Why data-driven?

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Outline

- Background
- What is data-driven about?
- Is it really useful for computer science and technology?

The largest challenge of Today's CS

- Big Data

- Big companies are collecting data!!!
  - Google, Apple, Facebook, IBM, Microsoft, Amazon, …

  - In china, Baidu, Alibaba, Tecent, Sina

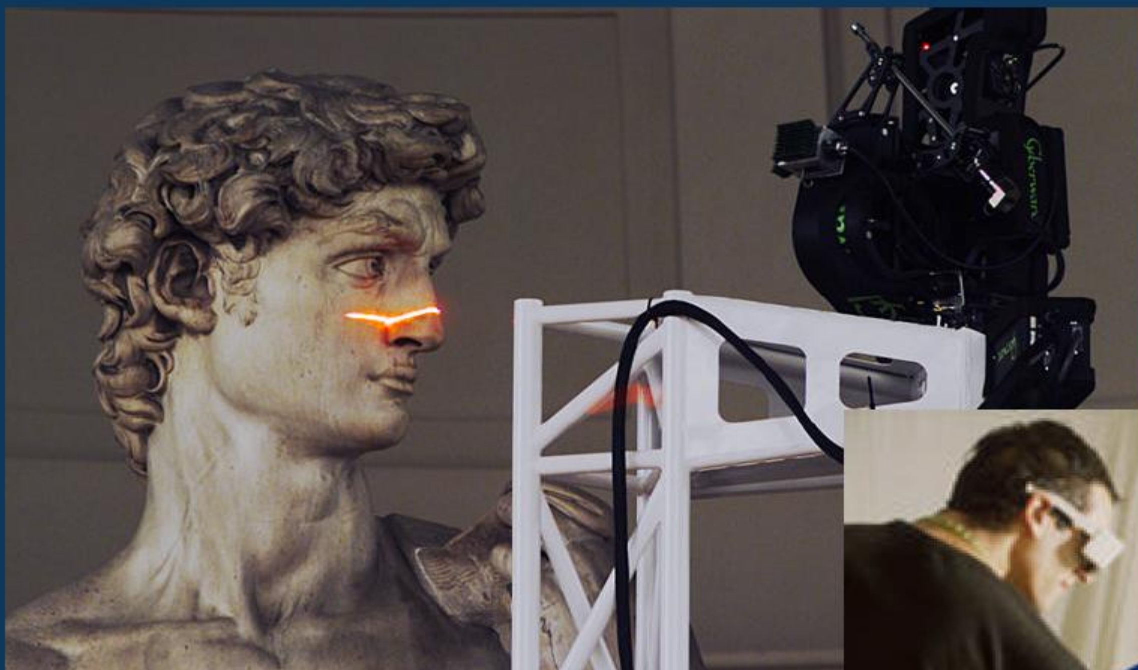
The largest challenge of Today's CS

- Data, Data, Data …
  - The tedious effort required to create digital worlds and digital life.
    - Finding new ways to communicate and new kinds of media to create.
    - Experts are expensive: scientists, engineers, filmmakers, graphic designers, fine artists, and game designers.
- Process existing data and then create new ones from them.

Computers are really fast

- If you can create it, you can render it

How do you create it?



Digital Michaelangelo Project

Steven Schkolne

Pure procedural synthesis vs. Pure data

- Creating motions for a character in a movie
  - Pure procedural synthesis.
    - compact, but very artificial, rarely used in practice.
  - “By hand” or “pure data”.
    - higher quality but lower flexibility.

  - the best of both worlds: hybrid methods?!?

