



भारतीय
ICAR

PUBLICATION NO. ICAR/ED(A) PUB-17/8-2001

**CURRICULA AND SYLLABI FOR
MASTER'S DEGREE PROGRAMS**

IN

**AGRICULTURAL STATISTICS,
BIO-STATISTICS**

AND

COMPUTER APPLICATION

**ACCREDITATION BOARD SECRETARIAT
EDUCATION DIVISION**

**INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II, PUSA, NEW DELHI-110 012**

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PRINTED : DECEMBER, 2001

Director (DIPA) : A. CHAKRAVARTY
Chief Production Officer : VIRENDER KUMAR BHARTI
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Published by Shri A. Chakravarty, Director (DIPA), Indian Council of Agricultural Research, New Delhi, Laser typeset by M/s Vee Kay Printers, 37-A, Kundan Nagar, Near Bank Enclave, Laxmi Nagar, Delhi-110092 and printed at M/s Vinayak Press, B-177/1, Okhla, Phase-I, New Delhi-110020.

PREFACE

The discipline of Statistical Sciences has seen significant developments during the last sixty years. There have been continual efforts to enrich and refine the training and teaching of statistical sciences to cater to the changing needs of physical, social, agricultural, animal, biological and medical sciences and also to keep the curricula competitive and acceptable at the international level. A number of State Agricultural Universities (SAUs) and Deemed Universities (DUs) under the Indian Council of Agricultural Research (ICAR) have introduced M.Sc. programme in statistical sciences. The revision of curricula and syllabi has been undertaken by the SAUs and DUs from time to time on need basis.

In order to meet the future requirements of teaching, the ICAR constituted a Broad Subject Matter Committee (BSMC) on Statistical Sciences with Dr. P. K. Malhotra, Head, Division of Computer Applications, IASRI, New Delhi as the Coordinator. The members of the committee were Dr. S. D. Sharma, Director, IASRI, New Delhi; Dr. G. Nageswara Rao, Head, Dept. of Statistics, ANGRAU, Hyderabad; Dr. S.P. Dhall, Asso. Prof., Agril. Statistics, Dept. of Basic Sciences, DYSPUHF, Solan; Dr. V.K. Gupta, Head, Division of Design of Experiments, IASRI, New Delhi and Dr Mahesh Kumar, Senior Scientist, Division of Computer Applications, IASRI, New Delhi. The area covered for restructuring were Agricultural Statistics, Bio-Statistics and Computer Application.

BSMC obtained information from all the SAUs and DUs on the courses being offered, their syllabi, admission policy, etc. Draft syllabi were prepared keeping in view the recommendations of the 3rd Deans' Committee on Agricultural Education in India and the sample syllabi from some of the leading universities offering the Statistical Science programs. The draft of new syllabi for the PG courses was sent to the concerned SAUs and DUs for comments. The feed back received was duly taken into consideration and draft syllabi were modified. The modified draft was discussed in a meeting cum workshop of Subject Matter Specialists held on 4th October, 1999 at IASRI, New Delhi and finalized.

We acknowledge gratefully the information and feedback given by SAUs and DUs. In the preparation of the new syllabi, significant input was received from Dr. Prajneshu, Head, Division of Biometrics, Dr. V.K. Bhatia, Principal Scientist, Dr. R.C. Goyal, Principal Scientist, Dr. Rajender Parsad, Senior Scientist and Sh. Sanjeev Kumar, Scientist as well as scientists in other Divisions at IASRI and IARI. We will be failing in our duty if we do not acknowledge the valuable suggestions given by Dr.S.L. Mehta, Ex- Deputy Director General (Edn.), ICAR for revision of the curricula. We also acknowledge with thanks the help provided by Dr.(Mrs.) Tej Verma, DDG(Edn) In-charge, ICAR in restructuring the curricula.

We gratefully acknowledge the guidance and encouragement received from Dr R.S. Paroda, Former Secretary(DARE) and DG, ICAR and Chairman of Accreditation Board in restructuring PG course curricula and syllabi for Agricultural

Statistical Sciences. We are thankful to all members of the committee and invitees of the meeting cum workshop for their inputs in developing new course curricula and preparation of this document.

We hope that this document will serve as guide and help in achieving uniformly high standard of postgraduate education in statistical Sciences. The Accreditation Board Secretariat will appreciate comments and suggestions for improving and updating this publication in future.

R. K. Malhotra
N. L. Maurya
G. D. Diwakar

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1. INTRODUCTION

During the last sixty years momentous developments have taken place in different branches of statistics leading to outstanding achievements in many interdisciplinary areas like agricultural statistics, bio-statistics, computer application, etc. There have been continual efforts to enrich and refine the training and teaching of statistical sciences to cater to the changing needs of physical, social, agricultural, animal, biological and medical sciences. In view of this, the role of statistical sciences in the country has undergone significant changes both quantitatively and qualitatively. The quantitative change can be seen from the number of SAUs and Deemed Universities that have introduced M.Sc. programmes in statistical sciences. The qualitative change is that with the support being given to teaching and training by the Education Division of the Indian Council of Agricultural Research (ICAR), a positive effect is being visualized in the improvement of teaching and research in the National Agriculture Research and Education System (NARES). This has come in the form of revision of curriculum and syllabi, financial support for strengthening teaching through setting up the Centre of Advanced Studies in the different disciplines of agricultural and animal sciences.

The origin of the discipline of Agricultural Statistics can be traced way back to 1930 with the setting up a small Statistical Section in the then Imperial Council of Agricultural Research to assist the State Departments of Agriculture and Animal Husbandry in planning their experiments and analysis of data. The activities of this section were increased rapidly and acquired International recognition as a centre for research and training in the field of Agricultural Statistics. Training programmes were started in this discipline in 1945. This activity resulted in the conversion of this section to a full-fledged Institute named as Institute of Agricultural Research Statistics (IARS) where subsequently the M.Sc. and Ph.D. degree courses in Agricultural Statistics were started in 1964 in collaboration with Indian Agricultural Research Institute (IARI). With the strengthening of the NARS through more SAUs and ICAR Institutes, the demand for trained and qualified manpower in Agricultural Statistics increased rapidly which resulted in starting of M.Sc. and Ph. D. degree courses in Agricultural Statistics in many other SAUs and DUs. This discipline evolved over a period of time with latest techniques has helped agricultural and animal scientists in understanding the underlying biological phenomena and arriving at valid conclusions.

