

# Outline of machine learning

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The following outline is provided as an overview of and topical guide to machine learning:

**Machine learning** – subfield of computer science<sup>[1]</sup> (more particularly soft computing) that evolved from the study of pattern recognition and computational learning theory in artificial intelligence.<sup>[1]</sup> In 1959, Arthur Samuel defined machine learning as a "Field of study that gives computers the ability to learn without being explicitly programmed"<sup>[2]</sup>. Machine learning explores the study and construction of algorithms that can learn from and make predictions on data.<sup>[3]</sup> Such algorithms operate by building a model from an example training set of input observations in order to make data-driven predictions or decisions expressed as outputs, rather than following strictly static program instructions.

## Contents

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### What *type* of thing is machine learning?

#### Branches of machine learning

- Subfields of machine learning
- Cross-disciplinary fields involving machine learning

#### Applications of machine learning

#### Machine learning hardware

#### Machine learning tools

- Machine learning frameworks
- Machine learning libraries
- Machine learning algorithms

#### Machine learning methods

- Dimensionality reduction
- Ensemble learning
- Meta learning
- Reinforcement learning
- Supervised learning
- Unsupervised learning
- Semi-supervised learning
- Deep learning
- Other machine learning methods and problems

#### Machine learning research

#### History of machine learning

#### Machine learning projects

#### Machine learning organizations

- Machine learning conferences and workshops

#### Machine learning publications

- Books on machine learning
- Machine learning journals

#### Persons influential in machine learning

#### See also

- Other

#### Further reading

#### References

#### External links

# What *type* of thing is machine learning?

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- An academic discipline
- A branch of science
  - An applied science
    - A subfield of computer science
      - A branch of artificial intelligence
      - A subfield of soft computing

## Branches of machine learning

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### Subfields of machine learning

Subfields of machine learning

- Computational learning theory– studying the design and analysis of machine learning algorithms.<sup>[4]</sup>
- Grammar induction
- Meta learning

### Cross-disciplinary fields involving machine learning

Cross-disciplinary fields involving machine learning

- Adversarial machine learning
- Predictive analytics
- Quantum machine learning
- Robot learning
  - Developmental robotics

## Applications of machine learning

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Applications of machine learning

- Biomedical informatics
- Computer vision
- Customer relationship management–
- Data mining
- Email filtering
- Inverted pendulum– balance and equilibrium system.
- Natural language processing(NLP)
  - Automatic summarization
  - Automatic taxonomy construction
  - Dialog system
  - Grammar checker
  - Language recognition
    - Handwriting recognition
    - Optical character recognition
    - Speech recognition
  - Machine translation

- [Question answering](#)
- [Speech synthesis](#)
- [Text mining](#)
  - [Term frequency–inverse document frequency\(tf–idf\)](#)
- [Text simplification](#)
- [Pattern recognition](#)
  - [Facial recognition system](#)
  - [Handwriting recognition](#)
  - [Image recognition](#)
  - [Optical character recognition](#)
  - [Speech recognition](#)
- [Recommendation system](#)
  - [Collaborative filtering](#)
  - [Content-based filtering](#)
  - [Hybrid recommender systems\(Collaborative and content-based filtering\)](#)
- [Search engine](#)
  - [Search engine optimization](#)

## Machine learning hardware

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### [Machine learning hardware](#)

- [Graphics processing unit](#)
- [Tensor processing unit](#)
- [Vision processing unit](#)

## Machine learning tools

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### [Machine learning tools \(list\)](#)

- [Comparison of deep learning software](#)
  - [Comparison of deep learning software/Resources](#)

## Machine learning frameworks

### [Machine learning framework](#)

#### Proprietary machine learning frameworks

##### [Proprietary machine learning frameworks](#)

- [Amazon Machine Learning](#)
- [Microsoft Azure Machine Learning Studio](#)
- [DistBelief](#) – replaced by [TensorFlow](#)
- [Microsoft Cognitive Toolkit](#)

#### Open source machine learning frameworks

##### [Open source machine learning frameworks](#)

- [Apache Singa](#)
- [Caffe](#)

- [H2O](#)
- [PyTorch](#)
- [MLPACK](#)
- [TensorFlow](#)
- [Torch](#)
- [Accord.Net](#)

## Machine learning libraries

[Machine learning library](#) (list)

- [Deeplearning4j](#)
- [Theano](#)
- [Scikit-learn](#)

## Machine learning algorithms

[Machine learning algorithm](#)

### Types of machine learning algorithms

- [Almeida–Pineda recurrent backpropagation](#)
- [ALOPEX](#)
- [Backpropagation](#)
- [Bootstrap aggregating](#)
- [CN2 algorithm](#)
- [Constructing skill trees](#)
- [Dehaene–Changeux model](#)
- [Diffusion map](#)
- [Dominance-based rough set approach](#)
- [Dynamic time warping](#)
- [Error-driven learning](#)
- [Evolutionary multimodal optimization](#)
- [Expectation–maximization algorithm](#)
- [FastICA](#)
- [Forward–backward algorithm](#)
- [GeneRec](#)
- [Genetic Algorithm for Rule Set Production](#)
- [Growing self-organizing map](#)
- [HEXQ](#)
- [Hyper basis function network](#)
- [IDistance](#)
- [K-nearest neighbors algorithm](#)
- [Kernel methods for vector output](#)
- [Kernel principal component analysis](#)
- [Leabra](#)
- [Linde–Buzo–Gray algorithm](#)
- [Local outlier factor](#)
- [Logic learning machine](#)
- [LogitBoost](#)
- [Manifold alignment](#)
- [Minimum redundancy feature selection](#)
- [Mixture of experts](#)
- [Multiple kernel learning](#)

