Introduction to Pattern Recognition

WS 12/13

Dr. Elli Angelopoulou

Lehrstuhl für Mustererkennung (Informatik 5)

Friedrich-Alexander-Universität Erlangen-Nürnberg

16.10.2012

Overview

- Administrative information
- A short journey through

  Introduction to Pattern Recognition
- Pattern Recognition in practice

Introduction to Pattern Recognition (IntroPR)

- Lecture (3 SWS - 5 ECTS)
  - Tue 10:15 – 11:45 (00.151-113)
  - Wed 12:15 – 13:45 (0.68)
  - Elli Angelopoulou
  - elli@i5.cs.fau.de
- Exercises (1 SWS - 2.5 ECTS)
  - Wed 16:15 – 17:45 (09.150)
  - Thu 10:15 – 11:45 (E 1.12)
  - Christian Riess
  - riess@i5.cs.fau.de
- Exercises are application oriented
- There are no exercises the first week of classes.

Intro PR - Exams

- Certificates
  - Oral exam at the end of the semester
  - Graded certificate *(benoteter Schein)* or exam through the *Prüfungsamt*
    - 7.5 ECTS - 30 min. oral exam on lecture **and** exercises
    - 5 ECTS - 30 min. oral exam on lecture material only
  - Pass/Fail certificate *(unbenoteter Schein)*
    - 7.5 ECTS - 20 min. oral exam on lecture **and** exercises
    - 5 ECTS - 20 min. oral exam on lecture material only

Additional Material for IntroPR

- When applicable, printed slides will be made available through the web.
- The videotapes of the lectures are available at StudOn under Inf5 (Mustererkennung).
- You are still expected to take notes yourself.
- Slides and notes do not replace the textbooks (see next slide).
- Most of the slides can be understood only with the additional explanation provided during the lecture and through the use of additional material from textbooks.

PR Reading Material:

- Recommended Textbooks:

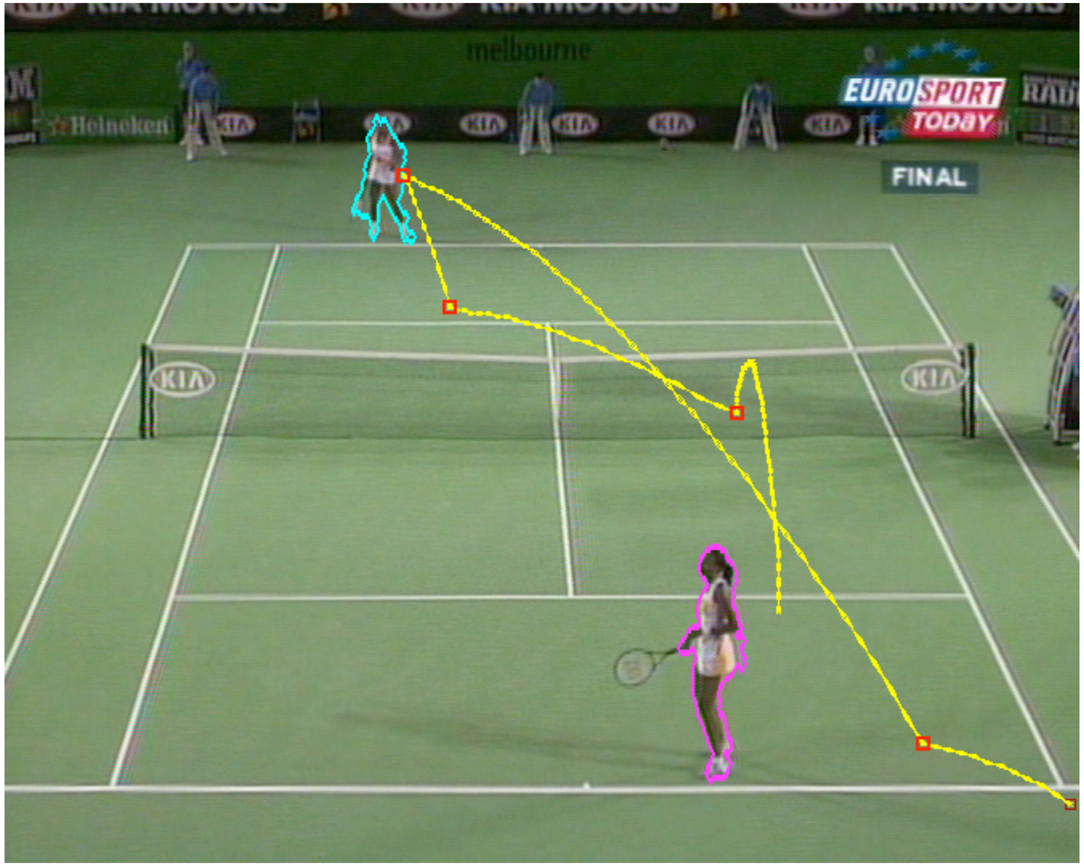
[1] H. Niemann. *Klassifikation von Mustern*. Springer, Berlin, Heidelberg, 1983.
Second expanded edition available via Internet:
http://www5.informatik.uni-erlangen.de/en/our-team/niemann-heinrich