Bio-Statistics has become a very large branch of statistical sciences during the past 60 years. It covers practically the whole field of biology, genetics including agriculture and livestock. The students doing their M.Sc. in Bio-Statistics are trained in statistics with emphasis on Bio-statistical techniques. The courses covered in this discipline also cater to the requirements of the

biologists and are so designed that they learn the statistical techniques needed to carry out analysis of their data. As such, while designing curricula in bio-statistics, in particular for veterinary sciences, due care is to be taken to cover all statistical techniques required especially for life sciences. Currently M.Sc. in bio-statistics is being offered at Indian Veterinary Research Institute, **Izatnagar**. Some of courses of bio-statistics are also offered in the curriculum of Agricultural Statistics/Statistics in SAUs and Deemed Universities.

Use of computers in Agricultural Research began more than three decades ago. Initially the electronic data processing requirements of agricultural research workers and students in the NARS were catered by IASRI. Late sixties and seventies saw statisticians - programmers at IASRI shouldering the onerous responsibility of training agricultural research workers in the use of computers. Around the same time a course on Computer Programming was introduced and offered in the curriculum of M.Sc. and Ph.D. students of PG School of IARI and subsequently at many other SAUs. Seventies witnessed an increase in the computing facilities in NARS; there was a great demand for qualified and trained manpower to manage these facilities. During mid eighties, an M.Sc. Course in Computer Application in Agriculture was introduced in the PG programme of IARI. Meanwhile the computing environment was changing and Mainframe computers were out and PCs were in. Concepts like LAN, WAN, Information Technology, Databases, Information Systems, etc., all became bywords among agricultural research workers. PG Programme in Computer Science/Application was also introduced in other SAUs. Computer Application became an important discipline in agricultural research and as such this discipline was introduced in the Agricultural Research Service of the ICAR in 1985.

Any course curriculum needs revision once every five years so as to incorporate latest state-of-art. In a **multidisciplinary** environment, it is also necessary to formulate additional courses to be offered to students from other disciplines. In pursuance of this, ICAR constituted a Broad Subject Matter Committee (BSMC) on Statistical Sciences which after detailed deliberations, has finalized New Syllabi for the M.Sc Courses in Agricultural Statistics, Bio-Statistics and Computer Applications. It is hoped that this new syllabi will be helpful in equipping the students to face future challenges more effectively.

2. Agricultural Statistics

2.1 Major*	31 Credits
	(L+P)
1. Probability Theory**	(2+0)
2. Statistical Methods**	(3+1)
3. Design of Experiments - I**	(2+1)
4. Sampling Techniques - I**	(2+1)
5. Statistical Genetics - I**	(2+1)
6. Applied Multivariate Methods**	(2+1)
7. Statistical Inference**	(2+1)
8. Mathematical Methods	(3+0)
9. Design of Experiments - II	(2+1)
10. Sampling Techniques - II	(2+1)
11. Statistical Genetics-II	(2+1)
12. Data Analysis in Agriculture	(1+1)
13. Stochastic Processes	(2+0)
14. Non-linear Statistical Modeling	(2+1)
15. Official Statistics	(1+0)
16. Econometrics	(2+1)
17. Seminar	(0+1)
2.2 Supporting Courses	10 Credits
To be decided by the Students Advisory Committee	
2.3 Thesis and Viva-Voce	15 Credits

* The Broad Subject Matter Committee (BSMC) recommended that 31 credits may be taken by a student from the major discipline in view of students coming to this programme from different streams of agriculture and basic sciences.

** Similarly the BSMC recommended that Courses 1-7 as listed above are essential and may be treated as core-courses. Remaining major courses to the extent of 10 credits can be taken as optional as decided by the Students Advisory Committee.

2. Agricultural Statistics

1. Probability Theory

(2+0)

Probability—classical and frequency definitions, Axiomatic approach — laws of probability: addition and multiplication theorems, conditional probability. Elements of measure theory. Bayes' theorem. Random variable — discrete and continuous. Mathematical expectation and its laws. Moments, coefficient of skewness and kurtosis. Distribution, characteristic and moment generating functions, Inversion and uniqueness theorems for characteristic functions. Derived distributions. Chebychev's and Kolmogorov's inequalities. Modes of stochastic convergence. Weak and strong laws of large numbers, Central limit theorems. Discrete probability distributions — Bernoulli, binomial, Poisson, negative binomial, geometric. Uniform, hypergeometric, multinomial. Continuous probability distributions — rectangular, Cauchy, normal.

Suggested Readings

Cramer, H. (1946). *Mathematical Methods of Statistics*. Princeton University Press, Princeton, New Jersey.

Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.

Feller, W. (1972). *An Introduction to Probability Theory and its Applications*. Vol. I. John Wiley and Sons, New York.

Goon, A.M., Gupta, M.K. and Dasgupta, B. (1977). *An Outline of Statistical Theory*. Vol.1. The World Press Pvt. Ltd., Calcutta.

Goon, A.M., Gupta, M.K. and Dasgupta, B. (1983). *Fundamentals of Statistics*. Vol.1. The World Press Pvt. Ltd., Calcutta.

Hoel, P.G. (1971), *Introduction to Mathematical Statistics*. John Wiley and Sons, New York.

Hogg, R.V. and Craig, T.T. (1978). *Introduction to Mathematical Statistics*. MacMillan, New York.

Johnson, N.L. and Kotz, S. (1990). *Continuous Univariate Distributions*. Vol. I and II. Houghton Mifflin Company, Boston.

Johnson, N.L. and Kotz, S. (1990). *Multivariate Distributions*. Houghton Mifflin Company, Boston.

- Johnson, N.L. and Kotz, S. (1990). Discrete Univariate Distributions. Houghton Mifflin Company, Boston.
- Kendall, N.G. and Stuart, A. (1960). Advanced Theory of Statistics. Vol I. Charles Griffen and Co. Ltd., London.
- Marek, F. (1963). Probability Theory and Mathematical Statistics. John Wiley and Sons, New York.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (1974). Introduction to Theory of Statistics. McGraw Hill Book Co., New York.
- Parzen, E. (1972). Modern Probability Theory and its Applications. Wiley Eastern Ltd., New Delhi.
- Rohatgi, V.K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd., New Delhi.
- Snedecor, G.W. and Cochran, W.G. (1989). Statistical Methods. Iowa State University Press, Ames, Iowa.
- Weatherburn, C.E. (1947). A First Course in Mathematical Statistics. Cambridge University Press, London.
- Wilks, S.S. (1962). Mathematical Statistics. John Wiley and Sons, New York.

