

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



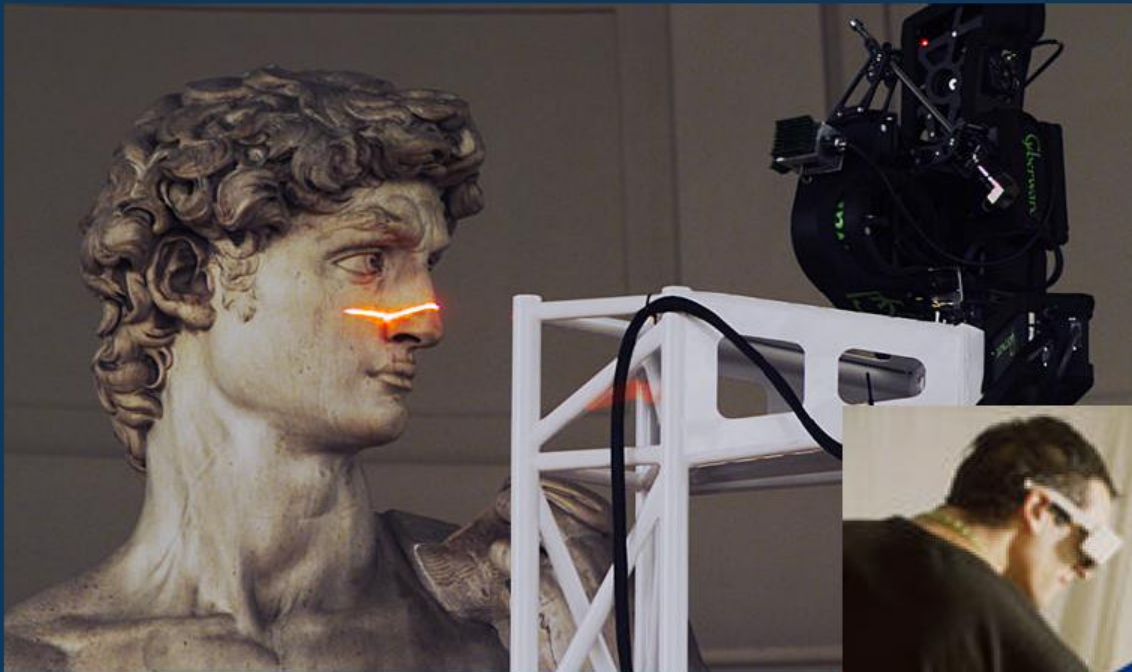
- Data, Data, Data...
 - The tedious effort required to create digital worlds and digital life.
 - Finding new ways to communicate and new kinds of media to create.
 - Experts are expensive: scientists, engineers, filmmakers, graphic designers, fine artists, and game designers.
- Process existing data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



