DEPARTMENT OF STATISTICS

Scheme and Syllabus
M.Sc. (Statistics)
2018-20

CENTRALUNIVERSITY OF HARYANA
JANT-PALI, MAHENDERGARH
HARYANA-123031

Department of Statistics
Central University of Haryana
Mahendergarh, Haryana-123031

Scheme and Syllabus of M.Sc. Statistics
(CHOICE BASED CREDIT SYSTEM)

……

Course Type

- Core (C)
- Generic Elective (GE)
- Discipline Centric Elective (DCE)
- Skill Enhancement Elective (SEE)

Total Credits: 96

Semester wise distribution of credits: 24 + 24 + 24 + 24.

SEMESTER I

Total Credits: 24 (C: 20, GE: 4)

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Analysis and Linear Algebra	SPMS ST 01 101 C 3104	3	1	0	4
2.	Probability Theory	SPMS ST 01 102 C 3104	3	1	0	4
3.	Distribution Theory	SPMS ST 01 103 C 3104	3	1	0	4
4.	Sampling Techniques	SPMS ST 01 104 C 3104	3	1	0	4
5.	Practical	SPMS ST 01 105 C 0044	0	0	4	4
6.	GE (to be taken from other departments)					

Courses for other departments (GE):

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Introductory Statistics	SPMS ST 01 101 GE 3014	3	0	1	4
2.	Operations Research	SPMS ST 01 102 GE 3014	3	0	1	4

SEMESTER II

Total Credits: 24 (C: 16, DCE: 4, GE: 4)

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Statistical Inference - I	SPMS ST 01 201 C 3104	3	1	0	4
2.	Linear Models and Regression Analysis	SPMS ST 01 202 C 3104	3	1	0	4
3.	Design of Experiments	SPMS ST 01 203 C 3104	3	1	0	4
4.	Practical	SPMS ST 01 204 C 0044	0	0	4	4
5.	DCE		3	1	0	4
6.	GE (to be taken from other departments)					

Courses for students of M.Sc. Statistics only (DCE):

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Time Series and Statistical Quality Control	SPMS ST 01 201 DCE 3104	3	1	0	4
2.	Operations Research	SPMS ST 01 202 DCE 3104	3	1	0	4
3.	Categorical Data Analysis	SPMS ST 01 203 DCE 3104	3	1	0	4

Courses for other departments (GE):

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Applied Statistics	SPMS ST 01 201 GE 3014	3	0	1	4
2.	Programming in R	SPMS ST 01 202 GE 3104	3	1	0	4

SEMESTER III

Total Credits: 24 (C: 20, DCE: 4)

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Multivariate Analysis	SPMS ST 01 301 C 3104	3	1	0	4
2.	Statistical Inference - II	SPMS ST 01 302 C 3104	3	1	0	4
3.	Econometrics	SPMS ST 01 303 C 3104	3	1	0	4
4.	Seminar	SPMS ST 01 304 C 4004	4	0	0	4
5.	Practical	SPMS ST 01 305 C 0044	0	0	4	4
6.	DCE		3	1	0	4

Courses for students of M.Sc. (Statistics) only (DCE):

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Stochastic Processes	SPMS ST 01 301 DCE 3104	3	1	0	4
2.	Demography and Vital Statistics	SPMS ST 01 302 DCE 3104	3	1	0	4
3.	Biostatistics	SPMS ST 01 303 DCE 3104	3	1	0	4
4.	Actuarial Statistics	SPMS ST 01 304 DCE 3104	3	1	0	4

SEMESTER IV

S. No.	Course Title	Course Code	L	T	P	Credit
Total Credits: 24 (PROJ: 24)*						
1.	Major Project/Dissertation	SPMS ST 01 401 PROJ 00016	-	-	-	24
OR						
Total Credits: 24 (DCE: 8, PROJ: 16)						
1.	Minor Project/Dissertation	SPMS ST 01 402 PROJ 00016	-	-	-	16
2.	DCE		3	1	0	4
3.	DCE		3	1	0	4

Courses for students of M.Sc. (Statistics) only (DCE):

S. No.	Course Title	Course Code	L	T	P	Credit
1.	Order Statistics	SPMS ST 01 401 DCE 3104	3	1	0	4
2.	Survival Analysis	SPMS ST 01 402 DCE 3104	3	1	0	4
3.	Decision Theory and Sequential Analysis	SPMS ST 01 403 DCE 3104	3	1	0	4
4.	Statistical Computation and Simulation	SPMS ST 01 404 DCE 3104	3	1	0	4
5.	Generalized Linear Models	SPMS ST 01 405 DCE 3104	3	1	0	4
6.	Nonparametric Inference	SPMS ST 01 406 DCE 3104	3	1	0	4

*On Departmental Committee Recommendation

Semester I

ANALYSIS AND LINEAR ALGEBRA

(SPMS ST 01 101 C 3104)

Objectives: This course provides help to understand the mathematical concept of convergence and its mathematical formalisms. Students will be able to use some fundamental theorems of mathematical analysis. Students will have knowledge of the special character of functions of a complex variable and their properties. The students also will be well equipped to apply these techniques in many major Statistics courses like Linear Inference, Multivariate Analysis during this course.

UNIT I

Recap of elements of set theory, introduction to real numbers, open and closed intervals (rectangles), compact sets, Bolzano-Weirstrass theorem. Sequences and series, their convergence, real valued functions, continuous functions.

UNIT II

Uniform continuity, Uniform convergence. Maxima-minima of functions. Complex numbers, analytic function, Cauchy fundamental theorem, Cauchy integral theorem, contour integrations.

UNIT III

Determinant and trace, rank, ranks of product of two matrices, elementary matrices and Echelon forms. Partitioned matrices: addition, multiplication and inverse. Cayley Hamilton Theorem, diagonalization, generalized inverse: Definition and its computation.

UNIT IV

Definite and semi definite quadratic forms, index and signatures, simultaneous diagonalization of symmetric matrices (equivalent quadratic forms). Vector spaces, sub-spaces, linearly dependence and independence, orthogonalization process, orthonormal basis.

Suggested Readings:

1. Bartle, R.G. & Sherbert, D.R. (2011). Introduction to Real Analysis, 4th Edition. Wiley.
2. Saff, E.B. & Snider, A.D. (2014). Fundamentals of Complex Analysis with Applications to Engineering, Science and Mathematics, 3rd Edition. Pearson.
3. Rudin, W. (2013). Principles of Mathematical Analysis, 3rd Edition. McGraw Hill.
4. Biswas, S. (2012). A Textbook of Matrix Algebra, 3rd Edition. PHI Learning.

PROBABILITY THEORY

(SPMS ST 01 102 C 3104)

Objectives: This course will lay the foundation to probability theory and statistical modelling of outcomes of real life random experiments through various statistical distributions.

