Deep Learning

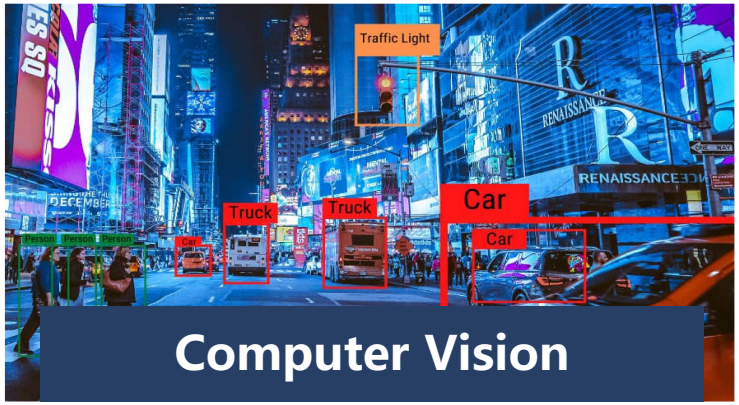
西湖大學 WESTLAKE UNIVERSITY

Introduction to Data Science

(Part 1)

Stan Z. Li

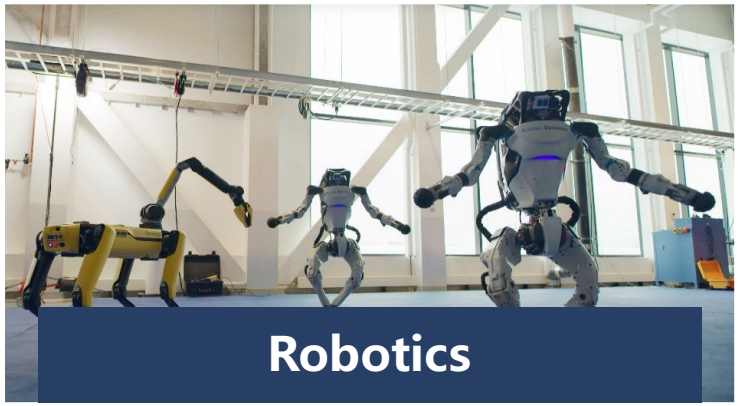
AI Research (Main-Stream Tasks)



Computer Vision

Speech and Language

Smart Sensors



Robotics

AI for Sciences

Optimization/ Decision Making

Protein Folding and Design

Drug Design and Synthesis

Examples of AI Modeling Problems

- Face Recognition
- Speech
- Natural Language Processing
- Robot Sensing and Control
- Whether forecasting
- Protein Computing (Structure Prediction and Sequence Design)
- Mass-spectrometric Data Analysis
- Single-Cell Clustering and Hierarchy/Lineage
- Drug Design (Large and Small Molecules)
- ……

