What is machine learning?

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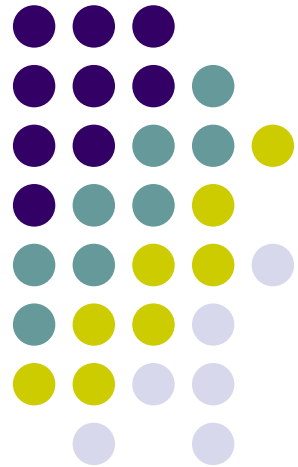
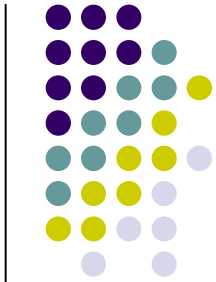


Outline

- Background
- What is Machine Learning?
- Is it really useful for computer science and technology?

The largest challenge of Today's CS

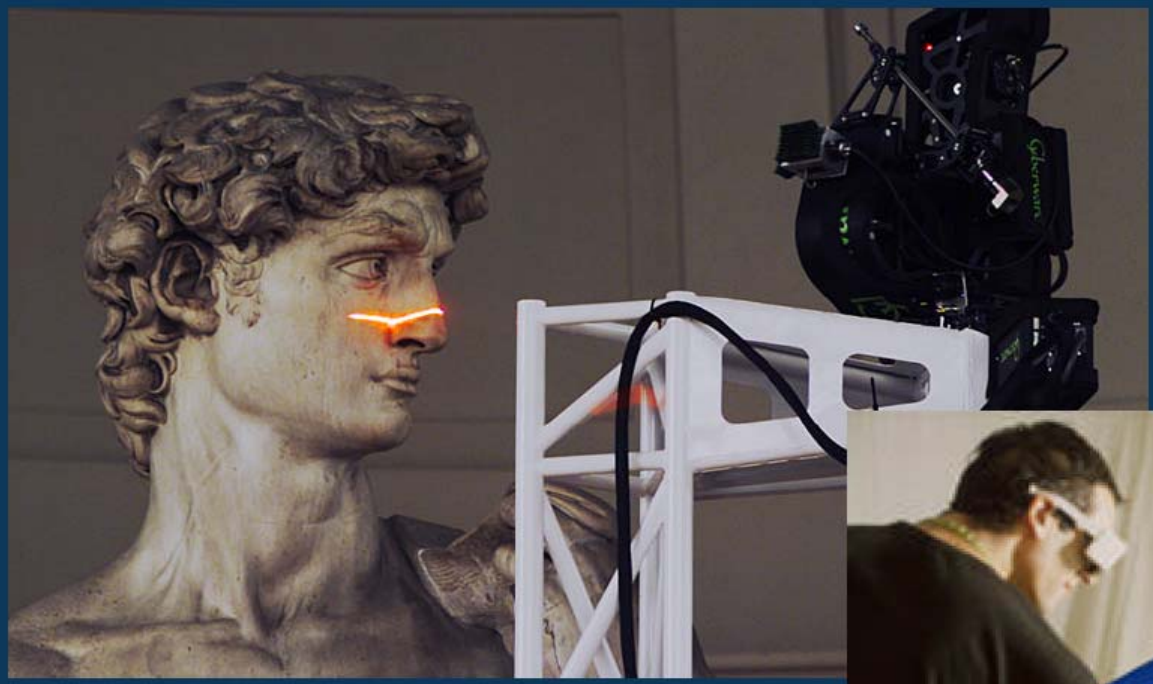


- Data, Data, Data…
  - The tedious effort required to create digital worlds and digital life.
    - Finding new ways to communicate and new kinds of media to create.
    - Experts are expensive: scientists, engineers, filmmakers, graphic designers, fine artists, and game designers.
- Process existing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

Computers are really fast

- If you can create it, you can render it

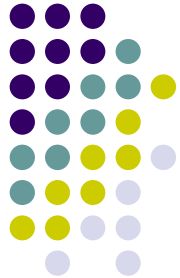
How do you create it?



Digital Michaelangelo Project

Steven Schkolne

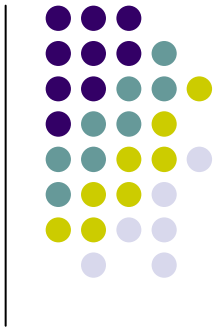
Pure procedural synthesis vs. Pure data



- 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?!?

