

Image Processing and Computer Graphics

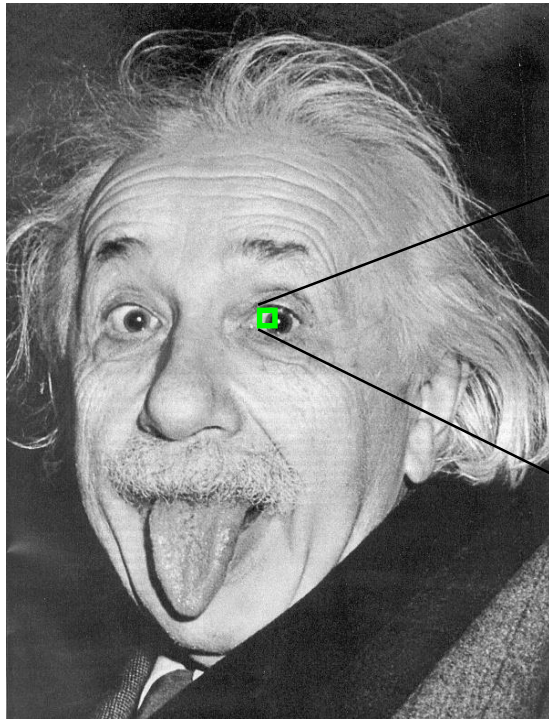
Image Processing

Class 1 Introduction

- Language: English (older German recordings available)
- Type of lecture:
 - 3 hours classroom lecture, 1 hours tutorial (6 ECTS = 180h)
 - Course gives you an overview on computer vision and graphics
 - Required for a specialization in our groups (e.g. Bachelor thesis, projects)
- Prerequisites
 - Solid undergraduate mathematics
 - Programming experience in C/C++
(for the programming assignments)

- Tutorials
 - ~every second Tuesday in the computer pools (see webpage for dates)
 - Advisors: Mostafa Morsy, Benjamin Ummenhofer, Nima Sedaghat
 - Consists of programming assignments
 - Online forum with link on the course webpage (access with your RZ-account)
- Exam
 - Written exam
 - Make sure you are registered for the exam in time
- These slides are made available at:
<http://lmb.informatik.uni-freiburg.de/lectures> (user: open, passwd: thebox)

- Aim primarily for **education**, not just expert knowledge or the next exam
- Your not in school anymore:
It is your responsibility to make good use of what we offer
- This course provides you with opportunities to:
 - Improve your understanding of math and abstract concepts
 - Train your programming and debugging skills
 - Challenge your ability to solve problems independently
 - Efficiently search for missing information (asking the right questions)
 - Exploit the advantages of team work
 - Improve your English skills
- Not all of this will be tested and graded in the exam, but in life
- Improve your abilities, not just your CV



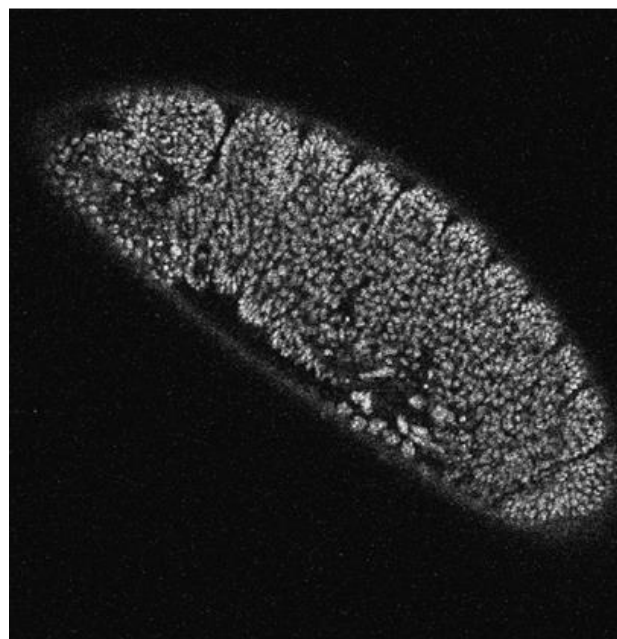
Author: Daniel Cremers

- Digital image: regular grid I_{ij} of intensity values
- Continuous function $I : (\Omega \subset \mathbb{R}^2) \rightarrow \mathbb{R} \quad (x, y) \mapsto I(x, y)$