- Non-negative matrix factorization
- Online machine learning
- Out-of-bag error
- Prefrontal cortex basal ganglia working memory
- PVLV
- Q-learning
- Quadratic unconstrained binary optimization
- Query-level feature
- Quickprop
- Radial basis function network
- Randomized weighted majority algorithm
- Reinforcement learning
- Repeated incremental pruning to produce error reduction (RIPPER)
- Rprop
- Rule-based machine learning
- Skill chaining
- Sparse PCA
- State–action–reward–state–action
- Stochastic gradient descent
- Structured kNN
- T-distributed stochastic neighbor embedding
- Temporal difference learning
- Wake-sleep algorithm
- Weighted majority algorithm (machine learning)

## Machine learning methods

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Machine learning method (list)

- Instance-based algorithm
  - K-nearest neighbors algorithm(KNN)
  - Learning vector quantization(LVQ)
  - Self-organizing map(SOM)
- Regression analysis
  - Logistic regression
  - Ordinary least squares regression(OLSR)
  - Linear regression
  - Stepwise regression
  - Multivariate adaptive regression splines(MARS)
- Regularization algorithm
  - Ridge regression
  - Least Absolute Shrinkage and Selection Operator(LASSO)
  - Elastic net
  - Least-angle regression(LARS)
- Classifiers
  - Probabilistic classifier
    - Naive Bayes classifier
  - Binary classifier
  - Linear classifier
  - Hierarchical classifier

# Dimensionality reduction

## Dimensionality reduction

- Canonical correlation analysis(CCA)
- Factor analysis
- Feature extraction
- Feature selection
- Independent component analysis(ICA)
- Linear discriminant analysis(LDA)
- Multidimensional scaling(MDS)
- Non-negative matrix factorization(NMF)
- Partial least squares regression(PLSR)
- Principal component analysis(PCA)
- Principal component regression(PCR)
- Projection pursuit
- Sammon mapping
- t-distributed stochastic neighbor embedding(t-SNE)

# Ensemble learning

## Ensemble learning

- AdaBoost
- Boosting
- Bootstrap aggregating(Bagging)
- Ensemble averaging– process of creating multiple models and combining them to produce a desired output, as opposed to creating just one model. Frequently an ensemble of models performs better than any individual model, because the various errors of the models "average out."
- Gradient boosted decision tree(GBRT)
- Gradient boosting machine (GBM)
- Random Forest
- Stacked Generalization(blending)

# Meta learning

## Meta learning

- Inductive bias
- Metadata

# Reinforcement learning

## Reinforcement learning

- Q-learning
- State–action–reward–state–action(SARSA)
- Temporal difference learning (TD)
- Learning Automata

# Supervised learning

## Supervised learning

- AODE
- Artificial neural network

- Association rule learning algorithms
  - Apriori algorithm
  - Eclat algorithm
- Case-based reasoning
- Gaussian process regression
- Gene expression programming
- Group method of data handling(GMDH)
- Inductive logic programming
- Instance-based learning
- Lazy learning
- Learning Automata
- Learning Vector Quantization
- Logistic Model Tree
- Minimum message length(decision trees, decision graphs, etc.)
  - Nearest Neighbor Algorithm
  - Analogical modeling
- Probably approximately correct learning(PAC) learning
- Ripple down rules a knowledge acquisition methodology
- Symbolic machine learning algorithms
- Support vector machines
- Random Forests
- Ensembles of classifiers
  - Bootstrap aggregating(bagging)
  - Boosting (meta-algorithm)
- Ordinal classification
- Information fuzzy networks(IFN)
- Conditional Random Field
- ANOVA
- Quadratic classifiers
- k-nearest neighbor
- Boosting
  - SPRINT
- Bayesian networks
  - Naive Bayes
- Hidden Markov models
  - Hierarchical hidden Markov model

## **Bayesian**

### Bayesian statistics

- Bayesian knowledge base
- Naive Bayes
- Gaussian Naive Bayes
- Multinomial Naive Bayes
- Averaged One-Dependence Estimators(AODE)
- Bayesian Belief Network(BBN)
- Bayesian Network(BN)

## **Decision tree algorithms**

### Decision tree algorithm

- Decision tree
- Classification and regression tree(CART)
- Iterative Dichotomiser 3(ID3)
- C4.5 algorithm
- C5.0 algorithm
- Chi-squared Automatic Interaction Detector(CHAID)
- Decision stump
- Conditional decision tree
- ID3 algorithm
- Random forest
- SLIQ