Bayesian Reasoning

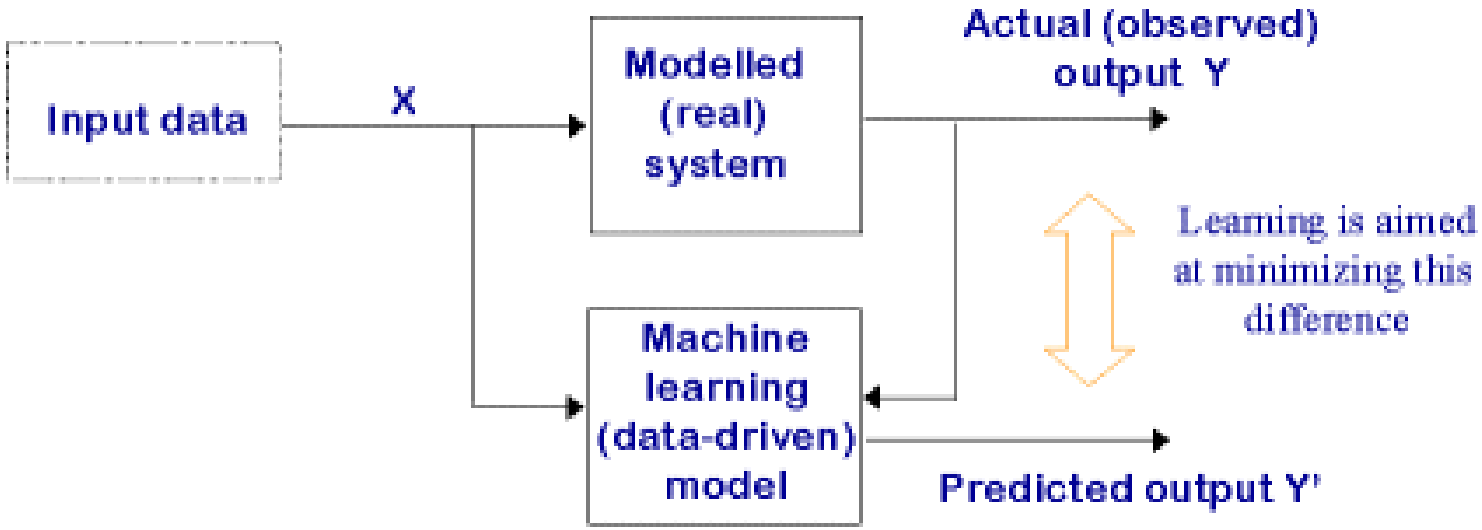


- Principle modeling of uncertainty.
- General purpose models for unstructured data.
- Effective algorithm for data fitting and analysis under uncertainty.

