Why data-driven?

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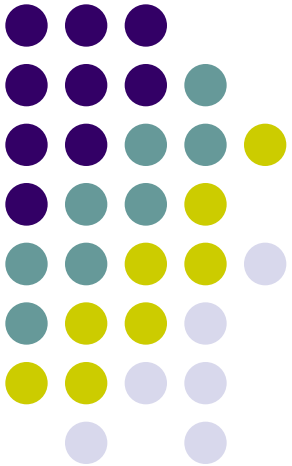
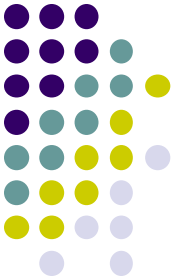


Outline

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

The largest challenge of Today's CS

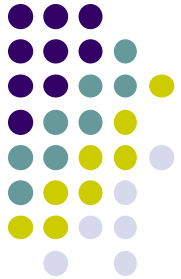


- Big Data

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

  - In China, Baidu, Alibaba, Tecent, 360, DiDi, Netease, Xiaomi, Sina, Huawei

The largest challenge of Today's CS

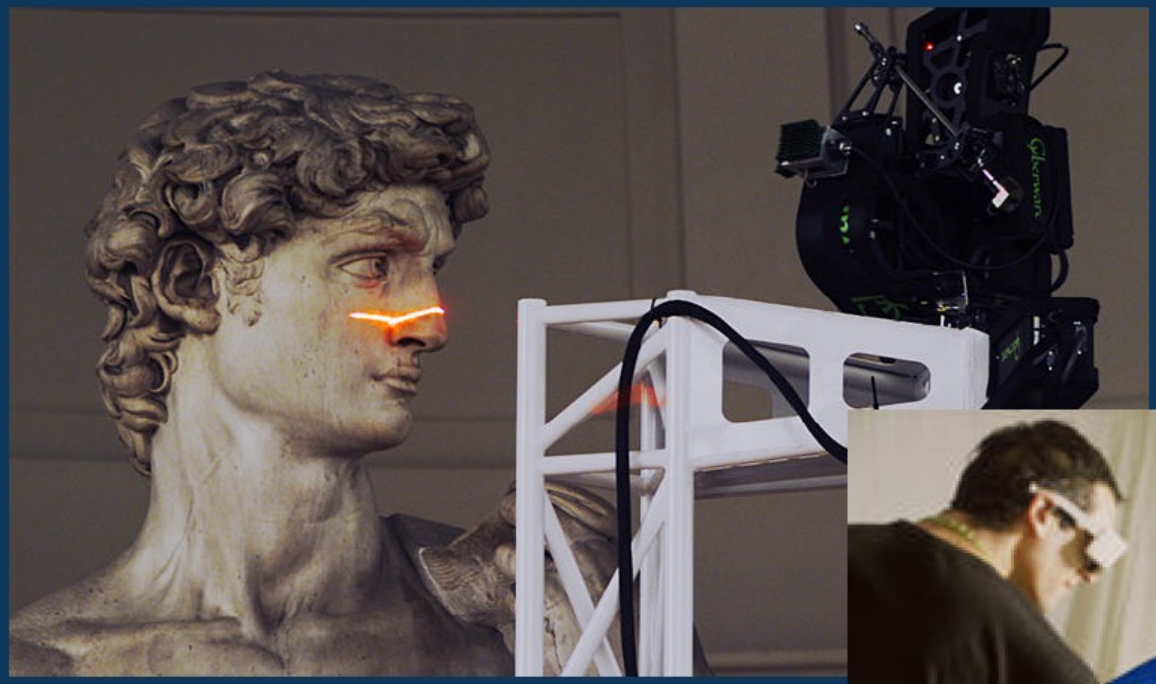


- Data, Data, Data … (in computer graphics)
  - The tedious effort required to create digital worlds and digital life.
    - Finding new ways to communicate and new kinds of media to create.
    - Experts are expensive: scientists, engineers, filmmakers, graphic designers, fine artists, and game designers.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

Computers are really fast

- If you can create it, you can render it

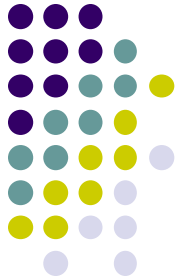
How do you create it?



Digital Michaelangelo Project

Steven Schkolne

Pure procedural synthesis vs. Pure data



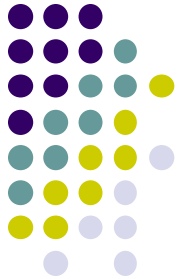
- Creating motions for a character in a movie
  - Pure procedural synthesis (model)
    - compact, but very artificial, rarely used in practice.
  - “By hand” or “pure data” (data)
    - higher quality but lower flexibility.

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

Everything but Avatar

Make it easy and true

Bayesian Reasoning

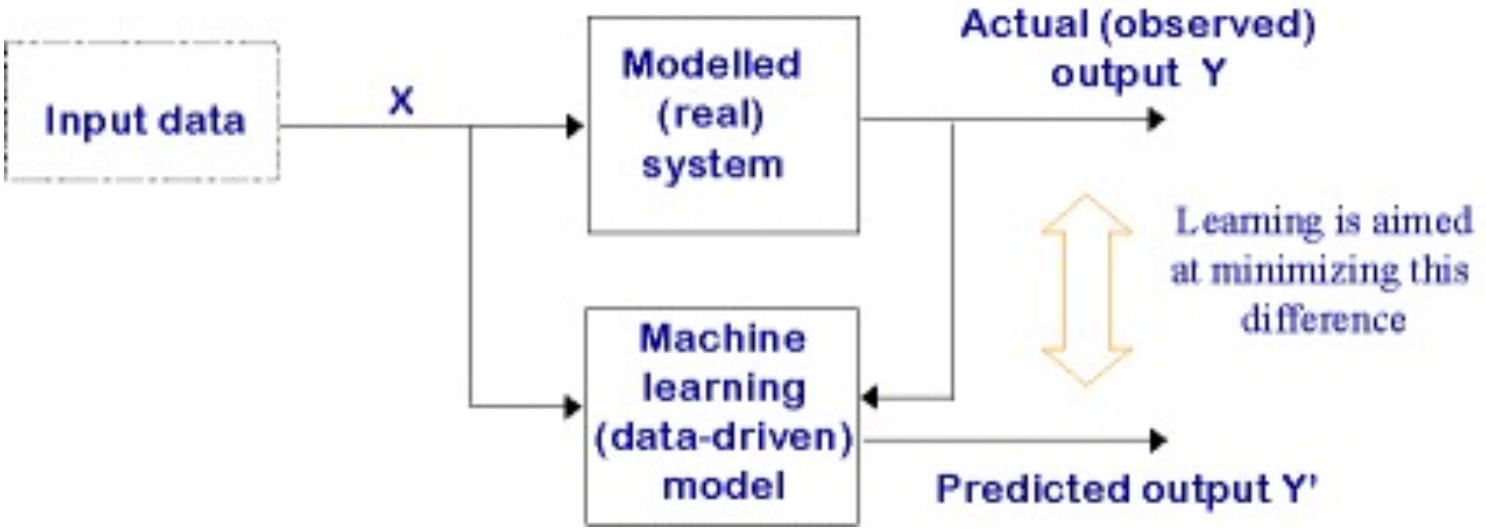


- Principle modeling of uncertainty.
- General purpose models for unstructured data.
- Effective algorithm for data fitting and analysis under uncertainty.

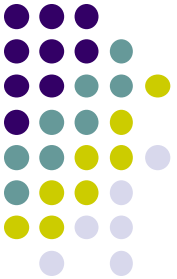
- But currently it is always used as a black box.

