

## Image Processing and Computer Graphics

### Image Processing

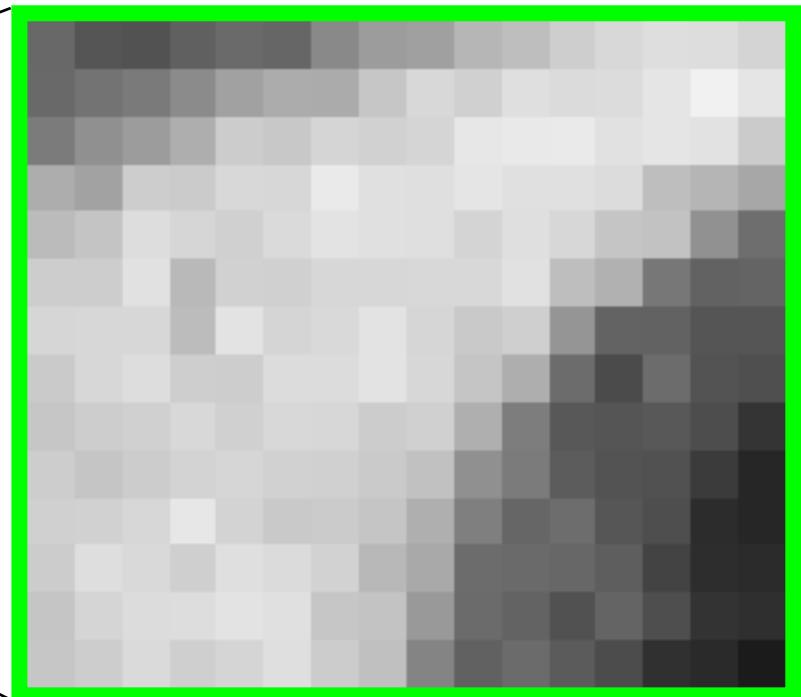
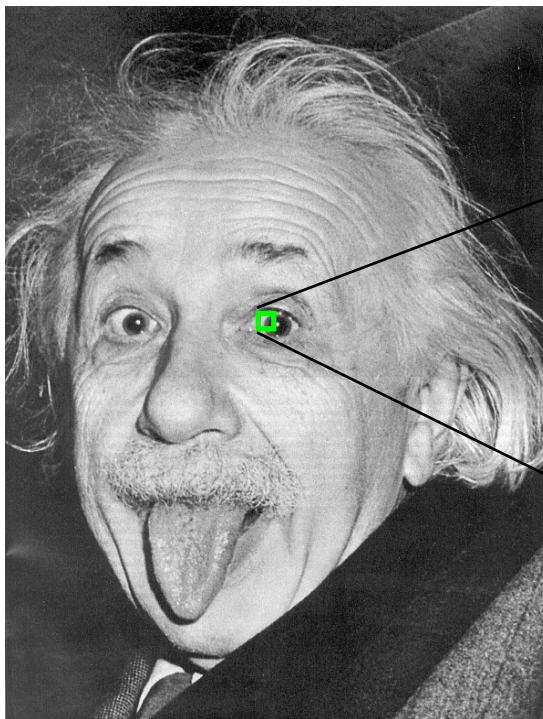
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#### Class 1 Introduction

# Organizational issues

- Tutorials
  - ~every second Tuesday in the computer pools (see webpage for dates)
  - Advisors: Max Argus, Huizhong Zhou
  - Consists of programming assignments
  - Online forum with link on the course webpage (access with your RZ-account)
- These slides are made available at:  
<http://imb.informatik.uni-freiburg.de/lectures> (user: open, passwd: thebox)

# What is an image?



Author: Daniel Cremers

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

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

# Difference between image processing and computer vision

- 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 is a part of artificial intelligence and shares some motivation with cognitive neuroscience (biological vision)