西湖大学AI 三大研究版块

AI 基础研究

- 数据科学基础
- 深度学习方法
- 序列结构建模

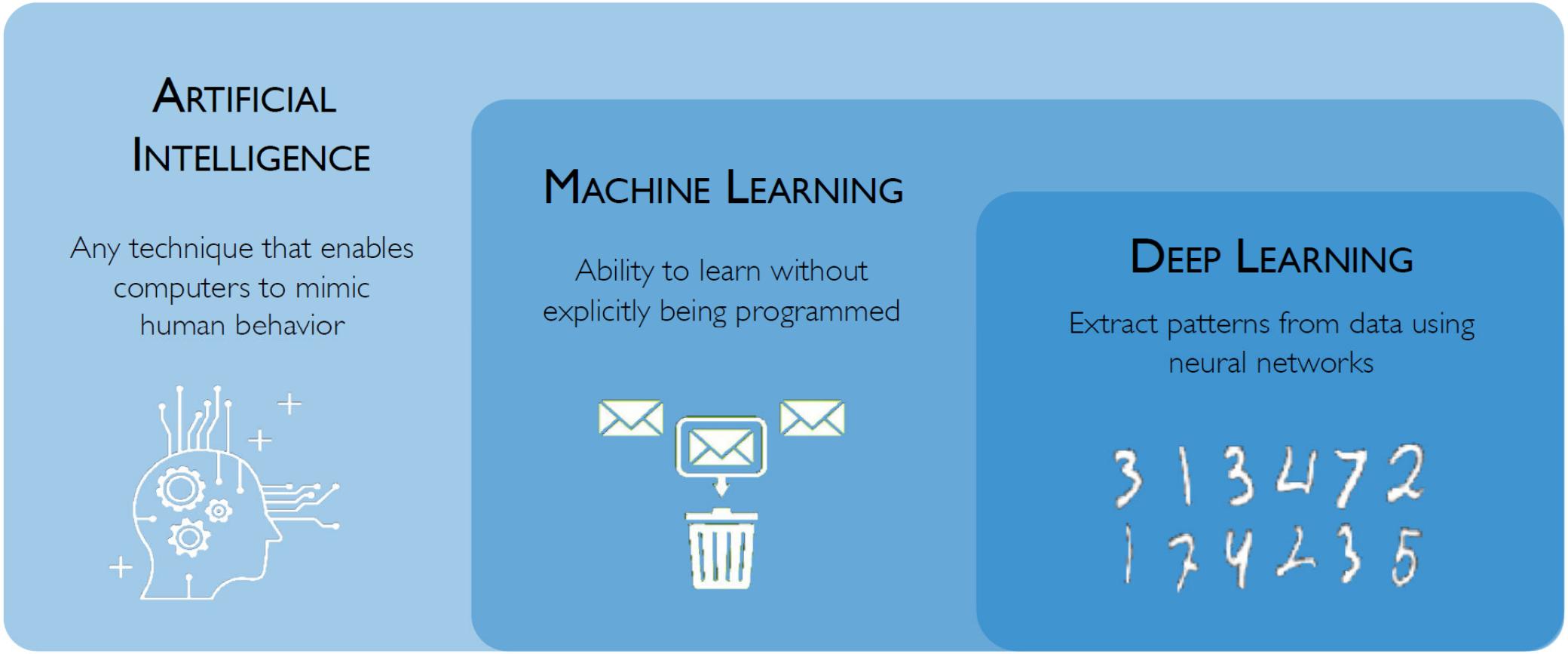
AI 核心应用

- 计算机视觉
- 语音语言处理
- 机器人学

AI 学科交叉

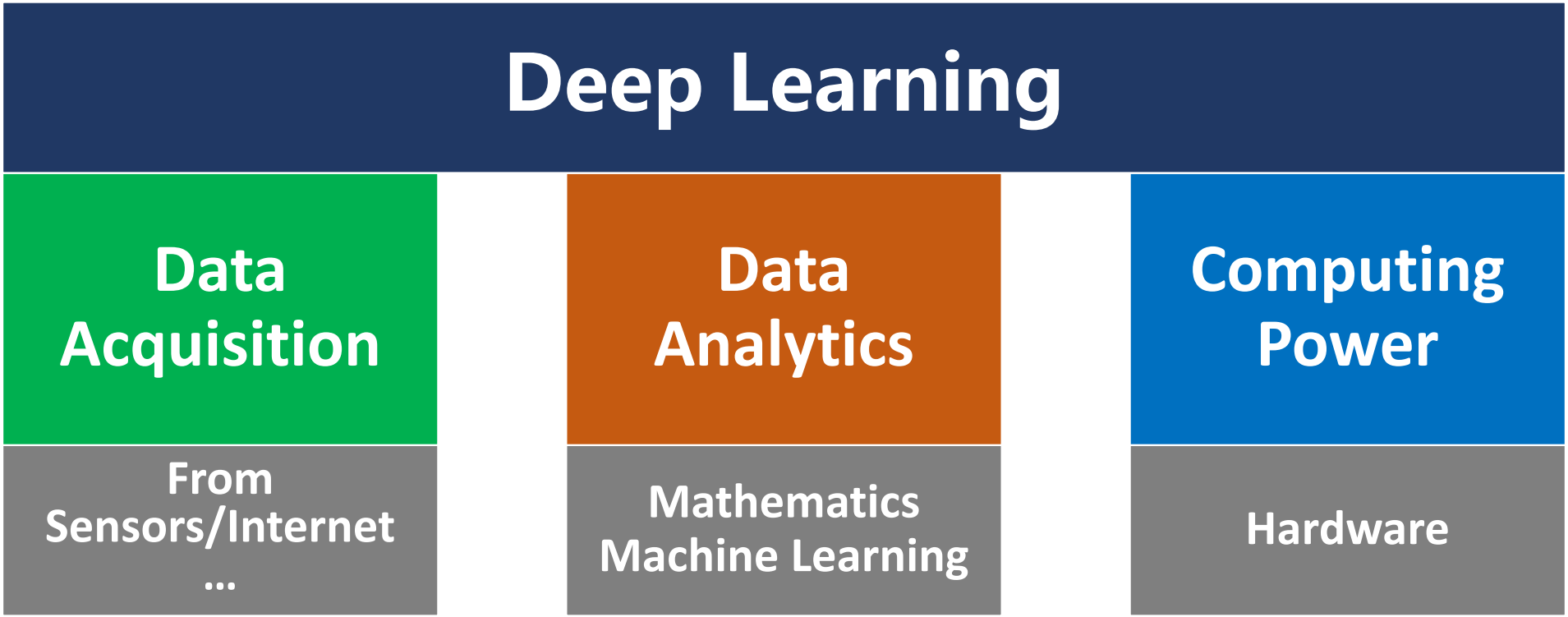
- 生命科学
- 生物医药
- 其他 学科

AI and Machine Learning

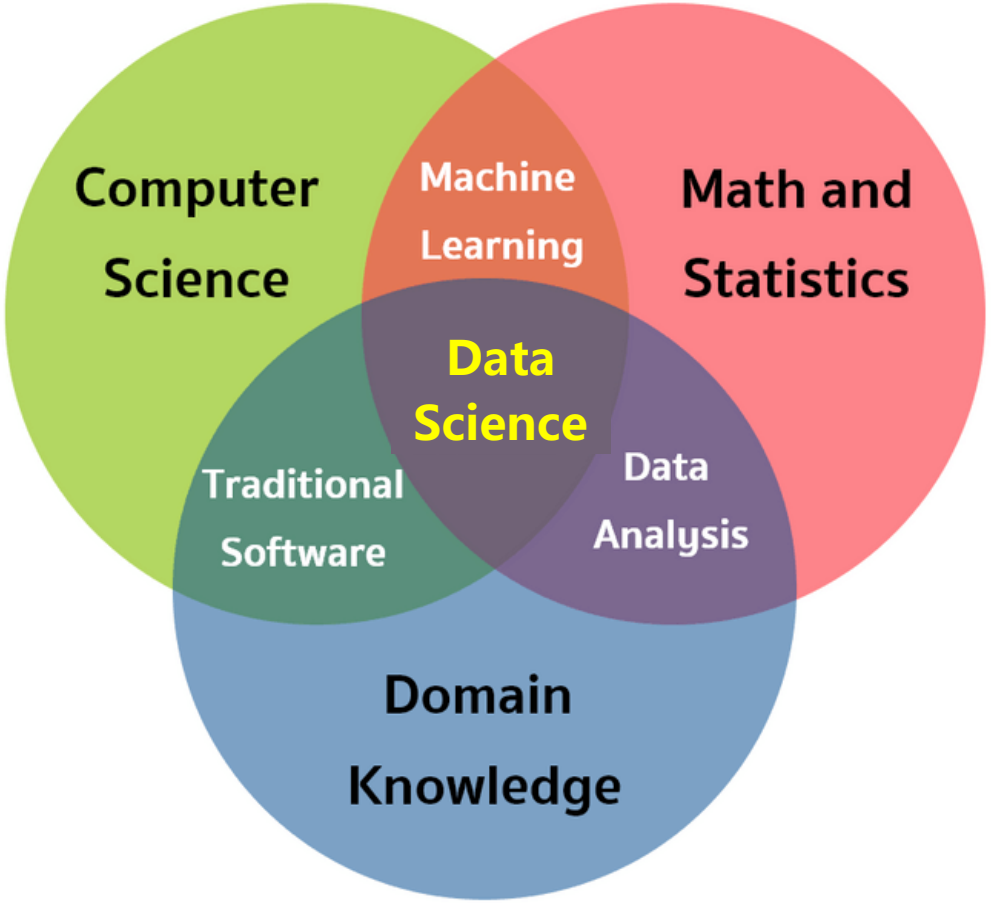


