* **Practice**

Top of Form

Bottom of Form

* [Sign In](https://auth.geeksforgeeks.org/?to=https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp)
* [AI ML DS](https://www.geeksforgeeks.org/ai-ml-ds/?ref=shm)
* [Data Science](https://www.geeksforgeeks.org/data-science-for-beginners/?ref=shm)
* [Data Analysis](https://www.geeksforgeeks.org/what-is-data-analysis/?ref=shm)
* [Data Visualization](https://www.geeksforgeeks.org/data-visualization-and-its-importance/?ref=shm)
* [Machine Learning](https://www.geeksforgeeks.org/what-is-machine-learning/?ref=shm)
* [Deep Learning](https://www.geeksforgeeks.org/introduction-deep-learning/?ref=shm)
* [NLP](https://www.geeksforgeeks.org/natural-language-processing-overview/?ref=shm)
* [Computer Vision](https://www.geeksforgeeks.org/computer-vision-introduction/?ref=shm)
* [Artificial Intelligence](https://www.geeksforgeeks.org/What-is-ai-artificial-intelligence/?ref=shm)
* [AI ML DS Interview Series](https://www.geeksforgeeks.org/ai-ml-ds-interview/?ref=shm)
* [AI ML DS Projects series](https://www.geeksforgeeks.org/ai-ml-ds-projects/?ref=shm)
* [Data Engineering](https://www.geeksforgeeks.org/how-to-become-a-data-engineer/?ref=shm)
* [Web Scrapping](https://www.geeksforgeeks.org/introduction-to-web-scraping/?ref=shm)
* [Share Your Experiences](https://write.geeksforgeeks.org/#experiences)
* [Machine Learning Tutorial](https://www.geeksforgeeks.org/machine-learning/?ref=lbp)

**Prerequisites for Machine Learning**

* [Python for Machine Learning](https://www.geeksforgeeks.org/python-for-machine-learning/?ref=lbp)
* [SQL for Machine Learning](https://www.geeksforgeeks.org/sql-for-machine-learning/?ref=lbp)

**Getting Started with Machine Learning**

* [Advantages and Disadvantages of Machine Learning](https://www.geeksforgeeks.org/what-is-machine-learning/?ref=lbp)
* [Why ML is Important ?](https://www.geeksforgeeks.org/why-ml-is-important/?ref=lbp)
* [Real- Life Examples of Machine Learning](https://www.geeksforgeeks.org/real-life-applications-of-machine-learning/?ref=lbp)
* [What is the Role of Machine Learning in Data Science](https://www.geeksforgeeks.org/role-of-machine-learning-in-data-science/?ref=lbp)
* [Top Career Paths in Machine Learning](https://www.geeksforgeeks.org/top-career-paths-in-machine-learning/?ref=lbp)
* [Difference Between Machine Learning and Artificial Intelligence](https://www.geeksforgeeks.org/difference-between-machine-learning-and-artificial-intelligence/?ref=lbp)

**Machine Learning Foundations**

* [Statistics For Machine Learning](https://www.geeksforgeeks.org/statistics-for-machine-learning/?ref=lbp)
* [**Machine Learning Mathematics**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp)
* [Top Machine Learning Dataset: Find Open Datasets](https://www.geeksforgeeks.org/top-machine-learning-dataset-find-open-datasets/?ref=lbp)

**Packages For Machine Learning**

* [7 Best R Packages for Machine Learning](https://www.geeksforgeeks.org/7-best-r-packages-for-machine-learning/?ref=lbp)
* [Best Python libraries for Machine Learning](https://www.geeksforgeeks.org/best-python-libraries-for-machine-learning/?ref=lbp)

**Data Preprocessing**

* [ML | Introduction to Data in Machine Learning](https://www.geeksforgeeks.org/ml-introduction-data-machine-learning/?ref=lbp)
* [ML | Understanding Data Processing](https://www.geeksforgeeks.org/ml-understanding-data-processing/?ref=lbp)
* [ML | Overview of Data Cleaning](https://www.geeksforgeeks.org/data-cleansing-introduction/?ref=lbp)

**Creating Machine Learning Model**

* [Machine Learning Models](https://www.geeksforgeeks.org/machine-learning-models/?ref=lbp)
* [Flowchart for basic Machine Learning models](https://www.geeksforgeeks.org/flowchart-for-basic-machine-learning-models/?ref=lbp)
* [Creating a simple machine learning model](https://www.geeksforgeeks.org/creating-a-simple-machine-learning-model/?ref=lbp)
* [Machine Learning Model Evaluation](https://www.geeksforgeeks.org/machine-learning-model-evaluation/?ref=lbp)
* [Steps to Build a Machine Learning Model](https://www.geeksforgeeks.org/steps-to-build-a-machine-learning-model/?ref=lbp)