UNIT I

Classes of sets, field, sigma field, minimal sigma field, Borel field, sequence of sets, limits of a sequence of sets, measure, probability measure, Integration with respect to measure. Random experiment, outcomes, sample space, events, various definitions of probability, laws of total and compound probability. Boole's inequality. Conditional probability, independence of events. Bayes Theorem.

UNIT II

Random variable, probability mass function, probability density function, cumulative distribution function. Expectation of a random variable, properties of expectation, conditional expectation and its properties. Bivariate distributions and the joint probability distribution. Independence of random variables. Marginal and conditional distributions.

UNIT III

Moment generating function, probability generating function, cumulant generating function, characteristic function and their properties. Inversion, continuity and uniqueness theorems.

UNIT IV

Convergence in probability, almost sure convergence, convergence in distribution and their relationships. Chebyshev's inequality, weak law of large numbers (WLLN), strong law of large numbers (SLLN), central limit theorems.

Suggested Readings:

1. Rohatgi V.K. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
2. Rao, B.L.S.P. (2010): A First Course in Probability and Statistics. World Scientific.
3. Hogg, R.V., McKean, J. & Craig, A.T. (2013). Introduction to Mathematical Statistics, 7th Edition. Pearson.
4. Mukhopadhyay, P. (2015). Mathematical Statistics. New Central Book Agency.

DISTRIBUTION THEORY

(SPMS ST 01 103 C 3104)

Objective: The main objective of the course is to provide the detailed knowledge of the characterization of all the useful discrete and continuous distributions.

UNIT I

Bernoulli, Binomial, Poisson, Geometric, Negative Binomial, Multinomial, Hypergeometric and discrete uniform distributions; their means, variances, modes, moment generating functions, cumulant generating function, probability generating functions and characteristic functions, important properties with their proofs related to these distributions.

UNIT II

Continuous uniform, Exponential, Gamma, Normal, Beta, Cauchy, Laplace, Weibull, Pareto and lognormal with their properties including proofs; their means, variances, moment generating functions, cumulant generating function and characteristic functions.

UNIT III

Compound, truncated and mixture distributions. Central and Non-central χ^2, t and F distributions with their properties. Multidimensional random variables, its pdf/pmf and cdf.

UNIT IV

Bivariate normal distribution with its applications and important properties. Multivariate normal distribution, its marginal and conditional distributions and related properties.

Suggested Readings:

1. Krishnamoorthy, K. (2015). Handbook of Statistical Distributions with Applications, 2nd Edition. CRC Press.
2. Rohatgi V.K. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I. World Press.
4. Forbes, C., Evans, M., Hastings, N. & Peacock, B. (2010). Statistical Distributions, 4th Edition. Wiley.

SAMPLING TECHNIQUES

(SPMS ST 01 104 C 3104)

Objectives: The objective of this course is to acquaint the students about: (i) the need & merits of sampling over census and (ii) the implementation of various sampling schemes along with their merits, demerits and comparisons in appropriate practical situations.

UNIT I

Introduction to sampling, census and sample surveys, sampling and non-sampling errors. Simple random sampling, sampling from finite populations with and without replacement, unbiased estimation and confidence intervals for population mean and total, simple random sampling of attributes.

UNIT II

Stratified sampling, reasons for stratification, choice of strata, choice of sampling unit, estimation of population mean and its variance, choice of sample sizes in different strata, variances of estimates with different allocation, effects of deviation from optimum allocations, estimation of the gain in precision due to stratification, cost function, construction of strata. Systematic Sampling: merits and demerits of systematic sampling, estimation of sample mean and its variance, comparison of systematic sampling with simple random and stratified sampling.

UNIT III

Ratio and regression methods of estimation, variances of the estimates, optimum property of ratio estimates, comparison among ratio, regression and simple random sampling estimates, ratio estimate in stratified sampling, comparison with the ratio and mean per unit. Cluster Sampling, estimates of mean and its variance for equal and unequal clusters, efficiency in terms of intraclass correlation, optimum unit of sampling, sampling with replacement, estimation of mean and its variance.

UNIT IV

Sampling with varying probabilities with and without replacement, sampling with probability proportional to size, Lahiri's method of selection, Horvitz-Thompson estimator, its variance and unbiased estimate of this variance. Introduction of multistage sampling, two stage sampling with equal first stage units, estimation of its mean and variance, introduction of multiphase sampling, double sampling for ratio and regression methods of estimation.

Suggested Readings:

1. Singh, D. & Chaudhary, F.S. (2016). Theory and Analysis of Sample Survey Designs. New Age International Publishers.
2. Arnab, R. (2017). Survey Sampling Theory and Applications. Academic Press.
3. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. & Ashok, C. (2014). Sampling Theory of Surveys with Applications. New Delhi: Piyush Publications.
4. Cocharn, W.G. (2007). Sampling Techniques, 3rd Edition. Wiley.

PRACTICAL

(SPMS ST 01 105 C 0044)

Practicals based on Distribution Theory (SPMS ST 01 103 C 3104) and Sampling Techniques (SPMS ST 01 104 C 3104).

INTRODUCTORY STATISTICS

(SPMS ST 01 101 GE 3014)

Objectives: The objective of this course is to define a variety of basic statistical terms and concepts, solve fundamental statistical problems, understanding of statistical fundamentals to interpret data.

UNIT I

Introduction to Statistical Analysis, Measures of Central Tendency: Mean, median, mode, geometric mean, harmonic mean. Measures of Dispersion: range, mean deviation, variance, standard deviation. Quartiles. Quartile deviation, coefficient of variation, measures of skewness, measures of kurtosis.

UNIT II

Random experiment, outcomes, sample space, events, classical definition of probability, random variables, probability mass function, probability density function, cumulative distribution function, mathematical expectation, Variance, Binomial, Poisson, Geometric, Exponential, Normal distributions.

UNIT III

Null hypothesis, alternative hypothesis, type I error, type II error, level of significance, p-value and power of test. Tests for mean based on normal distribution – one sample t-test, two-sample t-test, paired-sample t-test. Tests for variance based on normal distribution – one sample and two-sample problem. One-way and Two-way analysis of variance (ANOVA) techniques.

UNIT IV

Karl Pearson's correlation coefficient, Spearman's rank correlation coefficient, principle of least square, lines of regression, simple linear regression, coefficient of determination. Multiple linear regression, coefficient of multiple determination.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I & II. World Press.
2. Das, N.G. (2012). Statistical Methods, Vol I & II. Tata McGraw Hill.
3. Walpole, R.E., Myers, R.H., Myers, S.L. & Ye, K.E (2012). Probability and Statistics for Engineers and Scientists. Pearson.
4. Daniel, W.W. & Cross, C.L. (2012). Biostatistics: A Foundation for Analysis in the Health Sciences, 10th Edition. Wiley.