Picture Courtesy of MIT 6.S191

Contemparaty AI and Deep Learning

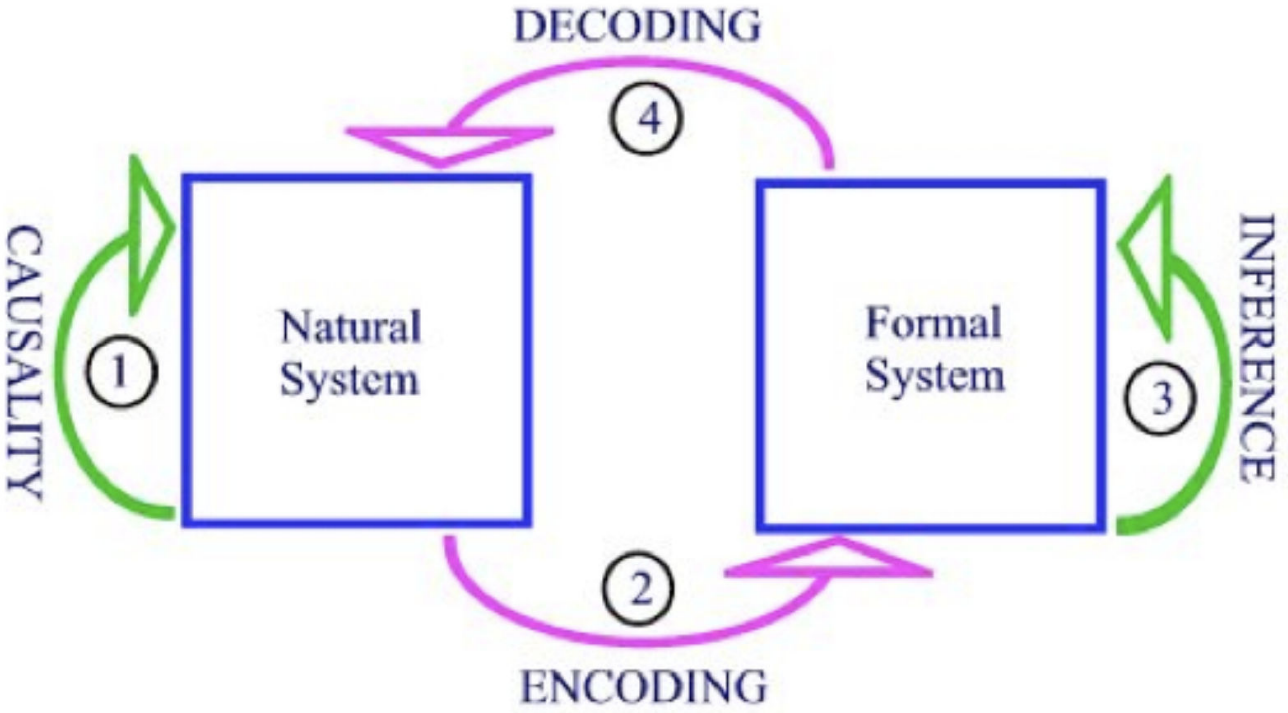


Data Science



Scientific Modeling

Generate Observable Data



Convert into Internal Representation

Different Types of Models

- **Conceptual models:** to better understand
- **Operational models:** to operationalize
- **Mathematical models:** to quantify
- **Computational models:** to simulate

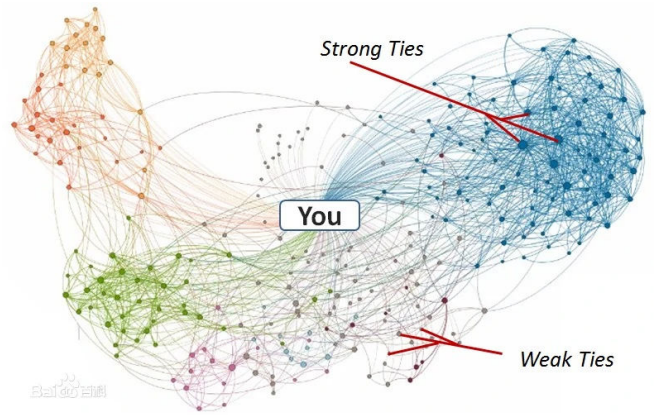
  (and to encode / decode)
- **Graphical models:** to visualize the subject

