Model Curriculum for Three/Four Year Degree Course

(With Multiple Entry/Exit Option)

Based on NEP-2020

Statistics

Odisha State Higher Education Council, Bhubaneswar

Government of Odisha

Contents

Outline of Syllabus

STATISTICS

Table-I: Structure for Certificate Courses Exit after First Academic year

[One academic year (First & Second Semesters) and a Summer/Vocational Course and Community Work]

Semester	Core-I	Core-II	Core-III	Multidisciplinary	AEC	SEC	VAC	Community Engagement& Services/Field work /Internship	Total Minimum Credit
I	**2X4=8**	**1X4=4**		**1X3=3**	**1X4=4** Odia		**1x3=3** Environmental Studies and Disaster management		**22**
II	**2X4=8**		**1X4=4**	**1X3=3**	**1X4=4** English	**1X3=3**			**22**
Total	**4x4=16**	**1X4=4**	**1X4=4**	**2x3=6**	**2x4=8**	**1x3=3**	**1x3=3**		**44**
Vocational Course of 4 credits for Certificate									

Table-II: Structure for Diploma Certificate Course Exit after Second Academic year

[*Two academic years (First, Second, Third & Four Semesters and a Summer Vocational Course and Community Work)]*

Semester	Core-I	Core-II	Core-III	Multi-disciplinary	AEC	SEC	VAC	Community Engagement& Services/Field work /Internship	Total Minimum Credit
I	**2X4=8**	**1X4=4**		**1X3=3**	**1X4=4** Odia		**1x3=3** Environmental Studies and Disaster management		**22**
II	**2X4=8**		**1X4=4**	**1X3=3**	**1X4=4** English	**1X3=3**			**22**
									44
III	**3X4=12**	**1X4=4**		**1X3=3**			**1X3=3**		**22**
IV	**3X4=12**		**1X4=4**					**1x4=4**	**20**
									42
Total	**10x4=40**	**2x4=8**	**2x4=8**	**3x3=9**	**2x4=8**	**1X3=3**	**2X3=6**	**1x4=4**	**86**
Vocational Course of 4 credits for Diploma Certificate									

Core-II and Core-III are interchangeable.

Table-III: Three Year Degree Course Single Major with Two Minor

Semester	Core-I	Core-II	Core-III	Multi-disciplinary	AEC	SEC	VAC	Community Engagement & Services/Fieldwork /Internship	Total Minimum Credit
I	2X4=8	1X4=4		1X3=3	1X4=4 Odia		1x3=3 Environmental Studies and Disaster management		22
II	2X4=8		1X4=4	1X3=3	1X4=4 English	1X3=3			22
									44
III	3X4=12	1X4=4		1X3=3			1X3=3		22
IV	3X4=12		1X4=4					1x4=4	20
									42
V	3X4=12	1X4=4				1X3=3	1x3=3		22
VI	2X4=8		1X4=4			1X3=3	1x3=3		18
									40
Total	15X4=60	3X4=12	3X4=12	3X3=9	2X4=8	3X3=9	4X3=12	1x4=4	126

In case student opts for NCC and clears “C” certificate additional 16 Credits shall be awarded and total credit shall be 126+16 = 142 Credit

Table-IV: Three Year Degree Course Double Major Course

Semester	Core-I	Core-II	Multi-disciplinary	AEC	SEC	VAC	Community Engagement& Services/Fieldwork /Internship	Total Minimum Credit
I	2X4=8	2X4=8	1X3=3	1X4=4 Odia		1x3=3 Environmental Studies and Disaster management		26
II	2X4=8	2X4=8	1X3=3	1X4=4 English	1X3=3			26
								52
III	3X4=12	2X4=8	1X3=3			1X3=3		26
IV	3X4=12	2X4=8					1x4=4	24
								50
V	3X4=12	2X4=8			1X3=3	1X3=3		26
VI	2X4=8	2X4=8			1X3=3	1x3=3		22
								48
Total	15X4=60	12X4=48	3X3=9	2X4=8	3X3=9	4X3=12	1x4=4	150

Table-V: Three Year Degree Course with Three Core without Major

Semester	Core-I	Core-II	Core-III	Multi-disciplinary	AEC	SEC	VAC	Community Engagement& Services/Field work /Internship	Total Minimum Credit
I	1X4=4	1X4=4	1X4=4	1X3=3	1X4=4 Odia		1x3=3 Environmental Studies and Disaster management		22
II	1X4=4	1X4=4	1X4=4	1X3=3	1X4=4 English	1X3=3			22
									44
III	2X4=8	1X4=4	1X4=4	1X3=3			1X3=3		22
IV	1X4=4	2X4=8	1X4=4					1x4=4	20
									42
V	1X4=4	1X4=4	2X4=8			1X3=3	1X3=3		22
VI	1X4=4	1X4=4	1X4=4			1X3=3	1x3=3		18
									40
Total	7X4=28	7X4=28	7X4=28	3X3=9	2X4=8	3X3=9	4X3=12	1x4=4	126

In case student opts for NCC and clears “C” certificate additional 16 Credits shall be awarded and total credit shall be 126+16 = 142 Credit

Table-VI: Fourth Year Hons. Without Research

Semester	Core-I	Core-II	Core-III	Multi-disciplinary	AEC	SEC	VAC	Community Engagement& Services/Field work /Internship	Total Minimum Credit
I	2X4=8	1X4=4		1X3=3	1X4=4 Odia		1x3=3 Environmental Studies and Disaster management		22
II	2X4=8		1X4=4	1X3=3	1X4=4 English	1X3=3			22
									44
III	3X4=12	1X4=4		1X3=3			1X3=3		22
IV	3X4=12		1X4=4					1x4=4	20
									42
V	3X4=12	1X4=4				1X3=3	1x3=3		22
VI	2X4=8		1X4=4			1X3=3	1x3=3		18
									40
VII	4x4=16	1x4=4							20
VIII	4x4=16	1x4=4							20
									40
Total	23X4=92	5X4=20	3X4=12	3X3=9	2X4=8	3X3=9	4X3=12	1x4=4	166

Table-VII: Fourth Year Hons. With Research

Semester	Core-I	Core-II	Core-III	Multi-disciplinary	AEC	SEC	VAC	Community Engagement & Services/Fieldwork /Internship	Total Minimum Credit
I	2X4=8	1X4=4		1X3=3	1X4=4 Odia		1x3=3 Environmental Studies and Disaster management		22
II	2X4=8		1X4=4	1X3=3	1X4=4 English	1X3=3			22
									44
III	3X4=12	1X4=4		1X3=3			1X3=3		22
IV	3X4=12		1X4=4					1x4=4	20
									42
V	3X4=12	1X4=4				1X3=3	1x3=3		22
VI	2X4=8		1X4=4			1X3=3	1x3=3		18
									40
VII	3x4=12	2x4=8							20
VIII	2x4=8							Research 12	20
									40
Total	20X4=80	5X4=20	3X4=12	3X3=9	2X4=8	3X3=9	4X3=12	16	166

Tabular Presentation of the Papers Semester wise

Semester	Name of the Papers
I	1. Descriptive Statistics
	2. Linear Algebra
II	3. Probability and Probability Distributions
	4. Calculus
III	5. Sampling Distributions
	6. Parametric Statistical Inference
	7. Survey Sampling & Indian Official Statistics
IV	8. Real & Numerical Analysis
	9. Linear Regression Analysis and Forecasting (NPTEL)
	10. Statistical Quality Control
V	11. Design of Experiments
	12. Statistical Computing using R Programming
	13. Operations Research
VI	14. Non-parametric Statistical Inference
	15. Multivariate Analysis
VII (With Research)	16. Time Series Analysis
	17. Optimization Techniques
	18. Econometrics
VII (Without Research)	16. Time Series Analysis
	17. Optimization Techniques
	18. Econometrics
	19. Stochastic Process
VIII (With Research)	20. Scientific Computing using MATLAB (NPTEL)
	21. Actuarial Statistics
	Dissertation
VIII (Without Research)	20. Scientific Computing using MATLAB (NPTEL)
	21. Actuarial Statistics
	22. Bayesian Parametric Inference
	23. Strategy: An Introduction to Game Theory (NPTEL)

Programme Offered: B.A./B.Sc.(Hons.) Statistics

PROGRAM OUTCOME

When the student joins college after school they are free to make their own choices which are very instrumental in changing their attitude towards life and society. It is very important to give theman appropriateand conducive environment to learn and grow. After completion of the degree apart from his/her specialty in the program of his/her choice the student learns a lot during their three years stay that makes them mature enough to take the right decisions at the right time. Students develop analytical thinking and good communication skills during classroom teaching (through projects/presentation/practical) and also as they participate in various activities both at departmental as well as college level. Being a State University, the student gets a chance to communicate with students of other districts of Odisha and other states of India which makes them culturally sensitive and socially interactive. As part of various departmental /college seminars and workshops he learns to respect and protect the environment. These programs also help in generating gender sensitization and building of ethical values to become a responsible citizen when he/she graduates from the college.

OUTCOME DETAILS

PSO1	Apply the concepts, principles and methods of statistics to variousfieldsof study
PSO2	Understand the importance and value of statistical principles and convert a problem description into testable research hypotheses.
PSO3	Select appropriate statistical tools to investigate are search hypothesis.
PSO4	Perform data analysis by apply appropriate statistical methodology and interpret result in a variety of settings.
PSO5	Compute statistical measures using software and programs.
PSO6	Apply likelihood principles and calculus to derive fundamental results in probability, estimation and hypothesis testing.
PSO7	Select standard experiment designs, with consideration of selection process, data collection, issues of bias, causality and confounding, based on specifications of a scientific study.
PSO8	Write code to extract and reform at real data and to utilize statistical programming environments.
PSO9	Acquire skills to write competitive examinations and get opportunities for job placements in various sectors
PSO10	Move for higher level learning

Statistics is the language of the uncertainties riddled modern information age. This program is a compact combination of detailed courses of Statistics and adequate number of courses on Computer Science, Mathematics and Operations research to complement and offer diversification after the completion of program. The thrust of the program is to provide a platform for pursuing higher studies leading to post-graduate or doctorate degrees. Along with these students are equipped with skill enhancement courses like Research methodology, Statistical packages and R language. This enhances theoretical rigor with technical skills which prepare students to become globally competitive to enter into a promising professional life even after graduation. This program offers a range of traditional avenues in academics, Govt. Service, IAS, Indian Statistical/ Economic Services,Industries, Commerce, Investment Banking, Banks and Insurance Sectors, CSO andNSSO, Research Personnel/Investigator in Govt. organizations such as NCAER, IAMR, ICMR, ICAR, RBI, Statistical and Economic Bureau & various PSUs., Market Research, Actuarial Sciences, Biostatistics, Demography etc. It also provides an array of non- traditional employment avenues ranging from Stock Brokers Analyst, Sports Analyst, Poll Analyst, Business Analyst, Financial Analyst, Content Analyst etc.