Everything but Avatar

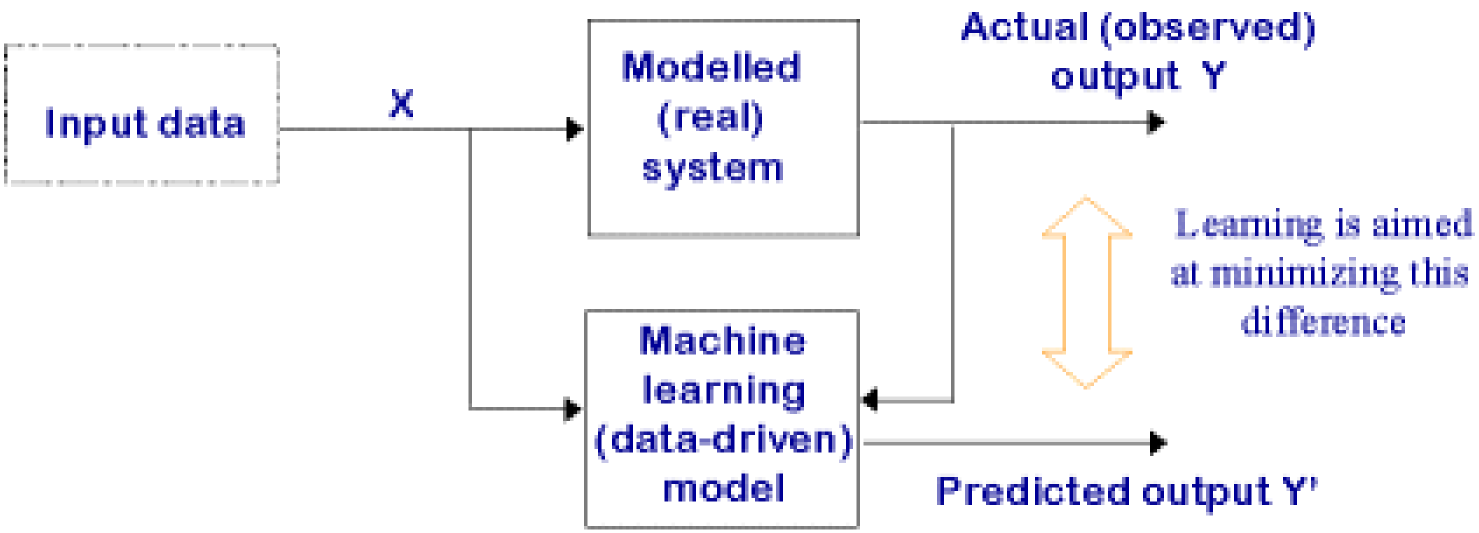
Bayesian Reasoning

- Principle modeling of uncertainty.
- General purpose models for unstructured data.
- Effective algorithm for data fitting and analysis under uncertainty.

- But currently it is always used as a black box.