2. Statistical Methods

(3+1)

Continuous probability distributions $\frac{3}{4}$ exponential, gamma, beta, Weibull, lognormal, logistic. Characteristic property of normal distribution. Distribution of quadratic forms. Cochran theorem. Central and non-central t, χ^2 and F distributions, their applications and tests of significance based on them: Bartlett's test of homogeneity of variances, Large sample tests, Tests for correlation coefficient, regression coefficient etc. Concept of characterization of distributions. Transformation of variables and their distribution functions. Correlation, Regression analysis, Partial and multiple correlation and regression, Regression diagnostics - residuals, multicollinearity, testing adequacy of fit and validation in regression analysis. Sampling distribution of correlation and regression coefficients. Concept of random vectors and moments and their distributions. General Gauss Markoff set up, Gauss-Markoff's theorem, Theory of linear estimation, Test of hypothesis in linear models. Aitken's transformation, Weighted least squares. Truncated and compound distributions, Pearsonian distributions. Bivariate normal distribution % conditional and marginal. Correlation ratio, intra-class correlation. Index numbers, Elements of time series and Arima modelling.

Practical

Problems based on large sample tests, Chi-square, t and F-distribution. Computation of simple, multiple and partial correlation coefficient, Correlation ratio and intra-class correlation. Regression coefficients and regression equations. Regression diagnostics - residuals, multicollinearity, testing, adequacy of fit. Fitting of truncated distribution. Fitting of Pearsonian curves. Analysis of categorical data and log-linear models. Analysis of time series data and ARIMA modelling.

Suggested Readings

- Agresti, A. (1990). *Categorical Data Analysis*. John Wiley & Sons, New York.
- Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. John Wiley and Sons, New York.
- Chatterjee, S. and Price, B. (1977). *Regression Analysis by Example*. John Wiley and Sons, New York.
- Christensen, R. (1990). *Log Linear Models*. Springer Text in Statistics, Springer - Verlag, New York.
- Cramer, H. (1946). *Mathematical Methods of Statistics*. Princeton University Press, Princeton, New Jersey.
- David, H.A. (1981). *Order Statistics*. John Wiley and Sons, New York.
- Draper, N.R. and Smith, H. (1981). *Applied Regression Analysis*. Wiley Eastern Ltd., New Delhi.
- Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1977). *An Outline of Statistical Theory*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1983). *Fundamentals of Statistics*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Hoel, P.G. (1971). *Introduction to Mathematical Statistics*. John Wiley and Sons, New York.
- Hogg, R.V. and Craig, T.T. (1978). *Introduction to Mathematical Statistics*. MacMillan, New York.
- Johnson, N.L. and Kotz, S. (1990). *Continuous Univariate Distributions*. Vol. I and II. Houghton Mifflin Company, Boston.

- Johnson, N.L. and Kotz, S. (1990). *Multivariate Distributions*. Houghton Mifflin Company, Boston.
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- Kendall, N.G. and Stuart, A. (1960). *Advanced Theory of Statistics*. Vol I. Charles Griffen and Co. Ltd., London.
- Little, R.C., Freund, R.J. and Spector, P.C. (1991). *SAS System for Linear Models*. SAS Institute Inc. USA.
- Montgomery, D.C. and Peck, E.A. (1982). *Introduction to Linear Regression Analysis*. John Wiley and Sons, New York.
- Mood; A.M., Graybill, F.A. and Boes, D.C. (1974). *Introduction to Theory of Statistics*. McGraw Hill Book Co., New York.
- Rao, C.R. (1965). *Linear Statistical Inference and its applications*. John Wiley and Sons, New York.
- Rohatgi, V.K. (1976). *An Introduction to Probability Theory and Mathematical Statistics*. Wiley Eastern Ltd., New Delhi.
- Searle, S.R. (1971). *Linear Models*. John Wiley and Sons, New York.
- Snedecor, G.W. and Cochran, W.G. (1989). *Statistical Methods*. Iowa State University Press, Ames, Iowa.
- Weatherburn, C.E. (1947). *A First Course in Mathematical Statistics*. Cambridge University Press, London.
- Wilks, S.S. (1962). *Mathematical Statistics*. John Wiley and Sons, New York.

3. **Design of Experiments - I** (2+1)

Planning and designing of experiments, Basic principles of Design of Experiments, uniformity trials, Fairfield Smith's law, Shape and size of plots and blocks. Elements of linear estimation. Variance stabilizing transformations. Analysis of variance and covariance. Completely randomized, Randomized block and Latin square designs. Mutually orthogonal latin squares. Missing plot techniques. Balanced incomplete block (BIB) designs-General properties and analysis with and without recovery of information. Repeated measurement designs. Groups of experiments. Factorial experiments, Confounding in symmetrical factorial (in particular 2^n and 3^n series) experiments, Split plot and Strip plot designs. Concepts of association scheme, Partially balanced incomplete block (PBIB) designs with two associate classes. Sampling in field experiments, Experiments on cultivators' fields, Long term

and rotational experiments. Preparation of layout plans and field visits related to applications of these designs.

Practical

Determination of size and shape of plots and blocks from uniformity trials data. Analysis of data generated from completely randomized design, randomized complete block design, BIB design, lattice design, PBIB designs, latin square design, Youden square design, $2n$, $3n$ factorial experiments without and with confounding, split and strip plot designs, repeated measurement design. Analysis of covariance. Analysis of Groups of experiments. Missing plot techniques. Analysis of clinical trial experiments. Sampling in field experiments.

Suggested Readings

- Chakraborti, M.C. (1962). Mathematics of Design and Analysis of Experiments. Asia Publishing House, Bombay.
- Cochran, W.G. and Cox, D.R. (1987). Experimental Designs. John Wiley and Sons, New York.
- Cox, D.R. (1958). Planning of Experiments. John Wiley and Sons, New York.
- Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments. Wiley Eastern Ltd., New Delhi.
- Dean, A.M. and Voss, D. (1999). Design and Analysis of Experiments. Springer Texts in Statistics, Springer-Verlag, New York.
- Dey, A (1986). Theory of Block Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. (1986). Orthogonal Fractional Factorial Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. and Mukerjee, R. (1999). Fractional Factorial Plans. John Wiley and Sons, New York.
- Federer, W.T. (1963). Experimental Designs. Oxford and IBH Publishing Co., London.
- Fisher, R.A. (1953). Design and Analysis of Experiments. Oliver and Boyd, London.
- Fisher, R.A. (1958). The Genetical Theory of Natural Selection. Dover Publication, New York.