Important Information

i. **Core – I** is the Major in Statistics.
ii. **Core-II** and **Core-III** are interchangeable; will be Minor-I and Minor-II respectively to be offered as Minor to students who have not opted Statistics as Major
iii. Statistics Department offers the following Papers as Minor:

Semester	Core-I	Core-II	Core-III
I	**2X4=4**	**1X4=4** Descriptive Statistics	
II	**2X4=4**		**1X4=4** Probability and Probability Distributions
III	**3X4=12**	**1X4=4** Survey Sampling & Indian Official Statistics	
IV	**3X4=12**		**1X4=4** Statistical Quality Control
V	**3X4=12**	**1X4=4** Statistical Computing using R Programming	
VI	**2X4=8**		**1X4=4** Non-parametric Statistical Inference
VII	**4x4=16**	**1x4=4** Time Series Analysis	
VIII	**4x4=16**	**1x4=4** Scientific Computing using MATLAB (NPTEL)	
Total	**23X4=92**	**5X4=20**	**3X4=12**

List of Multidisciplinary Courses for Model Curriculum

Note: The Board of Studies in Statistics selected 03 subjects

Any 03 Selected Subjects from the Multidisciplinary Course:

1.	Statistical Methods for Scientists and Engineers (NPTEL)
2.	Survival Analysis and Biostatistics
3.	Machine Learning

List of Vocational Courses for Model Curriculum

Note: The Board of Studies in Statistics will select any 03 subjects

03 Selected Subjects from the Vocational Course:

1.	Biostatistics
2.	Applied Ethics-Cyber Ethics
3.	Social Impact Assessment Study

List of Value Added Courses for Model Curriculum

Note: The Board of Studies in Statistics will select any 04 subjects

04 Selected Subjects from the Value added Course:

1.	Environmental Studies & Disaster Management
2.	Understanding India
3.	Understanding Odisha
4.	Research Methodology

List of Skill Enhancement Courses under Model Curriculum

Note: The Board of Studies in Statistics will select any 03 subjects

03 Selected Subjects from the Skill Enhancement Course:

1.	Introduction to Statistics and Data Analyses
2.	Data Analytics I
3.	Data Analytics II

CORE COURSES

SEMESTER-I

CORE-I: DESCRIPTIVE STATISTICS

COURSE OUTCOMES

- Understand the scope and necessity of Statistics.
- Tabulate and represent the data in diagrams and graphs.
- Apply the formula and calculate descriptive measures of statistics.
- Analyze the nature of data and interpret the measures
- Analyze the data and predict the future values using curve fitting.

LEARNING OUTCOMES

The learning objectives include summarizing the data and to obtain its salient features from the vast mass of original data. After completing this course, the students should have developed a clear understanding of Concepts of statistical population and sample, variables and attributes.

UNIT-I

Statistical Methods: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement nominal, ordinal, interval and ratio. Presentation: tabular and graphical, including histogram, stem and leaf diagram and Ogives, consistency and independence of data with special reference to attributes.

UNIT-II

Measures of Central Tendency: mean, median and mode, Measures of Dispersion: Range, Inter Quartile Range, Quartile Deviation, Mean Deviation, Variance and Standard Deviation, Coefficient of Variation, Moments, Absolute Moments, Skewness and Kurtosis, Sheppard's Corrections.

UNIT-III

Bivariate data: Definition, Scatter Diagram, Simple, Partial and Multiple Correlation (3variablesonly), Rank Correlation. Simple linear regression, Principle of least squares and fitting of polynomials and exponential curves.

UNIT-IV

Index Numbers: Definition, construction of index numbers and problems there of for weighted and unweighted index numbers including Laspeyer's, Paasche's, Edgeworth-Marshall and Fisher's Ideal Index numbers. Errors in Index numbers. Chain base index numbers, conversion of fixed based to chain-based index numbers and vice-versa. Consumer price index numbers, Cost of living index number, Uses and limitations of index numbers.

TEXT BOOKS

- ✓ P.N Arora, Sumeet Arora: Comprehensive Statistical Methods, S Chand
- ✓ Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, The World Press, Kolkata.
- ✓ Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Mathematical Statistics,4thEdition, Sultan Chand &Sons

SUGGESTED READINGS

- ✓ Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7thEdn.), Pearson Education, Asia.
- ✓ Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- ✓ R S N Pillai & Bagavathi: Practical Statistics, S Chand
- ✓ C B Gupta: An Introduction to Statistical Methods, Vikas Publishing

LIST OF PRACTICALS

Emphasis should be given on interpretation of results.

1. Graphical representation of data – Simple Bar Diagram, Multiple Bar Diagram and Divided Bar Diagram, Histogram, Stem and leaf diagram, Pie diagram, Frequency polygon and frequency curve.
2. Problems based on Measures of Central Tendency.
3. Problems based on Measures of Dispersion.
4. Problems based on Moments, Skewness and Kurtosis.
5. Scatter Diagram, Karl Pearson correlation coefficient and rank correlation coefficient (with and without tie).
6. Lines of regression, angle between lines and estimated values of variables.
7. Calculate price, quantity and cost of living index numbers.

CORE-II: LINEAR ALGEBRA

COURSE OUTCOMES

- Be able to gain proficiency in solving systems of Linear equations using matrices and demonstrate a working knowledge of algebraic properties of matrices.
- Be able to acquire facility working with general vector spaces, linear¬ transformations, coordinate vectors and the changing of bases.
- Use the basic concepts of vector and matrix algebra, including linear dependence / independence, basis and dimension of a subspace, rank and nullity, for analysis of matrices and systems of linear equations.
- Evaluate determinants and use them to discriminate between invertible and noninvertible Matrices; Use the characteristic polynomial to compute the eigen values and eigenvectors of a square matrix and use them to diagonalizable matrices when this is possible.
- Discriminate between diagonalizable and non- diagonalizable matrices; orthogonally diagonalizable symmetric matrices and quadratic forms.

LEARNING OUTCOMES

To learn the basic ideas of abstract algebra and techniques with proof in pure mathematics and further, it can be use in many other courses. Algebra is one of the most important courses in the field of statistical computing. The course serves as a building block that will enable students to learn more advanced techniques that will help them to solve problems more quickly and easily. After completing course, students should have developed a clear understanding of: Theory of equations; Properties of matrices and determinants; Linear equations; Rank of a matrix; Generalized inverse; Characteristics roots and vectors; Quadratic forms. The students will be conversant for their potential studies of Markov chain & stochastic process, Multivariate analysis, Regression analysis, Design of Experiments.

UNIT-I

Theory of equations, statement of the fundamental theorem of Algebra and its consequences. Relation between roots and coefficients of any polynomial equations. Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis.

UNIT-II

Algebra of matrices - A review, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, Hermitian and skew Hermitian matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, unitary, involuntary and nilpotent matrices.

UNIT-III

Determinants of Matrices: Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Adjoint and inverse of a matrix and related properties. Solution to the system of linear equations $AX = b$: Cramer's rule and matrix method, row reduction and echelon forms.

UNIT-IV

Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Characteristic roots and Characteristic vectors, Properties of characteristic roots, Cayley Hamiltontheorem and Quadratic forms.

TEXTBOOKS

- ✓ V K Khanna & S K Bhambri: A Course in Abstract Algebra, Vikas Pub.
- ✓ Krishnamurthy V., Mainra V.P. and Arora J.L.: An Introduction to Linear Algebra

SUGGESTED READINGS

- ✓ Biswas, S.(1997):A Text book of Matrix Algebra, New Age International,1997.
- ✓ Datta K.B.: Matrix and Linear Algebra. Prentice Hall of India Pvt.Ltd.,2002.
- ✓ Hadley G.: Linear Algebra. Narosa Publishing House (Reprint),2002.
- ✓ Searle S.R.: Matrix Algebra Useful for Statistics. JohnWiley&Sons.
- ✓ Schaum's Outlines: Linear Algebra, TataMcGraw-Hill,3rdEdition,2006.

LIST OF PRACTICALS

1. Finding roots of an algebraic equations
2. Solution of linear equations by matrix method.
3. Rank and Inverse of a matrix
4. Characteristics roots and characteristics vector of a matrix.
5. Applications of matrices.

SEMETER-II

CORE-III: PROBABILITY AND PROBABILITY DISTRIBUTIONS

COURSE OUTCOMES

- Concept of probability, different approaches to the theory of probability. Concept of events, mutually exclusive independent and exhaustive events. Sample space and its properties. Use the basic probability rules including addition and multiplicative laws, conditional probability and Bayes theorem.
- Gain knowledge on random variables. Distinguish between discrete and continuous random variables. Probability mass function and probability density function.
- Understand Mathematical expectation of a random variable. Conditional expectation and variance and conditional expectations.
- Understand the most common discrete and continuous probability distributions and their real-life applications. Identify their characteristics.
- Identify the type of statistical situation to which different distributions can be applied. Use the different distributions in solving statistical problems.

LEARNING OUTCOMES

To present the general theory of statistical distributions as well as the standard distributions found in statistical practice. To train students with essential tools for statistical analyses at the post graduate level. Fostering understanding through real-world statistical applications. A probability distribution is a statistical model that shows the possible outcomes of a particular event or course of action as well as the statistical likelihood of each event. Probability distribution functions are quite important and widely used in actuarial science (insurance), engineering, physics, evolutionary biology, computer science and even social sciences such as psychiatry, economics and even medical trials.

UNIT-I

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

UNIT-II

Random variables: discrete and continuous random variables, probability mass function (p.m.f.), probability density function (p.d.f.) and cumulative distribution function (c.d.f.), illustrations and properties of random variables, univariate transformations with illustrations. Two dimensional random variables: discrete and continuous type, joint, marginal and conditional p.m.f, p.d.f., and c.d.f., independence of variables.

UNIT-III

Mathematical Expectation and Generating Functions: Expectation of single and bivariate random variables and its properties. Moments and Cumulants, moment generating function, Cumulants generating function and characteristic function. Uniqueness and inversion theorems (without proof) along with applications. Conditional expectations.

UNIT-IV

Standard discrete probability distributions: Uniform, Bernoulli, Binomial, Poisson, Geometric, along with their properties and limiting/approximation cases. Standard continuous probability distributions: Uniform, Normal, Exponential, Beta and Gamma along with their properties and limiting/approximation cases.

TEXT BOOKS:

- ✓ Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- ✓ Ravish R Singh & Mukul Bhatt: Probability and Statistics, S Chand
- ✓ Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of MathematicalStatistics,4thEdition (Reprint), Sultan Chand &Sons

SUGGESTED READINGS:

- ✓ Miller, Irwin and Miller, Marylees(2006): John E.Freund's Mathematical Statistics with Applications, (7thEdn.), Pearson Education, Asia.
- ✓ Iyengar: Probability and Statistics S Chand
- ✓ Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory ofStatistics,3rdEdn.,(Reprint),Tata McGraw-Hill Pub. Co. Ltd.
- ✓ Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I, 8thEdn. The World Press, Kolkata.
- ✓ Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi

LIST OF PRACTICALS

1. Fitting of Binomial and Geometric distributions
2. Fitting of Poisson distributions
3. Fitting of Normal and One-parameter exponential distributions
4. Application problems based on Binomial, Geometric, Poisson, One-parameter exponential and Normal distributions.

CORE-IV: CALCULUS

COURSE OUTCOMES

- Understand the type of variable and useful in the development of the function.
- Verify the value of the limit of a function at a point using the definition of the limit.
- Understand the consequences of the Intermediate value theorem for continuous function.
- Know the chain rule and use it to find derivatives of composite functions and obtain expression for higher order derivatives of a function using the rule of differentiation.
- Solve integrals and evaluation of multiple integrals with numerical problems and solve the partial differential equations.

LEARNING OUTCOMES

Calculus is versatile and Valuable tool for the statistics. Calculus being used in statistics involves integrating over sections of a probability distribution. The content of this paper involves differential calculation, integral calculus and solution of different differential equations which are extremely prevalent in more advanced statistical application. To compute and analyze limits, derivatives, and integrals functions. To recognize the appropriate tools of calculus to solve applied problems.