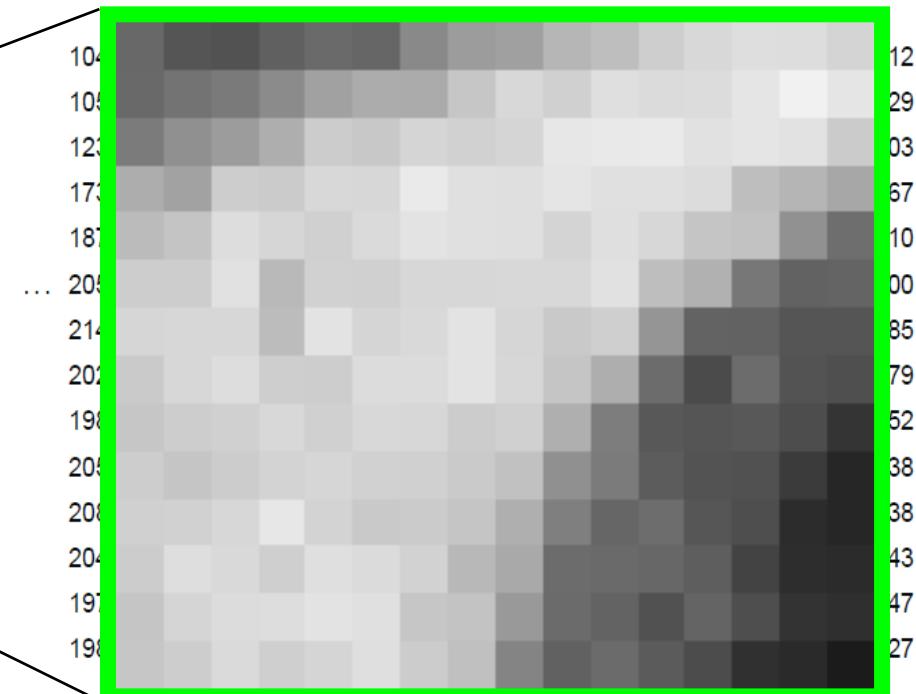
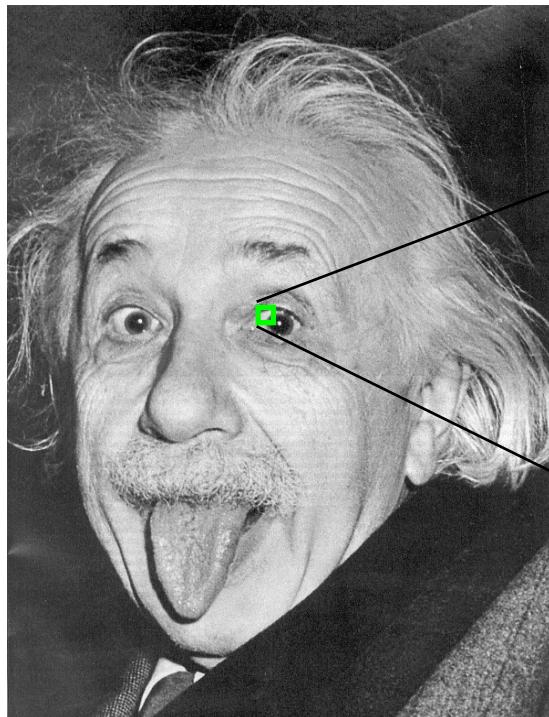
# Why is computer vision difficult?

- 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



# Images are only a structured grid of numbers

- What's this?



Author: Daniel Cremers

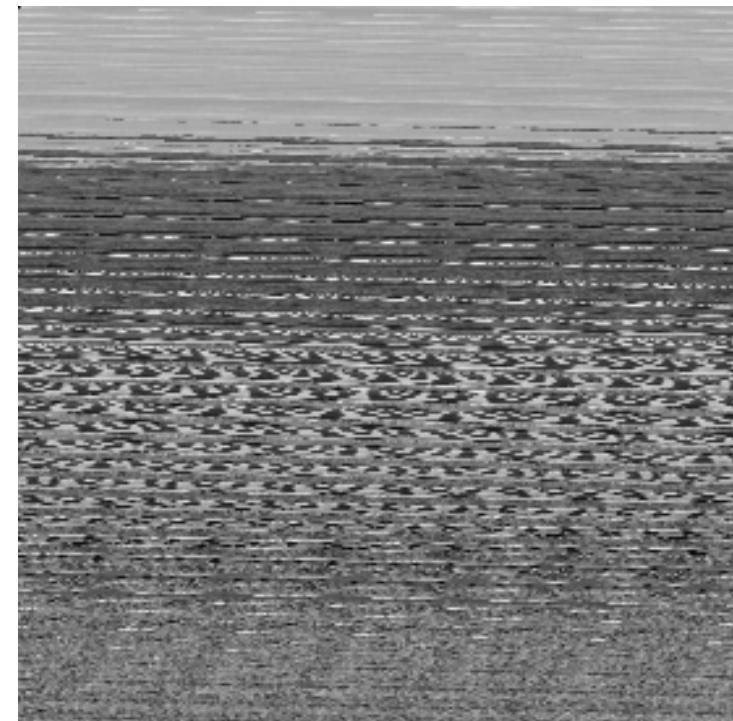
- This is how the computer sees Einstein
- Demonstrates what our brain achieves at the unconscious level