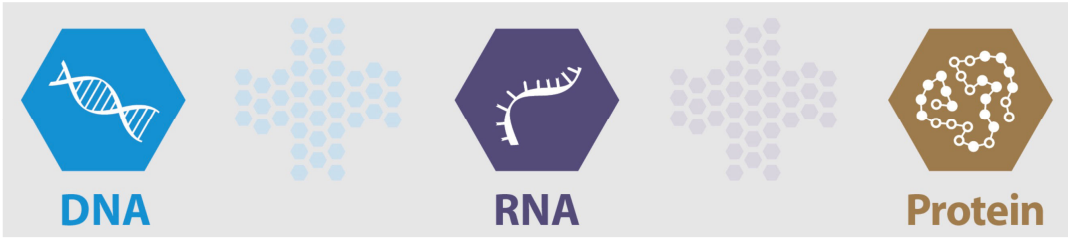
Outline

1. AI – How it has been evolving
2. High-Dimensional Data Analysis
3. Modeling by Deep Learning and Neural Nets

High-Dimensional Data

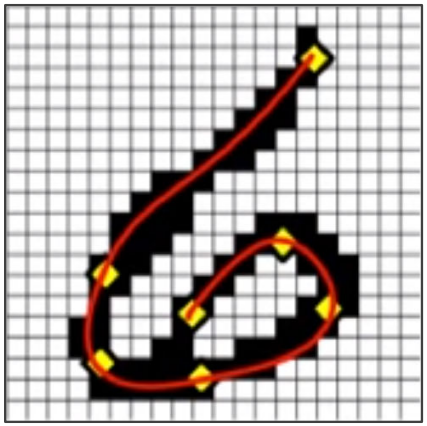
- Images, Videos, Text, Audio,
- Web pages, Social Networks
- Molecular Structures
- DNA Sequences
- Protein Sequence-Structures

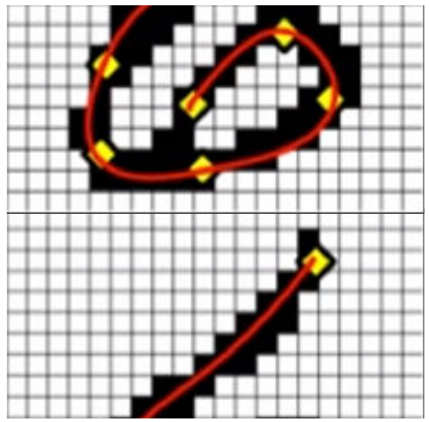




Handwritten Digit images

- Image size 20x20 = 400
- Pixel values in {0,1}
- Image Space $\mathbb{S} = \{0,1\}^{400}$
- $\#\mathbb{S} = 2.58 \times 10^{120}$
- Only a tiny portion of $\mathbb{S}$ is of digits
- The digit pattern lives in a
  low dim subspace (manifold)





Face Image Data

- Image size 100x100 = 10^4 pixels
- RGB image size $3x10^4$ pixels
- **Dimensionality = $3x10^4$**
- Pixel values in {0,…,255}
- #Possibility = $256^{30,000} \cong$ infinity
- Only a tiny portion is of faces
- **Face pattern lives in low dim subspace**

