

EE 1322: Intro to Electrical & Computer Engineering

Module 9: Intro to Machine Learning and Artificial Intelligence

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What is Machine Learning?

“Learning is any process by which a system improves performance from experience.”

- Herbert Simon

Definition by Tom Mitchell (1998):

Machine Learning is the study of algorithms that

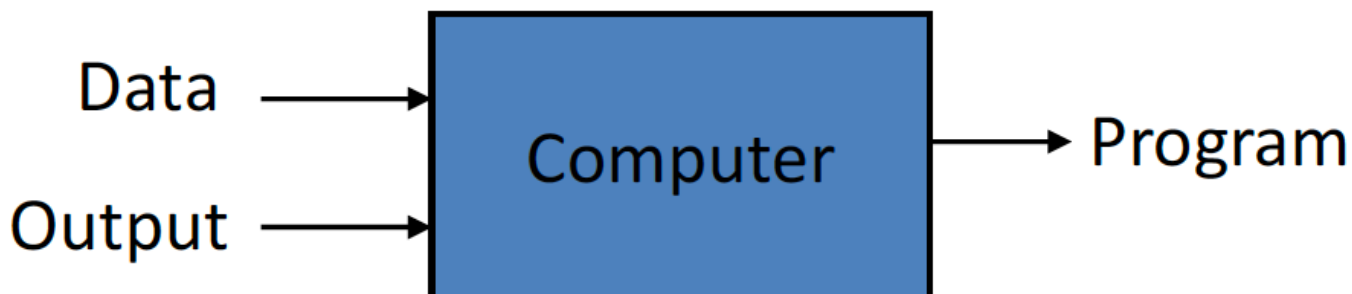
- improve their performance P
- at some task T
- with experience E .

A well-defined learning task is given by $\langle P, T, E \rangle$.

Traditional Programming



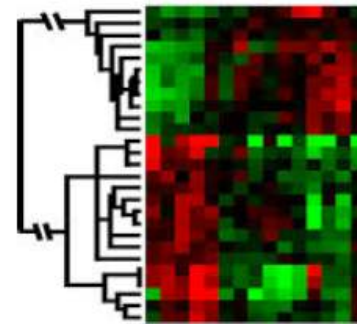
Machine Learning



When Do We Use Machine Learning?

ML is used when:

- Human expertise does not exist (navigating on Mars)
- Humans can't explain their expertise (speech recognition)
- Models must be customized (personalized medicine)
- Models are based on huge amounts of data (genomics)



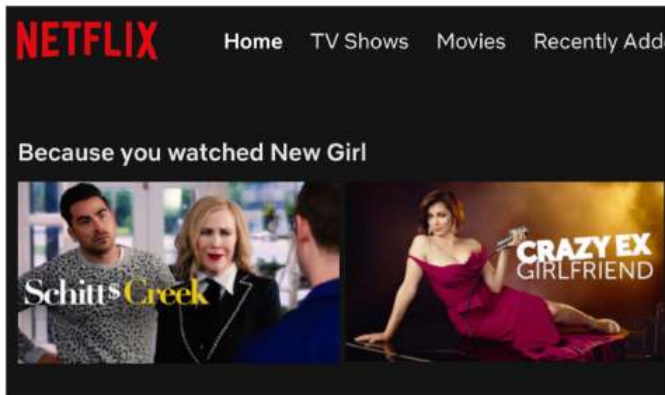
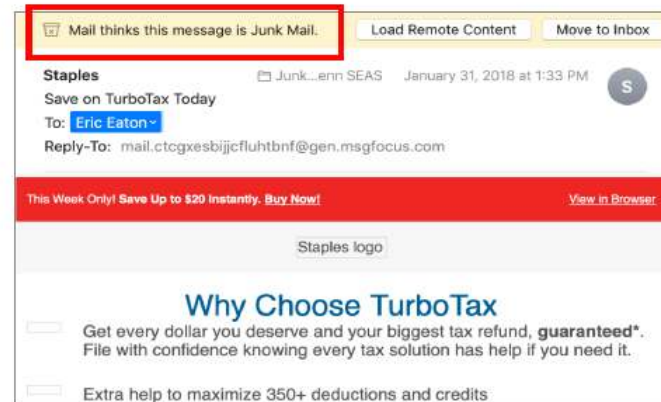
Learning isn't always useful:

- There is no need to “learn” to calculate payroll

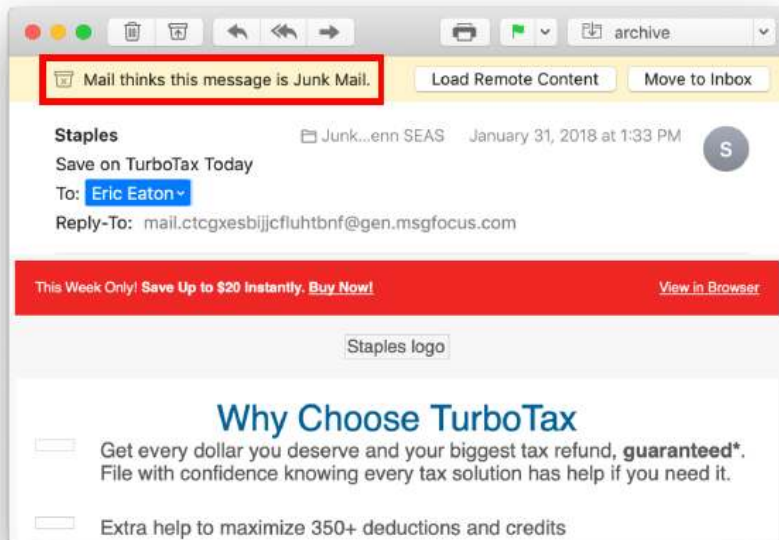
State of the Art in Machine Learning Applications