# Importance of the spatial arrangement

- 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

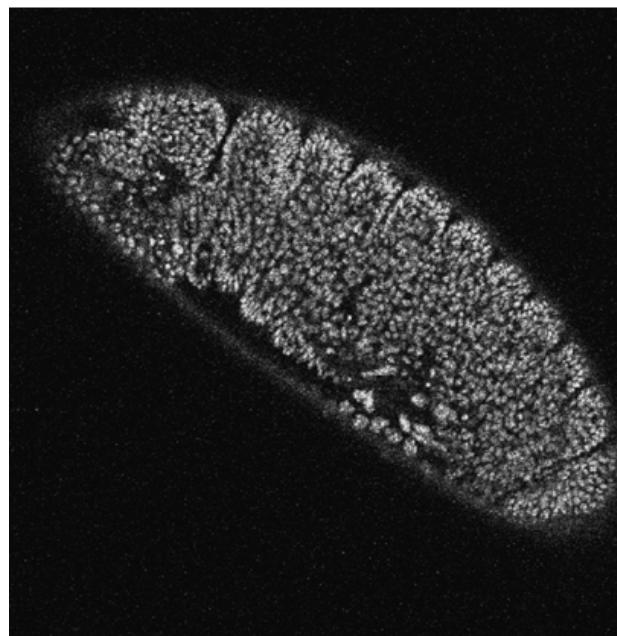
# Ambiguities resolved by context



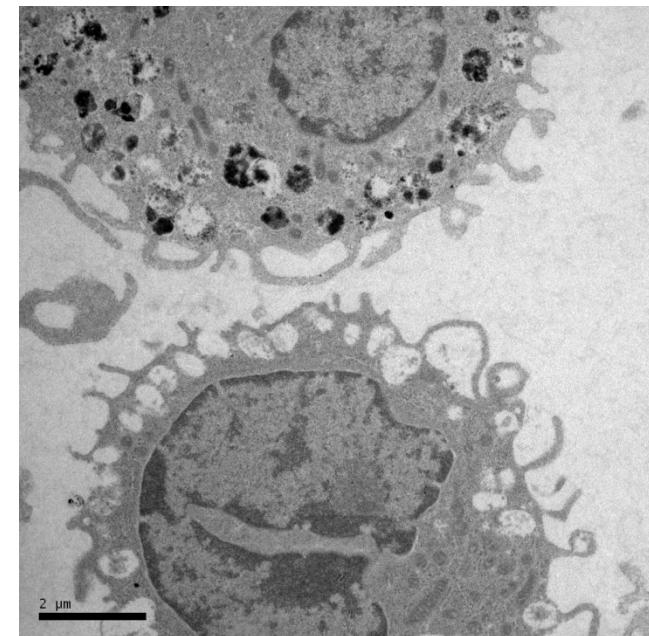
# Imaging – MRI, confocal or electron microscopy