Belief v.s. Probability

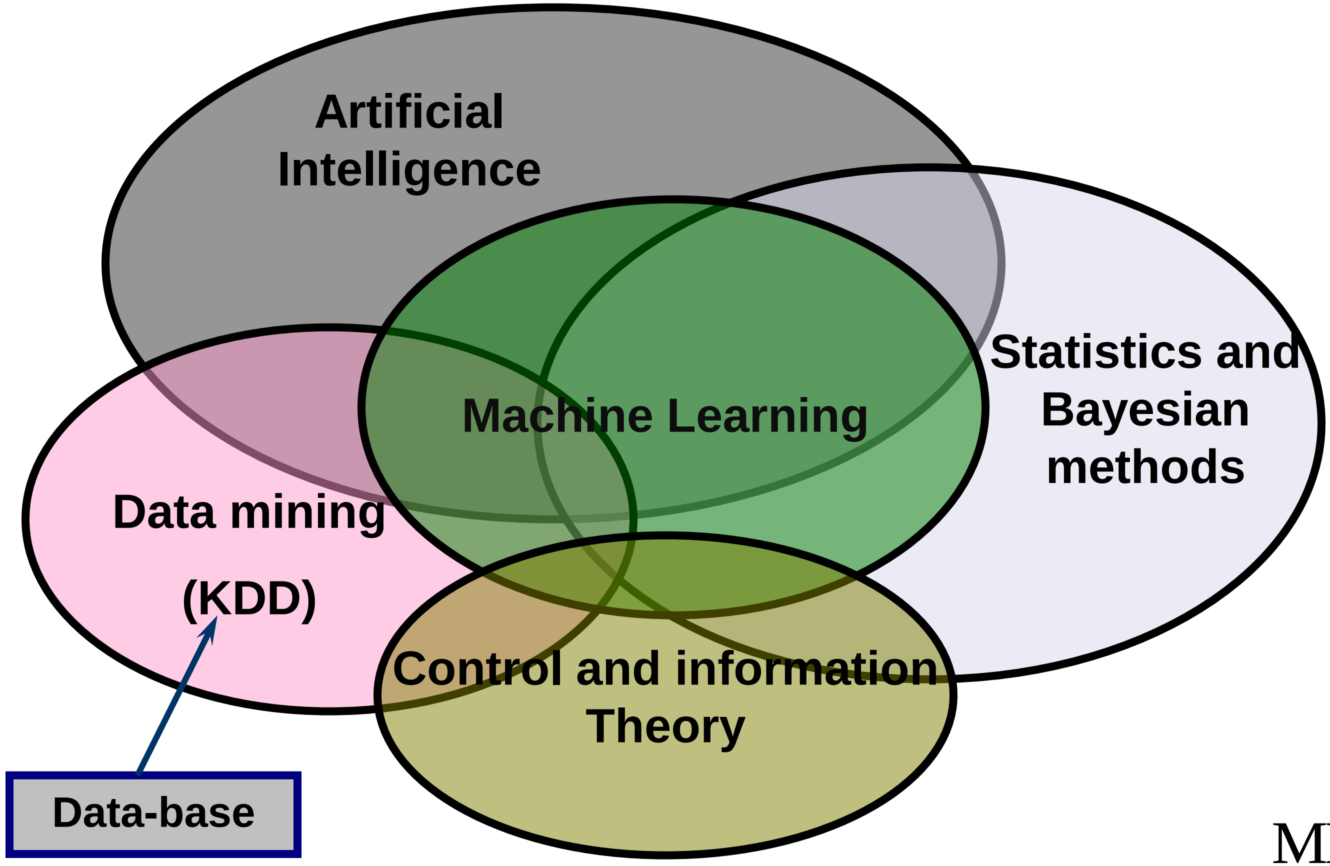
Data driven modeling



Data-driven vocabulary

- Data
  - data-driven, data mining
- Learning
  - machine learning, statistical learning
- Uncertainty
  - probability, likelihood
- Intelligent
  - Inference, decision, detection, recognition

Data-driven related techniques



ML $\neq$ AI

Computer Vision | Multi-media | Bio-informatics | Computer Graphics | Information retrieval

Data-driven system

- Learning systems are not directly programmed to solve a problem, instead develop own program based on:
  - examples of how they should behave
  - from trial-and-error experience trying to solve the problem

Different from standard CS: want to implement unknown function, only have access to sample input-output pairs (training examples)

Main categories of learning problems

Learning scenarios differ according to the available information in training examples

- **Supervised**: correct output available
  - **Classification**: 1-of-N output (speech recognition, object recognition,medical diagnosis)
  - **Regression**: real-valued output (predicting market prices, temperature)
- **Unsupervised**: no feedback, need to construct measure of good output
  - **Clustering** : Clustering refers to techniques to segmenting data into coherent “clusters.”
  - **Novelty-detection**: detecting new data points that deviate from the normal.
- **Reinforcement**: scalar feedback, possibly temporally delayed

Main class of learning problems

Learning scenarios differ according to the available information in training examples

- **Supervised**: correct output available
  - …
- **Semi-Supervised**: only a part of output available
  - **Ranking**:
- **Unsupervised**: no feedback, need to construct measure of good output
  - …
- *Reinforcement*: scalar feedback, possibly temporally delayed

And more …

- Time series analysis.
- Dimension reduction.
- Model selection.
- Generic methods.
- Graphical models.

Why data driven methods?

- **Develop enhanced computer systems**
  - automatically adapt to user, customize
  - often difficult to acquire necessary knowledge
  - discover patterns offline in large databases (*data mining*)
- **Improve understanding of human, biological learning**
  - computational analysis provides concrete theory, predictions
  - explosion of methods to analyze brain activity during learning
- **Timing is good**
  - growing amounts of data available
  - cheap and powerful computers
  - suite of algorithms, theory already developed

Is it really useful for computer science and technology?

- Con: Everything is machine learning or everything is human tuning?
  - Sometimes, this may be true.

- Pro: more understanding of learning, but yields much more powerful and effective algorithms.
  - Problem taxonomy.
  - General-purpose models.
  - Reasoning with probabilities.

❖ I believe the mathematic magic.