OPERATIONS RESEARCH

(SPMS ST 01 102 GE 3104)

Objective: To provide the ideas of formulating mathematical modeling and their optimum solution in the context of practical problems belonging to Government/Private Sectors. Also, to give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents.

UNIT I

Origin and development of operations research (O.R.), modelling in O.R., applications of O.R., opportunities and shortcomings of O.R. Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the LPP, generating extreme point solutions.

UNIT II

The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique.

UNIT III

Two phase method and Charnes M-method with artificial variables. The duality problem of linear programming and its economic interpretation, transportation and assignment problems.

UNIT IV

Game theory problem as a linear programming problem, integer programming. Replacement models and sequencing theory. Inventory management: characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time.

Suggested Readings:

1. Taha, H.A. (2017). Operations Research: An Introduction, 10th Edition. Pearson.
2. Gass, S.I. (2010). Linear Programming, Methods and Applications, 5th Edition. Dover Books.
3. Gross, D., Shortle, J.F., Thompson, J.M. & Harris, C.M. (2017). Fundamentals of Queueing Theory, 5th Edition. Wiley.
4. Water, D. (2013). Inventory Control and Management, 2nd Edition. Wiley.

Semester II

STATISTICAL INFERENCE - I

(SPMS ST 01 201 C 3104)

Objective: The objective of estimation theory is to arrive at an estimator that exhibits optimality. The estimator takes observed data as an input and produces an estimate of the parameters. Also, to provide a systematic account of Neyman Pearson theory of testing and closely related theory of point estimation and confidence sets, together with their applications.

UNIT I

Criteria of a good estimator- unbiasedness, consistency, efficiency, sufficiency. Minimal sufficient statistic. Exponential and Pitman families of distributions. Cramer-Rao lower bound approach to obtain minimum variance unbiased estimator. Uniformly minimum variance unbiased estimator, Complete statistic, Rao-Blackwell theorem, Lehmann-Scheffe theorem.

UNIT II

Method of moments, minimum chi-square estimation, maximum likelihood estimator and its properties, CAN & BAN estimators. Ancillary statistic and Basu' s theorem. Simple and composite hypothesis, concept of critical regions, test functions, two types of error, power of the test, level of significance, Neyman-Pearson lemma, uniformly most powerful (UMP) tests.

UNIT III

Types A, A1 critical regions, likelihood ratio test (LRT) with its asymptotic distribution, UMP tests for monotone likelihood ratio family of distributions. Similar tests with Neyman structure, Construction of similar and UMPU tests through Neyman structure.

UNIT IV

Confidence interval, construction of confidence intervals using pivotal, shortest expected length confidence interval, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses.

Suggested Readings:

1. Rohatgi, V.K. & Saleh, A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
2. Lehmann, E.L. & Casella, G. (2014). Theory of Point Estimation, 2nd Edition. Springer.
3. Lehmann, E.L. & Romano, J.P. (2010). Testing Statistical Hypotheses, 3rd Edition. Springer.
4. Casella, G. & Berger, R.L. (2013). Statistical Inference, 2nd Edition. Cengage Learning.

LINEAR MODELS AND REGRESSION ANALYSIS

(SPMS ST 01 202 C 3104)

Objective: The students will get familiar with the need of modeling random responses using independent predictors through linear and logistic (for binary responses) models in real life situations. Least square estimation of parameters of these models will be discussed along with their statistical significance.

UNIT I

Gauss-Markov linear Models, theory of linear estimation, estimability of linear parametric functions, method of least squares, normal equations, Gauss-Markov theorem, estimation of error variance. Distribution of quadratic forms.

UNIT II

Simple Linear Regression: Simple linear regression model. Least-squares estimation of parameters. Hypothesis testing on the slope and intercept. Interval estimation in simple linear regression. Prediction of new observations. Coefficient of determination. Estimation by maximum likelihood. Multiple linear regression: Multiple linear regression models. Estimation of the model parameters. Hypothesis testing in multiple linear regression. Confidence intervals in multiple regression. Coefficient of determination and Adjusted R^2.

UNIT III

Model Adequacy: Checking of linearity between study and explanatory variable, Residual Analysis, Detection and treatment of outliers, Residual plots. The PRESS statistic. Outlier test based on Studentized Residual (R-student). Test for lack of fit of the regression model. Transformation and Weighting to Correct Model Inadequacies: Variance stabilizing transformations. Transformations to linearize the model. Analytical methods for selecting a transformation on study variable. Diagnostic for Leverage and Influence: Leverage, measures of influence.

UNIT IV

Polynomial Regression Models: Polynomial models in one variable. Orthogonal Polynomials. Piecewise polynomial (Splines). Variable Selection and Model Building: Incorrect model specifications. Evaluation of subset regression model. Computational techniques for variable selection. Logistic Regression: Introduction, Linear predictor and link functions, logit, probit, odds ratio, test of hypothesis.

Suggested Readings:

1. Bapat, R.B. (2012). Linear Algebra and Linear Models, 3rd Edition. Hindustan Book Agency.
2. Montegomery, D.C., Peck, E.A. & Vining, G.G. (2015). Introduction to Linear Regression Analysis, 5th Edition. Wiley.
3. Khuri, A.I. (2010). Linear Model Methodology. CRC Press.
4. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
5. Draper, N.R. & Smith, H. (2011). Applied Regression Analysis, 3rd Edition. Wiley.

DESIGN OF EXPERIMENTS

(SPMS ST 01 203 C 3104)

Objective: To provide orientation of statistics while designing statistical experiments, particularly in agricultural set-up and in pharmaceutical production processes. Exposure to various statistical designs leading to the analysis of variance, eliminating heterogeneity of the data, construction of designs will be provided.

UNIT I

Introduction to design of experiments. Three basic principles of design of experiments: randomisation, replication and local control. Uniformity trials. Analysis of basic design, asymptotic relative efficiency, missing plot techniques, analysis of covariance for CRD and RBD.

UNIT II

Factorial experiments: 2^k, 3^2 and 3^3 systems only. Complete and partial confounding, factorial replication in 2^k systems. Two-level fractional factorial designs: introduction, the one-quarter fraction of the 2^k design. Alias structure in fractional factorials and other designs.

UNIT III

Incomplete block design: balanced incomplete block design, simple lattice design, split-plot design, strip-plot design, comparison of two treatments, efficiency of BIBD relative to RBD.

UNIT IV

Response surface methodology, first order designs, and orthogonal designs, treatment-control designs, model variation and use of transformation.

