Image Processing Introduction Part 1

SS 2020

Prof. Dr. Simone Frintrop

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Wer sind wir?

Lecturer

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Excercises:

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Arbeitsgruppe**: Computer Vision:**
https://www.inf.uni-hamburg.de/en/inst/ab/cv.html

Fragen? Per Email (Adressen oben, schreiben Sie nicht in Stine)

Oder nutzen Sie unser Moodle Forum

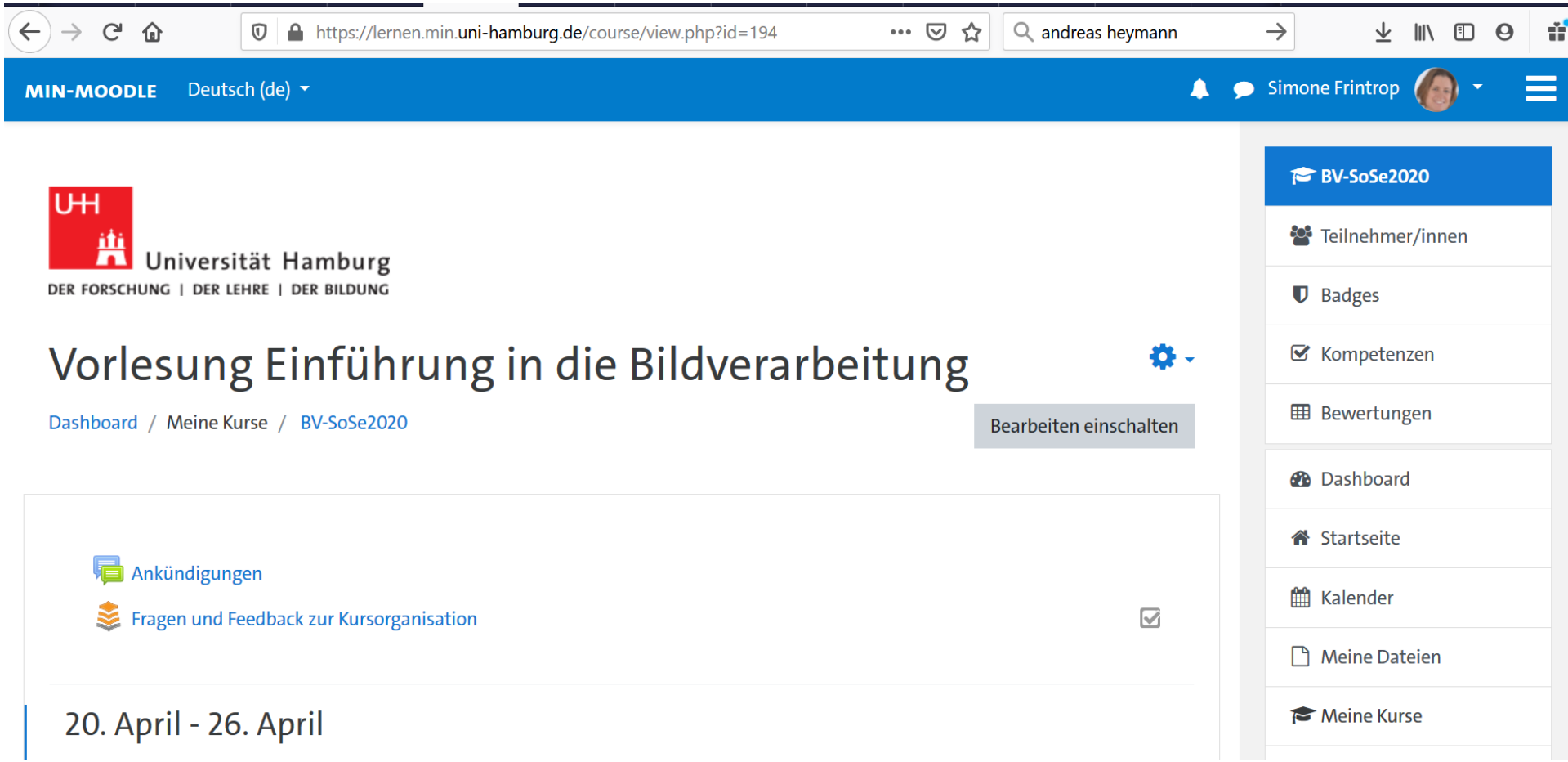
Feedback

- Die aktuelle Situation ist neu für uns alle: wir präsentieren zum ersten Mal einen online Kurs, Sie besuchen vielleicht zum ersten Mal einen (zumindest einen studienrelevanten Kurs, der rein online stattfindet)
- Geben Sie uns Feedback!
  Was läuft gut, was nicht? Wo gibt es Verbesserungsbedarf? Nutzen Sie gerne unser Moodle Forum für Verbesserungsvorschläge!
- Fragen Sie, wenn etwas unklar ist! Egal, ob inhaltliche Fragen, oder Fragen zum Ablauf des Kurses. Nutzen Sie unsere Moodle Foren oder schreiben Sie uns per Email.
- Sagen Sie Bescheid, wenn Sie wegen der aktuellen Situation Lernprobleme haben (kein Computer? Schlechte Internetverbindung? Kein ruhiges Plätzchen zum Lernen?) Wir werden versuchen, flexible Lösungen zu finden, oder Sie entsprechend weiterzuverweisen.

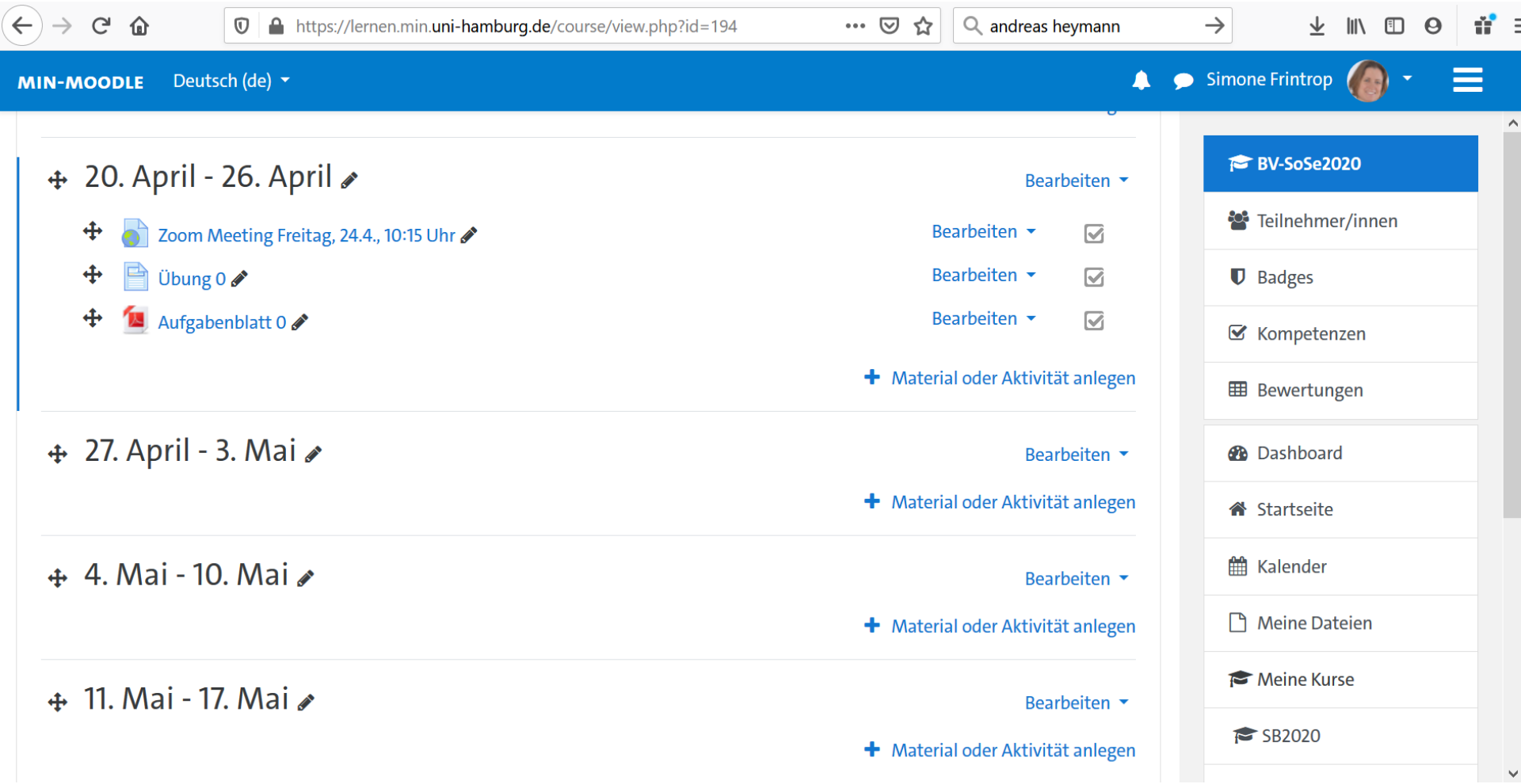
Stine und Moodle

- Wir nutzen Stine und Moodle
- Stine für Noten, Zeiten, gelegentliche Ankündigungen
- Moodle: online Plattform für alles andere: Materialen teilen (Folien, Videos, Übungszettel), Diskussionen (Foren)

Moodle


https://lernen.min.uni-hamburg.de/course/view.php?id=194
andreas heymann
MIN-MOODLE
Deutsch (de)
Simone Frintrop
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG
Vorlesung Einführung in die Bildverarbeitung
Dashboard / Meine Kurse / BV-SoSe2020
Bearbeiten einschalten
Ankündigungen
Fragen und Feedback zur Kursorganisation
20. April - 26. April
BV-SoSe2020
Teilnehmer/innen
Badges
Kompetenzen
Bewertungen
Dashboard
Startseite
Kalender
Meine Dateien
Meine Kurse

Moodle


https://lernen.min.uni-hamburg.de/course/view.php?id=194
andreas heymann
MIN-MOODLE
Deutsch (de)
Simone Frintrop
20. April - 26. April
Bearbeiten
Zoom Meeting Freitag, 24.4., 10:15 Uhr
Übung 0
Aufgabenblatt 0
Material oder Aktivität anlegen
27. April - 3. Mai
4. Mai - 10. Mai
11. Mai - 17. Mai
BV-SoSe2020
Teilnehmer/innen
Badges
Kompetenzen
Bewertungen
Dashboard
Startseite
Kalender
Meine Dateien
Meine Kurse
SB2020

Organization

Vorlesung: Freitags 10:15 – 12:15
(blocken Sie den Zeitslot für gelegentliche Zoom Videokonferenzen (nicht jede Woche))

Übungen: Montags (10-12, 12-14):

(blocken Sie den Zeitslot für gelegentliche Zoom Videokonferenzen (nicht jede Woche))

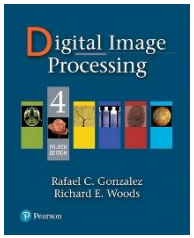
- Theoretische Übungen
- Praktische Übungen in Python

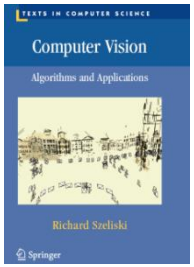
Siehe Übungs-Intro in Moodle von Christian Wilms

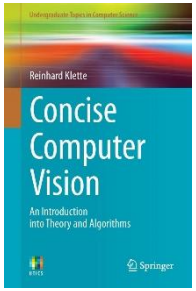
Literature

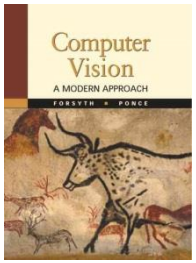
- Primärliteratur:
  - Rafael C. Gonzalez and Richard E. Woods: Digital Image Processing, Addison-Wesley Publishing Company, 4th edition: 2017.
    (we use the Standard Edition, not the global edition!) Online:
    https://dl.ebooksworld.ir/motoman/Pearson.Digital.Image.Processing.4th.Edition.StandardEdition.www.EBooksWorld.ir.rar

- Andere Bildverarbeitungsbücher:
  - Computer Vision: Algorithms and Applications, Richard Szeliski, Microsoft Research, 2010 (also online: szeliski.org/Book)
  - R. Klette: Concise Computer Vision: An Introduction into Theory and Algorithms, Springer 2014
  - D.A. Forsyth, J. Ponce: Computer Vision, A Modern Approach (2nd edition), Prentice-Hall 2012









Literature

- Zusätzliche Literaturhinweise am Ende jeder Vorlesung (letzter Teil eines Themenbereiches)
- Primary literature: bezieht sich direkt auf Vorlesungsinhalt. Zum besseren Verständnis der Vorlesung bitte lesen.
- Secondary literature: Referenzen und zusätzliche Literatur

Organization

- Zum Bestehen der Übungen:
  - Mind. 50% der Punkte der theoretischen Übungen
  - Mind. 50% der Punkte der praktischen Übungen

- Klausuren (aktueller Stand):
  1. Klausur: 23.7.2020 9:30-11:30
  2. Klausur: 24.9.2020 9:30-11:30
  (wird je nach Corona Situation aktualisiert)

- Sie können auch an der Klausur teilnehmen, wenn Sie die Übungen nicht bestanden haben, aber dann müssen Sie die Übungen nächstes Jahr nachholen, um das Modul zu bestehen

Und nicht vergessen:

Nehmen Sie aktiv am Kurs teil und Geben Sie uns Feedback☺

Image Processing Introduction Part 2

SS 2020

Prof. Dr. Simone Frintrop

Computer Vision Group, Department of Informatics
University of Hamburg, Germany

Outline

- Part 1: Organization of course (last video)
- Part 2: What is image processing?
- Part 2: Image Processing vs Computer Vision
- Part 3: Why is image processing of interest?
- Part 3: Applications of image processing
- Part 3: Why is image processing hard?
- Part 4: History of image processing
- Part 5: Research in our group
- Part 6: Topics of this lecture, overview of course content

What is Image Processing?

- Image Processing (IP) and Computer Vision (CV) both deal with the *automatic processing of visual signals via algorithms*
  (German: “Bildverarbeitung” for both IP and CV)

- IP and CV cover a spectrum of methods to process visual signals from low level (IP) to high level (CV)

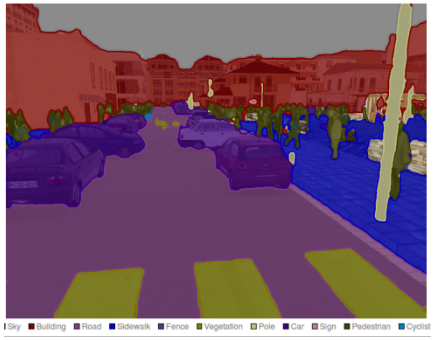
Image Processing & Computer Vision

Low-level

- Smoothing/Sharpening/Enhancement
- Edge detection
- Color processing
- Stereo
- Motion detection
- Etc.

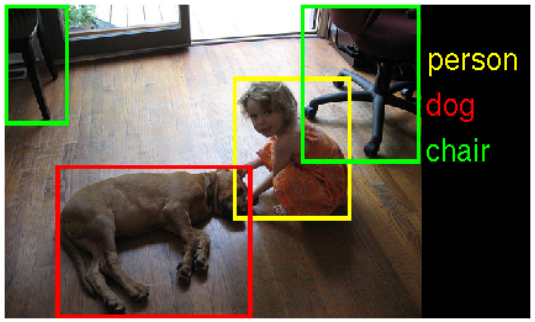
Mid-level

- Segmentation
- Object tracking
- Etc.



High-level

- Detection / classification of
  - Objects
  - Scenes
  - Activities
- Understanding visual scenes



[adapted from Forsyth/Ponce]

What is Computer Vision?