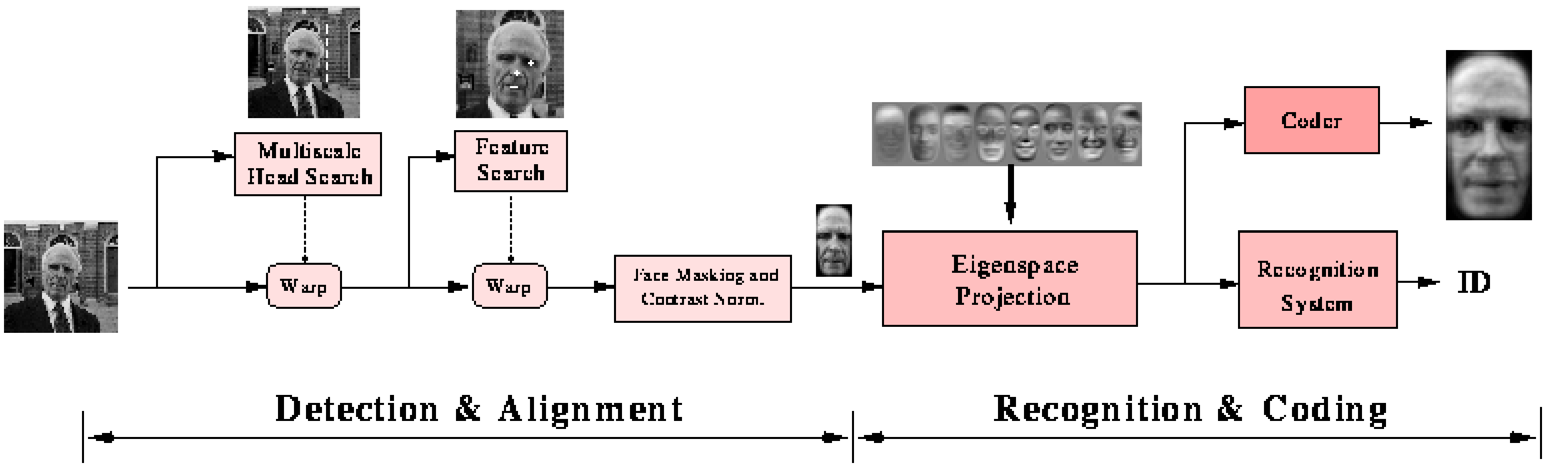
What will be a successful D-D algorithm?

- Computational efficiency
- Robustness
- Statistical stability

The First Example: Google!

- 每天过滤200亿个网页
- 每天追踪300亿个的独立URL
- 每月接受1000亿次搜索请求

Object detection and recognition - the power of DD



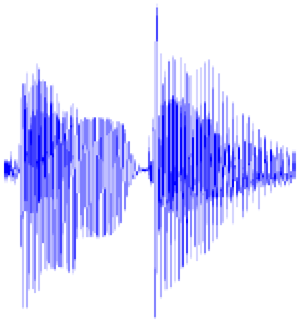
The image is copied from
http://vismod.media.mit.edu/vismod/demos/facerec/

Object detection and recognition

Face [Vaillant et al IEE 1994] [Garcia et al PAMI 2005] [Osadchy et al JMLR 2007]
Pedestrian: [Kavukcuoglu et al. NIPS 2010] [Sermanet et al. CVPR 2013]

Speech recognition

- Modern architecture for pattern recognition
  - Speech recognition: early 90's – 2011



MFCC → Mix of Gaussians → Classifier →

fixed | unsupervised | supervised

  - Object Recognition: 2006 - 2012

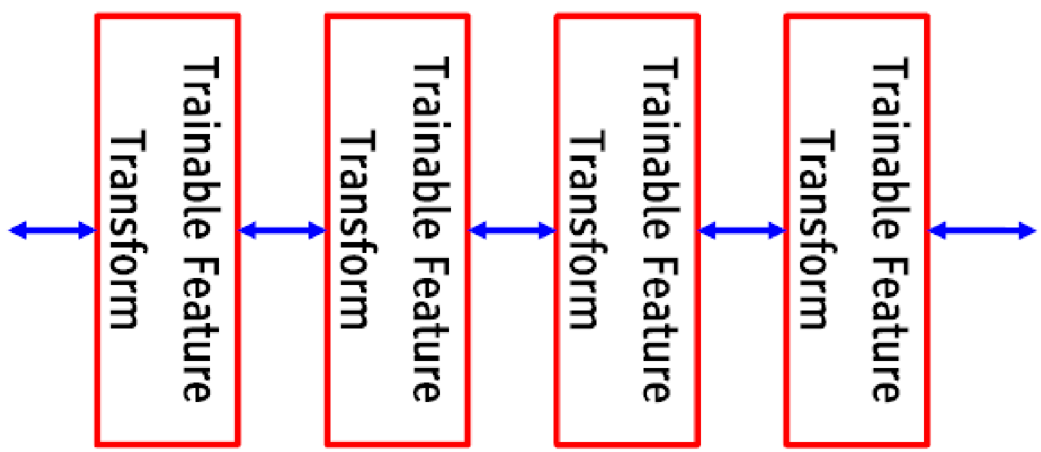
SIFT HoG → K-means Sparse Coding → Pooling → Classifier →