[2] S. Theodoridis and K. Koutroumbas, *Pattern Recognition*, 4th ed. Academic Press, 2009.

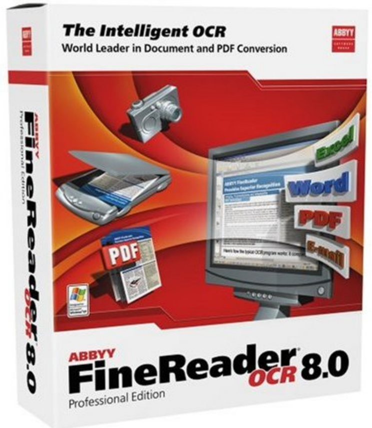
[3] R. Duda, P. Hart, D. Stork, *Pattern Classification*, 2nd ed., Wiley Interscience, 2001.

What is Pattern Recognition?

- Pattern Recognition involves the design of systems which (semi) automatically recognize patterns in sensed data.



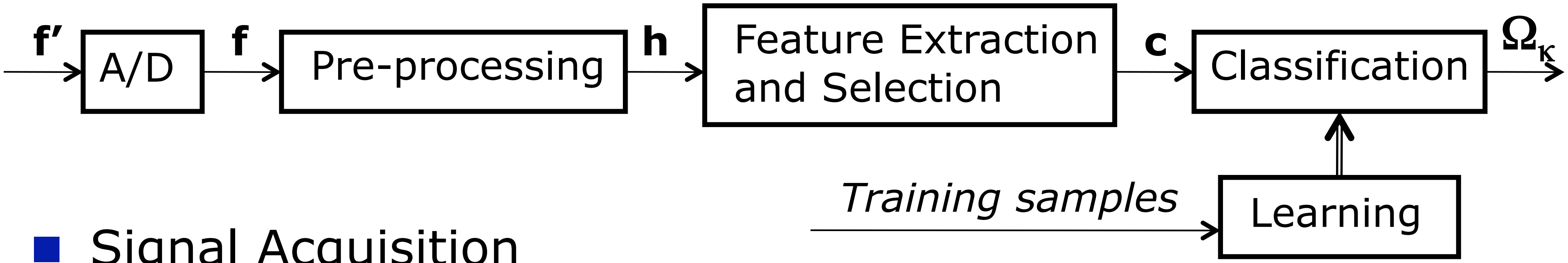
Pattern Recognition in Everyday Life



Components of a Pattern Recognition System

- **Sensor**
  - Collect information
  - Camera, microphone, sonar, X-ray machine
- **Preprocessing**
  - Remove noise from the collected information
  - Bring data in a standardized format
- **Extract Features**
  - Compute numeric or symbolic information from the “raw” collected data
  - Selection of appropriate features has great impact on the success of a PR system
- **Classification**
  - Main recognition step
  - Machine learning (supervised or unsupervised)

Pattern Recognition Topics



- Signal Acquisition
- Preprocessing
- Feature Extraction
- Feature Reduction
- Classification (continued in PR and PA)
- Pattern recognition is at the borderline between computer science and electrical engineering.
- Topics of pattern recognition in Erlangen: medical image processing, computer vision, speech recognition and digital sports.

