



UNIVERSITY OF GEORGIA

CSCI/ARTI 4530/6530: Introduction to Robotics

Guest Lecture: An Overview of Machine Learning

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What is Machine Learning?

- One formal definition of *machine learning algorithms*:

"A computer program is said to **learn** from **experience E** with respect to some class of **tasks T** and **performance measure P** if its performance at tasks in T, as measured by P, **improves** with experience E."

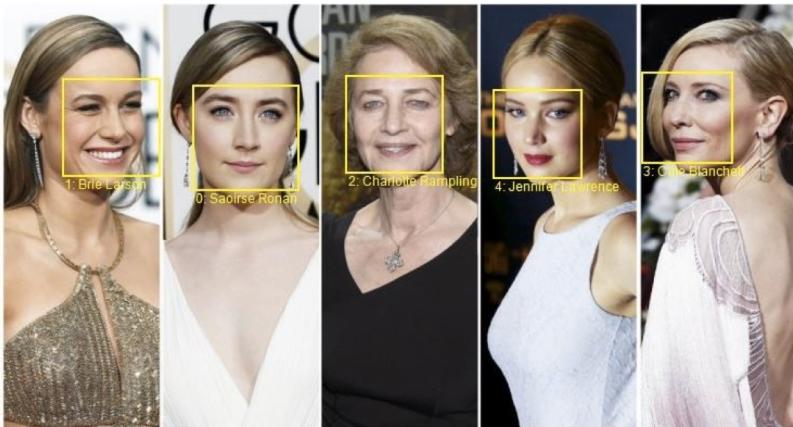
----Tom M. Mitchell

- *Experience E*: data, labels, etc.
- *Tasks T*: image classification, activity prediction, etc.
- *Performance measure P*: accuracy, speed, etc.

Machine Learning Applications

- Classification—*predict discrete class labels*

Face Recognition



Sentiment Classification

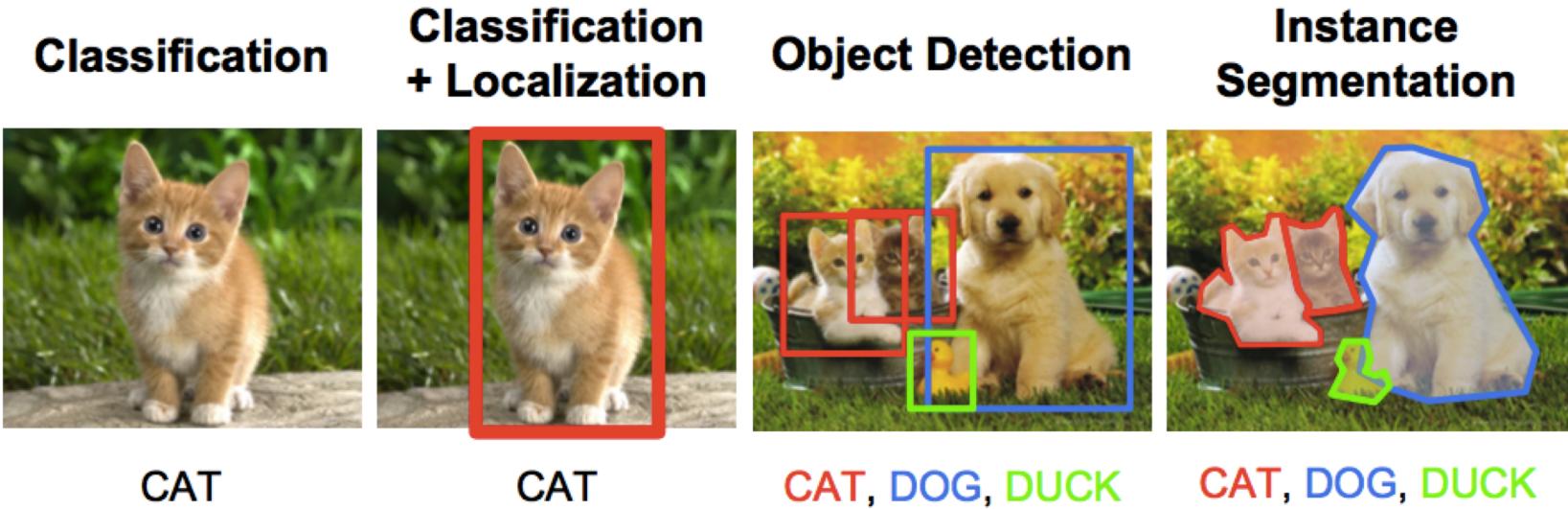


MS-Celeb-1M Challenge (2016)