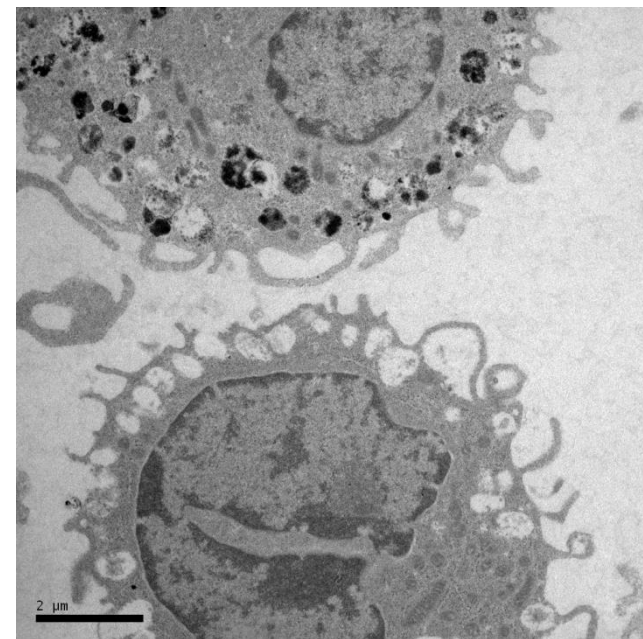
- Imaging (e.g. photography, ultrasound, magnetic resonance, microscopy)
- Image enhancement and modification (e.g. Adobe Photoshop)
- Image and video compression
- Computer graphics (model \rightarrow image)
- Computer vision (image \rightarrow model)
- Focus of our group: computer vision



Magnetic resonance
image of a human head



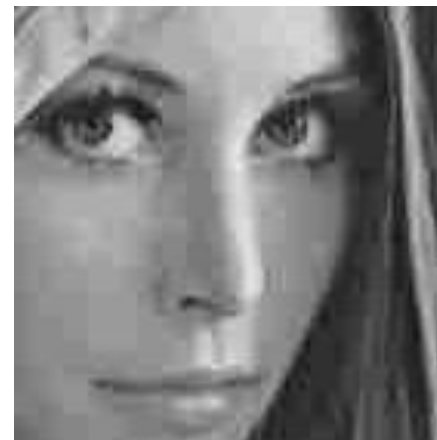
Confocal microscope
image of a fruit fly embryo