Belief v.s. Probability

Data driven modeling

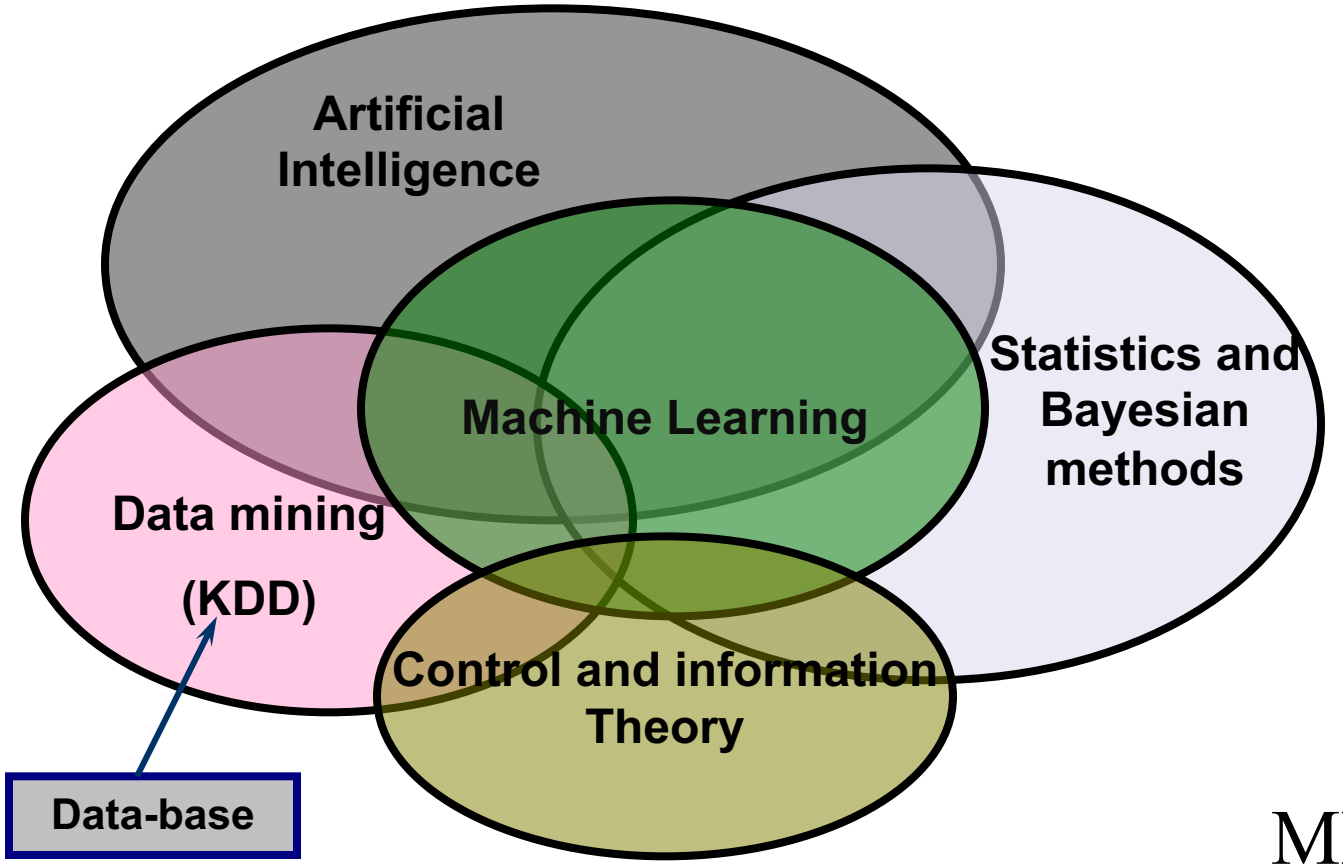


Data-driven vocabulary



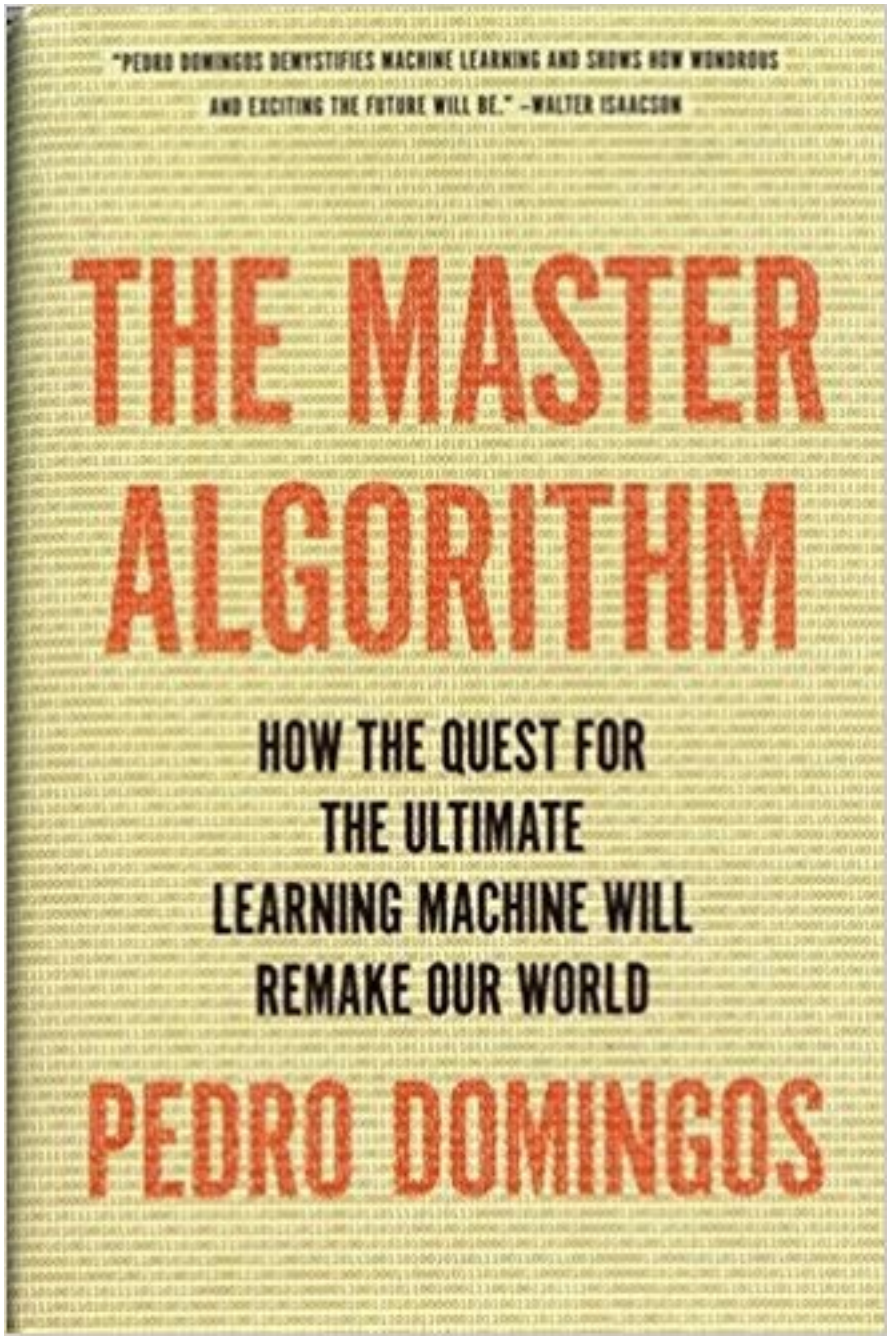
- Data
  - data-driven, data mining
- Learning
  - machine learning, statistical learning
- Uncertainty
  - probability, likelihood
- Intelligent
  - Inference, decision, detection, recognition