Magnetic resonance  
image of a human head

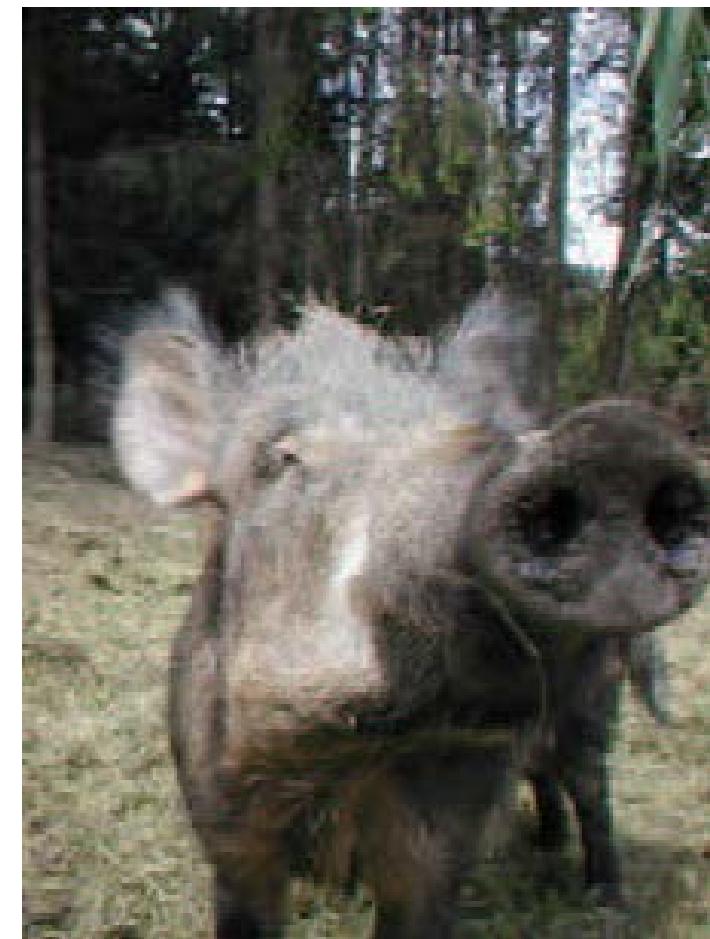
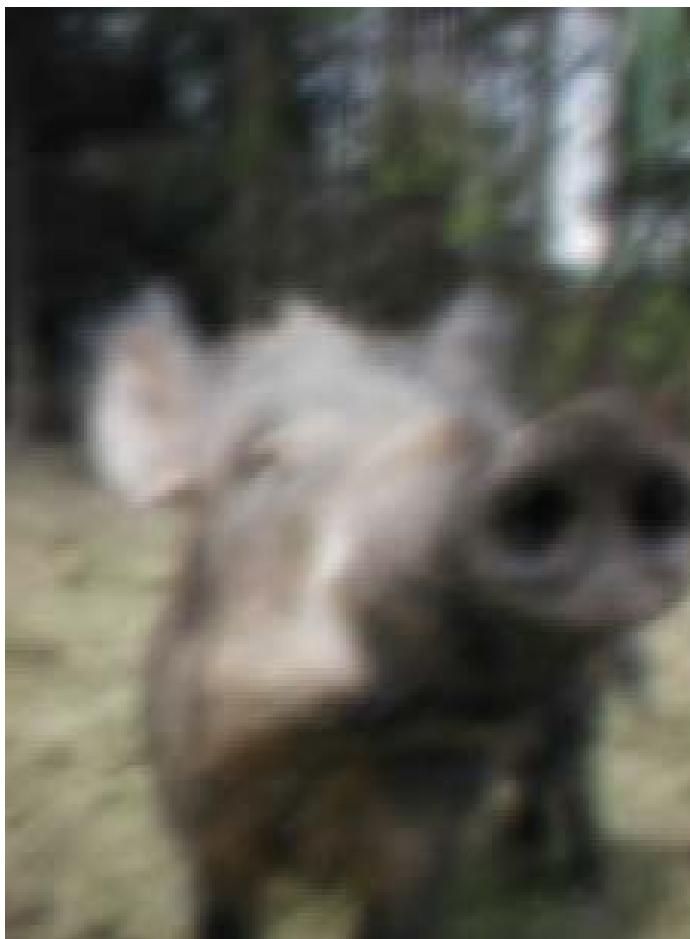