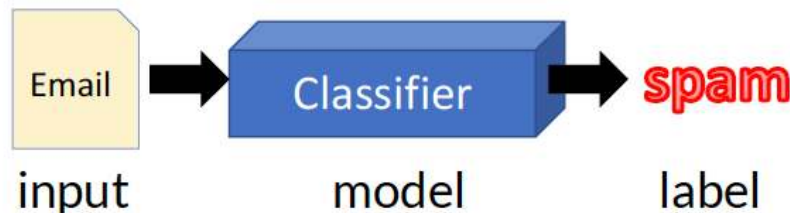
Machine Learning is Everywhere



Applications: Spam Detection

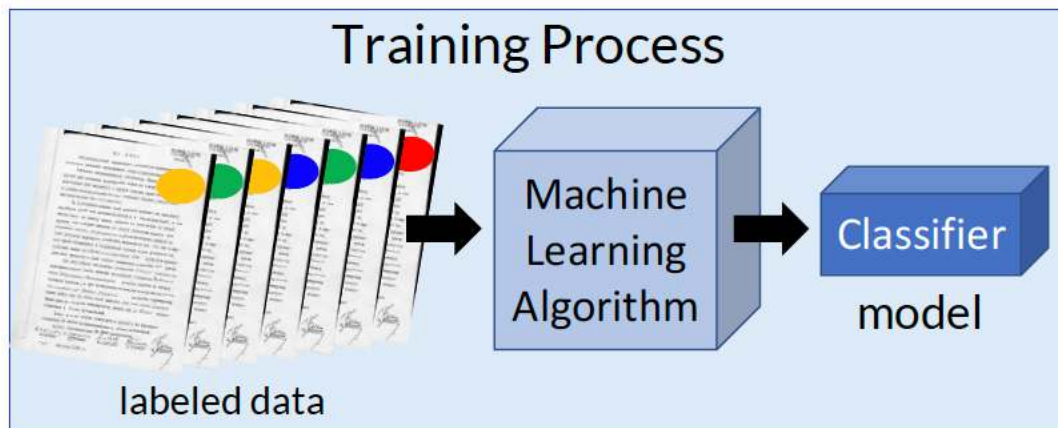
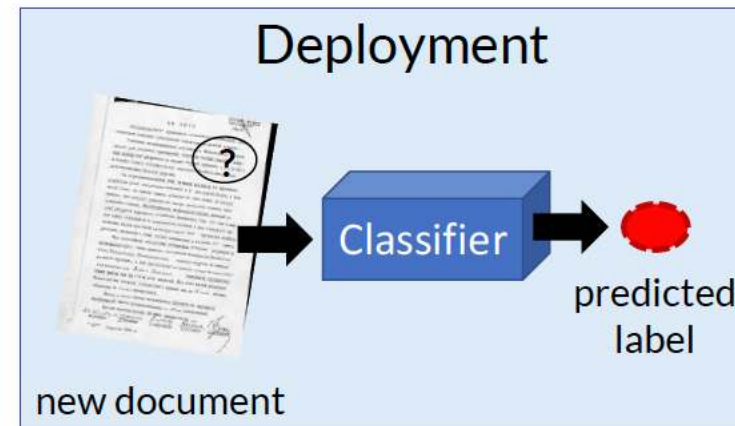


- This is a **binary classification task**: Assign **label** (i.e. spam/not-spam) to the **input** (an email message)
- Classification requires a **model** (a classifier) to determine which label to assign to input.



Applications: Document Classification

- This is a multi-class classification task:
 - Assign label (i.e. **Politics**, **Sports**, **Finance**, **Arts**) to the input



Applications: Document Classification

- This idea generalizes to many types of data and applications



Data

Documents

Sentences

Phrases

Images

Medical records

...

Labels

Politics, Sports, Finance

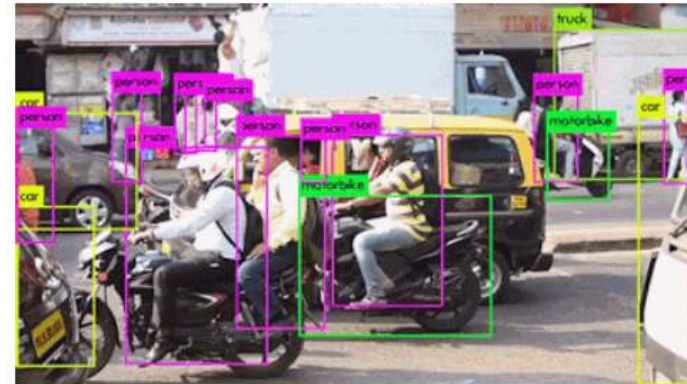
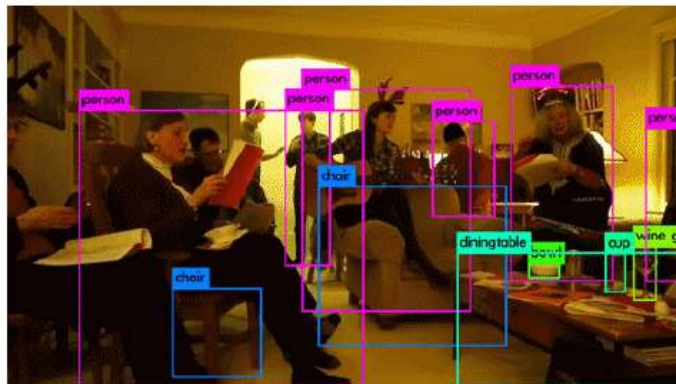
Positive, Negative