- Garcia, D., A. and Phillips, D.T. (1995). Principles of Experimental Design and Analysis. Chapman and Hall, London.
- Hall, M. Jr. (1986). Combinatorial Theory. John Wiley and Sons, New York.
- Hicks, C.R. (1964). Fundamental Concepts in the Design of Experiments. Hort, Rinchart and Winton, New York.
- John, J.A. and Quenouille, M.H. (1977). Experiments: Design and Analysis. Charles and Griffin Co. Ltd., London.
- John, J.A., Wolock, F.W. and David, H.A. (1972). Cyclic Designs. National Bureau of Standards, Applied Math. Series, 62, Washington, D.C.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments. Macmillan, New York.
- Kempthorne, O. (1976). Design and Analysis of Experiments. John Wiley and Sons, New York.
- Khuri, A.I. and Cornell, J.A. (1989). Response Surface Designs and Analysis. Marcel and Dekker, New York.
- Little, R.C., Freund, R.J. and Spector, P.C. (1991). SAS System for Linear Models. SAS Institute Inc. USA.
- Mead, R. (1988). The Design of Experiments. Cambridge University Press, Cambridge.
- Meinert, C.L. (1986). Clinical Trials: Design, Conduct and Analysis. Oxford University Press, New York.
- Nigam, A.K. and Gupta, V.K. (1979). Hand Book on Analysis of Agricultural Experiments. IASRI Publication, New Delhi.
- Nigam, A.K., Puri, P.D. and Gupta, V.K. (1988). Characterization and Analysis of Block Designs. Wiley Eastern Ltd., New Delhi.
- Ogawa, J. (1974). Statistical Theory of the Analysis of Experimental Designs. Marcel and Dekker, New York.
- Pearce, S.C. (1983). The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley and Sons, New York.
- Raghavarao, D. (1971). Construction and Combinatorial Problems in Design of Experiments. John Wiley and Sons, New York.

Rao, C.R. (1965). *Linear Statistical Inference and its applications*. John Wiley and Sons, New York.

Scheffe, H. (1959). *The Analysis of Variance*. John Wiley and Sons, New York.

Searle, S.R. (1971). *Linear Models*. John Wiley and Sons, New York.

Shah, K.R. and Sinha, B.K. (1989). *Theory of Optimal Designs*. Lecture notes in Statistics, Vol. 54, Springer-Verlag, New York.

Street, A.P. and Street, D.J. (1987). *Combinatorics of Experimental Designs*. Oxford Science Pub., Clarendon Press, Oxford.

4. Sampling Techniques - I (2+1)

Probability sampling, sample space, sampling design, simple random sampling, estimation of proportions, confidence-interval, determination of sample size, inverse sampling. Sampling with varying probabilities, Stratified sampling, Ratio and regression methods of estimation, Cluster sampling, Multistage sampling with equal probability, Double sampling, Systematic sampling, Non-sampling errors - sources and classification, non-response in surveys, Imputation methods, Randomized response techniques, response errors - interpenetrating sub-sampling. Ordered and unordered estimates, Sampling strategies due to Horvitz and Thompson, Midzuno-Sen, Rao-Hartley-Cochran. Planning of a survey, methods of data collection, questionnaire versus schedule, problem of sampling frame, choice of sampling design.

Practical

Determination of sample size and selection of sample. Simple random sampling, Inverse sampling, Sampling with varying probabilities, Stratified sampling, Ratio and regression methods of estimation. Cluster, systematic, double, multi-stage sampling. Imputation methods. Randomized response techniques.

Suggested Readings

Cochran, W.G. (1977). *Sampling Techniques*. John Wiley and Sons, New York.

Kish, L. (1965). *Survey Sampling*. John Wiley and Sons, New York.

Murthy, M.N. (1977). *Sampling Theory and Methods*. Statistical Publishing Society, Calcutta.

Sarndal, C.E., Swensson, B. and Wretman, J. (1992). *Model Assisted Survey Sampling*. Springer-Verlag, New York.

Singh., D., Singh, P. and Kumar, P. (1979). Hand Book of Sampling Theory. IASRI Publication, New Delhi.

Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Application. Iowa State University Press, Ames, Iowa and Indian Society of Agricultural Statistics, New Delhi.

5. Statistical Genetics - I

(2+1)

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters, disturbed segregation. Gene and genotypic frequencies. Random mating and Hardy-Weinberg law. Application and extension of the equilibrium law. Disequilibrium due to linkage for two pairs of genes, sex-linked genes. Forces affecting gene frequency—selection, mutation and migration, equilibrium between forces in large populations. Polymorphism. Fisher's fundamental theorem of natural selection. Theory of path co-efficients. Regular systems of inbreeding. Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning. Correlation between relatives, Heritability, Repeatability and Genetic correlation.

Practical

Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation. Detection and estimation of linkage parameter by different procedures. Genotypic and gene frequency from a given data. Hardy-Weinberg law. Estimation of change in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient.

Suggested Readings

Bailey, N.T.J. (1961). The Mathematical Theory of Genetic Linkage. Clarendon Press, Oxford.

Balding, D.J., Bishop, M. and Cannings, C. (2001). Hand Book of Statistical Genetics. John Wiley and Sons, New York.

Crow, J.F. and Kimura, M. (1970). An Introduction of Population Genetics Theory. Harper and Row, New York.

Dahlberg, G. (1948). Mathematical Methods for Population Genetics. Inter Science Publications, New York.

East, E.M. and Jones, D.F. (1919). Inbreeding and Outbreeding. J B Lippincott Co, London and Philadelphia.