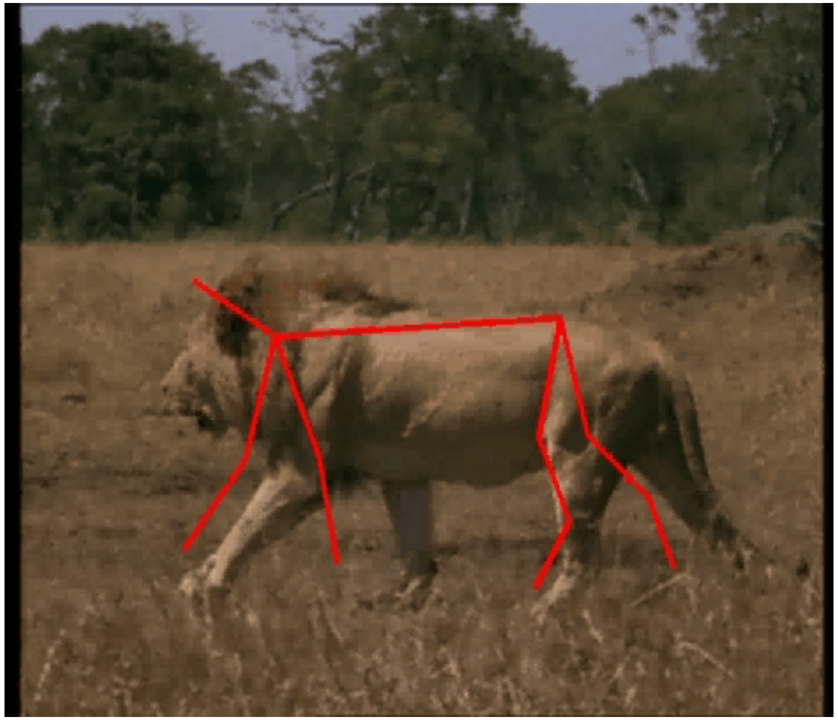
Signal Acquisition

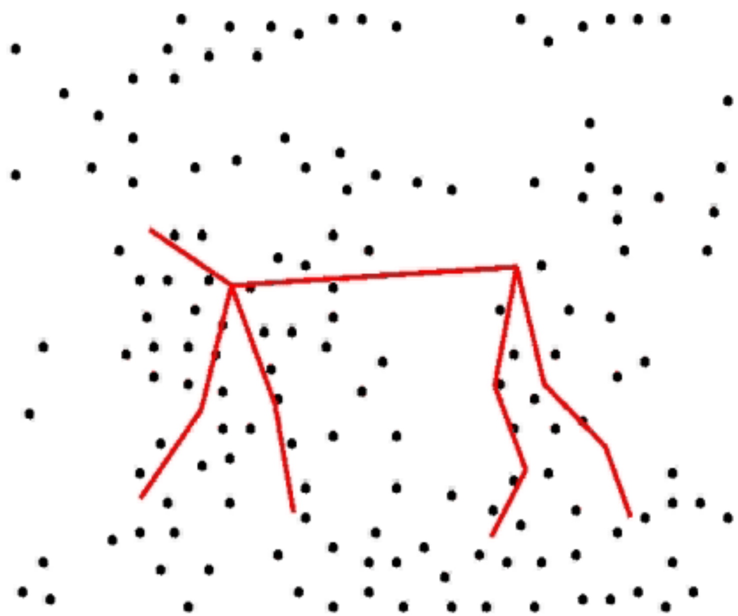
- Depending on the application we can use different types of sensors to acquire data:
  - microphones
  - cameras
  - Xrays, MRIs, CTs, ultrasound
  - GPS sensors, gyroscopes
  - heartrate monitors, perspiration sensors, blood pressure sensors
  - ….
- Once the type of sensor is selected, choosing a particular model can have a significant impact on the overall performance of our PR system:
  - noise levels
  - data acquisition speed
  - amount of collected information
  - built-in preprocessing
  - ….

Feature Extraction/Selection

- Are point features sufficient for object recognition?

