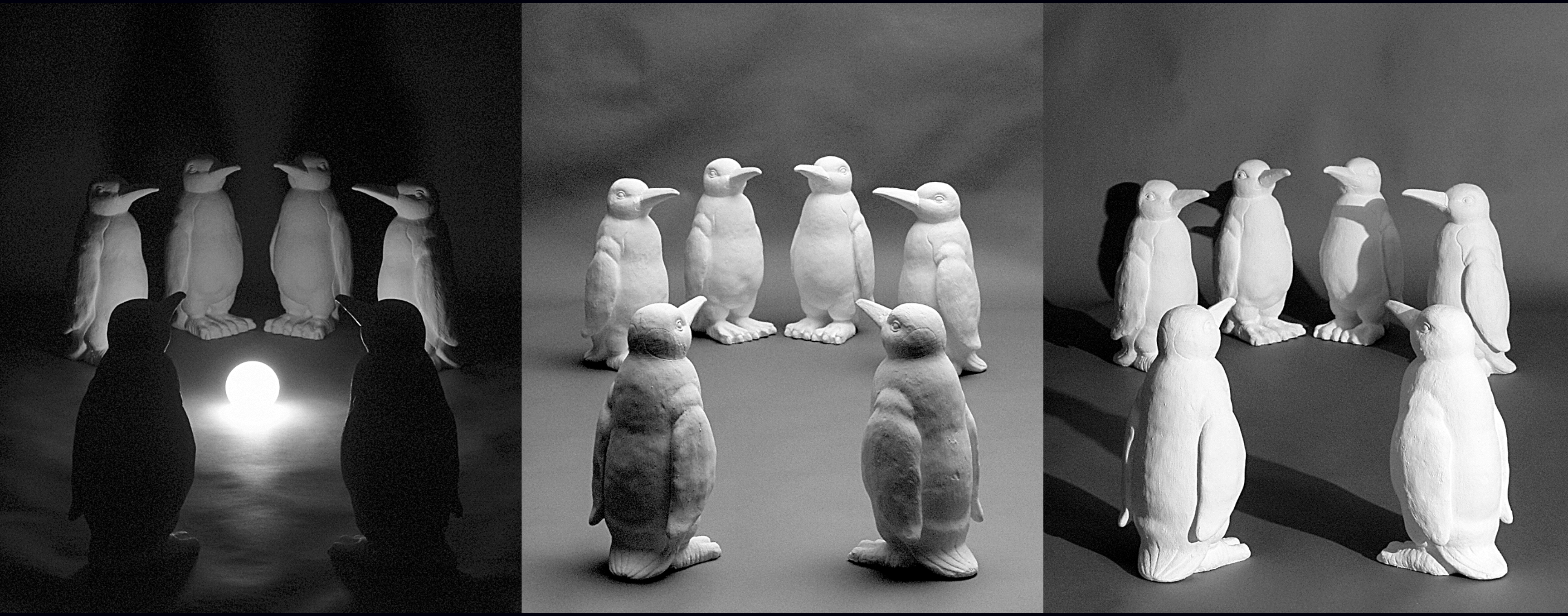
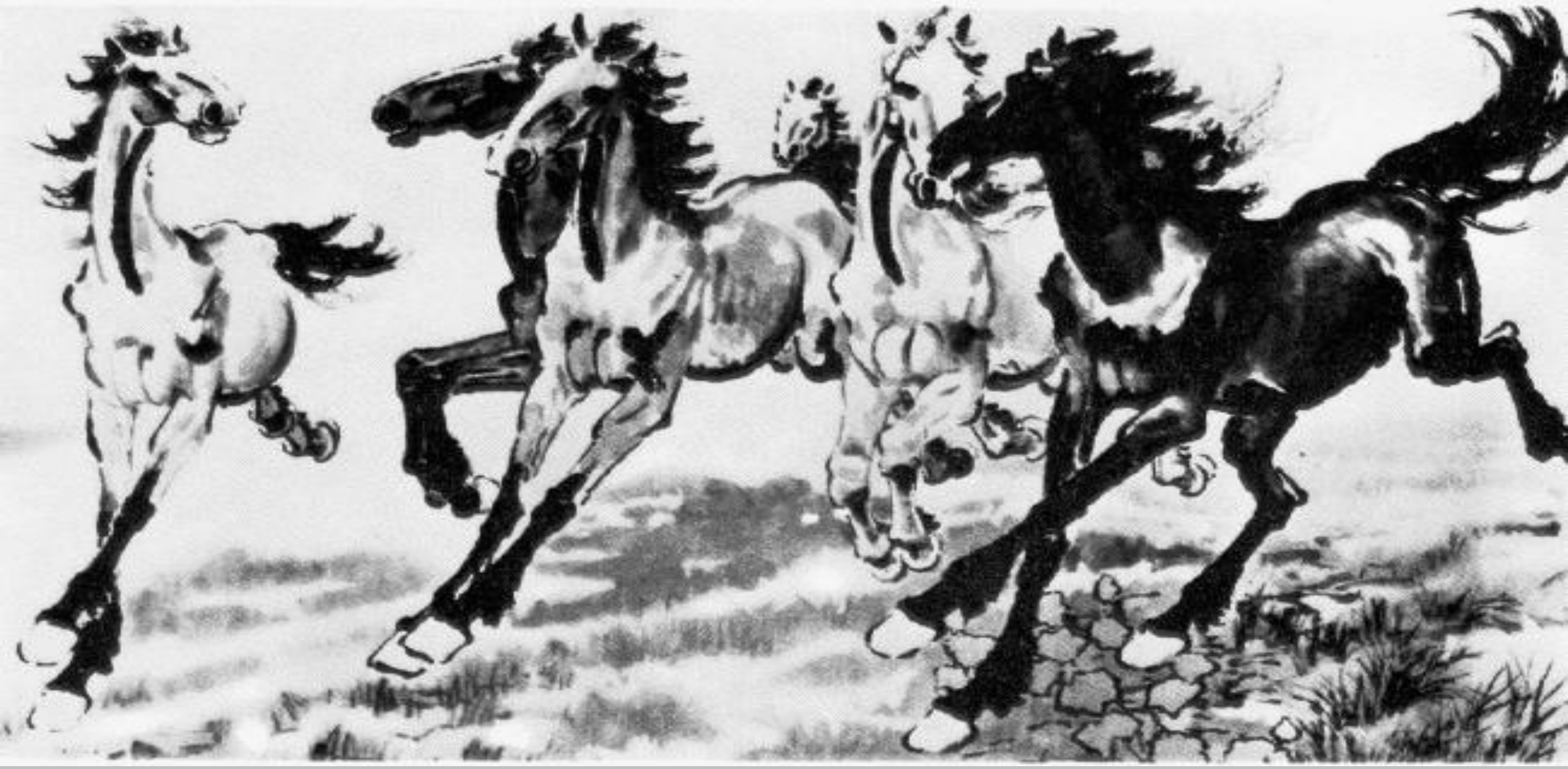