Suggested Readings:

1. Montgomery, D.C. (2013). Design and Analysis of Experiments, 8th Edition. Wiley.
2. Toutenburg, H. & Shalabh (2010). Statistical Analysis of Designed Experiments, 3rd Edition. Springer.
3. Cobb, G.W. (2014). Introduction to Design and Analysis of Experiments. Wiley.
4. Lawson, J. (2014). Design and Analysis of Experiments with R. CRC Press.

PRACTICAL

(SPMS ST 01 204 C 0044)

Practicals based on Statistical Inference -I (SPMS ST 01 201 C 3104), Linear Models and Regression Analysis (SPMS ST 01 202 C 3104) and Design of Experiments (SPMS ST 01 203 C 3104).

TIME SERIES AND STATISTICAL QUALITY CONTROL

(SPMS ST 01 201 DCE 3104)

Objective: The objective of this course is to equip the students of M.Sc. Statistics with knowledge of industrial statistics as well as applications of Time series in real life.

UNIT I

Time series: objects, decomposition, examples of time series, trend component, polynomial, logistic, Gompertz, log-normal trend functions, smoothing of moving average, Spencer's formulae and effects, variate difference method, Measurement of seasonal and cyclical functions, Peridogram and harmonic analysis.

UNIT II

Concepts of auto regression, autocorrelation, partial autocorrelation and correlogram analysis. Linear models for stationary time series. First order moving average (MA(1)) process, second order moving average (MA(2)) process. First order autoregressive process (AR(1)), second order autoregressive process (AR(2)). Autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models.

UNIT III

Concept of quality and meaning of control, Chance and assignable causes of quality variation, product and process controls. Concept of 3-sigma limits. Modified and specifications limits. Different types of control charts like $\bar{X}$, R, np, p and c with their applications in industry.

UNIT IV

Sampling inspection v/s 100% inspection. Single, double, multiple and sequential sampling plans for attributes. Operating characteristic (OC), AOQL, ASN and ATI curves. Concept of producer's and consumer's risk, AQL and LTPD. Variable sampling plans.

Suggested Readings:

1. Montgomery,D.C., Jennings, C.L. & Kulahci, M. (2015). Introduction to Time Series Analysis and Forecasting, 2nd Edition. Wiley.
2. Brockwell, P.J. & Davis R.A. (2016). Introduction to Time Series and Forecasting, 2nd Edition. Springer.
3. Montgomery, D.C. (2012). Introduction to Statistical Quality Control, 7th Edition. Wiley.
4. Grant, E. & Leavenworth, R. (2012). Statistical Quality Control, 7th Edition. Tata McGraw Hill.

OPERATIONS RESEARCH

(SPMS ST 01 202 DCE 3104)

Objective: To provide the ideas of formulating mathematical modeling and their optimum solution in the context of practical problems belonging to Government/Private Sectors. Also, to give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents.

UNIT I

Origin and development of operations research (O.R.), modelling in O.R., applications of O.R., opportunities and shortcomings of O.R. Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the LPP, generating extreme point solutions.

UNIT II

The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique. Two phase method and Charnes M-method with artificial variables. The duality problem of linear programming and its economic interpretation, transportation and assignment problems.

UNIT III

Inventory management: characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time. All unit and incremental discounts. Single period stochastic models.

UNIT IV

Queueing Theory: Introduction of the queuing system, Various components of a queueing system. Pure Birth Process; Pure Death Process, Birth and Death Process, M/M/1 , M/M/1 (Generalized), M/M/1/FCFS/K/∞, M/M/C, Erlang's loss model.

Suggested Readings:

1. Taha, H.A. (2017). Operations Research: An Introduction, 10th Edition. Pearson.
2. Gass, S.I. (2010). Linear Programming, Methods and Applications, 5th Edition. Dover Books.
3. Gross, D., Shortle, J.F., Thompson, J.M. & Harris, C.M. (2017). Fundamentals of Queueing Theory, 5th Edition. Wiley.
4. Water, D. (2013). Inventory Control and Management, 2nd Edition. Wiley.

CATEGORICAL DATA ANALYSIS

(SPMS ST 01 203 DCE 3104)

Objectives: This course deals with the analysis of categorical data measured on different scales. The estimation and testing techniques related to various advance models are discussed. Fitting of models and strategies in model selection are also discussed.

UNIT I

Categorical response variables: Nominal, ordinal, interval. Probability structure for contingency tables: joint, marginal and conditional probabilities, sensitivity and specificity, independence. Comparing proportions in 2x2 Tables: difference of proportions, relative risk. Odds Ratio: definitions and properties of odds ratio with examples, inference for odds ratio and log odds ratio, relationship between odds ratio and relative risk. Chi-square tests of independence: Pearson statistic, likelihood ratio statistic, tests of independence, partitioning Chi-squared.

UNIT II

Testing independence for ordinal data: linear trend alternative to independence, extra power with ordinal test, choice of score, trend tests for Ix2 and 2xJ tables, nominal-ordinal tables. Exact inference for small samples: Fisher's exact test for 2x2 table, p-values and conservatism for actual P(Type I error), small sample confidence interval for odds ratio. Association in three-way table: partial tables, conditional versus marginal associations, Simpson's paradox, conditional and marginal odds ratios, conditional independence versus marginal independence, homogeneous associations.

UNIT III

Models for binary response variables: logit, log linear, linear probability and logistic regression models. Logit models for categorical data, probit and extreme value models, models with log-log link, model diagnostics. Fitting logit models, conditional logistic regression, exact trend test. Loglinear models for two dimensions - independence model, saturated model and models for cell probabilities.

UNIT IV

Loglinear models for two-way and three-way tables: loglinear model of independence for two-way table, saturated model for two-way tables, loglinear models for three-way tables. Inference for loglinear models: Chi-squared goodness of fit tests, loglinear cell residuals, tests about conditional associations, confidence intervals for conditional odds ratios, three factor interactions, large samples and statistical versus practical significance.

Suggesting Readings:

1. Agresti, A. (2013): Categorical Data Analysis, Third Edition, Wiley.
2. Upton, G.J.G. (2017): Categorical Data Analysis by Example, Wiley.
3. Sutradhar, B. C. (2014): Longitudinal Categorical Data Analysis, Springer.
4. Bilder, C. R. And Loughin, T.M. (2013): Analysis of Categorical Data with R, CRC Press.

APPLIED STATISTICS

(SPMS ST 01 201 GE 3014)

Objective: The course aims to study various models and components of time series analysis for forecasting purposes and various methods to control the quality of a product. It also gives the study of distribution of population with respect to birth, migration, aging and death.

UNIT I

Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series, measurement of trend by method of moving averages, method of semi-averages and method of least squares (linear, quadratic and exponential). Measurement of seasonal variations by method of simple averages, method of ratio to trend.