## **Linear classifier**

### Linear classifier

- Fisher's linear discriminant
- Linear regression
- Logistic regression
- Multinomial logistic regression
- Naive Bayes classifier
- Perceptron
- Support vector machine

## **Unsupervised learning**

### Unsupervised learning

- Expectation-maximization algorithm
- Vector Quantization
- Generative topographic map
- Information bottleneck method

## **Artificial neural networks**

### Artificial neural network

- Feedforward neural network
  - Extreme learning machine
- Logic learning machine
- Self-organizing map

## **Association rule learning**

### Association rule learning

- Apriori algorithm
- Eclat algorithm
- FP-growth algorithm

## **Hierarchical clustering**

### Hierarchical clustering

- Single-linkage clustering



- Conceptual clustering

## Cluster analysis

### Cluster analysis

- BIRCH
- DBSCAN
- Expectation-maximization (EM)
- Fuzzy clustering
- Hierarchical Clustering
- K-means algorithm
- K-means clustering
- K-medians
- Mean-shift
- OPTICS algorithm

## Anomaly detection

### Anomaly detection

- k-nearest neighbors classification(k-NN)
- Local outlier factor

## Semi-supervised learning

### Semi-supervised learning

- Active learning– special case of semi-supervised learning in which a learning algorithm is able to interactively query the user (or some other information source) to obtain the desired outputs at new data points.<sup>[5]</sup> <sup>[6]</sup>
- Generative models
- Low-density separation
- Graph-based methods
- Co-training
- Transduction

## Deep learning

### Deep learning

- Deep belief networks
- Deep Boltzmann machines
- Deep Convolutional neural networks
- Deep Recurrent neural networks
- Hierarchical temporal memory
- Deep Boltzmann Machine(DBM)
- Stacked Auto-Encoders

## Other machine learning methods and problems

- Anomaly detection
- Association rules
- Bias-variance dilemma
- Classification

- [Multi-label classification](#)
- [Clustering](#)
- [Data Pre-processing](#)
- [Empirical risk minimization](#)
- [Feature engineering](#)
- [Feature learning](#)
- [Learning to rank](#)
- [Occam learning](#)
- [Online machine learning](#)
- [PAC learning](#)
- [Regression](#)
- [Reinforcement Learning](#)
- [Semi-supervised learning](#)
- [Statistical learning](#)
- [Structured prediction](#)
  - [Graphical models](#)
    - [Bayesian network](#)
    - [Conditional random field\(CRF\)](#)
    - [Hidden Markov model\(HMM\)](#)
- [Unsupervised learning](#)
- [VC theory](#)

## Machine learning research

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### [Machine learning research](#)

- [List of artificial intelligence projects](#)
- [List of datasets for machine learning research](#)

## History of machine learning

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### [History of machine learning](#)

- [Timeline of machine learning](#)

## Machine learning projects

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### [Machine learning projects](#)

- [DeepMind](#)
- [Google Brain](#)

## Machine learning organizations

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### [Machine learning organizations](#)

- [Knowledge Engineering and Machine Learning Group](#)

## Machine learning conferences and workshops

- [Artificial Intelligence and Security \(AISec\) \(co-located workshop with CCS\)](#)
- [Conference on Neural Information Processing Systems\(NIPS\)](#)
- [ECML PKDD](#)

- [International Conference on Machine Learning\(ICML\)](#)

## Machine learning publications

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### Books on machine learning

[Books about machine learning](#)

### Machine learning journals

- [Machine Learning](#)
- [Journal of Machine Learning Research\(JMLR\)](#)
- [Neural Computation](#)

## Persons influential in machine learning

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- [Alberto Broggi](#)
- [Andrei Knyazev](#)
- [Andrew McCallum](#)
- [Andrew Ng](#)
- [Armin B. Cremers](#)
- [Ayanna Howard](#)
- [Barney Pell](#)
- [Ben Goertzel](#)
- [Ben Taskar](#)
- [Bernhard Schölkopf](#)
- [Brian D. Ripley](#)
- [Christopher G. Atkeson](#)
- [Corinna Cortes](#)
- [Demis Hassabis](#)
- [Douglas Lenat](#)
- [Eric Xing](#)
- [Ernst Dickmanns](#)
- [Geoffrey Hinton](#) – co-inventor of the backpropagation and contrastive divergence training algorithms
- [Hans-Peter Kriegel](#)
- [Hartmut Neven](#)
- [Heikki Mannila](#)
- [Jacek M. Zurada](#)
- [Jaime Carbonell](#)
- [Jerome H. Friedman](#)
- [John D. Lafferty](#)
- [John Platt](#) – invented SMO and Platt scaling
- [Julie Beth Lovins](#)
- [Jürgen Schmidhuber](#)
- [Karl Steinbuch](#)
- [Katia Sycara](#)
- [Leo Breiman](#) – invented bagging and random forests
- [Lise Getoor](#)
- [Luca Maria Gambardella](#)
- [Léon Bottou](#)
- [Marcus Hutter](#)
- [Mehryar Mohri](#)
- [Michael Collins](#)