- Output of image processing/computer vision methods:
  1. A new image (after smoothing, edge detection, etc.), or
  2. An image description/interpretation (“attributes”) (e.g., “the image shows two faces”) or
  3. A combination of both: an image with labels for each pixel

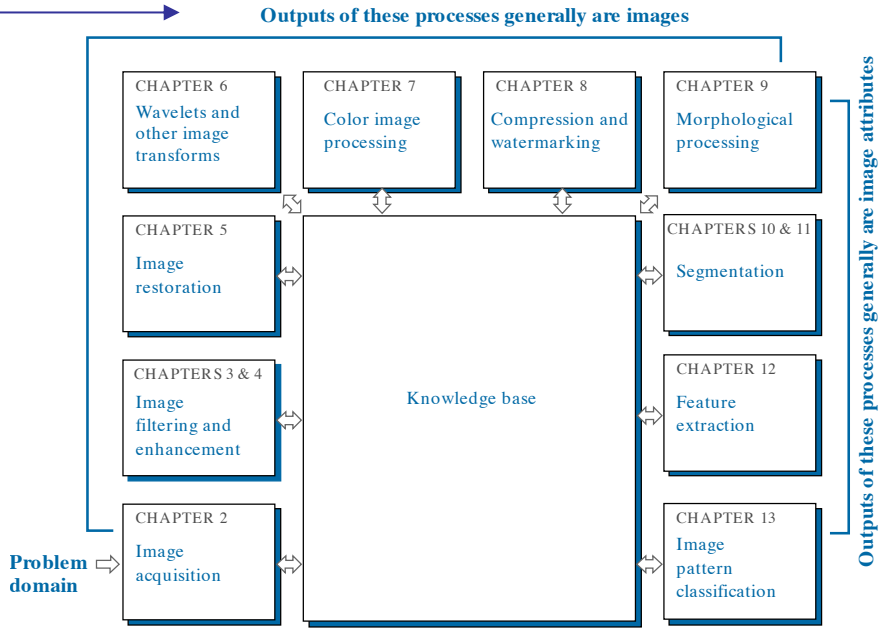
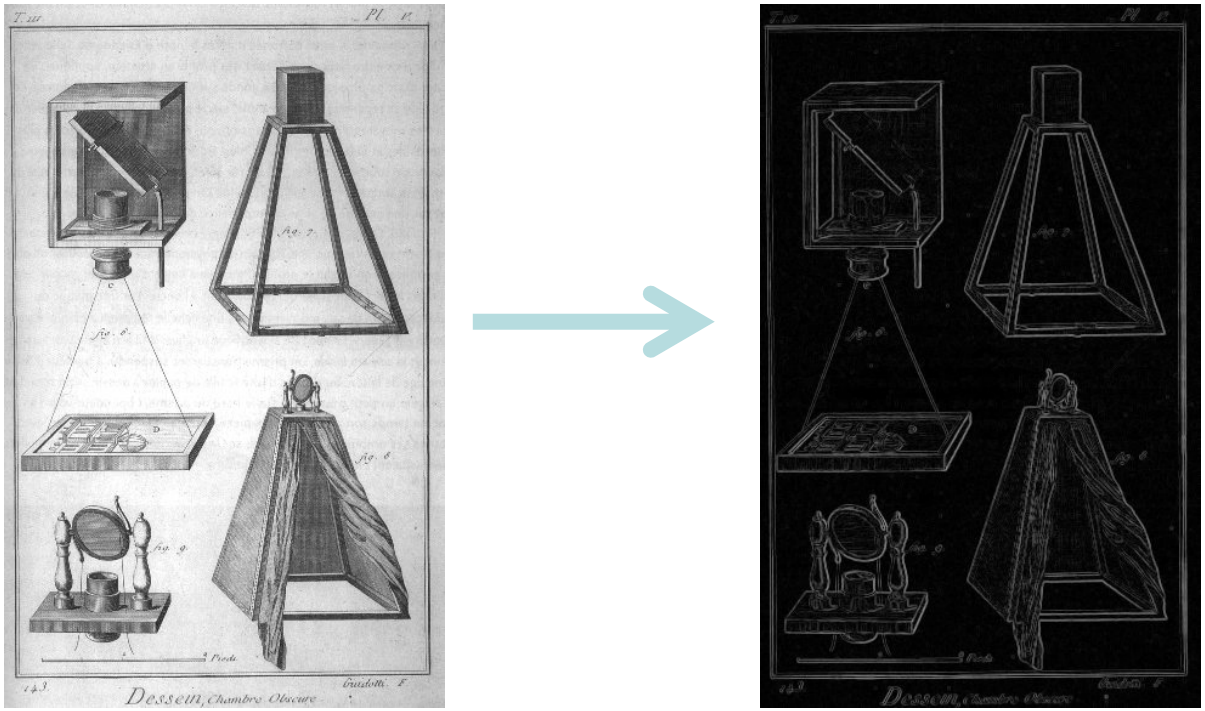


FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

[Gonzales/Woods]

Output: Image

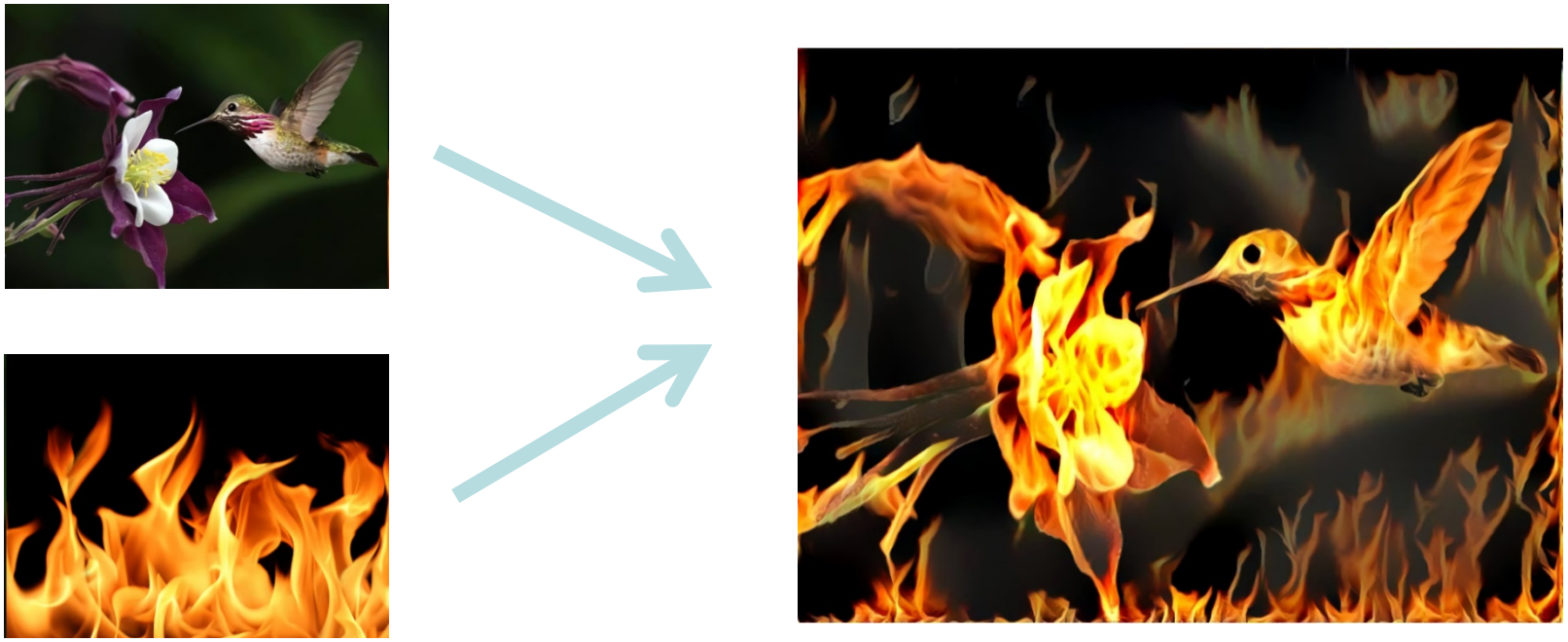
1. Example for “output is image”: edge detection



[Wikipedia: Kantendetektion]

Output: Image

1. A bit more fancy: DeepStyle (based on deep learning):



Output: Attributes

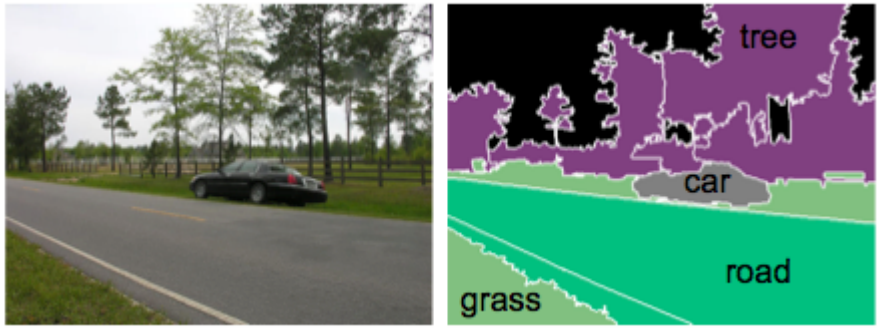
2. Example for “output is image description/attribute”: scene recognition

“beach”
“beach with waves and people”

[Wikimedia Commons]

Output: image + attributes

3. Example for combination of both:
   output: image with labels



[Wikimedia Commons]

Related Vision Fields

- **Digital Image Processing (2D images)**
- Video Processing (Videos)
- Computer Vision (joint term: Process images, videos, and RGB-D data)
- Image Analysis (2D images, focus more on analysis and interpretation than on processing)
- Visual Scene Interpretation (high-level computer vision focusing on interpreting scenes)
- Machine Vision (focus on industrial settings and robot vision)
- Robot Vision (Vision for (usually autonomous) robots)
- Visual computing (all disciplines dealing with images and 3D models, i.e., computer graphics, image processing, visualization, computer vision, virtual and augmented reality, video processing, …)
- Pattern recognition (automatic recognition of patterns in data, often images, but also every other type of data)

The fields are overlapping and there are no clear definitions and boundaries. Differences are sometimes subtle.

Related Disciplines

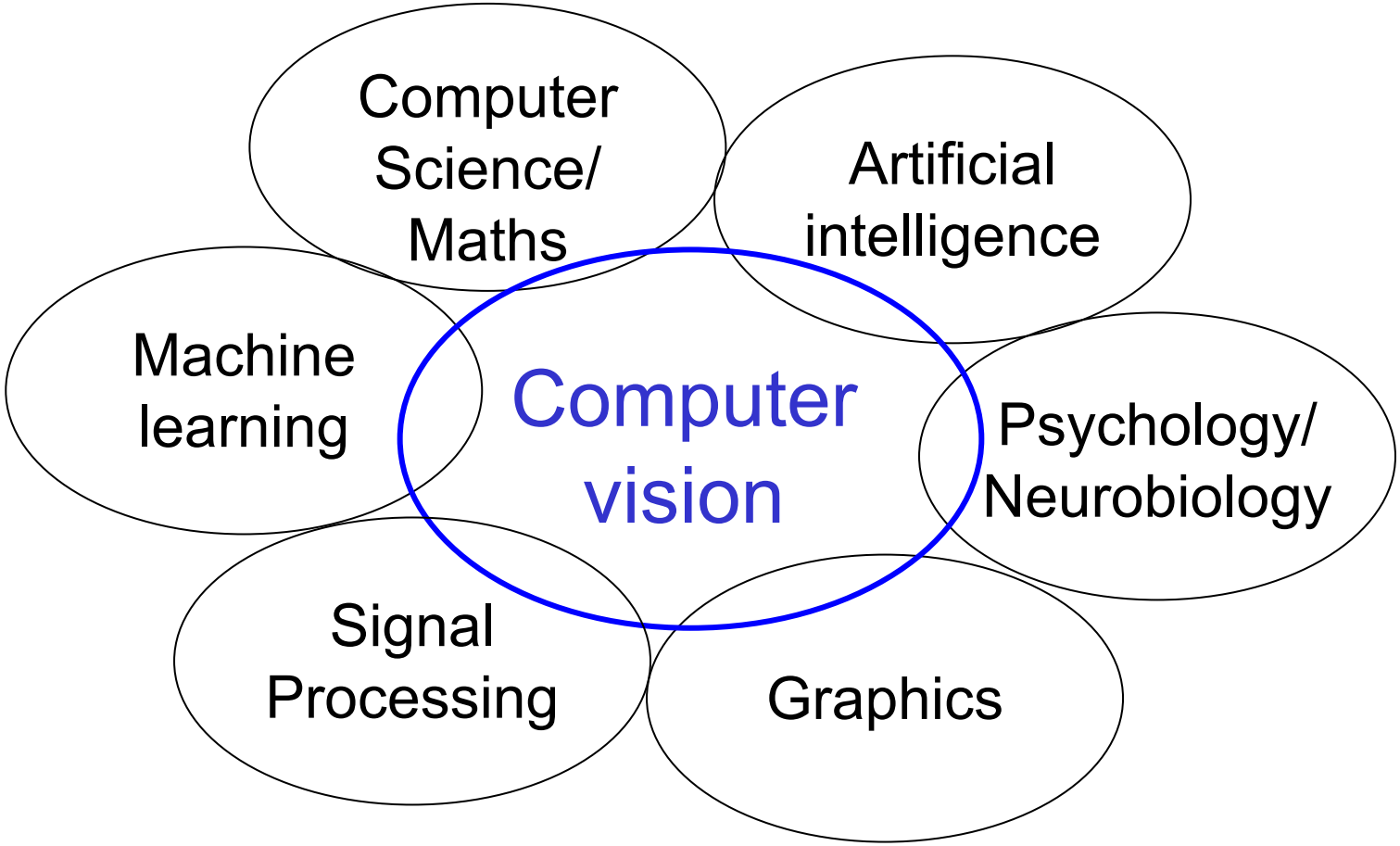


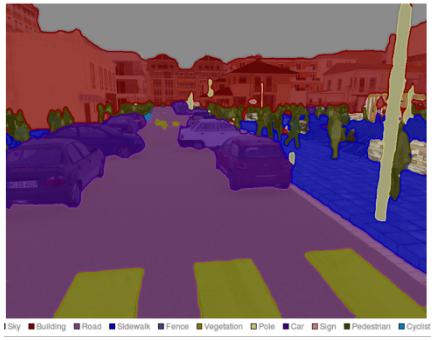
Image Processing

Low-level

- Smoothing/Sharpening/Enhancement
- Edge detection
- Color processing

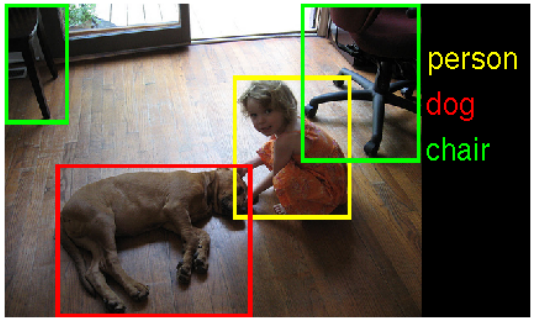
Mid-level

- Segmentation



High-level

- Detection / classification of
  - Objects
  - Scenes
  - etc.



[Forsyth/Ponce]

Image Processing Introduction Part 3

SS 2020

Prof. Dr. Simone Frintrop

Computer Vision Group, Department of Informatics
University of Hamburg, Germany

Outline

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Why Image Processing?

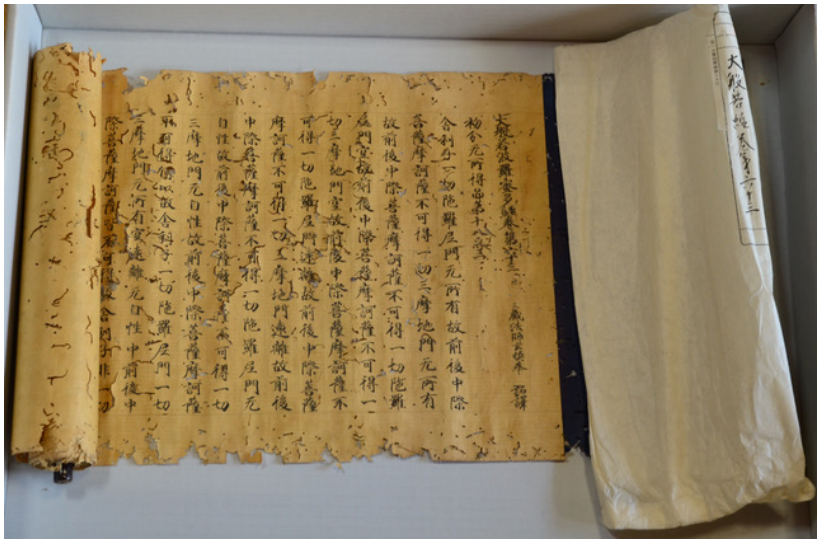
Cameras and images are everywhere nowadays:

Billions of photos and videos taken every day and shared every day on social media

[AFP/Getty Images]

Why Image Processing?