Positive and Negative Online Reviews

Machine Learning Applications

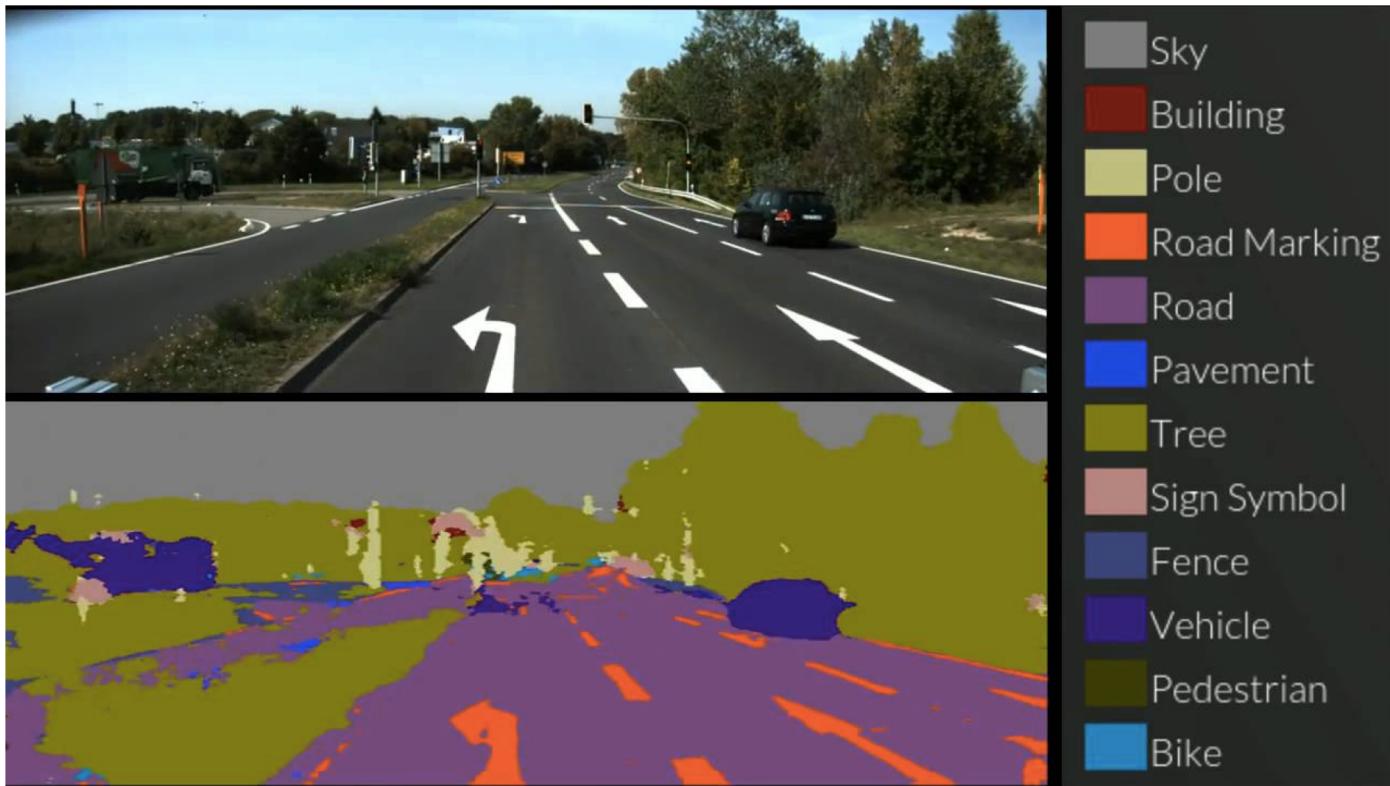
- **Classification**—*predict discrete class labels*



Computer Vision Example: Object Classification, Detection, and Segmentation

Machine Learning Applications

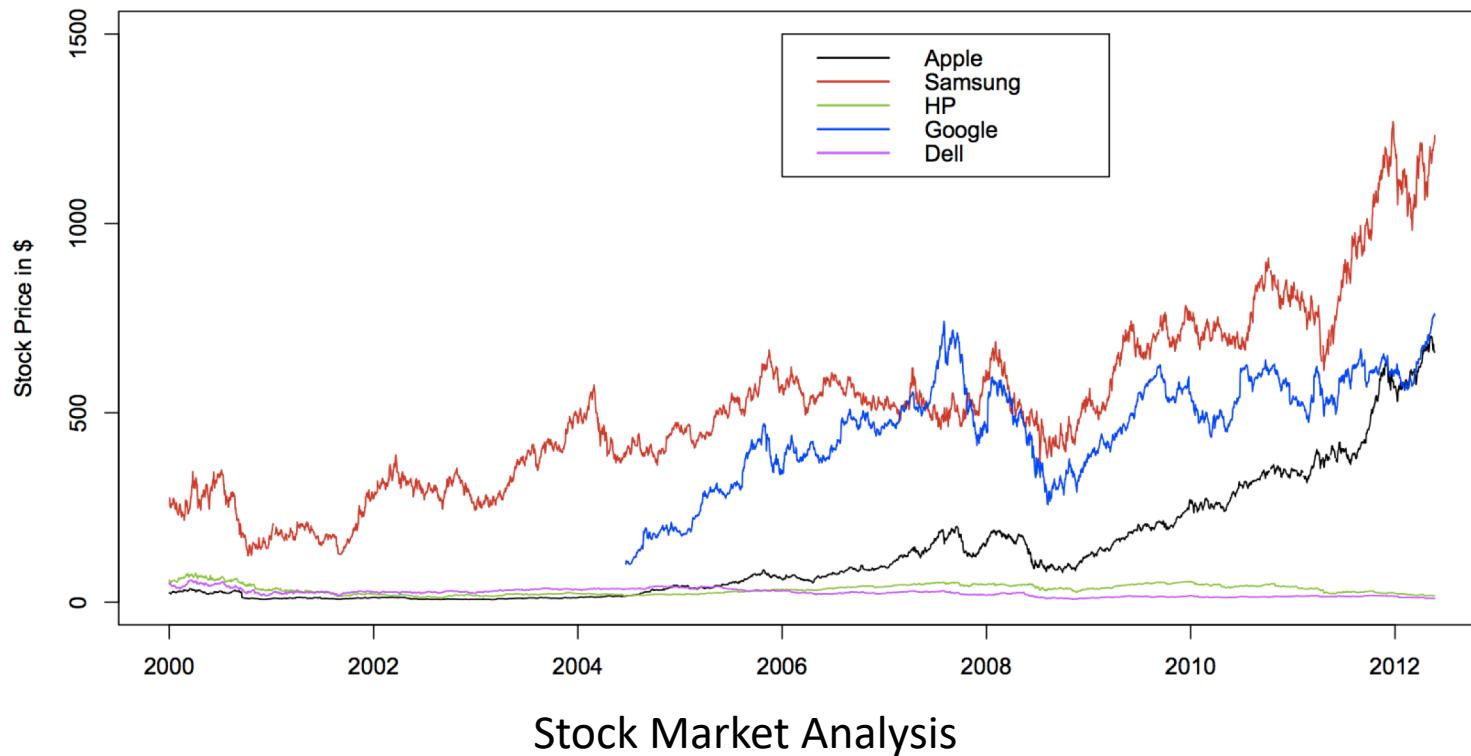
- Classification—*predict discrete class labels*



Computer Vision Example: Road Scene Understanding for Self-driving Car

Machine Learning Applications

- Regression—*predicting numeric values*



Machine Learning Applications

- Ranking—producing a permutation of items in the given list

Google

Google search results for "machine learning". The search bar shows "machine learning". Below it is a list of suggested queries: machine learning introduction, machine learning course, machine learning wiki, machine learning examples, machine learning applications, machine learning coursera, machine learning pdf, and what is machine learning used for. At the bottom, there are ads for "Reimagine Your Boardroom" and "Free BI Strategy Report".