Person, Location

Cat, Dog, Snake, Horse

Re-admit soon/Not

Applications: Object Recognition



Autonomous Cars

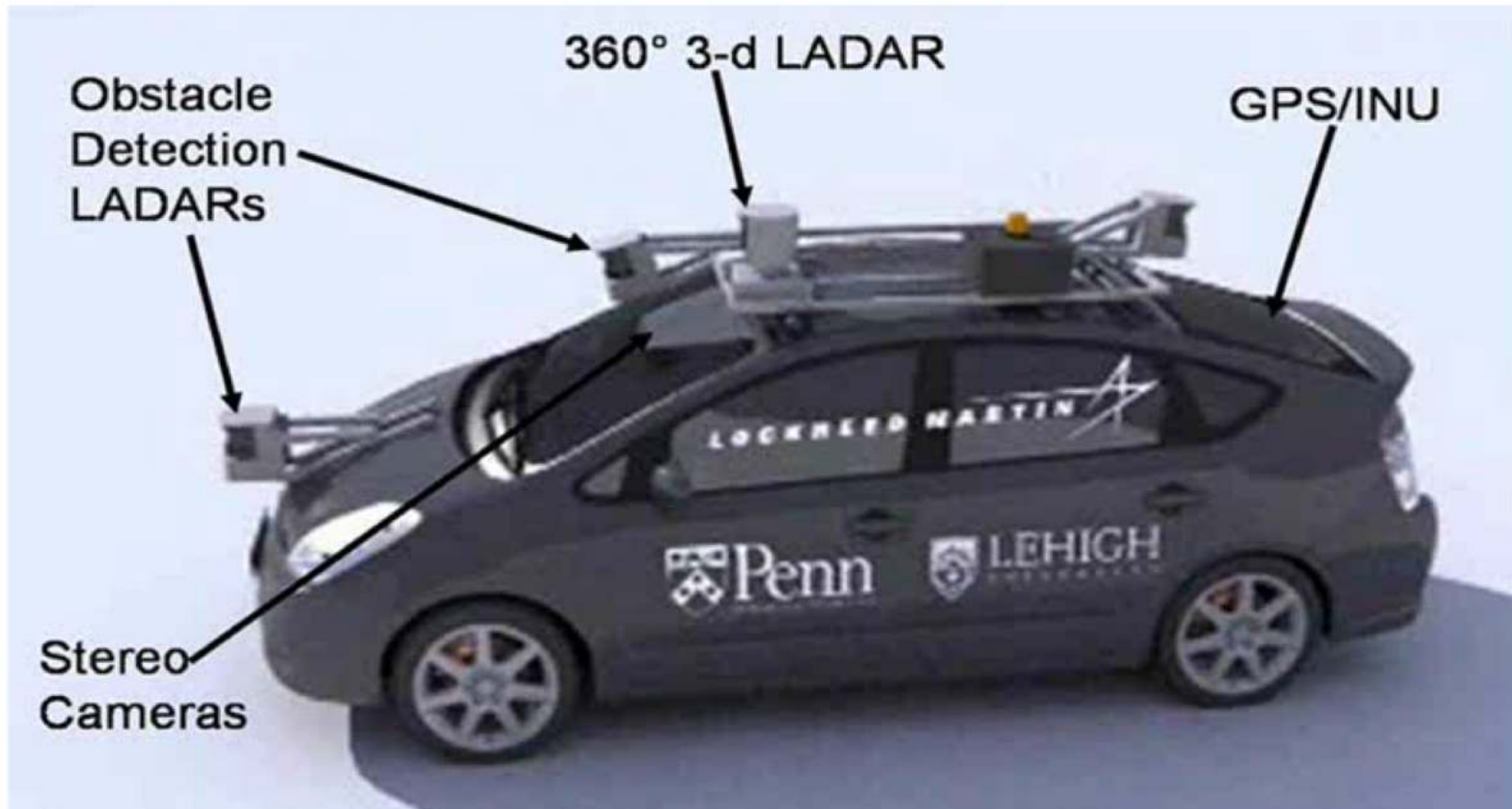


- Nevada was the first to legalize autonomous cars to drive on roads (in June 2011)
- As of 2019, 37 states have enacted legislation regarding autonomous cars

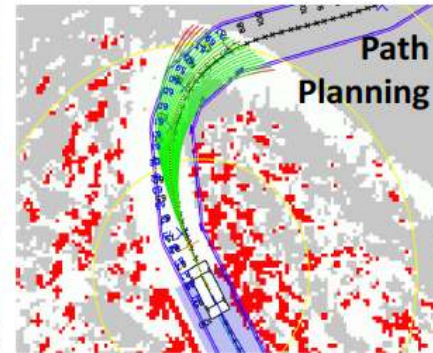
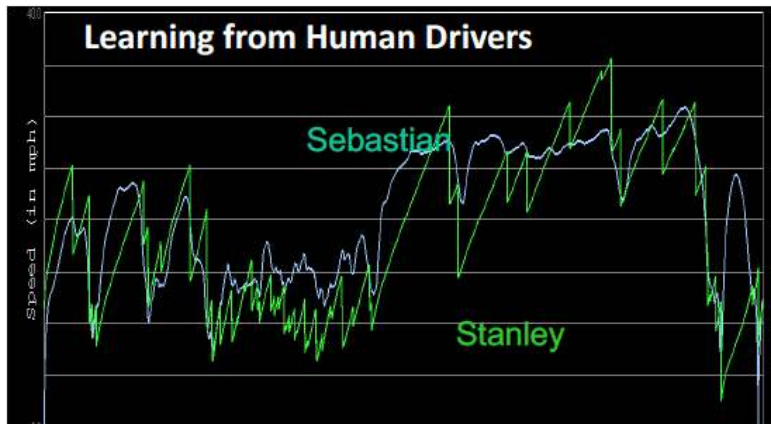


Penn's Autonomous Car

Autonomous Car Sensors



Autonomous Car Technology



Deep Learning in the Headlines



How elite investors use artificial intelligence and machine learning to gain an edge

By Matt Egan, CNN Business
Updated 11:14 AM ET, Sun February 17, 2019

Google has started using AI to build more advanced AI

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David Nield | ScienceAlert | 22 May 2017 11:44 AM | 1227



BloombergBusinessweek Technology

The Race to Buy the Human Brains Behind Deep Learning Machines

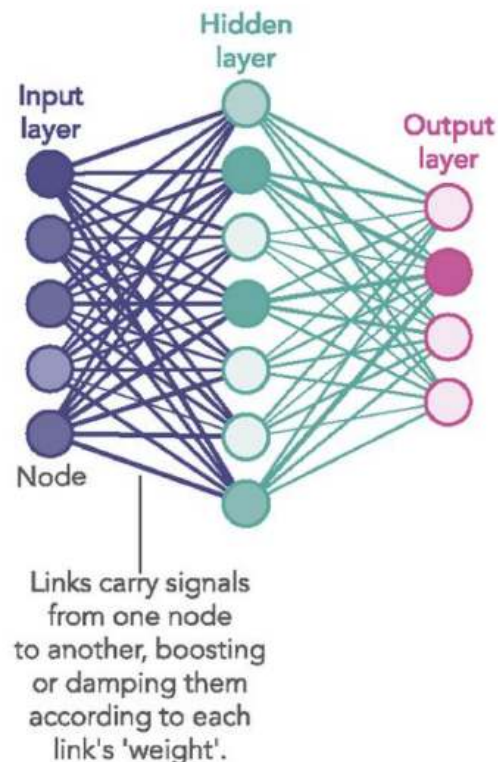
By Ashlee Vance | January 27, 2014

intelligence projects. "DeepMind is bona fide in terms of its research capabilities and depth," says Peter Lee, who heads Microsoft Research.