UNIT-I

Differential Calculus: Limits of function, continuous functions, properties of continuous functions, partial differentiation and total differentiation (two variables). Indeterminate forms: L-Hospital's rule, Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions. Maxima and minima of functions of one and two variables. Transformations and Jacobians.

UNIT-II

Integral Calculus: Review of integration and definite integral. Differentiation under integral sign, double integral. Beta and Gamma functions: properties and relationship between them.

UNIT-III

Differential Equations: Exact differential equations, integrating factors, change of variables, Total differential equations, Differential equations of first order and first degree, Differential equations of first order but not of first degree, Equations of the first degree in x and y, Clairaut's equations. Higher Order Differential Equations. Homogeneous differential equations of order n with constant coefficients.

UNIT-IV

Formation and solution of a partial differential equations. Equations easily integrable. Linear partial differential equations of first order. Homogeneous linear partial differential equations with constant coefficients. Different cases for complimentary functions and particular integrals.

TEXTBOOKS

- ✓ Shanti Narayan & P K Mittal: Differential Calculus S Chand
- ✓ Shanti Narayan: Integral Calculus S Chand

SUGGESTED READINGS:

- ✓ Zafar Ahsan: Differential Equations and their Applications, Prentice-Hall of India Pvt. Ltd., New Delhi (2nd Edition-2004).
- ✓ Surjeet Singh & Qazi Zameeruddin: Modern Algebra, Vikas Publishing
- ✓ S K Shah & S C Garg: A Text Book of Algebra, Vikas Publishing
- ✓ Piskunov , N: Differential and Integral Calculus, Peace Publishers, Moscow.
- ✓ Differential calculus by Das & Mukherjee, U.NDhar Publication, Kolkatta, 2010.
- ✓ Integral Calculus by Das & Mukherjee, U.N Dhar Publication, Kolkatta,2010.
- ✓ Advanced Differential Equations by Md Raisinghania, S Chand & Company Pvt Ltd.

LIST OF PRACTICALS

1. Determination of Maxima and Minima
2. Using definite integral obtain the area under curve.
3. Applications of differential equations.
4. Applications Partial Differential Equations.
5. Applications of Beta and Gamma function.

SEMESTER-III

CORE-V: SAMPLING DISTRIBUTIONS

COURSE OUTCOMES

- To understand the concept of sampling distributions and their applications in statistical inference.
- To understand the process of hypothesis testing and its significance. Analyze the properties and applications of various probability functions and Weak law of Large Numbers
- Testing of statistical hypothesis, Neymann Pearson Lemma
- Understand Likelihood Ratio test, applications and properties
- Understand test of significance, tests based on normal, t, F and Chi-square distributions

LEARNING OUTCOMES

Statistical Inference is a crucial part of the process of informing ourselves about the world around us. Statistical inference helps us understand our world and make sound decisions about how to act. The content of this paper is based on basic statistical methodology which is vital for industry, biosciences and others streams. To learn the development of null and alternative hypotheses.

UNIT-I

Limit laws: convergence in probability, almost sure convergence, convergence in mean square and convergence in distribution and their interrelations, Chebyshev's inequality, Weak law of large numbers (W.L.L.N.), Strong law of large numbers (S.L.L.N.) and their applications, De-Moivre Laplace theorem, Central Limit Theorem (C.L.T.)for i.i.d. variates, applications of C.L.T.

UNIT-II

Definitions of random sample, parameter and statistics, sampling distribution of a statistics, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. Null and alternative hypotheses, critical region, level of significance, Type I and Type II errors, concept of p-value. Large sample tests for testing single proportion, difference of two proportions, single mean, difference of two means, standard deviation and difference of standard deviations by classical and p-value approaches.

UNIT-III

Exact sampling distribution: Definition and derivation of p.d.f. of Chi-square with n degrees of freedom(d.f.) using m.g.f., nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., Cumulant generating function, mode, additive property and limiting form of Chi-square distribution. Tests of significance and confidence intervals based on Chi-square distribution.

UNIT-IV

Exact sampling distributions: Student's t-distribution (including Behrens–Fisher problem), Snedecor's F-distribution, derivations of their p.d.fs., nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of these distributions. Relationship between t, F and Chi-square distributions. Test of significance and confidence Intervals based on t and F distributions.

TEXT BOOKS

- ✓ Goon, A.M., Gupta, M.K. and Dasgupta, B.(2003): An Outline of Statistical Theory, Vol. I, 4thEdn. World Press, Kolkata.
- ✓ P.N Arora, Sumeet Arora: Comprehensive Statistical Methods, S Chand

SUGGESTED READINGS

- ✓ Rohatgi V.K. and Saleh, A.K. Md. E. (2009):An Introduction to Probability and Statistics. 2ndEdn., John Wiley and Sons.
- ✓ Hogg, R.V. and Tanis, E.A. (2009): A Brief Course in Mathematical Statistics. Pearson Education.
- ✓ Johnson, R.A. and Bhattacharya, G.K. (2001): Statistics-Principles and Methods,4th Edn. John Wiley and Sons.
- ✓ Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory ofStatistics,3rdEdn. (Reprint).Tata Mc Graw-Hill Pub. Co. Ltd.
- ✓ Deepak Chawala: Research Methodology, Vikas publication.

LIST OF PRACTICALS:

1. Testing of significance and confidence intervals for single proportion and difference of two proportions
2. Testing of significance and confidence intervals for single mean and difference of two means and paired tests.
3. Testing of significance and confidence intervals for difference of two standard deviations.
4. Exact Sample Tests based on Chi-Square Distribution.
5. Testing if the population variance has a specific value and its confidence intervals.
6. Testing of goodness of fit.
7. Testing of independence of attributes.
8. Testing based on 2×2 contingency table without and with Yates' corrections.
9. Testing and confidence intervals of equality of two population variances.

CORE-VI: PARAMETRIC STATISTICAL INFERENCE

COURSE OUTCOMES

- Understand the concept of Statistical Inference, types of inference, Characteristics of point estimation
- Know the concept of efficiency, sufficiency, CR inequality and its applications
- Know the concept of sufficient statistic, Neyman Factorization theorem, Rao-Blackwell theorem and its applications. Formulate null and alternative hypotheses and apply small, large sample.
- Know the different methods of estimation. Compute probabilities of types of error, MP tests and MLR property.
- Know the concept of interval estimation, Confidence intervals for parameters of some distributions Binomial, Poisson, Normal. Understand UMP and UMPU test with their applications. Obtain asymptotic confidence interval of a parameter and its relation with testing of hypothesis problem.
- Can understand the sequential sampling procedures

LEARNING OUTCOMES

Statistical inference: Drawing conclusions about the whole population on the basis of a sample. Statistical inference is the process of deducing properties of an underlying probability distribution by analysis of data. Inferential statistical analysis infers properties about a population, this includes testing hypotheses and deriving estimates. To learn the development of null and alternative hypotheses. To learn types of errors, non-parametric tests. To perform Test of hypothesis as well as obtain MP, UMP tests.

UNIT-I

Estimation: Concepts of point estimation, Criterion of a good estimator, unbiasedness, sufficiency, consistency and efficiency. Factorization theorem. Complete statistics. Minimum variance unbiased estimator (MVUE), Rao- Blackwell and Lehmann-Scheffe theorems and their applications. , minimal and complete statistics, Cramer-Raoinequality and MVB estimators (statement and applications).

UNIT-II

Methods of Estimation: Method of moments, method of maximum likelihood, Method of minimum Chi-square, method of minimum variance, method of least square, basic idea of Bayes' estimators.

UNIT-III

Principles of test of significance: Null and alternative hypotheses (simple and composite),Type-I and Type-II errors, critical region, level of significance, size and power, best critical region, most powerful test, uniformly most powerful test, Neyman

Pearson Lemma (statement and applications to construct most powerful test). Likelihood ratio test, properties of likelihood ratio tests (without proof).

UNIT-IV

Sequential Analysis: Sequential probability ratio test (SPRT) for simple vs simple hypotheses. Fundamental relations among α, β, A and B, determination of A and B in practice. Wald's fundamental identity and the derivation of operating characteristics (OC) and average sample number (ASN) functions, examples based on binomial and normal distributions.

TEXT BOOKS

- ✓ Goon A.M., Gupta M.K.: Das Gupta. B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
- ✓ Gun, A.M., Gupta, M.K. and Dasgupta, B.: An Outline of Statistical Theory, Vol. II, (4^{th} ed.), World Press.

SUGGESTED READINGS

- ✓ Rohatgi, V.K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability andStatistics.2^{nd}Edn. John Wiley and Sons.
- ✓ Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6^{th} Edition),Prentice Hall of India.
- ✓ Dudewicz, E.J., and Mishra, S.N.(1988):Modern Mathematical Statistics John Wiley & Sons.
- ✓ Mood A.M, Graybill F.A. and Boes D.C,: Introduction to the Theory of Statistics, McGraw Hill.
- ✓ Bhat B.R, Srivenkatramana T and Rao Madhava K.S.(1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.

LIST OF PRACTICALS

1. Unbiased estimators (including unbiased but absurd estimators)
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Maximum Likelihood Estimation
4. Most powerful critical region (NP Lemma)
5. Uniformly most powerful critical region
6. Unbiased critical region
7. Power curves
8. OC function and OC curve, ASN function and ASN curve

CORE-VII: SURVEY SAMPLING & INDIAN OFFICIAL STATISTICS

COURSE OUTCOMES

- Understand the basic principles underlying survey design and estimation.
- Apply the different sampling methods for designing and selecting a sample from a population.
- Implement Cluster sampling, Ratio and Regression estimation in real life problems.
- Apply unequal probability sampling designs viz. PPSWR, PPSWOR including Lahiri's method and Murthy's estimator for survey. Analyze the nature of data and interpret the measures.
- Understand the structure and functioning of Indian Official Statistical System.

LEARNING OUTCOMES

Survey Sampling provides the tolls/ techniques for selecting a sample of elements from a target population keeping in mind the objectives and nature of population. Most of the research work is done through Sample Survey. The students are able to know about Indian Official Statistical System. After completing the course, students should have developed clear understanding of: Basic concepts of survey sampling, Principles of survey sampling and main steps involved in selecting a sample, Simple random sampling, Stratified random sampling, Systematic sampling, Ratio and Regression method of estimation, Cluster sampling (equal cluster size), Concepts of sub sampling, Indian Official Statistical System.

UNIT-I

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: probability and non-probability samplings,basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of theseestimates, estimates of the invariances and sample size determination.

UNIT-II

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision. Systematic Sampling: Technique$(N = nk)$, estimates of population mean and total, variances of these estimates. Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections.

UNIT-III

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), variances of these estimates and estimates of these variances, comparison with SRSWOR. Cluster sampling(equal clusters only) estimation of population mean and its variance.

UNIT-IV

Present official statistical system in India, methods of collection of official statistics, its quality and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), National Statistical Office (NSO) and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population,industry and finance.

TEXT BOOKS

- ✓ Sukhatme,P.V.,Sukhatme,B.V.Sukhatme,S.Asok,C.(1984).SamplingTheoriesof SurveyWith Application,IOWAStateUniversityPressandIndianSocietyofAgriculturalStatistics
- ✓ Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
- ✓ http://mospi.nic.in/

SUGGESTED READINGS

- ✓ Cochran W.G.(1984):Sampling Techniques(3rd Ed.),Wiley Eastern.
- ✓ Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- ✓ DesRajandChandhokP.(1998):SampleSurveyTheory,NarosaPublishingHouse.
- ✓ Goon A.M., Gupta M.K. and Dasgupta B.(2001):Fundamentals of Statistics(Vol.2), World Press.
- ✓ J K Sharma (2014) Business Statistics, Vikas Publication.