- Falconer, D.S. (1985). Introduction to Quantitative Genetics. English Language Book, Longman, Essex, England.
- Fisher, R.A. (1949). The Theory of Inbreeding. Oliver and Boyd, Edinburgh.*
- Fisher, R.A. (1950). Statistical Methods for Research Workers. Oliver and Boyd, Edinburgh.
- Fisher, R.A. (1958). The Genetical Theory of Natural Selection. Dover Publication, New York.
- Haldane, J.B.S. (1932). The Causes of Evolution. Harper and Bros., London.
- Jain, J.P. (1982). Statistical Techniques in Quantitative Genetics. Tata McGraw Hill, New Delhi.
- Kempthorne, O. (1957). An Introduction to Genetic Statistics. The Iowa State University Press, Ames, Iowa.
- Lerner, I.M. (1950). Population Genetics and Animal Improvement. The University Press, Cambridge.
- Lerner, I.M. (1954). Genetic Homeostasis. Oliver and Boyd, Edinburgh.
- Lerner, I.M. (1958). The Genetic Theory of Selection. John Wiley and Sons, New York.
- Li, C.C. (1982). Population Genetics, The University of Chicago Press, Chicago.
- Mather, K. (1949). Biometrical Genetics. Methuen, London.
- Mather, K. (1951). The Measurement of Linkage in Heredity. Methuen and Co., London.
- Mather, K. and Jinks, J.L. (1977). Introduction to Biometrical Genetics. Chapman and Hall, London.
- Mather, K. and Jinks, J.L. (1982). Biometrical Genetics. Chapman and Hall, London.
- Narain, P. (1990). Statistical Genetics. Wiley Eastern Ltd., New Delhi.
- Narain, P., Bhatia, V.K. and Malhotra, P.K. (1979). Handbook of Statistical Genetics. IASRI Publication, New Delhi.
- Pearce, S.C. (1965). Biological Statistics: An Introduction. McGraw Hill, New York.

6. Applied Multivariate Methods

(2+1)

Multivariate normal distribution, marginal and conditional distribution, Characterizations, maximum likelihood estimates of mean vector and dispersion matrix. Wishart distribution, Hotelling's T² and Mahalanobis' D² statistics, Test of hypothesis on means, Multivariate analysis of variance and covariance, Cluster analysis, Classification by linear discriminant function, Canonical correlations, Principal components, Factor analysis. Applications of multivariate analysis techniques.

Practical

Maximum likelihood estimates of mean-vector and dispersion matrix, Testing of hypothesis on means, Multivariate analysis of variance and covariance, Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis.

Suggested Readings

Anderson, T.W. (1958). An Introduction to Multivariate Statistical Analysis. John Wiley and Sons, New York.

Johnson, R.A. and Wichern, D.W. (1988). Applied Multivariate Statistical Analysis. Prentice Hall, London.

Kshirsagar, A.M. (1972). Multivariate Analysis. Marcel and Dekker, New York.

Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.

Srivastava, M.S. and Khatri, C.G. (1979). Introduction to Multivariate Statistics. Elsevier North Holland Inc.

7. Statistical Inference

(2+1)

Point estimation, Properties of estimators: unbiasedness, consistency, efficiency and sufficiency. Frechet, Cramer-Rao inequality, Rao-Blackwell theorem, completeness and bounded completeness, Basu's theorem. Methods of estimation — Maximum likelihood, least squares, minimum χ^2 , minimum distance, moments, maximum entropy. Testing of hypothesis: Two kinds of errors, Neyman-Pearson lemma, power function, uniformly most powerful tests and their constructions, unbiased tests, likelihood ratio tests, testing of composite hypothesis. Confidence-interval estimation. Non-parametric tests: run, sign, rank, median, Wilcoxon, Mann-Whitney, Kruskal Wallis, Friedmann two way ANOVA by ranks. Sequential analysis: Sequential probability ratio test. Elements of Decision theory and Bayesian inference.

Practical

Consistency and Unbiasedness, Method of estimation - Maximum Likelihood, Minimum and Modified Minimum c^2 , Moments. Confidence Interval Estimation. MP and UMP tests. Non-parametric tests. Sequential Probability Ratio Test.

Suggested Readings

- Box, G.E.P. and Tiao, G.C. (1973). *Bayesian Inference in Statistical Analysis*. Addison Wesley, London.
- Christensen, R. (1990). *Log Linear Models*. Spring Text in Statistics, Springer - Verlag, New York.
- Conover, W.J. (1980). *Practical Nonparametric Statistics*. John Wiley and Sons, New York.
- Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.
- Hogg, R.V. and Craig, T.T. (1978). *Introduction to Mathematical Statistics*. MacMillan, New York.
- Kendall, N.G. and Stuart, A. (1960). *Advanced Theory of Statistics*. Vol I. Charles Griffen and Co. Ltd., London.
- Lehman, E.L. (1983). *Theory of Estimation*. John Wiley and Sons, New York.
- Lehman, E.L. (1986). *Testing of Statistical Hypotheses*. John Wiley and Sons, New York.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (1974). *Introduction to Theory of Statistics*. McGraw Hill Book Co., New York.
- Rao, C.R. (1965). *Linear Statistical Inference and its applications*. John Wiley and Sons, New York.
- Rohatgi, V.K. (1976). *An Introduction to Probability Theory and Mathematical Statistics*. Wiley Eastern Ltd., New Delhi.
- Rohatgi, V.K. (1984). *Statistical Inference*. John Wiley and Sons, New York.
- Siegel, S., Johan, N. and Casellan Jr. (1956). *Non-parametric Tests for Behavior Sciences*. John Wiley and Sons, New York.

Tiku, M.L., Tan, W.Y. and Balakrishnan, N. (1986). Robust Inference. Marcel and Dekker, New York.

Wald, A. (1947). Sequential Analysis. John Wiley and Sons, New York.

8. Mathematical Methods (3+0)

Introduction to Matrix Algebra. Characteristic roots and equations. Linear and quadratic forms. Gramian root. Kronecker and Hadamard product of matrices. Permutation matrices, Full rank factorization, Equations having many solutions, Generalized inverses. Spectral decomposition of matrices, Projection operators, Convex sets. Differentiation and integration of matrices. Minimization and Maximization, Rayleigh's theorem. Calculus: Differentiation of functions, successive differentiation, Partial differentiation, Integration by simple methods. Real Analysis: Convergence and Uniform convergence of infinite series, Use of comparison test, D'Alembert's Ratio - test, Cauchy's root test, Raabe's test for convergence of infinite series. Riemann integration, concept of Lebesgue integration, Power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals. Linear Algebra: Groups, fields, rings and vector spaces, linear transformations, Gram Schmidt's orthogonalisation. Galois field % Fermat's theorem and primitive elements. Concepts of Graph theory and its applications. Numerical Analysis: Operators like E, D. Simple interpolation, Divided differences. Numerical differentiation and integration, Euler - Maclaurin summation formula. Solution of Linear Differentialequations.

Suggested Readings

Brand, L. (1955). Advanced Calculus. John Wiley and Sons, New York.

Chakraborti, M.C. (1962). Mathematics of Design and Analysis of Experiments. Asia Publishing House, Bombay.