image credit: J. Koenderink

Challenges: scale

slide credit: Fei-Fei, Fergus & Torralba

Challenges: deformation



Xu, Beihong 1943

slide credit: Fei-Fei, Fergus & Torralba

Challenges: occlusion, clutter

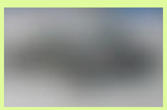
Image source: National Geographic

Challenges: Motion

Challenges: object intra-class variation

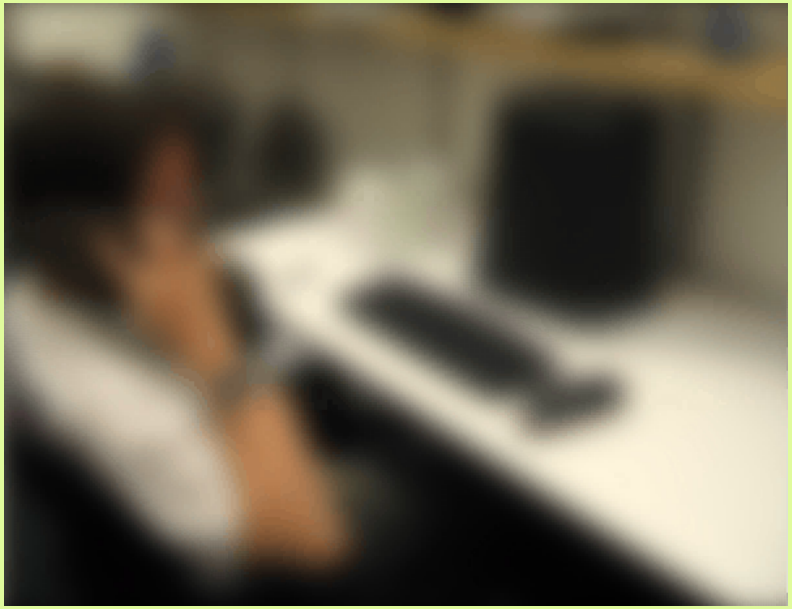
slide credit: Fei-Fei, Fergus & Torralba

Challenges: local ambiguity



slide credit: Fei-Fei, Fergus & Torralba

Challenges: local ambiguity



Source: Rob Fergus and Antonio Torralba

Challenges: local ambiguity

Source: Rob Fergus and Antonio Torralba

Challenges: Inherent ambiguity

- Many different 3D scenes could have given rise to a particular 2D picture

Challenges or opportunities?

- Images are confusing, but they also reveal the structure of the world through numerous cues
- Our job is to interpret the cues!