**Machine Learning Deployment**

* [Machine learning deployment](https://www.geeksforgeeks.org/machine-learning-deployment/?ref=lbp)
* [Deploy your Machine Learning web app (Streamlit) on Heroku](https://www.geeksforgeeks.org/deploy-your-machine-learning-web-app-streamlit-on-heroku/?ref=lbp)
* [Deploy a Machine Learning Model using Streamlit Library](https://www.geeksforgeeks.org/deploy-a-machine-learning-model-using-streamlit-library/?ref=lbp)
* [Deploy Machine Learning Model using Flask](https://www.geeksforgeeks.org/deploy-machine-learning-model-using-flask/?ref=lbp)
* [Python - Create UIs for prototyping Machine Learning model with Gradio](https://www.geeksforgeeks.org/python-create-uis-for-prototyping-machine-learning-model-with-gradio/?ref=lbp)
* [How to Prepare Data Before Deploying a Machine Learning Model?](https://www.geeksforgeeks.org/how-to-prepare-data-before-deploying-a-machine-learning-model/?ref=lbp)
* [Deploying ML Models as API using FastAPI](https://www.geeksforgeeks.org/deploying-ml-models-as-api-using-fastapi/?ref=lbp)

**Advance Topics in Machine Learning**

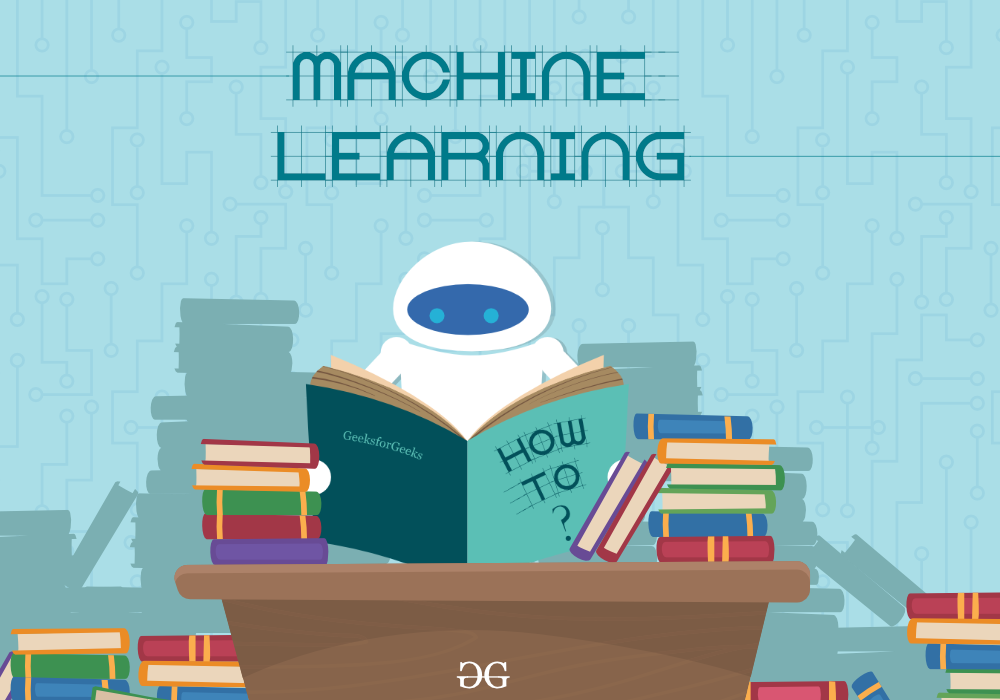
* [Introduction to Deep Learning](https://www.geeksforgeeks.org/introduction-deep-learning/?ref=lbp)
* [What is Transfer Learning?](https://www.geeksforgeeks.org/ml-introduction-to-transfer-learning/?ref=lbp)
* [Collaborative Learning - Federated Learning](https://www.geeksforgeeks.org/collaborative-learning-federated-learning/?ref=lbp)
* [100 Days of Machine Learning - A Complete Guide For Beginners](https://www.geeksforgeeks.org/100-days-of-machine-learning/?ref=lbp)
* [7 Major Challenges Faced By Machine Learning Professionals](https://www.geeksforgeeks.org/7-major-challenges-faced-by-machine-learning-professionals/?ref=lbp)
* [Machine Learning Interview Question & Answers](https://www.geeksforgeeks.org/machine-learning-interview-questions/?ref=lbp)
* [100+ Machine Learning Projects with Source Code [2024]](https://www.geeksforgeeks.org/machine-learning-projects/?ref=lbp)
* [Machine Learning & Data ScienceCourse](https://www.geeksforgeeks.org/courses/data-science-live?utm_source=geeksforgeeks&utm_medium=leftbar_lcta&utm_campaign=courses)