Recognition based on Point Features

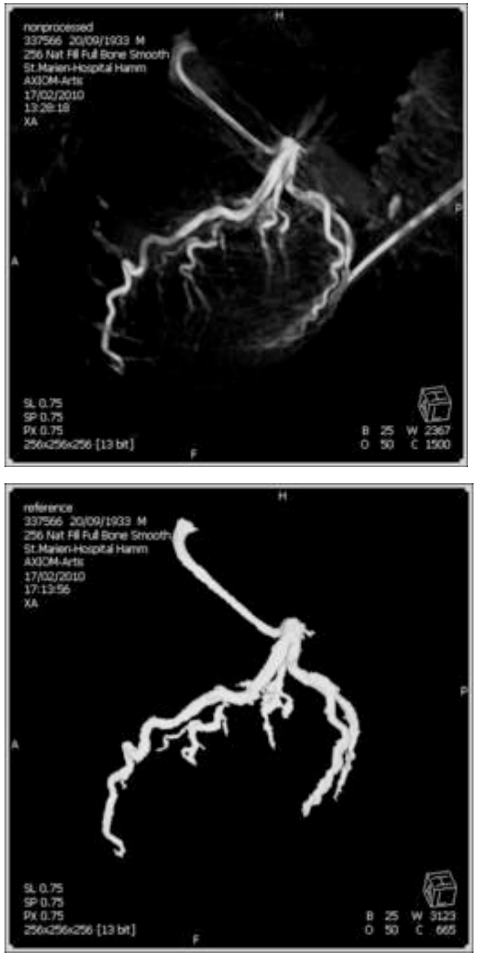




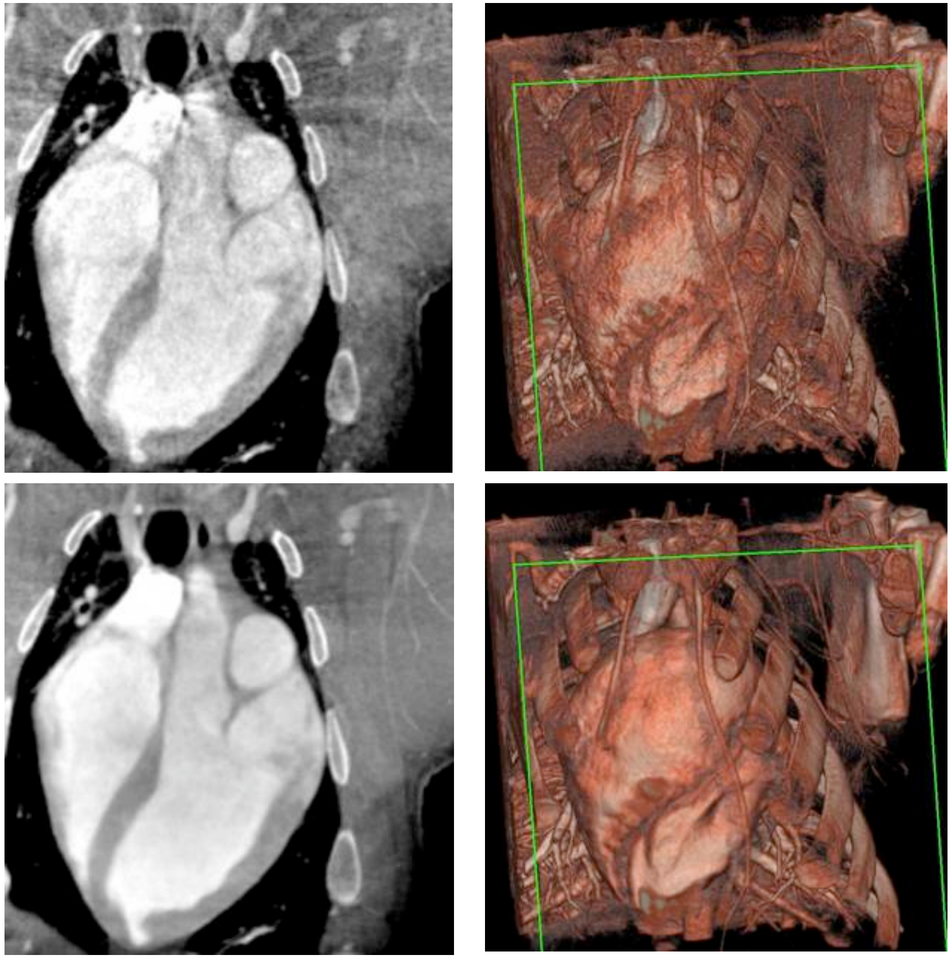
Videoclips courtesy of Ruixuan Wang, Wee Kheng Leow and Hon Wai Leong,
"3D-2D Spatiotemporal Registration for Sports Motion Analysis", CVPR 2008