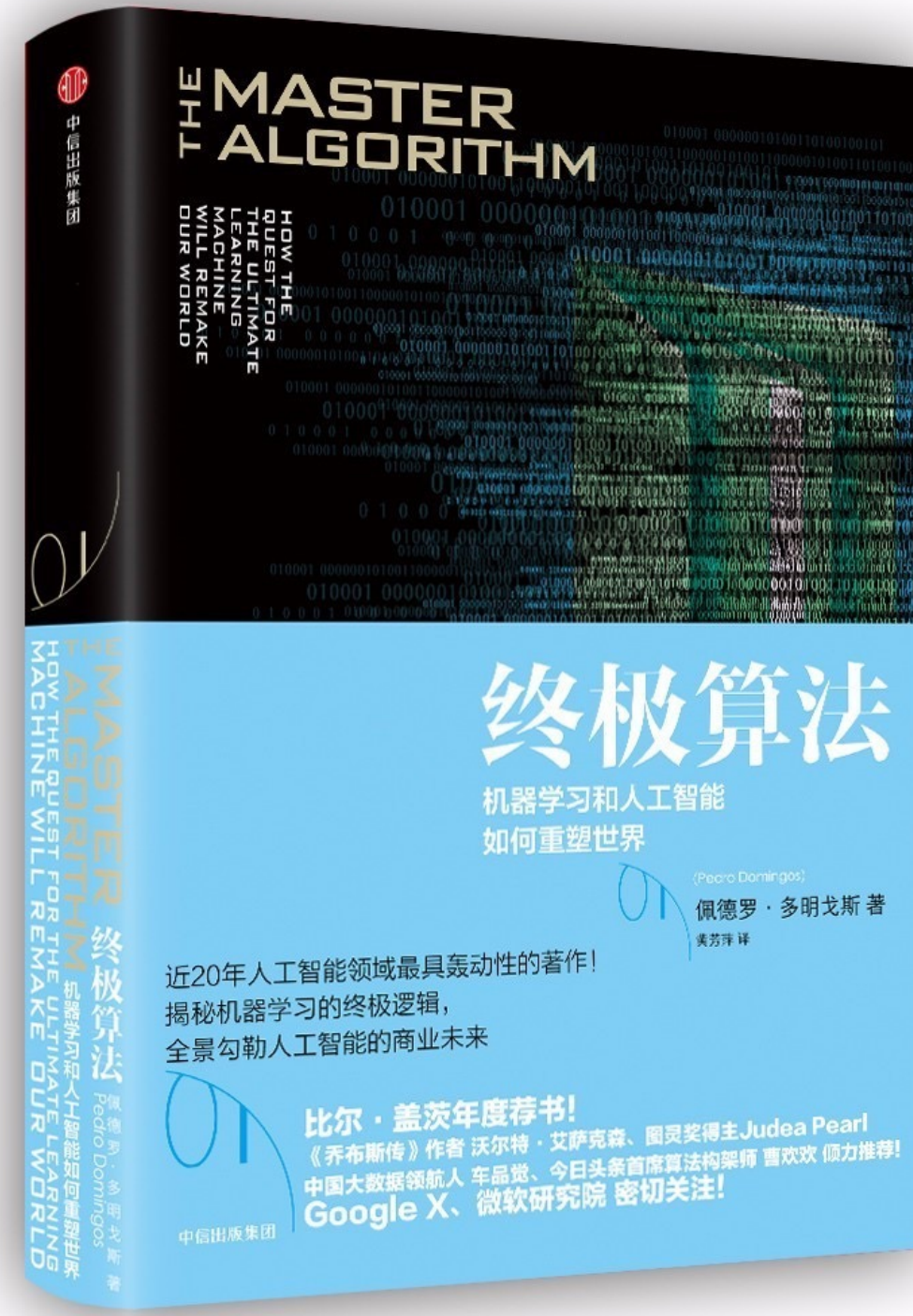
Data-driven related techniques



$ML \neq AI$

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


"PEDRO DOMINGOS DEMYSTIFIES MACHINE LEARNING AND SHOWS HOW WONDROUS AND EXCITING THE FUTURE WILL BE." –WALTER ISAACSON
THE MASTER ALGORITHM
HOW THE QUEST FOR THE ULTIMATE LEARNING MACHINE WILL REMAKE OUR WORLD
PEDRO DOMINGOS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THE MASTER ALGORITHM
HOW THE QUEST FOR THE ULTIMATE LEARNING MACHINE WILL REMAKE OUR WORLD
终极算法
机器学习和人工智能如何重塑世界
Pedro Domingos
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近20年人工智能领域最具轰动性的著作!
揭秘机器学习的终极逻辑,
全景勾勒人工智能的商业未来
比尔·盖茨年度荐书!
《乔布斯传》作者 沃尔特·艾萨克森、图灵奖得主Judea Pearl
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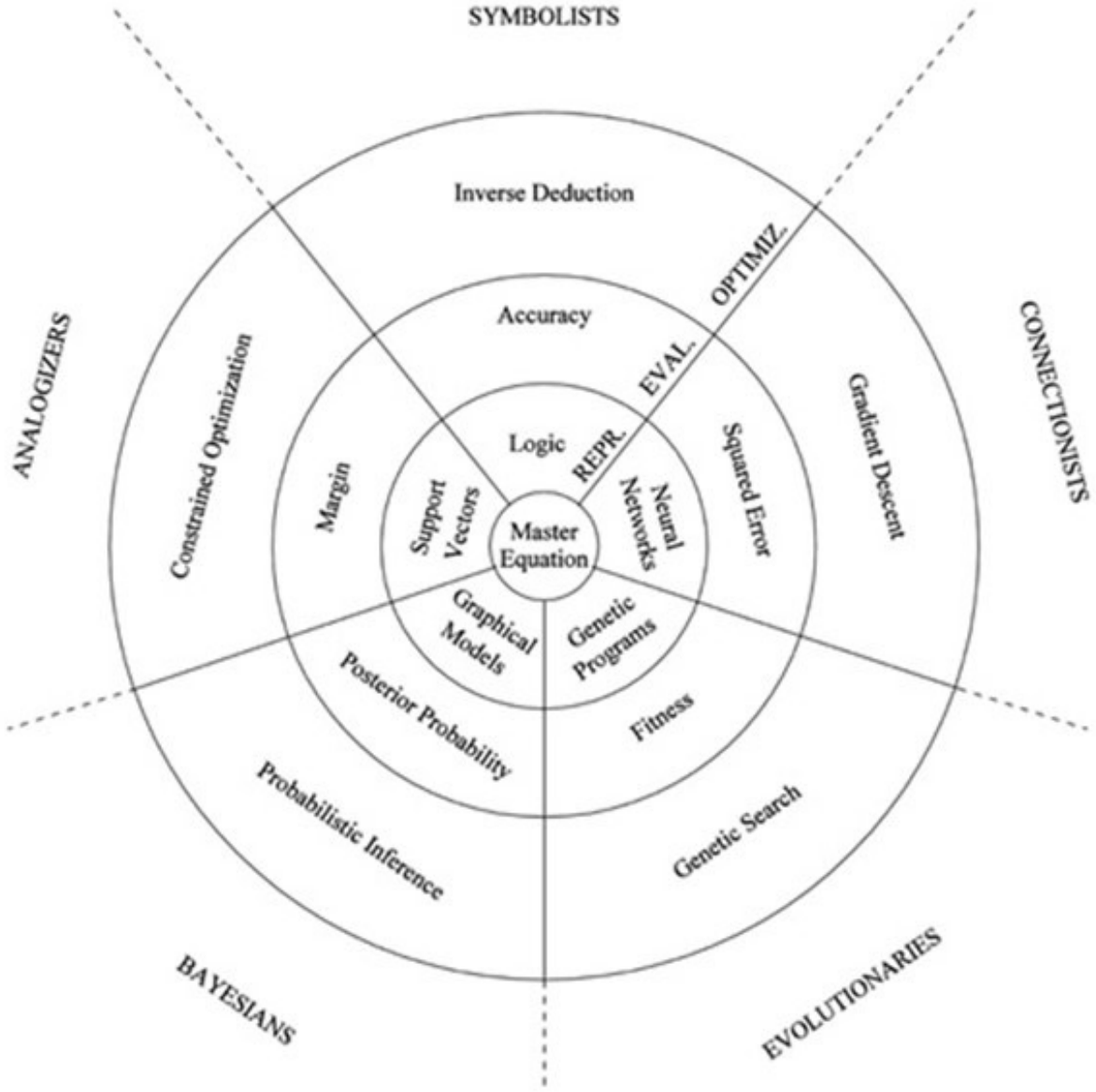