Steven Schkolne

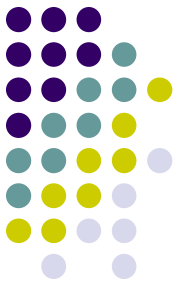
Pure procedural synthesis vs. Pure data



- 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



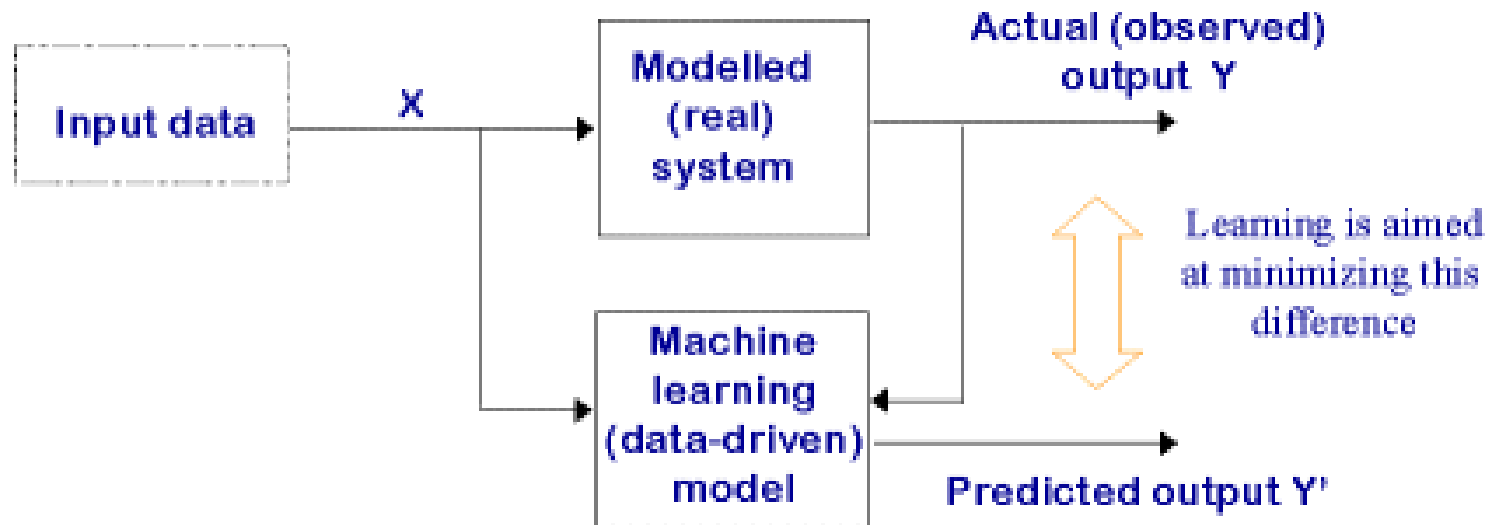
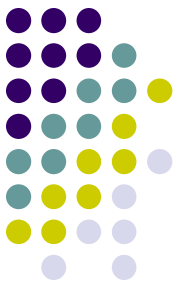


Bayesian Reasoning

- ❖ 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.