fixed | unsupervised | supervised

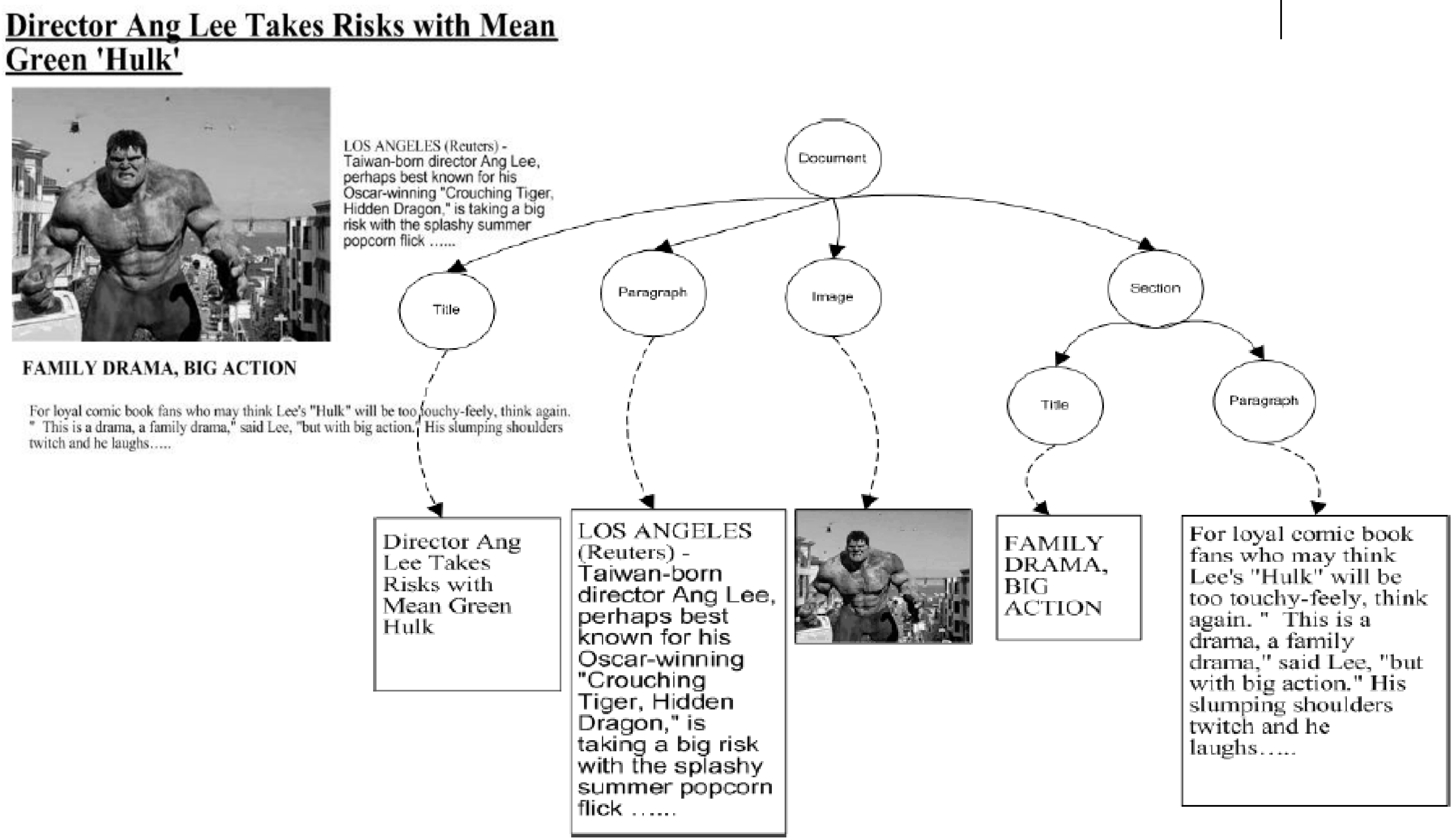
Low-level Features | Mid-level Features

Speech recognition

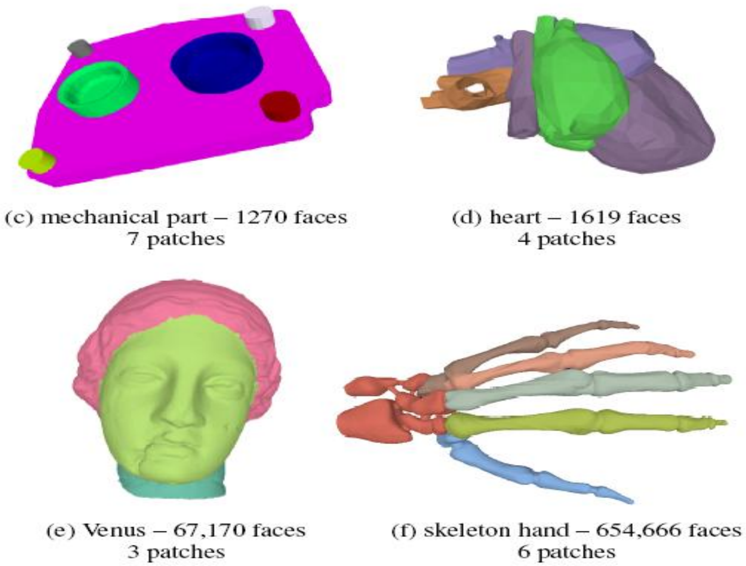
- Hierarchy of representations with increasing level of abstraction
- Each stage is a kind of trainable feature transform
- Image recognition
  - Pixel → edge → texton → motif → part → object