Mast cell image from an
electron microscope

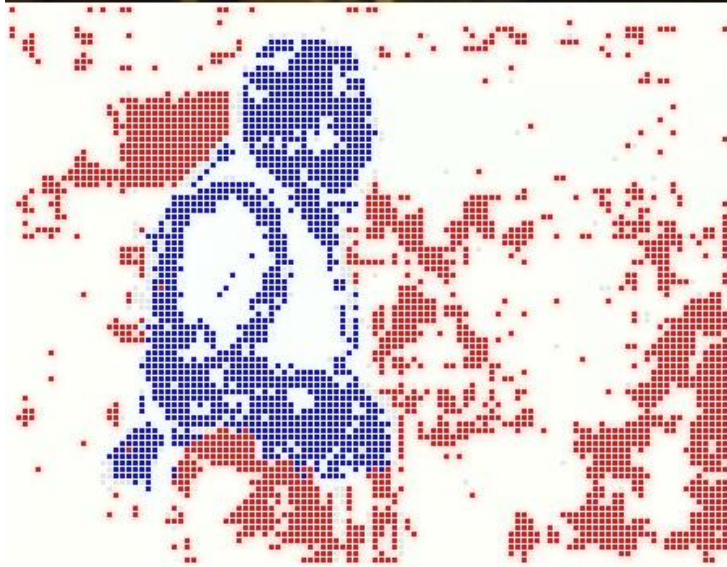


Welk et al. 2005: variational deblurring





Wedel et al. 2007: obstacle detection and segmentation



Brox-Malik ECCV 2010: motion segmentation from point trajectories

Citywall Data Set

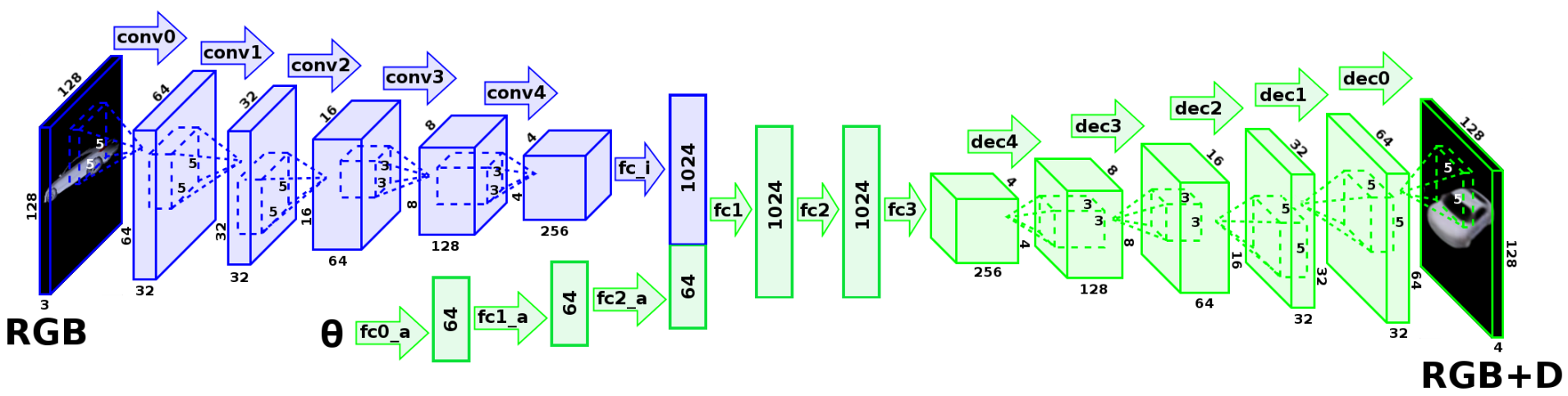
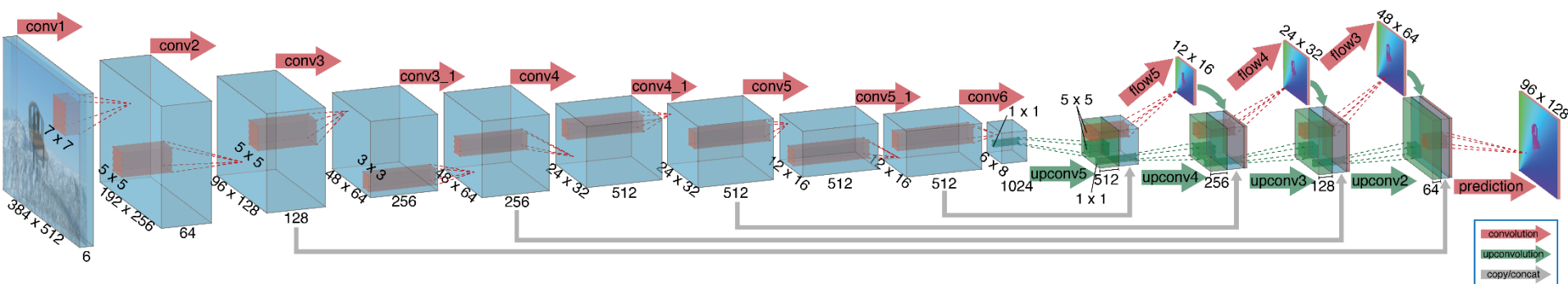
Input: 256 million points