UNIT II

Statistical Quality Control: Importance of statistical methods in industrial research and practice, determination of tolerance limits, causes of variations in quality: chance and assignable. General theory of control charts, process and product control, control charts for variables: X- bar and R-charts, control charts for attributes: p and c-charts.

UNIT III

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events, measurement of mortality: Crude Death Rate, Specific Death Rate (w. r. t. age and sex), Infant Mortality Rate, Standardized death rates.

UNIT IV

Life (mortality) tables: definition of its main functions and uses, measurement of fertility and reproduction: Crude Birth Rate, General Fertility Rate and Total Fertility Rate. Measurement of population growth: Gross Reproductive Rate, Net Reproductive Rate.

Suggested Readings:

1. Mukhopadhyay, P. (2011). Applied Statistics, 2nd Edition. Books and Allied (P.) Ltd.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. II. 9th Edition. World Press.
3. Montegomery, D.C. (2013). Statistical Quality Control: A Modern Introduction, 7th Edition. Wiley.
4. Burr, J.T. (2014). Elementary Statistical Quality Control, 2nd Edition. CRC Press.

PROGRAMMING IN R

(SPMS ST 01 202 GE 3014)

Objectives: The objective of the course is to enhance the programming skills and working knowledge of available numerical and statistical packages in software R.

UNIT I

Data types in R: Numeric/character/logical; real/integer/complex, creation of new variables, vectors, matrices, dataframes, lists, accessing elements of a vector or matrix, import and export of files, for loop, repeat loop, while loop, if command, if else command.

UNIT II

Graphics in R: the plot command, histogram, bar-plot, box-plot, points, lines, segments, arrows, inserting mathematical symbols in a plot, pie diagram, customization of plot setting, graphical parameters, adding text, saving to a file, adding a legend.

UNIT III

Vector matrix operations: matrix operations such as addition, subtraction, multiplication, rank, eigenvalues, matrix inverse, generalized inverse, solution of linear equations.

UNIT IV

Basic statistics using R: measures of central tendency and dispersion. Covariance, correlation, regression, some discrete and continuous probability distributions, one and two sample z and t tests, Bartlett's test, F test for equality of variances, Chi-square tests, confidence intervals, one-way and two-way ANOVA, random number generation.

Suggested Readings:

1. Crawley, M.J. (2015). Statistics: An Introduction Using R, 2nd Edition. Wiley.
2. Crawley, M.J. (2012). The R Book, 2nd Edition. Wiley.
3. Zuur, A.F., Leno, E.N. & Meesters, E.H.W.G. (2010). A Beginner's Guide to R. Springer.
4. Maindonald, J.H. & Braun, J. (2010). Data Analysis and Graphics Using R, 3rd Edition. Cambridge University Press.

Semester III

MULTIVARIATE ANALYSIS

(SPMS ST 01 301 C 3104)

Objectives: Multivariate analysis is the analysis of observations on several correlated random variables for a number of individuals. This analysis has been used in almost all scientific studies. For example, the data may be the nutritional anthropometrical measurements like height, weight, arm circumference, chest circumference, etc. taken from randomly selected students to assess their nutritional studies. Since here we are considering more than one variable this is called multivariate analysis.

UNIT I

Multivariate normal distribution, its properties and characterization. Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters. Distribution of sample mean vector. Inference concerning the mean vector when the covariance matrix is known. Matrix normal distribution. Multivariate central limit theorem.

UNIT II

Wishart matrix, its distribution and properties. Distribution of sample generalized variance. Hotelling's T^2 statistic and its distribution and properties. Applications in tests on mean vector for one and more multivariate normal populations. Mahalanobis' D^2.

UNIT III

Likelihood ratio test criteria for testing of independence of sets of variables, equality of covariance matrices, identity of several multivariate normal populations, equality of a covariance matrix to a given matrix, equality of a mean vector and a covariance matrix to a given vector and a given matrix.

UNIT IV

Classification and discrimination procedures for discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, classification into more than two multivariate normal populations. Principal components, canonical variables and canonical correlations. Multivariate analysis of variance [MANOVA] of one-way classified data. Wilk's lambda criterion.

Suggested Readings:

1. Johnson, R.A. and Wichern, D.W.: (2015). Applied Multivariate Statistical Analysis, Sixth Edition, Pearson Education India.
2. Hardle, W.K. and Hlavka, Z. (2015): Multivariate Statistics, Springer.
3. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, Third Edition, Wiley.
4. Härdle, W.K. and Simar, L. (2015): Applied Multivariate Statistical Analysis, Springer.
5. Singh, B.M. (2004): Multivariate statistical analysis, South Asian Publishers.

STATISTICAL INFERENCE - II

(SPMS ST 01 302 C 3104)

Objectives: The main objective of the course is to provide the detailed knowledge of the characterization of another inferential procedure that is Bayesian and non-parametric Inference.

UNIT I

Elements of the Bayesian paradigm. Introduction to prior and posterior distributions, loss functions. Bayes risks, Bayesian paradigm versus classical paradigm. Prior distribution, subjective determination of prior distribution, improper priors, non-informative priors, conjugate prior families, construction of conjugate families using sufficient statistic for fixed dimensions.

UNIT II

Bayesian estimation of parameters of some well-known distributions like binomial, multinomial, Poisson, normal, lognormal, exponential, Rayleigh and Weibull distributions. Credible and highest posterior density (HPD) interval, HPD credible intervals in case of normal, gamma, exponential and Weibull distributions.

Unit III

Concept of nonparametric and distribution-free methods, probability integral transformation, empirical distribution function, kernel, one-sample and two-sample *U*-Statistics, test of independence, sign test, rank-order statistics, Wilcoxon signed-Rank test. Wald-Wolfowitz runs test, Kolmogorov-Smirnov two-sample test, median test, Mann-Whitney U test.

Unit IV

The sequential probability ratio test (SPRT) and its application to binomial, Poisson, geometric, exponential, normal, operating characteristic (OC) function of SPRT, average sample number (ASN) function and their application, Wald's fundamental identity and its uses.

Suggested Readings:

1. Berger, J.O. (2013): Statistical Decision Theory and Bayesian Analysis, Springer.
2. Hollander, M., Wolfe, D. and Chicken, E. (2013): Nonparametric Statistical Methods, 3rd Edition, Wiley.
3. Gibbons, J.D. and Chakraborti, S. (2010): Nonparametric Statistical Inference, 5th Edition, CRC Press.
4. Rohatgi, V.K. & Saleh, A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.

ECONOMETRICS

(SPMS ST 01 303 C 3104)

Objective: The purpose of this course is to give students a solid foundation in econometric techniques, various functions for economic analysis and future forecasting. Many of the methods introduced in this course are also useful in business, finance and many other disciplines.