Challenges – Medical Image Processing

- Need for accuracy
- Thorough evaluation



Coronary tree extraction



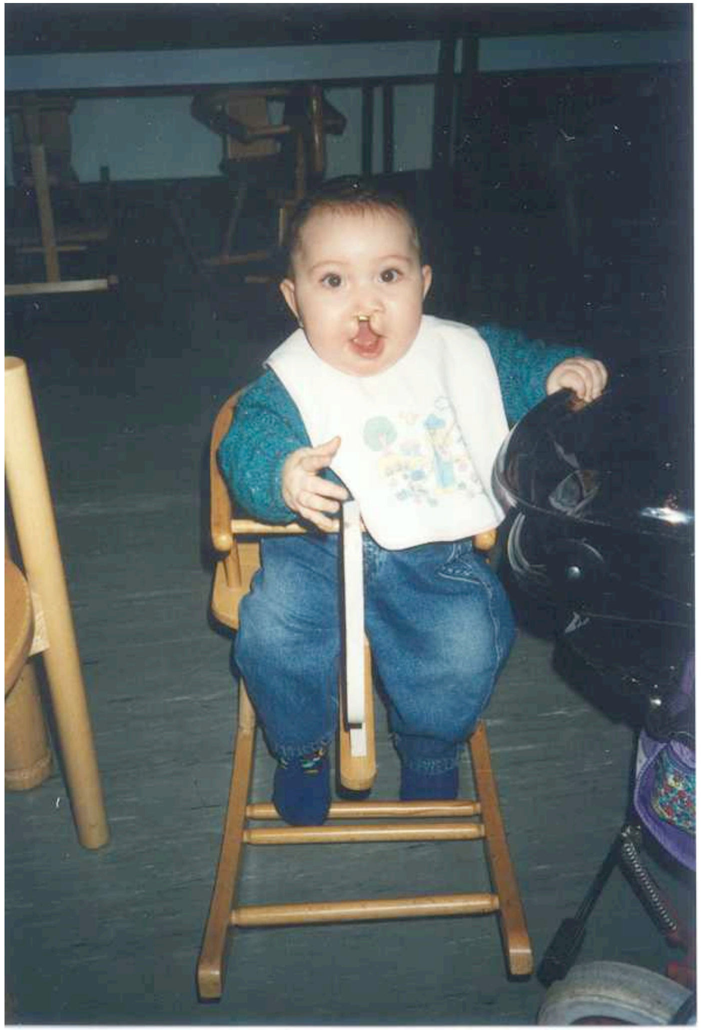
Correction for heartbeat motion using ECG (top) and just image data (bottom)

Challenges – Speech Recognition

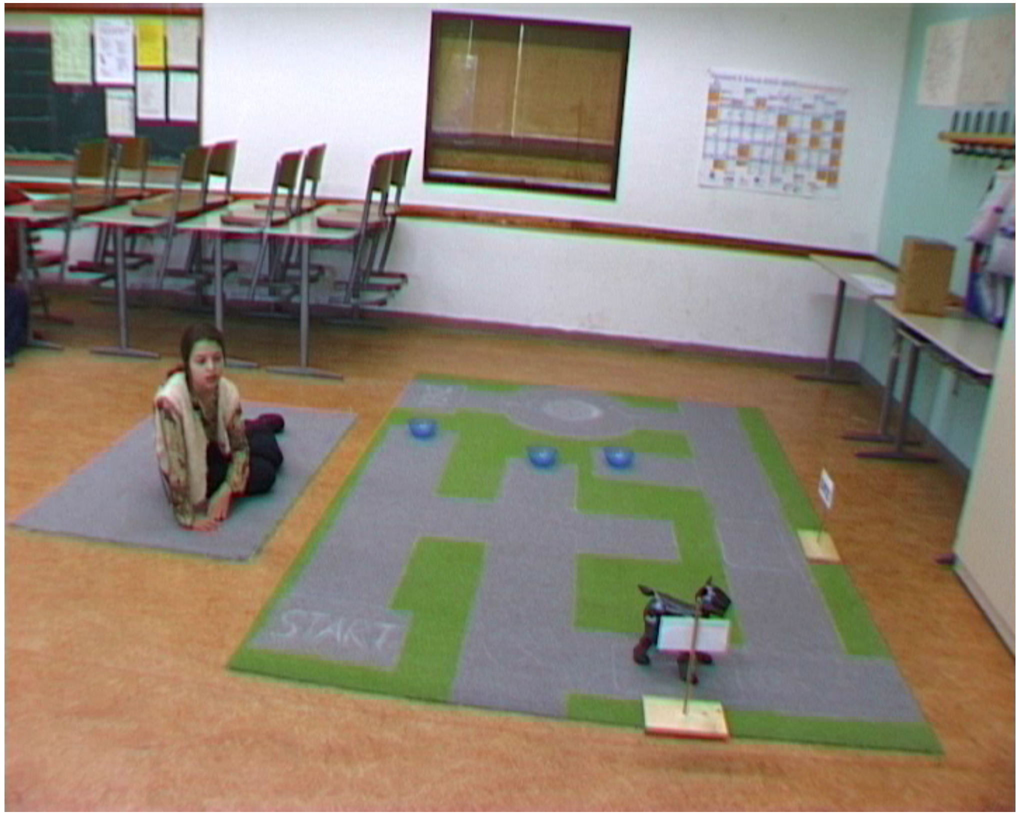
- Why is speech recognition so difficult:
  - Ambiguities (here vs. hear)
  - Emotions
  - Non-distinctive articulation
  - Accents/Dialects
  - Technical problems (microphones, encoding, …)