**Machine Learning Mathematics**

if you want to build your career in the field of Machine Learning as a beginner or professional looking for a career change then before directly jumping into machine learning you have to know the few Mathematical Concepts which include Statistics, Probability Distribution, [Linear Algebra](https://www.geeksforgeeks.org/linear-algebra/) and Matrix, Regression, Geometry, Dimensionality Reduction, Vector Calculus etc. Those Concepts are used very frequently in machine learning for example:- In ML what do we do? We Make a prediction model (Algorithms/classifiers) which is based on training data and then we use that model for making predictions for new data. To evaluate the quality of our model, we use a confusion matrix, which is based on the concept of conditional probability – a crucial mathematical concept. By understanding these mathematical concepts beforehand, it becomes easier for us to understand the concepts of machine learning.

So, That’s how mathematics is used in machine learning and that makes it a crucial part of Machine Learning.

***Machine Learning****is the field of study that gives computers the capability to learn without being explicitly programmed. Math is the core concept in machine learning which is used to express the idea within the machine learning model.*



*Mathematics for Machine Learning*

In this tutorial, we will look at different mathematics concepts and will learn about these modules from basic to advance with the help particular algorithm.

| * [**Linear Algebra and Matrix**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#lin) | * [**Regression**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#reg) |
| --- | --- |
| * [**Geometry**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#geo) | * [**Dimensionality Reduction**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#dim) |
| * [**Vector Calculus**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#vec) | * [**Vector Models**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#mod) |
| * [**Probability Distribution**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#prob) | * [**Miscellaneous**](https://www.geeksforgeeks.org/machine-learning-mathematics/?ref=lbp#mis) |

**Linear Algebra and Matrix**

Linear Algebra is an algebra extension to an undefined number of dimensions. Linear Algebra concerns the focus on linear equation systems.

* Vectors and Matrices
  + [Matrix Introduction](https://www.geeksforgeeks.org/matrix-introduction/)
  + Matrix Addition
    - [Matrix Addition using NumPy Arrays](https://www.geeksforgeeks.org/python-program-add-two-matrices/)
  + Matrix Multiplication
    - [Matrix Multiplication](https://www.geeksforgeeks.org/python-program-multiply-two-matrices/) using Python
  + [Matrix Manipulation using NumPy Arrays](https://www.geeksforgeeks.org/matrix-manipulation-python/)
  + Inverse of a Matrix
    - [Evaluating Inverse using NumPy Arrays](https://www.geeksforgeeks.org/compute-the-inverse-of-a-matrix-using-numpy/)
  + Transpose of a Matrix
    - [Evaluating Transpose using NumPy Arrays](https://www.geeksforgeeks.org/transpose-matrix-single-line-python/)
  + [Properties of Matrix](https://www.geeksforgeeks.org/properties-of-matrix-addition-and-scalar-multiplication-class-12-maths/)
  + [Determinant](https://www.geeksforgeeks.org/determinant-of-a-matrix/)
  + [Trace](https://www.geeksforgeeks.org/program-find-normal-trace-matrix/)
* System of Linear Equations
  + [System of Linear Equation](https://www.geeksforgeeks.org/system-linear-equations/)
  + [Solving Linear Equations using Gaussian Elimination](https://www.geeksforgeeks.org/gaussian-elimination/)
  + [LU Decomposition of Linear Equation](https://www.geeksforgeeks.org/l-u-decomposition-system-linear-equations/)
  + [Matrix Inversion](https://www.geeksforgeeks.org/inverse-of-a-matrix/)
* Matrix Factorization
  + Gram-Schmidt Process
  + QR Decomposition
  + [Cholesky Decomposition](https://www.geeksforgeeks.org/cholesky-decomposition-matrix-decomposition/)
  + [Singular Value Decomposition](https://www.geeksforgeeks.org/singular-value-decomposition/?ref=gcse)
  + [Matrix Factorization](https://www.geeksforgeeks.org/non-negative-matrix-factorization/)
  + [Diagonalization](https://www.geeksforgeeks.org/matrix-diagonalization/)
  + [Eigenvalues and Eigenvectors](https://www.geeksforgeeks.org/eigen-values-and-eigen-vectors/)
  + [Eigenspace](https://www.geeksforgeeks.org/eigenspace-and-eigenspectrum-values-in-a-matrix/)
* Vector Spaces
  + [Vector Operations](https://www.geeksforgeeks.org/dot-and-cross-products-on-vectors/)
  + Vector Spaces and SubSpaces
  + Basis and Dimension
* [Row Echelon Form](https://www.geeksforgeeks.org/row-echelon-form/)
* [Linear Mappings](https://www.geeksforgeeks.org/linear-mapping/?ref=gcse)
* Least Square and Curve Fitting
* [Affine Spaces](https://www.geeksforgeeks.org/affine-space/?ref=gcse)