机器学习主要有5个学派：

符号学派

将学习看作逆向演绎，并从哲学、心理学、逻辑学中寻求洞见；

联结学派

对大脑进行逆向分析，灵感来源于神经科学和物理学；

进化学派

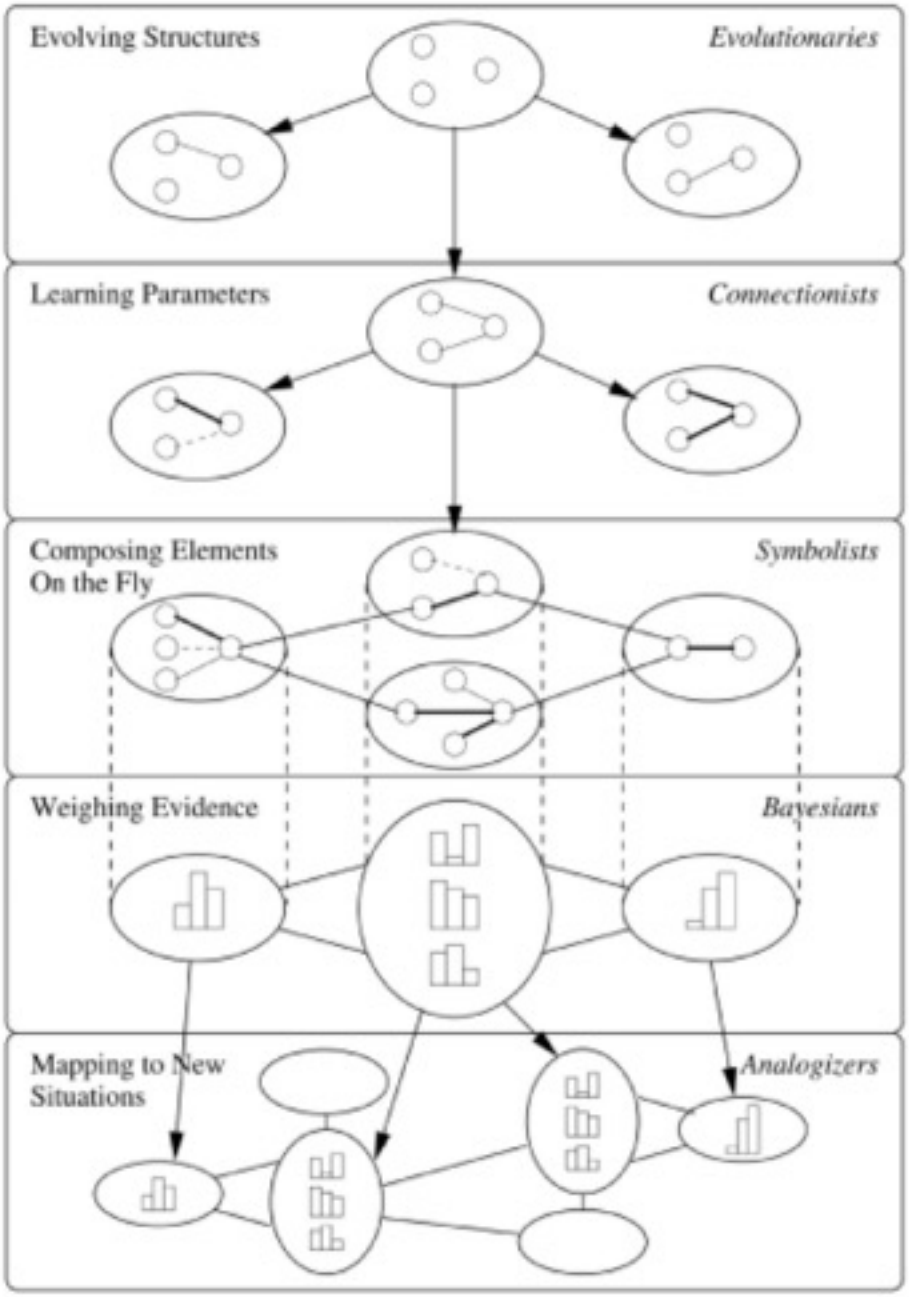
在计算机上模拟进化，并利用遗传学和进化生物学知识；

贝叶斯学派

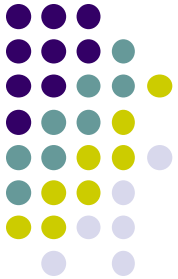
认为学习是一种概率推理形式，理论根基在于统计学；

类推学派

通过对相似性判断的外推来进行学习，并受心理学和数学最优化的影响。


Evolving Structures
Evolutionaries
Learning Parameters
Connectionists
Composing Elements
On the Fly
Symbolists
Weighing Evidence
Bayesians
Mapping to New
Situations
Analogizers

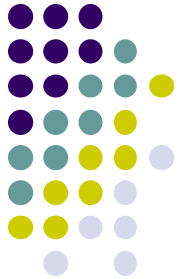
What is machine learning?



- 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.

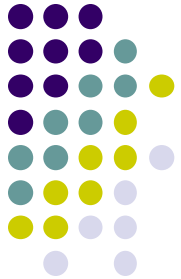
Data-driven system



- 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)

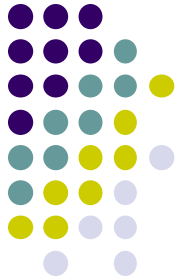
Main categories of learning problems



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

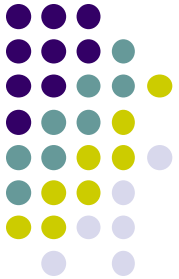
Main class of learning problems



Learning scenarios differ according to the available information in training examples

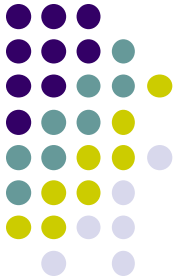
- **Supervised**: correct output available
  - …
- **Semi-Supervised**: only a part of output available
  - **Ranking**:
- **Unsupervised**: no feedback, need to construct measure of good output
  - …
- *Reinforcement*: scalar feedback, possibly temporally delayed

And more …



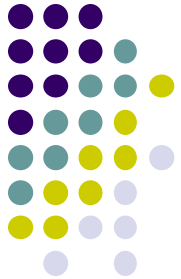
- Time series analysis
- Dimension reduction
- Model selection
- Generic methods
- Graphical models

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?

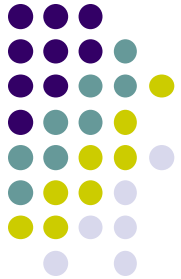


- Con: Everything is machine learning or everything is human tuning?
  - Sometimes, this may be true

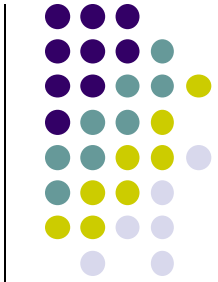
- Pro: more understanding of learning, but yields much more powerful and effective algorithms.
  - Problem taxonomy
  - General-purpose models
  - Reasoning with probabilities

- I believe the mathematic magic

What will be a successful D-D algorithm?



- Computational efficiency
- Robustness
- Statistical stability



Old and New …

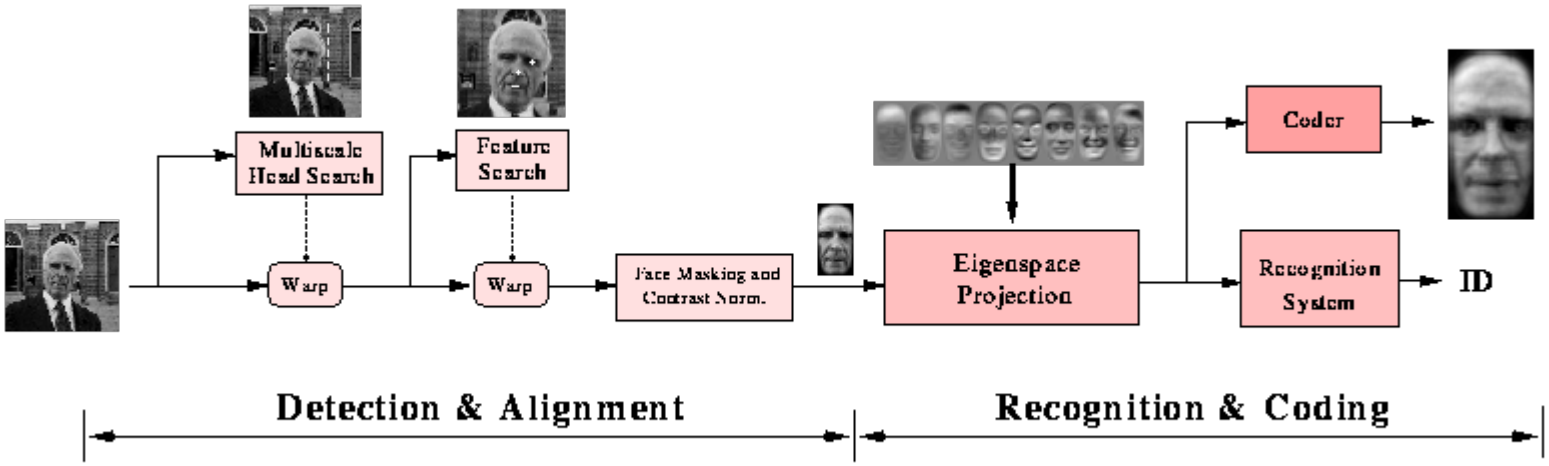
APPLICATIONS OF DATA-DRIVEN

The First Example: Google!