UNIT I

Introduction to econometrics. A review of least squares and maximum likelihood estimation methods of parameters in classical linear regression model and their properties. Generalized least squares estimation and prediction, construction of confidence regions and tests of hypotheses, use of dummy variables and seasonal adjustment.

UNIT II

Regression analysis under linear restrictions, restricted least squares estimation method and its properties. Problem of Multicollinearity, its implications and tools for handling the problem. Ridge regression. Hetroscedasticity, consequences and tests for it, estimation procedures under hetroscedastic disturbances, Bartlett's test, Breusch Pagan test and Goldfelf Quandt test.

UNIT III

Autocorrelation, sources and consequences, Autoregressive process tests for autocorrelation, Durbin Watson test. Asymptotic theory and regressors. Instrumental variable estimation, errors in variables.

UNIT IV

Simultaneous equations model, problem of identification, necessary and sufficient condition for the identifiability of parameters in a structural equation, ordinary least squares, indirect least squares, two-stage least squares and limited information maximum likelihood method.

Suggested Readings:

1. Gujrati, D.N. & Porter, D.C. (2017). Basic Econometrics, 6th Edition. McGraw Hill.
2. Maddala, G.S. & Lahiri, K. (2010). Introduction to Econometrics, 4th Edition. Wiley.
3. Greene, W.H. (2012). Econometric Analysis, 7th Edition. Pearson.
4. Studenmund, A.H. & Johnson, B.K. (2017). Using Econometrics: A Practical Guide, 7th Edition. Pearson.

SEMINAR

(SPMS ST 01 304 C 4004)

Each student must present at least one seminar which will be followed by discussion session with participation from other students and the concerned faculty members present. The student must also submit the slides/write-up of the presentation content to the Student Advisor (Faculty). The seminar, participation in discussions, the submitted slides and overall attendance (as per ordinance) will form the basis of the evaluation. There will be no separate final exam for this course.

PRACTICAL

(SPMS ST 01 305 C 0044)

Practicals based on Multivariate Analysis (SPMS ST 01 301 C 3104), Statistical Inference – II (SPMS ST 01 302 C 3104) and Econometrics (SPMS ST 01 302 CC 4004).

STOCHASTIC PROCESSES

(SPMS ST 01 301 DCE 3104)

Objective: The objective of this course is to apprise the students with the basic concepts of the theory of stochastic processes in continuous time, also to make them able to use various analytical and computational techniques to study stochastic models that appears in applications.

UNIT I

Stochastic Processes: Introduction, classification according to state space and time domain. Countable state Markov chains, transition probability matrix, Chapman-Kolmogorov equations, calculation of n-step transition probabilities and their limits, stationary distribution.

UNIT II

Branching Processes: Properties of generating function of branching processes, probability of ultimate extinction, distribution of the total number of progeny, generalization of the classical Galton-Watson branching process, general branching processes, random walk and gambler's ruin problem.

UNIT III

Continuous-time Markov Processes: Poisson process and related distributions, generalizations of Poisson process, simple birth-process, simple death-process, simple birth-death process, linear birth-death process. First passage time distribution.

UNIT IV

Renewal Theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem, central limit theorem for renewals, study of residual and excess lifetime's process. Renewal reward Process, Markov renewal and semi- Markov processes, Markov renewal equations.

Suggested Readings:

1. Medhi, J. (2012). Stochastic Processes, 3rd Edition. New Age International.
2. Ross, S.M. (2016). Stochastic Processes, 2nd Edition. Wiley India.
3. Karlin, S. & Taylor, H.M. (2012). A First Course in Stochastic Processes, 2nd Edition. Academic Press.
4. Prabhu, N.U. (2010). Stochastic Processes: Basic Theory and its Applications. World Scientific.

DEMOGRAPHY AND VITAL STATISTICS

(SPMS ST 01 302 DCE 3104)

Objective: The objective of the course is to make the students conversant with various techniques used in summarization and analysis of data related to demographic and vital events.

UNIT I

Coverage and content errors in demographic data, use of balancing equations and Chandrasekharan-Deming formula to check completeness of registration data, adjustment of age data. Use of Whipple, Myer and UN indices, population composition, dependency ratio, population transition theory.

UNIT II

Measures of Fertility: Stochastic models for reproduction, distribution of time to first birth, inter-live birth intervals and of number of births. Estimation of parameters, estimation of parity progression ratio from open birth interval data.

UNIT III

Measures of Mortality: Construction of abridged life tables, distribution of life table functions and their estimation. Stable and quasi-stable populations, intrinsic growth rate models for population growth and their fitting to population data. Stochastic models for population growth.

UNIT IV

Stochastic models for migration and for social and occupational mobility based on Markov chains. Estimation of measures of mobility. Methods for population projection. Use of Leslie matrix. Nuptuality and its measurements.

Suggested Readings:

1. Kumar, R. (2006): Technical Demography, New age International (P) Ltd, New Delhi.
2. Samuel, P., Patrick, H. and Michel, G. (2000): Demography: Measuring and Modeling Population Processes, Wiley-Blackwell.
3. Rowland, D.T. (2003): Demographic Methods and Concepts, Oxford university press, Inc., New York.
4. Pathak, K. B. and Ram, F. (2013): Techniques of Demographic Analysis, Himalaya Publishing House.
5. Keyfitz, N. and Caswell, H. (2005): Applied Mathematical Demography, Springer.

BIO-STATISTICS

(SPMS ST 01 303 DCE 3104)

Objective: The course gives the application of statistics in handling survival data. The course introduces the concept of censoring and the various distributions used to analyse such data. Various models are also suggested to deal with survival data.

UNIT I

Functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shape hazard function. Tests of goodness of fit for survival distributions.

UNIT II

Analysis of epidemiologic and clinical data: studying association between a disease and a characteristic: (a) types of studies in epidemiology and clinical research (i) prospective study retrospective study (iii) cross-sectional data, (b) dichotomous response and dichotomous risk factor: 2x2 tables (c) expressing relationship between a risk factor and a disease (d) inference for relative risk and odds ratio for 2x2 table, sensitivity, specificity and predictivity. Cox proportional hazard model.

UNIT III

Type I and type II censoring schemes with biological examples, estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples. Non-parametric methods for estimating survival function and variance of the estimator. Competing risk theory, indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death under competing risks by maximum likelihood. Theory of independent and dependent risks.

UNIT IV

Stochastic epidemic models: simple and general epidemic models (by use of random variable technique). Basic biological concepts in genetics, Mendels law, Hardy-Weinberg equilibrium, random mating, distribution of allele frequency (dominant/co-dominant cases), approach to equilibrium for X-linked genes, natural selection, mutation, genetic drift, equilibrium when both natural selection and mutation are operative, detection and estimation of linkage in heredity.