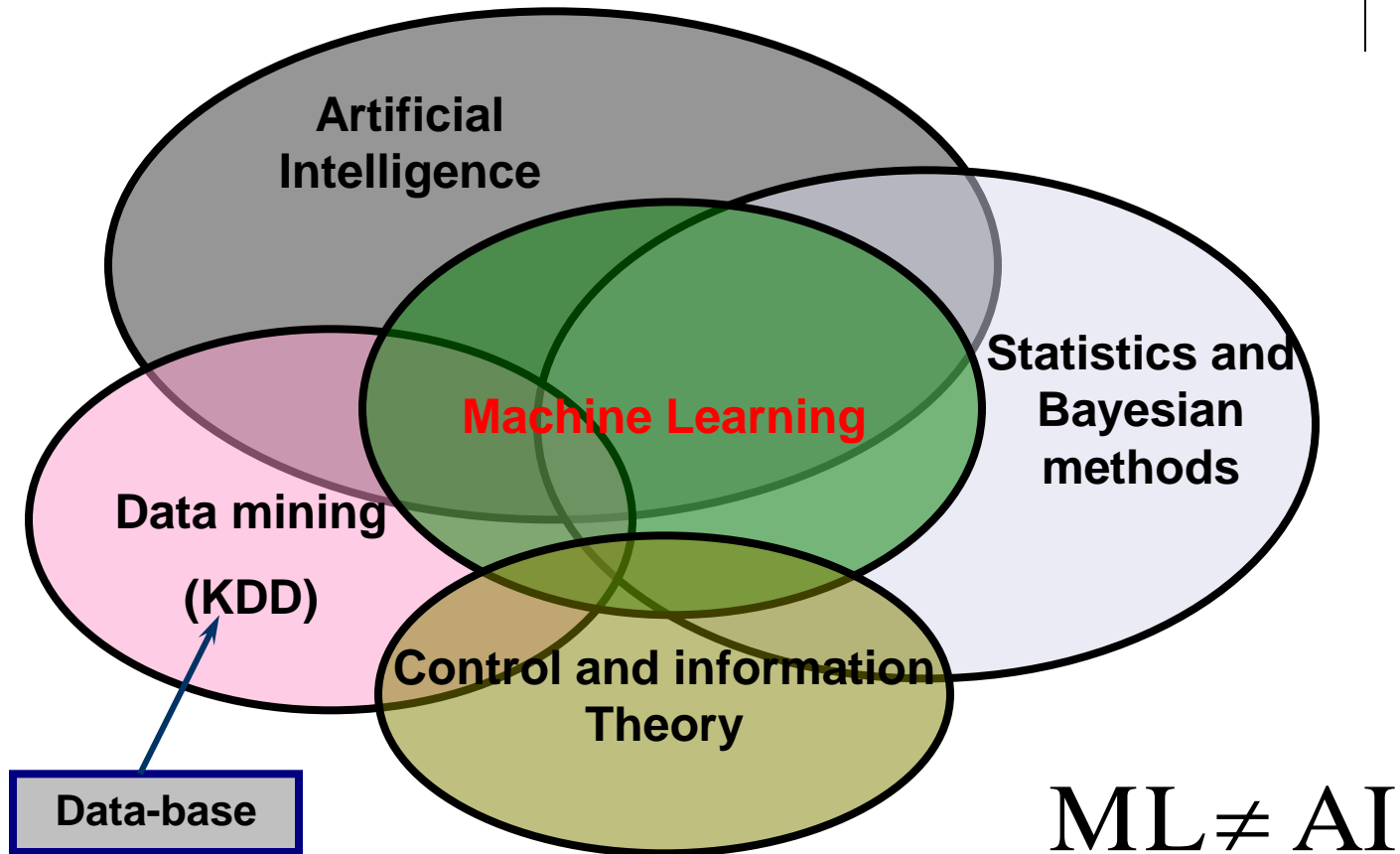
Belief v.s. Probability

Data driven modeling



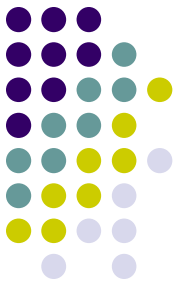


What is machine learning?



- | | | | | |
|-----------------|-------------|-----------------|-------------------|-----------------------|
| 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

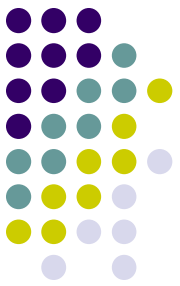
Different from standard CS: want to implement unknown function, only have access to sample input-output pairs (training examples)

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



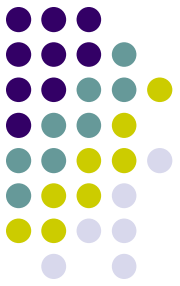
Main class of learning problems

Learning scenarios differ according to the available information in training examples

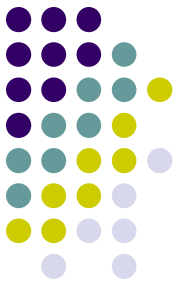
- **Supervised**: correct output available
 - ...
- **Semi-Supervised**: only a part of output available
 - **Ranking**:
- **Unsupervised**: no feedback, need to construct measure of good output
 - ...
- *Reinforcement*: scalar feedback, possibly temporally delayed

And more ...

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

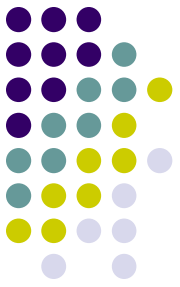


Why Study Machine Learning?



- **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

Is it really useful for computer science and technology?



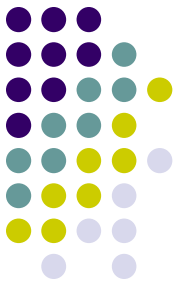
- Con: Everything is machine learning or everything is human tuning?
 - Sometimes, this may be true.
- Pro: more understanding of learning, but yields much more powerful and effective algorithms.
 - Problem taxonomy.
 - General-purpose models.
 - Reasoning with probabilities.
- ❖ I believe the mathematic magic.

What will be a successful ML algorithm?