LIST OF PRACTICALS

1. To select a SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimate mean, standard error, the sample size
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS.
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.
7. Ratio and Regression estimation: Calculate the population mean or total of the

population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.

8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra- class correlation coefficient, efficiency as compared to SRS.

SEMESTER-IV

CORE-VIII: REAL AND NUMERICAL ANALYSIS

COURSE OUTCOMES

- Describe fundamental properties of the real numbers that lead to the formal development of real analysis. Comprehend rigorous arguments developing the theory underpinning real analysis.
- Demonstrate an understanding of limits and how they are used in sequences, series, differentiation and integration. Construct rigorous mathematical proofs of basic results in real analysis. Understand abstract ideas and rigorous methods in mathematical analysis to solve practical problems.
- Solve equations using numerical methods.
- Interpolate the value using techniques of numerical methods.
- Perform numerical integration using Trapezoidal and Simpson's rule.

LEARNING OUTCOMES

Students will have the knowledge of basic properties of the field of real numbers, the knowledge of the series of real numbers and convergence, Bolzano –Weirstrass theorem, Cauchy criteria, the knowledge of real functions-limits of functions and their properties, notion of continuous functions and their properties and the differentiability of real functions and related theorems Numerical Analysis: Theory of finite differences deals with the changes that take place in the value of the dependent variable due to finite changes in the independent variable. On completion of the course, students should have achieved as follows:

1) Mathematical Operators (Forward and Backward difference operators, Shift Operator, Central difference operator, Derivative)
2) Approximating a given set of data by a function using interpolation formula.
3) Newton Gregory interpolation formula (forward and backward) for arguments at equal intervals
4) Newton's Divided difference interpolation formula and Lagrange's interpolation formula (for unequal intervals)
5) Central Difference interpolation formula (Gauss and Stirling's)
6) Representation of a polynomial in factorial Notation
7) Numerical Quadrature using the interpolation formula (Trapezoidal Rule, Simpson's 1/3rd and 3/8th quadrature formula
8) Solution of Differential equations.

UNIT-I

Real Analysis: Representation of real numbers as points on the line and the set of real numbers as complete ordered field. Bounded and unbounded sets,

neighborhoods and limit points, Supremum and infimum, open and closed sets, sequences and their convergence. Infinite series, positive termed series and their convergence, Comparison test, D'Alembert's ratio test, Cauchy's nth root test, Raabe's test. Gauss test, Cauchy's condensation test and integral test (Statements and Examples only).

UNIT-II

Review of limit, continuity and differentiability, uniform Continuity and boundedness of a function. Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with lagrange's and Cauchy's form of remainder (without proof). Taylor's and Maclaurin's series expansions.

UNIT-III

Numerical Analysis: Factorial, finite differences and interpolation. Operators, E and divided difference. Newton's forward, backward and divided differences interpolation formulae. Lagrange's interpolation formulae. Central differences, Gauss and Stirling interpolation formulae.

UNIT-IV

Numerical integration. Trapezoidal rule, Simpson's one-third rule, three-eighths rule, Weddle's rule with error terms. Stirling's approximation to factorial. Solution of differential equations of first order.

TEXT BOOKS

- ✓ Malik S.C. and Savita Arora: Mathematical Analysis, Second Edition, Wiley Eastern Limited, New Age International Limited, NewDelhi,1994.
- ✓ Shanti Narayan: A Course of Mathematical Analysis S Chand
- ✓ GoelB.S.andMittalS.K.:NumericalAnalysis,PragatiPrakashan,ND,2008

SUGGESTED READINGS

- ✓ Somasundram D. and Chaudhary B.: A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi,1987.
- ✓ Shanti Narayan: A course of Mathematical Analysis, 12thEdition, S. Chand &Co.(Pvt.) Ltd.,New Delhi,1987.
- ✓ Singal M.K. and Singal A.R.: A First Course in Real Analysis, 24th Edition, R. Chand &Co.,New Delhi,2003.
- ✓ Bartle, R.G. and Sherbert, D.R.(2002):Introduction to Real Analysis(3rdEdition), John Wiley and Sons (Asia) PVT. Ltd.
- ✓ Jain,M. K., Iyengar, S. R. K. and Jain, R. K. (2003): Numerical methods for scientific and engineering computation, New age International Publisher, India.

LIST OF PRACTICALS

1. Interpolation with equal and unequal intervals.

2. Problems on Lagrange’s interpolation
3. Numerical Integration (Trapezoidal, Simpson’s and Weddle’s method)
4. Stirling’s approximation

CORE-IX: LINEAR REGRESSION ANALYSIS AND FORECASTING (NPTEL)

COURSE OUTCOMES

- To understand about the correlation structure among the variables and understand the linear regression equation and least square method for estimating the parameters of the model
- Can able to test the hypothesis related to the significance of regression coefficients
- Understand the Gauss-Markov set-up and estimation of error variance.
- Can be able to analyze the graphs before fitting the model and check for the model validation
- Can handle the problem of Correlated errors and collinearity in the model
- Can be able to forecast with regression and also build scenario-based forecasting. Can Build a predictive regression model and check for fitted values and cross-validation.
- Understand the concepts of Nonlinear regression

LEARNING OUTCOMES

Forecasting is an important aspect of any experimental study. The forecasting can be done by finding the model between the input and output variables. The tools of linear regression analysis help in finding out a statistical model between input variables and output variable which in turn provides forecasting. For example, the yield of a crop depends upon the area of crop, quantity of seeds, rainfall etc. The statistical relation between yield and area of crop, quantity of seeds, rainfall etc. can be determined by the regression analysis and forecasting can be done to know the yield in future. The accuracy of forecasting depends upon the goodness of obtained model. What are its steps and checks required to obtain a good model and in turn, how to do forecasting is being aimed to be taught in this course.

UNIT-I

Regression Analysis, Steps in regression Analysis, Simple Linear Regression Model: Covariance and Correlation coefficient Estimation by Method of least squares, Testing of Hypothesis of regression coefficient, Confidence Intervals, Predictions, Measuring the quality of fit. Multiple Linear Regression, Centering and scaling, Properties of Least square estimators, multiple correlation coefficient, Tests of hypothesis of regression coefficients in a linear model, Variable selection procedures: Forward selection procedure and backward elimination procedure.

UNIT-II

Gauss-Markov set-up: Theory of linear estimation, Estimability of linear parametric functions, Gauss-Markov theorem, Estimation of error variance.

Regression Diagnostics: The standard regression assumptions, various types of residuals, Graphical methods, Graphs before fitting a model, Graphs after fitting a

model, model checking assumptions for linearity and normality, Leverage, influence and outliers, measures of influence: Cook's distance

UNIT-III

Problem of multicollinearity, its effect on inference and forecasting, detection of multi-collinearity, criteria for evaluating equations: Residual mean square, Mallows Cp, Information criteria, Problem of autocorrelation, detection and removal, Durbin-Watson statistic and its limitations.

UNIT-IV

Forecasting with regression, Ex-ante versus ex-post forecasts, Scenario based forecasting, Building a predictive regression model, Prediction intervals, Fitted values and cross-validation, Nonlinear regression, Forecasting with a nonlinear trend, Correlation, causation and forecasting.

For details please visit

https://archive.nptel.ac.in/content/syllabus_pdf/111104098.pdf

TEXT BOOKS

- ✓ Draper, N.R. and Smith, H.: Applied Regression Analysis, John Wiley &Sons.
- ✓ Chatterjee, S. and Hadi A. S.: Regression Analysis by Example, Wiley

SUGGESTED READINGS

- ✓ Sengupta, D, Linear model: an integrated approach, World Scientific Pub.
- ✓ Weisberg, S.(2005).Applied Linear Regression (Third edition).Wiley.
- ✓ Wu, C.F.J. And Hamada, M.(2009). Experiments, Analysis, and Parameter Design Optimization (Second edition),John Wiley.
- ✓ Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons

LIST OF PRACTICALS

1. Estimability of linear functions (full rank and not a full rank case)
2. Simple Linear Regression
3. Multiple Regression
4. Tests for Regression diagnostics
5. Autocorrelation testing
6. Nonlinear regression

CORE-X: STATISTICAL QUALITY CONTROL

COURSE OUTCOMES

- Understand the concept of quality, specification limits and tolerance limits
- Construct and draw control charts for variables, attributes and interpret them.
- Understand basic of production process monitoring and apply concept of control charts on it. Apply various sampling plans for product control.
- Analyze the nature of data and interpret the quality of product. Apply the acceptance and continuous sampling plans in production process. Compute capability indices.
- Apply reliability and other related measures based on standard distributions. Know and apply the concept of weighted control charts, six sigma, ISO: 9000 series standards and Taguchi design.

LEARNING OUTCOMES

Acquire knowledge and develop analysis skills and industrial experimentation. Acquire knowledge on acceptance sampling principles and methods. Develop skills to analyse quality related data using advanced statistical methods. To develop scientific view to analyze the industrial data about specific perspective. To learn the statistical quality control techniques used in industries such as control charts, acceptance sampling plans etc. To learn some advanced control charts, capability indices and the concept of six-sigma.

UNIT-I

Quality: Definition, dimensions of quality, historical perspective of quality control and improvements starting from World War II, historical perspective of Quality Gurus and Quality Hall of Fame. Quality system and standards: Introduction to ISO quality standards, Quality registration. Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation. Statistical Control Charts- Construction and Statistical basis of 3-σ Control charts, Rational Sub-grouping.

UNIT-II

Control charts for variables: X-bar & R-chart, X-bar & s-chart. Analysis of patterns on control chart, estimation of process capability. Control charts for attributes: np- chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes.

UNIT-III

Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with

graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.

UNIT-IV

Introduction to Six-Sigma: Overview of Six Sigma, Lean Manufacturing and Total Quality Management (TQM).Organizational Structure and Six Sigma training Plans-Selection Criteria for Six-Sigma roles and training plans. Voice of customers (VOC): Importance and VOC data collection.

TEXT BOOKS

- ✓ Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

SUGGESTED READINGS:

- ✓ Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I &II,8thEdn. The World Press, Kolkata.
- ✓ Mukhopadhyay,P(2011):Applied Statistics, 2nd edition revised reprint, Books and Allied (P)Ltd.
- ✓ Montogomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, WileyIndia Pvt.Ltd.
- ✓ Ehrlich, B.Harris (2002): Transactional Six Sigma and Lean Servicing,2ndEdition, St. Lucie Press.
- ✓ Hoyle, David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.

LIST OF PRACTICALS

1. Construction and interpretation of statistical control charts
2. X-bar & R-chart
3. X-bar & s-chart
4. np-chart, p-chart, c-chart and u-chart
5. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD,ASN,ATI, AOQ, AOQL curves

SEMESTER-V

CORE-XI: DESIGN AND ANALYSIS OF EXPERIMENTS

COURSE OUTCOMES

- Experimental Design Replication, Randomization and Local control. Concepts of experimental design.
- One-way and two-way classification without interactions
- CRD, RBD and LSD Layout and their Statistical analysis- Efficiencies of LSD over RBD and CRD
- Analysis of RBD and LSD with one observation and two observations per cell
- Factorial Experiment: main and interaction effects and statistical analysis in 2^2, 2^3 and 3^2 designs. Concepts of Total and partial confounding.