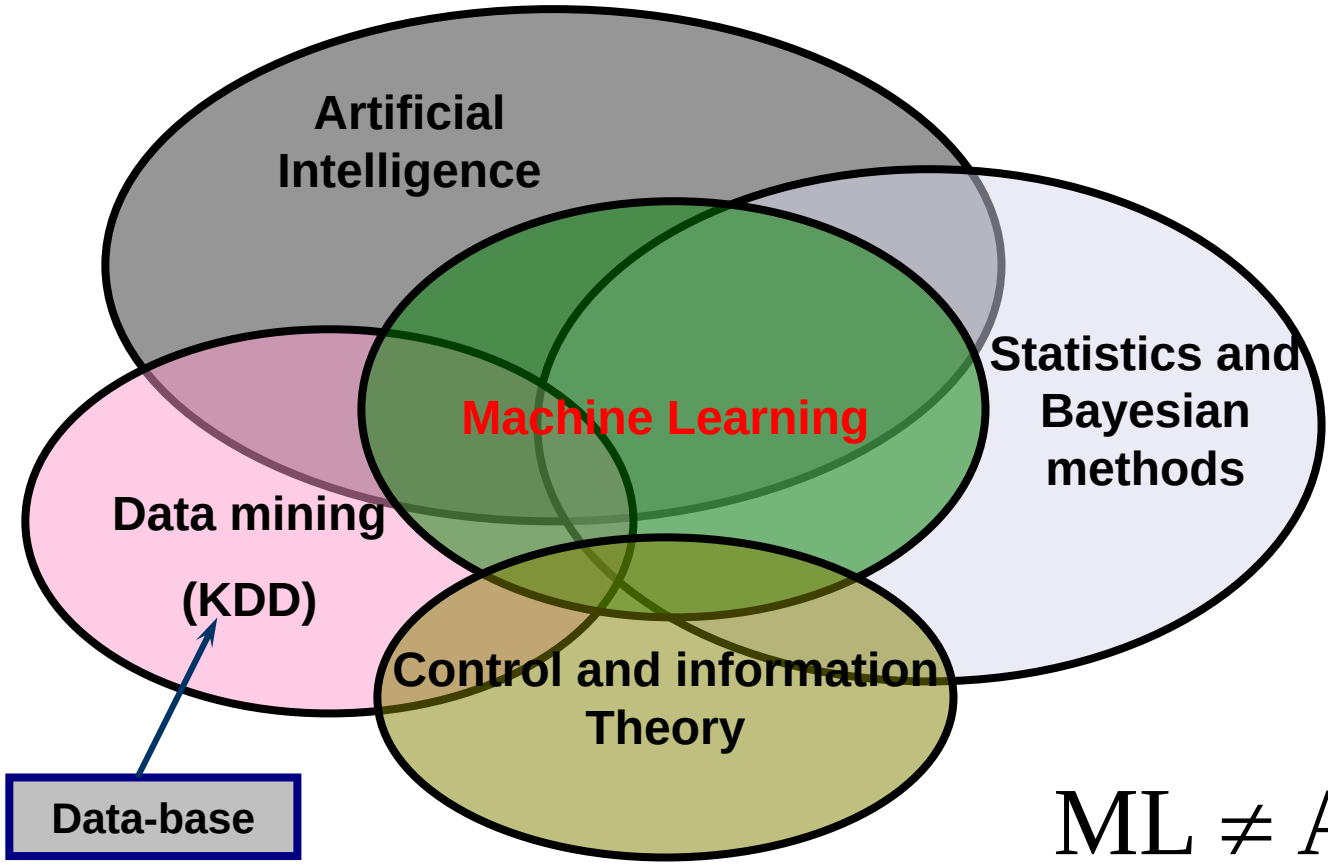
- But currently it is always used as a black box.

Belief v.s. Probability

Data driven modeling



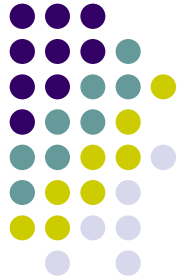
What is machine learning?



$ML \neq AI$

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

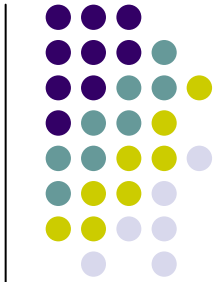
What is machine learning? (Cont.)



- Definition by Mitchell, 1997
  - *A program learns from experience E with respect to some class of tasks T and performance measure P, if its performance at task T, as measured by P, improves with experience E.*
  - 机器学习乃于某类任务兼性能度量的经验中学习之程序；若其作用于任务，可由度量知其于已知经验中获益。

- Comments from Hertzmann, 2003
  - For the purposes of computer graphics, machine learning should really be viewed as a set of techniques for leveraging data. Given some data, we can model the process that generated the data.

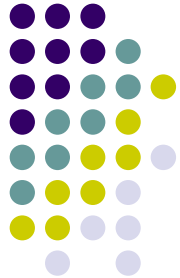
What is machine learning? (Cont.)



- 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

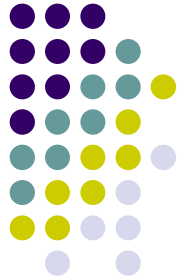
And more …

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

Why Study Machine Learning?

- **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

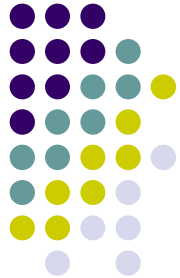
Growth of Machine Learning



- **Machine learning is preferred approach to**
  - Speech recognition, Natural language processing
  - Computer vision
  - Medical outcomes analysis
  - Robot control
  - …

- **This trend is accelerating**
  - Improved machine learning algorithms
  - Improved data capture, networking, faster computers
  - Software too complex to write by hand
  - New sensors I / O devices
  - Demand for self-customization to user, environment

Is it really useful for computer science and technology?