**Statistics**

Statistics is the collection of data, tabulation, and interpretation of numerical data, and it is applied mathematics concerned with data collection analysis, interpretation, and presentation.

* [Mean, Standard Deviation, and Variance](https://www.geeksforgeeks.org/mathematics-mean-variance-and-standard-deviation/)
  + [Calculating Mean, Standard Deviation, and Variance using Numpy Arrays](https://www.geeksforgeeks.org/calculate-the-average-variance-and-standard-deviation-in-python-using-numpy/)
* [Sample Error and True Error](https://www.geeksforgeeks.org/true-error-vs-sample-error/?ref=gcse)
* [Bias Vs Variance](https://www.geeksforgeeks.org/bias-vs-variance-in-machine-learning/) and [Its Trade-Off](https://www.geeksforgeeks.org/ml-bias-variance-trade-off/)
* [Hypothesis Testing](https://www.geeksforgeeks.org/understanding-hypothesis-testing/)
  + [T-test](https://www.geeksforgeeks.org/t-test/)
  + [Paired T-test](https://www.geeksforgeeks.org/paired-t-test-a-detailed-overview/)
  + [p-value](https://www.geeksforgeeks.org/p-value-in-machine-learning/)
  + [F-Test](https://www.geeksforgeeks.org/f-test/)
  + [z-test](https://www.geeksforgeeks.org/z-test/)
* [Confidence Intervals](https://www.geeksforgeeks.org/confidence-interval/)
* [Correlation and Covariance](https://www.geeksforgeeks.org/mathematics-covariance-and-correlation/)
* [Correlation Coefficient](https://www.geeksforgeeks.org/program-find-correlation-coefficient/)
* Covariance Matrix
* [Normal Probability Plot](https://www.geeksforgeeks.org/normal-probability-plot/)
* [Q-Q Plot](https://www.geeksforgeeks.org/quantile-quantile-plots/)
* [Residuals Leverage Plot](https://www.geeksforgeeks.org/residual-leverage-plot-regression-diagnostic/?ref=gcse)
* [Robust Correlations](https://www.geeksforgeeks.org/robust-correlation/?ref=rp?ref=gcse)
* Hypothesis Testing
  + [Null and Alternative Hypothesis](https://www.geeksforgeeks.org/difference-between-null-and-alternate-hypothesis/)
  + Type 1 and Type 2 Errors
  + p-value interaction
  + Parametric Hypothesis Testing
    - [T-test](https://www.geeksforgeeks.org/t-test/)
    - Paired Samples t-test
    - ANOVA Test
  + Non-Parametric Hypothesis Testing
    - Mann-Whitney U test
    - Wilcoxon signed-rank test
    - [Kruskal-Wallis test](https://www.geeksforgeeks.org/kruskal-wallis-test/)
    - [Friedman test](https://www.geeksforgeeks.org/friedman-test/)
* Theory of Estimation
  + Difference between Estimators and Estimation
  + Methods of Estimation
    - Method of Moments
    - Bayesian Estimation
    - Least Square Estimation
    - [Maximum Likelihood Estimation](https://www.geeksforgeeks.org/probability-density-estimation-maximum-likelihood-estimation/)
  + Likelihood Function and Log-Likelihood Function
  + Properties of Estimation
    - Unbiasedness
    - Consistency
    - Sufficiency
    - Completeness
    - Robustness
* Confidence Intervals

**Geometry**

Geometry is the branch of mathematics that deals with the forms, angles, measurements, and proportions of ordinary objects.