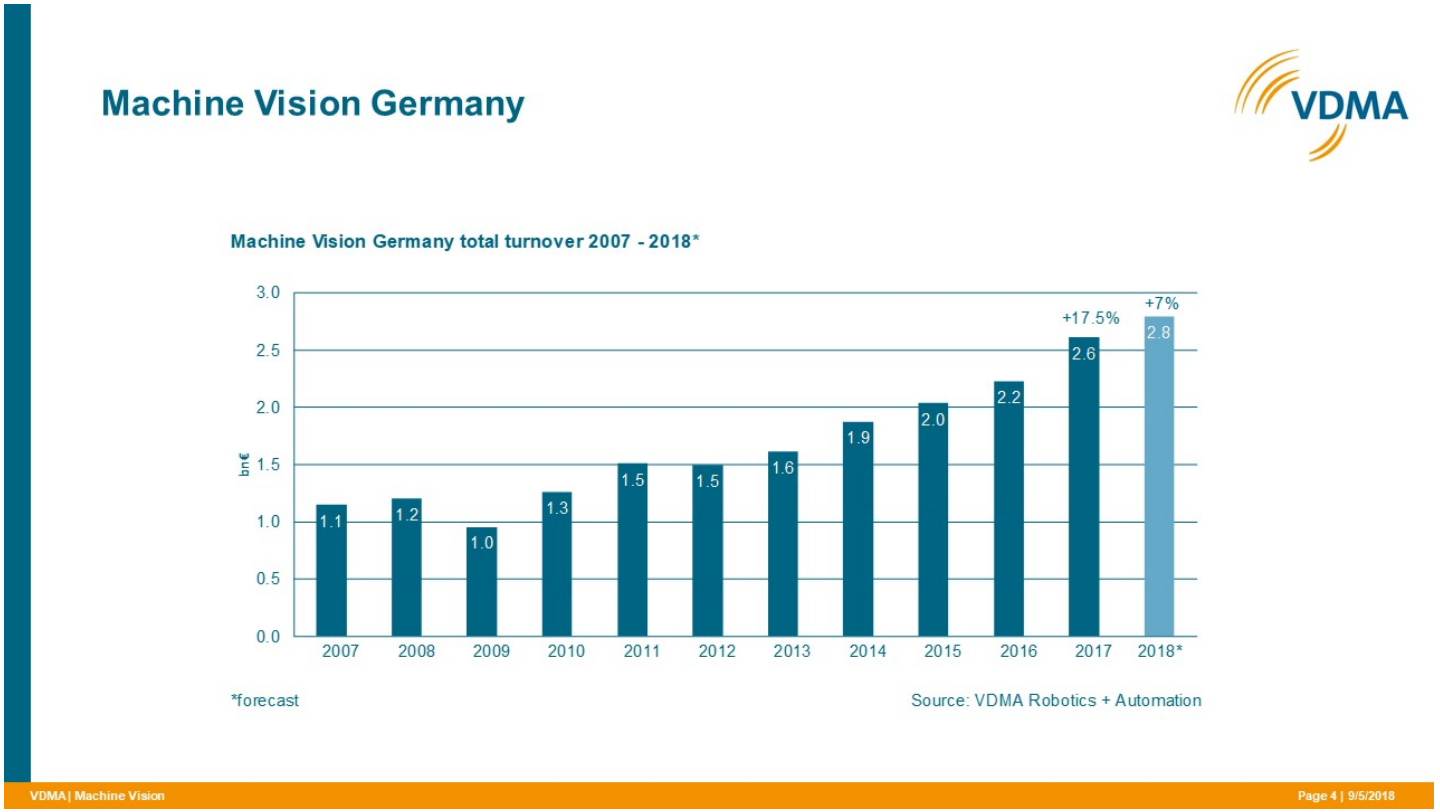
Millions of photos in archives
(e.g. 11 million images of German history in archive "Bundesarchiv")



[Left: Platz der Republik, Berlin, 1926. Source: Bundesarchiv;
Right: manuscript from excellence cluster „Understanding written artifactcs]

Why Image Processing?

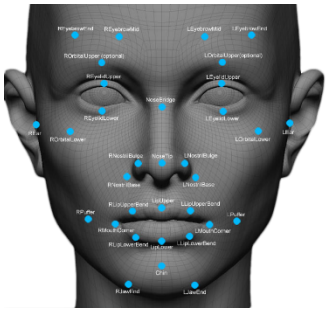
"In 2017, the German machine vision industry achieved record sales of 2.6 billion euros – a rise of 17 percent compared to the previous year."

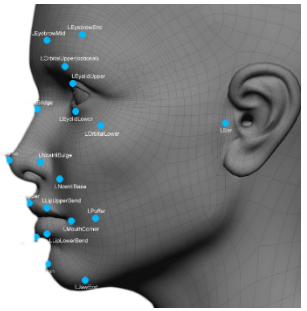


https://ibv.vdma.org/en/viewer/-/v2article/render/26787213

Applications

- Let us look at some applications of image processing/computer vision…

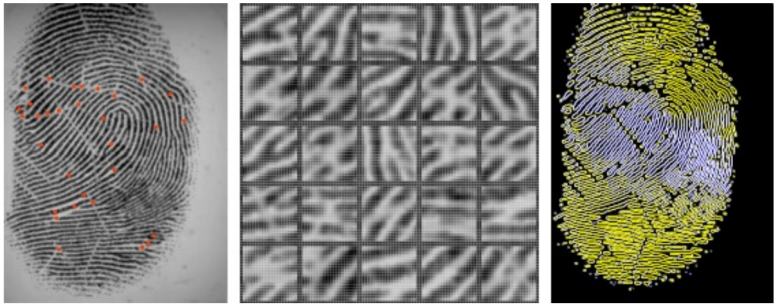




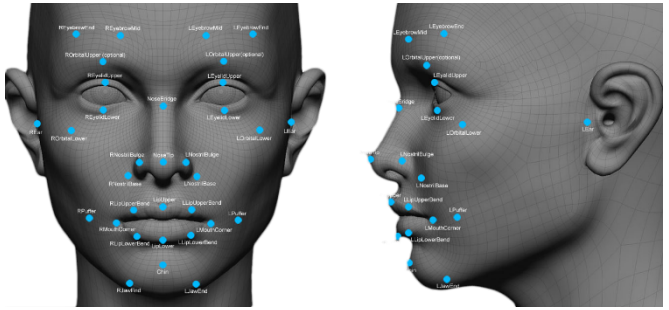
[Gonzales/Woods]

Face detection on smartphones

Biometric authentication

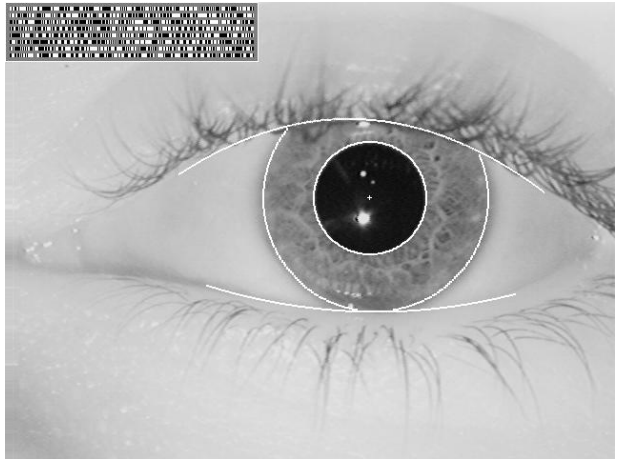


Fingerprint feature extraction and segmentation



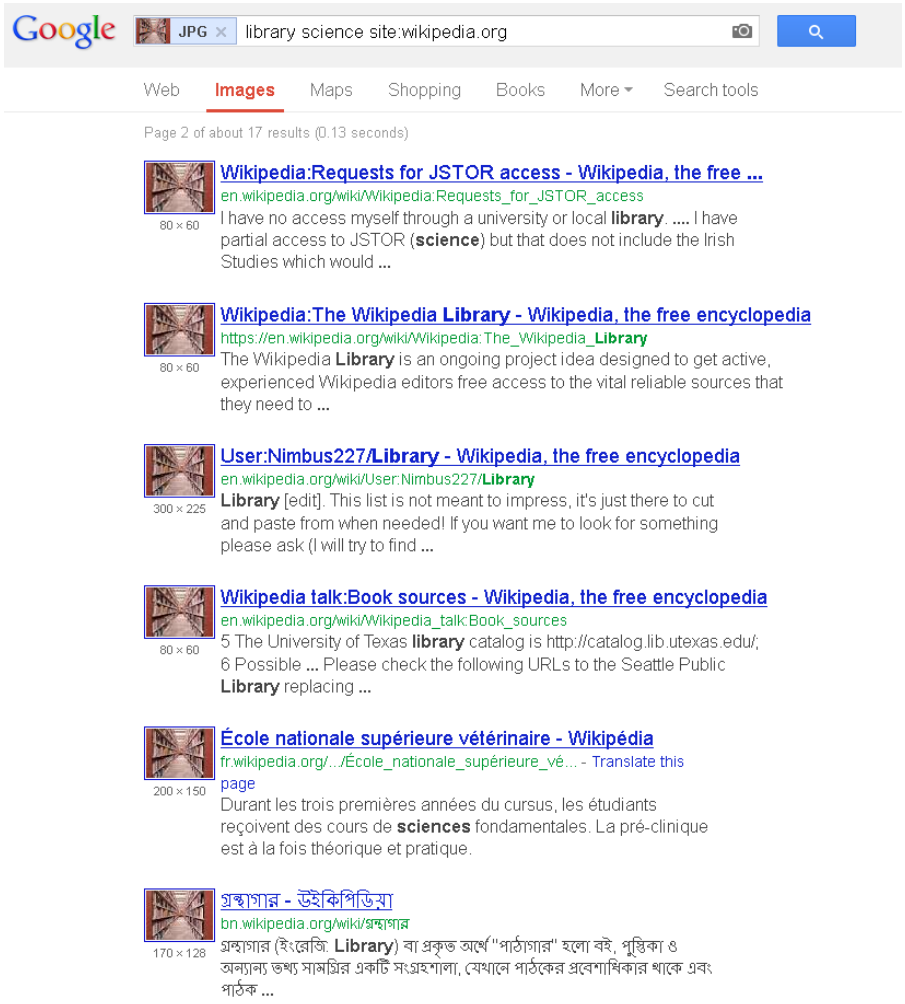
Face recognition for security clearance

Palmprint biometrics



Iris scanning and recognition

Google image search

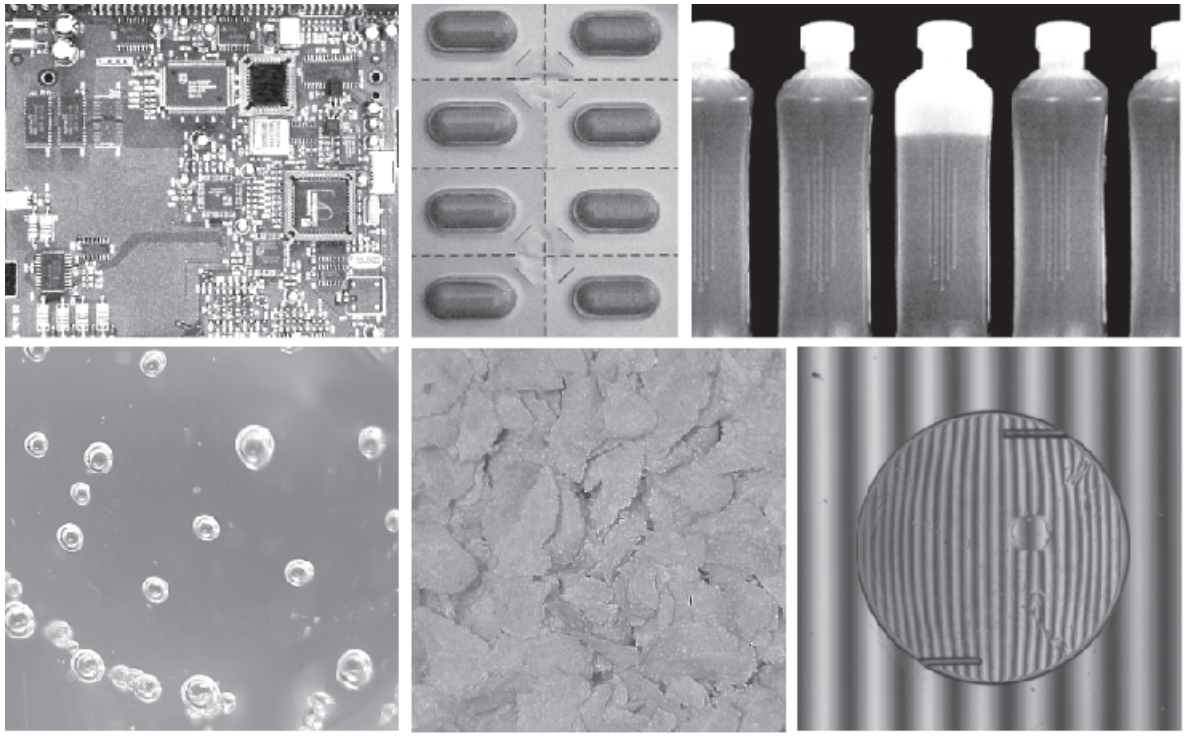


Upload picture instead the usual textual description

A picture upload will trigger the retreival of similar images, and/or the same image in different resolutions, along with the web pages hosting these pictures.

https://en.wikipedia.org/wiki/Google_Images

Applications

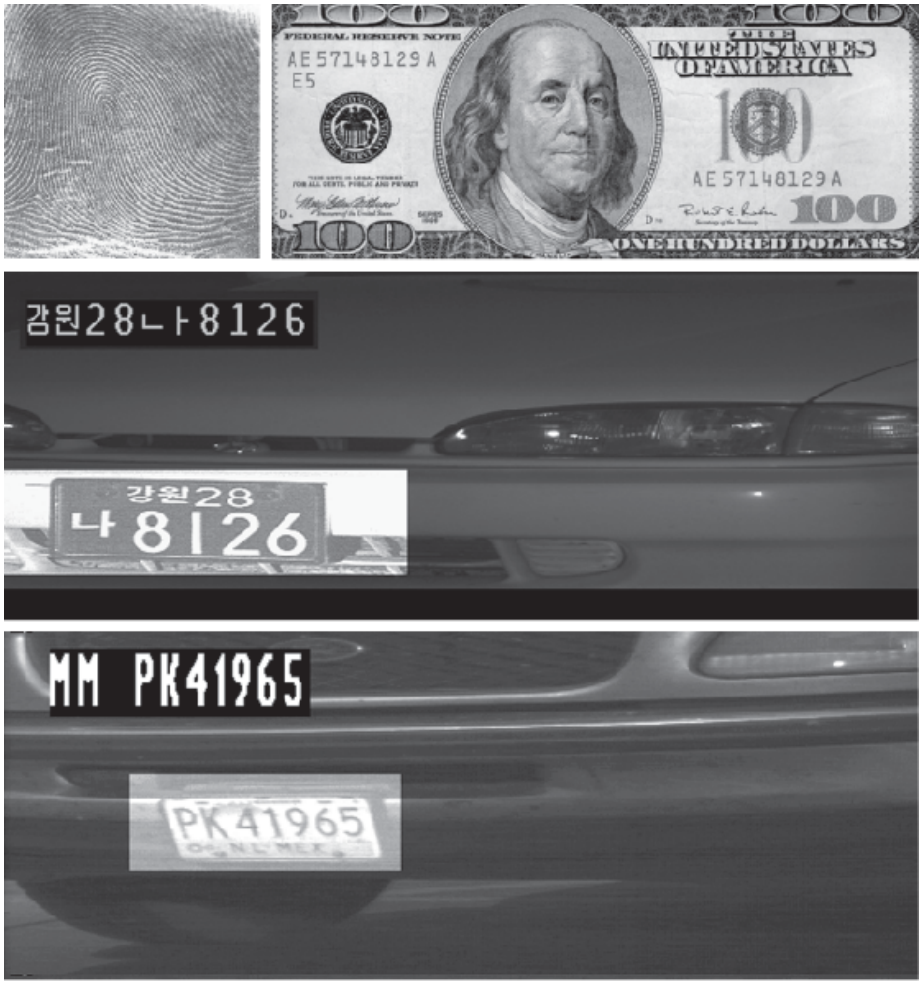


a b c
d e f

FIGURE 1.14 Some examples of manufactured goods checked using digital image processing. (a) Circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear plastic product. (e) Cereal. (f) Image of intraocular implant. (Figure (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