- Text
  - Character → word → word group → clause → sentence → story
- Speech
  - Sample → spectral band → sound → … → phone → phoneme → word →

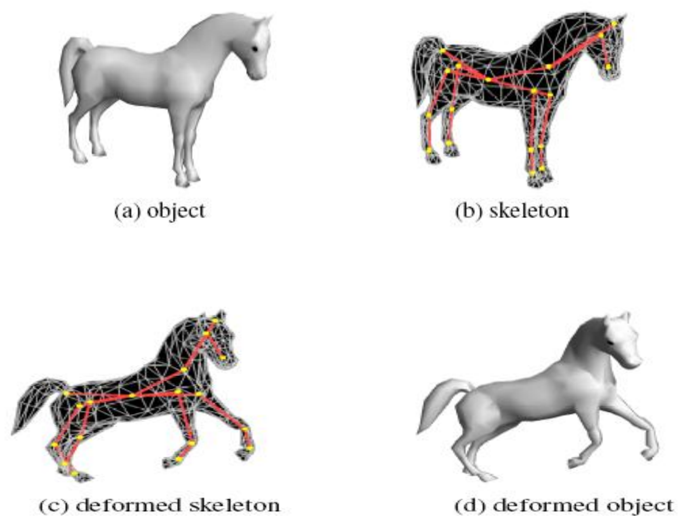


Document processing – Bayesian classification



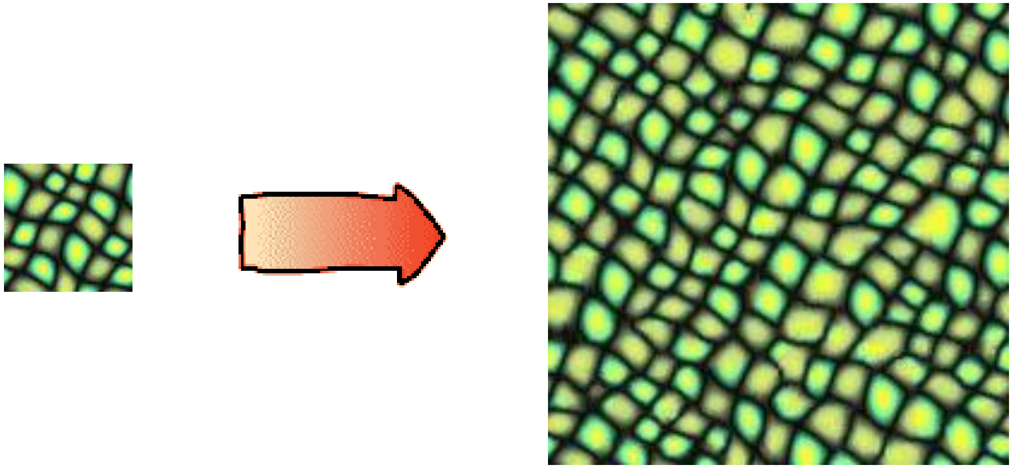
Mesh Processing –
Data clustering/segmentation