Suggested Readings:

1. Collett, D. (2014). Modelling Survival Data in Medical Research, 3rd Edition, Chapman & Hall/CRC.
2. Friedman, L.M., Furburg, C.D., DeMets, D.L., Reboussin and Granger, C.B. (2015). Fundamentals of Clinical Trials, 5th Edition, Springer.
3. Indrayan, A. (2012). Medical Biostatistics, 3rd Edition, Chapman & Hall/CRC.
4. Lee, E.T. and Wang J.W. (2013). Statistical Methods for Survival Data Analysis, Wiley.

ACTUARIAL STATISTICS

(SPMS ST 01 304 DCE 3104)

Objectives: Actuarial Science is the discipline that applies mathematical and statistical methods to assess risk in the insurance and finance industries. In view of the uncertainties involved, probability theory, statistics and economic theories provide the foundation for developing and analysing actuarial models.

UNIT I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality. Life table and its relation with survival function, examples. Multiple life functions, joint life and last survivor status.

UNIT II

Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement. Distribution of aggregate claims, compound Poisson distribution and its applications. Claim Amount distributions, approximating the individual model, Stop-loss insurance.

UNIT III

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor. Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance. Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, varying annuities.

UNIT IV

Net premiums: Continuous and discrete premiums, true monthly payment premiums. Net premium reserves: Continuous and discrete net premium reserves, reserves on a semi continuous basis, reserves based on true monthly premiums.

Suggested Readings:

1. Tse, Y. K. and Chan, W. S (2017): Financial Mathematics For Actuaries, World Scientific.
2. Medina, P.K. and Merino, S. (2003): A discrete introduction: Mathematical finance and Probability, Birkhauser.
3. Vecer, J. (2017): Stochastic Finance: A Numeraire Approach, CRC Press.
4. Perna, C. and Sibillo, M. (2016): Mathematical and Statistical Methods for Actuarial Sciences and Finance, Springer.

Semester IV

Major Project/Dissertation

(SPMS ST 01 401 PROJ 00024)

The aim of the dissertation or project work is to familiarize the students with advanced research. A departmental committee will distribute the topics according to the skill and merit of the students. The project report/dissertation will be evaluated by a committee constituted by the Head of Department of Statistics having at least one external member.

Minor Project/Dissertation

(SPMS ST 01 402 PROJ 00016)

The aim of the dissertation or project work is to familiarize the students with advanced research. The topic for the project work is to be decided by the supervisor/guide concerned. The project report/ dissertation is to be evaluated by a committee constituted by the Head of Department of Statistics having at least one external member.

ORDER STATISTICS

(SPMS ST 01 401 DCE 3104)

Objective: The objective of the course is to learn general strategies for problems about order statistics and how to learn to find the median (or k-th largest) in linear average-case number of comparisons (and time).

UNIT I

Introduction to order statistics, joint, marginal and conditional distributions of order statistics (discrete and continuous cases). Distribution of the range and other systematic statistics, order statistics as a Markov chain. Examples based on discrete and continuous distributions.

UNIT II

Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range. Approximations to moments in terms of the quantile function and its derivatives.

UNIT III

Moments of order statistics, recurrence relations and identities for moments of order statistics. Large sample approximations to mean and variance of order statistics. Asymptotic distributions of order statistics.

UNIT IV

Order statistics for independently and not identically distributed (i.ni.d.) variates, Concomitants of order statistics. Random division of an interval and its applications. Order statistics from a sample containing a single outlier. Concepts of record values and generalized order statistics.

Suggested Readings:

1. Shahbaz, M.Q., Ahsanullah, M., Shahbaz, S.H. & Al-Zahrani, B.M. (2016). Ordered Random Variables: Theory and Applications. Springer.
2. David, H.A. & Nagaraja, H.N. (2005). Order Statistics, 3rd Edition. Wiley.
3. Ahsanullah, M., Nevzorov, V.B. & Shakil, M. (2013). An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
4. Arnold, B.C., Balakrishnan, N. & Nagaraja, H.N. (2008). A First Course in Order Statistics. SIAM Publishers.

SURVIVAL ANALYSIS

(SPMS ST 01 402 DCE 3104)

Objective: The objective of this course is to provide the applications of statistics in handling survival data. This course introduces the concept of censoring and various life time distributions used to analyse such data.

UNIT I

Concepts of survival function, failure rate or hazard function, mean residual life and their properties. Ageing classes- IFR, DFR, IFRA, DFRA, NBU, NBUE, BT and UBT, scaled TTT transform and characterization of ageing classes.

UNIT II

Life testing plans or censoring methods, right and left censoring, concepts of Type-I (time) and Type-II (failure), random censoring schemes. Life distributions-exponential, Weibull, log-logistic, gamma, log-normal distributions. Parametric inference- estimation of parameters associated with various life time distributions and life testing plans.

UNIT III

Nonparametric methods of estimation of survival function - actuarial estimator, Kaplan-Meier estimator. Tests of exponentiality against non-parametric classes-Total time on Test, Deshpande Test.

UNIT IV

Two sample problem - Gehan test, log-rank test, Mantel-Haenzel test. Cox proportional hazards model, competing risks model.

Suggested Readings:

1. Deshpande, J.V. & Purohit, S.G. (2016). Life Time Data: Statistical Models and Methods, 2nd Edition. Word Scientific.
2. Lee, E.T. & Wang, J.W. (2015). Statistical Methods for Survival Data Analysis, 4th Edition. Wiley.
3. Miller, R.G. (2011). Survival Analysis, 2nd Edition. Wiley.
4. Moore, D.F. (2016). Applied Survival Analysis using R. Springer.

DECISION THEORY AND SEQUENTIAL ANALYSIS

(SPMS ST 01 403 DCE 3104)

Objectives: The main objective of this course is to provide the detailed knowledge of the decision theory and sequential analysis.

UNIT I

Elements of decision theory: Expected loss, decision rules and risks - Bayesian expected loss, frequentist risks, randomized and nonrandomized decision rules, admissible decision rule, complete, essential complete and minimal complete classes of decision rules and their relationship, minimax and Bayes decision rule, estimation testing viewed as decision rule problem, Bayes and minimax estimators. Minimax and Bayes tests in simple cases.

UNIT II

Decision principles: the conditional Bayes decision principle and frequentist decision principles. Misuse of classical Inference procedures, the frequentist perspective, the conditional perspective, the likelihood principle, choosing a paradigm or decision principle. Utility theory: introduction, the utility of money.

UNIT III

Bayesian decision theory: Posterior decision analysis, estimation, finite action problems and hypothesis testing. Minimax Analysis: Introduction, game theory, basic elements, general techniques for solving games, finite games, the minimax theorem.