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[Machine learning - Wikipedia](#)

https://en.wikipedia.org/wiki/Machine_learning ▾

Machine learning is a subset of artificial intelligence in the field of computer science that often uses statistical techniques to give computers the ability to "learn" (i.e., progressively improve performance on a specific task) with data, without being explicitly programmed.
[Machine Learning - Online machine learning](#) · [Outline of machine learning](#) · H2O

[Machine Learning | Coursera](#)

<https://www.coursera.org/learn/machine-learning> ▾

Machine learning is the science of getting computers to act without being explicitly programmed. In the past decade, machine learning.

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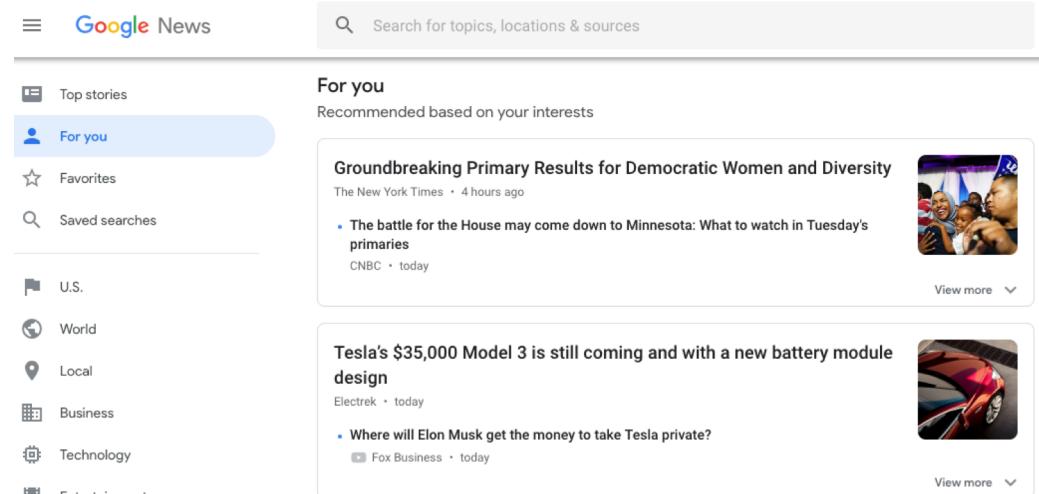
Machine Learning Applications

- Collaborative Filtering—*completing matrix with missing values*



John	Argo	The Usual Suspects	Seven	Heat
Tom	5	1	3	5
Alice	?	?	?	2
	4	?	3	?

Movie Recommendation



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Search for topics, locations & sources

For you

Recommended based on your interests

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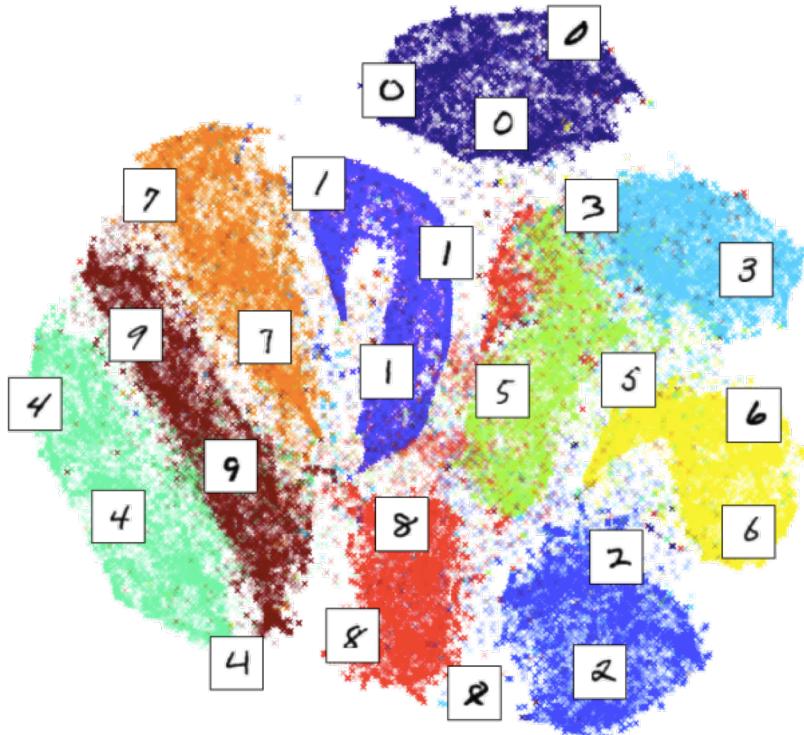
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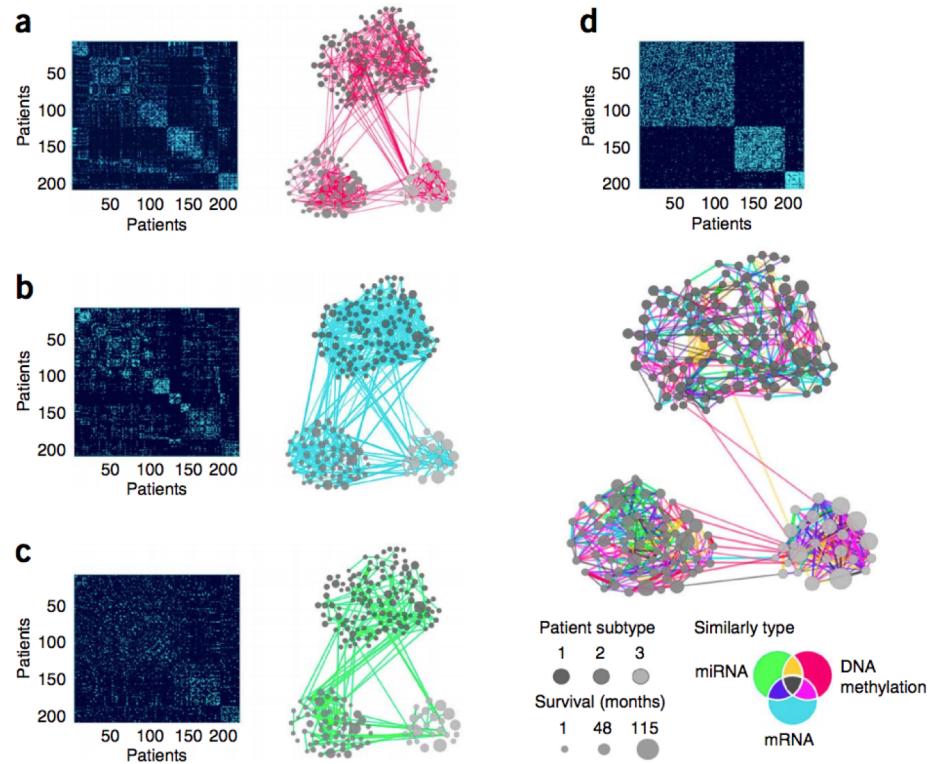
Google News Personalization