Confocal microscope  
image of a fruit fly embryo



Mast cell image from an  
electron microscope

# Image enhancement - deblurring



Welk et al. 2005: variational deblurring

# Image compression - JPEG

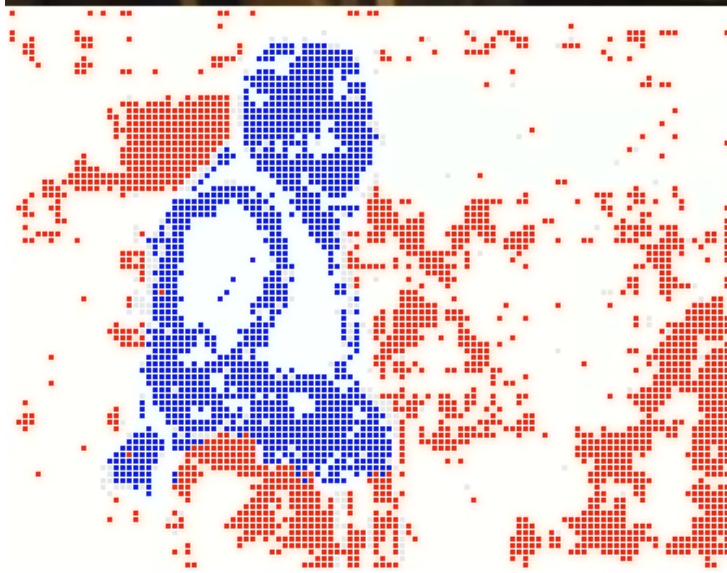


# Computer vision - segmentation



Wedel et al. 2007: obstacle detection and segmentation

# Computer vision – motion segmentation



Brox-Malik 2010: motion segmentation from point trajectories

# Computer Vision – 3D reconstruction



Ummenhofer & Brox 2015: Multi-scale depth map fusion



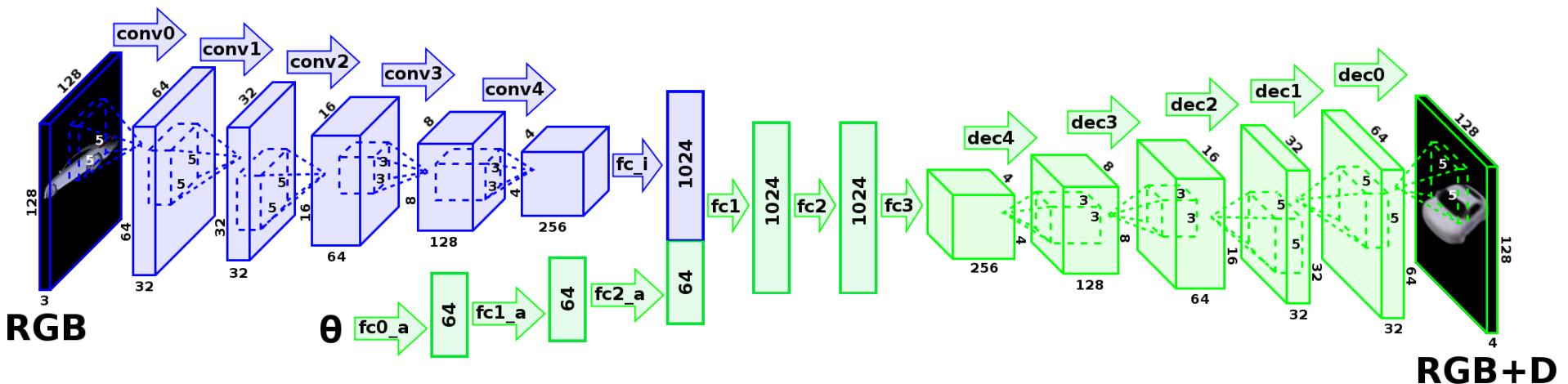
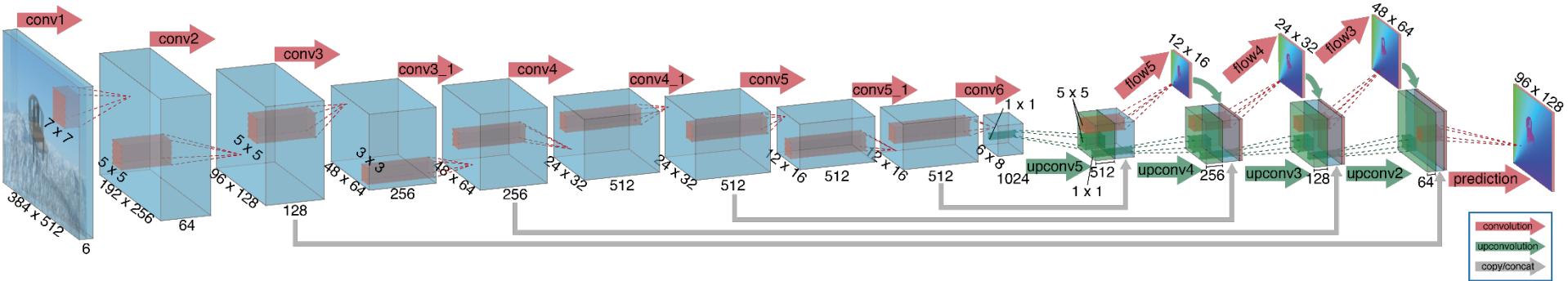
Dosovitskiy et al. 2015: Optical flow with deep learning

# Depth estimation



Mayer et al. 2016: DispNet result on KITTI dataset

# Deep learning can help with (almost) everything in computer vision



# Generating images



Dosovitskiy et al. 2015

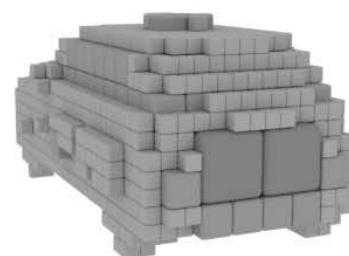
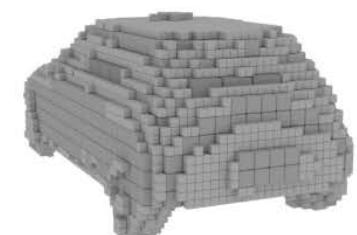
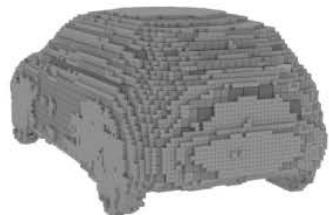
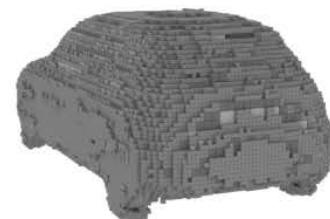
# 3D morphing of cars