- Computational efficiency
- Robustness
- Statistical stability

The First Example: Google!



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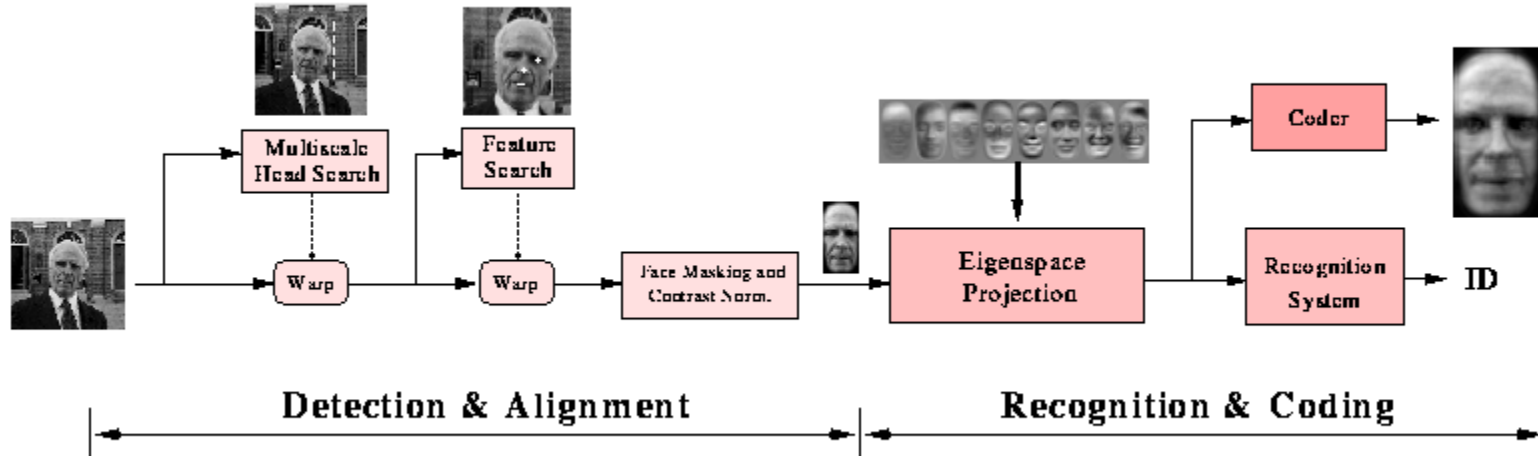
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Object detection and recognition - the power of learning