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

The great example in China: TikTok/Douyin (ByteDance)

Object detection and recognition - the power of DD

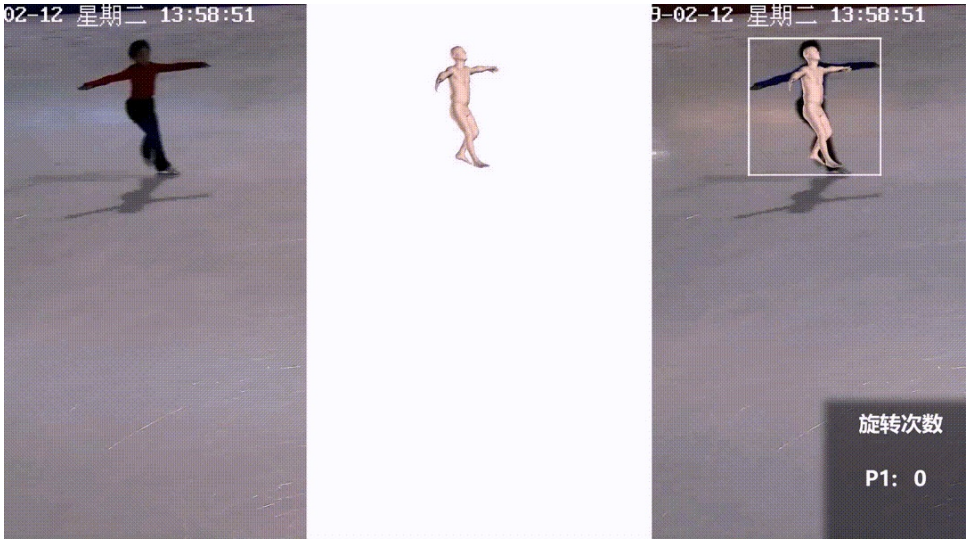


The image is copied from
http://vismod.media.mit.edu/vismod/demos/facerec/

Object detection and recognition

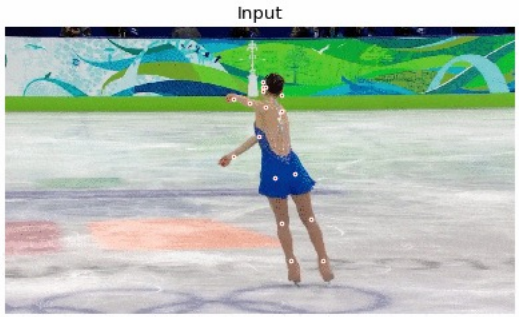
Face [Vaillant et al IEE 1994] [Garcia et al PAMI 2005] [Osadchy et al JMLR 2007]
Pedestrian: [Kavukcuoglu et al. NIPS 2010] [Sermanet et al. CVPR 2013]

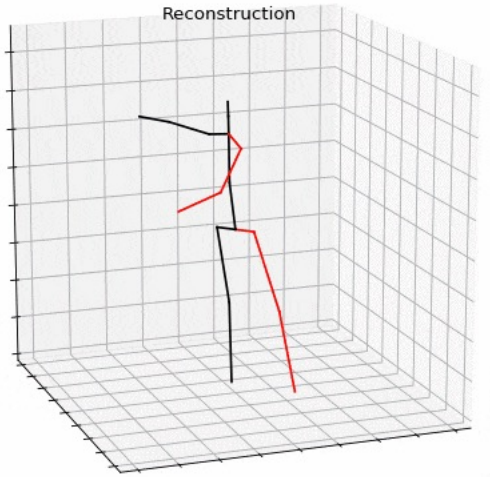
In Olympic Games Beijing 2022



3D Modeling and Visualization

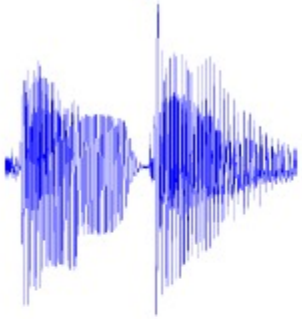
3D Skeleton Detection





Speech recognition

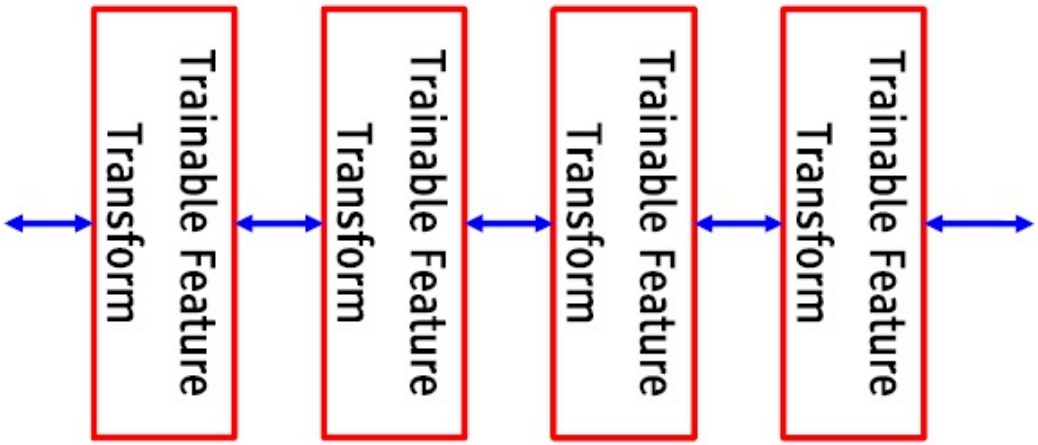
- Modern architecture for pattern recognition
  - Speech recognition: early 90's – 2011



  - Object Recognition: 2006 - 2012

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 →



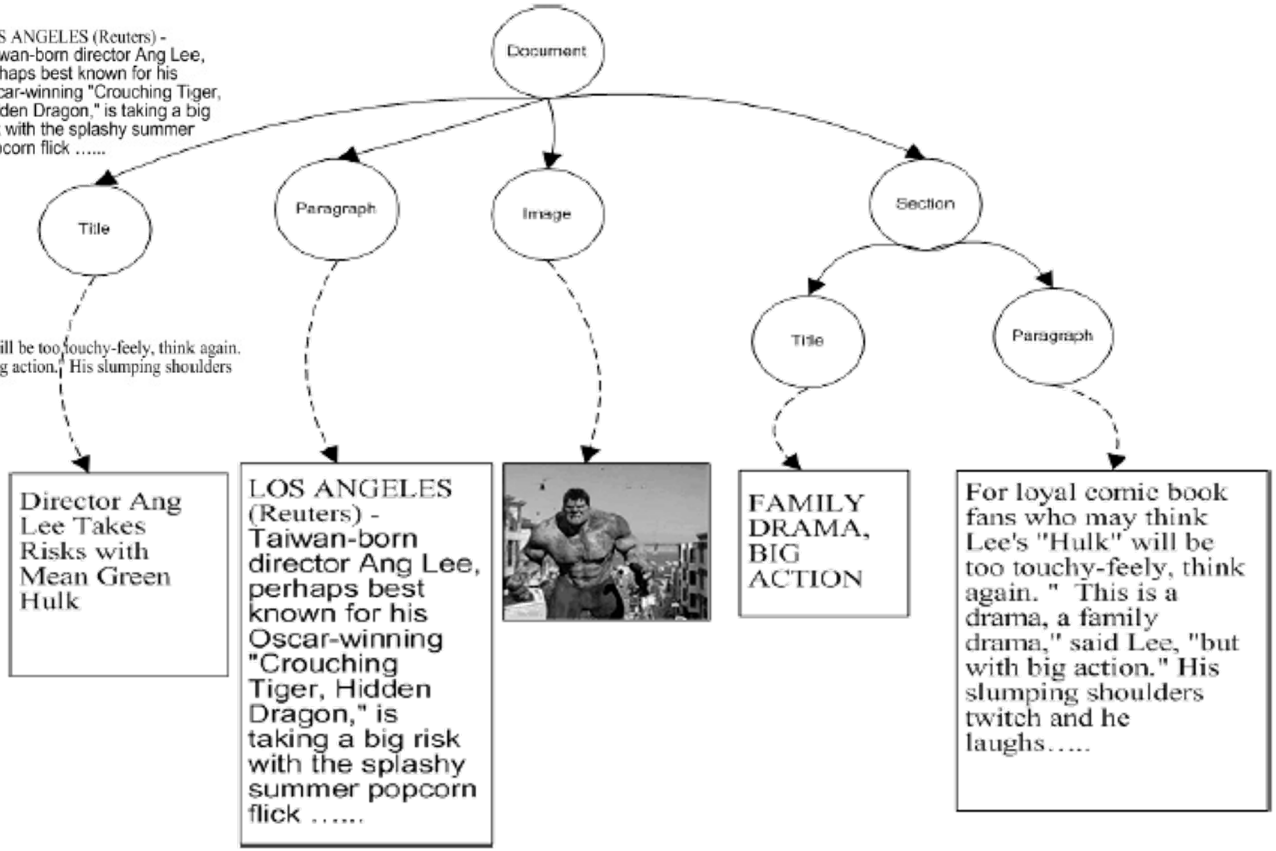
Document processing – Bayesian classification