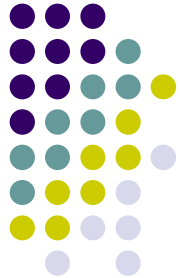


- Con: Everything is machine learning or everything is human tuning?
  - Sometimes, this may be true.

- 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.

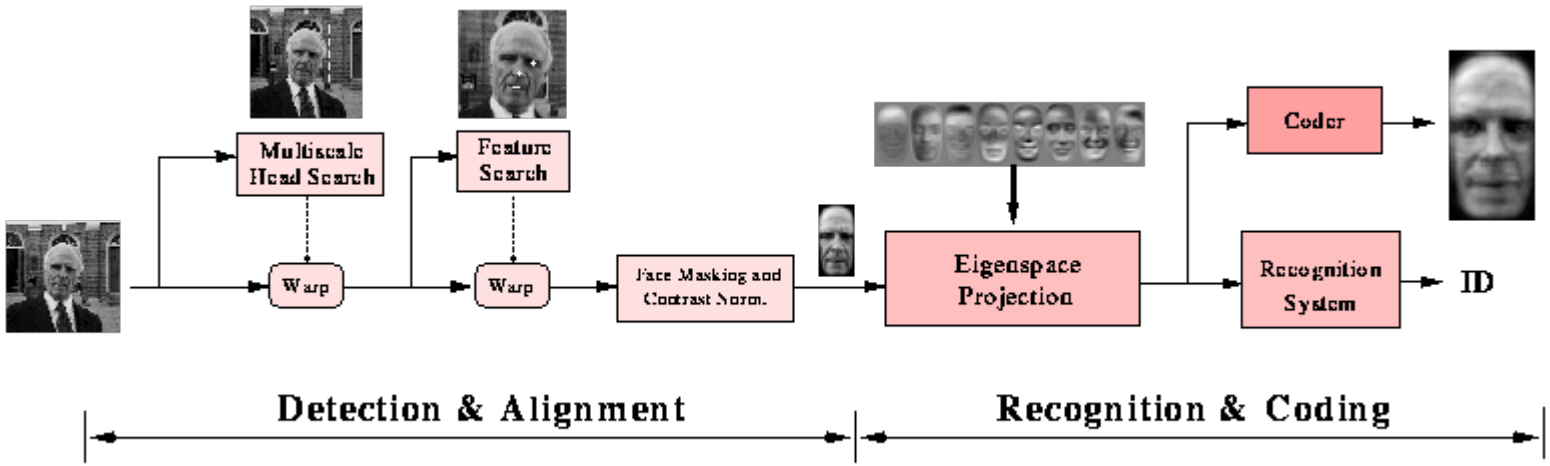
What will be a successful ML algorithm?



- Computational efficiency
- Robustness
- Statistical stability

The First Example: Google!