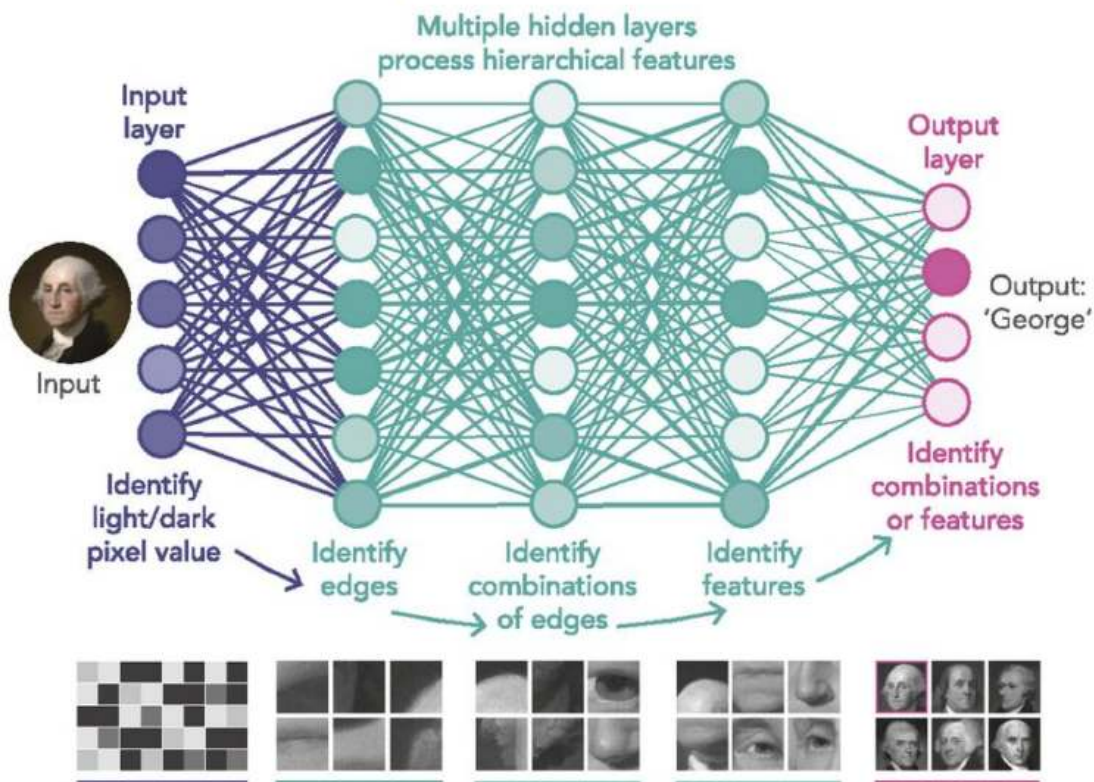
According to Lee, Microsoft, Facebook (FB), and Google find themselves in a battle for deep learning talent. Microsoft has gone from four full-time deep learning experts to 70 in the past three years. "We would have more if the talent was there to

Deep Networks Learn Layered Representations

1980s-Era Neural Network



Deep Neural Networks

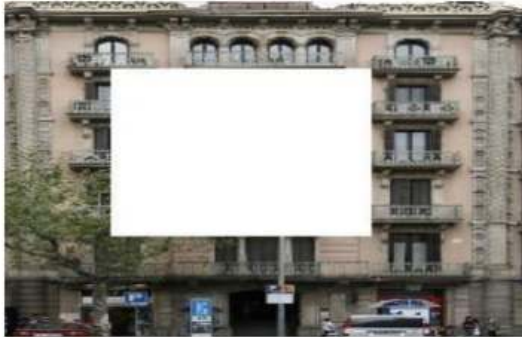
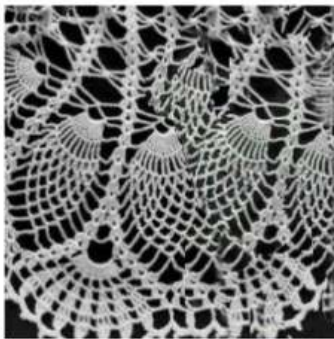


Scene Labeling via Deep Learning

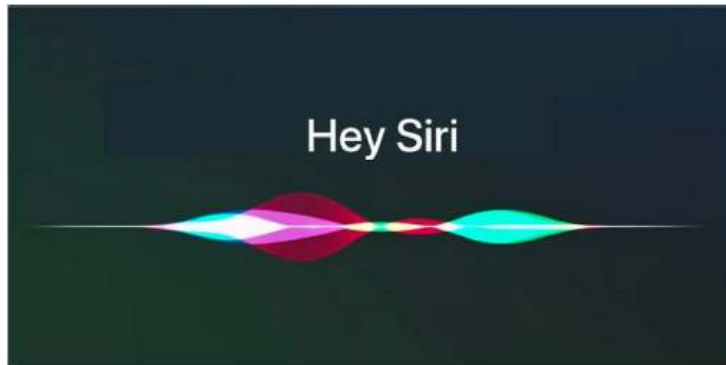
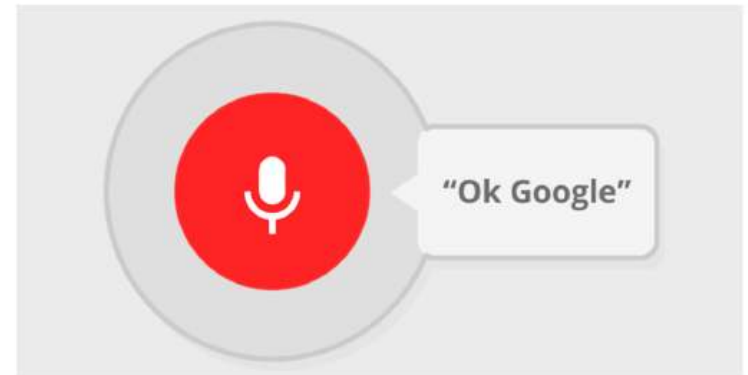