P. Fischer, A. Dosovitskiy, E. Ilg, P. Häusser, C. Hazırbas, V. Golkov
P. v.d. Smagt, D. Cremers, T. Brox

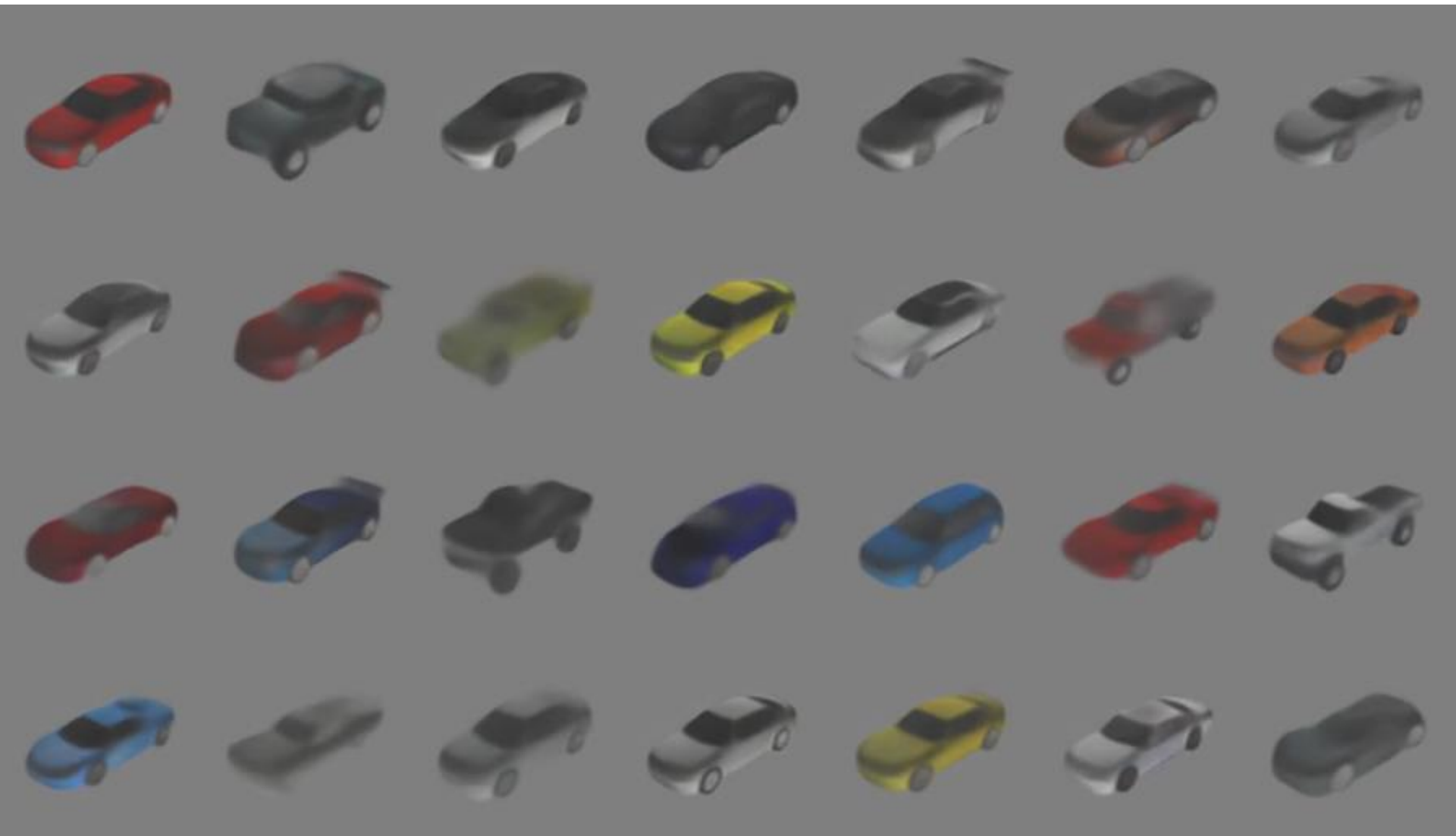
FlowNet: Learning Optical Flow with Convolutional Networks



DispNet result on KITTI 2015







Artistic style transfer for videos

Manuel Ruder
Alexey Dosovitskiy
Thomas Brox

University of Freiburg
Chair of Pattern Recognition and Image Processing

Master project of Manuel Ruder (Ruder et al. 2016)
Won a GCPR Best Paper Honorable Mention
Featured in the ARD Nachtmagazin



Carreira et al. ECCV 2012

Image caption generation



"girl in pink dress is jumping in air."