- *Hierarchical Mesh Decomposition using Fuzzy Clustering and Cuts.* By Sagi Katz and Ayellet Tal, SIGGRAPH 2003

Texture synthesis and analysis – Hidden Markov Model

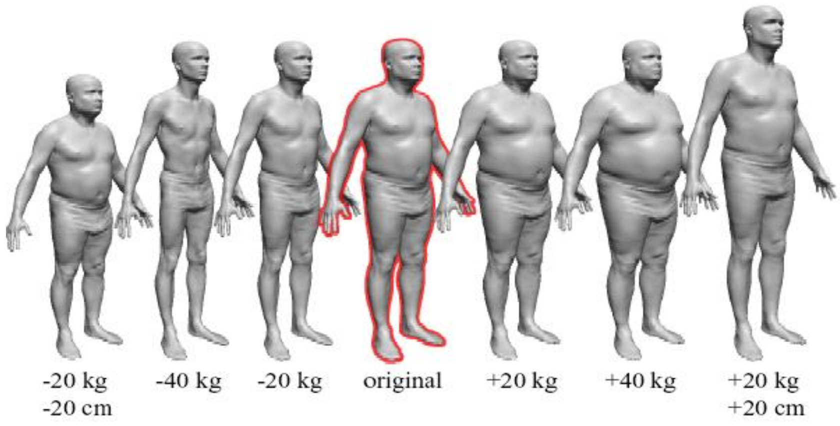


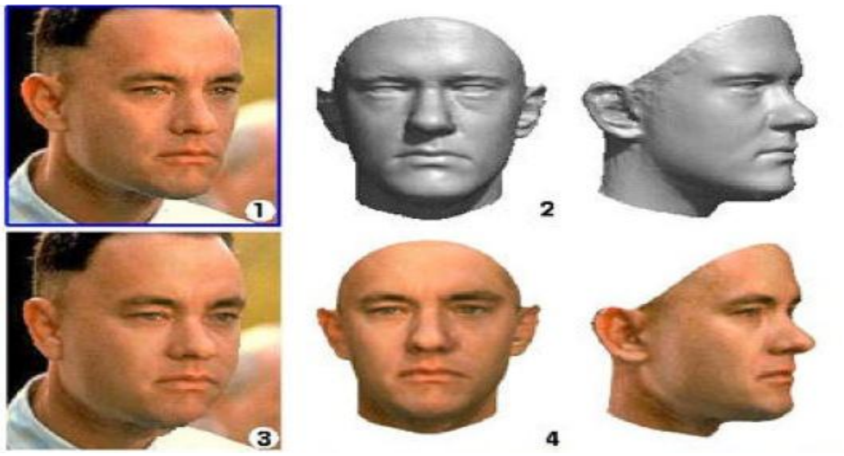
- *Texture Synthesis over Arbitrary Manifold Surfaces.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2001.
- *Fast Texture Synthesis using Tree-structured Vector Quantization.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2000.

Reflectance texture synthesis – Dimension reduction

- *Synthesizing Bidirectional Texture Functions for Real-World Surfaces.* Xinguo Liu, Yizhou Yu and Heung-Yeung Shum. SIGGRAPH 2001.
- More recent papers…