- [Michael I. Jordan](#)
- [Michael L. Littman](#)
- [Nando de Freitas](#)
- [Ofer Dekel](#)
- [Oren Etzioni](#)
- [Pedro Domingos](#)
- [Peter Flach](#)
- [Pierre Baldi](#)
- [Pushmeet Kohli](#)
- [Ray Kurzweil](#)
- [Rayid Ghani](#)
- [Ross Quinlan](#)
- [Salvatore J. Stolfo](#)
- [Sebastian Thrun](#)
- [Selmer Bringsjord](#)
- [Sepp Hochreiter](#)
- [Shane Legg](#)
- [Stephen Muggleton](#)
- [Steve Omohundro](#)
- [Tom M. Mitchell](#)
- [Trevor Hastie](#)
- [Vasant Honavar](#)
- [Vladimir Vapnik](#) – co-inventor of the SVM and VC theory
- [Yann LeCun](#) – invented convolutional neural networks
- [Yasuo Matsuyama](#)
- [Yoshua Bengio](#)
- [Zoubin Ghahramani](#)

## See also

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- [Outline of artificial intelligence](#)
  - [Outline of computer vision](#)
  - [Outline of natural language processing](#)
- [Outline of robotics](#)
- [Accuracy paradox](#)
- [Action model learning](#)
- [Activation function](#)
- [Activity recognition](#)
- [ADALINE](#)
- [Adaptive neuro fuzzy inference system](#)
- [Adaptive resonance theory](#)
- [Additive smoothing](#)
- [Adjusted mutual information](#)
- [Aika \(software\)](#)
- [AIVA](#)
- [AIXI](#)
- [AlchemyAPI](#)
- [AlexNet](#)
- [Algorithm selection](#)
- [Algorithmic inference](#)
- [Algorithmic learning theory](#)
- [AlphaGo](#)
- [AlphaGo Zero](#)
- [Alternating decision tree](#)

- [Apprenticeship learning](#)
- [Causal Markov condition](#)
- [Competitive learning](#)
- [Concept learning](#)
- [Decision tree learning](#)
- [Distribution learning theory](#)
- [Eager learning](#)
- [End-to-end reinforcement learning](#)
- [Error tolerance \(PAC learning\)](#)
- [Explanation-based learning](#)
- [Feature](#)
- [GloVe](#)
- [Hyperparameter](#)
- [IBM Machine Learning Hub](#)
- [Inferential theory of learning](#)
- [Learning automata](#)
- [Learning classifier system](#)
- [Learning rule](#)
- [Learning with errors](#)
- [M-Theory \(learning framework\)](#)
- [Machine learning control](#)
- [Machine learning in bioinformatics](#)
- [Margin](#)
- [Markov chain geostatistics](#)
- [Markov chain Monte Carlo\(MCMC\)](#)
- [Markov information source](#)
- [Markov logic network](#)
- [Markov model](#)
- [Markov random field](#)
- [Markovian discrimination](#)
- [Maximum-entropy Markov model](#)
- [Multi-armed bandit](#)
- [Multi-task learning](#)
- [Multilinear subspace learning](#)
- [Multimodal learning](#)
- [Multiple instance learning](#)
- [Multiple-instance learning](#)
- [Never-Ending Language Learning](#)
- [Offline learning](#)
- [Parity learning](#)
- [Population-based incremental learning](#)
- [Predictive learning](#)
- [Preference learning](#)
- [Proactive learning](#)
- [Proximal gradient methods for learning](#)
- [Semantic analysis](#)
- [Similarity learning](#)
- [Sparse dictionary learning](#)
- [Stability \(learning theory\)](#)
- [Statistical learning theory](#)
- [Statistical relational learning](#)
- [Tanagra](#)
- [Transfer learning](#)
- [Variable-order Markov model](#)
- [Version space learning](#)

- [Waffles](#)
- [Weka](#)
- [Loss function](#)
  - [Loss functions for classification](#)
  - [Mean squared error \(MSE\)](#)
  - [Mean squared prediction error \(MSPE\)](#)
  - [Taguchi loss function](#)
- [Low-energy adaptive clustering hierarchy](#)

## Other

- [Anne O'Tate](#)
- [Ant colony optimization algorithms](#)
- [Anthony Levandowski](#)
- [Anti-unification \(computer science\)](#)
- [Apache Flume](#)
- [Apache Giraph](#)
- [Apache Mahout](#)
- [Apache SINGA](#)
- [Apache Spark](#)
- [Apache SystemML](#)
- [Aphelion \(software\)](#)
- [Arabic Speech Corpus](#)
- [Archetypal analysis](#)
- [Arthur Zimek](#)
- [Artificial ants](#)
- [Artificial bee colony algorithm](#)
- [Artificial development](#)
- [Artificial immune system](#)
- [Astrostatistics](#)
- [Averaged one-dependence estimators](#)
- [Bag-of-words model](#)
- [Balanced clustering](#)
- [Ball tree](#)
- [Base rate](#)
- [Bat algorithm](#)
- [Baum–Welch algorithm](#)
- [Bayesian hierarchical modeling](#)
- [Bayesian interpretation of kernel regularization](#)
- [Bayesian optimization](#)
- [Bayesian structural time series](#)
- [Bees algorithm](#)
- [Behavioral clustering](#)
- [Bernoulli scheme](#)
- [Bias–variance tradeoff](#)
- [Biclustering](#)
- [Binarization of consensus partition matrices](#)
- [Binary classification](#)
- [Bing Predicts](#)
- [Bio-inspired computing](#)
- [Biogeography-based optimization](#)
- [Biplot](#)
- [Bondy's theorem](#)