[Gonzales/Woods]

Applications



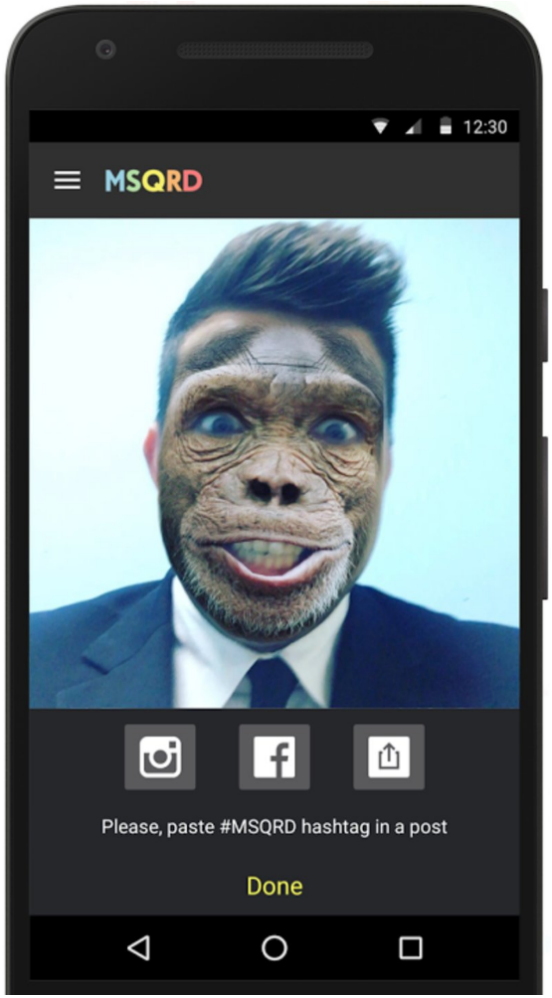
a b
c
d

FIGURE 1.15
Some additional examples of imaging in the visible spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

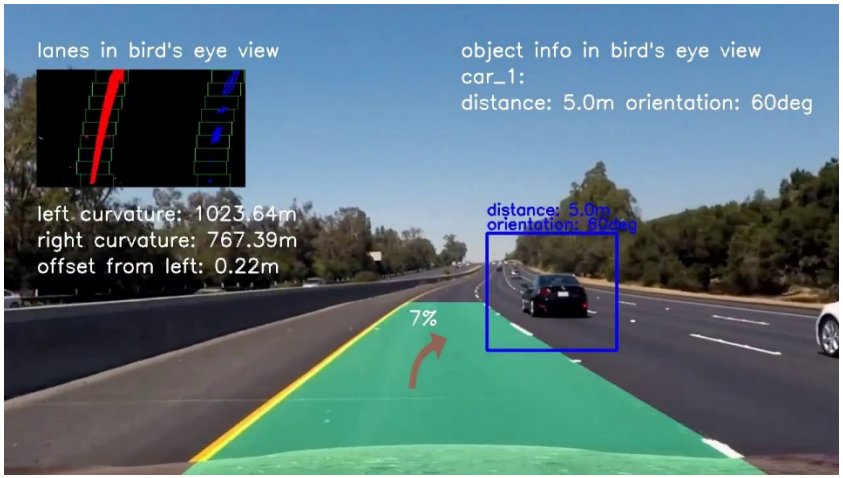
[Gonzales/Woods]

Masken-Apps


12:30
MSQRD

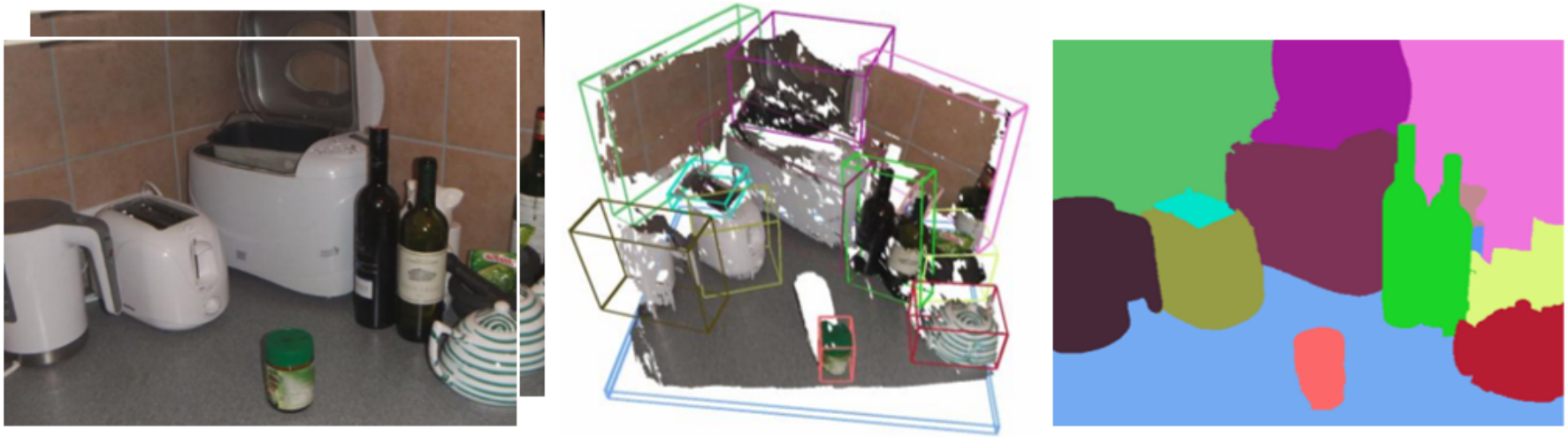

12:30
MSQRD
Please, paste #MSQRD hashtag in a post
Done

Self driving cars



Lane detection along with other vehicles and entities participating in traffic

Scene understanding



Machine vision interpreting an indoor scene

https://hci.iwr.uni-heidelberg.de/vislearn/research/scene-understanding/

Why is Image Processing hard?

What we see

39	24	9	15	19	27	36	37	32	27	26	36	36	35	34	36	41	50	57	50	47
51	40	19	12	16	26	36	38	34	31	31	39	34	33	41	53	60	57	51	61	56
48	48	39	13	17	25	33	35	32	31	34	36	33	34	45	59	64	56	46	64	61
35	45	50	18	20	25	31	31	28	29	33	31	34	39	46	51	52	50	48	59	59
19	36	61	35	17	19	35	37	32	31	33	25	41	50	46	46	52	51	43	61	53
24	28	38	79	51	23	26	49	59	42	21	41	53	58	48	40	46	57	64	68	75
42	37	34	71	60	32	27	60	77	56	33	43	52	62	68	70	77	90	101	107	114
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212	210	208	205	210	214	215	212	210	211	213	220	220	220	218	215	216	220	224	225	227

What the computer sees

[WikiImages]

Image Processing Introduction Part 4

SS 2020

Prof. Dr. Simone Frintrop

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University of Hamburg, Germany

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History

- First digital images in the newspaper industry:
- Pictures send via submarine cable between London and New York

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special typefaces. (McFarlane.) [References in the bibliography at the end of the book are listed in alphabetical order by authors' last names.]

- reduced the time to transport a picture across the Atlantic from more than a week to less than three hours.
- But: no digital computer involved in image creation [Gonzales/Woods]

History

- **1960s:**
  - First computers powerful enough to process images
  - US space program started in the early 1960s: development of image processing for space applications

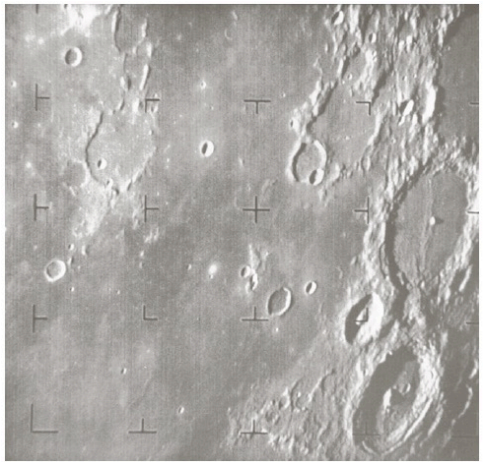


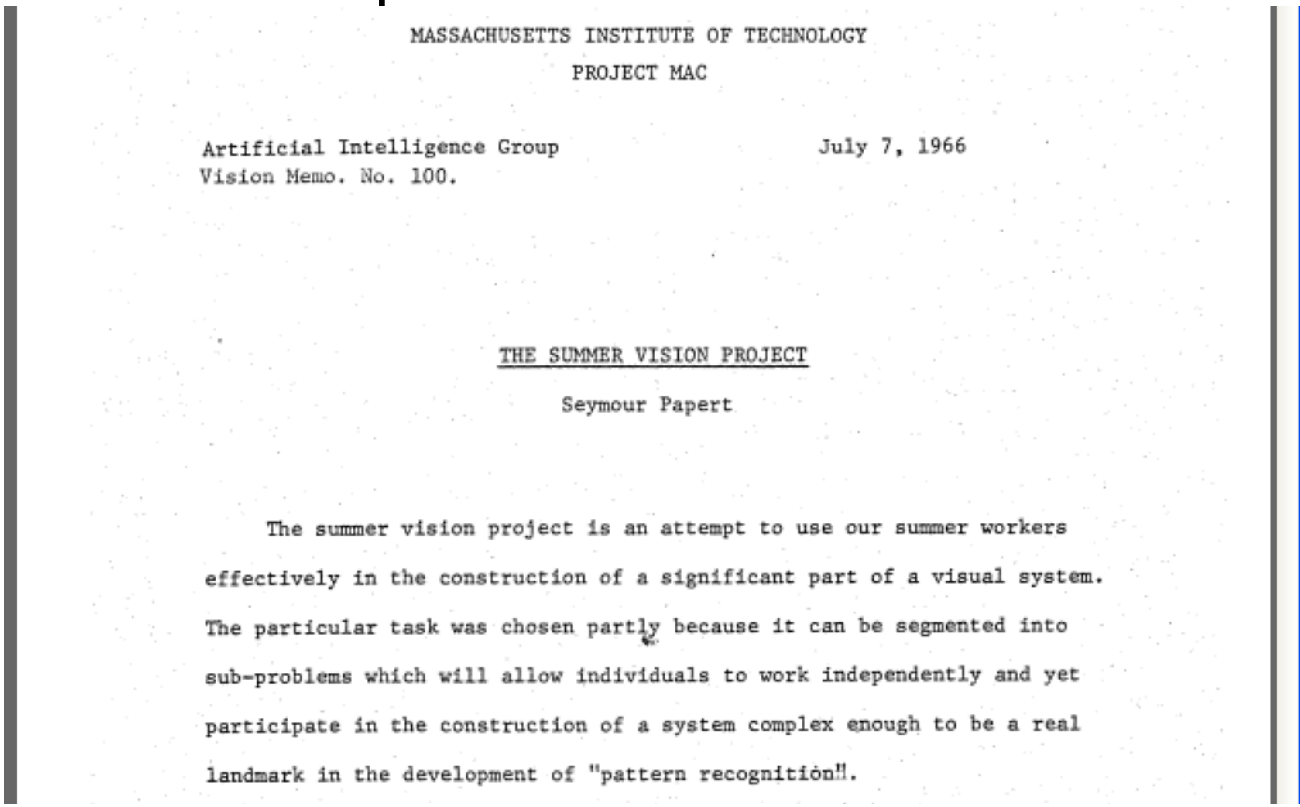
FIGURE 1.4
The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

  - satellite imagery, medical image processing, character recognition, astronomy
  - Computer vision as part of AI: endow machines with intelligent behavior and enable them to see. High expectations.

[Gonzales/Woods]

High expectations in the 60s

- 1966: Seymour Papert directs an undergraduate student to solve “the problem of computer vision” as a summer project.



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

July 7, 1966

THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".

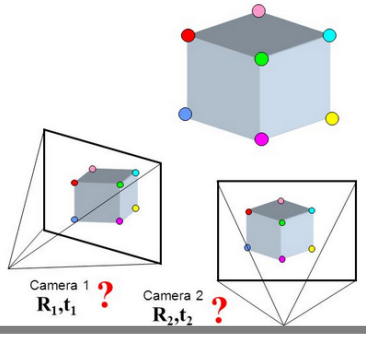
- Obviously, computer vision was too difficult for that…

History of IP/CV

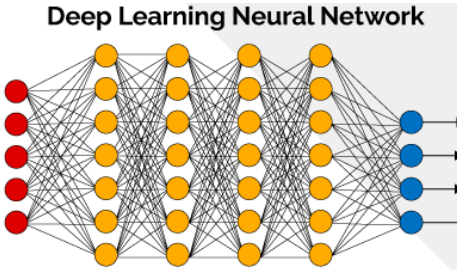
- **1970s:**
  - invention of CT (computerized tomography) led to important advanced in medical image processing.
  - many methods that form the basis of todays algorithms: edge detection, optical flow, motion estimation
- **1980s:** mathematical foundations developed: scale-space theory, shape from X, contour models, Markov random fields
- **1990s:** 3D reconstruction (influences from photogrammetry), stereo vision and multi-view geometry, start of statistical learning methods, first CNNs (neural networks for image processing)
- **2000s:** strong focus on machine learning methods, e.g., Boosting, SVMs, MRFs (NNs considered less powerful and interesting by most researchers)
- **Since 2012:** “Deep learning”, revival of convolutional neural networks

History of IP/CV

1970s:
Edge detection, optical flow, motion estimation



1990s:
3D reconstruction, stereo vision, multi-view geometry



2010s:
"**Deep learning**", revival of convolutional neural networks

1960 1970 1980 1990 2000 2010

1960s:
- **satellite imagery, medical image processing, character recognition,** Computer vision as part of AI: **High expectations**.