LEARNING OUTCOMES

DOE is a tool to develop an experimentation strategy that maximizes learning using a minimum of resources. Extensively used by engineers and scientists involved in the improvement of manufacturing processes to maximize yield and decrease variability. It is widely used in many fields with broad application across all the natural and social sciences, to name a few: Biostatistics, Agriculture, Marketing, Software engineering. Industry etc. After completing Course in DOE students should have developed a clear understanding of: The fundamental concepts of design of experiments. To learn the basic principles in the design of simple experiments. To learn different tests for comparing pairs of treatment means, ANOVA, factorial experiments, fractional factorial experiments, confounding, BIBD, PBIBD with solving real life examples. To learn the applications of different designs in agriculture.

UNIT-I

Analysis of variance: Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effect and random effect models (one observation per cell), Analysis of variance and covariance in two-way classified data with one observation per cell for fixed effect and random effect models.

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks.

UNIT-II

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD)–layout, model and statistical analysis, relative efficiency, Analysis with missing observations.

UNIT-III

Factorial experiments: advantages and disadvantages, notations and concepts,2^2, 2^3, 2^n and 32 factorial experiments, design and its analysis and applications.

UNIT-IV

Total and Partial confounding for 2^n ($n \leq 5$), 3^2 and 3^3. Factorial experiments in a single replicate. Advantages and disadvantages. Balanced Incomplete Block Design (BIBD)–parameters, relationships among its parameters.

TEXT BOOKS

- ✓ Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4thEdition(Reprint), Sultan Chand &Sons
- ✓ Goon, A.M., Gupta, M.K. and Dasgupta, B.(2005):Fundamentals of Statistics. Vol. II,8th Edn. World Press, Kolkata.

SUGGESTED READINGS

- ✓ Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
- ✓ Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
- ✓ Kempthorne, O.(1965):The Design and Analysis of Experiments. John Wiley.
- ✓ Montgomery, D.C.(2008): Design and Analysis of Experiments, John Wiley.

LIST OF PRACTICALS

1. Analysis of a CRD
2. Analysis of an RBD
3. Analysis of an LSD
4. Analysis of an RBD with one missing observation
5. Analysis of an LSD with one missing observation
6. Analysis of 2^2 and 2^3 factorial in CRD and RBD
7. Analysis of a completely confounded two level factorial design in 2 blocks
8. Analysis of a completely confounded two level factorial design in 4 blocks
9. Analysis of a partially confounded two level factorial design

CORE-XII: STATISTICAL COMPUTING USING R PROGRAMMING

COURSE OUTCOMES

- Get familiar with R software and learn basics of R with descriptive statistics. Access online resources for R and import new function packages into the R workspace. Import, review, manipulate and summarize data-sets in R.
- Compute probabilities and fitting of probability distribution and plotting with R environment.
- Explore small and large data-sets to create testable hypotheses and identify appropriate statistical tests.
- Perform correlation, regression analysis and appropriate statistical tests for real life situations using R.
- Perform appropriate statistical tests and ANOVA for real life situations using R.

LEARNING OUTCOMES

After understanding R the student is able to familiar and to develop learning mindsets to analyze statistical data through R software and to learn basic syntax, coding and vocabulary to aid in data analysis.

UNIT - I

Introduction to R: Downloading and installation of R and R-Studio. Introduction to R and R-Studio.
Directory and working vectors: Setting of working directory, Entering and manipulating data in R, Basic classes of objects (character, numeric, integer, complex, logical), Vectors and their attributes (names, length, type).
Arrays and Data types: (matrices, frames, list), Combining data (cbind, rbind). Importing/Exporting data into R
Generating Sequences, function repeats, component extraction (for vectors, matrices, list, frames), Creating factors, Basic statistical functions (mean, median, mode, standard deviation, skewness, kurtosis etc.), installing packages and library, importing data from other sources (Excel etc.).

UNIT- II

Descriptive Statistics and Probability Distribution- Introduction, Working with Univariate, Descriptive Statistics in R; Measuring the Central Tendency – Mean and Median, Measuring Spread – Quartiles and the Five-Number Summary, Understanding Numeric Data – Uniform and Normal Distributions; Probability Distribution.

Plotting- Introduction, Visualizing Numeric Variables – Boxplots, Visualizing Numeric Variables – Histograms, Exploring Relationships between Variables, Visualizing Relationships – Scatter Plots; Correlation Plots from Data Sets.

UNIT- III

Correlation and Regression: Correlation (Karl Pearson & Spearman's rank correlation), Linear models in R (simple and multiple). Scatter plot and Regression line, testing of correlation and regression coefficients. Generating a Diagnostic Plot of a Fitting Model, Summarizing Linear Model Fits, Using Linear Regression to Predict Unknown Values, Generating a Diagnostic Plot of a Fitting Model.

UNIT - IV

Testing Normality: Anderson-darling test, Shapiro-Wilk test

Estimation and Testing: Tests of significance for the parameters of normal distribution i.e. mean and variance (one sample and two sample problems) and the relevant confidence intervals. One-way and Two-way Analysis of Variance, Chi-square test for independence and association.

TEXT BOOKS:

- ✓ Fundamentals of Computers, E. Balagurusamy
- ✓ ANSI C, Balagurusamy
- ✓ Introduction to Statistics and Data Analysis- With Exercises, Solutions and Applications in R, Christian Heumann, Michael Schomaker, Shalabh
- ✓ Gardener, M. Beginning R:TheStatisticalProgrammingLanguage,WileyIndia
- ✓ Monalisha Pattnaik, Statistical Computing using R Programming, Kalyani Publishing.

SUGGESTED READINGS:

- ✓ Balagurusamy, E.(2011): Programming in ANSIC, 6th Edition, Tata McGraw Hill.
- ✓ Kernighan, B.W. and
- ✓ Gottfried,B.S.(1998): Schaum's Outlines: Programming with C, 2nd Edition, Tata Mc GrawHill

LIST OF PRACTICALS

1. Different types of Plotting
2. Mean, Median and Mode and descriptive statistics of Data
3. Skewness and kurtosis of Data
4. Student's t test and Chi-square test
5. One way ANOVA and Two way ANOVA.
6. Correlation analysis
7. Regression analysis
8. Binomial distribution

CORE XIII- OERATIONS RESEARCH

COURSE OUTCOMES

- Understand basics and formulation of linear programming problems and appreciate their limitations; solve linear programming problems using graphical method.
- Apply simplex method to solve real life problems.
- Solve artificial variable technique, duality theory, revised simplex method, sensitivity analysis, transportation and assignment problems.
- Understand the concept of Game theory, PERT/ CPM, simulation, investment analysis with real life applications. Understand the concept and solving the problem of game theory
- Understand the concept of inventory model and solving the problem of inventory models.

LEARNING OUTCOMES

The 'Operations Research' is not only confined to any specific agency like defense services but today it is widely used in all industrial organizations. It can be used to find the best solution to any problem be it simple or complex. It is useful in every field of human activities. Thus, it attempts to resolve the conflicts of interest among the components of organization in a way that is best for the organization as a whole. Main fields where OR is extensively used are: 1. National Planning and Budgeting 2. Defense Services 3. Industrial Establishment and Private Sector Units 4. Research & Development and Engineering. To develop the optimization techniques that will be useful in the personal and professional life. To learn the mathematical formulation of complex decision-making problems and arrives at optimal or near-optimal solutions using different techniques of operations research.

UNIT-I

Introduction to Operations Research (O.R.), phases of O.R., model building, various types of O.R. problems. Linear Programming Problem, Mathematical formulation of the L.P.P, graphical solutions of a L.P.P. Simplex method for solving L.P.P. Charne's M-technique for solving L.P.P. involving artificial variables. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method.

UNIT-II

Transportation Problem: Initial solution by North West corner rule, least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution, special cases of transportation problem. Assignment problem: Hungarian method to find optimal assignment problem.

UNIT-III

Game theory: rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance and modified dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Networking: Shortest route and minimal spanning tree problem.

UNIT-IV

Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks.

TEXT BOOKS

- ✓ Kanti Swarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons.
- ✓ D S Hira: Operation Research S Chand

SUGGESTED READINGS

- ✓ Taha,H.A.(2007):OperationsResearch:AnIntroduction,8th Edition,Prentice Hall of India.
- ✓ Hadley,G:(2002):Linear Programming, Narosa Publications
- ✓ Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research Concepts and cases, 9th Edition, Tata McGraw Hill
- ✓ Kalavathy: Operation Research, Vikas Publishing

LIST OF PRACTICALS

1. Mathematical formulation of L.P. P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation (Unbounded, Infeasible and alternate solution)
3. Allocation problem using Transportation model
4. Allocation problem using Assignment model
5. Problems based on game matrix

SEMESTER-VI

CORE-XIV: NON-PARAMETRIC STATISTICAL INFERENCE

COURSE OUTCOMES

- Reinforce and supplement prior knowledge of fundamental statistical topics such as the goals of a statistical analysis; elements and principles of hypothesis testing and confidence intervals; comparative studies. Understand and apply the general concept of nonparametric statistics.
- Perform a variety of nonparametric statistical analyses such as: One and two sample tests (e.g. binomial test, Wilcoxon test, etc.), K-sample methods (Kruskal-Wallis test, etc.)
- Can understand modern use of computing in nonparametric statistics.
- Understand the data management and performance of basic nonparametric statistical analyses.
- Explain findings with others using appropriate statistical and non-statistical language.

LEARNING OUTCOMES

The essential ideas and implementations of both traditional and contemporary nonparametric statistical methods of data analysis are covered. Allows students to investigate nonparametric methods on a more in-depth level than in previous courses and apply it to data in their particular disciplines. Students will understand the general concept of nonparametric statistics and performs variety of nonparametric statistical analyses. Students will communicate findings with others in a global environment using appropriate statistical and non-statistical language.

UNIT-I

Some tests based on Binomial Distribution: The Binomial Test, The quantile Test, Tolerance limits, The Sign Test and some variations, The McNemar Test for Significance of changes.

UNIT-II

The contingency Tables: The 2×2 Contingency table, The $r \times c$ Contingency table, The Chi-square Test for differences in Probabilities, The Chi-Square Test for independence, The Chi-Square Test for Fixed Marginal Totals, The median Test, Measures of Dependence, Cramer's and Pearson's Contingency Coefficient, The Phi Coefficient, A Goodness of Fit Test, Cochran's test for correlated Observations

UNIT-III

The Use of Ranks: The One Sample or Matched pairs case, The Wilcoxon Signed Ranks Test, Confidence interval for the median, Two independent Samples: The Mann-Whitney Test, Measures of Rank Correlation, Spearman's Rho, Kendall's Tau, Kendall's partial correlation coefficient, Several Independent Samples: Kruskal-Walis Test

UNIT-IV

Statistics of the Kolmogorov-Smirnov Type: Kolmogorov goodness of fit test, Confidence band for population distribution function, The Lilliefors Test, The Cramer-von Misses Goodness of fit test, Tests for two independent samples: The Smirnov test, The Cramer-von Misses two sample test, Tests for several independent samples – The Birnbaum-Hall Test

TEXT BOOKS

- ✓ Conover, W.J., Practical Non-parametric Statistics, John Wiley & Sons.