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



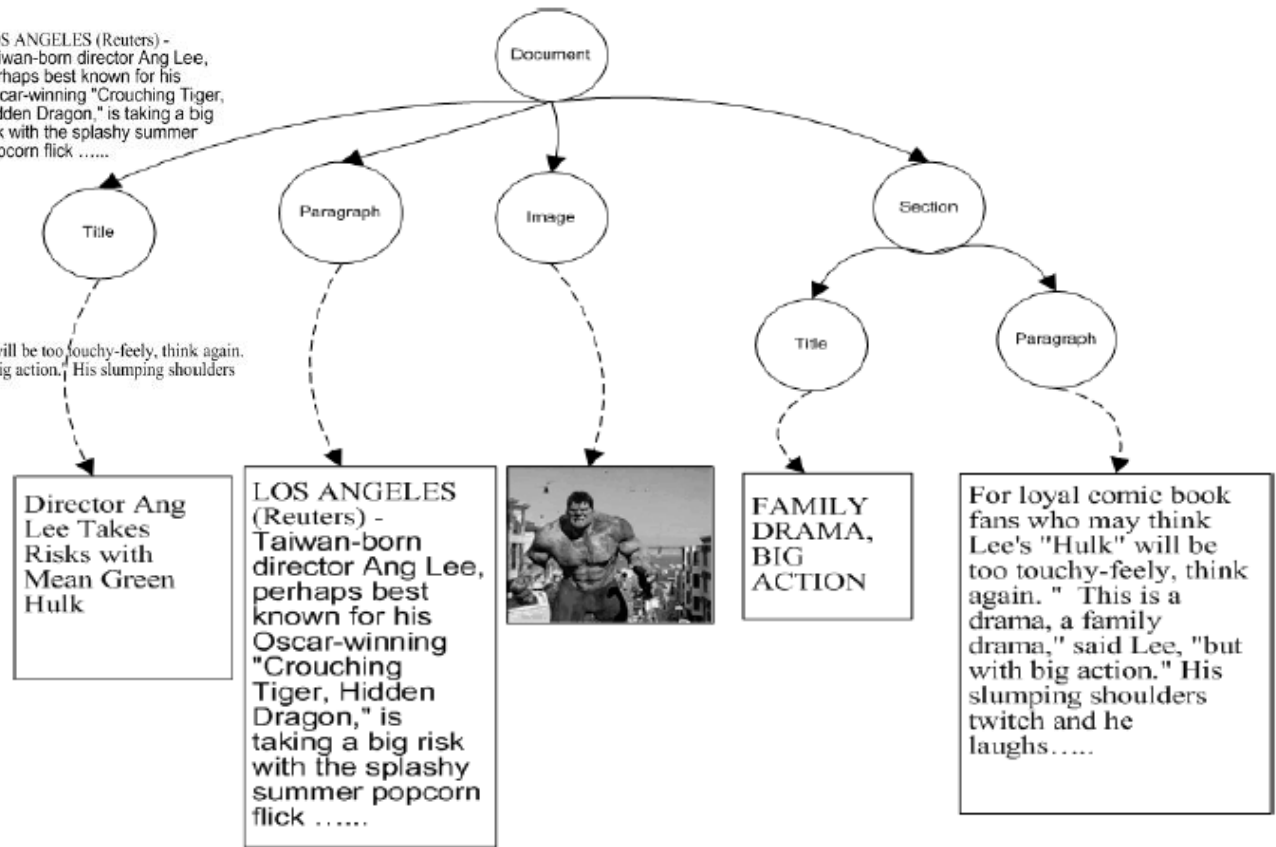
Director Ang Lee Takes Risks with Mean Green 'Hulk'



LOS ANGELES (Reuters) - Taiwan-born director Ang Lee, perhaps best known for his Oscar-winning "Crouching Tiger, Hidden Dragon," is taking a big risk with the splashy summer popcorn flick

FAMILY DRAMA, BIG ACTION

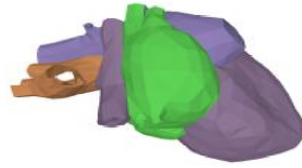
For loyal comic book fans who may think Lee's "Hulk" will be too touchy-feely, think again. " This is a drama, a family drama," said Lee, "but with big action." His slumping shoulders twitch and he laughs.....



Mesh Processing – Data clustering/segmentation



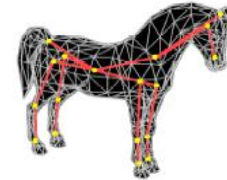
(c) mechanical part – 1270 faces
7 patches