- [Bongard problem](#)
- [Bradley–Terry model](#)
- [BrownBoost](#)
- [Brown clustering](#)
- [Burst error](#)
- [CBCL \(MIT\)](#)
- [CIML community portal](#)
- [CMA-ES](#)
- [CURE data clustering algorithm](#)
- [Cache language model](#)
- [Calibration \(statistics\)](#)
- [Canonical correspondence analysis](#)
- [Canopy clustering algorithm](#)
- [Cascading classifiers](#)
- [Category utility](#)
- [CellCognition](#)
- [Cellular evolutionary algorithm](#)
- [Chi-square automatic interaction detection](#)
- [Chromosome \(genetic algorithm\)](#)
- [Classifier chains](#)
- [Cleverbot](#)
- [Clonal selection algorithm](#)
- [Cluster-weighted modeling](#)
- [Clustering high-dimensional data](#)
- [Clustering illusion](#)
- [CoBoosting](#)
- [Cobweb \(clustering\)](#)
- [Cognitive computer](#)
- [Cognitive robotics](#)
- [Collostructional analysis](#)
- [Common-method variance](#)
- [Complete-linkage clustering](#)
- [Computer-automated design](#)
- [Concept class](#)
- [Concept drift](#)
- [Conference on Artificial General Intelligence](#)
- [Conference on Knowledge Discovery and Data Mining](#)
- [Confirmatory factor analysis](#)
- [Confusion matrix](#)
- [Congruence coefficient](#)
- [Connect \(computer system\)](#)
- [Consensus clustering](#)
- [Constrained clustering](#)
- [Constrained conditional model](#)
- [Constructive cooperative coevolution](#)
- [Correlation clustering](#)
- [Correspondence analysis](#)
- [Cortica](#)
- [Coupled pattern learner](#)
- [Cross-entropy method](#)
- [Cross-validation \(statistics\)](#)
- [Crossover \(genetic algorithm\)](#)
- [Cuckoo search](#)
- [Cultural algorithm](#)
- [Cultural consensus theory](#)

- Curse of dimensionality
- DADiSP
- DARPA LAGR Program
- Darkforest
- Dartmouth workshop
- DarwinTunes
- Data Mining Extensions
- Data exploration
- Data pre-processing
- Data stream clustering
- Dataiku
- Davies–Bouldin index
- Decision boundary
- Decision list
- Decision tree model
- Deductive classifier
- DeepArt
- DeepDream
- Deep Web Technologies
- Defining length
- Dendrogram
- Dependability state model
- Detailed balance
- Determining the number of clusters in a data set
- Detrended correspondence analysis
- Developmental robotics
- Diffbot
- Differential evolution
- Discrete phase-type distribution
- Discriminative model
- Dissociated press
- Distributed R
- Dlib
- Document classification
- Documenting Hate
- Domain adaptation
- Doubly stochastic model
- Dual-phase evolution
- Dunn index
- Dynamic Bayesian network
- Dynamic Markov compression
- Dynamic topic model
- Dynamic unobserved effects model
- EDLUT
- ELKI
- Edge recombination operator
- Effective fitness
- Elastic map
- Elastic matching
- Elbow method (clustering)
- Emergent (software)
- Encog
- Entropy rate
- Erkki Oja
- Eurisko



- [European Conference on Artificial Intelligence](#)
- [Evaluation of binary classifiers](#)
- [Evolution strategy](#)
- [Evolution window](#)
- [Evolutionary Algorithm for Landmark Detection](#)
- [Evolutionary algorithm](#)
- [Evolutionary art](#)
- [Evolutionary music](#)
- [Evolutionary programming](#)
- [Evolvability \(computer science\)](#)
- [Evolved antenna](#)
- [Evolver \(software\)](#)
- [Evolving classification function](#)
- [Expectation propagation](#)
- [Exploratory factor analysis](#)
- [F1 score](#)
- [FLAME clustering](#)
- [Factor analysis of mixed data](#)
- [Factor graph](#)
- [Factor regression model](#)
- [Factored language model](#)
- [Farthest-first traversal](#)
- [Fast-and-frugal trees](#)
- [Feature Selection Toolbox](#)
- [Feature hashing](#)
- [Feature scaling](#)
- [Feature vector](#)
- [Firefly algorithm](#)
- [First-difference estimator](#)
- [First-order inductive learner](#)
- [Fish School Search](#)
- [Fisher kernel](#)
- [Fitness approximation](#)
- [Fitness function](#)
- [Fitness proportionate selection](#)
- [Fluentd](#)
- [Folding@home](#)
- [Formal concept analysis](#)
- [Forward algorithm](#)
- [Fowlkes–Mallows index](#)
- [Frederick Jelinek](#)
- [Frrole](#)
- [Functional principal component analysis](#)
- [GATTO](#)
- [GLIMMER](#)
- [Gary Bryce Fogel](#)
- [Gaussian adaptation](#)
- [Gaussian process](#)
- [Gaussian process emulator](#)
- [Gene prediction](#)
- [General Architecture for Text Engineering](#)
- [Generalization error](#)
- [Generalized canonical correlation](#)
- [Generalized filtering](#)
- [Generalized iterative scaling](#)