Manifold Assumption

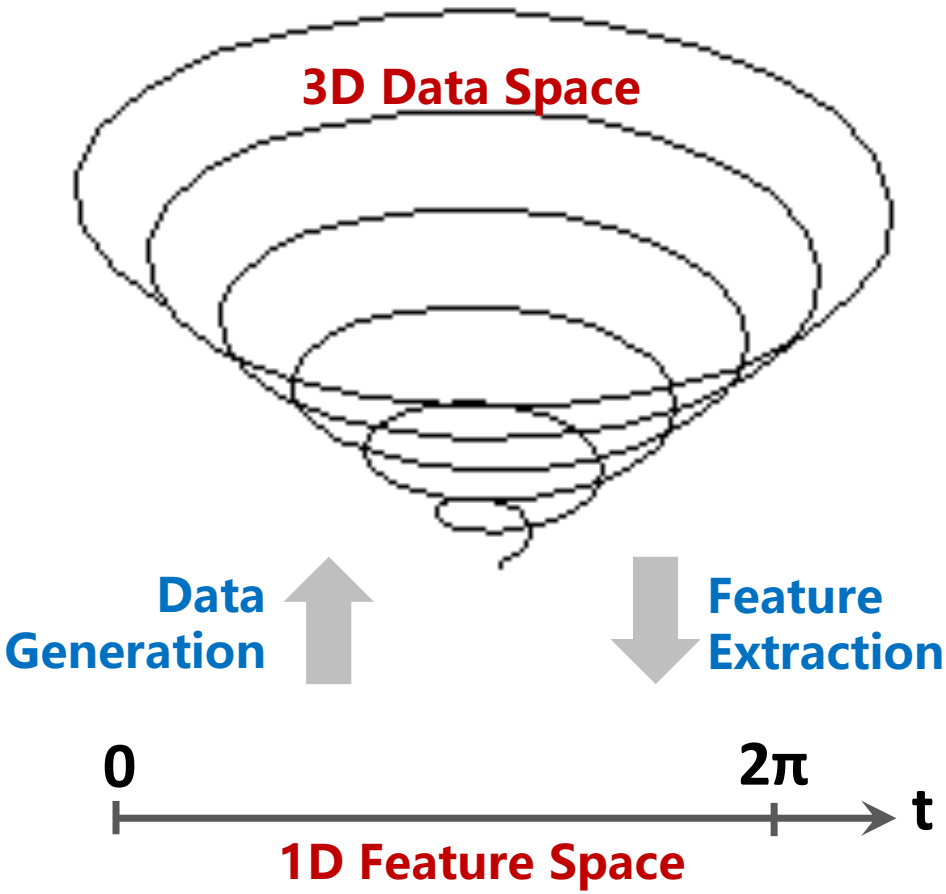
High-Dimensional Data: Images, Web pages, Gene sequences, ….

Dimension Reduction into Coordinate System of a Lower Dim

- **For representation learning (feature extraction)**
- **For data visualization – in 2D or 3D**

Manifold Assumption: an interesting pattern in high dimensional data resides on a low dimensional manifold

Manifold in Hi-D Data Space: 1D Curve in 3D Space



Conical Helix:

$x=t*\cos(6t),\ y=t*\sin(6t),\ z=t$

$0 \le t \le 2\pi$

1D line segment

Latent variable t

2D Manifold in 3D Space

Swiss Roll:

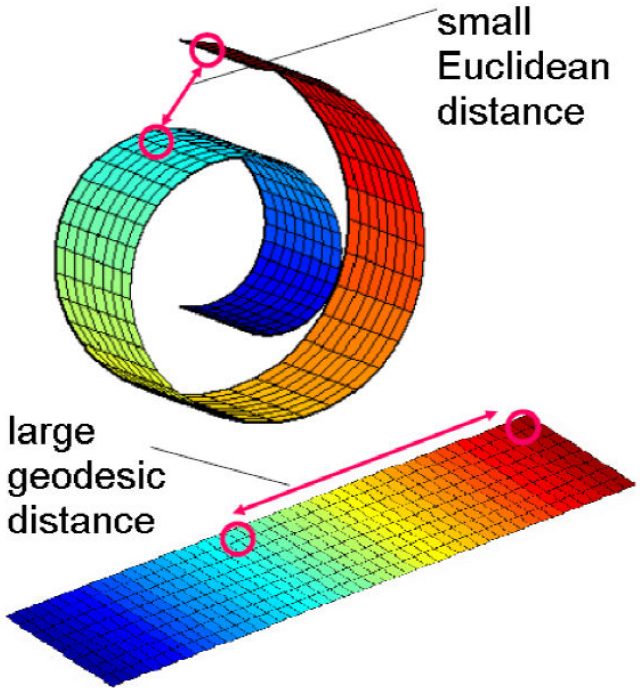
$x=\varphi\cos(\varphi)$, $y=\varphi\sin(\varphi)$, $z=\psi$