1980s:
scale-space theory, shape from X, contour models


Shading

2000s:
Machine learning methods, e.g., Boosting, SVMs, MRFs

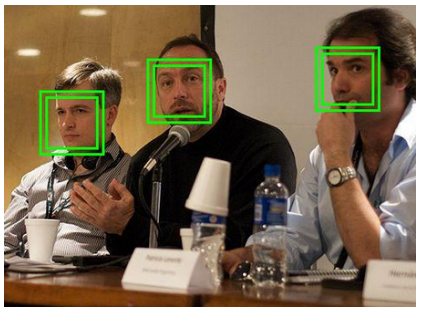


Image Processing Introduction Part 5

SS 2020

Prof. Dr. Simone Frintrop

Computer Vision Group, Department of Informatics
University of Hamburg, Germany

Outline

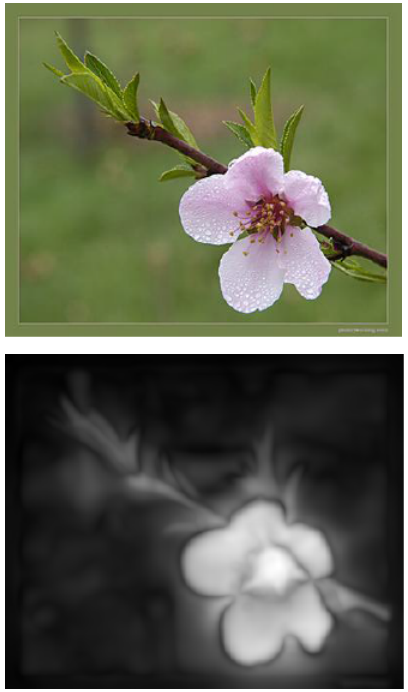
- Part 1: Organization of course (last video)
- Part 2: What is image processing?
- Part 2: Image Processing vs Computer Vision
- Part 3: Why is image processing of interest?
- Part 3: Applications of image processing
- Part 3: Why is image processing hard?
- Part 4: History of image processing
- Part 5: Research in our group
- Part 6: Topics of this lecture, overview of course content

Research in our group

Saliency computation: find regions that automatically attract human attention

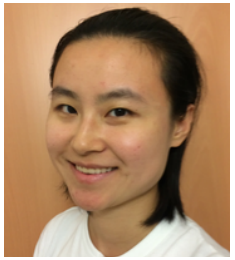
Input image

Output:
Saliency map



AIM [Bruce/Tsotsos 2009]

VOCUS2 [Frintrop et al. 2015]



Research in our group

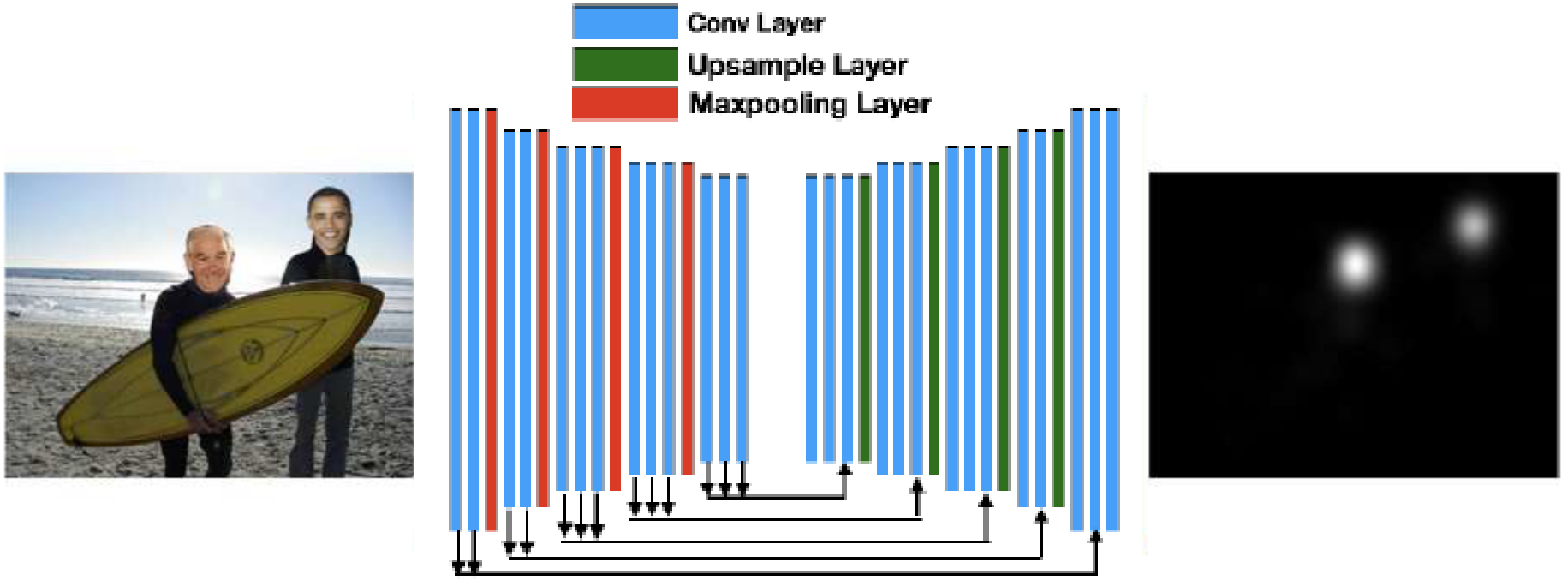
With Ge Gao:

- Attentive Trixie: attend to salient regions

- Cooperation with group of Prof. Jianwei Zhang (TAMS, UHH)

Research in our group

Deep Learning Saliency Model: simulate eye fixations with encoder-decoder architecture (work of Faiz Ul Wahab):



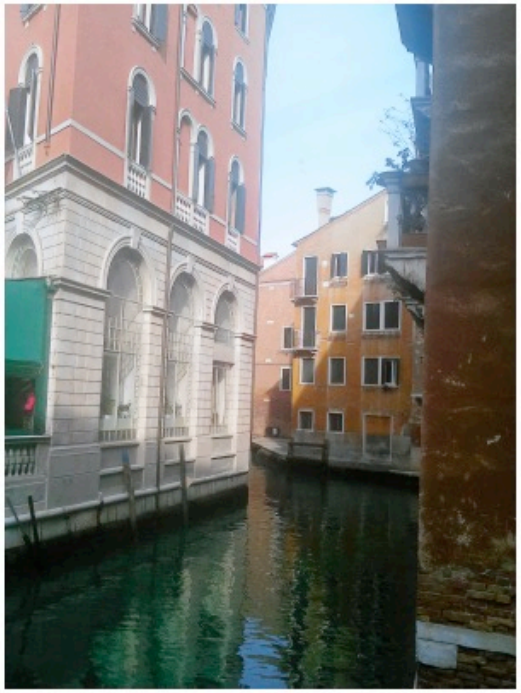
[Ul Wahab 2018]

Research in our group

Cooperation with Adobe Research, Hamburg:

- Image enhancement with saliency
- Train a GAN network by using saliency to compute the loss

(a) Original [fli].



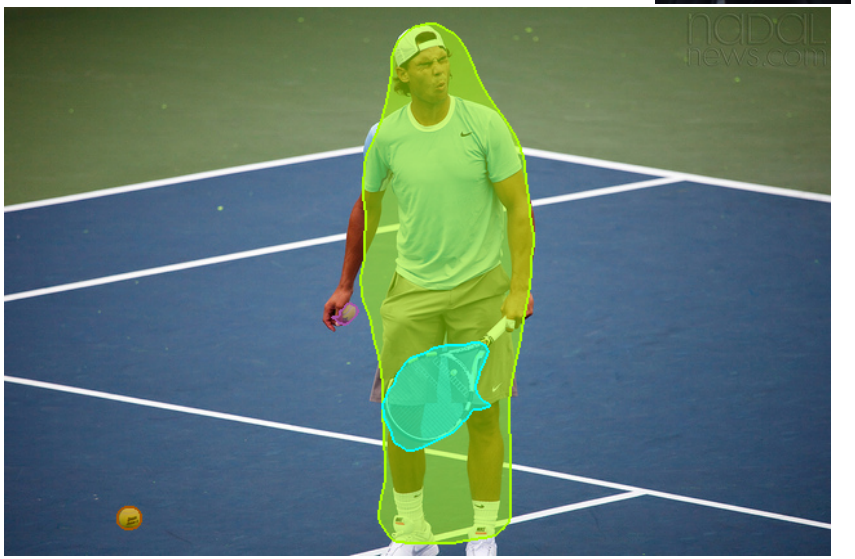
(b) Enhanced.

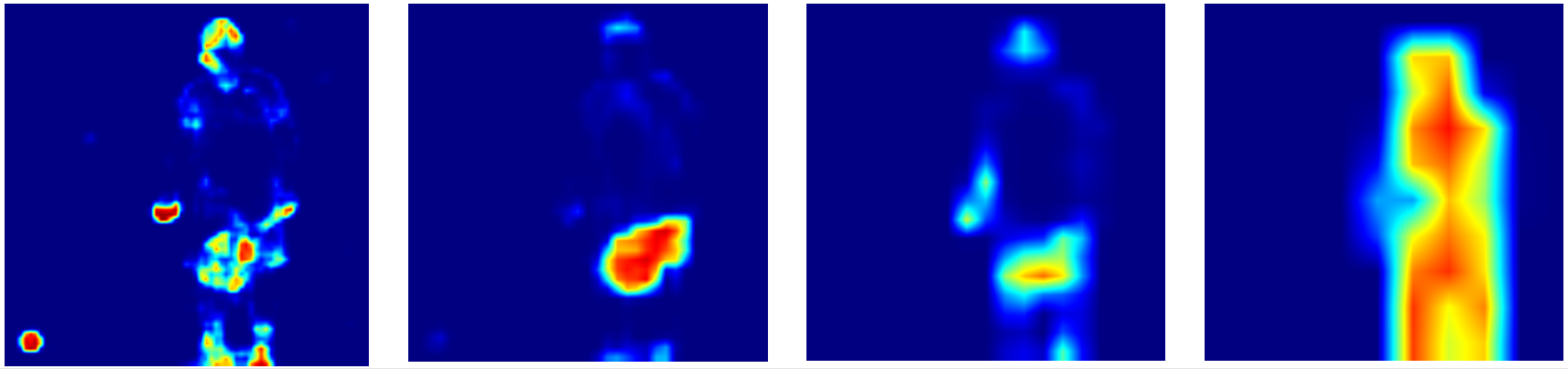
[Soroka 2018]

Research in our group

AttentionMask [Wilms/Frintrop 2018]

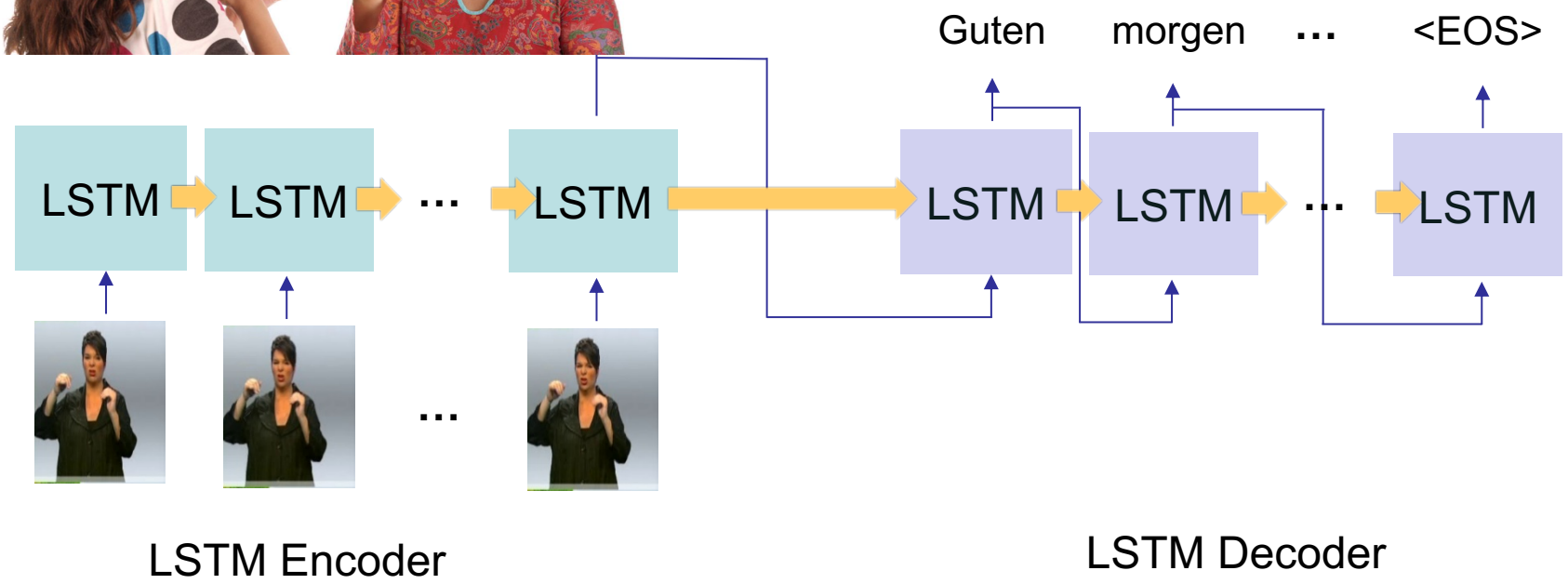
- Object proposal detection: find promising object candidates in images
- Scale-based attention focuses processing on promising parts of the image





Research in our group

Sign language recognition (with Noha Sarhan)



Research in our group

- Cooperation with ZeroG (Lufthansa Spin off)
  (with Christian Wilms & Rafael Heid)
- Detect & recognize plane logos in smartphone images

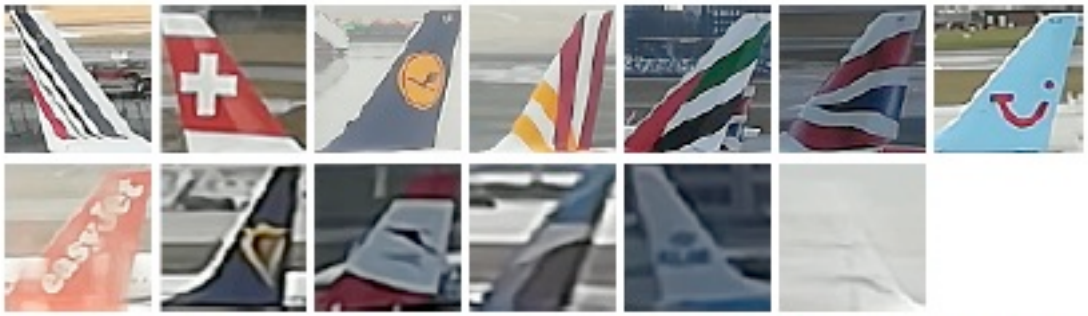
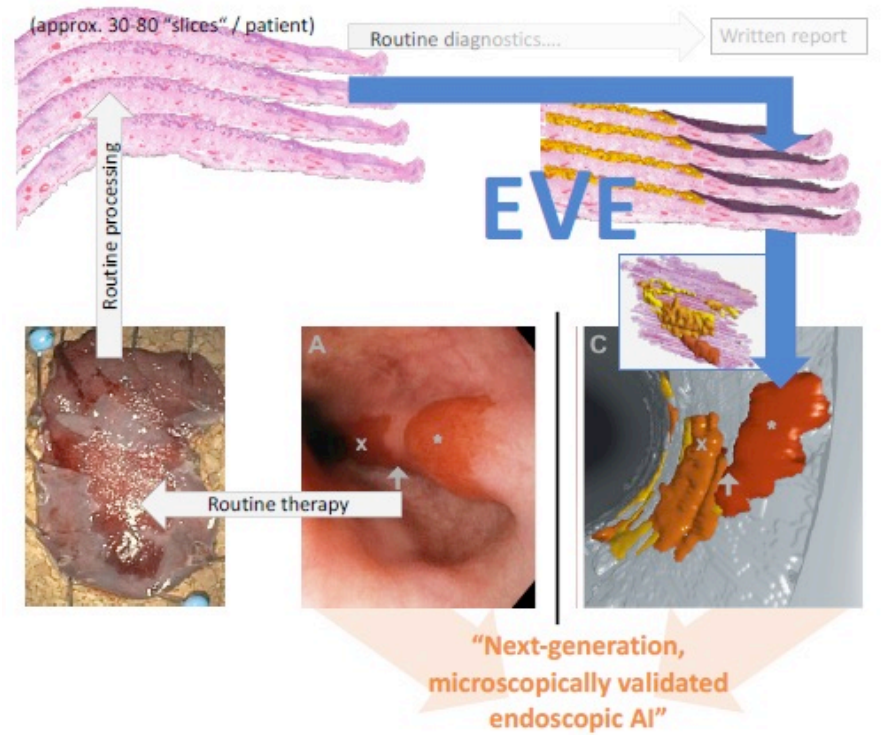
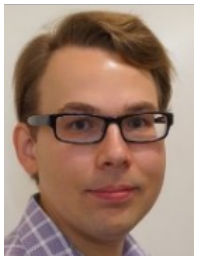


Abbildung 4.4: Beispielbilder, der 13, am Hamburger Flughafen aufgenommenen, Airlines aus dem HAM-AirLogo Datensatz.