  Also:
  - Diseases of the oral apparatus

Cleft Palate



Spontaneous Child Speech

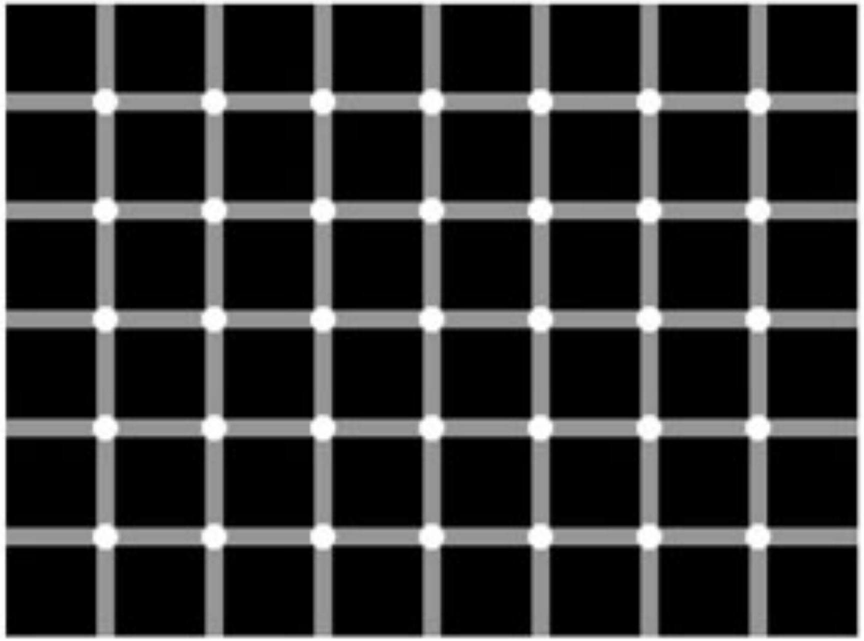


geradeaus Aibolein ja M fein M gut M machst M du M *da M | *tz läufst du mal bitte nach links | stopp E Aibo stopp | nach links E umdrehen | nein M <*ne> nein M <*ne> nein M <*ne> so M weit M *simma M noch M nicht M aufstehen M Schlafmütze M komm M hoch M | ja M so M ist M es M <*is> guter M Hund M lauf mal jetzt nach links | nach links Aibo | Aibolein M aufstehen M *son M sonst M werd' M ich M böse M hoch E | nach A links A | Aibo A nach A links A | Aibolein A ganz A böser A Hund A jetzt A stehst A du A auf A | hoch A | dreh dich ein bisschen | ja M so ist es <*is> gut stopp Aibo stopp | *tz lauf g'radeaus

