Brief Introduction to Machine Learning

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What Is Machine Learning?

- A subfield of AI that is rapidly growing in importance.

- Performance of a system is improved based on learning experience.

- Learning from data.

Why Machine Learning?

- Abundance of data: the data deluge.

  – Scientific instruments.

  – Data acquisition devices.

  – Internet and the web.

  – All sectors of human society producing and digitizing data (e.g., your cell phone).

- Not enough human expertise or human power to make sense of such huge amounts of data.

Machine Learning in the News

IBM's Watson   Google DeepMind's AlphaGo

- IBM's Watson beats human champions: Jeopardy (game show)

- Google detects cats from YouTube videos.

- Google Glass app recognizes people it sees.

- Legal, medical, financial applications.

- Google DeepMind: Atari 2600 game playing, AlphaGo, AlphaStar

What Does It Take to do ML?

A lot of math:

- Linear algebra

- Calculus

- Probability and statistics

- Differential geometry

- Numerical methods

Types of Machine Learning

1. Supervised learning

   - Input-Target pairs

   - $\{\langle \vec{x}_i, \vec{t}_i \rangle | i = 1, 2, .., n\}$
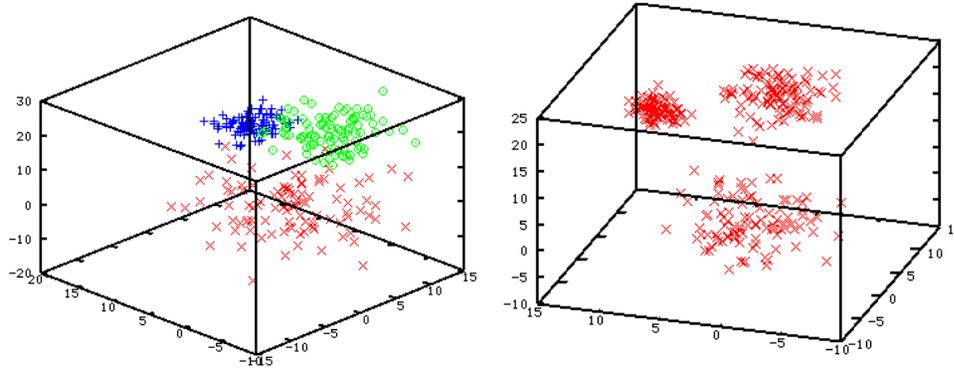
2. Unsupervised learning

   - A bunch of inputs (unlabeled)

   - $\{\vec{x}_i | i = 1, 2, ..., n\}$

3. Reinforcement learning

   - state$_1$ $\xrightarrow{\text{action}_1}$ state$_2$ $\xrightarrow{\text{action}_2}$ state$_3$, ... , reward

   - $s_{t+1} = \delta(s_t, a_t), r_{t+1} = \rho(s_t, a_t)$

Example Data

- Left: supervised

- Right: unsupervised

- Typically very high dimensional (10,000, 1 million [or more]).

High-dimensional Data

$\longrightarrow [240, 240, ..., 232, ...]$

2,500-D vector

- Images: these are 2D images, but ...

- These are 50×50 = 2,500-dimensional vectors.

    - Each such image is a single point in 2,500-dimensional space.
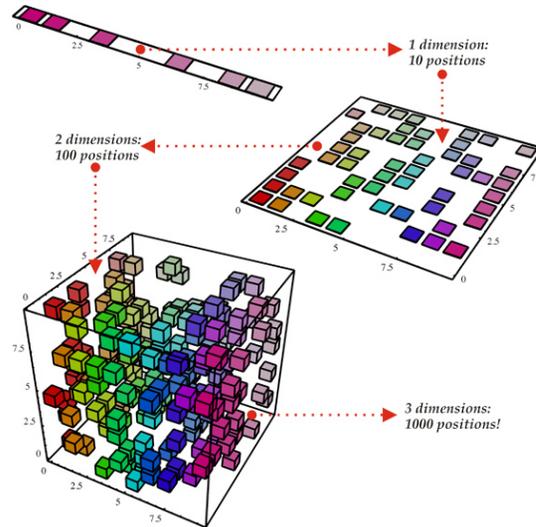
Supervised Learning

Supervised Learning

- Regression: approximating $y = f(x)$

- Classification: face recognition, hand-written character recognition, credit risk assessment, etc.

- Techniques:

  - Neural networks

  - Decision tree learning

  - Support vector machines

  - Radial basis functions

  - Naive Bayes learning

  - k-nearest neighbor

Supervised Learning Issues

- How well will it do on training inputs?

- How well will it do on novel inputs?

  – Generalization.

- How many samples needed for sufficient performance and generalization?

  – Sample complexity

  – Curse of dimensionality

  – Computational learning theory

- Catastrophic forgetting (online learning hard).

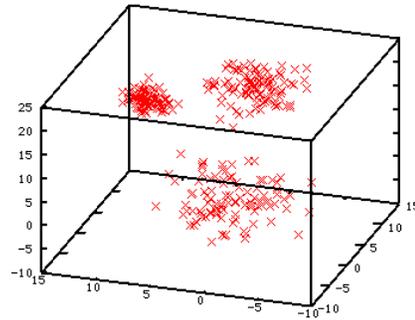# Addendum: Curse of Dimensionality

From: Yoshua Bengio's page

- Exponentially many points needed to achieve same density of training samples.

Unsupervised Learning

Unsupervised Learning

Clustering, feature extraction, blind source separation, dimensionality reduction, etc.

- Principal Component Analysis (PCA)

- Self-Organizing Maps (SOM)

- Independent Component Analysis (ICA)

- Multi-Dimensional Scaling (MDS)

- ISOMAP, Locally Linear Embedding (LLE)

- t-distr. Stochastic Neighbor Embedding (t-SNE)

Unsupervised Learning Issues

- Discovering structure.

- Discovering features.

- Removing redundancy.

- How many clusters?

- What distance measures to use?

Reinforcement Learning

Reinforcement Learning

- Very different from supervised and unsupervised learning.

- Multi agent control, robot control, game playing, scheduling, etc.

- Techniques:

  - Value function-based: Q-learning, Temporal difference (TD) learning

  - Direct policy search: Neuroevolution, genetic algorithms.

Reinforcement Learning Issues

- Discrete states and actions was a norm.

- Scalability an issue.

- Certain assumptions: state-action pair visited infinitely often.

- Online learning, safety, transfer, imitation, etc.

- Deep reinforcement learning disrupted a lot of the traditional assumptions.

Wrap Up

Summary

- Machine learning is a rapidly developing field with great promise:

  - Big data

  - Deep neural networks

  - Fast computing: GPGPU, cloud, etc.

- Three types of ML:

  - Supervised learning

  - Unsupervised learning

  - Reinforcement learning

- Need to look beyond ML:

  - ML good at solving problems, but not posing problems (Choe and Mann 2012).