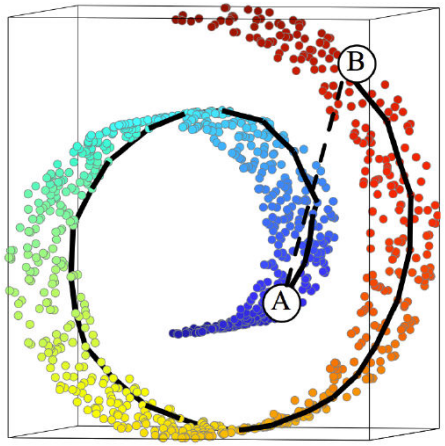
$1.5\pi \le \varphi \le 4.5\pi$, $0 \le \psi \le 10$

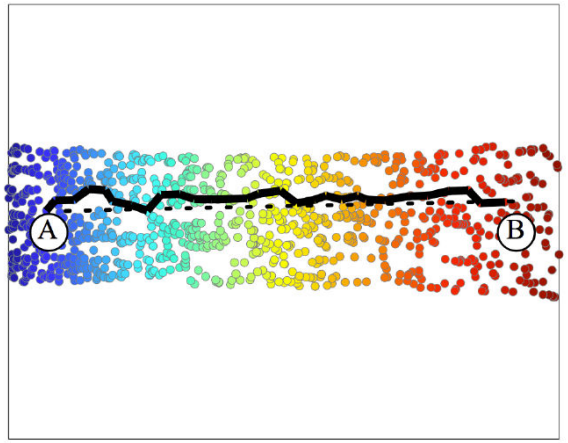
Manifold: 2D rectangle

generated by two latent variables φ, ψ

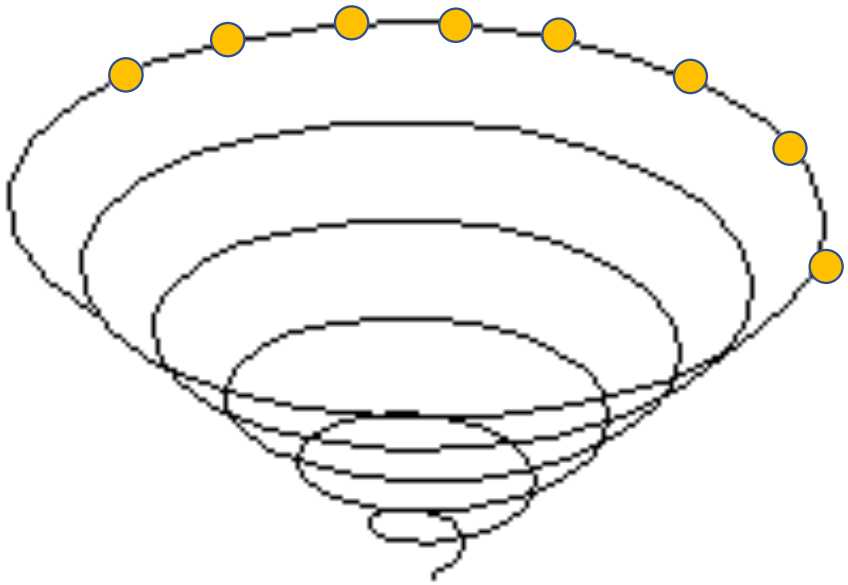
Geodesic Distance on Manifolds



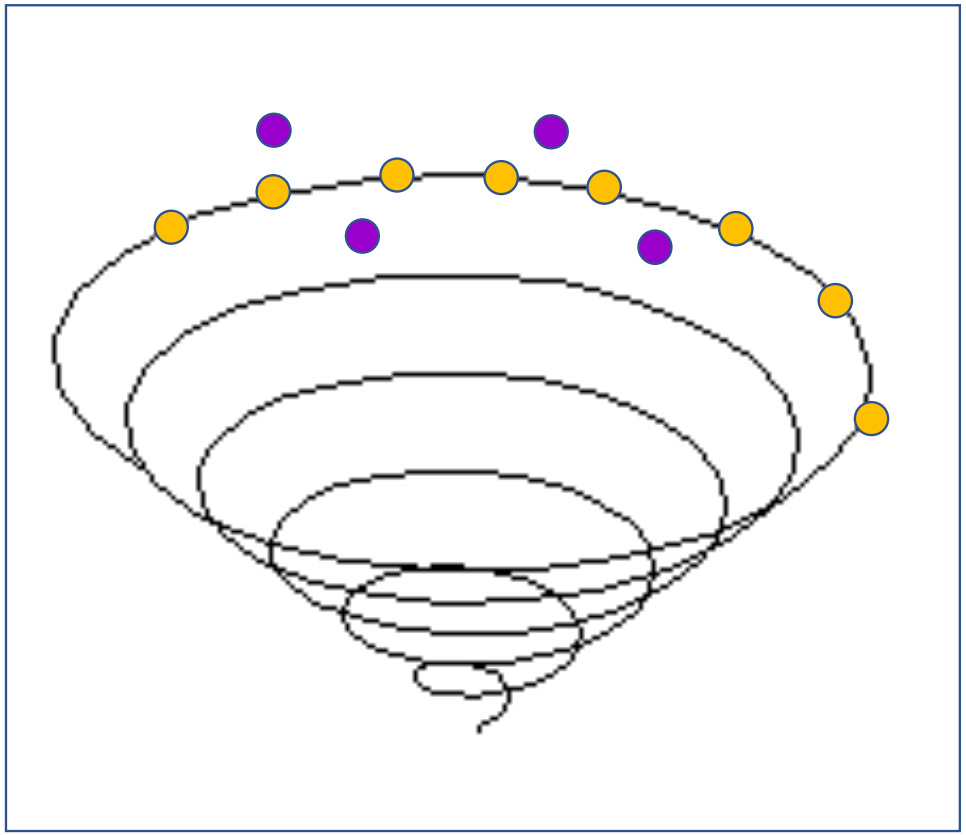