Chatterjee, S.K. (1970). Mathematical Analysis. Oxford and IBH Publishing Co., London,

Deo, N. (1984). Graph Theory with Application to Engineering and Computer Science. Prentice Hall of India Pvt. Ltd., New Delhi.

Gibson, G.A. (1954). Advanced Calculus. Macmillan, London.

Hadley, G. (1969). Linear Algebra. Addison Wesley, London.

Henrice, P. (1964). Elements of Numerical Analysis. John Wiley and Sons, New York.

- Hildebrand, F.B. (1956). Introduction to Numerical Analysis. Tata McGraw Hill, New Delhi.
- Malik, S.C. and Arora, S. (1991). Mathematical Analysis. Wiley Eastern Ltd., New Delhi.
- Mirsky, L. (1972). Introduction to Linear Algebra. Oxford University Press. London.
- Narayan, S. (1988). Text Book of Matrices. S.Chand & Co. Pvt. Ltd., New Delhi.
- Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.
- Scarborough, J.B. (1976). Numerical Mathematical Analysis. Oxford and IBH Publishing Co., London.
- Searle, S.R. (1982). Matrix Algebra Useful for Statistics. John Wiley and Sons, New York.

9. Design of Experiments - II

(2+1)

General analysis and properties of block designs. Construction of BIB designs, Partially balanced incomplete block (PBIB) designs with two associate classes-properties, analysis and construction. Construction of mutually orthogonal latin squares. Fractional replication of symmetrical factorials. Asymmetrical factorial- construction and analysis of balanced confounded designs. Augmented designs. Response surface designs- Symmetrical and asymmetrical factorials, Second order rotatable designs. Intercropping experiments, Agroforestry experiments.

Practical

General analysis of block designs. Field layout of block designs. Analysis of data generated from PBIB designs, fractional factorial experiments, asymmetrical factorial experiments, balanced confounded factorial experiments. Augmented designs. Response surface designs. Inter-cropping experiments.

Suggested Readings

- Chakraborti, M.C. (1962). Mathematics of Design and Analysis of Experiments. Asia Publishing House, Bombay.
- Cochran, W.G. and Cox, D.R. (1987). Experimental Designs. John Wiley and Sons, New York.

- Cox, D.R. (1958). Planning of Experiments. John Wiley and Sons, New York.
- Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments. Wiley Eastern Ltd., New Delhi.
- Dean, A.M. and Voss, D. (1999). Design and Analysis of Experiments. Springer Texts in Statistics, Springer-Verlag, New York.
- Dey, A (1986). Theory of Block Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. (1986). Orthogonal Fractional Factorial Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. and Mukerjee, R. (1999). Fractional Factorial Plans. John Wiley and Sons, New York.
- Federer, W.T. (1963). Experimental Designs. Oxford and IBH Publishing Co., London.
- Fisher, R.A. (1953). Design and Analysis of Experiments. Oliver and Boyd, London.
- Fisher, R.A. (1958). The Genetical Theory of Natural Selection. Dover Publication, New York.
- Garcia, D., A. and Phillips, D.T. (1995). Principles of Experimental Design and Analysis. Chapman and Hall, London.
- Hall, M. Jr. (1986). Combinatorial Theory. John Wiley and Sons, New York.
- Hicks, C.R. (1964). Fundamental Concepts in the Design of Experiments. Hort, Rinchart and Winton, New York.
- John, J.A. and Quenouille, M.H. (1977). Experiments: Design and Analysis. Charles and Griffin Co. Ltd., London.
- John, J.A., Wolock, F.W. and David, H.A. (1972). Cyclic Designs. National Bureau of Standards, Applied Math. Series, 62, Washington, D.C.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments. Macmillan, New York.
- Kempthorne, O. (1976). Design and Analysis of Experiments. John Wiley and Sons, New York.
- Khuri, A.I. and Cornell, J.A. (1989). Response Surface Designs and Analysis.

Marcel and Dekker, New York.

Little, R.C., Freund, R.J. and Spector, P.C. (1991). SAS System for Linear Models. SAS Institute Inc. USA.

Mead, R. (1988). The Design of Experiments. Cambridge University Press, Cambridge.

Nigam, A.K. and Gupta, V.K. (1979). Hand Book on Analysis of Agricultural Experiments. IASRI Publication, New Delhi.

Nigam, A.K., Puri, P.D. and Gupta, V.K. (1988). Characterization and Analysis of Block Designs. Wiley Eastern Ltd., New Delhi.

Ogawa, J. (1974). Statistical Theory of the Analysis of Experimental Designs. Marcel and Dekker, New York.

Pearce, S.C. (1983). The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley and Sons, New York.

Raghavarao, D. (1971). Construction and Combinatorial Problems in Design of Experiments. John Wiley and Sons, New York.

Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.

Scheffe, H. (1959). The Analysis of Variance. John Wiley and Sons, New York.

Searle, S.R. (1971). Linear Models. John Wiley and Sons, New York.

Shah, K.R. and Sinha, B.K. (1989). Theory of Optimal Designs. Lecture notes in Statistics, Vol. 54, Springer-Verlag, New York.

Street, A.P. and Street, D.J. (1987). Combinatorics of Experimental Designs. Oxford Science Pub., Clarendon Press, Oxford.

10. Sampling Techniques - II

(2+1)

PPS systematic sampling, p-PS sampling, sampling on two occasion, super-population concept-comparison of various sampling strategies, design effect, Bernoulli and poisson sampling, number of strata and optimum stratification, systematic sampling in two dimensions, unbiased ratio and regression type estimators, multivariate ratio and regression type of estimators, systematic sampling in two dimensions, multistage sampling with unequal probabilities, self weighting designs, integration of surveys - Lahiri and Keyfitz procedures, controlled selection.

Practical

PPS systematic sampling, sampling on two occasions, optimum sampling in two dimensions, multivariate ratio and regression type of estimates, self weighing design, controlled selection.

Suggested Readings

Cochran, W.G. (1977). Sampling Techniques. John Wiley and Sons, New York.

Kish, L. (1965). Survey Sampling. John Wiley and Sons, New York.

Murthy, M.N. (1977). Sampling Theory and Methods. Statistical Publishing Society, Calcutta.

Sarndal, C.E., Swensson, B. and Wretman, J. (1992), Model Assisted Survey Sampling. Springer-Verlag, New York.

Singh., D., Singh, P. and Kumar, P. (1979). Hand Book of Sampling Theory. IASRI Publication, New Delhi.

Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Application. Iowa State University Press, Ames, Iowa and Indian Society of Agricultural Statistics, New Delhi.