UNIT IV

Sequential Decision rule: Stopping rule, terminal decision rule. Bayes and minimax sequential decision Rules. Invariant sequential decision problems, sequential test of a simple hypothesis. The sequential probability ratio test, the fundamental identity of sequential analysis.

Suggested Readings:

1. Robert, C.P. (2013): The Bayesian Choice: A Decision Theoretic Motivation, Springer.
2. Berger J.O. (2013): Statistical Decision Theory and Bayesian Analysis, Springer.
3. Wald, A. (2013): Sequential Analysis, Dover Publications.
4. Mukhopadhyay, N. and de Silva, B.M. (2008): Sequential Methods and Their Applications, CRC Press.

STATISTICAL COMPUTATION AND SIMULATION

(SPMS STAT 01 404 DCE 3104)

Objectives: The students will study the statistical simulation using Computers. It contains introduction to System, Models, Simulation, Random Number Generation and Variance Reduction Techniques.

UNIT I

Introduction and need of statistical simulation. Random number generation, requisites of a good random number, methods of random number generation such as linear congruential and mixed congruential, statistical tests for pseudo random numbers. Methods of generating random variables such as inverse transforms, composition and acceptance-rejection methods.

UNIT II

Monte Carlo integration and variance reduction techniques: Hit or miss Monte Carlo method, sample mean Monte Carlo method, importance sampling, correlated sampling control variates, stratified sampling, antithetic variates, partition of region.

UNIT III

EM algorithm: applications to missing and incomplete data problems, mixture models. Smoothing with kernels, density estimation, simple non-parametric regression. Smoothing with kernels: density estimation, choice of kernels.

UNIT IV

Simulation based testing: simulating test statistics and power functions, permutation tests. Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals, bootstrapping in regression. Jackknife and cross validation: Jacknife in sample surveys, cross-validation for tuning parameters.

Suggesting Readings:

1. Rubinstein, R.Y. and Kroese, D.P. (2008): Simulation and the Monte Carlo Method, Second Edition, Wiley.
2. Voss, J. (2014): An Introduction to Statistical Computing: A Simulation Approach, Wiley.
3. Ross, S.M. (2012): Simulation, Fifth Edition, Academic Press.
4. Thomopoulos, N.T. (2013): Essentials of Monte Carlo Simulation, Springer.

GENERALIZED LINEAR MODELS

(SPMS ST 01 405 DCE 3104)

Objectives: The students will get familiar with the need of modelling random responses using independent predictors through linear and logistic (for binary responses) models in real life situations. Least square estimation of parameters of these models will be discussed along with their statistical significance.

UNIT I

Review of Linear models, least square model fitting, Testing the general linear hypothesis: t-test and F-test. Simple linear regression. Multiple linear regression. Interpretation of the coefficients. Residuals, Leverage and influence. Optimality of least squares and generalized least squares.

UNIT II

Binary data. The binomial distribution. Grouped and ungrouped data. Odds and log-odds. The logit transformation. Logistic regression. Maximum likelihood estimation and testing in logistic regression models. The comparison of two groups. The odds ratio. Comparison of several groups. Regression models for binary data. Models with two predictors. Main effects and interactions. Multifactor models. Model selection. Alternative links for binary data. Probit analysis. The c-log-log link. Regression diagnostics with binary data.

UNIT III

Count data. The Poisson distribution. The log link. Maximum likelihood estimation and testing in Poisson regression. The Poisson deviance. Modelling heteroscedastic counts. Models for rates of events. Exposure and the use of an offset in the linear predictor. Extra-Poisson variation. The negative binomial model. Zero-inflated models for counts. Multinomial response models.

UNIT IV

Multinomial logits. Independence of irrelevant alternatives. Random utilities and the conditional logit model. Sequential logits. Sequential binary choice and continuation ratio models. Equivalence with logit models. Models for ordered categorical data. Ordered logits and probits. Latent variable formulation and interpretation of the coefficients.

Suggesting Readings:

1. Myers, R.H, Monetgomery, D.C., Vining, G.G. and Robinson, T.J. (2010): Generalized Linear Models with Applications in Engineering and the Sciences, Second Edition, Wiley.
2. Stroup, W. W. (2013): Generalized Linear Mixed Models: Modern Concepts, Methods and Applications, CRC Press.
3. Agresti, A. (2015): Foundations of Linear and Generalized Linear Models, Wiley.
4. Dobson, A.J. and Barnett, A.G. (2008): Introduction to Generalized Linear Models, Third Edition, CRC Press.

NONPARAMETRIC INFERENCE

(SPMS ST 01 406 DCE 3104)

Objective: The objective of this course is to apprise the students about various techniques of hypothesis testing when the assumptions of parametric set up are not fulfilled. Thrust will be to study various nonparametric analogues to one, two and c-sample location problems as well as two sample scale problem.

UNIT I

Concept of nonparametric and distribution-free methods, probability integral transformation, empirical distribution function, kernel, one-sample and two-sample *U*-Statistics, UMVUE property and asymptotic distribution of *U*-Statistics. Rank order statistics, treatment of ties in rank tests, linear rank statistics, distribution and properties of linear rank statistics.

UNIT II

Tests of randomness: Tests based on total number of runs, exact null distribution of *R*, asymptotic null distribution of *R*, tests based on runs up and down and related applications. The Chi-square goodness-of-fit test, the Kolmogorov-Smirnov one-sample statistic. The Sign test and Wilcoxon Signed Rank test for one-sample and paired sample problems.

UNIT III

Independence in bivariate sample: Kendall's and Spearman's rank correlation. The general two-sample problem: median test, Mann-Whitney test, Wilcoxon Rank Sum test, Terry-Hoeffding (Normal Scores) test. Tests for scale problem: Mood test, Klotz Normal-Scores test, and Sukhatme test.

UNIT IV

Tests for *k* independent samples: Kruskal-Wallis one-way ANOVA test and multiple comparisons, Jonckheere-Terpstra test for ordered alternatives. Friedman's two-way ANOVA by ranks. Asymptotic relative efficiency (ARE): Theoretical basis for calculating the ARE, Examples of the calculation of efficacy and ARE.

Suggested Readings:

1. Gibbons, J.D. & Chakraborti, S. (2010). Nonparametric Statistical Inference, 5th Edition. CRC Press.
2. Hollander, M., Wolfe, D. & Chicken, E. (2013). Nonparametric Statistical Methods, 3rd Edition. Wiley.
3. Bonnini, S., Corain, L., Marozzi, M. & Salmaso, L. (2014). Nonparametric Hypothesis Testing Rank and Permutation Methods with Applications in R. Wiley.
4. Sprent, P. & Smeeton, N.C. (2013). Applied Nonparametric Statistical Methods, 4th Edition. CRC Press.