Machine Learning Applications

- Clustering—*discovering the underlying structure in data*



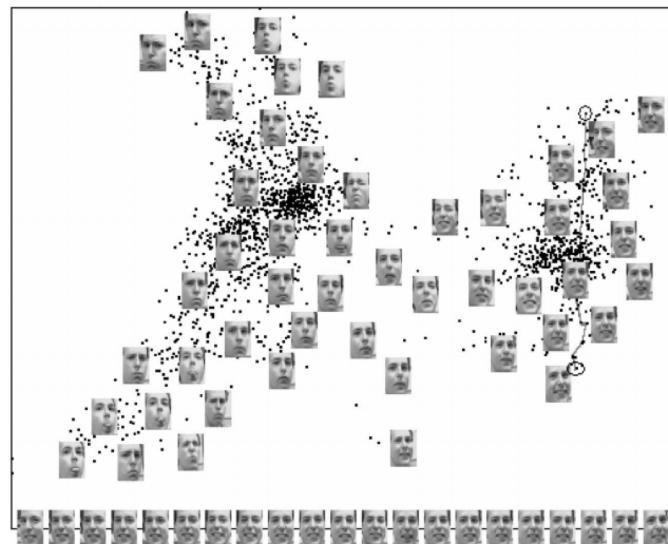
Clustering MNIST Digits



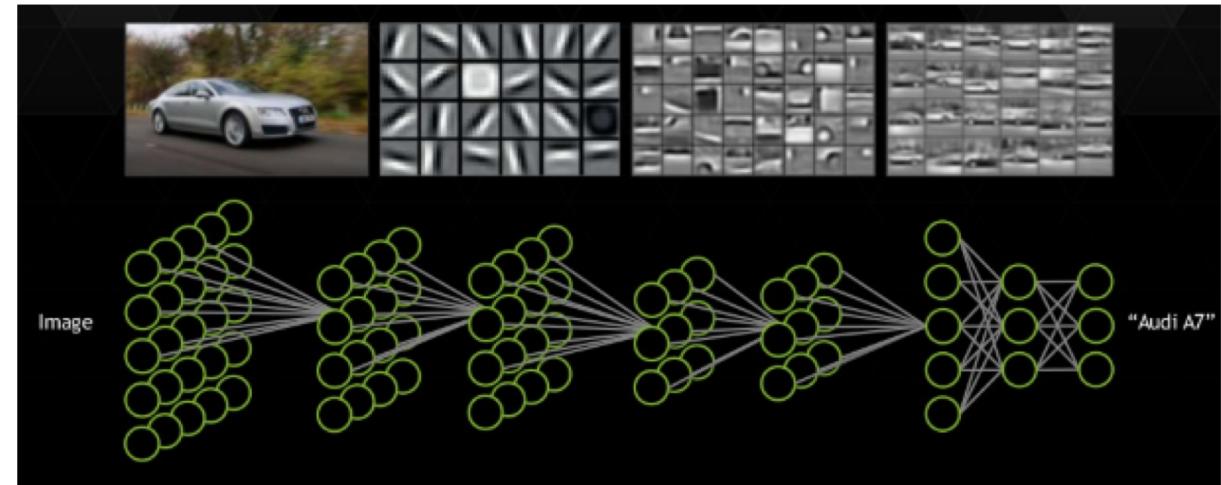
Patients Clustering (*Nature Methods*, 2014)

Machine Learning Applications

- **Representation Learning**—*extracting low-dimensional features from high-dimensional data*