Depth cues: Linear perspective

Depth cues: Aerial perspective

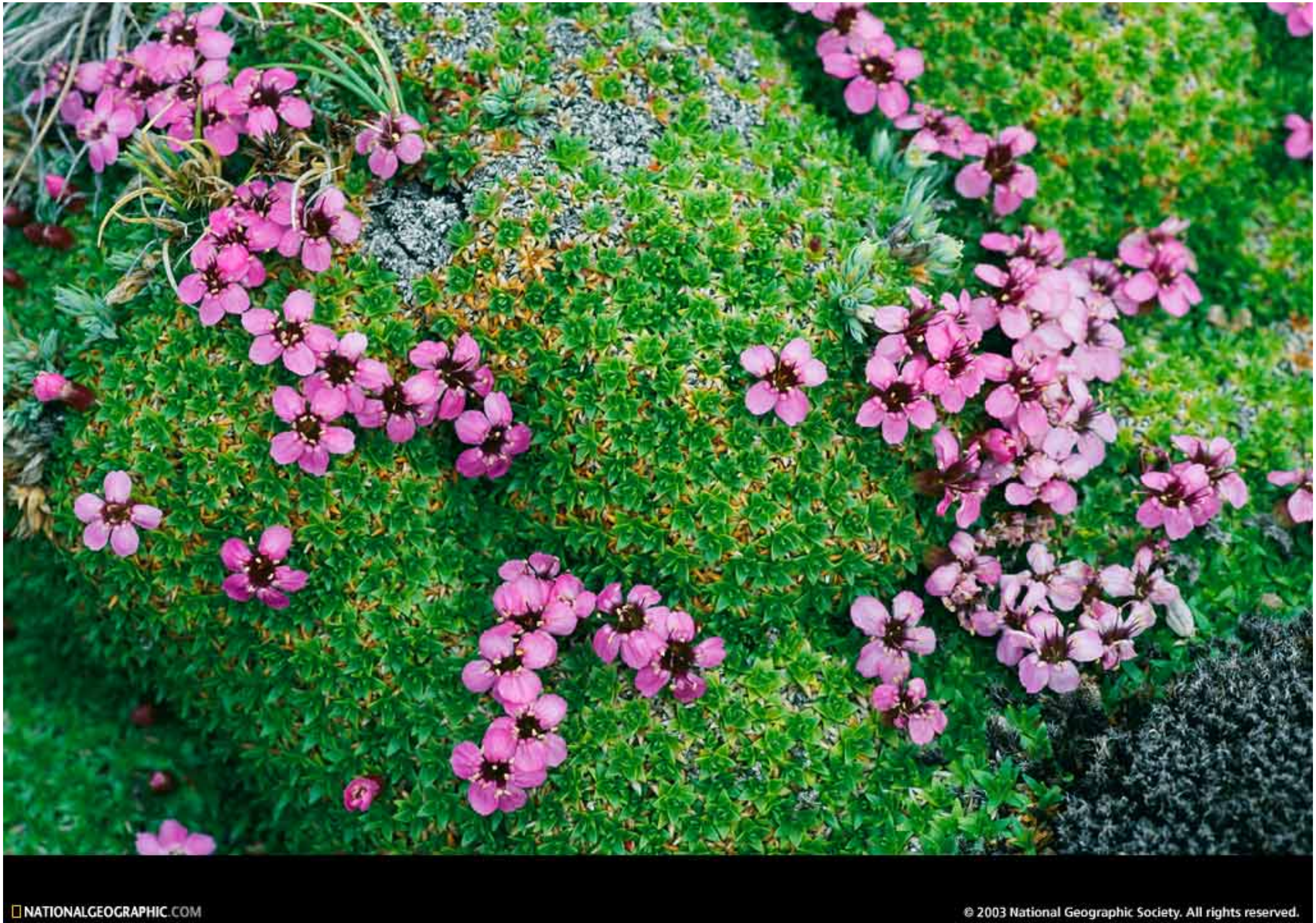
Depth ordering cues: Occlusion

Shape cues: Texture gradient

Shape and lighting cues: Shading

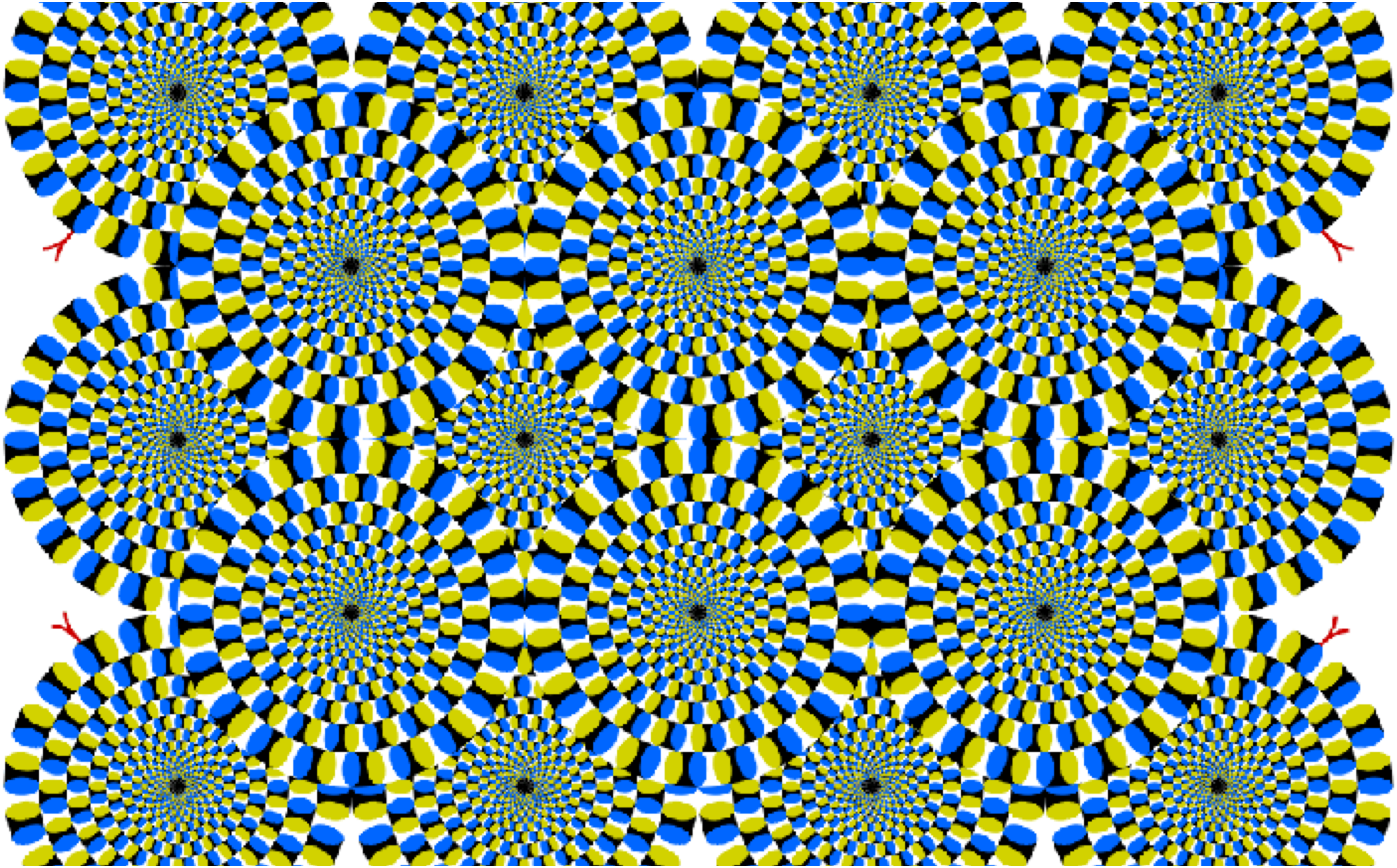
Position and lighting cues: Cast shadows