<https://www.youtube.com/watch?v=ZJMtDRbqH40>

Inference from Deep Learned Models



Impact of Deep Learning on Speech



Fakes



<https://thispersondoesnotexist.com/>

Deep Fakes



Alpha Go



Image: Google via Getty Images

Oct 2015: beat Fan Hui, Europe's top player
 Mar 2016: beat Lee Sedol (9-dan) 4:1 games
 2017: beat Ke Jie, the world #1-ranked player



Image Credit: Google

Sample Applications



Web Search



Computational
Biology



Robotics



Finance



Social Networks



Software
Debugging



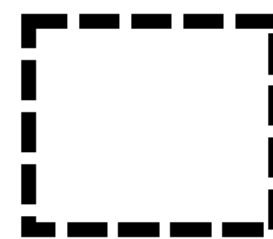
Space
Exploration



E-Commerce



Information
Extraction



Your Favorite
Area

Potential Definitions



“Learning is any process by which a system improves performance from experience.”

- Herbert Simon

“Learning denotes changes in the system that are adaptive in the sense that they enable the system to do the task or tasks drawn from the same population more efficiently and more effectively the next time.”

- Herbert Simon

Learning requires generalization: the ability to perform a task in a novel situation

Potential Definitions

Definition by Tom Mitchell (1998):



Machine Learning is the study of algorithms that

- improve their performance P
- at some task T
- with experience E

A well-defined learning task is given by $\langle P, T, E \rangle$

Examples:

T: Playing Chess (or Go)

P: Percent games won against an opponent

E: Playing games against itself

T: Classify emails as legitimate or spam

P: Percentage of emails labeled correctly

E: Repository of emails, some with human-specified labels

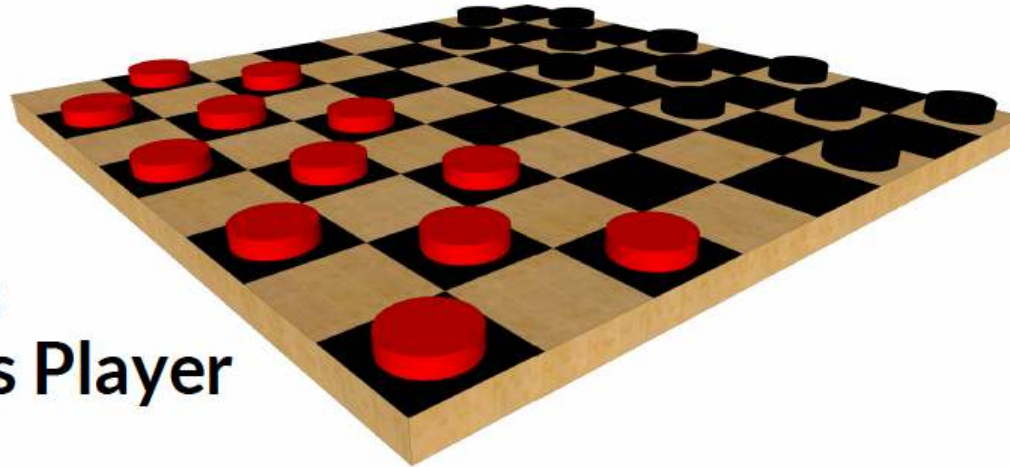
Potential Definitions



“Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed.”

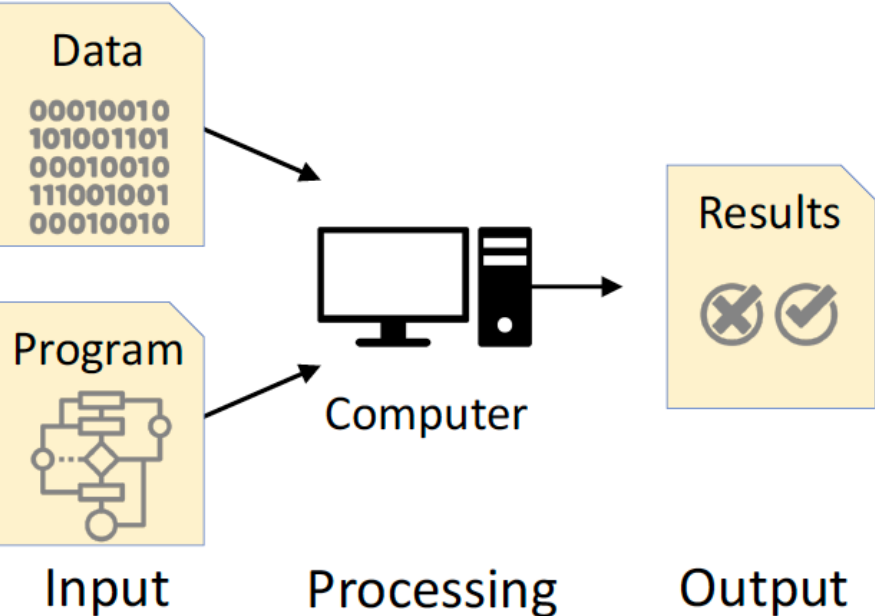
-Arthur Samuel (1959)