Medical image processing

Starting cooperation with UKE (Rüdiger Schmitz, PD Dr. Rene Werner, Prof. Rösch)
Tumor detection in endoscopic images of oesophagus

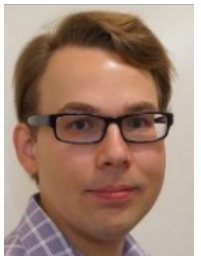




Active Perception

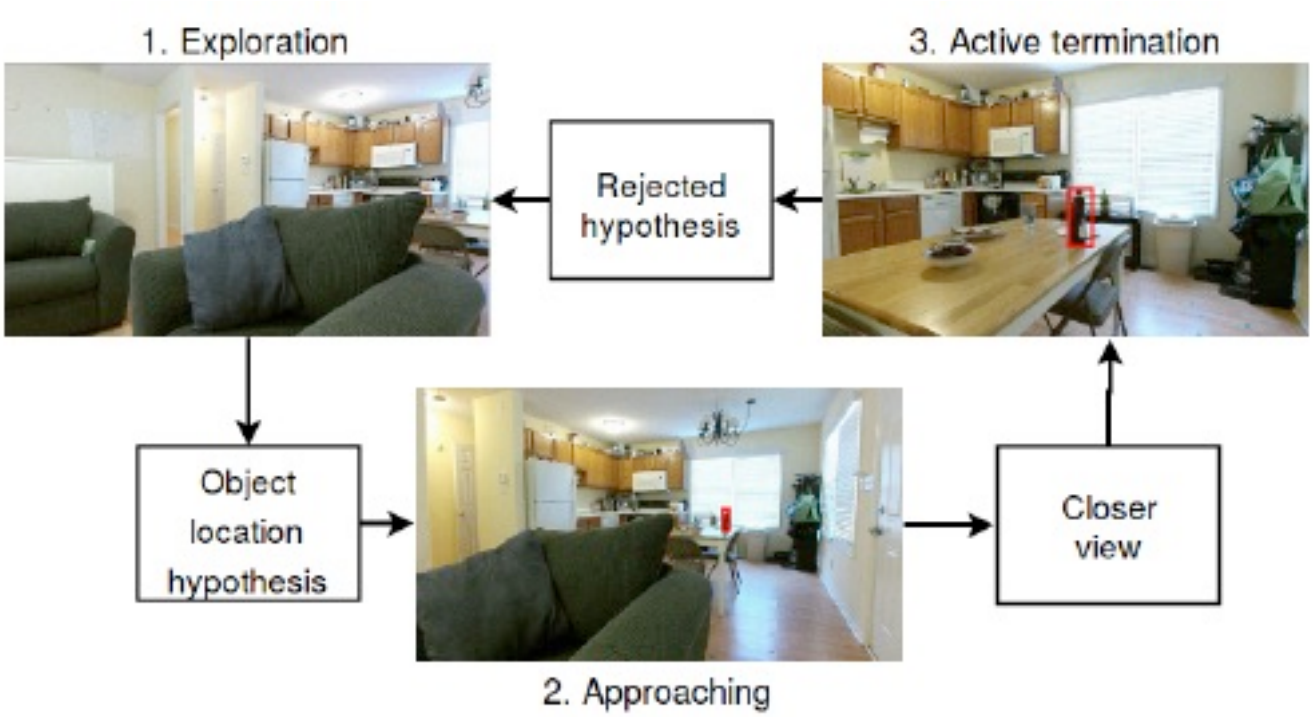
How to guide attention to increase information gain?

Current work: estimating next best view (with Mikko Lauri)

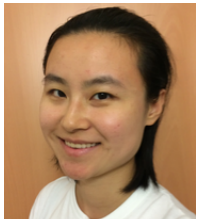


Active Visual Object Search

(with Jan Fabian Schmid & Mikko Lauri)

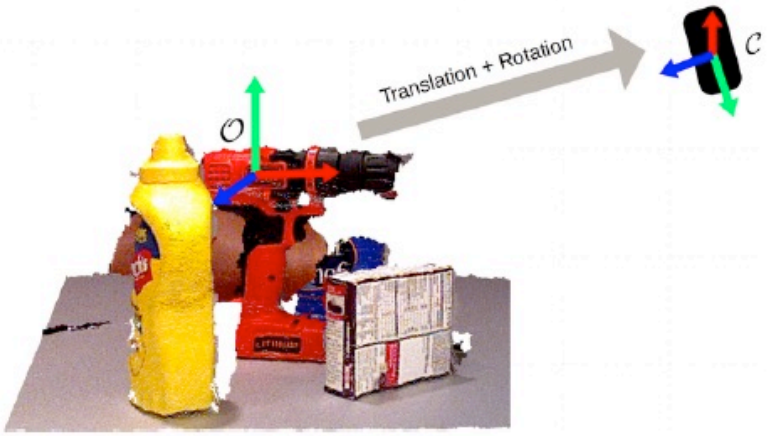


Jan Fabian Schmid, Mikko Lauri, Simone Frintrop: **Explore, Approach and Terminate: Evaluating Subtasks in Active Visual Object Search Based on Deep Reinforcement Learning**, in IEEE/RSJ Int'l Conf. on Intelligent Robots and Systems (IROS), 2019

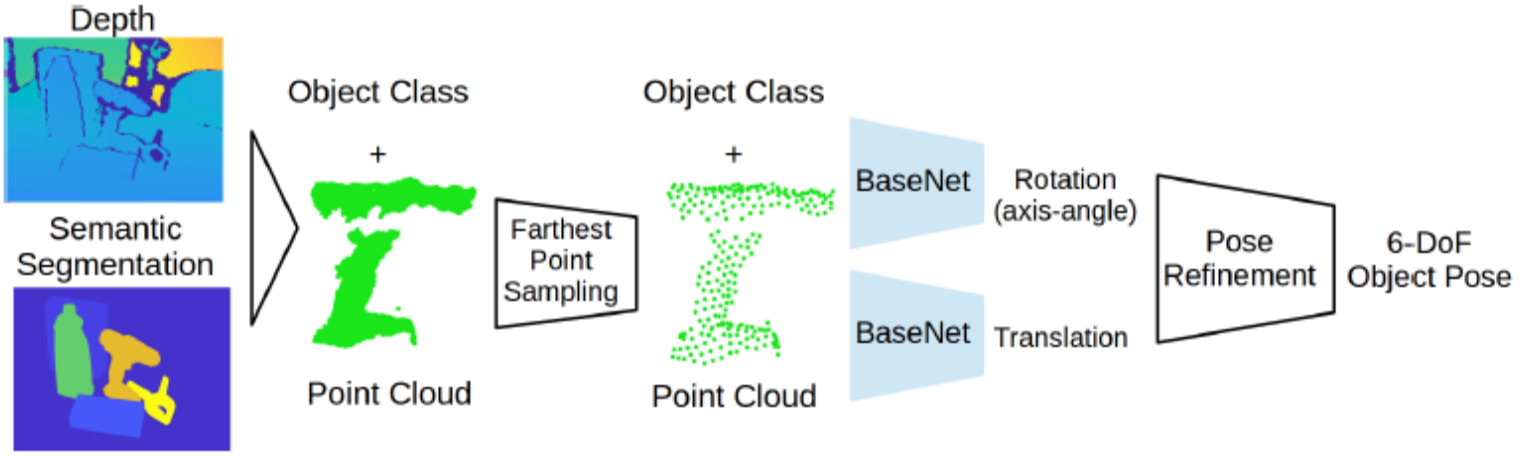


6DoF Object Pose Estimation

Estimate 6D Pose directly from Point Clouds: [Gao et al, 2018]



Network architecture:



Research in our group

Ahoi.digital project: **Adaptive crossmodale Sensordatenerfassung**
(with Prof. Gerkmann, Prof. Knopp (TUHH) and Prof. Schlaefer (TUHH))

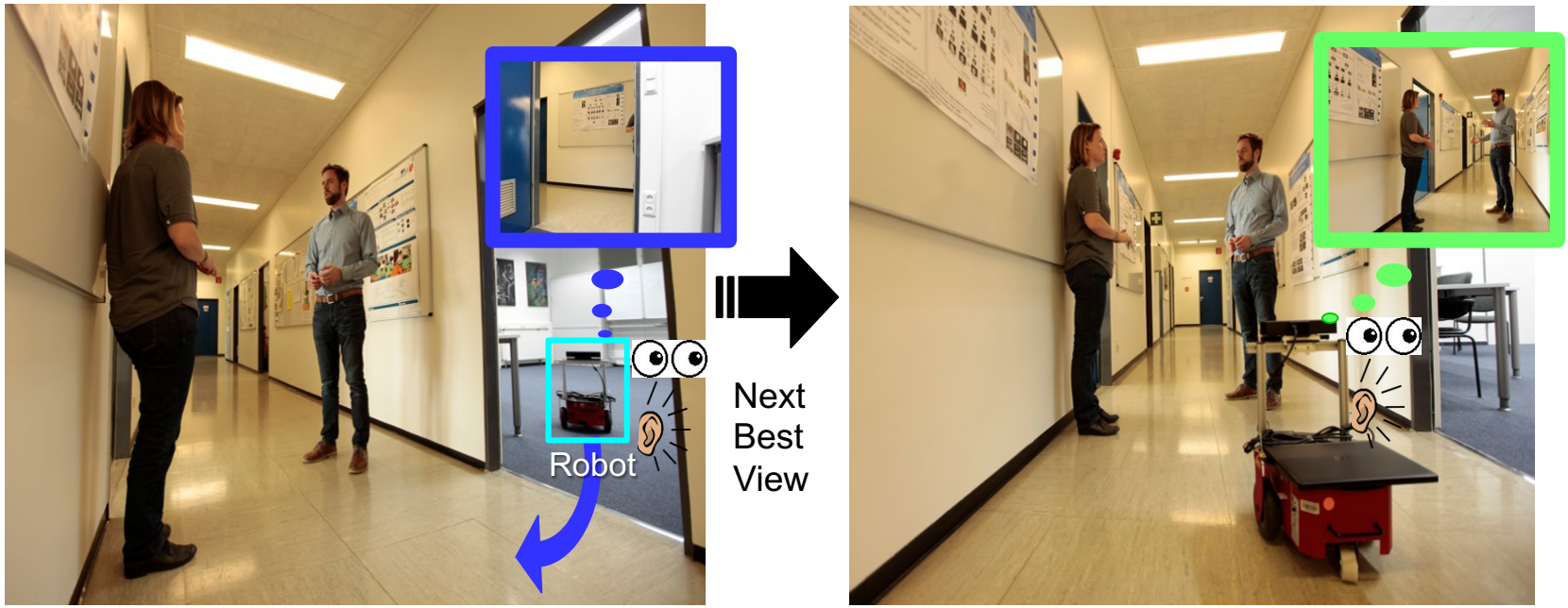


Image Processing Introduction Part 6

SS 2020

Prof. Dr. Simone Frintrop

Computer Vision Group, Department of Informatics
University of Hamburg, Germany

Outline

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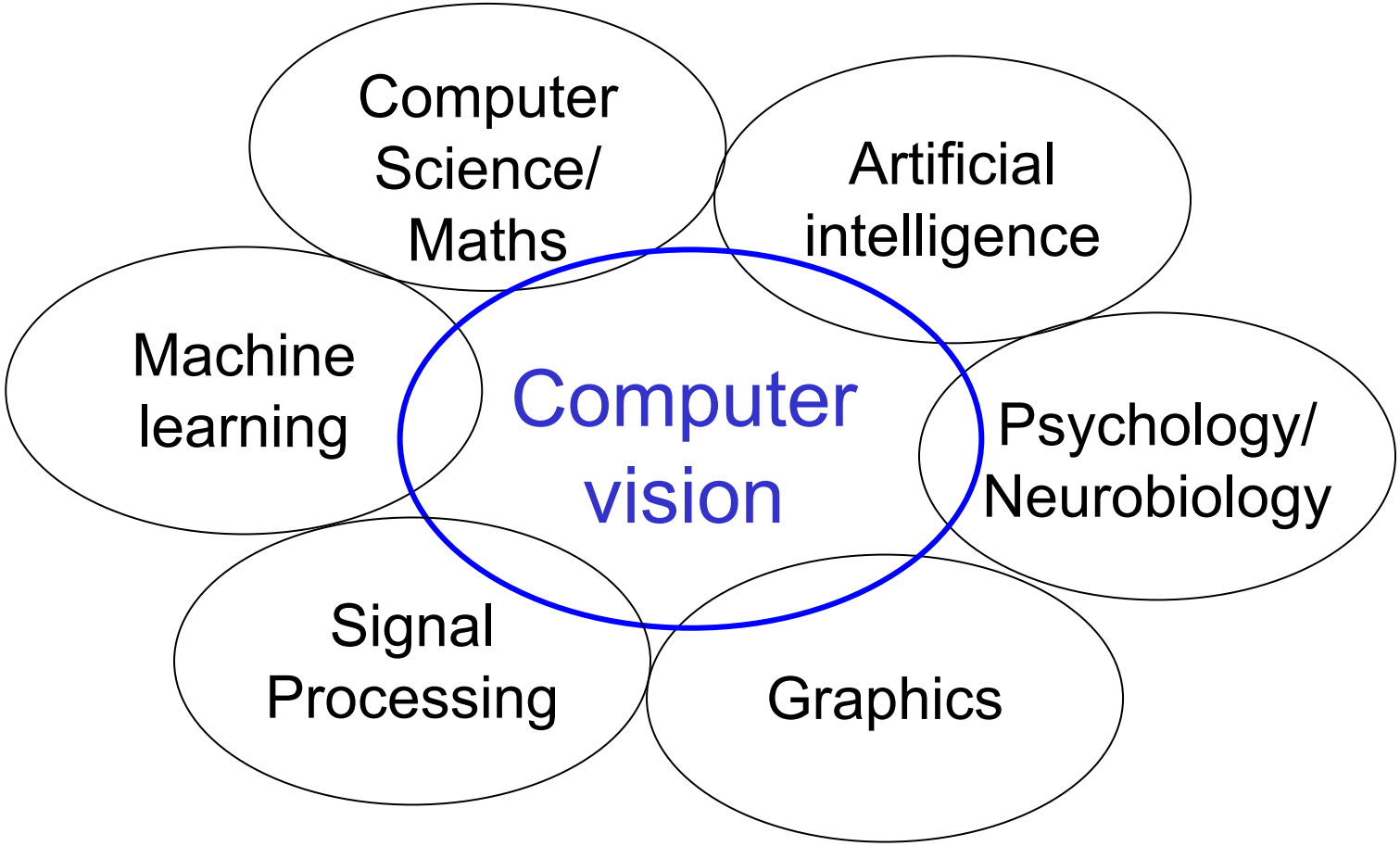
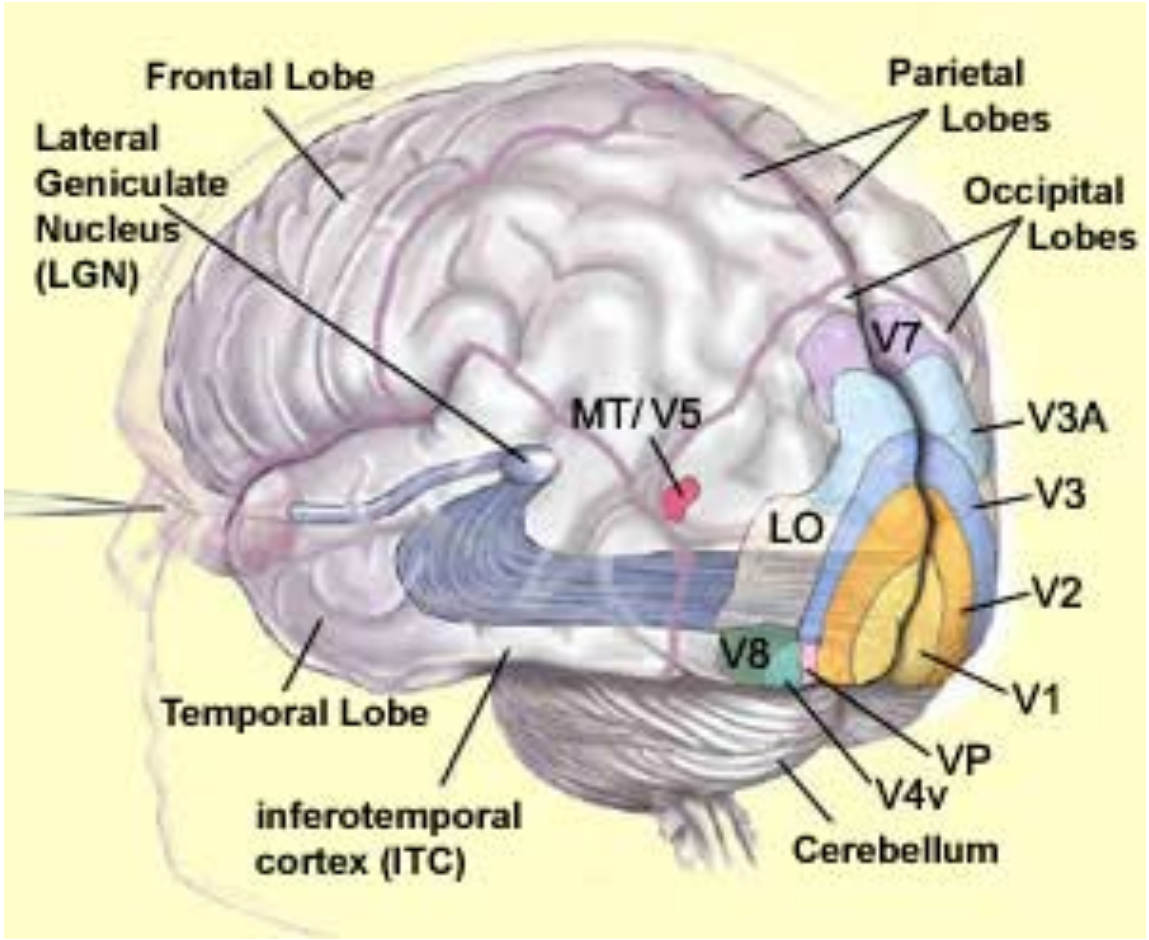
Course Outline