- [Generalized multidimensional scaling](#)
- [Generative adversarial network](#)
- [Generative model](#)
- [Genetic algorithm](#)
- [Genetic algorithm scheduling](#)
- [Genetic algorithms in economics](#)
- [Genetic fuzzy systems](#)
- [Genetic memory \(computer science\)](#)
- [Genetic operator](#)
- [Genetic programming](#)
- [Genetic representation](#)
- [Geographical cluster](#)
- [Gesture Description Language](#)
- [Geworkbench](#)
- [Glossary of artificial intelligence](#)
- [Glottochronology](#)
- [Golem \(ILP\)](#)
- [Google matrix](#)
- [Grafting \(decision trees\)](#)
- [Gramian matrix](#)
- [Grammatical evolution](#)
- [Granular computing](#)
- [GraphLab](#)
- [Graph kernel](#)
- [Gremlin \(programming language\)](#)
- [Growth function](#)
- [HUMANT \(HUMANoid ANT\) algorithm](#)
- [Hammersley–Clifford theorem](#)
- [Harmony search](#)
- [Hebbian theory](#)
- [Hidden Markov random field](#)
- [Hidden semi-Markov model](#)
- [Hierarchical hidden Markov model](#)
- [Higher-order factor analysis](#)
- [Highway network](#)
- [Hinge loss](#)
- [Holland's schema theorem](#)
- [Hopkins statistic](#)
- [Hoshen–Kopelman algorithm](#)
- [Huber loss](#)
- [IRCF360](#)
- [Ian Goodfellow](#)
- [Ilastik](#)
- [Ilya Sutskever](#)
- [Immunocomputing](#)
- [Imperialist competitive algorithm](#)
- [Inauthentic text](#)
- [Incremental decision tree](#)
- [Induction of regular languages](#)
- [Inductive bias](#)
- [Inductive probability](#)
- [Inductive programming](#)
- [Influence diagram](#)
- [Information Harvesting](#)
- [Information fuzzy networks](#)

- [Information gain in decision trees](#)
- [Information gain ratio](#)
- [Inheritance \(genetic algorithm\)](#)
- [Instance selection](#)
- [Intel RealSense](#)
- [Interacting particle system](#)
- [Interactive machine translation](#)
- [International Joint Conference on Artificial Intelligence](#)
- [International Meeting on Computational Intelligence Methods for Bioinformatics and Biostatistics](#)
- [International Semantic Web Conference](#)
- [Iris flower data set](#)
- [Island algorithm](#)
- [Isotropic position](#)
- [Item response theory](#)
- [Iterative Viterbi decoding](#)
- [JOONE](#)
- [Jabberwacky](#)
- [Jaccard index](#)
- [Jackknife variance estimates for random forest](#)
- [Java Grammatical Evolution](#)
- [Joseph Nechvatal](#)
- [Jubatus](#)
- [Julia \(programming language\)](#)
- [Junction tree algorithm](#)
- [K-SVD](#)
- [K-means++](#)
- [K-medians clustering](#)
- [K-medoids](#)
- [KNIME](#)
- [KXEN Inc.](#)
- [K q-flats](#)
- [Kaggle](#)
- [Kalman filter](#)
- [Katz's back-off model](#)
- [Keras](#)
- [Kernel adaptive filter](#)
- [Kernel density estimation](#)
- [Kernel eigenvoice](#)
- [Kernel embedding of distributions](#)
- [Kernel method](#)
- [Kernel perceptron](#)
- [Kernel random forest](#)
- [Kinect](#)
- [Klaus-Robert Müller](#)
- [Kneser–Ney smoothing](#)
- [Knowledge Vault](#)
- [Knowledge integration](#)
- [LIBSVM](#)
- [LPBoost](#)
- [Labeled data](#)
- [LanguageWare](#)
- [Language Acquisition Device \(computer\)](#)
- [Language identification in the limit](#)
- [Language model](#)
- [Large margin nearest neighbor](#)