11. Statistical Genetics-II

(2+1)

Genetic drift, Genetic load. Effect of finite population size. Effect of linkage, epistasis and inbreeding on quantitative characters. Multiple allelism in continuous variation. Maternal effects. Genotype x environment interaction—its role in analysis of yield stability, estimation of various stability measures. Outbreeding and crossbreeding in plant and animal experiments. Various mating designs including their genetic analysis. Concepts of general and specific combining ability. Diallel, partial diallel and triallel cross. Basis of selection. Response to selection. Combined selection. Selection for several traits. Selection indices. Restricted selection indices. Phenotypic index. Response to selection. Correlated response to selection. Progeny testing and sire evaluation.

Practical

Effect of linkage, epistasis and inbreeding on mean and variance of metric traits. Stability parameters. Mating designs - complete and partial diallel cross experiments, triallel cross experiments. Selection index including phenotypic index, restricted selection index, correlated response to selection, progeny testing and estimation of sire-index.

Suggested Readings

- Bailey, N.T.J. (1961). *The Mathematical Theory of Genetic Linkage*. Clarendon Press, Oxford.
- Balding, D.J., Bishop, M. and Cannings, C. (2001). *Hand Book of Statistical Genetics*. John Wiley and Sons, New York.
- Crow, J.F. and Kimura, M. (1970). *An Introduction of Population Genetics Theory*. Harper and Row, New York.
- Dahlberg, G. (1948). *Mathematical Methods for Population Genetics*. Inter Science Publications, New York.
- East, E.M. and Jones, D.F. (1919). *Inbreeding and Outbreeding*. J B Lippincott Co, London and Philadelphia.
- Falconer, D.S. (1985). *Introduction to Quantitative Genetics*. English Language Book, Longman, Essex, England.
- Fisher, R.A. (1949). *The Theory of Inbreeding*. Oliver and Boyd, Edinburgh.
- Fisher, R.A. (1950). *Statistical Methods for Research Workers*. Oliver and Boyd, Edinburgh.
- Fisher, R.A. (1958). *The Genetical Theory of Natural Selection*. Dover Publication, New York.
- Haldane, J.B.S. (1932). *The Causes of Evolution*. Harper and Bros., London.
- Jain, J.P. (1982). *Statistical Techniques in Quantitative Genetics*. Tata McGraw Hill, New Delhi.
- Kempthorne, O. (1957). *An Introduction to Genetic Statistics*. The Iowa State University Press, Ames, Iowa.
- Lerner, I.M. (1950). *Population Genetics and Animal Improvement*. The University Press, Cambridge.
- Lerner, I.M. (1954). *Genetic Homeostasis*. Oliver and Boyd, Edinburgh.
- Lerner, I.M. (1958). *The Genetic Theory of Selection*. John Wiley and Sons, New York.
- Li, C.C. (1982). *Population Genetics*. The University of Chicago Press, Chicago.

- Mather, K. (1949). Biometrical Genetics. Methuen, London.
- Mather, K. (1951). The Measurement of Linkage in Heredity. Methuen and Co., London.
- Mather, K. and Jinks, J.L. (1977). Introduction to Biometrical Genetics. Chapman and Hall, London.
- Mather, K. and Jinks, J.L. (1982). Biometrical Genetics. Chapman and Hall, London.
- Narain, P. (1990). Statistical Genetics. Wiley Eastern Ltd., New Delhi.
- Narain, P., Bhatia, V.K. and Malhotra, P.K. (1979). Handbook of Statistical Genetics. IASRI Publication, New Delhi.
- Pearce, S.C. (1965). Biological Statistics: An Introduction. McGraw Hill, New York.

12. Data Analysis in Agriculture

(1+1)

Use of Software packages for: Summarization and tabulation of data; Descriptive statistics; Graphical representation of data; Fitting and testing the goodness of fit of probability distributions; Testing of hypothesis; t-test, Chi-square test and F-test; Concept of analysis of variance and covariance of data for one-way and multi-classified experiments; Analyzing crossed and nested classified designs; Analysis of mixed models; Estimation of variance components; Testing the significance of contrasts; Correlation and regression including multiple regression; Discriminant function; Factor analysis; Principle component analysis; Analysis of time series data etc.

Practical

Use of software packages for Summarization and tabulation of data, Measures of central tendency, dispersion, skewness and kurtosis, To obtain frequencies and basic statistics including graphical representation of data, Robust Estimation, Testing linearity and normality assumption, Estimation of trimmed means etc., Cross tabulation of data including its statistics, cell display and table format and means for different sub-classifications, Fitting and testing the goodness of fit of probability distributions, Testing the hypothesis for one sample T-test, two sample T-test, paired T-test, test for large samples - Chi-squares test, F test, One way analysis of variance , contrast and its testing, pairwise comparisons, Multiway classified analysis of variance - cross-classification, nested classification, factorial set up, fixed effect models, random effect models, mixed effect models, estimation of variance components, Generalized linear models - analysis of unbalanced data sets, testing and

significance of contrasts, Estimation of variance components in unbalanced data sets - maximum likelihood, ANOVA, REML, MINQUE, Bivariate and partial correlation, Distances - to obtain a distance matrix, dissimilarity measures, similarity measures, Linear regression, Multiple regression, Regression plots, Variable selection, Regression statistics, Fitting of growth models - curve estimation models, examination of residuals, Discriminant analysis - fitting of discriminant functions, identification of important variables, Factor analysis - descriptive statistics and correlation coefficients. different extraction methods, working different factor scores, Principal component analysis - obtaining principal component, spectral composition, Analysis of time series data - fitting of ARIMA models, working out moving averages. Preparation of report on the analysis of a data set.

Suggested Readings

- Anderson, C W and Loynes R M (1987) *The Teaching of Practical Statistics*, Wiley, Chichester.
- Atkinson, A C (1985) *Plots Transformations and Regression*, Oxford University Press, Oxford.
- Chambers, J M , Cleveland W S , Kleiner, B and Tukey, P A (1983) *Graphical Methods for Data Analysis*, Wadsworth, Belmont, California.
- Chatfield, C (1983) *Statistics for Technology*, 3rd Edn., Chapman and Hall, London.
- Chatfield, C (1995) *Problem Solving: A statistician's guide*, Chapman and Hall, London.
- Chatfield, C and Collins A J (1980) *Introduction to Multivariate Analysis*, Chapman and Hall, London
- Cleveland, W S (1985) *The Elements of Graphing Data*, Wadsworth, Belmont, California.
- Ehrenberg, A S C (1982) *A Primer in Data Reduction*, Wiley, Chichester.
- Erickson, B H and Nosanchuk, T A (1992) *Understanding Data 2nd Edn*, Open University Press, Milton Keynes.
- Everitt, B S and Dunn, G (1991) *Advanced Multivariate Data Analysis*, 2nd Edn, Arnold, London.
- Geisser, S (1993) *Predictive Inference: An Introduction*, Chapman and Hall, New York.