(d) heart – 1619 faces
4 patches



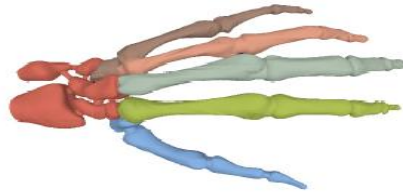
(a) object



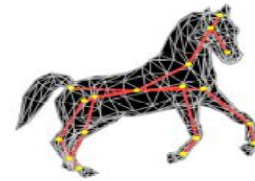
(b) skeleton



(e) Venus – 67,170 faces
3 patches



(f) skeleton hand – 654,666 faces
6 patches



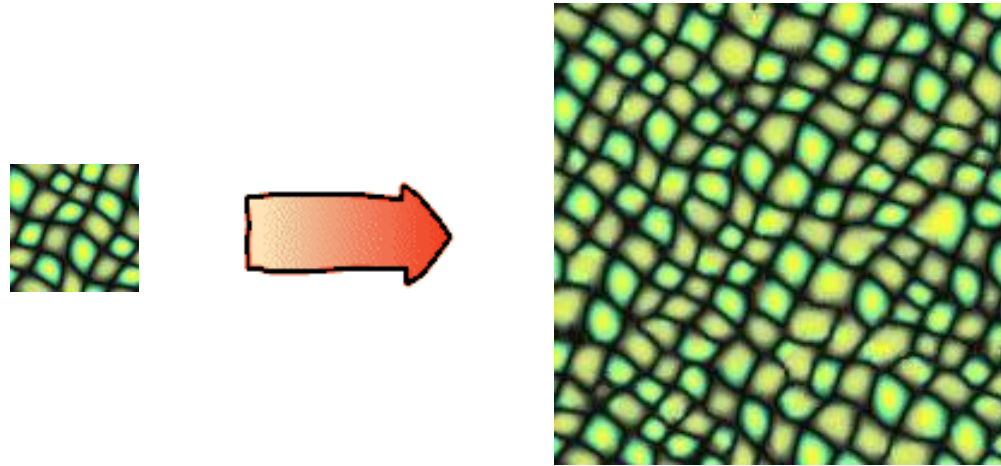
(c) deformed skeleton



(d) deformed object

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

Texture synthesis and analysis – Hidden Markov Model



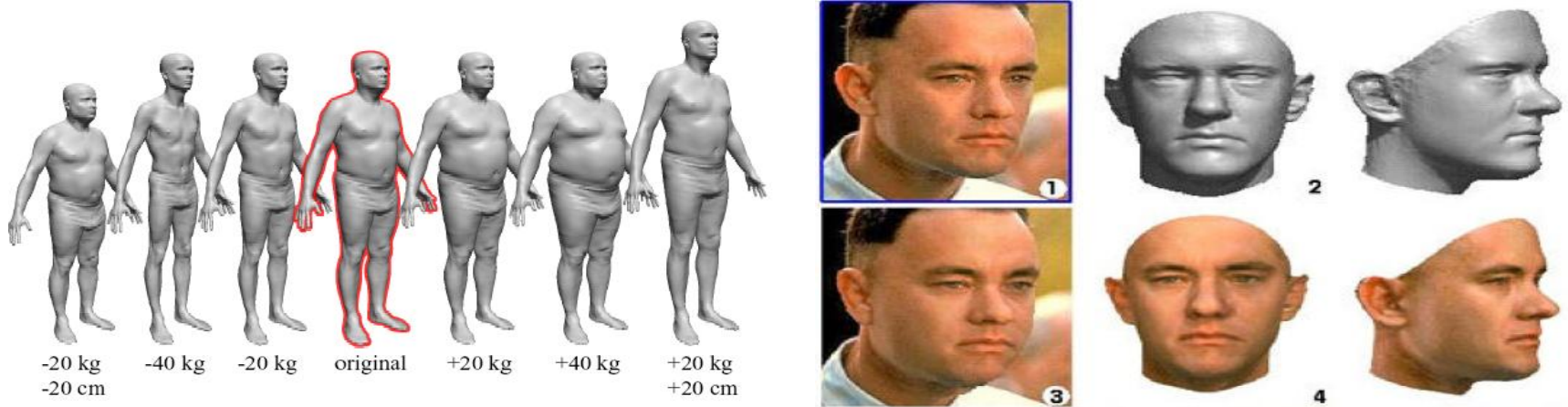
- *Texture Synthesis over Arbitrary Manifold Surfaces.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2001.
- *Fast Texture Synthesis using Tree-structured Vector Quantization.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2000.