Grouping cues: Similarity (color, texture, proximity)



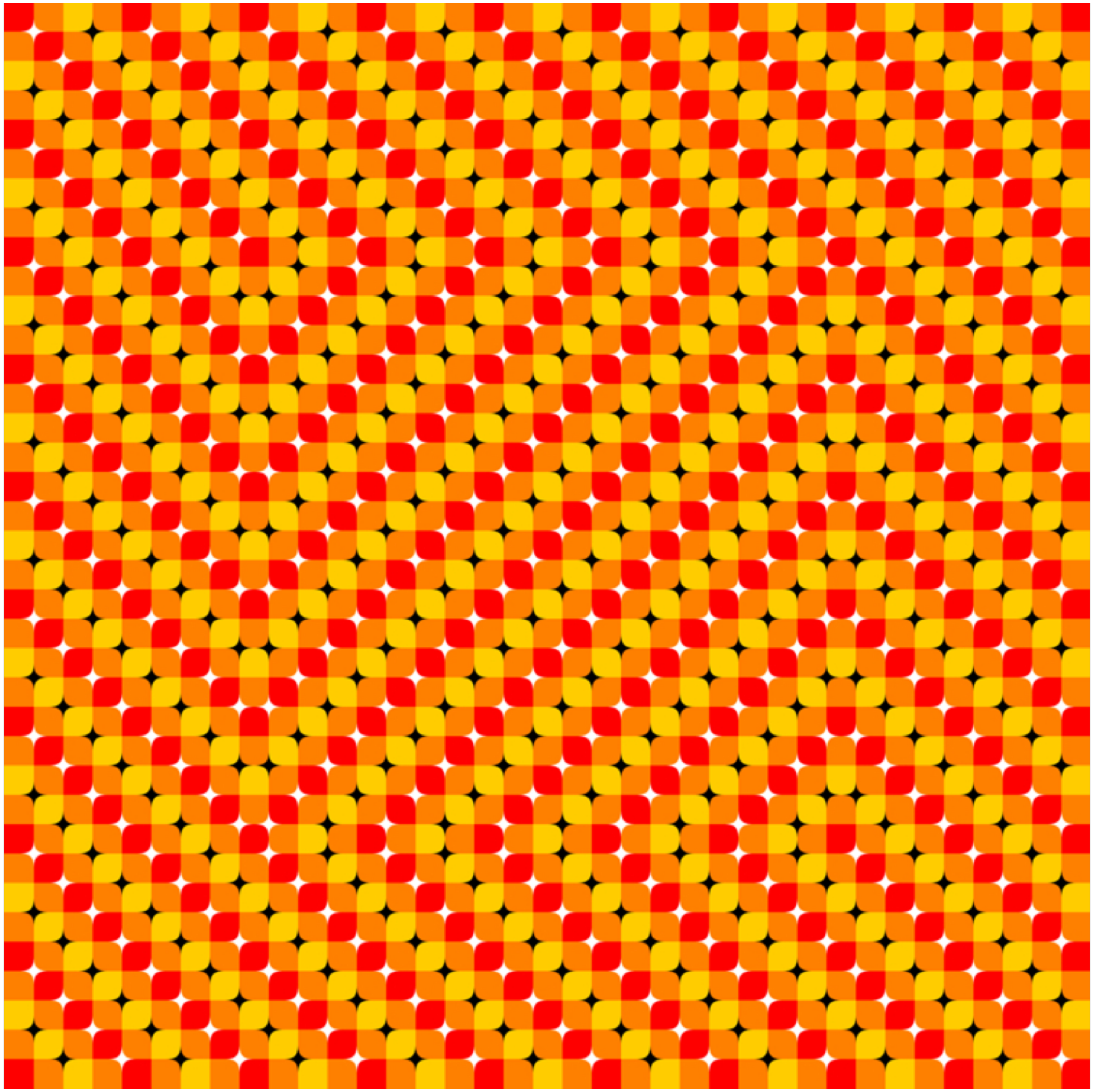
Grouping cues: “Common fate”

Perceptual illusions (limitations)