Tatarchenko et al. 2016

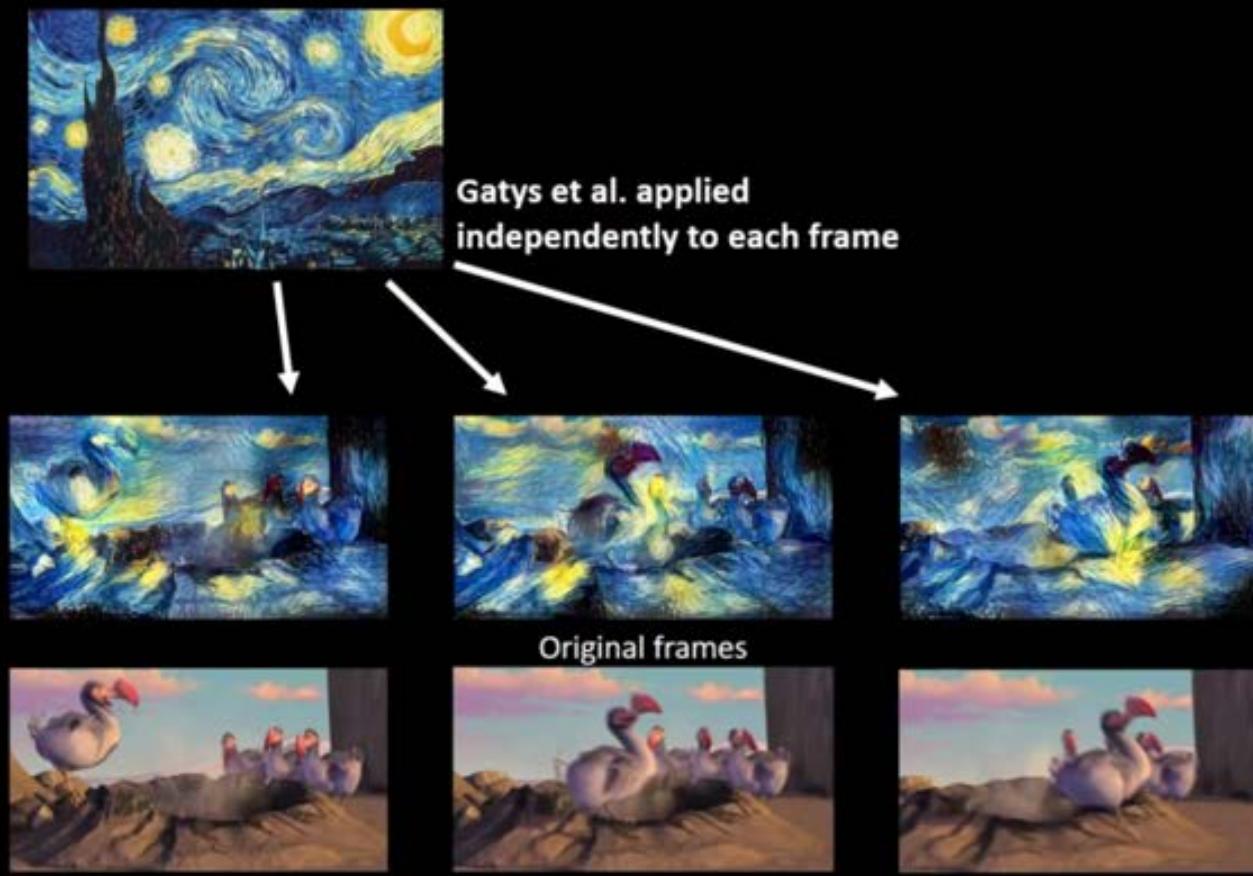
## 3D shape from a single image

Input

 $32^3$  $64^3$  $128^3$  $256^3$ GT  $256^3$ 

Tatarchenko et al. 2017

# Style transfer from an image to a video

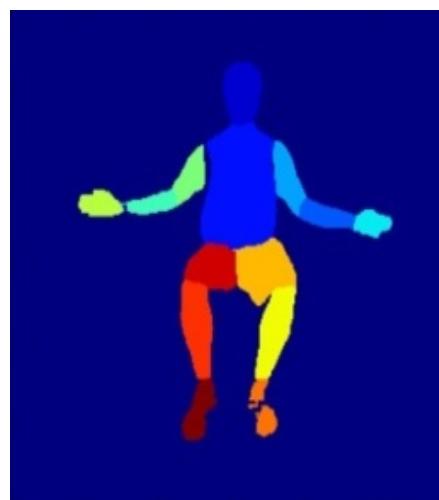


Master project of Manuel Ruder (Ruder et al. 2016)