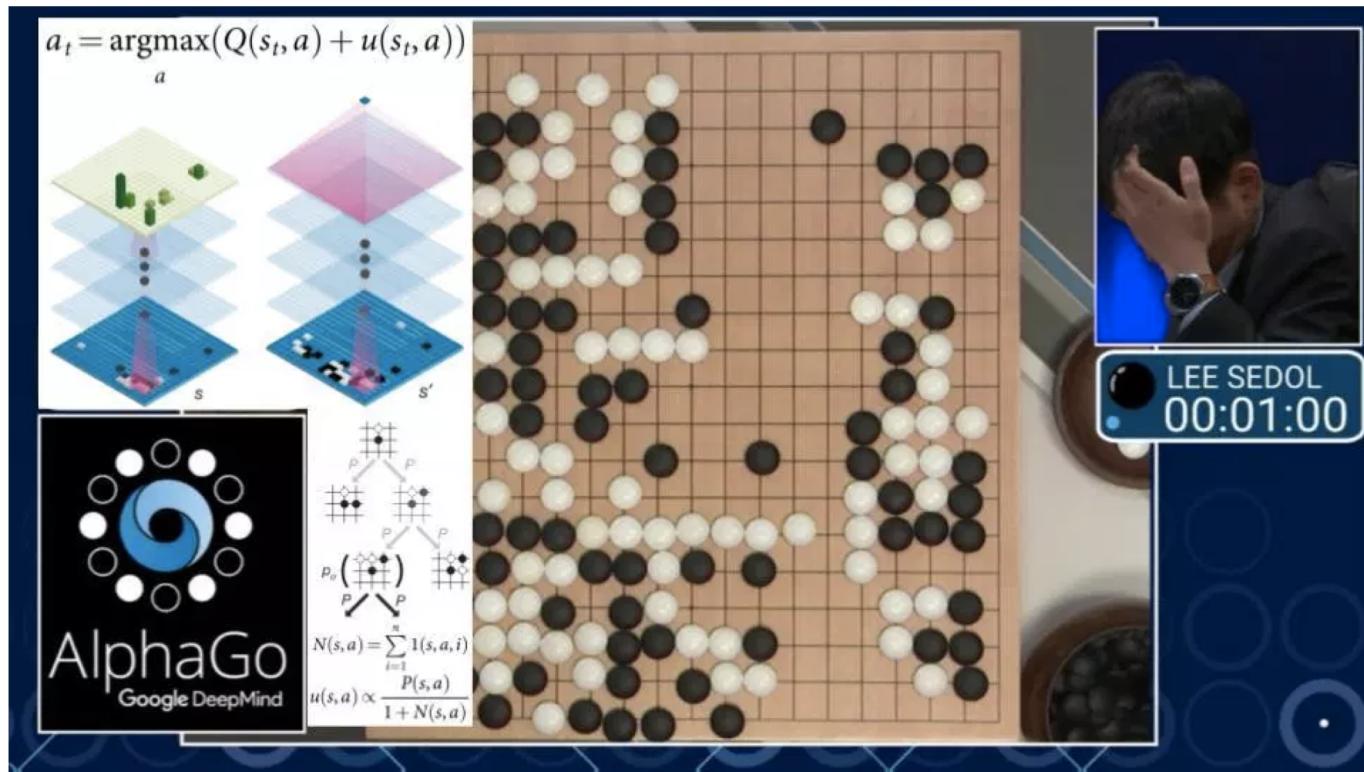
Manifold Embedding of Faces



Deep Representation Learning

Machine Learning Applications

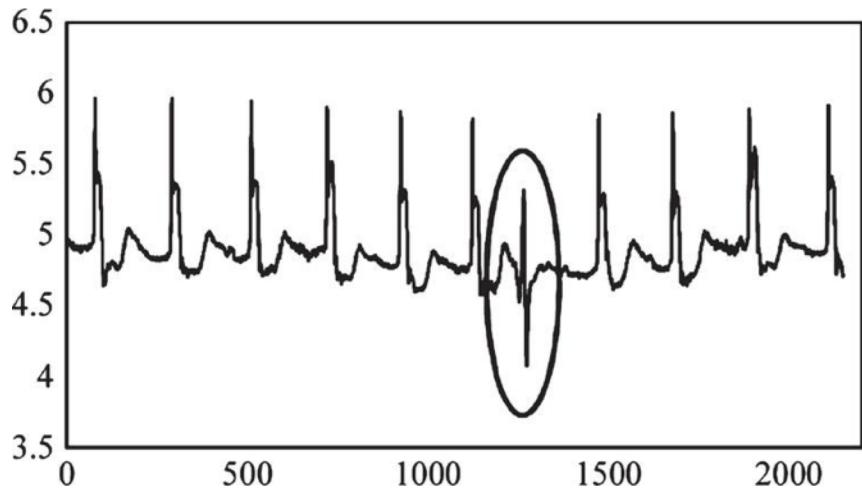
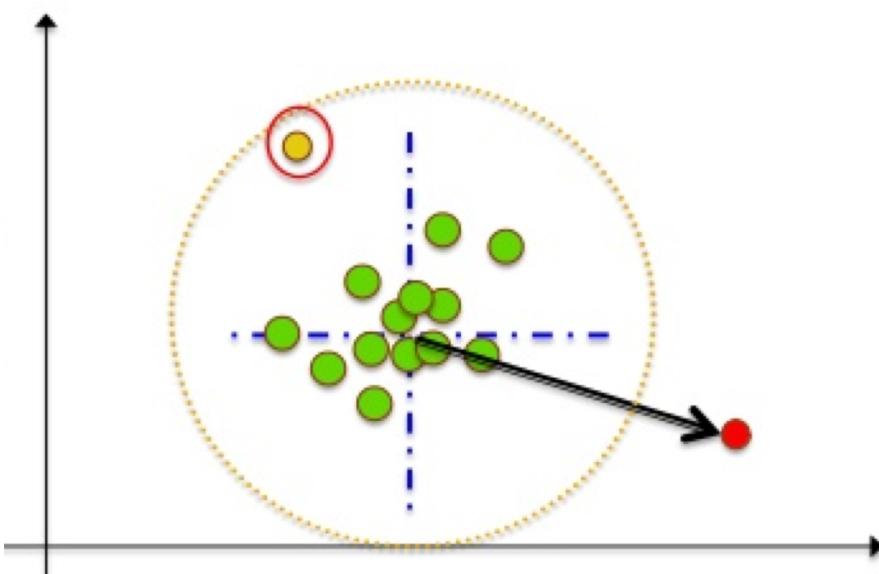
- Reinforcement Learning—*optimizing actions in an environment to maximize the reward*



AlphaGo by Google DeepMind

Machine Learning Applications

- **Anomaly Detection**—*identifying outliers in a given dataset*



Machine Learning: Classical Topics

- Supervised Learning
 - Classification
 - Regression
- Unsupervised Learning
 - Clustering
- Semi-supervised Learning
- Reinforcement Learning

Supervised Learning

- **Input:** Training set $\{(x_i, y_i) | i = 1, \dots, N\}$
- **Output:** A good approximation to $f: X \rightarrow Y$