**Samuel's
Checkers Player**



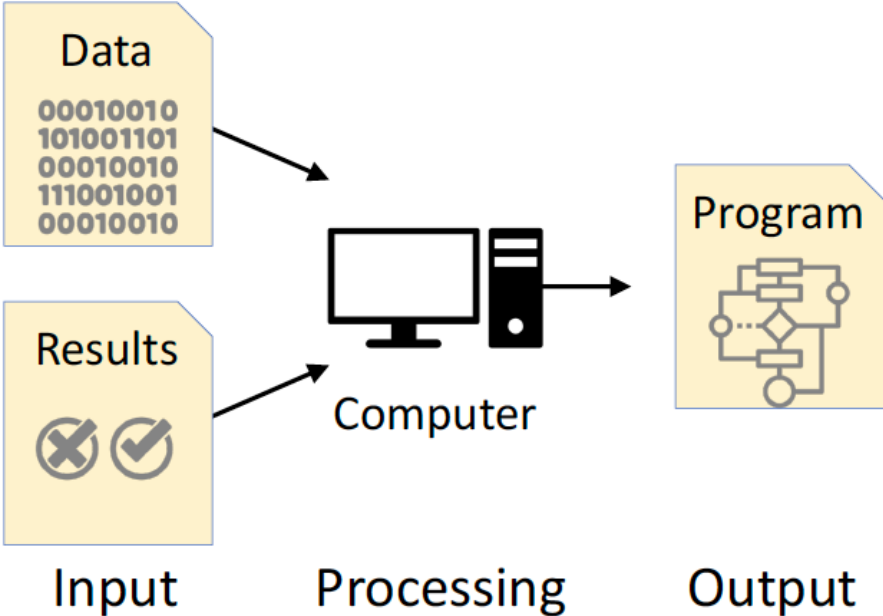
Traditional Programming

Works well when we know how to specify the program



Machine Learning

Needed when we don't know how to specify the program



When We Need Machine Learning

Tasks involving big data



- Genomics
- Internet search
- Anomaly detection

Tasks requiring customization



- Email filters
- Personalized medicine
- Image inpainting

Tasks for which it is challenging to specify our knowledge



- Facial recognition
- Understanding speech
- Medical diagnosis

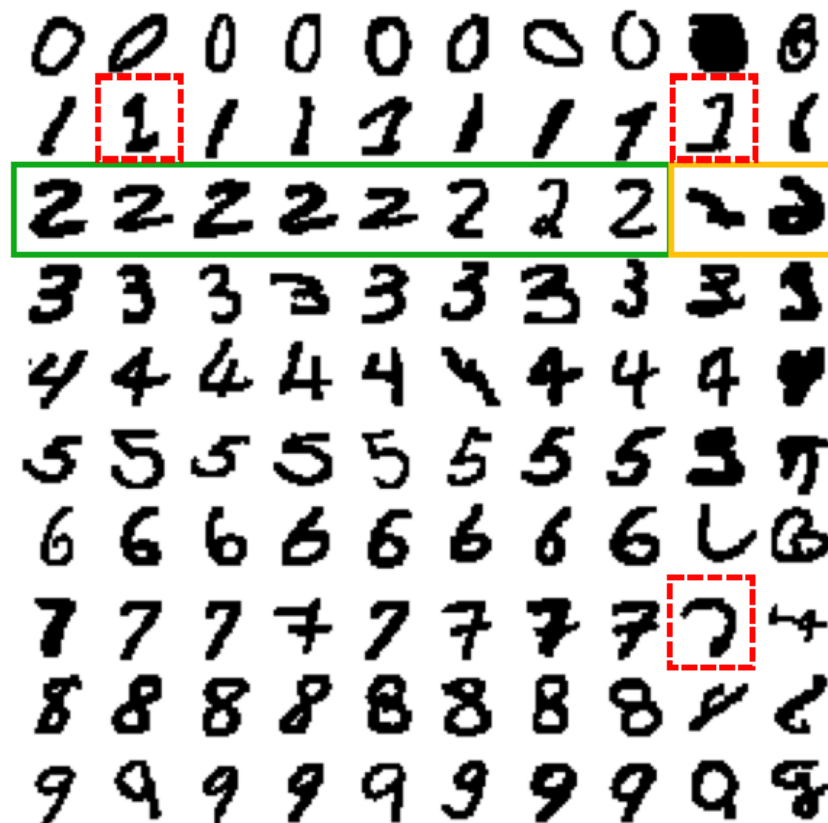
Tasks for which we don't have human expertise



- Space exploration
- Undersea manipulation
- Cellular robotics

Example Task: Digit Recognition

What is a '2'?



Types of Learning

Supervised (inductive) learning

- Given: training data + desired outputs (labels)

Semi-supervised learning

- Given: training data + some labels

Unsupervised learning

- Given: training data (without labels)

Reinforcement learning

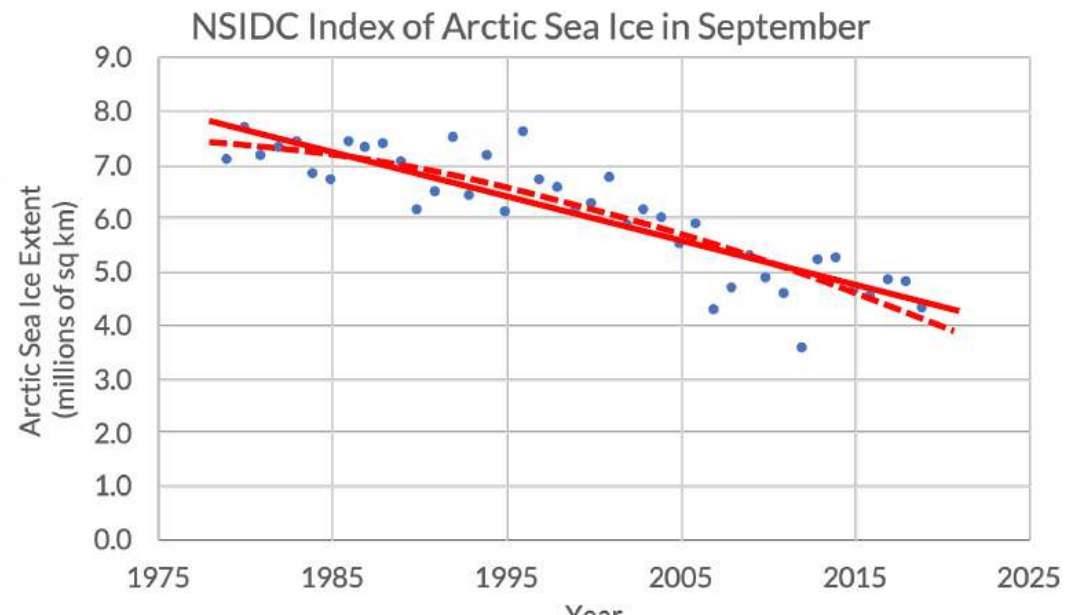
- Given: observations and periodic rewards as the agent takes sequential action in an environment