Won a GCPR Best Paper Honorable Mention

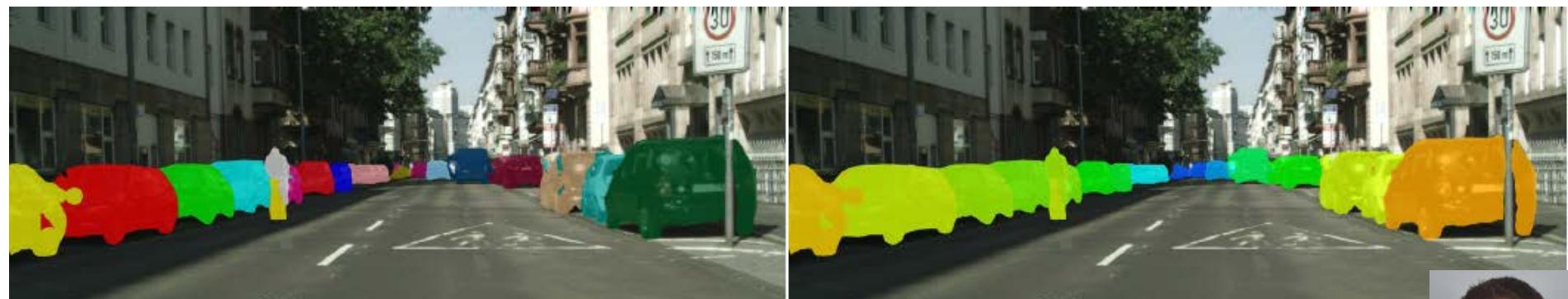
Featured in the ARD Nachtmagazin

# Computer vision – object class recognition and segmentation



Human body part  
segmentation

Oliveira et al. ICRA 2016

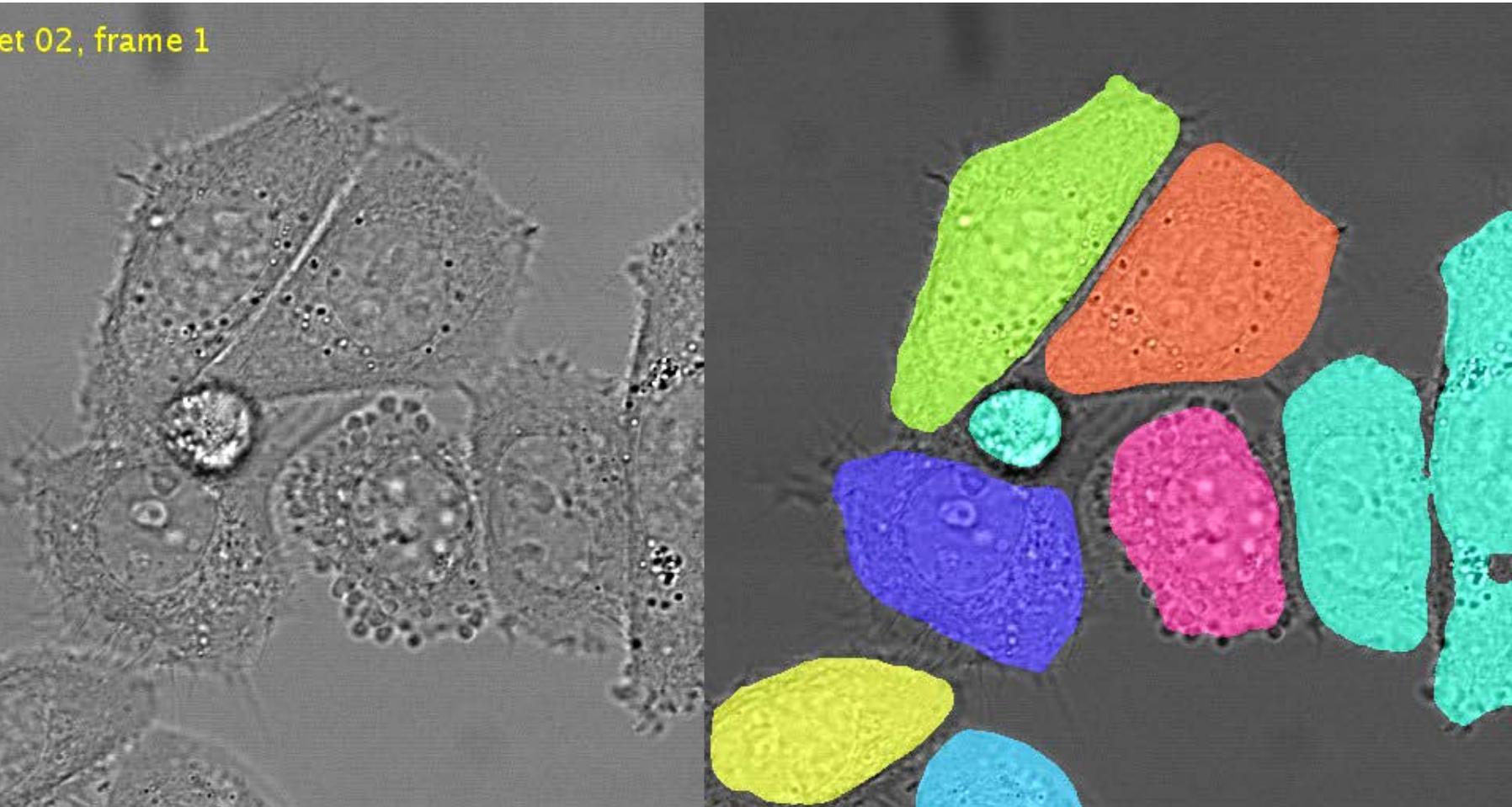


Instance segmentation and depth layering, Uhrig et al. 2016



# Multi-instance cell segmentation

dataset 02, frame 1



Ronneberger et al. 2015: Light microscopy, DIC-HeLa cell tracking

# 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

# Top conferences and journals

- 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

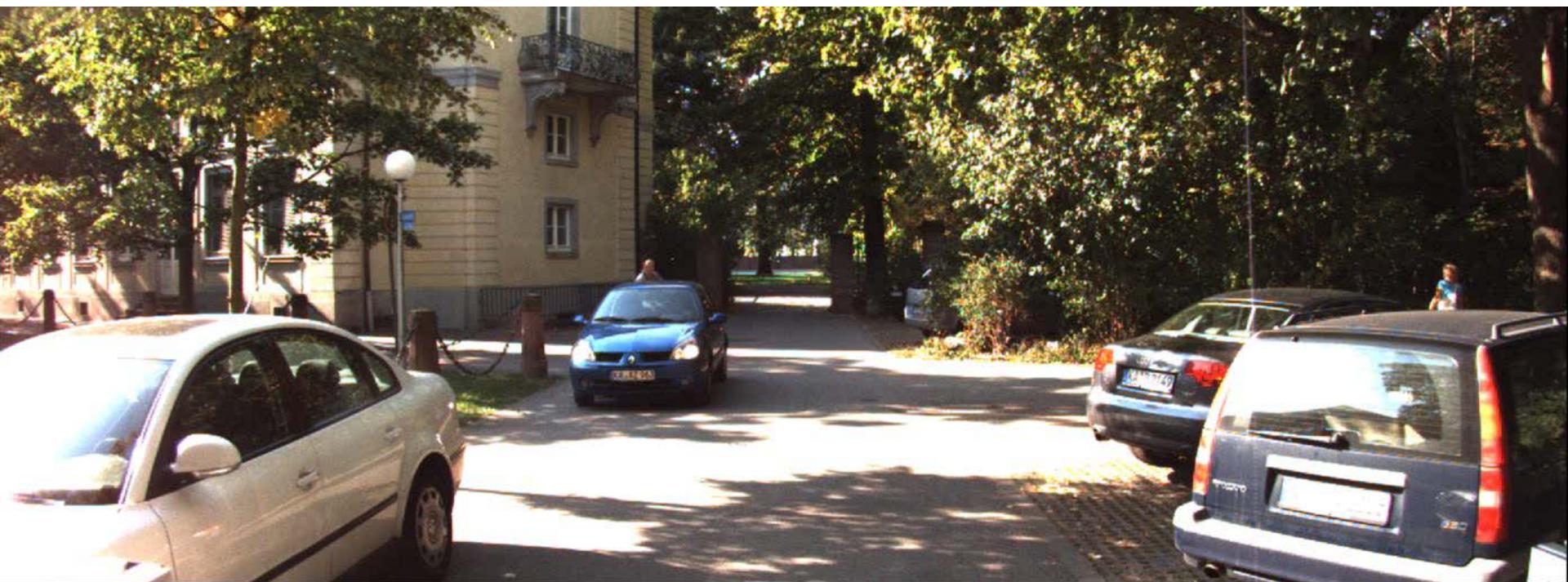
# Related sciences

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

# Some image processing applications

- Quality control, visual inspection
- Security systems
  - 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
  - Smart home
- 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

# No self-driving cars without computer vision



Video from the KITTI dataset

# Share price of Isra Vision AG



What is this?



**Available computer vision and machine learning specialists  
on the world-wide job market**

# What is in here?



A computer scientist who cannot code

# On the purpose of studying at a university

- Aim for **education**, not just the next exam
- You are 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
- Use it!
- Most of this will not be tested and graded in exams, but in life

- 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 (Eddy Ilg)
- 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)

# Other courses in image processing

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	Master project
						Interdisciplinary Project	Interdisciplinary Project
							Master Thesis

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

Also see courses in

Robotics (Burgard, Boedecker), Machine Learning (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.
- It is growing together more and more with other subfields of artificial intelligence (machine learning, robotics, language processing)

- 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, 2<sup>nd</sup> 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/>