Director Ang Lee Takes Risks with Mean Green 'Hulk'

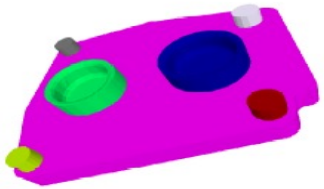
LOS ANGELES (Reuters) - Taiwan-born director Ang Lee, perhaps best known for his Oscar-winning "Crouching Tiger, Hidden Dragon," is taking a big risk with the splashy summer popcorn flick .....

FAMILY DRAMA, BIG ACTION

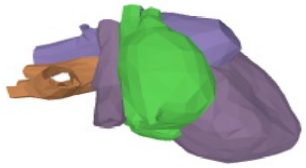
For loyal comic book fans who may think Lee's "Hulk" will be too touchy-feely, think again. " This is a drama, a family drama," said Lee, "but with big action." His slumping shoulders twitch and he laughs.....



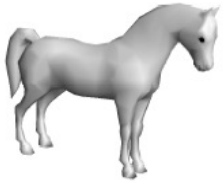
Mesh Processing – Data clustering/segmentation



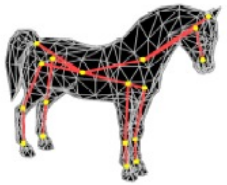
(c) mechanical part – 1270 faces
7 patches



(d) heart – 1619 faces
4 patches

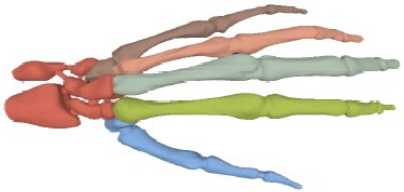


(a) object



(b) skeleton

(e) Venus – 67,170 faces
3 patches



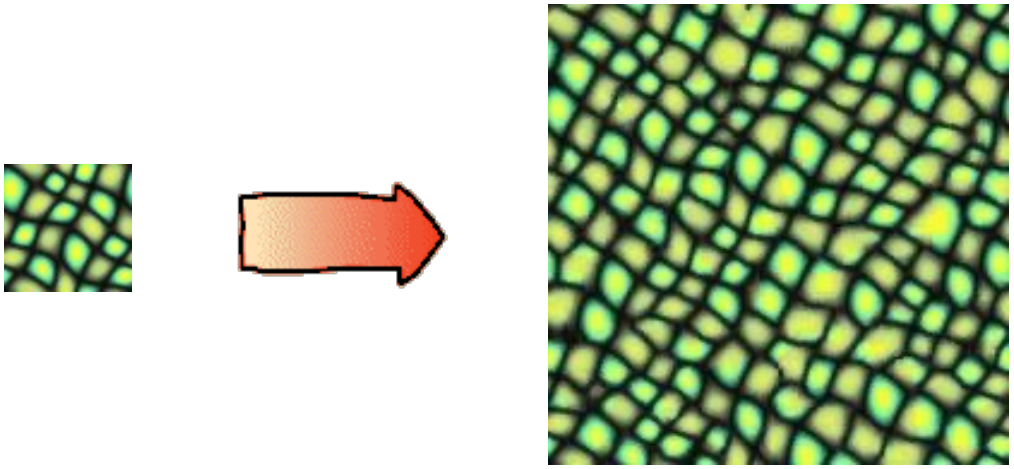
(f) skeleton hand – 654,666 faces
6 patches

(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



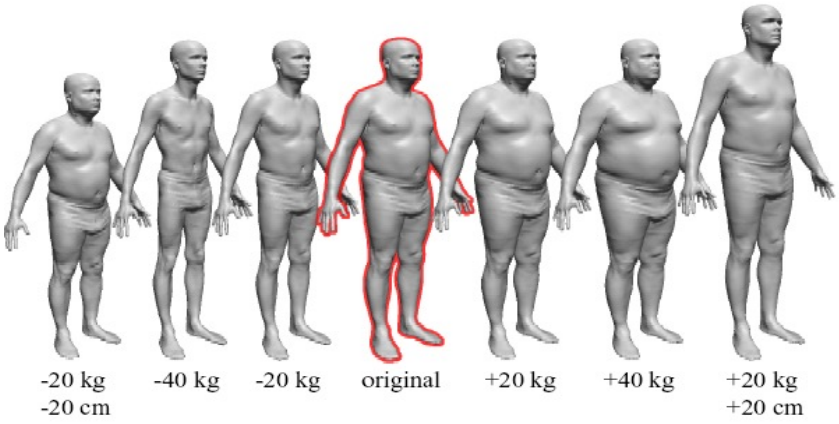
- *Texture Synthesis over Arbitrary Manifold Surfaces.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2001.

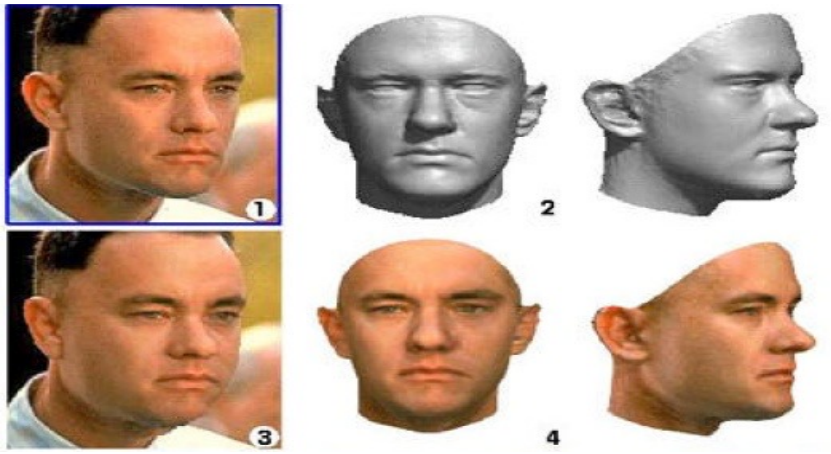
- *Fast Texture Synthesis using Tree-structured Vector Quantization.* Li-Yi Wei and Marc Levoy. SIGGRAPH 2000.