Object detection and recognition - the power of learning



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

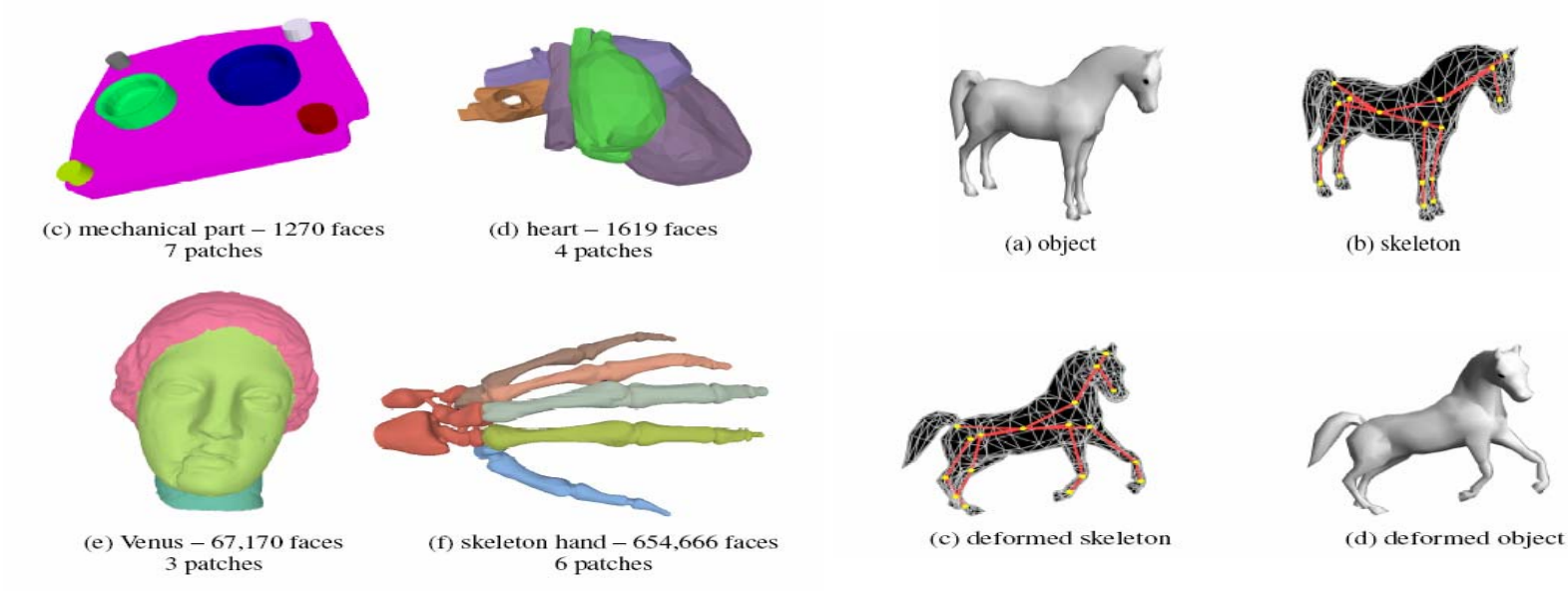
Object Detection

(Prof. H. Schneiderman)

Example training images
for each orientation

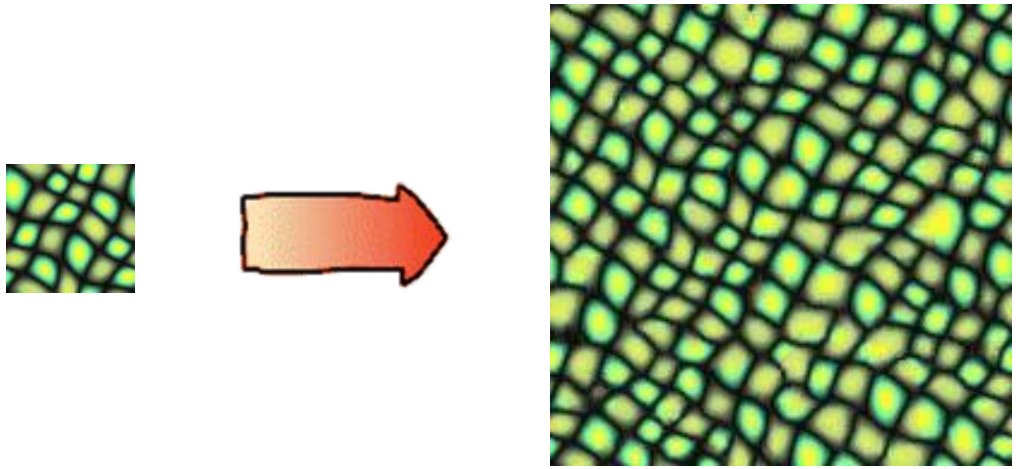
Document processing – Bayesian classification