SUGGESTED READINGS

- ✓ Nonparametric Statistical Methods, 3rd Edition, Myles Hollander, Douglas A. Wolfe, Eric Chicken, Wiley Series in Probability and Statistics

LIST OF PRACTICALS

1. The Binomial Test, The quantile Test
2. The Sign Test, The McNemar Test for Significance of changes
3. The Chi-square Test for differences in Probabilities, The Chi-Square Test for independence, The Chi-Square Test for Fixed Marginal Totals,
4. The median Test,
5. Cramer's and Pearson's Contingency Coefficient
6. The Wilcoxon Signed Ranks Test
7. Measures of Rank Correlation

CORE-XV: MULTIVARIATE ANALYSIS

COURSE OUTCOMES

- The understanding of basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- Analysing Multivariate data using multiple and partial correlation coefficient
- Understand Wishart distribution, Hotelling T^2 and Mahalanobis D^2 statistic.
- Implement dimension reduction techniques using software on real life problems.
- Demonstrate knowledge and understanding of the basic ideas behind discriminant, clustering analysis and ANN techniques with applications.

LEARNING OUTCOMES

The learning objectives include: Study of theoretical concepts of Bivariate Normal and Multivariate Normal Distributions along with their properties. Analyzing Multivariate data using data reduction techniques like Principal Component Analysis, Factor Analysis. To learn and develop scientific view to deal with multidimensional datasets and its uses in the analysis of research data. To understand the extensions of univariate techniques to multivariate frameworks and learn to apply dimension reduction techniques used in the data analysis.

UNIT-I

Bivariate Normal Distribution (BVND): probability density function (p.d.f.) of BVND, properties of BVND, marginal and conditional p.d.f. of BVND. Multivariate Data: Random Vector: Probability mass / density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions. Characteristic Function

UNIT-II

Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance – covariance matrix. Hotelling's T^2 Statistic for one sample and two samples (detailed derivations excluded), Optimum properties of T^2 test, Multiple and partial correlation coefficient and their properties.

UNIT-III

Principal Component Analysis: Method of extraction, graphical presentation, Properties of principal components.

Canonical Correlation Analysis: Population correlation analysis, sample canonical correlation analysis, interpretation from canonical correlation analysis

Cluster Analysis: Basic steps – Distance-type measures, matching type measures, Forming clusters – Agglomerative method.

UNIT-IV

Discriminant Analysis: Scope, Assumptions, justification and selection of variables, importance of variables, methods of discrimination – maximum likelihood method, discrete discriminant analysis, idea about artificial neural network and its application

TEXT BOOKS

- ✓ Bhuyan,KC.,MultivariateAnalysisanditsApplications,NewCentralBookAgency(P) Limited
- ✓ Gun, A.M., Gupta, M.K. and Dasgupta, B.: An Outline of Statistical Theory, Vol.II,(4thed.),World Press.

SUGGESTED READINGS

- ✓ Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn.Pearson & Prentice Hall
- ✓ Kshirsagar, A.M.(1972):Multivariate Analysis,1stEdn.Marcel Dekker.
- ✓ Anderson, T. W. (2003). An Introduction to Multivariate Statistical Analysis(3rd ed.), Wiley
- ✓ Bilodeau, M. & Brenner, D. (1999). Theory of Multivariate Statistics, Springer
- ✓ Härdle, W.K. & Simar, L. (2007). Applied Multivariate Statistical Analysis(2nd ed.), Springer
- ✓ Rencher, A.C. (2002). Methods of Multivariate Analysis(2nd ed.), Wiley
- ✓ Timm, N.H. (2002). Applied Multivariate Analysis, Springer.

LIST OF PRACTICALS

1. Multiple Correlation
2. Partial Correlation
3. Bivariate Normal Distribution
4. mean vector and variance – covariance matrix
5. Hotelling's T^2 Statistic.
6. Principal Component Analysis.
7. Canonical Correlation Analysis

SEMESTER-VII

CORE-XVI: TIME SERIES ANALYSIS

COURSE OUTCOMES

- Understand the concept of time series with its components and able to compute ACVF and ACF.
- Remove trend and seasonality using different methods to convert the time series into stationary.
- Apply auto regressive, moving average, ARMA, ARIMA models, Box-Jenkins approach to forecast time-series data empirically.
- Check and validate models with its residual analysis and diagnostic checking. Analyze the nature of data and interpret the measures
- Analyze the data and predict the future values using curve fitting and exponential smoothing techniques.

LEARNING OUTCOMES

Students of this course are taught to understand and predict the changes in economy. Areas of learning include Profit of experience, Safety from future, Utility Studies, Sales Forecasting, Budgetary Analysis, Stock Market Analysis, Yield Projections, Economic Forecasting, Census Analysis, Risk Analysis & Evaluation of changes. To learn and develop scientific view to understand the time series data and its analysis. To learn stationary and non-stationary, and seasonal and nonseasonal time series models. Learn to estimate model parameters and compare different models developed for the same dataset in terms of their estimation and prediction accuracy.

UNIT-I

Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series. Trend: Estimation of trend by free hand curve method, method of semi averages, fitting a various mathematical curve, growth curves.

UNIT-II

Trend Cont: Method of moving averages. Detrending. Effect of elimination of trend on Other components of the time series. Seasonal Component: Estimation of seasonal component by Method of simple averages, Ratio to (Linear) Trend.

UNIT-III

Seasonal Component: Ratio to Moving Averages and Link Relative method, Moving-average (MA) process and Autoregressive (AR) process of orders one and two, Estimation of the parameters of AR(1) and AR(2)–Yule-Walker equations.

UNIT-IV

Stationary Time series: Weak stationarity, autocorrelation function and correlogram of moving average; its applications. Random Component: Variate component method. Forecasting: Exponential smoothing methods.

TEXTBOOKS

- ✓ Kendall M.G.(1976):Time Series, Charles Griffin.
- ✓ Brockwell, P.J. and Davis, R.A.(2003).Introduction to Time Series Analysis, Springer

SUGGESTEDREADINGS

- ✓ Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4thEdition(Reprint), Sultan Chand &Sons
- ✓ Chatfield C. (1980): The Analysis of Time Series–An Introduction, Chapman & Hall.
- ✓ MukhopadhyayP.(2011):AppliedStatistics,2nded.Revisedreprint,BooksandAllied

LIST OF PRACTICALS

1. Fitting and plotting of modified exponential curve
2. Fitting and plotting of Gompertz curve
3. Fitting and plotting of logistic curve
4. Fitting of trend by Moving Average Method
5. Measurement of Seasonal indices Ratio-to-Trend method
6. Measurement of Seasonal indices Ratio-to-Moving Average method
7. Measurement of seasonal indices Link Relative method
8. Forecasting by exponential smoothing

CORE-XVII: OPTIMIZATION TECHNIQUES

COURSE OUTCOMES

- Comprehend the techniques and applications of Engineering optimization.
- Analyze characteristics of a general linear programming problem.
- Apply basic concepts of mathematics to formulate an optimization problem.
- Analyze various methods of solving the unconstrained minimization problem.
- Analyze and appreciate variety of performance measures for various optimization problems.

LEARNING OUTCOMES

At the end of this unit, the student will be able to explain importance of optimization. List out the design variables, constraints and objective function for optimization techniques. can analyze Kuhn Tucker conditions and method of multipliers. Analyze solution of nonlinear programming problems and also analyze various optimization methodologies.

UNIT-I

Convex sets: Open and closed sets in E_n, convex linear combinations, convex sets, intersection of convex sets, convex hull of a set, Vertices or extreme points of a convex set, convex polyhedron, Hyperplanes, half-spaces and polytopes, separating and supporting hyperplanes, vertices of a closed bounded convex set.

UNIT-II

Flow and potential in networks: Graphs – definition and notation, minimum path problem, spanning tree of minimum length, problem of minimum potential difference, scheduling of sequential activities, maximum flow problem, duality in maximum flow problem.

UNIT-III

Integer Programming: ILP in two-dimensional space, General ILP and MILP problems, cutting planes, Branch and bound method, The 0-1 variable.

Sensitivity analysis: changes in b_i, c_j and in a_{ij}, introduction of new variables, introduction of new constraints, deletion of variables and deletion of constraints

UNIT-IV

Kuhn-Tuker Theory and nonlinear programming: Lagrangian function, saddle point, relation between saddle point and minimal point, Kuhn-Tucker conditions

Geometric programming: Examples, general method, generalization through Kuhn-Tucker theory.

TEXT BOOKS

- ✓ Mital, K.V. and Mohan, C. Optimization methods in operations research and system analysis, New age international.

SUGGESTED READINGS

- ✓ Aoki, M.; Introduction to Optimization Techniques, Fundamentals and applications of Nonlinear Programming, Macmillan
- ✓ Bazaraa, M.S. and Shetty, C.M. Foundations of Optimization, Lecture Notes in Economics and Mathematical Systems, Springer-Verlag.
- ✓ Rao S.S, “Optimization – Theory and applications”, Wiley Easter Ltd., 1979.
- ✓ David G.Luerbeggan, “Introduction to Linear and Non Linear Programming”, Addison Wesley Publishing Co.
- ✓ 1973.
- ✓ Hadley G. “Nonlinear and – dynamic programming” Addison Wesley Publishing Co. 1964.
- ✓ Cordan C.C. Beveridge and Robert S. Schedther, “Optimization, Theory and Practice” McGraw Hill Co.1970.
- ✓ Harndy A.Tahh. “operations Research, An Introduction”, Macmillan Publishers Co.NewYork,1982.
- ✓ Beightfer and S. others, “Foundations of Optimization Pill”, New Delhi, 1979.

LIST OF PRACTICALS

1. Integer Programming Problem
2. Vertices or extreme points of a convex set.
3. Minimum path problem, spanning tree of minimum length
4. Sensitivity analysis: changes in b_i, c_j and in a_{ij}
5. Saddle point
6. Minimal point
7. Geometric programming

CORE-XVIII: ECONOMETRICS

COURSE OUTCOMES

- Know the scope and objectives of Econometrics
- Detect the absence of homoscedasticity, Autocorrelation and Multicollinearity.
- Derive the reduced form of a simultaneous equation model.
- Remove the autocorrelation effect in the data.
- Understand Auto correlation

LEARNING OUTCOMES

Econometrics deals with the measurement of economic relationships. It is an integration of economics, mathematical economics and statistics with an objective to provide numerical values to the parameters of economic relationships. It may be pointed out that the econometric methods can be used in other areas like engineering sciences, biological sciences, medical sciences, geosciences, agricultural sciences etc. In simple words, whenever there is a need of finding the stochastic relationship in mathematical format, the econometric methods and tools help. After completing this course, students should have developed a clear understanding of 1. The fundamental concepts of econometrics. 2. Specification of the model. 3. Multiple Linear Regression. 4. Multicollinearity. 5. Heteroscedasticity. 6. Autocorrelation. 7. Autoregressive and Lagmodels 8. Use of Dummy Variables 9. Specification Errors.

UNIT I

Nature of Econometrics and Economic Data, Definition of Econometrics – Steps in Empirical Economic Analysis - Econometric Model –The Role of Measurement in Economics – The Structure of Economic Data: Cross-Sectional data, Time Series data, Pooled Cross Section data, Panel Data. Linear modeland estimation of parameter and related tests, Estimation under linear restrictions.

UNIT II

Multicollinearity: Introduction and concepts, detection of multicollinearity, consequences, tests and solutions of multicollinearity, specification error.

Heteroscedastic disturbances: OLS estimator under heteroscedasticity. Consequences of heteroscedasticity.