- Introduction
- Human Visual System and Image Fundamentals
- Basis Tools in IP
- Transformations + Binarisation
- Colors and Color Spaces
- Histograms
- Digital Filters in the Spatial Domain
- Digital Filters in the Frequency Domain
- Edge Detection
- Morphological IP
- Segmentation
- Classification

Introduction



The Human Visual System



[http://thebrain.mcgill.ca/]

Image Fundamentals

39	24	9	15	19	27	36	37	32	27	26	36	36	35	34	36	41	50	57	50	47
51	40	19	12	16	26	36	38	34	31	31	39	34	33	41	53	60	57	51	61	56
48	48	39	13	17	25	33	35	32	31	34	36	33	34	45	59	64	56	46	64	61
35	45	50	18	20	25	31	31	28	29	33	31	34	39	46	51	52	50	48	59	59
19	36	61	35	17	19	35	37	32	31	33	25	41	50	46	46	52	51	43	61	53
24	28	38	79	51	23	26	49	59	42	21	41	53	58	48	40	46	57	64	68	75
42	37	34	71	60	32	27	60	77	56	33	43	52	62	68	70	77	90	101	107	114
34	29	20	22	45	42	35	52	54	42	45	86	80	81	93	103	106	107	110	99	117
52	52	46	39	65	73	76	88	84	86	112	99	87	81	91	103	111	120	130	163	162
86	85	80	88	81	68	69	76	67	65	84	96	100	112	128	140	151	169	185	212	210
88	82	77	81	70	71	91	110	117	126	139	163	175	190	200	203	205	210	216	232	224
106	109	110	132	137	159	179	182	183	192	200	214	215	215	214	216	218	217	214	222	223
169	190	190	201	203	210	215	214	209	207	209	210	217	215	213	215	213	211	218	225	225
210	217	209	208	210	215	219	216	210	207	209	210	217	215	213	216	213	212	218	224	225
208	214	208	208	210	214	218	215	208	206	208	211	217	216	213	216	214	212	219	224	225
198	207	204	206	208	213	216	214	209	208	210	211	218	217	214	217	214	213	219	223	225
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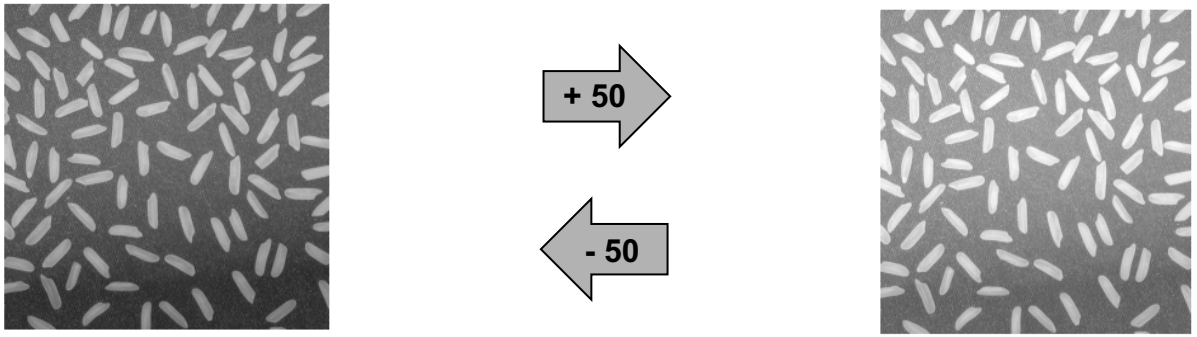
212	210	208	205	210	214	215	212	210	211	213	220	220	220	218	215	216	220	224	225	227

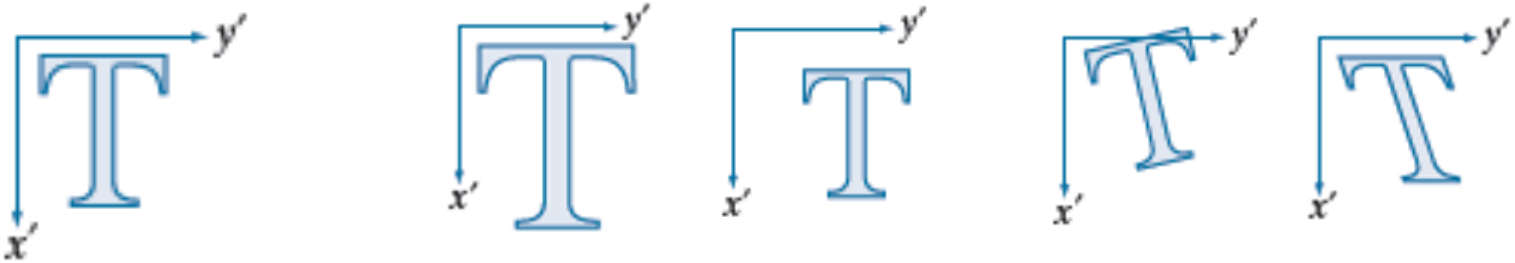
Basis Tools in IP

Addition / Subtraction

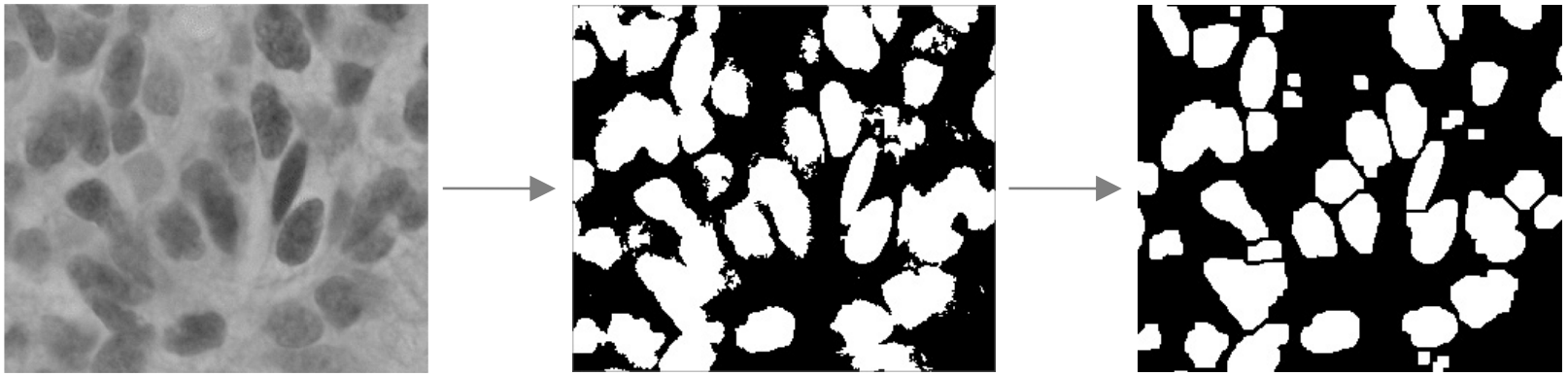


https://homepages.inf.ed.ac.uk/rbf/HIPR2/pixsub.htm

Transformations and Binarisation



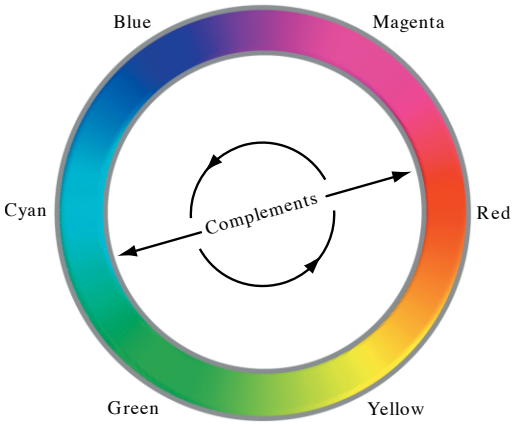
Original | Scaling | Translation | Rotation | Shear



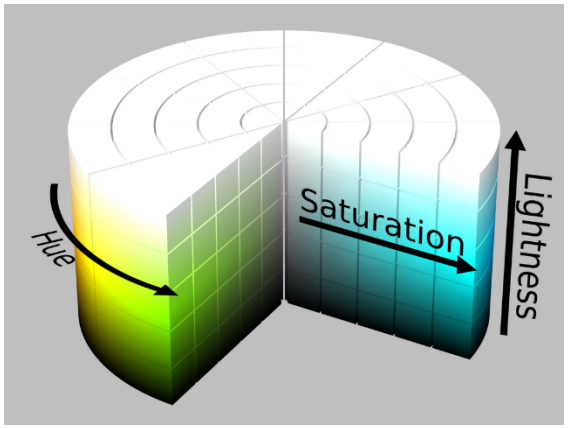
Original | Binarized image | cleaned up image

[Kim et al. 1999]

