The Book of Statistical Proofs

I. General Theorems

- 1. Probability theory
 - 1.1. Central limit theorems
 - 1.1.1. Classical central limit theorem
 - 1.1.2. Generalized central limit theorem
 - 1.2. Bayesian inference
 - 1.2.1. Bayes' theorem
 - 1.2.2. Bayes' rule
 - 1.3. Probability distributions
 - 1.3.1. Equivalence of moment-generating function and probability density function
 - 1.3.2. Equivalence of characteristic function and cumulative distribution function
- 2. Estimation theory
 - 2.1. Point estimates
 - 2.1.1. Arithmetic mean minimizes quadratic loss function
 - 2.1.2. Partition of mean squared error into bias and variance
 - 2.2. Interval estimates
 - 2.2.1. Equivalence of confidence interval and statistical test
 - 2.2.2. Construction of confidence intervals using Wilks's theorem
- 3. Information theory
 - 3.1. Shannon entropy
 - 3.1.1. Relationship between mutual information and entropy
 - 3.1.2. Relationship between continuous mutual information and differential entropy

II. Probability Distributions

- 1. Univariate discrete distributions
 - 1.1. Binomial distribution
 - 1.2. Poisson distribution
- 2. Multivariate discrete distributions
 - 2.1. Multinomial distribution
 - 2.2. Multinomial-Dirichlet distribution

- 3. Univariate Continuous distributions
 - 3.1. Uniform distribution
 - 3.1.1. Properties
 - 3.1.2. Estimation of maximum
 - 3.2. Normal distribution
 - 3.2.1. Properties
 - 3.2.2. Maximum entropy distribution
- 4. Multivariate continuous distributions
 - 4.1. Multivariate normal distribution
 - 4.1.1. Properties
 - 4.1.2. Linear transformation
 - 4.1.3. Marginal distributions
 - 4.2. Normal-gamma distribution
 - 4.2.1. Properties
 - 4.2.2. Marginal distributions
 - 4.2.3. Kullback-Leibler divergence
 - 4.3. Dirichlet distribution
 - 4.3.1. Properties
 - 4.3.2. Sampling from gamma distributions
 - 4.3.3. Exceedance probabilities
- 5. Matrix-variate continuous distributions
 - 5.1. Matrix-normal distribution
 - 5.1.1. Properties
 - 5.1.2. Equivalence to multivariate normal distribution
 - 5.1.3. Maximum likelihood estimation
 - 5.1.4. Linear transformation
 - 5.2. Wishart distribution
 - 5.2.1. Properties
 - 5.2.2. Relationship to multivariate normal distribution
 - 5.2.3. Maximum likelihood estimation
 - 5.2.4. Linear transformation

III. Statistical Models

- 1. Normal data
 - 1.1. Simple linear regression
 - 1.1.1. Least squares parameter estimates
 - 1.1.2. Maximum likelihood parameter estimates
 - 1.2. Multiple linear regression
 - 1.2.1. Ordinary least squares (linear algebra)
 - 1.2.2. Ordinary least squares (differential calculus)
 - 1.2.3. Total, explained and residual sum of squares
 - 1.2.4. Estimation, projection and residual-forming matrix
 - 1.2.5. Weighted least squares (probability theory)
 - 1.2.6. Weighted least squares (differential calculus)
 - 1.2.7. Maximum likelihood estimation
 - 1.3. Classical significance tests
 - 1.3.1. One-sample t-test
 - 1.3.2. Two-sample t-test
 - 1.3.3. Paired t-test
 - 1.3.4. Test for association
 - 1.3.5. Contrast-based t-test
 - 1.3.6. Omnibus F-test
 - 1.3.7. Contrast-based F-test
 - 1.4. Bayesian linear regression
 - 1.4.1. Conjugate prior distribution
 - 1.4.2. Posterior distribution
 - 1.4.3. Log model evidence
 - 1.5. General linear model
 - 1.5.1. Weighted least squares
 - 1.5.2. Maximum likelihood estimation
 - 1.5.3. Restricted maximum likelihood estimation
 - 1.6. Forward and backward GLM
 - 1.6.1. Existence of a backward model, given forward model
 - 1.6.2. Unbiasedness of weighted least squares estimates

- 1.6.3. Equivalence of log-likelihood ratios
- 1.7. Bayesian multivariate linear regression
 - 1.7.1. Conjugate prior distribution
 - 1.7.2. Posterior distribution
 - 1.7.3. Log model evidence
- 2. Poisson data
 - 2.1. Poisson distribution without exposure values
 - 2.1.1. Maximum likelihood estimation
 - 2.2. Poisson distribution with exposure values
 - 2.2.1. Conjugate prior distribution
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 - 2.2.3. Log model evidence
- 3. Probability data
 - 3.1. Estimating a Beta distribution
 - 3.1.1. Methods of moments
 - 3.1.2. Maximum likelihood estimation
 - 3.1.3. Estimation using Fisher information matrix
 - 3.2. Group-level Bayesian model selection
 - 3.2.1. Fixed-effects estimation
 - 3.2.2. Random-effects estimation (variational Bayes)
 - 3.2.3. Random-effects estimation (Gibbs sampling)
- 4. Categorical data
 - 4.1. Contingency tables
 - 4.1.1. Chi-squared test for independence
 - 4.1.2. Fisher's exact test
 - 4.2. Binomial-Beta model
 - 4.2.1. Posterior distribution
 - 4.2.2. Log model evidence
 - 4.3. Multinomial-Dirichlet model
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IV. Model Selection

- 1. Goodness-of-fit measures
 - 1.1. Residual variance
 - 1.1.1. Maximum likelihood estimator is biased
 - 1.1.2. Adjustment for effective number of parameters
 - 1.2. R-squared
 - 1.2.1. Derivation of R² and adjusted R²
 - 1.2.2. Relationship to maximum log-likelihood
 - 1.3. F-statistic
 - 1.3.1. Relationship between R² and the F-statistic
 - 1.4. Signal-to-noise ratio
 - 1.4.1. Relationship between R² and signal-to-noise ratio
 - 1.5. Correlation coefficient
 - 1.5.1. Fisher z-transformation for Pearson correlation coefficients
- 2. Classical information criteria
 - 2.1. Akaike's information criterion
 - 2.1.1. Derivation
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 - 2.2.1. Derivation
 - 2.3. Deviance information criterion
 - 2.3.1. Derivation
- 3. Bayesian model selection
 - 3.1. Log model evidence
 - 3.1.1. Derivation of the log model evidence
 - 3.1.2. Partition into accuracy and complexity
 - 3.1.3. Cross-validated log model evidence
 - 3.2. LME-derived quantities
 - 3.2.1. Log family evidence
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 - 3.2.3. Posterior model probabilities
 - 3.2.4. Bayesian model averaging