Supervised Learning: Regression



Supervised Learning: Regression

- Given $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$
- Learn a function $f(x)$ to predict y given x
 - y is numeric == regression



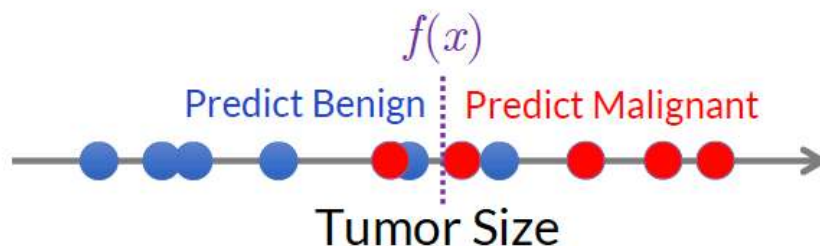
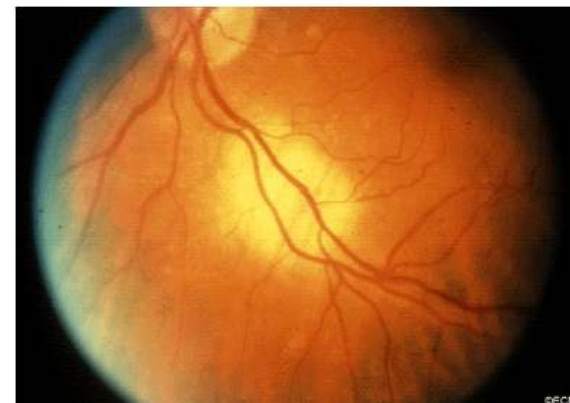
Supervised Learning: Classification

- Given $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$
- Learn a function $f(x)$ to predict y given x
 - y is categorical == classification

Ocular Tumor (Malignant / Benign)

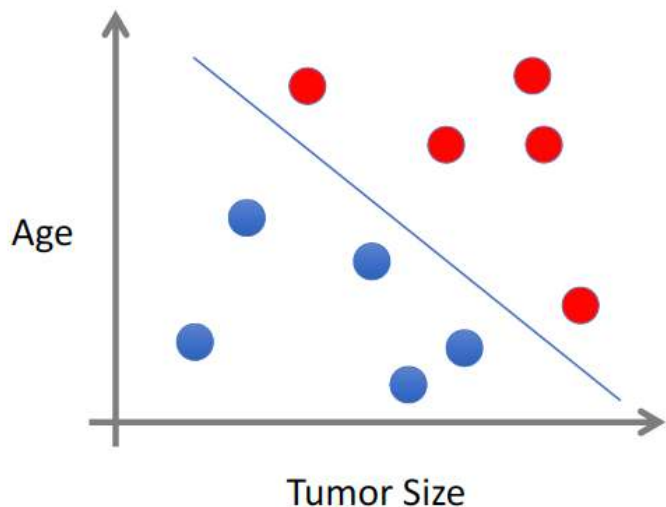
● Malignant

● Benign

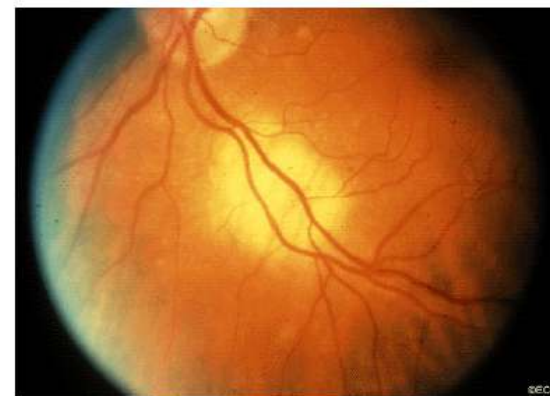


Supervised Learning

- x can be multi-dimensional
 - Each dimension corresponds to an attribute:



- Patient age
- Clump thickness
- Tumor Color
- Distance from optic nerve
- Cell type
- ...

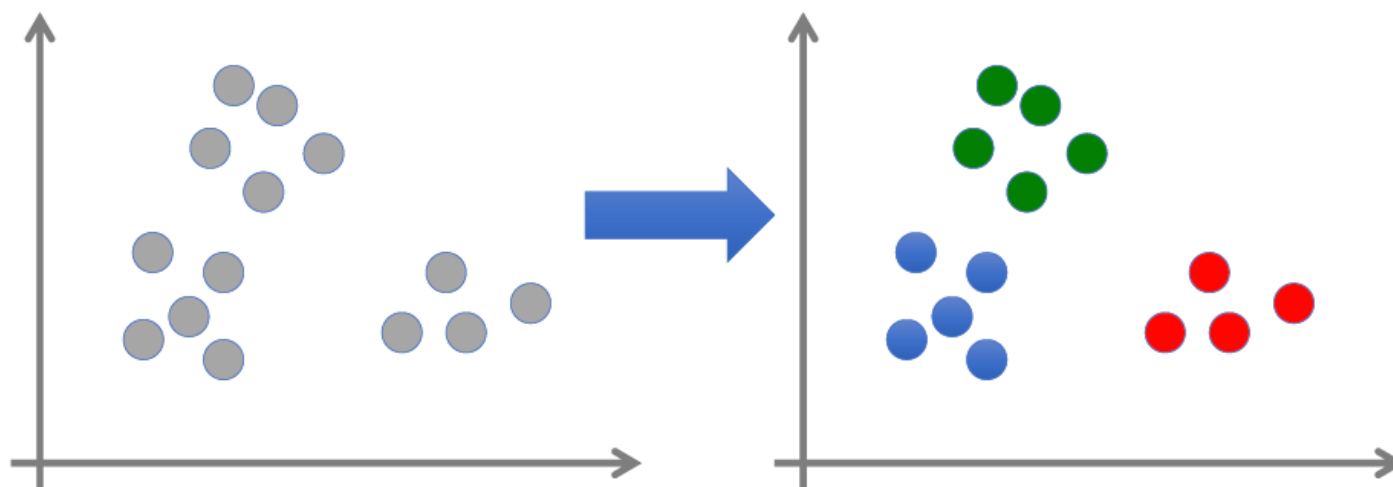


Cell type is the most telling feature, but it's risky to do a biopsy of the eye

- ML can help determine *when* a feature is needed

Unsupervised Learning

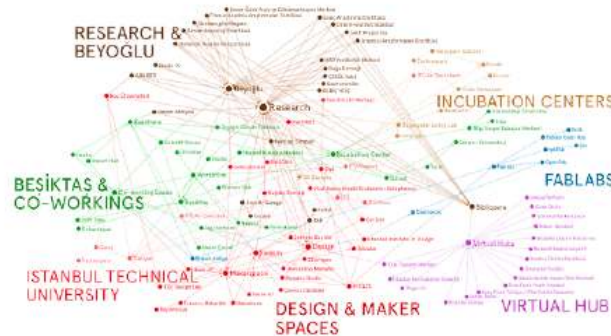
- Given $x_1, x_2, \dots, x_n$ (without labels)
- Output hidden structure behind the x 's
 - E.g., clustering