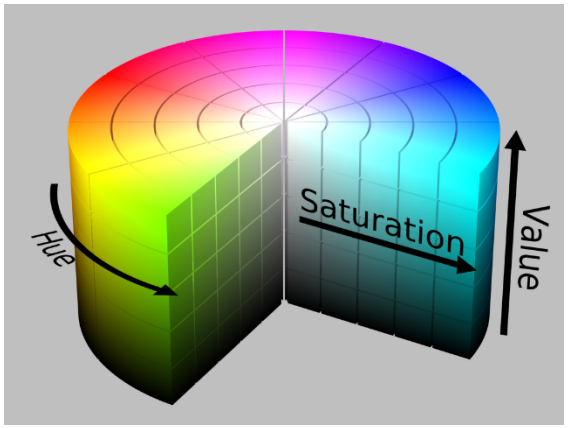
Colors and Color Spaces



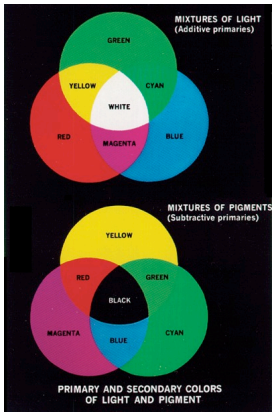
Color wheel



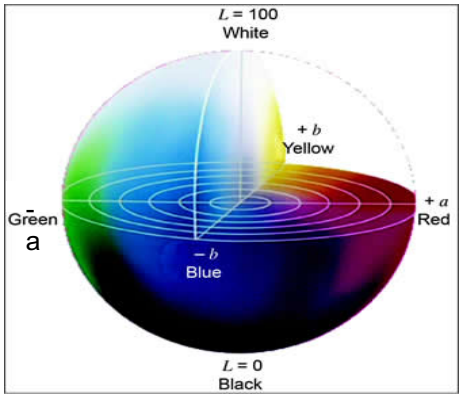
HSL color space



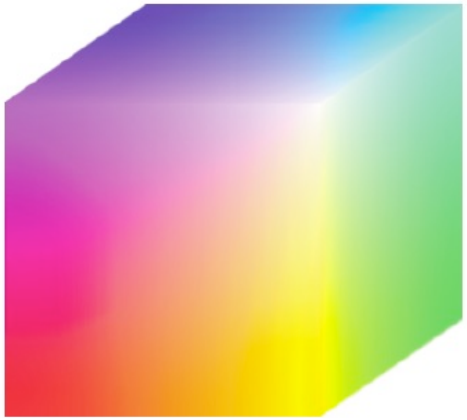
HSV color space



RGB color transformations

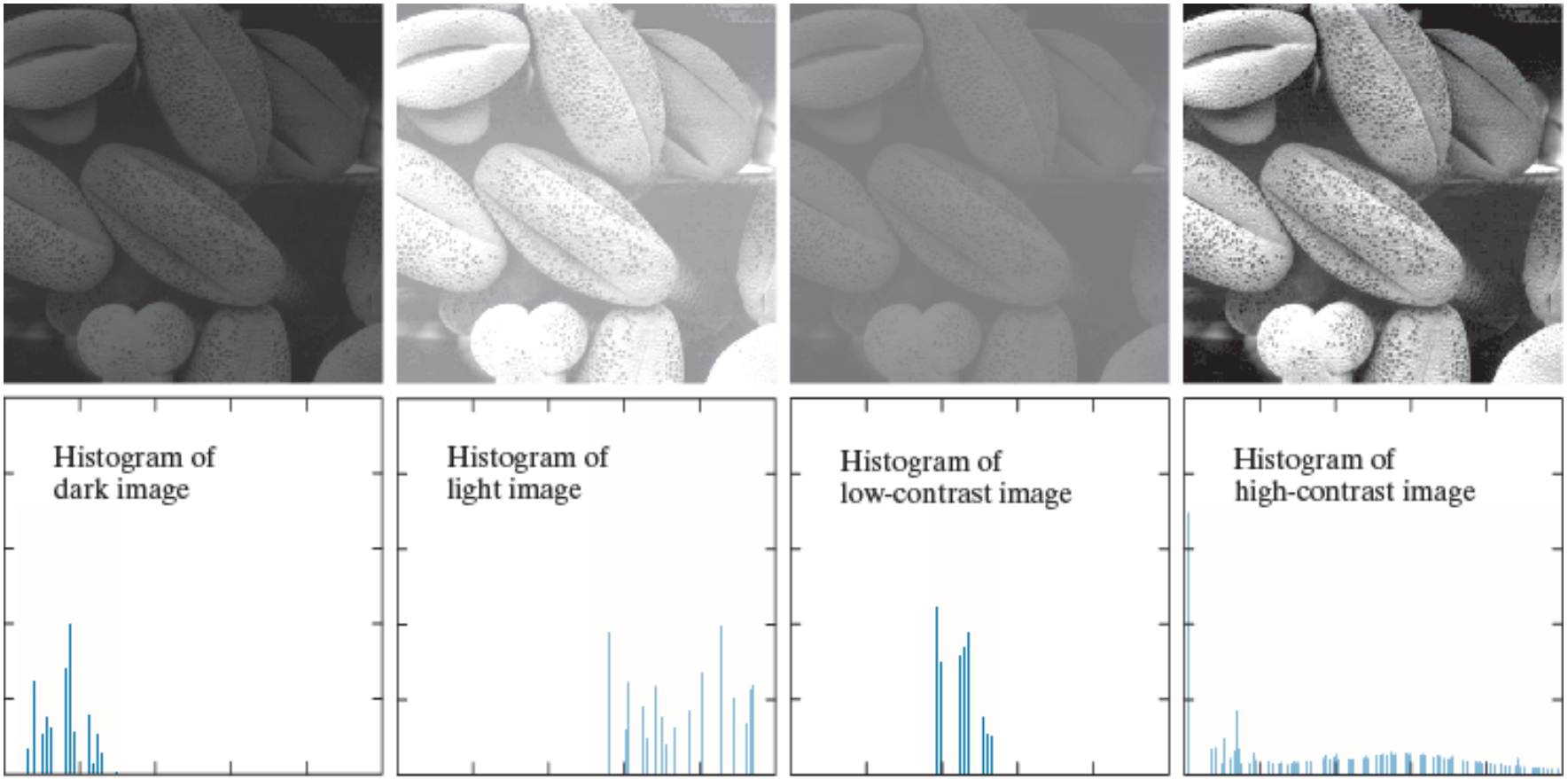


Opponent color space



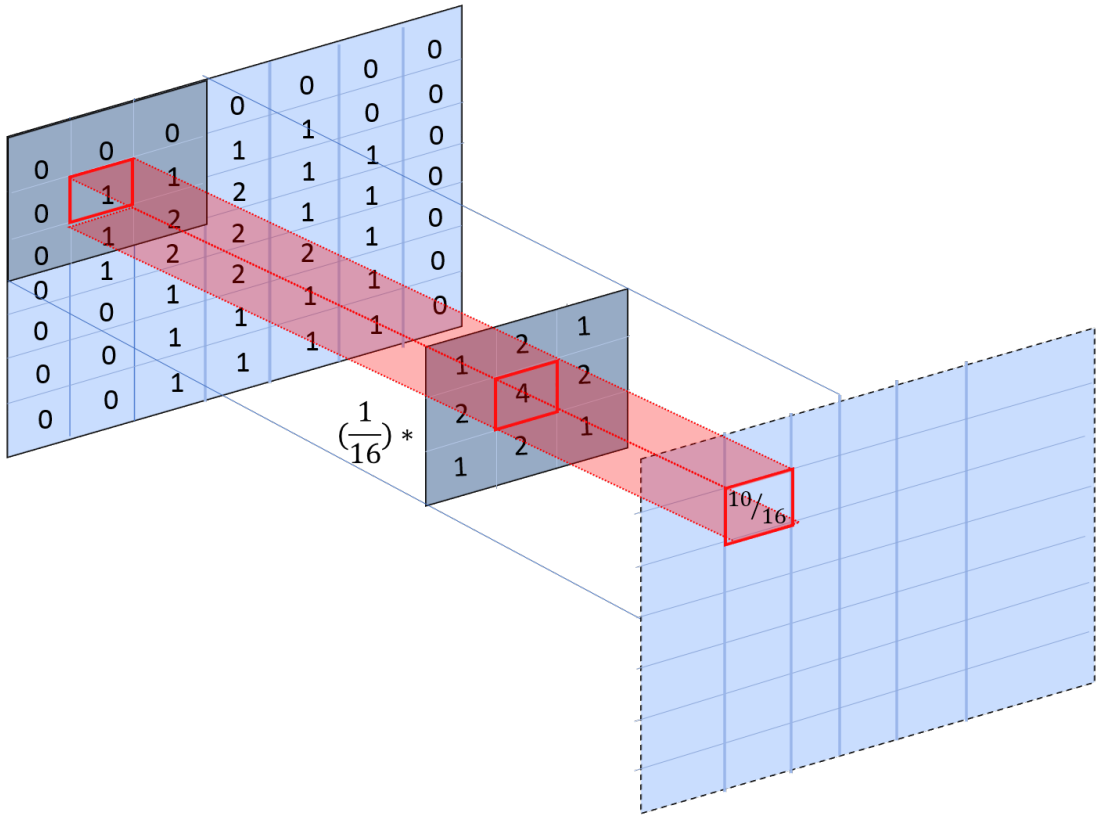
CMY color space

Histograms



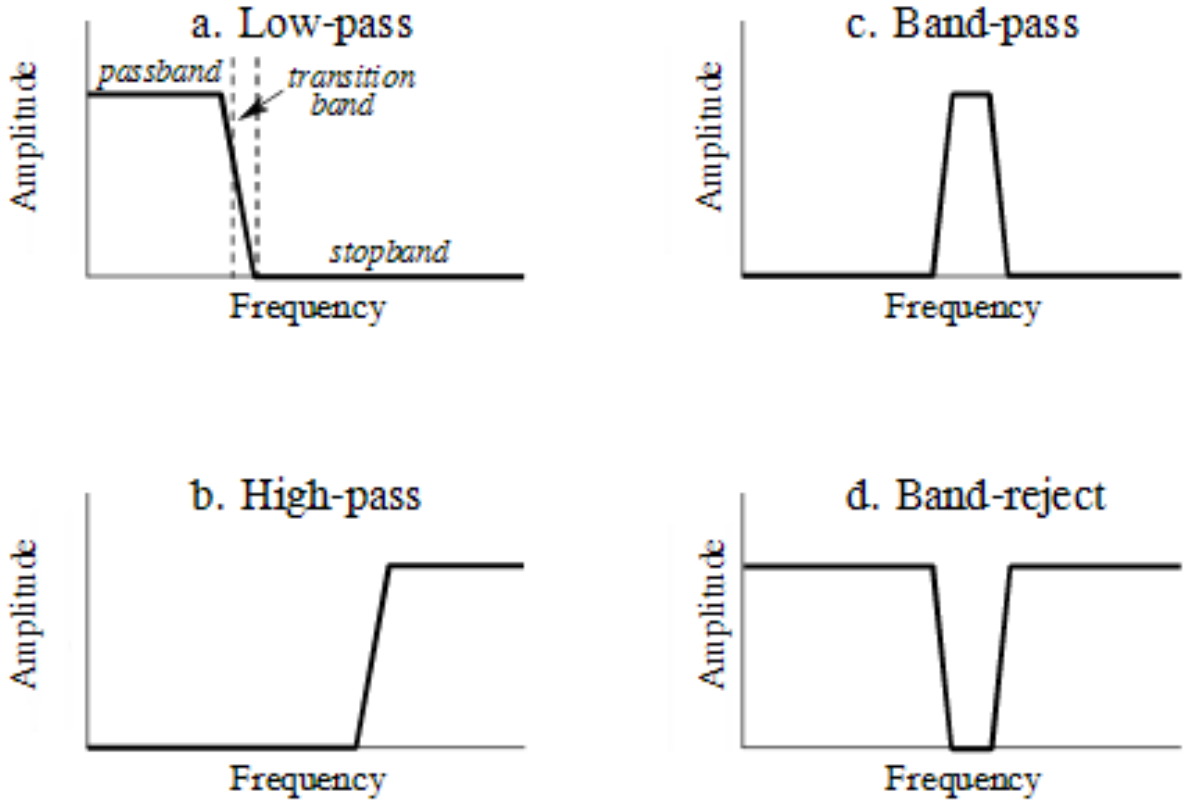
[Gonzalez/Woods]

Digital Filters in the Spatial Domain



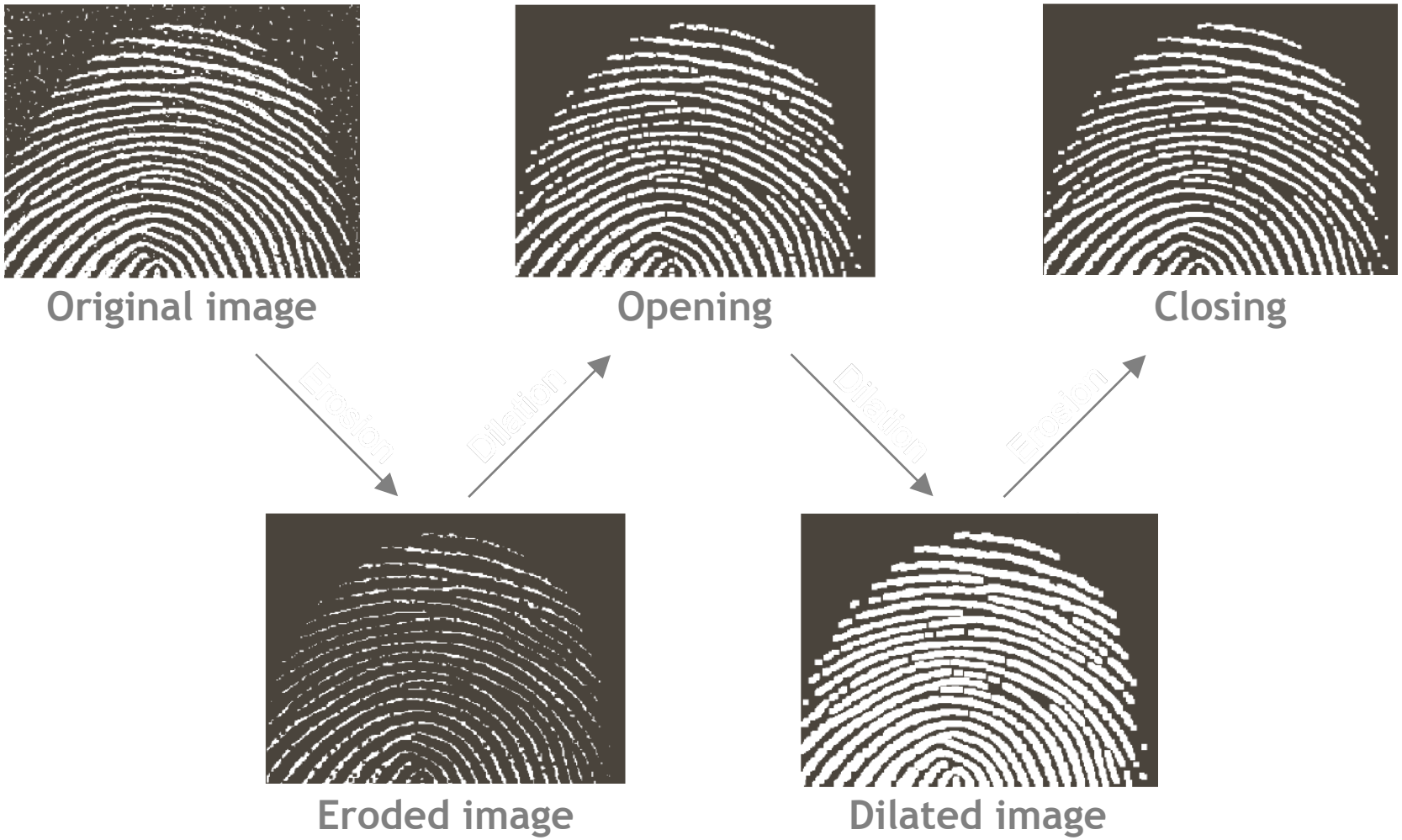
Correlation of an image with a 3 by 3 filter

Digital Filters in the Frequency Domain



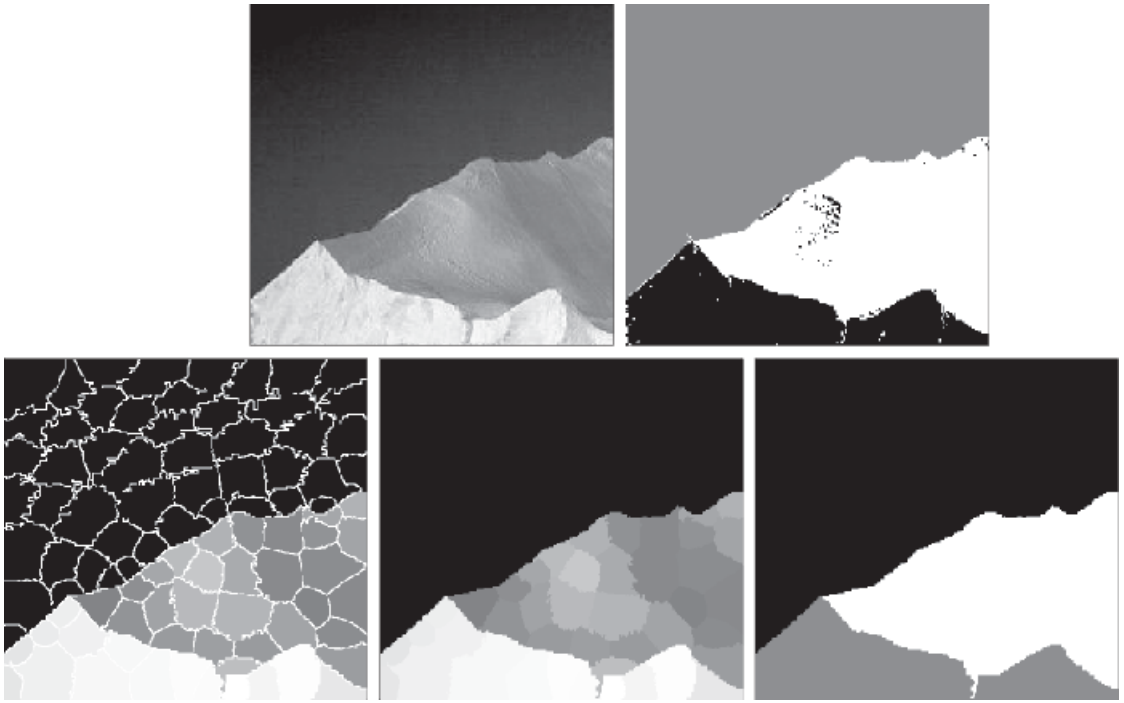
Edge Detection

Morphological IP



[Gonzalez/Woods]

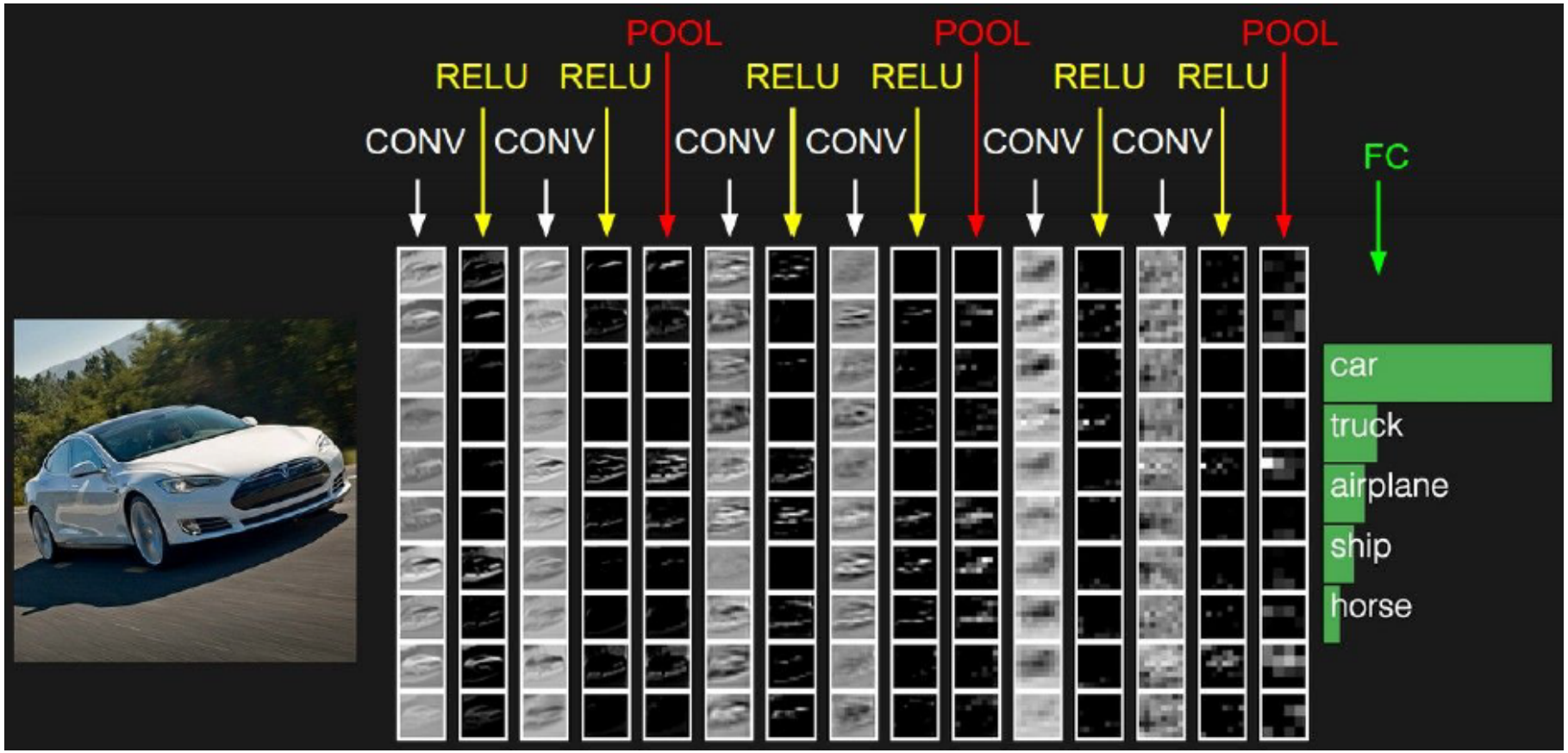
Segmentation



Various degrees of segmentation

[Gonzalez/Woods]

Classification



See the network in action at:
http://cs231n.stanford.edu/

More on Computer Vision

Interested in computer vision topics? Here you get more:

- **Mailing list at Informatikum:** announces talks on computer vision topics
  subscribe here:
  https://mailhost.informatik.uni-hamburg.de/mailman/listinfo/cv-talks
- **Computer Vision News** – the magazine of the algorithm community
  subscribe here:
  http://www.rsipvision.com/computer-vision-news/
- **Imageworld-digest:** International Mailing list announces worldwide events (conferences/workshops) and open jobs in computer vision. Subscribe here (in case you are interested in PhD positions):
  https://list.ku.dk/listinfo/sci-diku-imageworld
- **Initiative Bildverarbeitung e.V.** in Hamburg und Schleswig-Holstein (if you are looking for local job opportunities):
  http://www.initiative-bildverarbeitung.de/home/

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