* Vector Norms
* Inner, Outer, Cross Products
* [Distance Between Two Points](https://www.geeksforgeeks.org/distance-between-two-points/)
* Distance Measures
  + [Euclidean Distance](https://www.geeksforgeeks.org/euclidean-distance-using-scikit-learn-python/)
  + [Manhattan Distance](https://www.geeksforgeeks.org/how-to-calculate-manhattan-distance-in-r/)
  + [Minkowski Distance](https://www.geeksforgeeks.org/how-to-calculate-minkowski-distance-in-r/)
  + Chebysev Distance
* Similarity Measures
  + [Cosine Similarity](https://www.geeksforgeeks.org/cosine-similarity/)
  + [Jaccard Similarity](https://www.geeksforgeeks.org/how-to-calculate-jaccard-similarity-in-r/)
  + [Pearson Correlation Coefficient](https://www.geeksforgeeks.org/pearson-correlation-coefficient/)
  + [Kendall Rank Correlation Measure](https://www.geeksforgeeks.org/python-kendall-rank-correlation-coefficient/)
  + [Pearson Product-Moment Correlations](https://www.geeksforgeeks.org/pearson-product-moment-correlation/)
  + [Spearman’s Rank Correlation Measure](https://www.geeksforgeeks.org/spearmans-rank-correlation/)
* Orthogonality and Orthogonal Projections
  + [Orthogonality and Orthonormal Vectors](https://www.geeksforgeeks.org/orthogonal-and-orthonormal-vectors-in-linear-algebra/)
  + [Orthogonal Projections](https://www.geeksforgeeks.org/orthogonal-projections/?ref=gcse)
  + [Rotations](https://www.geeksforgeeks.org/rotate-matrix-elements/)
* Geometric Algorithms
  + Nearest Neighbor Search
  + Voronoi diagrams
  + Delaunay Triangulation
  + Geometric intersection and Proximity queries
* [Constraints and Splines](https://www.geeksforgeeks.org/constraint-cubic-spline/?ref=gcse)
* Box-Cox Transformations
  + [Box-Cox Transformation using Python](https://www.geeksforgeeks.org/box-cox-transformation-using-python/)
* [Fourier transformation](https://www.geeksforgeeks.org/fast-fourier-transformation-poynomial-multiplication/?ref=gcse)
  + [Properties of Fourier Transform](https://www.geeksforgeeks.org/properties-of-fourier-transform/)
* [Inverse Fast Fourier Transformation](https://www.geeksforgeeks.org/python-inverse-fast-fourier-transformation/)

**Calculus**

Calculus is a subset of mathematics concerned with the study of continuous transition. Calculus is also known as infinitesimal calculus or “infinite calculus.” The analysis of continuous change of functions is known as classical calculus

* Differentiation
  + [Implicit Differentiation](https://www.geeksforgeeks.org/implicit-differentiation/)
  + [Inverse Trigonometric Functions Differentiation](https://www.geeksforgeeks.org/differentiation-of-inverse-trigonometric-functions/)
  + [Logarithmic Differentiation](https://www.geeksforgeeks.org/logarithmic-differentiation/)
  + [Partial Differentiation](https://www.geeksforgeeks.org/engineering-mathematics-partial-derivatives/)
  + [Advanced Differentiation](https://www.geeksforgeeks.org/advanced-differentiation/)
* Mathematical Intuition Behind Gradients and their usage
  + [Implementation of Gradients using Python](https://www.geeksforgeeks.org/how-to-find-gradient-of-a-function-using-python/)
  + [Optimization Techniques using Gradient Descent](https://www.geeksforgeeks.org/optimization-techniques-for-gradient-descent/)
* [Higher-Order Derivatives](https://www.geeksforgeeks.org/higher-order-derivatives/)
* [Multivariate Taylor Series](https://www.geeksforgeeks.org/taylors-theorem-and-taylor-series/)
* Application of Derivation
  + [Application of Derivative – Maxima and Minima](https://www.geeksforgeeks.org/application-of-derivative-maxima-and-minima-mathematics/)
  + [Absolute Minima and Maxima](https://www.geeksforgeeks.org/absolute-minima-and-maxima/)
  + [Constrained Optimization](https://www.geeksforgeeks.org/optimization-for-data-science/?ref=gcse)
  + [Unconstrained Optimization](https://www.geeksforgeeks.org/unconstrained-multivariate-optimization/)
  + [Constrained Optimization – Lagrange Multipliers](https://www.geeksforgeeks.org/lagrange-multipliers/)
  + [Newton’s Method](https://www.geeksforgeeks.org/newtons-method-for-finding-roots/)
* [Uni-variate Optimization](https://www.geeksforgeeks.org/uni-variate-optimization-data-science/)
* [Multivariate Optimization](https://www.geeksforgeeks.org/multivariate-optimization-with-equality-constraint/)
* Convex Optimization
* [Lagrange’s Interpolation](https://www.geeksforgeeks.org/lagranges-interpolation/)
* [Area Under Curve](https://www.geeksforgeeks.org/area-under-the-curve/)

**Probability and Distributions**

Probability and distributions are statistical functions that describe all the possible values.