UNIT III

Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

Auto-regressive and Distributed Lag Models: Introduction – Types of Lag schemes - Koyck's lag model, Almon's Lag scheme, Partial Adjustment and Expectations models - Causality in Economics – The Granger Causality Test.

UNIT IV

Functional forms of Regression models – Loglinear models, Semi log- models and Reciprocal models – Choice of Functional Form.

TEXT BOOKS

- ✓ Johnston,J: Econometric Methods, McGraw-Hill Book Co., New York.

SUGGESTED READINGS

- ✓ Maddala, G.S: Econometrics, McGraw-Hill Book Co., New York, 3rd Rd.
- ✓ Gujarathi, D.N: Basic Econometrics, Fourth Edition, Tata McGraw-Hill, New Delhi.
- ✓ Tintner,G: Econometrics, John Wiley & Sons, New York.
- ✓ Wooldridge, Jeffery M: Econometrics, Cengage Learning India Pvt. Ltd, New Delhi.
- ✓ Koutsoyiannis, A. (2004): Theory of Econometrics, 2nd Edition, Palgrave MacmillanLimited,
- ✓ Maddala, G.S. and Lahiri, K. (2009): Introduction to Econometrics, 4th Edition, JohnWiley & Sons.

LIST OF PRACTICALS

1. Problems based on estimation of General linear model
2. Testing of parameters of General linear model
3. Forecasting of General linear model
4. Problems concerning specification errors
5. Problems related to consequences of Multicollinearity
6. Diagnostics of Multicollinearity
7. Problems related to consequences of Autocorrelation (AR(I))
8. Diagnostics of Autocorrelation
9. Estimation of problems of General linear model under Autocorrelation
10. Problems related to consequences Heteroscedasticity
11. Diagnostics of Heteroscedasticity
12. Estimation of problems of General linear model under Heteroscedastic distance terms
13. Problems related to General linear model under (Aitken Estimation)
14. Problems on Autoregressive and Lag models.

CORE-XIX: STOCHASTIC PROCESS

COURSE OUTCOMES

- Identify the situations which require stochastic modelling.
- Identify the states and model the situation using Markovian approach.
- Study and interpret the characteristics of queuing environment using stochastic modelling
- Apply Renewal Process to real time problems.
- Apply Birth-Death Process to Queuing problems

LEARNING OUTCOMES

After completing this course, students should have developed a clear understanding of the fundamental concepts of stochastic processes, tools needed to analyze stochastic processes, Markov chains, Stability of Markov chains, Poisson process and its variations, Queuing systems, Random walk and ruin theory, and to identify the real-life applications of stochastic processes. To learn and to understand stochastic processes predictive approach. To develop an ability to analyze and apply some basic stochastic processes for solving real life situations.

UNIT-I

Stochastic Process: Definition and specification Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains.

UNIT-II

Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, pure death process, birth and death process.

.**UNIT-III**

Stationary Processes: Stationarity, Gaussian processes, Time series: Introduction, White noise process, First order Markov process, moving average(MA) process, autoregressive(AR) process, Yule Process, ARMA process

UNIT-IV

Simulation: Generation of pseudorandom numbers, evaluation of integrals using random numbers, evaluation of multiple integrals, generation of continuous random variables: inverse transform method, rejection method, generation of Bernoulli, Binomial and Geometric random variables.

TEXT BOOKS

- ✓ Medhi, J.(2009):Stochastic Processes, New Age International Publishers.

SUGGESTED READINGS

- ✓ Basu, A.K.(2005):Introduction to Stochastic Processes, Narosa Publishing.
- ✓ Bhat, B.R.(2000): Stochastic Models: Analysis and Applications, New Age International Publishers.
- ✓ Karlin, S and Taylor H.M, A first course in Stochastic Process. Academic Press;

LIST OF PRACTICALS

1. Calculation of transition probability matrix
2. Identification of characteristics of reducible and irreducible chains.
3. Identification of types of classes
4. Calculation of probabilities for given birth and death rates and vice-versa
5. First order Markov process
6. Moving average (MA) process, autoregressive (AR) process, Yule Process
7. Generation of pseudorandom numbers

SEMESTER-VIII

CORE-XX: SCIENTIFIC COMPUTING USING MATLAB (NPTEL)

COURSE OUTCOMES

- Use MATLAB effectively to analyze and visualize data.
- Apply numeric techniques and simulations to solve engineering-related problems.
- Apply a top-down, modular, and systematic approach to design, write, test, and debug sequential MATLAB programs to achieve computational objectives.
- Have in depth understanding and use of Matlab fundamental data structures (classes).
- Create and control simple plot and user-interface graphics objects in MATLAB.
- Be able to understand and use Matlab Toolboxes for solving real life problems.

LEARNING OUTCOMES

After completion, a student can introduce the MATLAB software environment and fortify an organized, top-down way to define and solve big problems. He will be able to introduce common approaches, structures, and conventions for creating and evaluating computer programs, primarily in a procedural paradigm with an introduction to object-oriented concepts and terminology. He can apply a variety of common numeric techniques to solve and visualize engineering-related computational problems. He will be familiar with various toolboxes to solve real life applications

UNIT-I

Introduction: What is MATLAB? Use and requirements, basics of MATLAB: windows, online help, input-output, File types, platform dependence, some general commands, creating and working with arrays of numbers, creating and printing simple plots, creating, saving and executing with a script file, creating and executing a function file, working with files and directories.

UNIT-II

Interactive computation: Matrices and vectors – inputs, indexing, matrix manipulation, creating vectors, matrix and array operations – arithmetic, logical, elementary math operations, vectorization, command line functions, built-in functions.

UNIT-III

Saving and loading data in MATLAB, Plotting Graphs, Programming in MATLAB: scripts and functions – script files, function files, language specific features. Basic statistical functions and descriptive analysis.

UNIT-IV

Applications: Linear Algebra – solving linear equations, Gaussian elimination, finding eigen values and vectors

Curve fitting and interpolation – Polynomial curve fitting on the fly, least square curve fitting, interpolation.

Data analysis and statistics

TEXT BOOKS

- ✓ Rudra Pratap (2006). Getting started with MATLAB 7: A quick introduction for Scientists and Engineers, Oxford University Press.

SUGGESTED READINGS

- ✓ Stephen J. Chapman (2005). Essentials of MATLAB Programming, Cengage Learning.
- ✓ Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg (2001) A Guide to MATLAB: For Beginners and Experienced Users, Cambridge University Press

LIST OF PRACTICALS

1. Solving linear equations, Gaussian elimination, finding eigen values and vectors
2. Curve fitting and interpolation – Polynomial curve fitting on the fly, least square curve fitting, interpolation.
3. Data analysis and statistics

For details please visit

https://nptel.ac.in/courses/111102137

CORE-XXI: ACTUARIAL STATISTICS

COURSE OUTCOMES

- Understand the utility theory, insurance products and life tables.
- Understand the concept of interest.
- Understand the concept of life insurance.
- Understand the concept of existing insurance products of different insurance company.
- Know life annuities, net premium and net premium reserves.

LEARNING OUTCOMES

To learn the life tables used in insurance products. To learn the concept of interest, different life insurance products, life annuities, net premiums. To motivate students to prepare for exams required for employment in the actuarial science profession.

UNIT I

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

UNIT II

Principles of Premium Calculation: Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

UNIT III

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time-until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics, assumptions for fractional age, some analytical laws of mortality.

UNIT IV

Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Life annuities: continuous life annuities, discrete life annuities, life annuities with periodic payments. Premiums: continuous and discrete premiums.

TEXT BOOKS

- ✓ Dickson, C. M. D. (2005): Insurance Risk And Ruin (International Series On Actuarial Science), Cambridge University Press.

SUGGESTED READING:

- ✓ Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. And Nesbitt, C. J. (1997): Actuarial Mathematics, Society Of Actuaries, Itasca, Illinois, U.S.A.

LIST OF PRACTICALS

1. Risk computation for different utility models

2. Discrete and continuous risk calculations

3. Calculation of aggregate claims for collective risks

4. Calculation of aggregate claim for individual risks

5. Computing Ruin probabilities and aggregate losses

6. Annuity and present value of contract

7. Computing premium for different insurance schemes

8. Practical based on life models and tables

CORE-XXII: BAYESIAN PARAMETRIC INFERENCE

COURSE OUTCOMES

- Can use relative frequencies to estimate probabilities
- Can calculate conditional probabilities
- Can calculate posterior probabilities using Bayes' theorem and also can calculate simple likelihood functions
- Can describe the role of the posterior distribution, the likelihood function and the posterior distribution in Bayesian inference about a parameter.

LEARNING OUTCOMES

Bayesian statistics, as well as being able to 'understand the key ideas of Bayesian statistics' you should also find that your skills and confidence in tackling questions on probability are improving.

UNIT I

Subjective interpretation of probability in terms of fair-odds- Evaluation of subjective probability of an event of an event using a subjectively unbiased coin-Subjective prior distribution of a parameter-Bayes theorem and computation of the posterior distribution.

Natural Conjugate family of priors for a model –Hyper parameter of a prior from conjugate family- Conjugate family for exponential family models-admitting sufficient statistics of fixed dimensions-Enlarging the natural conjugate family by enlarging hyper parameter space, Mixtures from conjugate family-choosing an appropriate member of conjugate prior family, Non-informative, improper and invariant priors-Jerffrey"s invariant priors, Maximum entropy priors.

UNIT II

Bayesian point estimation: Prediction problem from posterior distribution-Bayes estimates for absolute error loss, squared error loss and Linex loss and Entropy loss function -Generalization to convex loss functions-Evaluation of the estimate in terms of the posterior risk.

UNIT III

Bayesian interval estimation: Credible intervals-Highest posterior density regions interpretation of the confidence coefficient of an interval.

Bayesian testing of hypothesis: Prior and posterior odds-Bayes factor for various types of testing hypothesis problem-Jeffery approach, Linley"s paradox for testing a point hypothesis for normal mean.

UNIT IV

Bayesian prediction problem: Standard Predictive distributions, Prediction for exponential family of distributions- predictive distributions and Reliability estimation-predictive interval, Ideas on Bayesian Robustness, Monte-Carlo Integration and Markov Chain Monte Carlo Technique (Without Proof).

TEXT BOOKS

- ✓ Bansal, A.K.(2007): Bayesian Parametric Inferences, Narosa Publications.

SUGGESTED READING

- ✓ Sinha, S.K.(1998): Bayesian Estimation, New Age International(P) Ltd., New Delhi.
- ✓ Berger,J.O.(1985): Statistical Decision Theory and Bayesian Analysis, 2/e Springer Verlag.
- ✓ Christian P. Robert : The Bayesian Choice, 2nd Edition, Springer
- ✓ Robert, C.P. and Casella,G.(2004): Monte Carlo Statistical Methods,2/e Springer Verlag.
- ✓ Degroot, M.H.(2004): Optimal Statistical Decisions, Welly Interscience.
- ✓ Gamerman, D. And Lobes, N.F.(200): Stochastic Simulation for Bayesian Inference,Taylor and Francis.
- ✓ Box, G.P. and Tiao, G.C.(1973): Bayesian Inference in Statistical Analysis, Adison Wesley..