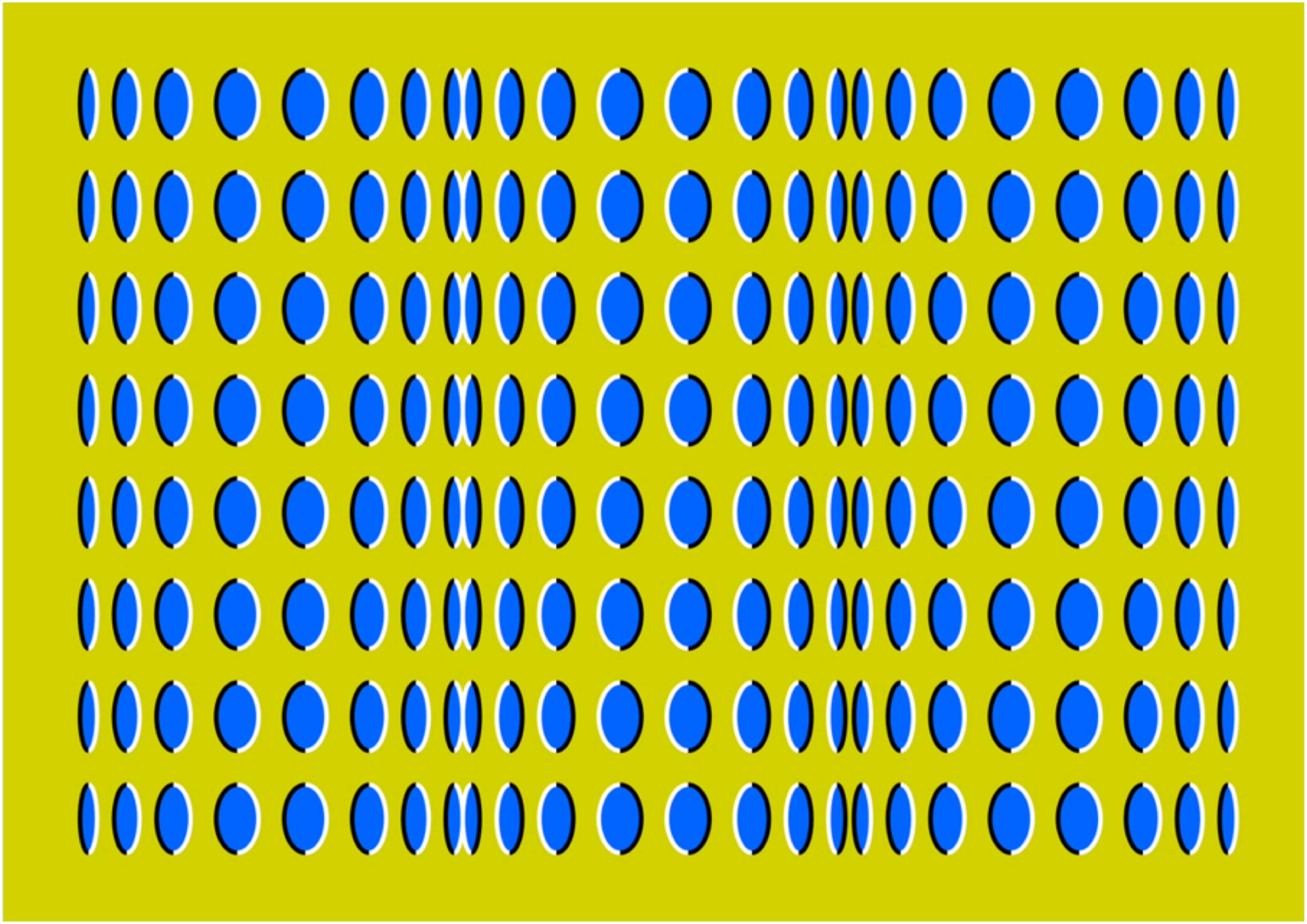


http://www.ritsumei.ac.jp/~akitaoka/index-e.html

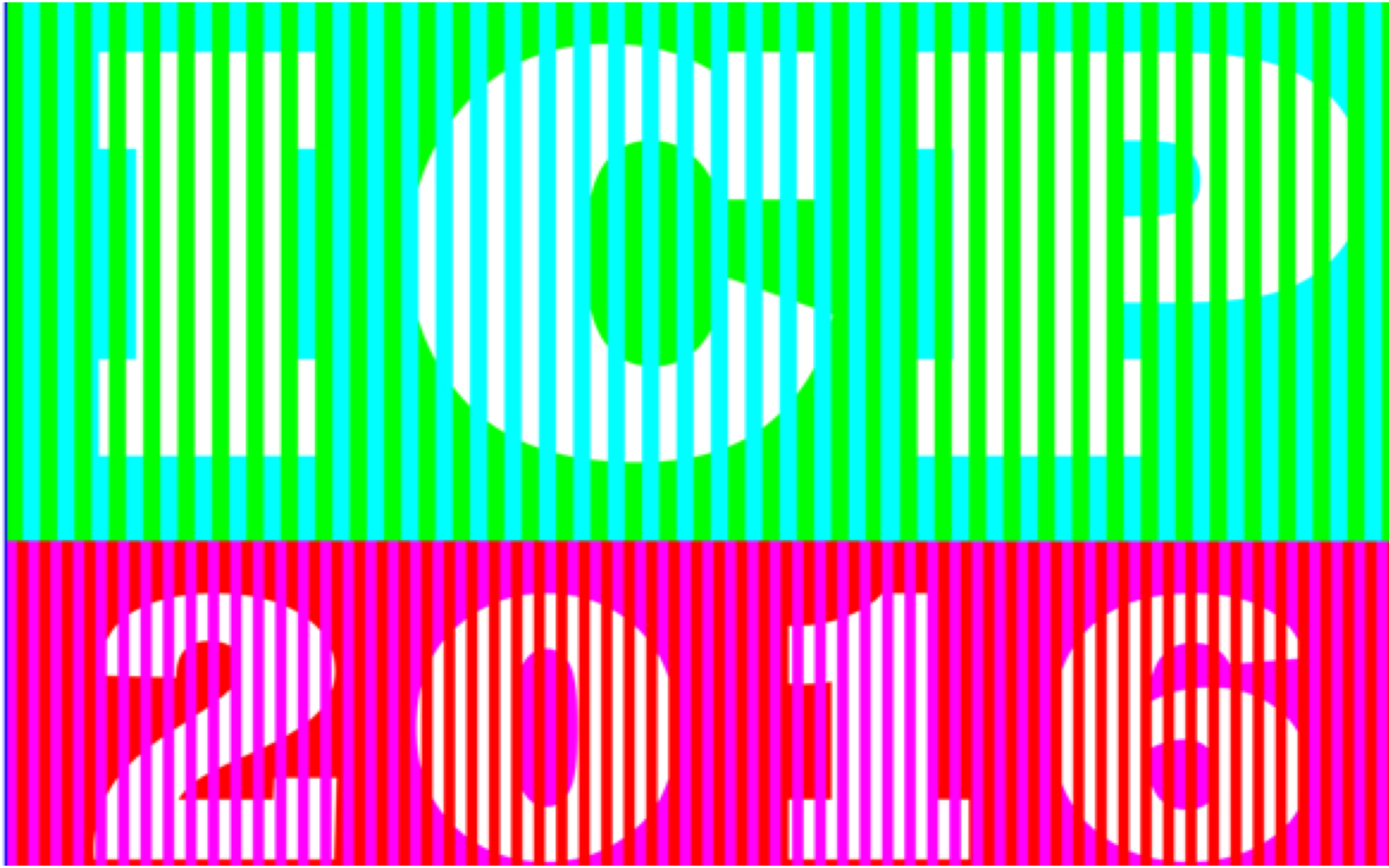
Perception: Moving inset



Perception: Rotating cylinders



Perception: Chromatic error



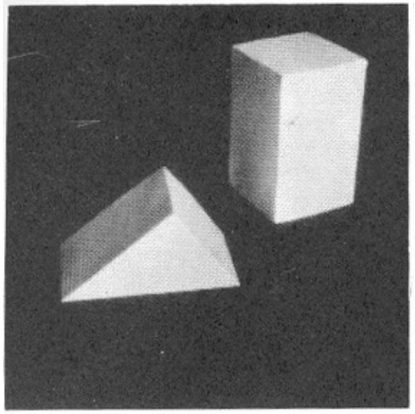
All letters are white