"black and white dog jumps over bar."



"young girl in pink shirt is swinging on swing."



"little girl is eating piece of cake."



"baseball player is throwing ball in game."



"woman is holding bunch of bananas."

Karpathy-Li 2014

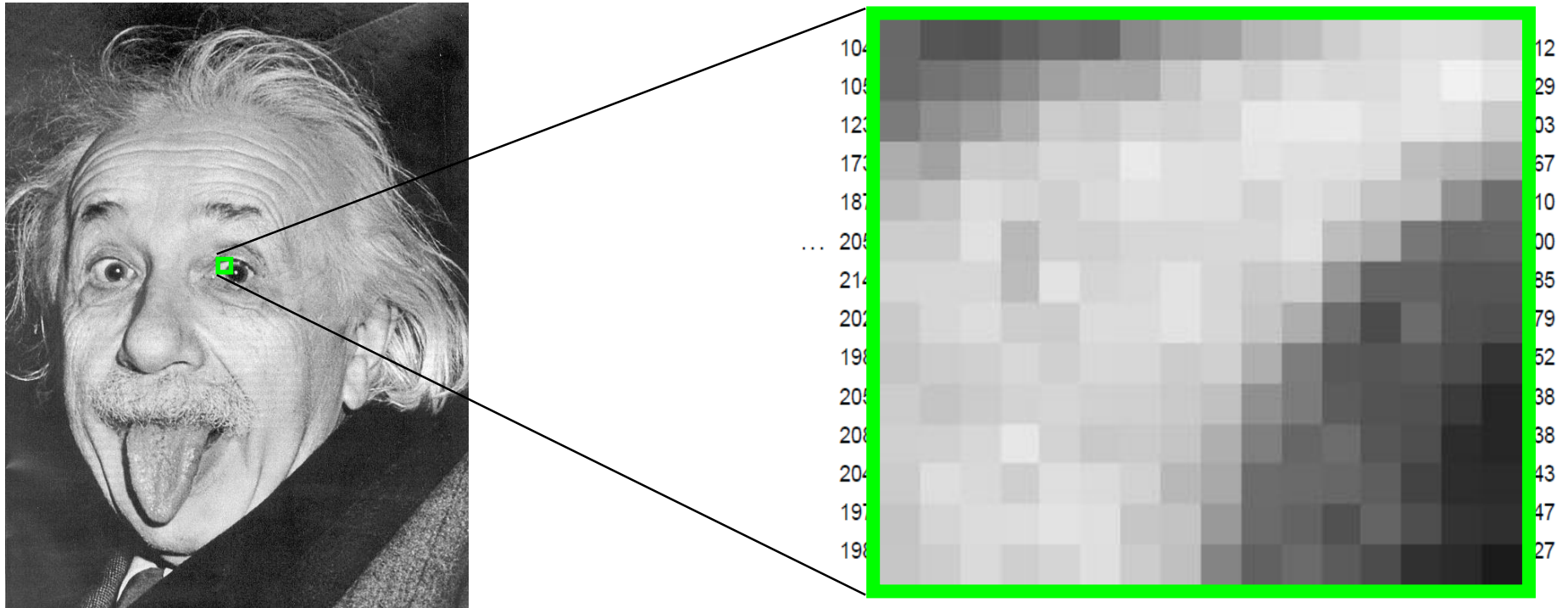
- The term “image processing” is used for the general subject of processing images with a computer
- Computer vision signifies the specific task to have the computer **interpret the content of images**
- Requires pattern recognition and machine learning techniques
- Computer vision has similar motivations as artificial intelligence and cognitive neuroscience (biological vision)

Why is computer vision difficult?

- Vision is a natural and easy task for humans (and many animals)
- This is not for free: ~50% of the primate's cortex deals with the processing of visual information (Felleman-van Essen 1991)
- Matching human visual capabilities means to solve a large part of the AI problem



- What's this?