LIST OF PRACTICALS

1. Bayes theorem and computation of the posterior distribution
2. Non-informative, improper and invariant priors
3. Credible intervals
4. Bayesian testing of hypothesis
5. Prediction for exponential family of distributions
6. Monte-Carlo Integration and Markov Chain Monte Carlo Technique

CORE-XXIII: STRATEGY: AN INTRODUCTION TO GAME THEORY (NPTEL)

BY Dr. VIMAL KUMAR & Prof. ADITYA K. JAGANNATHAM, IIT KANPUR

COURSE OUTCOMES

- Identify strategic situations and represent them as games.
- Solve simple games using various techniques.
- Analyze economic situations using game theoretic techniques.
- Recommend and prescribe which strategies to implement.
- Model any strategic interaction as a game and critically analyse the potential outcomes

LEARNING OUTCOMES

Games or 'Strategic Interactions' can be found in all walks of life. Examples of such scenarios are two firms competing for market share, politicians contesting elections, different bidders participating in an auction for wireless spectrum, coal blocks etc. Game theory provides a convenient framework to model and interpret the behaviour of participants in such strategic interactions. Hence it can be applied to solve a wide variety of problems involving diverse areas such as Markets, Auctions, Online Retail, Cold War, Paying Taxes, Bargaining, Elections, Portfolio Management etc. Therefore, both undergraduate and postgraduate students and professionals from diverse backgrounds such as Scientists, Engineers, Managers, Politicians and Political Scientists, Economists, Mathematicians etc. will find the course content useful. Examples and exercises will be motivated by problems close to real life scenarios.

UNIT I

Normal Games and Nash Equilibrium, Mixed Strategies.

UNIT II

Sequential Games.

Games with Incomplete Information

UNIT III

Auctions, Repeated Games

UNIT IV

Cooperative Games, Bargaining and Negotiation.

TEXT BOOKS

- ✓ T. Ferguson, Game Theory, Web Notes.

SUGGESTED READING:

- ✓ Karlin and Peres, Game Theory, Alive, AMS.
- ✓ DeVos and Kent, Game Theory: A Playful Introduction, AMS

For details please visit:
https://nptel.ac.in/courses/110104063

Important Remarks:

1. ***While preparing the detailed syllabus, the Board of Studies shall have to recommend the text books along with the specification of Chapter, Section and Subsections in detail to be covered in each paper for clarity on coverage both by the instructor and learner.***
2. ***A learner has to attend the NPTEL courses from NPTEL web site (https://nptel.ac.in/). However, he/she can submit course completion certificate from NPTEL or can opt for an examination by the concerned University / Autonomous College as conducted for other (non-NPTEL) papers.***

List of Equipment Required
for the Laboratory of +3 Syllabus

A well-equipped computer Lab with the number of computers (preferably two students per computer) with WINDOWS, MS Office and MATLAB software.

Minimum Specific Equipment

Operating System	Windows 11 / Windows 10 (version 21H2 or higher) Windows Server 2022
Processor	**Minimum:** Any Intel or AMD x86-64 processor with two or more cores **Recommended:** Any Intel or AMD x86-64 processor with four or more cores and AVX2 instruction set support **Note:** A future release of MATLAB will require a processor with AVX2 instruction set support
RAM	**Recommended**: 16 GB
Storage	3.8 GB for just MATLAB 4-6 GB for a typical installation 23 GB for an all products installation An SSD is strongly recommended
Graphics	No specific graphics card is required, but a hardware accelerated graphics card supporting OpenGL 3.3 with 1GB GPU memory is recommended.

MULTI-DISCIPLINARY COURSES

MD-I: STATISTICAL METHODS FOR SCIENTISTS AND ENGINEERS

By Prof. Somesh Kumar (NPTEL)

Course Objectives:

- The overall course objective is to understand basic concepts of probability and statistics and to be able to use them to solve engineering problems.
- Understand basic techniques for data summary and data presentation.
- Understand and be able to use basic probability rules and common probability distributions.
- Be able to estimate population parameters from random samples and perform error analyses.
- Be able to understand and apply the basic concepts of statistical inference, confidence limits and hypothesis testing.
- Be able to develop empirical linear models from data and evaluate their statistical properties.
- Be able to understand and apply the concepts of design of experiments and analysis of variance.
- Understand the theory and practice of statistical quality control and quality control charts.

UNIT-I

Review of Probability and Distributions: Rules for probability, random variables and their distributions, moments, special discrete and continuous distributions, laws of large numbers and central limit theorem, sampling distributions.

UNIT-II

Parametric Methods: Point estimation – unbiasedness, consistency, UMVUE, sufficiency and completeness, method of moments, maximum likelihood estimation and method of scoring. Bayes, minimax and admissible estimators. Interval estimation - confidence intervals for means, variances and proportions. Testing of Hypotheses - tests for parameters of normal populations and for proportions, goodness of fit test and its applications.

UNIT-III

Multivariate Analysis: Multivariate normal, Wishart and Hoteling's T 2 distributions and their applications in testing of hypotheses problems. Classification of observations, principal component analysis, canonical correlations and canonical variables.

UNIT-IV

Nonparametric Methods: Empirical distribution function, asymptotic distributions of order statistics, single sample problems, problems of location, prediction intervals, Kolmogorov Smirnov one sample statistics, sign test, Wilcoxon signed rank statistics, two sample

problems, Mann-Whitney-Wilcoxon tests, scale problems, Kolmogorov Smirnov two sample criterion, Hoeffding's U-statistics

TEXTBOOKS

- ✓ An Introduction to Probability and Statistics by V.K. Rohatgi & A.K. Md.E.Saleh.
- ✓ Modern Mathematical Statistics by E.J. Dudewicz& S.N. Mishra
- ✓ Introduction to Probability and Statistics for Engineers and Scientists by S.M. Ross
- ✓ An Introduction to Multivariate Analysis by T. W. Anderson
- ✓ Nonparametric Statistical Inference by J.D. Gibbons & S. Chakraborti

SUGGESTEDREADINGS

- ✓ Statistical Inference by G. Casella &R.L.Berger
- ✓ Applied Multivariate Statistical Analysis by R.A. Johnson & D.W. Wichern
- ✓ Nonparametric Inference by Z. Govindarajulu

For details please visit:

https://nptel.ac.in/courses/111105077

MD-II: SURVIVAL ANALYSIS AND BIOSTATISTICS

COURSE OUTCOMES

- Understand survival data and censoring and truncation mechanisms
- Estimate survival curves for censored survival data
- Fit survival models using the Cox proportional hazards model
- Evaluate the validity of assumptions underlying the Cox model and modify the Cox model to accommodate time-dependent variables and multiple outcomes
- Understand how to accommodate competing risks anddetermine the power and sample size requirements for a survival analysis study

LEARNING OUTCOMES

This course emphasizes concepts and applications used in public health studies. The product limit estimator, the Cox proportional hazard model, and parametric models will be discussed. Censoring and truncation patterns will also be studied. Model building and checking will be discussed throughout.

UNIT-I

Survival Analysis: Functions of survival times, survival distributions and their application,Gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function.

Censoring Schemes: Type I, Type II and progressive or random censoring 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: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.

UNIT-II

Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods. Theory of independent and dependent risks. Bivariate normal dependent risk model.

UNIT-III

Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic.

UNIT-IV

Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Coupling and Repulsion. Mendelian laws of Heredity, Random mating, Gametic Array, relation between genotypic array and gametic array under random mating. Distribution of genotypes under random mating. Clinical Trials: Planning and design of clinical trials, Phase I, II and III trials.

Single Blinding

TEXT BOOKS

- ✓ Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Edition, John Wiley and Sons.
- ✓ Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2ndCentral Edition, New Central Book Agency.

SUGGESTED READINGS

- ✓ Kleinbaum, D.G. (1996): Survival Analysis, Springer.
- ✓ Chiang, C.L. (1968): Introduction to Stochastic Processes in Biostatistics, John Wiley and Sons.
- ✓ Indrayan, A. (2008): Medical Biostatistics, 2nd Edition Chapman and Hall/CRC.

LIST OF PRACTICALS

1. To estimate survival function
2. To determine death density function and hazard function
3. To identify type of censoring and to estimate survival time for type I censored data
4. To identify type of censoring and to estimate survival time for type II censored data
5. To identify type of censoring and to estimate survival time for progressively type I censored data
6. Estimation of mean survival time and variance of the estimator for type I censored data
7. Estimation of mean survival time and variance of the estimator for type II censored data
8. Estimation of mean survival time and variance of the estimator for progressively type I censored data
9. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods
10. To estimate the survival function and variance of the estimator using Non-parametric methods with Kaplan-Meier method
11. To estimate Crude probability of death
12. To estimate Net-type I probability of death
13. To estimate Net-type II probability of death
14. To estimate partially crude prob

MD-III: MACHINE LEARNING

COURSE OUTCOMES

- Develop and apply pattern classification algorithms to classify multivariate data.
- Develop and apply regression algorithms for finding relationships between data variables.
- Develop and apply reinforcement learning algorithms for learning to control complex systems.
- Write scientific reports on computational machine learning methods, results and conclusions.

LEARNING OUTCOMES

This course covers fundamental concepts and methods of computational data analysis, including pattern classification, prediction, visualization, and recent topics in deep learning. The course will give the student the basic ideas and intuition behind modern machine learning methods as well as a bit more formal understanding of how, why, and when they work. The underlying theme in the course is statistical inference as it provides the foundation for most of the methods covered. After completion a student can understand pattern classification algorithms to classify multivariate data and implement the genetic algorithms. Can gain gain knowledge about Q-Learning and create new machine learning techniques.

UNIT I

BASICS Learning Problems Perspectives and Issues Concept Learning Version Spaces and Candidate eEliminations – Inductive bias – Decision Tree learning – Representation – Algorithm – Heuristic Space Search

UNIT II

NEURAL NETWORKS AND GENETIC ALGORITHMS: Neural Network Representation Problems Perceptions Multilayer Networks and Back Propagation Algorithms – Advanced Topics – Genetic Algorithms Hypothesis Space Search– Genetic Programming – Models of Evolutions and Learning.

UNIT III

BAYESIAN AND COMPUTATIONAL LEARNING: Bayes Theorem Concept Learning Maximum Likelihood Minimum Description Length Principle Bayes Optimal Classifier Gibbs Algorithm Naïve Bayes Classifier Bayesian Belief Network EM Algorithm Probability Learning Sample Complexity.

Finite and Infinite Hypothesis Spaces – Mistake Bound Model.

UNIT IV

INSTANT BASED LEARNING: K- Nearest Neighbor Learning Locally weighted Regression Radial Bases Functions – Case Based Learning.

ADVANCED LEARNING: Learning Sets of Rules Sequential Covering Algorithm Learning Rule Set, First Order Rules Sets of First Order Rules Induction on Inverted Deduction Inverting Resolution, Analytical Learning Perfect Domain Theories Explanation Base Learning – FOCL Algorithm -Reinforcement Learning Task Learning Temporal Difference Learning

TEXT BOOKS

- ✓ Tom M. Mitchell, “Machine Learning”, McGraw-Hill, 2010
- ✓ Bishop, Christopher. Neural Networks for Pattern Recognition. New York, NY: Oxford University Press, 1995

SUGGESTED READINGS

- ✓ Ethem Alpaydin, (2004) “Introduction to Machine Learning (Adaptive Computation and Machine Learning)”, The MIT Press
- ✓ T. astie, R. Tibshirani, J. H. Friedman, “The Elements of Statistical Learning”, Springer(2nd ed.), 2009

LIST OF PRACTICALS

1. Decision Tree learning
2. Neural Network Representation Problems
3. Genetic Algorithms
4. Mistake Bound Model
5. K- Nearest Neighbor Learning
6. Inverted Deduction Inverting Resolution
7. Reinforcement Learning