Perception: Colors

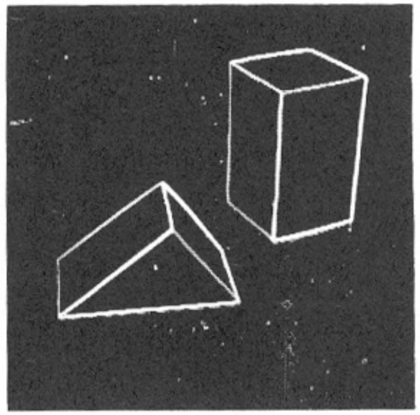
Lower part looks bluish but all pixels are red

Origins of computer vision

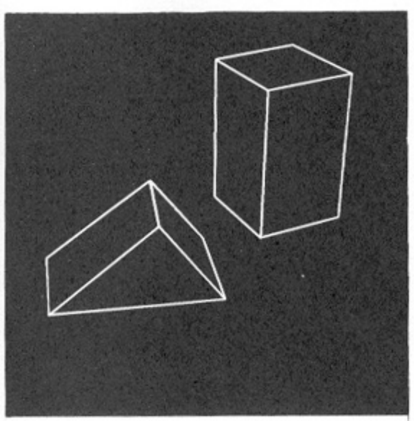
-23-4445(a-d)



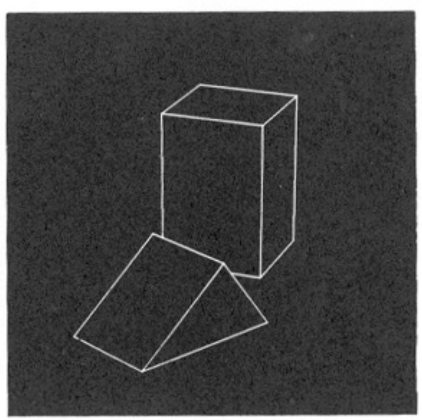
(a) Original picture.



(b) Differentiated picture.