- [Latent Dirichlet allocation](#)
- [Latent class model](#)
- [Latent semantic analysis](#)
- [Latent variable](#)
- [Latent variable model](#)
- [Lattice Miner](#)
- [Layered hidden Markov model](#)
- [Learnable function class](#)
- [Least squares support vector machine](#)
- [Leave-one-out error](#)
- [Leslie P. Kaelbling](#)
- [Linear genetic programming](#)
- [Linear predictor function](#)
- [Linear separability](#)
- [Lingyun Gu](#)
- [Linkurious](#)
- [Lior Ron \(business executive\)](#)
- [List of genetic algorithm applications](#)
- [List of metaphor-based metaheuristics](#)
- [List of text mining software](#)
- [Local case-control sampling](#)
- [Local independence](#)
- [Local tangent space alignment](#)
- [Locality-sensitive hashing](#)
- [Log-linear model](#)
- [Logistic model tree](#)
- [Low-rank approximation](#)
- [Low-rank matrix approximations](#)
- [MATLAB](#)
- [MIMIC \(immunology\)](#)
- [MXNet](#)
- [Mallet \(software project\)](#)
- [Manifold regularization](#)
- [Margin-infused relaxed algorithm](#)
- [Margin classifier](#)
- [Mark V. Shaney](#)
- [Massive Online Analysis](#)
- [Matrix regularization](#)
- [Matthews correlation coefficient](#)
- [Mean shift](#)
- [Mean squared error](#)
- [Mean squared prediction error](#)
- [Measurement invariance](#)
- [Medoid](#)
- [MeeMix](#)
- [Melomics](#)
- [Memetic algorithm](#)
- [Meta-optimization](#)
- [Mexican International Conference on Artificial Intelligence](#)
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- [MinHash](#)
- [Mixture model](#)
- [Mlpy](#)
- [Models of DNA evolution](#)
- [Moral graph](#)

- [Mountain car problem](#)
- [Movidius](#)
- [Multi-armed bandit](#)
- [Multi-label classification](#)
- [Multi expression programming](#)
- [Multiclass classification](#)
- [Multidimensional analysis](#)
- [Multifactor dimensionality reduction](#)
- [Multilinear principal component analysis](#)
- [Multiple correspondence analysis](#)
- [Multiple discriminant analysis](#)
- [Multiple factor analysis](#)
- [Multiple sequence alignment](#)
- [Multiplicative weight update method](#)
- [Multispectral pattern recognition](#)
- [Mutation \(genetic algorithm\)](#)
- [MysteryVibe](#)
- [N-gram](#)
- [NOMINATE \(scaling method\)](#)
- [Native-language identification](#)
- [Natural Language Toolkit](#)
- [Natural evolution strategy](#)
- [Nearest-neighbor chain algorithm](#)
- [Nearest centroid classifier](#)
- [Nearest neighbor search](#)
- [Neighbor joining](#)
- [Nest Labs](#)
- [NetMiner](#)
- [NetOwl](#)
- [Neural Designer](#)
- [Neural Engineering Object](#)
- [Neural Lab](#)
- [Neural modeling fields](#)
- [Neural network software](#)
- [NeuroSolutions](#)
- [Neuro Laboratory](#)
- [Neuroevolution](#)
- [Neuroph](#)
- [Niki.ai](#)
- [Noisy channel model](#)
- [Noisy text analytics](#)
- [Nonlinear dimensionality reduction](#)
- [Novelty detection](#)
- [Nuisance variable](#)
- [Numenta](#)
- [One-class classification](#)
- [Onnx](#)
- [OpenNLP](#)
- [Optimal discriminant analysis](#)
- [Oracle Data Mining](#)
- [Orange \(software\)](#)
- [Ordination \(statistics\)](#)
- [Overfitting](#)
- [PROGOL](#)
- [PSIPRED](#)

- [Pachinko allocation](#)
- [PageRank](#)
- [Parallel metaheuristic](#)
- [Parity benchmark](#)
- [Part-of-speech tagging](#)
- [Particle swarm optimization](#)
- [Path dependence](#)
- [Pattern language \(formal languages\)](#)
- [Peltarion Synapse](#)
- [Perplexity](#)
- [Persian Speech Corpus](#)
- [Picas \(app\)](#)
- [Pietro Perona](#)
- [Pipeline Pilot](#)
- [Piranha \(software\)](#)
- [Pitman–Yor process](#)
- [Plate notation](#)
- [Polynomial kernel](#)
- [Pop music automation](#)
- [Population process](#)
- [Portable Format for Analytics](#)
- [Predictive Model Markup Language](#)
- [Predictive state representation](#)
- [Preference regression](#)
- [Premature convergence](#)
- [Principal geodesic analysis](#)
- [Prior knowledge for pattern recognition](#)
- [Prisma \(app\)](#)
- [Probabilistic Action Cores](#)
- [Probabilistic context-free grammar](#)
- [Probabilistic latent semantic analysis](#)
- [Probabilistic soft logic](#)
- [Probability matching](#)
- [Probit model](#)
- [Product of experts](#)
- [Programming with Big Data in R](#)
- [Proper generalized decomposition](#)
- [Pruning \(decision trees\)](#)
- [Pushpak Bhattacharyya](#)
- [Q methodology](#)
- [Qloo](#)
- [Quality control and genetic algorithms](#)
- [Quantum Artificial Intelligence Lab](#)
- [Queueing theory](#)
- [Quick, Draw!](#)
- [R \(programming language\)](#)
- [Rada Mihalcea](#)
- [Rademacher complexity](#)
- [Radial basis function kernel](#)
- [Rand index](#)
- [Random indexing](#)
- [Random projection](#)
- [Random subspace method](#)
- [Ranking SVM](#)
- [RapidMiner](#)