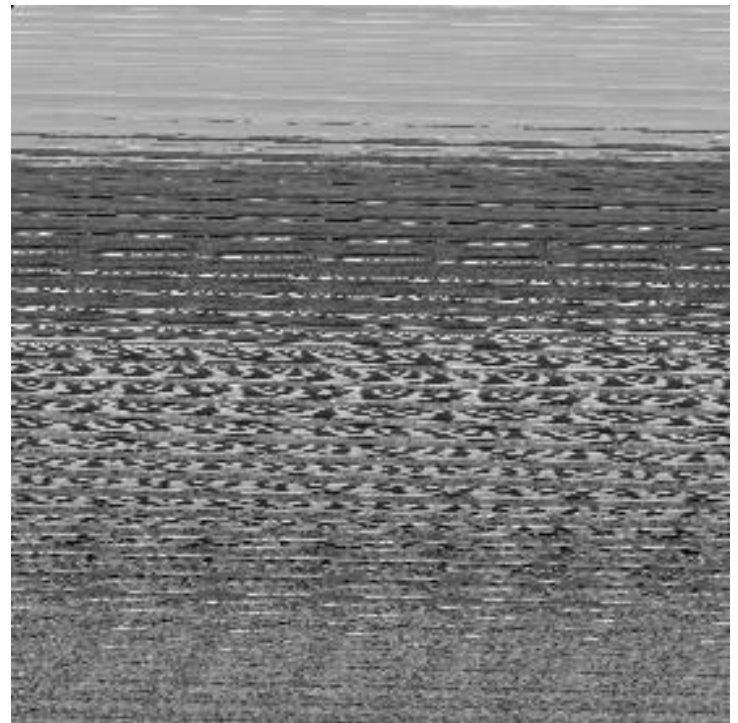
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- This is how the computer sees Einstein
- Demonstrates what our brain achieves at the unconscious level

- Image content is defined by the spatial arrangement of intensities
- It is not sufficient to treat images as vectors and to analyze these vectors



Zebra image



Same image with a different
row length

Ambiguities resolved by context



- Computer vision is a quite “young” research field
 - Main computer vision conference (ICCV) founded in 1987
 - Main computer vision journal (IJCV) founded in 1988
- Today one of the most influential fields in computer science
- Playground for new machine learning techniques
- Computer vision applications are sky rocketing due to progress in deep learning

| Rank | Abbreviated Journal Title (linked to journal information) | ISSN | Total Cites | Impact Factor |
|------|--|-----------|-------------|---------------|
| 1 | ACM COMPUT SURV | 0360-0300 | 2888 | 8.000 |
| 2 | IEEE T PATTERN ANAL | 0162-8828 | 25060 | 5.308 |
| 3 | IBM J RES DEV | 0018-8646 | 3049 | 5.216 |
| 4 | INT J COMPUT VISION | 0920-5691 | 9898 | 5.151 |
| 5 | MIS QUART | 0276-7783 | 7419 | 5.041 |
| 6 | SIAM J IMAGING SCI | 1936-4954 | 322 | 4.500 |
| 7 | IEEE T EVOLUT COMPUT | 1089-778X | 4681 | 4.403 |
| 8 | MED IMAGE ANAL | 1361-8415 | 2901 | 4.364 |
| 9 | INT J NEURAL SYST | 0129-0657 | 816 | 4.237 |
| 10 | HUM-COMPUT INTERACT | 0737-0024 | 1175 | 4.000 |
| 11 | J CHEM INF MODEL | 1549-9596 | 9556 | 3.822 |
| 12 | IEEE COMMUN SURV TUT | 1553-877X | 576 | 3.692 |
| 13 | IEEE T MED IMAGING | 0278-0062 | 11114 | 3.639 |
| 14 | ACM T GRAPHIC | 0730-0301 | 5892 | 3.632 |
| 15 | J ACM | 0004-5411 | 6116 | 3.375 |
| 16 | J COMPUT AID MOL DES | 0920-654X | 3273 | 3.374 |
| 17 | MATCH-COMMUN MATH CO | 0340-6253 | 1677 | 3.291 |
| 18 | COMPUT-AIDED CIV INF | 1093-9687 | 856 | 3.170 |
| 19 | INT J INF TECH DECIS | 0219-6220 | 534 | 3.139 |
| 20 | J AM MED INFORM ASSN | 1067-5027 | 3619 | 3.088 |