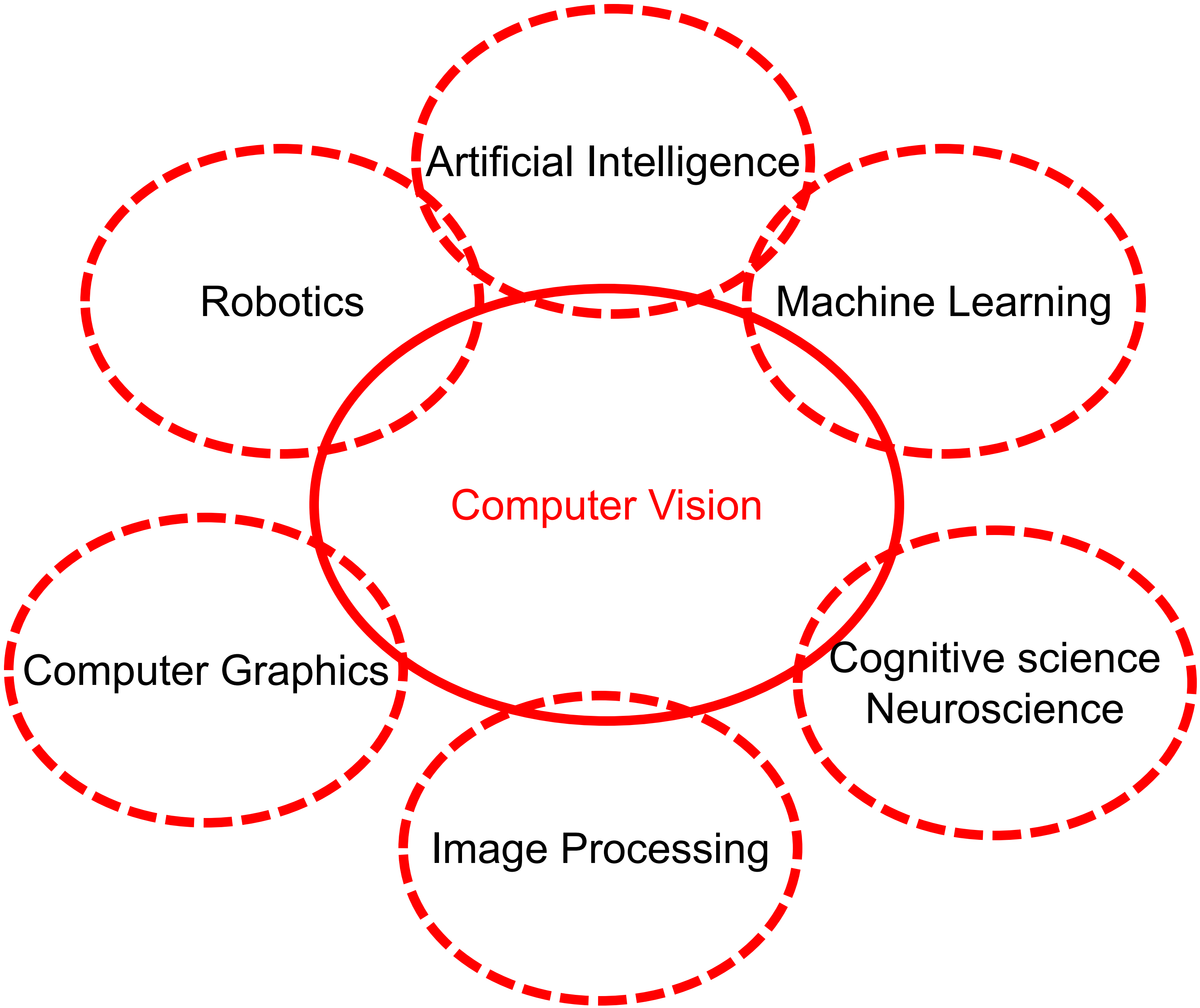
(c) Line drawing.



(d) Rotated view.

L. G. Roberts *Machine Perception of Three Dimensional Solids*

Connections to other disciplines



The computer vision industry

- A pre 2015 list of companies here:

  http://www.cs.ubc.ca/spider/lowe/vision.html

- Now there has been an explosion of companies especially in autonomous driving, virtual reality and recognition

Course overview

I. Image formation
   – camera and projection models

II. Image processing
   – filtering, edges, minimization framework

III. Correspondence
   – tracking, optical flow, registration, interest points, fitting

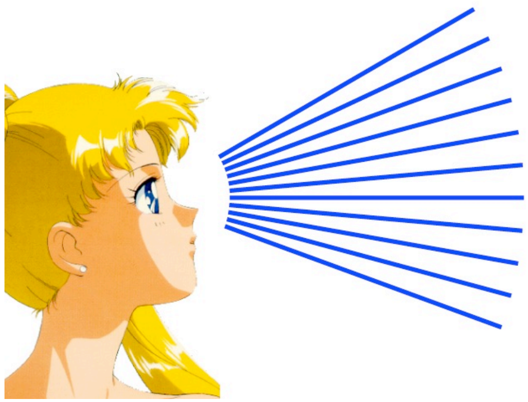
IV. 3D motion and geometry
   – epipolar geometry, (multiview) stereo and structure from motion

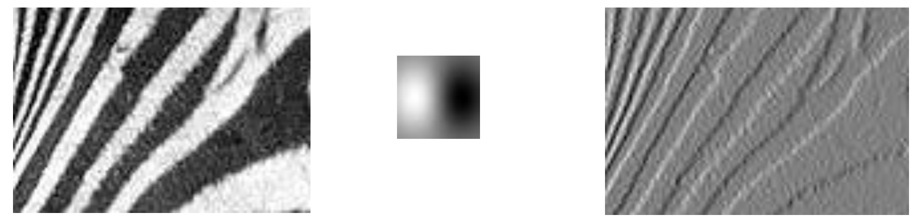
V. Numerical methods
   – Bayesian framework, advanced optimization techniques