Human shapes - Dimension reduction

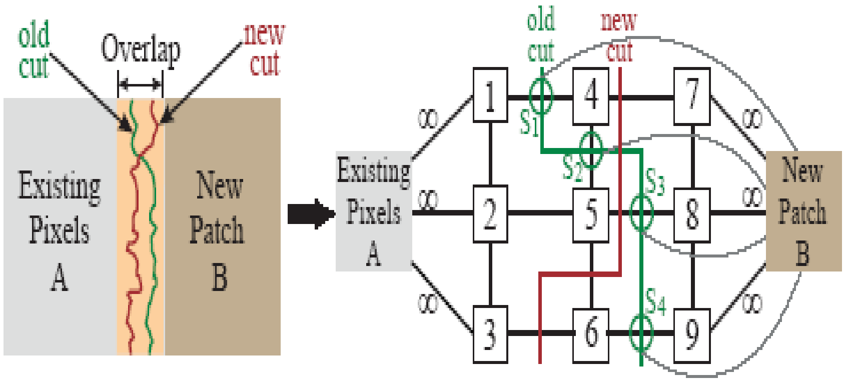


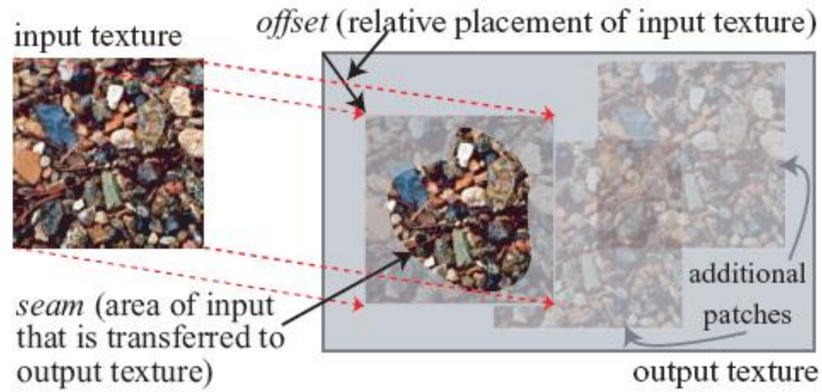


- *The Space of Human Body Shapes: Reconstruction and Parameterization From Range Scans.* Brett Allen, Brian Curless, Zoran Popovic. SIGGRAPH 2003.

- *A Morphable Model for the Synthesis of 3D Faces.* Volker Blanz and Thomas Vetter. SIGGRAPH 1999.

Image processing and synthesis - Graphical model

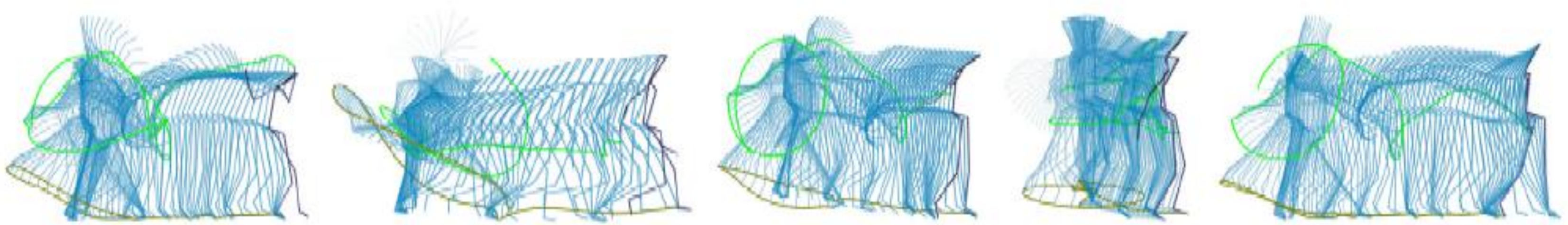




- *Image Quilting for Texture Synthesis and Transfer*. Alexei A. Efros and William T. Freeman. SIGGRAPH 2001.

- *Graphcut Textures: Image and Video Synthesis Using Graph Cuts*. V Kwatra, I. Essa, A. Schödl, G. Turk, and A. Bobick. SIGGRAPH 2003.

Human Motion - Time series analysis



A pirouette and promenade in five synthetic styles drawn from a space that contains ballet, modern dance, and different body types. The choreography is also synthetic. Streamers show the trajectory of the left hand and foot.

- *Style Machines.* M. Brand and A. Hertzmann. SIGGRAPH 2000.
- *A Data-Driven Approach to Quantifying Natural Human Motion*. L. Ren, A. Patrick, A. Efros, J. Hodgins, J. Rehg. SIGGRAPH 2005

Video Textures - Reinforcement Learning

- *Video textures*. Arno Schödl, Richard Szeliski, David H. Salesin, and Irfan Essa. *SIGGRAPH 2000*.

Summary

- Learning (from Data) is a nut-shell, :-D
  - Keywords
    - Noun: data, models, patterns, features;
    - Adj.: probabilistic, statistical;
    - Verb: fitting, reasoning, mining.

Homework

- Try to find potential learning based (data driven) applications in your research area

Reference

- Reinforcement learning: A survey

The End

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