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

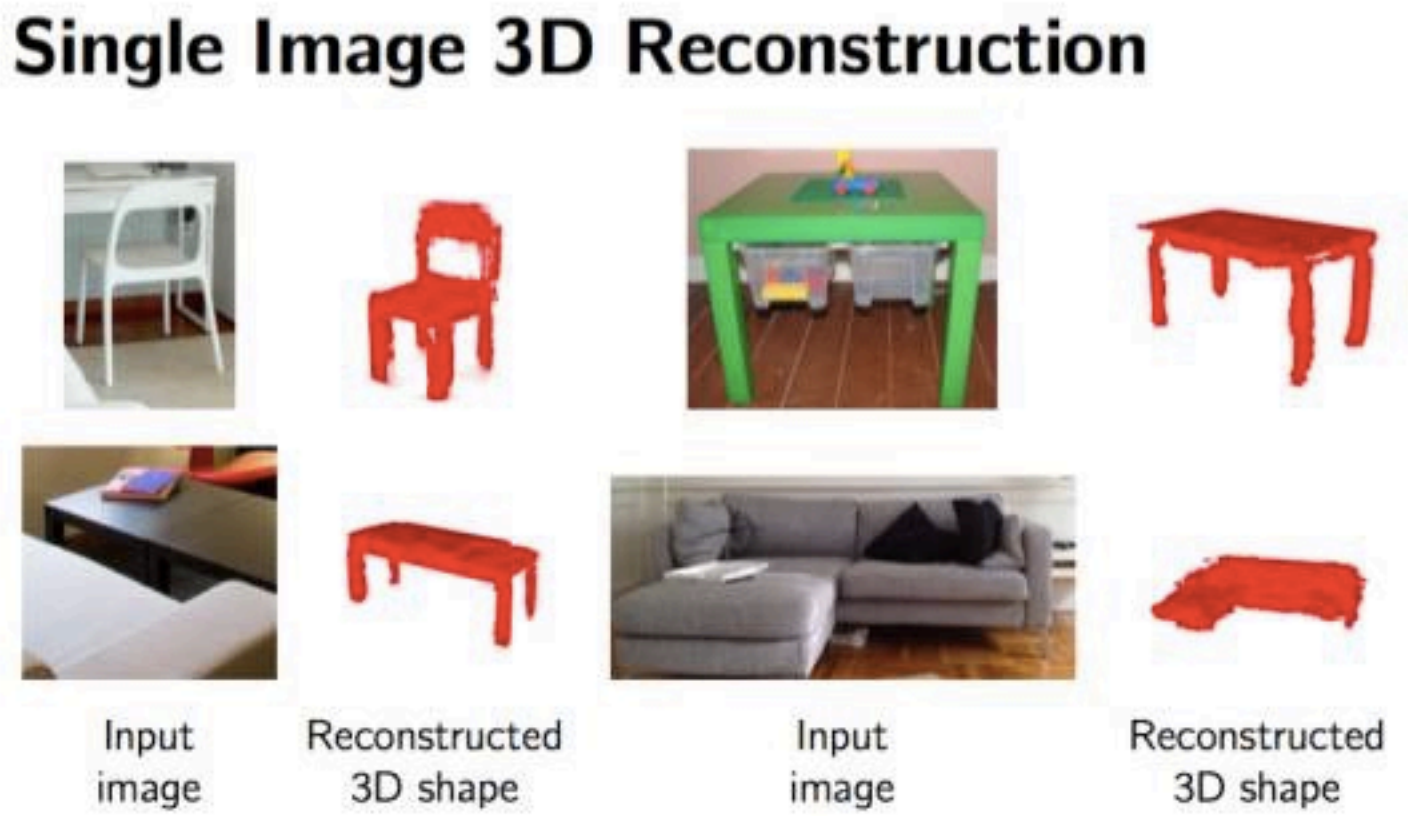




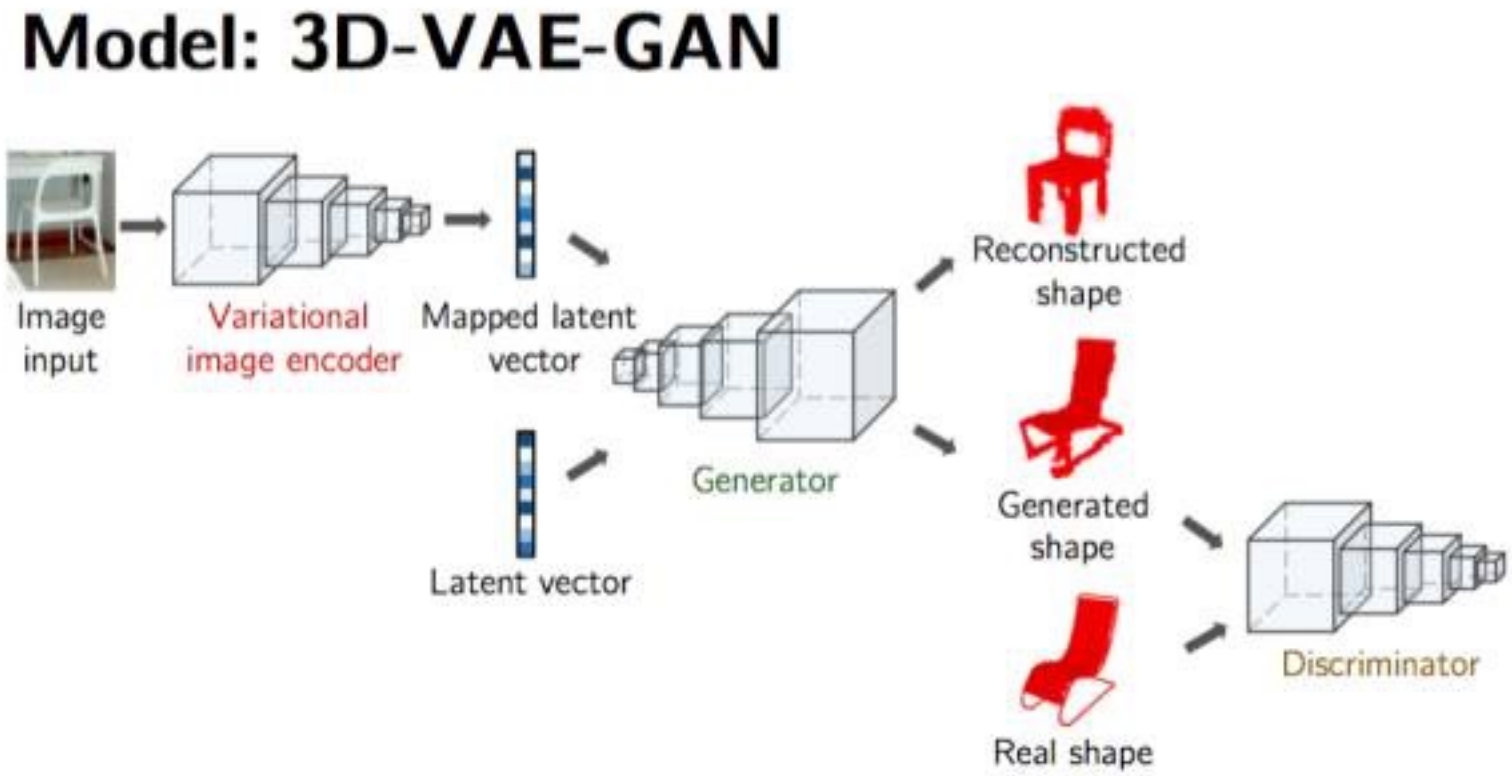
- *The Space of Human Body Shapes: Reconstruction and Parameterization From Range Scans.* Brett Allen, Brian Curless, Zoran Popovic. SIGGRAPH 2003.

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

Learning a Probabilistic Latent Space of Object Shapes – GANs (NIPS2016)

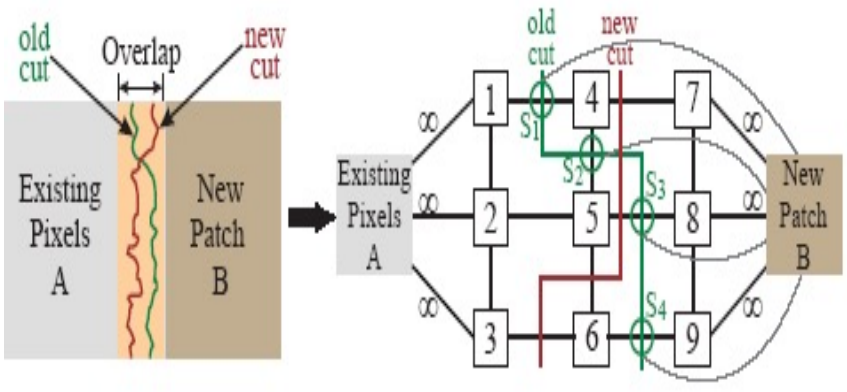


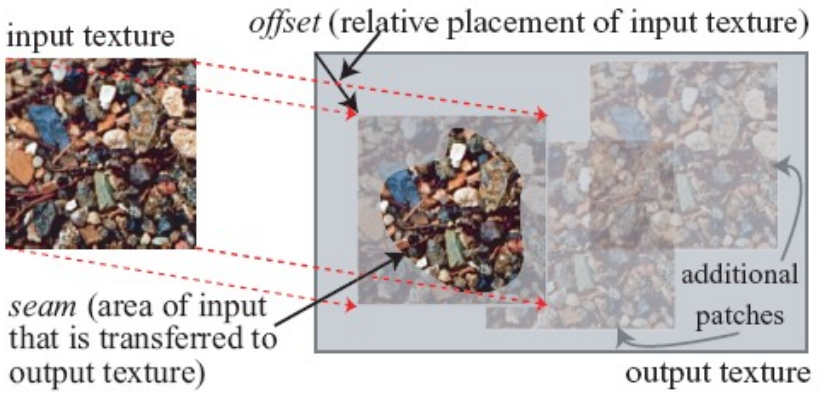
Learning a Probabilistic Latent Space of Object Shapes – GANs



We combine the encoder with 3D-GAN for reconstruction and generation.