Impact factors of the top 20 computer science journals

- Computer science
 - Machine learning
 - Robotics
 - Computer graphics
 - Parallel programming
- Mathematics
 - Optimization
 - Numerics
 - Statistics
 - Linear algebra
 - Functional analysis
 - Graph theory
- Electrical engineering
 - Signal processing
 - Systems engineering
 - Embedded systems
- Cognitive neuroscience
 - Psychophysics
 - Neurophysiology
 - Computational neuroscience

- Conferences
 - **ICCV:** International Conference on Computer Vision
 - **ECCV:** European Conference on Computer Vision
 - **CVPR:** Int. Conference on Computer Vision and Pattern Recognition
 - **NIPS:** Neural Information Processing Systems
 - **ICML:** International Conference on Machine Learning
 - **ICLR:** International Conference on Learning Representations
 - **GCPR:** German Conference on Pattern Recognition

- Journals
 - **IEEE Transactions on Pattern Analysis and Machine Intelligence**
 - **International Journal of Computer Vision**
 - IEEE Transactions on Image Processing
 - SIAM Journal of Imaging Sciences
 - Journal of Mathematical Imaging and Vision

- Quality control, visual inspection
- Security systems
 - Fingerprint recognition
 - Iris recognition
 - Face recognition
 - Surveillance systems
- Medical and biological tools
 - Image enhancement
 - Routine diagnostics
 - Bioinformatics
- Entertainment industry and consumer products
 - Motion capture
 - Augmented reality
 - Human-machine interaction
 - Smartapps
- Web scale data analysis
 - Image Search
 - Video Search
- Photography and video editing
 - Smart cameras
 - Video editing tools
- Driver assistance systems
 - Collision avoidance
 - Autonomous driving
- Robotics
 - Object recognition
 - Visual SLAM
 - Visual learning
 - Vision based control



Video from the KITTI dataset

- Class 1: Introduction
- Class 2: Human vision and image basics
- Class 3: Noise, basic operations and filters
- Class 4: Energy minimization
- Class 5: Variational methods
- Class 6: Motion estimation
- Class 7: Segmentation
- Class 8: Local descriptors
- Class 9: Shape from X
- Class 10: Recognition and deep learning
- Class 11: Biomedical image analysis (Dr. Falk)

- Computer Graphics (Prof. Teschner)

| 3. Semester | 4. | 5. Semester | 6. Semester | 7. Semester | 8.Semester | 9. Semester | 10. |
|-------------|-------------|---|---|-------------------------------------|---|--|------------------|
| | Optimierung | Kursvorlesung Bildverarbeitung u. Computergraphik | Spezialvorlesung Statistische Mustererkennung | Spezialvorlesung Computer Vision | | | |
| | | Spezialvorlesung Engineering meets Biology | | | | | |
| | | | Seminar | Seminar | Seminar | Seminar | |
| | | Deep Learning | Bachelor Thesis | Deep Learning | GPU Programming Master project Interdisciplinary Project | Master project Interdisciplinary Project | Master Thesis |

Computer Vision is part of the focus “Cognitive Technical Systems”

Also see courses in

Robotics (Burgard), Machine Learning (Boedecker, Hutter),
Optimization (Diehl)

- Image processing, especially computer vision, is an important research field.
- Thanks to deep learning it is currently growing enormously.
- Image processing makes use of techniques from various other sciences.
- Especially machine learning is closely related.

- R. Szeliski: Computer Vision: Algorithms and Applications, 2010. Available online for free: <http://szeliski.org/Book/>
- D. Forsyth, J. Ponce: Computer Vision: A Modern Approach, Prentice Hall, 2nd edition, 2012.
- R. C. Gonzalez, R. E. Woods: Digital Image Processing, Addison-Wesley, Reading, 2nd Edition, 2002.
- CV Online: Online compendium on numerous image processing and computer vision topics, <http://homepages.inf.ed.ac.uk/rbf/CVonline/>