* [Probability](https://www.geeksforgeeks.org/mathematics-probability/)
* [Chance and Probability](https://www.geeksforgeeks.org/chance-and-probability/)
* [Addition Rule for Probability](https://www.geeksforgeeks.org/addition-rule-for-probability/)
* [Law of total probability](https://www.geeksforgeeks.org/mathematics-law-of-total-probability/)
* [Bayes’ Theorem](https://www.geeksforgeeks.org/bayess-theorem-for-conditional-probability/)
* Discrete Probability Distributions
  + [Discrete Uniform Distribution](https://www.geeksforgeeks.org/mathematics-probability-distributions-set-1/?ref=rp)
  + Bernoulli Distribution
  + [Binomial Distribution](https://www.geeksforgeeks.org/mathematics-probability-distributions-set-4-binomial-distribution/)
  + [Poisson Distribution](https://www.geeksforgeeks.org/mathematics-probability-distributions-set-5-poisson-distribution/?ref=rp)
* Continuous Probability Distributions
  + Continuous Uniform Distribution
  + [Exponential Distribution](https://www.geeksforgeeks.org/probability-distributions-part-2-exponential-distribution/?ref=rp)
  + [Normal Distribution](https://www.geeksforgeeks.org/mathematics-probability-distributions-set-3-normal-distribution/?ref=rp)
  + [Beta Distribution](https://www.geeksforgeeks.org/mathematics-beta-distribution-model/)
    - Beta Distribution of First Kind
    - Beta Distribution of Second Kind
  + [Gamma Distribution](https://www.geeksforgeeks.org/gamma-distribution-model-in-mathematics/)
* Sampling Distributions
  + Chi-Square Distribution
  + F – Distribution
  + [t – Distribution](https://www.geeksforgeeks.org/students-t-distribution-in-statistics/)
* Central Limit Theorem
  + [Implementation of Central Limit Theorem](https://www.geeksforgeeks.org/python-central-limit-theorem/)
* Law of Large Numbers
* Change of Variables/Inverse Transformation

**Regression**

Regression is a statistical process for estimating the relationships between the dependent variables or criterion variables

* Parameter Estimation
* [Bayesian Linear Regression](https://www.geeksforgeeks.org/implementation-of-bayesian-regression/)
* Quantile Linear Regression
* [Normal Equation in Linear Regression](https://www.geeksforgeeks.org/ml-normal-equation-in-linear-regression/)
* [Maximum Likelihood as Orthogonal Projection](https://www.geeksforgeeks.org/orthogonal-projections/?ref=gcse)

**Dimensionality Reduction**

Dimensionality reduction is a technique to reduce the number of input variables in training data.

* [Introduction to Dimensionality Reduction](https://www.geeksforgeeks.org/dimensionality-reduction/)
* [Projection Perspective in Machine Learning](https://www.geeksforgeeks.org/projection-perspective-in-machine-learning/?ref=gcse)
* [Eigenvector Computation and Low-Rank Approximations](https://www.geeksforgeeks.org/eigenvector-computation-and-low-rank-approximations/?ref=gcse)
* [Mathematical Intuition Behind PCA](https://www.geeksforgeeks.org/mathematical-approach-to-pca/)
  + [PCA implementation in Python](https://www.geeksforgeeks.org/ml-principal-component-analysispca/)
* Latent Variable Perspective
* Mathematical Intuition Behind LDA
  + [Implementation of Linear Discriminant Analysis (LDA)](https://www.geeksforgeeks.org/ml-linear-discriminant-analysis/)
* Mathematical Intuition Behind GDA
  + [Implementation of Generalized Discriminant Analysis (GDA)](https://www.geeksforgeeks.org/gaussian-discriminant-analysis/)
* Mathematical Intuition Behind t-SNE Algorithm
  + [Implementation of the t-SNE Algorithm](https://www.geeksforgeeks.org/ml-t-distributed-stochastic-neighbor-embedding-t-sne-algorithm/)