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.

Data-driven based Rendering

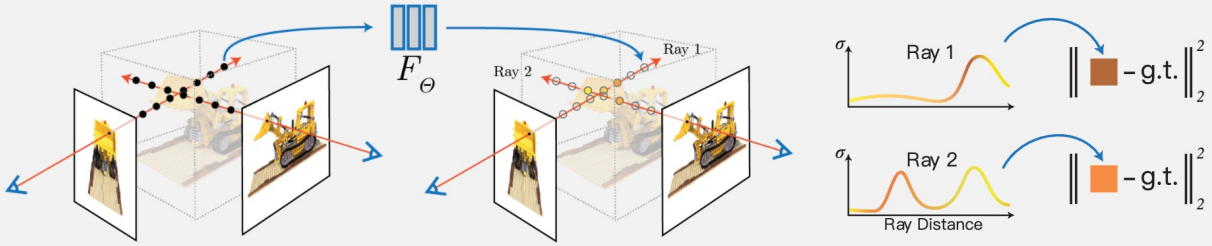
- [NeRF: Neural Radiance Fields (ECCV2020)]

Abstract & Method

We present a method that achieves state-of-the-art results for synthesizing novel views of complex scenes by optimizing an underlying continuous volumetric scene function using a sparse set of input views.

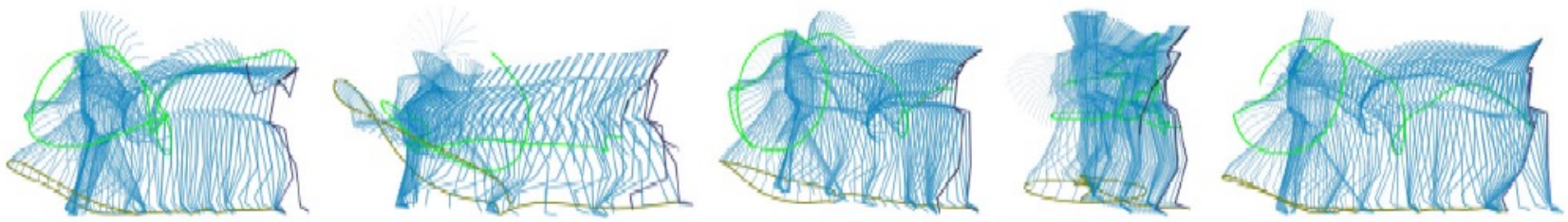
$$(x,y,z,\theta,\phi) \rightarrow F_\Theta \rightarrow (RGB\sigma)$$

Our algorithm represents a scene using a fully-connected (non-convolutional) deep network, whose input is a single continuous 5D coordinate (spatial location (x, y, z) and viewing direction (θ, φ)) and whose output is the volume density and view-dependent emitted radiance at that spatial location.



We synthesize views by querying 5D coordinates along camera rays and use classic volume rendering techniques to project the output colors and densities into an image. Because volume rendering is naturally differentiable, the only input required to optimize our representation is a set of images with known camera poses. We describe how to effectively optimize neural radiance fields to render photorealistic novel views of scenes with complicated geometry and appearance, and demonstrate results that outperform prior work on neural rendering and view synthesis.

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.

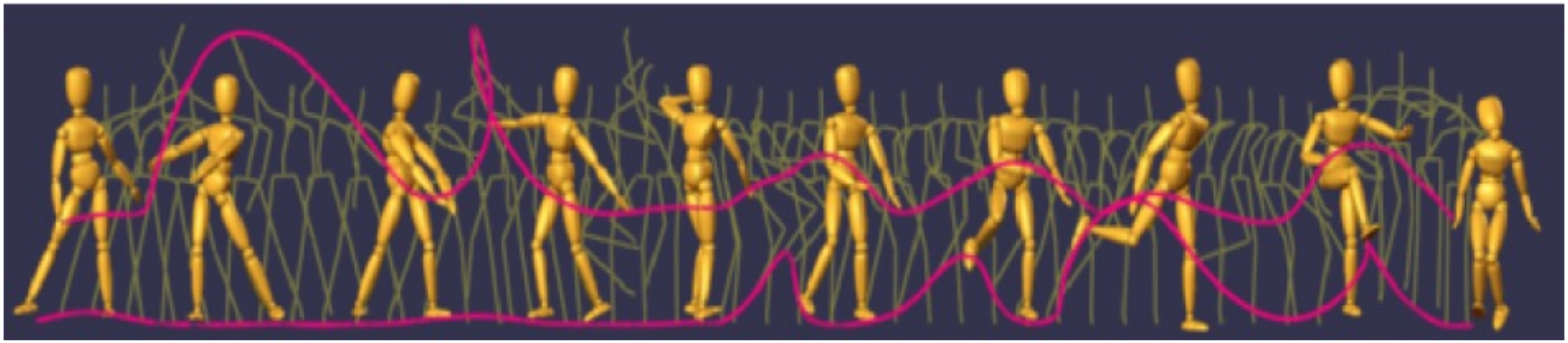
- *Style Machines.* M. Brand and A. Hertzmann. SIGGRAPH 2000.

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

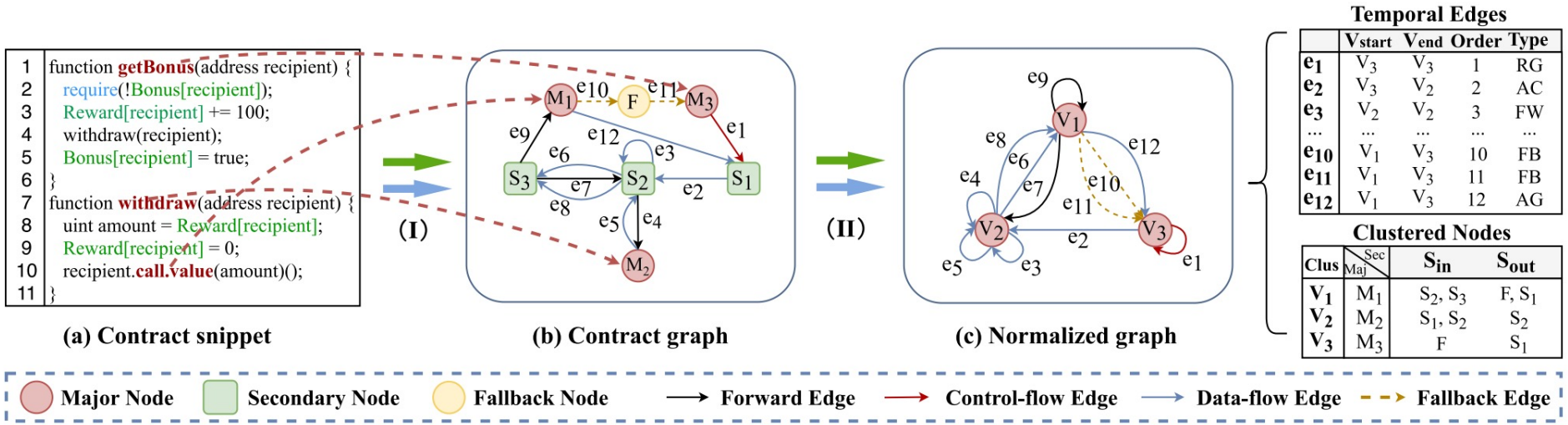
Video Textures - Reinforcement Learning

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

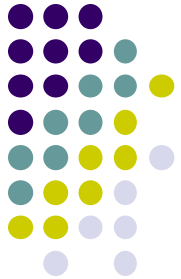
Motion texture - Linear dynamic system



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



Smart Contract Vulnerability Detection (IJCAI2020)



Summary

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

Questions for review

- Try to find potential learning based (data driven) applications in your research area
- Is there any disadvantage / weakness?

Reference

- Reinforcement learning: A survey

The End

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