Reflectance texture synthesis – Dimension reduction



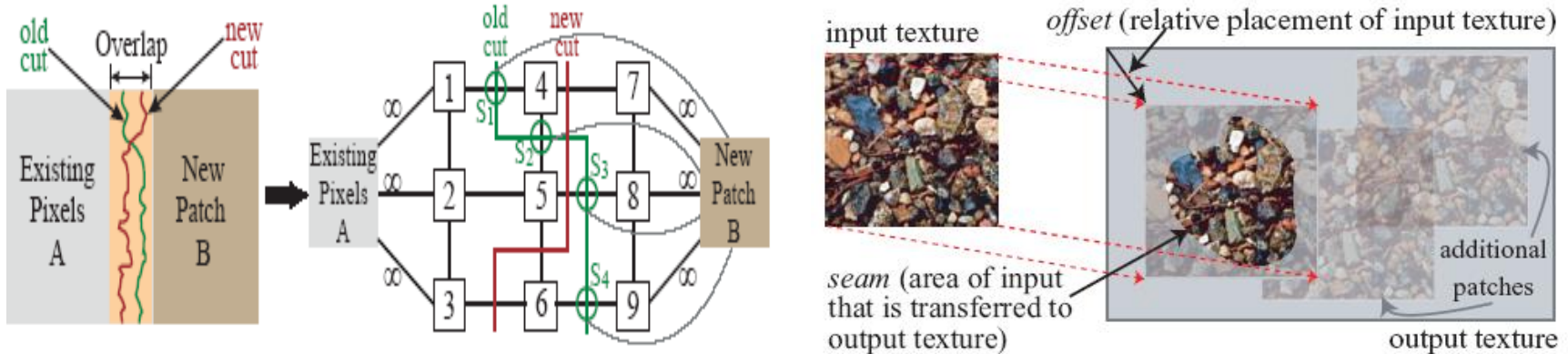
- *Synthesizing Bidirectional Texture Functions for Real-World Surfaces.* Xinguo Liu, Yizhou Yu and Heung-Yeung Shum. SIGGRAPH 2001.
- More recent papers...

Human shapes - Dimension reduction



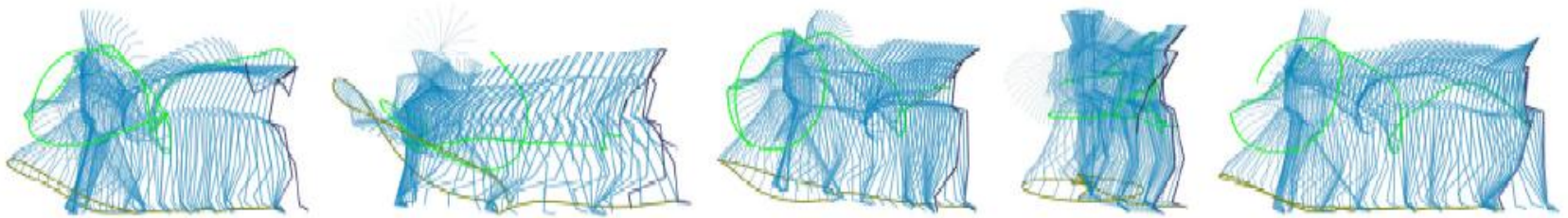
- *The Space of Human Body Shapes: Reconstruction and Parameterization From Range Scans.* Brett Allen, Brian Curless, Zoran Popovic. SIGGRAPH 2003.
- *A Morphable Model for the Synthesis of 3D Faces.* Volker Blanz and Thomas Vetter. SIGGRAPH 1999.

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



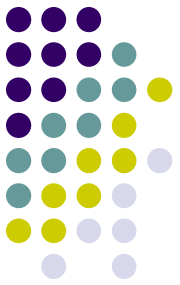
A pirouette and promenade in five synthetic styles drawn from a space that contains ballet, modern dance, and different body types. The choreography is also synthetic. Streamers show the trajectory of the left hand and foot.

- *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

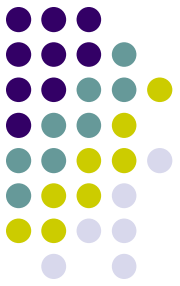


- [Video textures](#). Arno Schödl, Richard Szeliski, David H. Salesin, and Irfan Essa. *SIGGRAPH 2000*.



Summary

- 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.