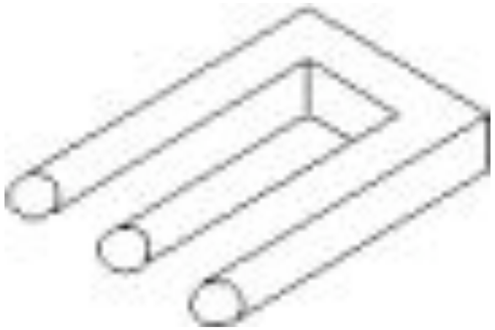
Challenges – Computer Vision

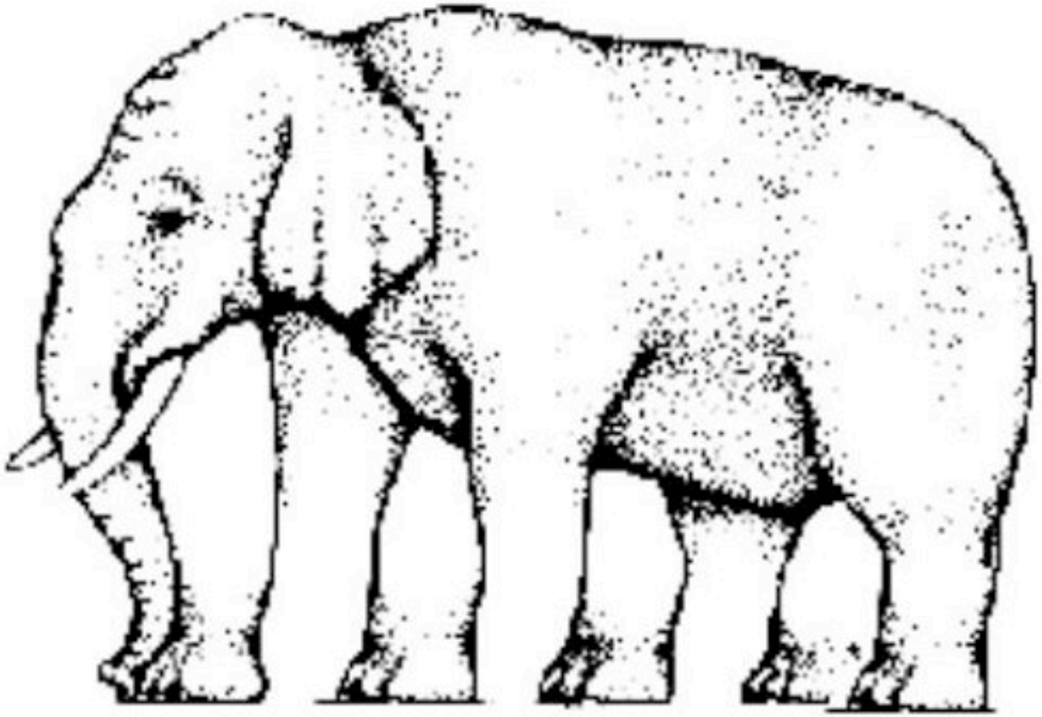
- Why is computer vision so difficult:
  - Ambiguities
  - Implicit knowledge
  - Prior information
  - Technical problems (noise, limited data, encoding...)

Influence of Entire Image



Implicit Knowledge





How many legs does this elephant have?

Is it Hopeless?

- We have a structured way of processing incoming signals (sound, light, etc.) in order to identify what is being conveyed by that signal.
- This framework (the Pattern Recognition pipeline) is general and can be applied to a variety of situations.
- There are many challenges.
- Can such a general framework be effective?

DARPA Grand Challenge

- A prize competition for driverless (autonomous) cars organized by DARPA (Defense Advanced Research Project Agency), the research oprganization of the USA Department of Defense.

- „DARPA Grand Challenge" of 2004 – Mojave Desert, CA, 240km
  - No competitor of the 21 participants finished the race
  - CMU won for completing the longest distance 11.78km

- „DARPA Grand Challenge" of 2005 – Mojave Desert, CA, 212km on a wider road with fewer curves
  - 5 out of the 23 (22%) participants finished the race
  - 22 out of the 23 participants surpassed the 11.78km distance.
  - 1st place: Stanford's „Stanley" (VW Touareg) after 6:54hrs of driving
  - 2nd place: CMU's „Sandstorm" at 7:05hrs
  - 3rd place: CMU's „Highlander" at 7:14hrs