Real-world examples of X and Y

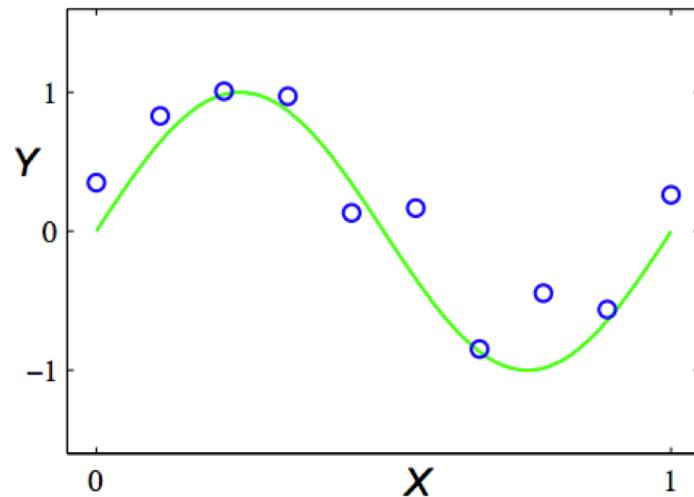
- House Price Prediction (*regression*)
 - X : historic prices; Y : new prices (continuous outputs)
- Spam detection (*binary classification*)
 - X : emails; Y : {Spam, Not Spam}
- Face Recognition (*multi-class classification*)
 - X : face images; Y : identity (a pre-defined set)

Supervised Learning

- **Input:** Training set $\{(x_i, y_i) | i = 1, \dots, N\}$
- **Output:** A good approximation to $f: X \rightarrow Y$

Regression

- Given 10 (x_i, y_i) data points with noise, the goal is to find function f to fit the data

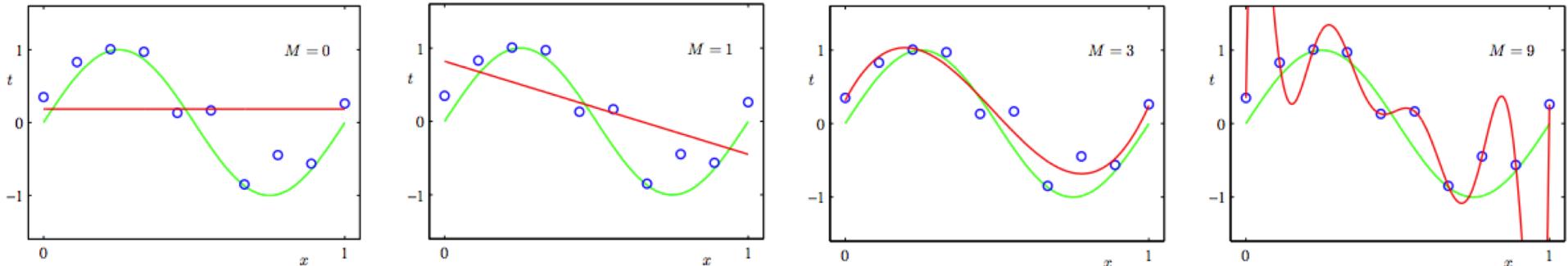


[Bishop]

Supervised Learning

Regression

- Given 10 (x_i, y_i) data points with noise, the goal is to find function f to fit the data



- To evaluate which one is the best, we need to measure error, using a loss function $L(Y, \hat{Y})$
- Squared **loss function** on the training data:

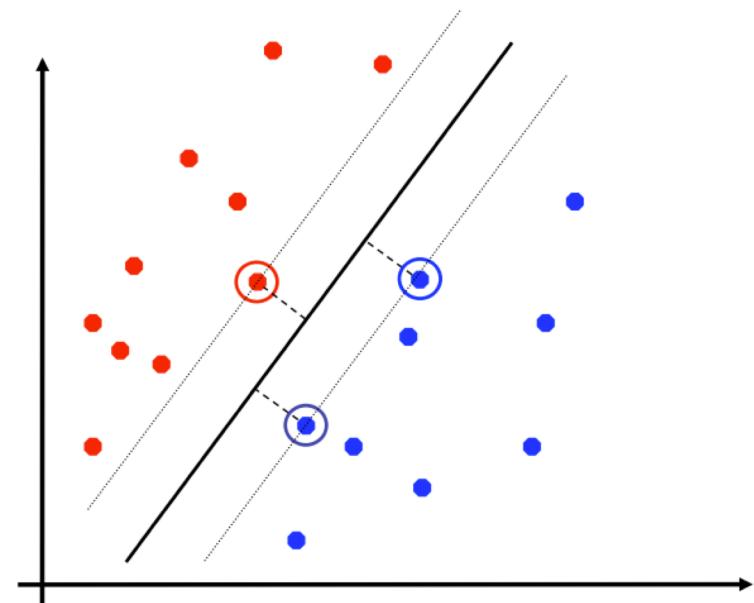
$$L(Y, \hat{Y}) = \frac{1}{N} \sum_{i=1}^N L(y_i, \hat{y}_i) = \frac{1}{N} \sum_{i=1}^N (y_i - f(x_i))^2$$

Supervised Learning

- **Input:** Training set $\{(x_i, y_i) | i = 1, \dots, N\}$, y_i are discrete labels
- **Output:** A good approximation to $f: X \rightarrow Y$