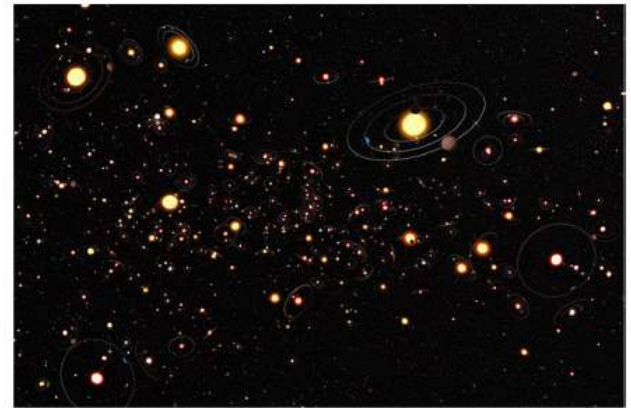
Unsupervised Learning Applications



Batch Computing Jobs



Find Groups in Social Networks



Identifying Types of Exoplanets

Reinforcement Learning

- Given a sequence of states and actions with (delayed) rewards, output a policy
 - Policy is a mapping from states $\rightarrow$ actions. It tells you what to do in a given state
- Examples:
 - Credit assignment problem
 - Game playing
 - Robot grasping an object
 - Balance a pole on your forehead



Reinforcement Learning



<https://www.youtube.com/watch?v=4cgWya-wjgY>

Learning as Search

- ML uses experience (data) to approximate a chosen target function
- There are thousands of ML algorithms (more every year!)

Learning is equivalent to searching (**optimization**) through the space of potential hypotheses (**representation**) to find one that best fits (**evaluation**) the training data

Components of Every ML Application

Representation

- How is the data specified?
- What is the form of the model?

Optimization

- How is the model trained on the data?

Evaluation

- How are we assessing whether the model is successful?
- What is the performance measure?

Representations

Numerical functions

- Linear regression
- Linear discriminant
- Neural network

Symbolic functions

- Decision tree
- Propositional logic rules
- First-order logic rules

Instance-based functions

- Nearest-neighbor
- Case-based

Probabilistic Graphical Models

- Naïve Bayes
- Bayesian network
- Hidden-Markov model (HMMs)
- Probabilistic context-free grammar (PCFGs)
- Markov network

Optimization and Search Techniques

Gradient Descent

- Perceptron
- Backpropagation
- Stochastic GD
- RMSprop
- ADAM

Dynamic Programming

- HMM training
- Viterbi algorithm

Divide and Conquer

- Decision tree induction
- Rule learning

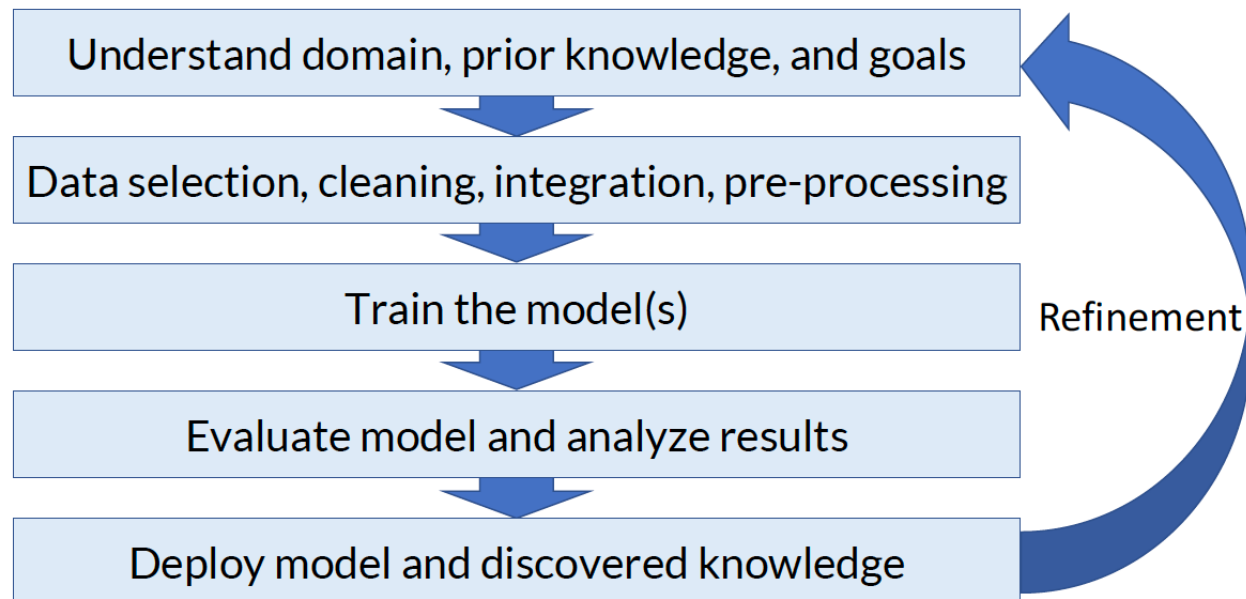
Evolutionary Computation

- Genetic Algorithms
- Neuro-evolution

Evaluation

- Accuracy
- Squared error
- Precision / recall
- F-measure
- Utility (expected cost)
- Likelihood
- Posterior probability
- Margin
- Information gain / Entropy
- KL divergence

ML in Practice



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