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



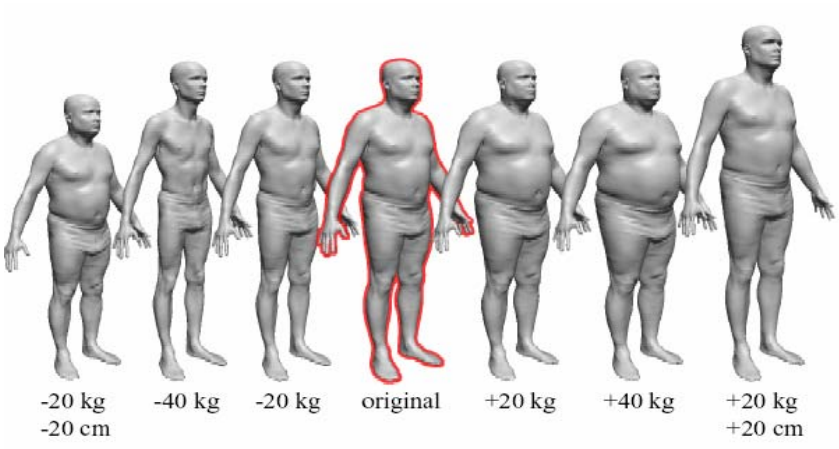
- *Texture Synthesis over Arbitrary Manifold Surfaces.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2001.

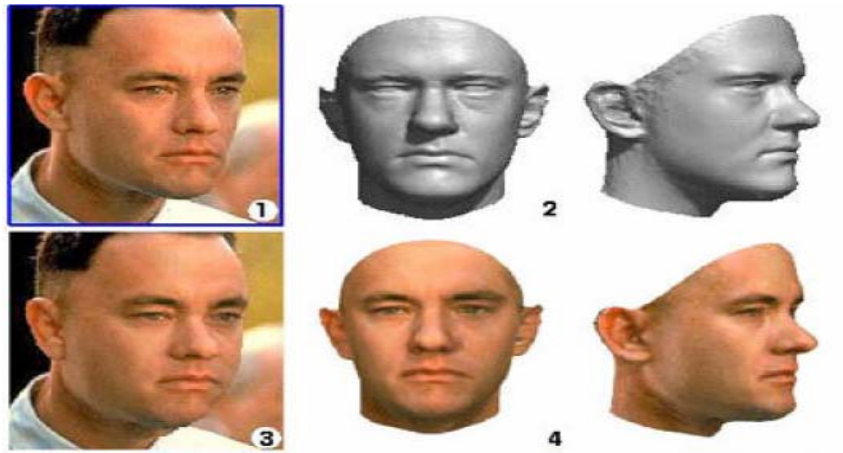
- *Fast Texture Synthesis using Tree-structured Vector Quantization.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2000.

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

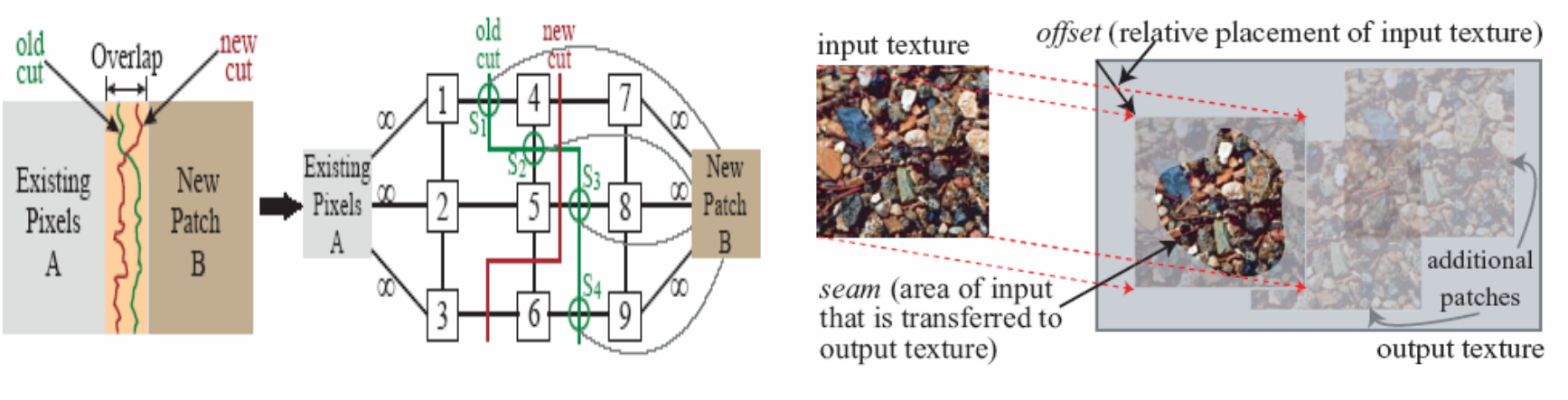




- *The Space of Human Body Shapes: Reconstruction and Parameterization From Range Scans.* Brett Allen, Brian Curless, Zoran Popovic. SIGGRAPH 2003.