Classification

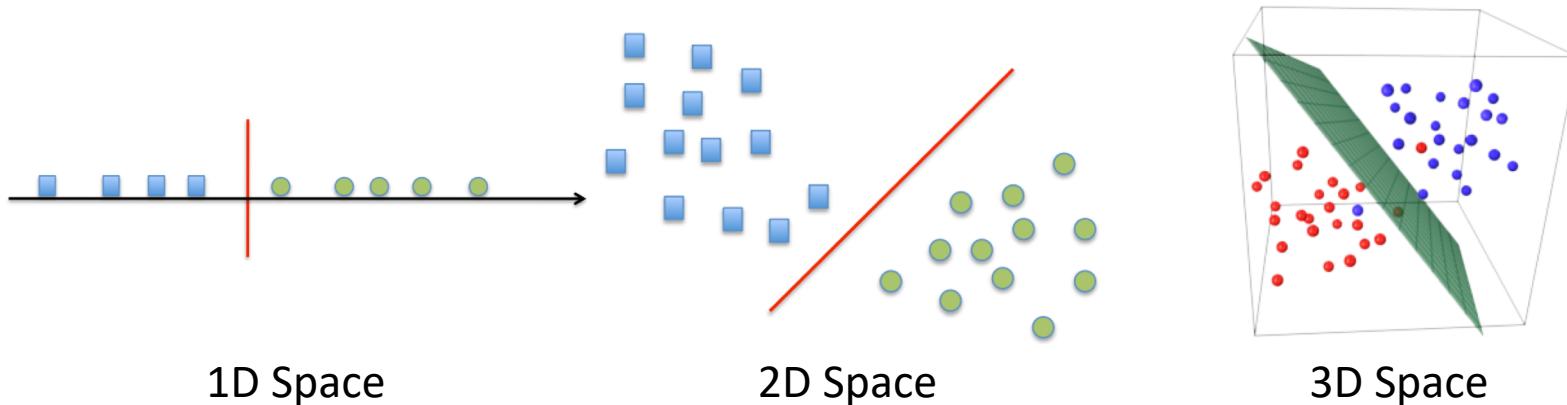
- Logistic Regression
- Support Vector Machines (SVM)
- Neural Networks



Supervised Learning

Classification

- Linear **Decision Boundary** in 1D, 2D and 3D Spaces



[Fidler]

- Binary classifier: $f(\mathbf{x}) = \text{sign}(\mathbf{w}_0 + \mathbf{w}^T \mathbf{x})$
- Loss functions

- Zero/one loss: $L(f(\mathbf{x}), y) = \begin{cases} 0 & \text{if } f(\mathbf{x}) = y \\ 1 & \text{if } f(\mathbf{x}) \neq y \end{cases}$
- Squared loss: $L(f(\mathbf{x}), y) = (y - f(\mathbf{x}))^2$

Unsupervised Learning

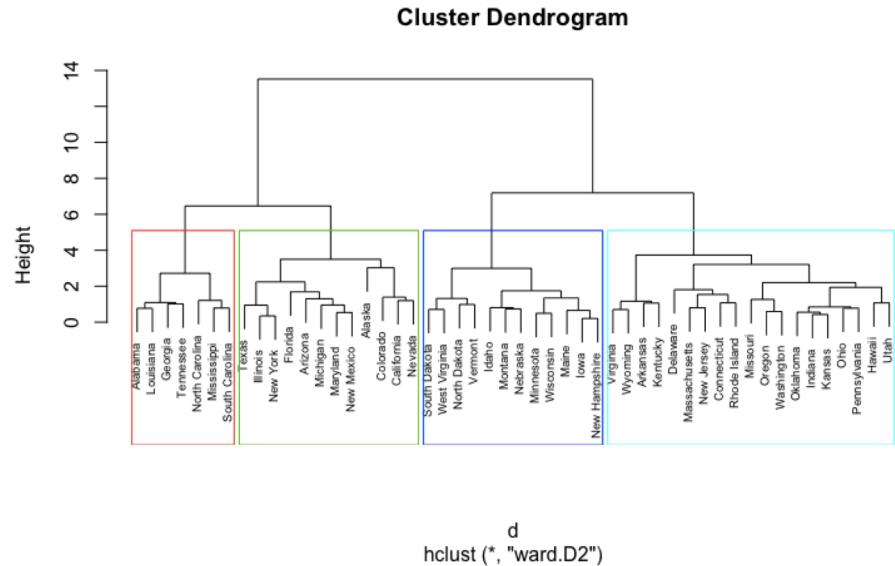
- **Input:** Training set $\{x_i | i = 1, \dots, N\}$
- **Output:** Structure of training set, e.g., clusters

Representative Approaches

- Clustering
 - Represent each sample using a prototype example
- Dimensionality Reduction
 - Represent each sample using a small number of variables (e.g., feature selection, feature extraction)
- Density Estimation
 - Estimate the probability distribution over the data space