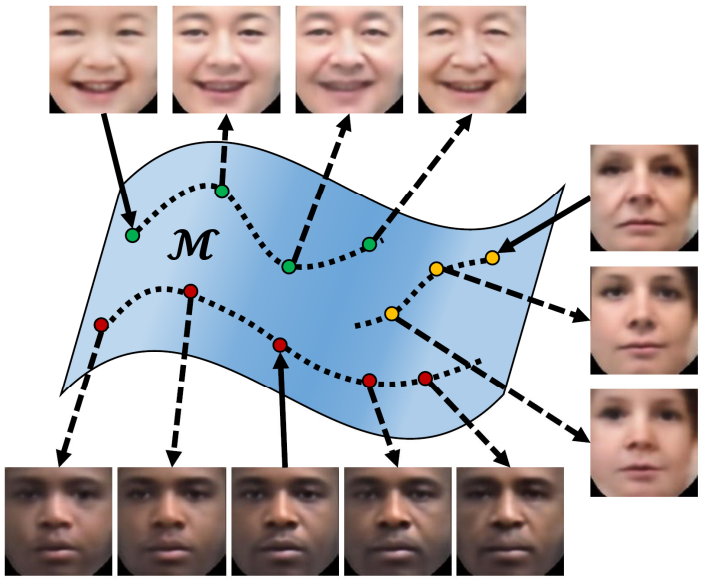
Samples in Data Space



Samples Close to the Face Manifold



2D Surface in 3D Space



特征提取变换
Feature Extraction

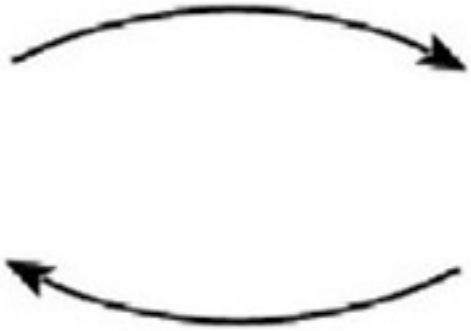


Image Generation
图像生成变换

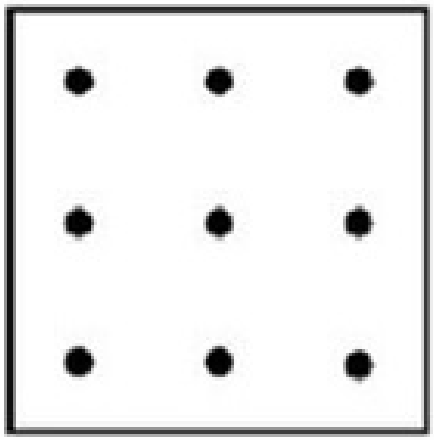


Image Space: 10^4–D

Feature Space: 10^2–D

Q & A

Thanks