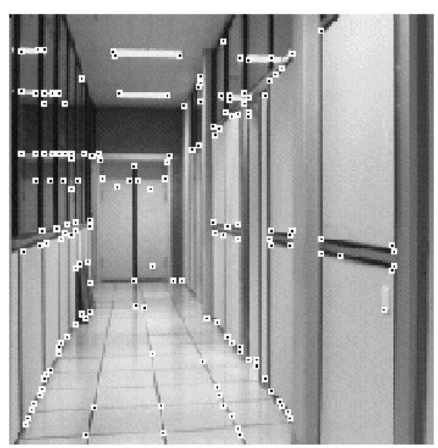
VI. Recognition and segmentation

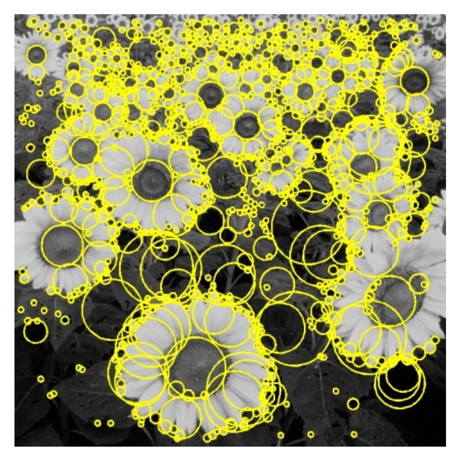
Early vision

- Basic image formation and processing

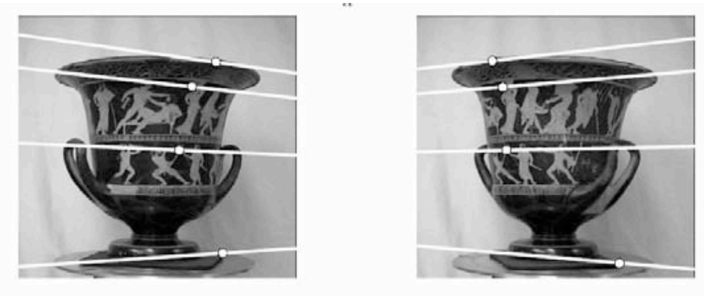


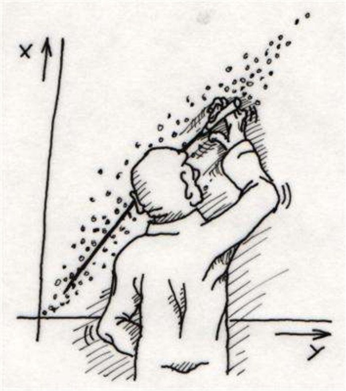


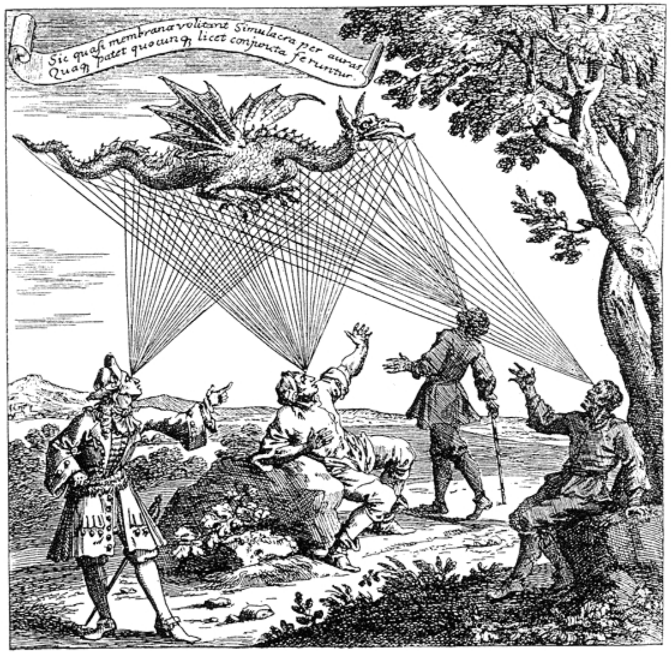




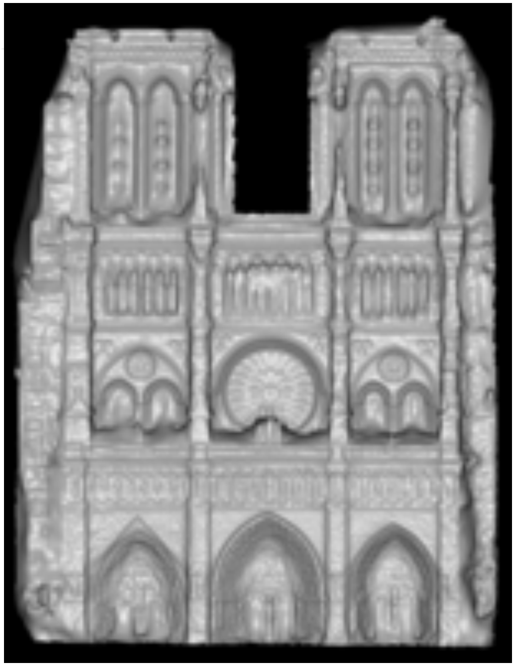
Correspondence and 3D







Драконъ, видимый подъ различными углами зрѣнія
По гравюрѣ на мѣди изъ „Oculus artificialis teledioptricus" Цана. 1702 года.



Numerical methods

- Bayesian framework, segmentation