- [Rattle GUI](#)
- [Raymond Cattell](#)
- [Reasoning system](#)
- [Regularization perspectives on support vector machines](#)
- [Relational data mining](#)
- [Relationship square](#)
- [Relevance vector machine](#)
- [Relief \(feature selection\)](#)
- [Renjin](#)
- [Repertory grid](#)
- [Representer theorem](#)
- [Reward-based selection](#)
- [Richard Zemel](#)
- [Right to explanation](#)
- [RoboEarth](#)
- [Robust principal component analysis](#)
- [RuleML Symposium](#)
- [Rule induction](#)
- [Rules extraction system family](#)
- [SAS \(software\)](#)
- [SNNS](#)
- [SPSS Modeler](#)
- [SUBCLU](#)
- [Sample complexity](#)
- [Sample exclusion dimension](#)
- [Santa Fe Trail problem](#)
- [Savi Technology](#)
- [Schema \(genetic algorithms\)](#)
- [Search-based software engineering](#)
- [Selection \(genetic algorithm\)](#)
- [Self-Service Semantic Suite](#)
- [Semantic folding](#)
- [Semantic mapping \(statistics\)](#)
- [Semidefinite embedding](#)
- [Sense Networks](#)
- [Sensorium Project](#)
- [Sequence labeling](#)
- [Sequential minimal optimization](#)
- [Shattered set](#)
- [Shogun \(toolbox\)](#)
- [Silhouette \(clustering\)](#)
- [SimHash](#)
- [SimRank](#)
- [Similarity measure](#)
- [Simple matching coefficient](#)
- [Simultaneous localization and mapping](#)
- [Sinkov statistic](#)
- [Sliced inverse regression](#)
- [SmartMatch](#)
- [Snakes and Ladders](#)
- [Soft independent modelling of class analogies](#)
- [Soft output Viterbi algorithm](#)
- [Solomonoff's theory of inductive inference](#)
- [SolveIT Software](#)
- [Spectral clustering](#)

- [Spike-and-slab variable selection](#)
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- [Statistical parsing](#)
- [Statistical semantics](#)
- [Stefano Soatto](#)
- [Stephen Wolfram](#)
- [Stochastic block model](#)
- [Stochastic cellular automaton](#)
- [Stochastic diffusion search](#)
- [Stochastic grammar](#)
- [Stochastic matrix](#)
- [Stochastic universal sampling](#)
- [Stress majorization](#)
- [String kernel](#)
- [Structural equation modeling](#)
- [Structural risk minimization](#)
- [Structured sparsity regularization](#)
- [Structured support vector machine](#)
- [Subclass reachability](#)
- [Sufficient dimension reduction](#)
- [Sukhotin's algorithm](#)
- [Sum of absolute differences](#)
- [Sum of absolute transformed differences](#)
- [Swarm intelligence](#)
- [Switching Kalman filter](#)
- [Symbolic regression](#)
- [Synchronous context-free grammar](#)
- [Syntactic pattern recognition](#)
- [TD-Gammon](#)
- [TIMIT](#)
- [Teaching dimension](#)
- [Teuvo Kohonen](#)
- [Textual case-based reasoning](#)
- [Theory of conjoint measurement](#)
- [Thomas G. Dietterich](#)
- [Thurstonian model](#)
- [Topic model](#)
- [Tournament selection](#)
- [Training, test, and validation sets](#)
- [Transiogram](#)
- [Trax Image Recognition](#)
- [Trigram tagger](#)
- [Truncation selection](#)
- [Tucker decomposition](#)
- [UIMA](#)
- [UPGMA](#)
- [Ugly duckling theorem](#)
- [Uncertain data](#)
- [Uniform convergence in probability](#)
- [Unique negative dimension](#)
- [Universal portfolio algorithm](#)
- [User behavior analytics](#)
- [VC dimension](#)
- [VGG Image Annotator](#)
- [VIGRA](#)



- [Validation set](#)
- [Vapnik–Chervonenkis theory](#)
- [Variable-order Bayesian network](#)
- [Variable kernel density estimation](#)
- [Variable rules analysis](#)
- [Variational message passing](#)
- [Varimax rotation](#)
- [Vector quantization](#)
- [Vicarious \(company\)](#)
- [Viterbi algorithm](#)
- [Vowpal Wabbit](#)
- [WACA clustering algorithm](#)
- [WPGMA](#)
- [Ward's method](#)
- [Weasel program](#)
- [Whitening transformation](#)
- [Winnow \(algorithm\)](#)
- [Win–stay, lose–switch](#)
- [Witness set](#)
- [Wolfram Language](#)
- [Wolfram Mathematica](#)
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## Further reading

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## External links

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- [Data Science: Data to Insights from MIT \(machine learning\)](#)
  - Popular online course by [Andrew Ng](#), at [Coursera](#). It uses [GNU Octave](#). The course is a free version of [Stanford University's](#) actual course taught by Ng, see [stanford.edu/Course/CS229](http://stanford.edu/Course/CS229) available for free].
  - [mloss](#) is an academic database of open-source machine learning software.
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