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

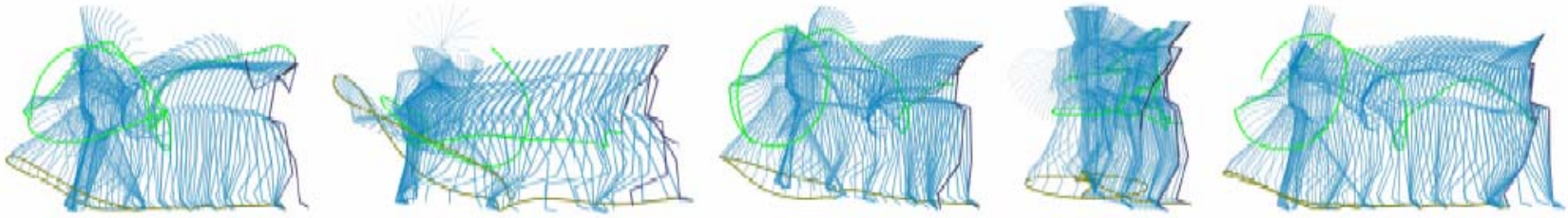
Image processing and synthesis - Graphical model



- *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.

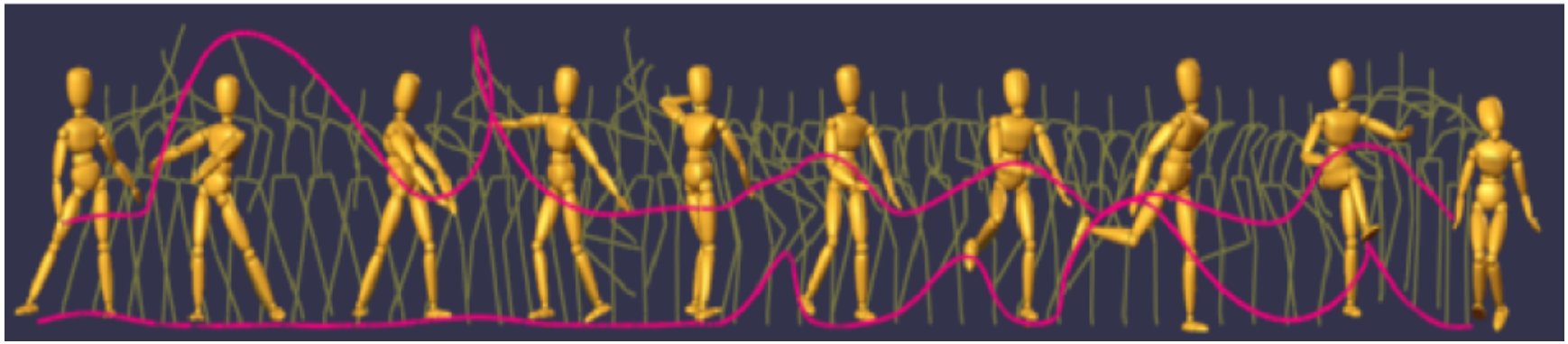
- *Style Machines.* M. Brand and A. Hertzmann. SIGGRAPH 2000.

- *A Data-Driven Approach to Quantifying Natural Human Motion*. L. Ren, A. Patrick, A. Efros, J. Hodgins, J. Rehg. SIGGRAPH 2005

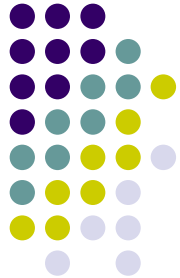
Video Textures - Reinforcement Learning

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

Motion texture - Linear dynamic system



- *Motion Texture: A Two-Level Statistical Model for Character Motion Synthesis.* Yan Li, Tianshu Wang, and Heung-Yeung Shum. SIGGRAPH 2002.



Summary

- Machine learning 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 applications in your research directions

Reference

- Reinforcement learning: A survey.