DARPA Grand Challenge

DARPA Grand Challenge Bloopers

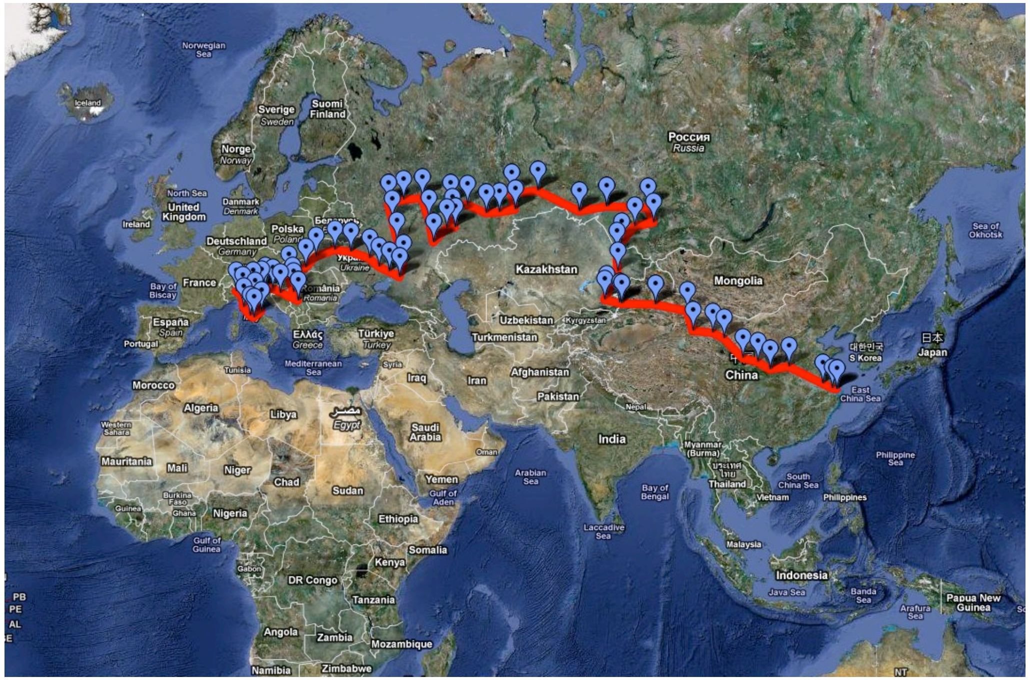
DARPA Urban Challenge Event

- Goal: Autonomous driving in an city setup
- Course:
  - 96km to be completed in less than 6hrs
  - Obey all traffic regulations
  - Handle obstacles and other cars on the road
  - Merge into traffic
- Day of Final Event: November 3, 2007
- Results:
  - 35 participants, 11 passed to the finals
  - 6 out of 11 finalists (55% of finalists, 17% of participants) completed the course
  - 1st place: CMU (Chevy Tahoe) after 4:10hrs of driving
  - 2nd place: Stanford (Volkswagen Passat) at 4:29hrs
  - 3rd place: Virginia Tech at 4:36hrs
  - Followed by MIT, UPenn and Cornell

DARPA Urban Challenge Event

VisLab Intercontinental Challenge

- Goal: Autonomous driving from Parma, Italy to Shanghai, China
- Course:
  - 13,000km of regular roads
  - Estimated travel time approx. 3 months (20. Jul 2010, 26 Oct. 2010)
  - 4 electric vehicles powered by solar energy



VisLab Intercontinental Challenge (2)

Leader-Follower Model

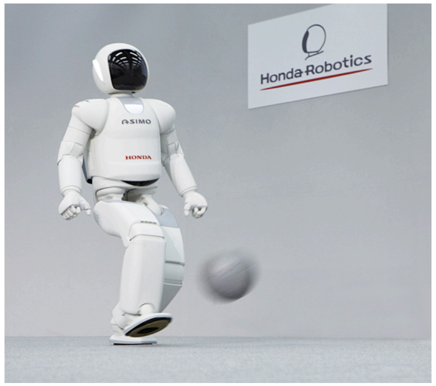
- First car drives autonomously **most** of the time. It collects a significant amount of data and performs tests on sensing, decision and control systems. Human **intervention is needed** for route selection and in critical situations.
- The 2nd car automatically follows the route defined by the preceding vehicle. It is **100% autonomous**.
- If the leader is visible, it follows it.
- If the leader is not visible, it uses the GPS coordinates that the leader has determined as part of the route.
- The follower uses local sensing to refine its position on the road, avoid obstacles and determine speed.

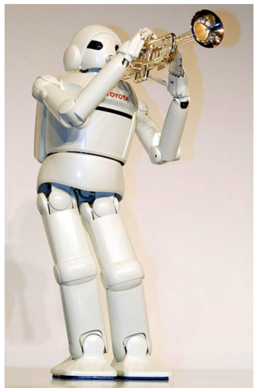
VisLab Intercontinental Challenge (3)

VisLab Intercontinental Challenge (3)

Latest DARPA Grand Challenge

- On April 2012 DARPA announced ist new Grand Challenge. It is on Humanoid Robots.
- Goal: Evaluate designs of humanoid robots that can be used on rough terrain and for industrial disasters
- Official details have not yet been announced.
- So far, there is only a test scenario for evaluating the robots.





Test of New DARPA Grand Challenge

- The humanoid robot should be able to:
  - Maneuver itself into and out of a car seat.
  - Drive a tractor-like vehicle.
  - Once out of the vehicle, unlock a locked door using a key.
  - Walk through the open door.
  - Walk down a 100m long hallway with rubble obstacles.
  - Climb a ladder at the end of the hallway.
  - Locate a leaky pipe.
  - Stop the leak by turning a nearby valve.
  - Replace a pump.

  So at the end the facility can resume normal operations.
- The robot should perform this semi-autonomously with at most tele-operation from a supervising person.