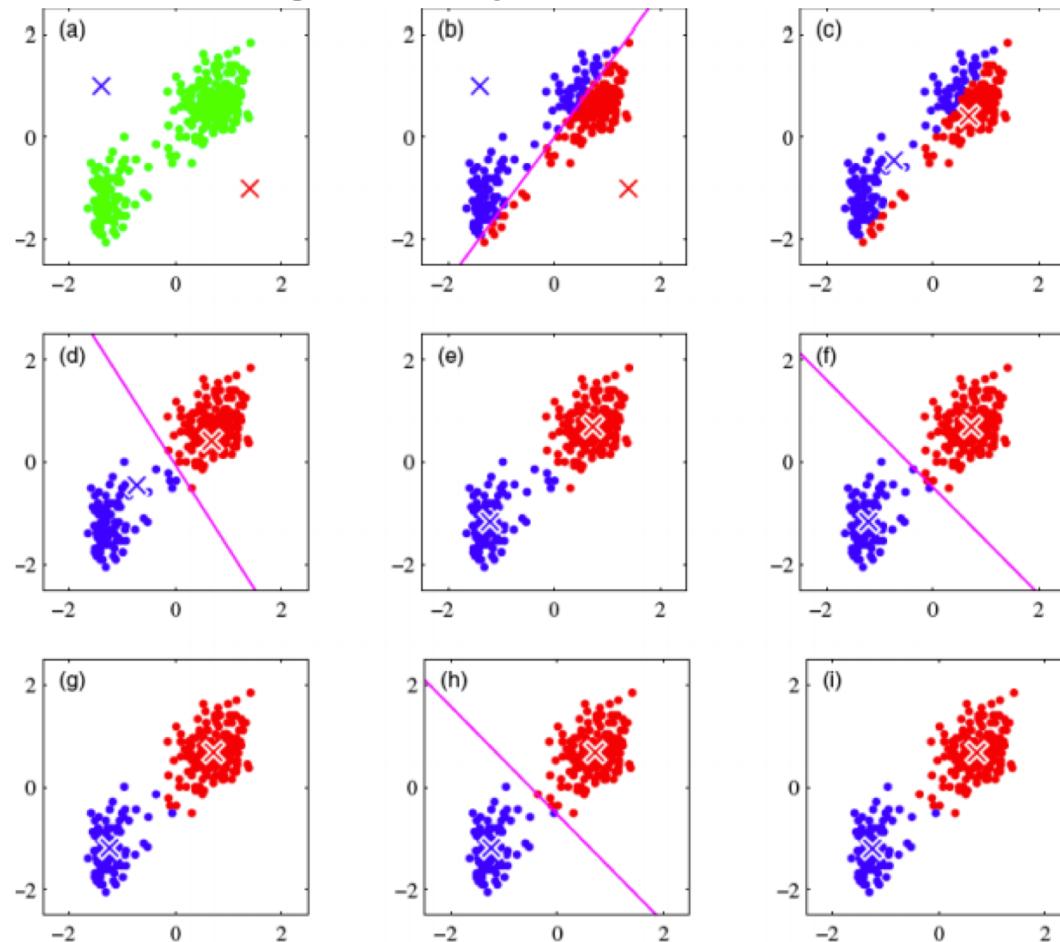
Unsupervised Learning

- **Clustering**
 - Grouping N samples into K clusters
 - We assume that the data were generated from a number of different classes (but, **how many?**)
- **Algorithms**
 - K-Means Clustering
 - Spectral Clustering
 - Hierarchical Clustering
 - Consensus Clustering
 - ...



Unsupervised Learning

- K-Means Clustering: Example

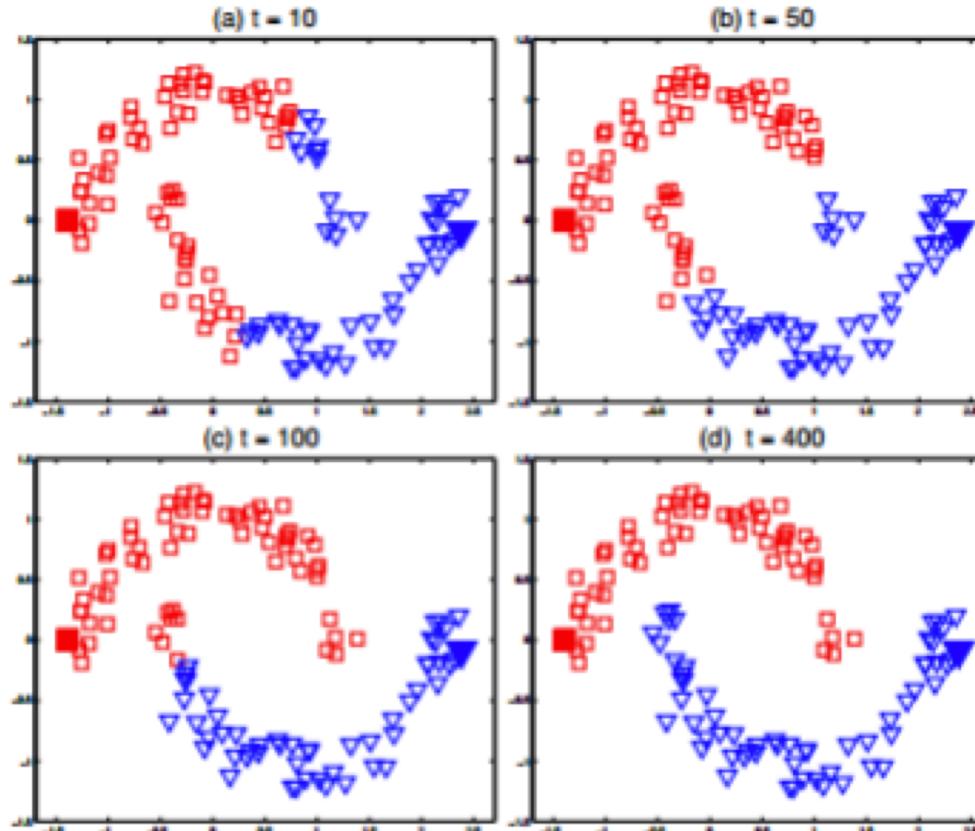


Semi-supervised Learning (SSL)

- **Input:** Training data include a **labeled** set, $\{(x_i, y_i) | i = 1, \dots, N_l\}$, and an **unlabeled** set $\{x_i | i = 1, \dots, N_u\}$
- **Output:** A good approximation to $f: X \rightarrow Y$
- Usually, the unlabeled set is *much larger* than the labeled set
- As labeling data is always expensive and time-consuming, SSL can take advantages of unlabeled data to boost the learning performance
- Approaches
 - Semi-supervised Regression
 - Graph-based Semi-Supervised Learning

Semi-supervised Learning (SSL)

- Graph-based Semi-Supervised Learning: Example



Label Propagation Results at Different Iterations

Model Evaluation

- How to evaluate how good is your model?

Supervised Learning Algorithms (e.g., classification)

- Classification accuracy
- Recall, Precision, ROC Curves
- F1 score, AUC score

Unsupervised Learning Algorithms (e.g., classification)

- Clustering accuracy (*if ground truth are available*)
- Normalized mutual information, NMI (*if ground truth are available*)
- Other internal measures

Other Advanced Topics

- Transfer Learning (supervised/unsupervised domain adaptation, multi-task learning, one-shot learning, zero-shot learning, etc.)
- Multi-view / Multi-source / Multimodal Learning
- Multi-label / Multi-instance Learning
- Online Learning
- Graphical Models, Generative Models
- Representation Learning
- Active Learning
- Reinforcement Learning
- Deep Learning
- ...

Top-tier Machine Learning Venues

Conferences

- Annual Conference on Neural Information Processing Systems (NIPS)
- International Conference on Machine Learning (ICML)

Journals

- Journal of Machine Learning Research (JMLR)
- IEEE Trans. Pattern Analysis and Machine Intelligence (T-PAMI)

Top Conferences in Related Areas

Incomplete List

- Artificial Intelligence: IJCAI, AAAI
- ML Conference with a focus on deep learning: ICLR
- Computer Vision: ICCV, CVPR, ECCV
- Natural Language Processing: ACL, EMNLP, NAACL
- Data Mining/Information Retrieval: KDD, SIGIR, WWW, CIKM, WSDM