- Miller, R G Jr. (1986) Beyond ANOVA, Basics of Applied Statistics, Wiley, Chichester
- Ryan, B F and Joiner, B L (1994) MINITAB Handbook, 3rd Edn., Duxbury Press, Belmont, California.
- Snell, E J (1987) Applied Statistics: A Handbook of BMDP Analyses, Chapman and Hall, London.
- Snell, E J and Simpson, H R (1991) Applied Statistics: A Handbook of GENSTAT Analyses, Chapman and Hall, London.
- Sprent P (1993) Applied Nonparametric Statistical Methods, 2nd Edn. Chapman and Hall, London.
- Tufte, E R (1983) The Visual Display of Quantitative Information, Graphics Press, Cheshire, Conn.
- Velleman P F and Hoaglin D C (1981) Application, Basics and Computing of Exploratory Data Analysis, Duxbury Press, Boston, Mass.
- Weisberg, S, (1985) Applied Linear Regression, Wiley, New York .
- Wetherill G B (1982) Elementary Statistical Methods, Chapman and Hall, London .
- Wetherill G B (1986) Regression Analysis with Applications, Chapman and Hall, London

13. Stochastic Processes

(2+0)

Basics of stochastic processes. Random walk models. Markov chains and their applications. Discrete branching processes. Markov processes in continuous time: Poisson process, Random-variable technique. Birth and death processes like pure birth process, linear birth and death process, immigration-birth-death process. Elements of queuing processes³/₄queues in series, queuing networks. Applications of queuing theory. Epidemic processes: Simple deterministic and stochastic epidemic model. General epidemic models³/₄Kermack and McKendrick's threshold theorem. Recurrent epidemics. Chain binomial models. Diffusion processes. Diffusion limit of a random walk and discrete branching process. Forward and backward Kolmogorov diffusion equations and their applications.

Suggested Readings

Bailey, N.T.J. (1964). Elements of Stochastic Processes with Applications to

the Natural Sciences. Wiley Eastern Ltd., New Delhi.

Bartlett, M.S. (1955). Introduction to Stochastic Processes. Cambridge University Press, Cambridge.

Bharucha-Reid, A.T. (1960). Elements of the Theory of Markov Processes and their Applications. McGraw Hill, New York.

Bhat, U.N. (1972). Elements of Applied Stochastic Processes. Wiley Eastern Ltd., New Delhi.

Cox, D.R. and Miller, H.D. (1965). The Theory of Stochastic Processes. Methuen, London.

Karlin, S. (1966). A First Course in Stochastic Processes. Academic Press, New York.

Lawler, G.F. (1995). Introduction to Stochastic Processes. Chapman and Hall, New York.

Medhi, J. (1982). Stochastic Processes. Wiley Eastern Ltd., New Delhi.

Parzen, E. (1962). Stochastic Processes. Holden-Day, San Francisco.

Prabhu, N.U. (1965). Stochastic Processes. Macmillan, New York.

14. Non-linear Statistical Modeling

(2+1)

Empirical and mechanistic models, Nonlinear growth models like monomolecular, logistic, Gompertz, Richards, Properties of these models, Applications in agriculture and fisheries, Formulation of nonlinear statistical models, Least squares methods for non-linear models, Estimation of parameters using iterative procedures like Taylor's. Steepest descent, Levenberg-Marquardt's, Choice of initial values, Examinations of residuals and adequacy of a model, Fitting of nonlinear statistical models using software packages. Compartmental modelling-first and second order input output systems, Dynamics of multivariate systems, Applications in plant growth and animal physiology, Two species system, Non-linear prey-predator models - Lotka-Volterra, Leslie-Gower and Holling-Tanner. Volterra's principle and its applications, Gause competition model, Multispecies modelling.

Practical

Fitting of Non-linear model like Logistic, Gompertz, and Richards. Estimation of parameters using iterative procedures like Taylor's, steepest, descent, choice of initial values. Testing adequacy of model. Compartmental modelling, Non-linear prey-predator model, Gause competition model, Multi-species models.

Suggested Readings

Draper, N.R. and Smith, H. (1981). Applied Regression Analysis. Wiley Eastern Ltd., New Delhi.

France, J. and Thornley, J.H.M. (1984). Mathematical Models in Agriculture. Butterworths, London.

Ratkowsky, D.A. (1983). Nonlinear Regression Modelling: a Unified Practical Approach. Marcel Dekker, New York.

Ratkowsky, D.A. (1990). Handbook of Nonlinear Regression Models. Marcel Dekker, New York.

Seber, G.A.F. and Wild, C.J. (1989). Non-linear Regression. John Wiley, New York.

15. Official Statistics (1+0)

Agricultural statistical system in India, Agricultural census, Agricultural surveys - some case studies, Crop estimation surveys, Statistics of livestock and livestock products, Fisheries statistics, Land use statistics, Role of different organisations engaged in data collection in India, Compilation and publication of agricultural statistics, Industrial classification and system of industrial statistics, Annual survey of industries. Monthly statistics of production and index of industrial production. The compilation and release of whole sale price index number.

16. Econometrics (2+1)

Econometric models. Concept of demand, production and cost functions. Ordinary least square methods, property of estimators. Maximum likelihood estimation. Multicollinearity. Use of dummy variables. Generalised Aitken least squares methods of estimation. Heteroscedasticity. Autocorrelation. Durbin-Watson Test. Regression with random coefficients. Mixed estimation. Stochastic regressors. Use of instrumental variables in regression analysis. Errors in variables models. Distributed lag models. Simultaneous equation systems-identification problem. Single equation methods of estimation - indirect least squares, two stage least squares and K-class estimators. System methods of estimation - three stage least squares and full information maximum likelihood methods.

Practical

Estimation of parameters of linear model through the methods of Ordinary Least Squares (OLS), Test of significance of the estimates. Problems based

on Restricted Ordinary Least Squares Method, Generalised Least Squares Method, Weighted Least Squares Method, Auto-correlation, Multicollinearity, Dummy variation, Heteroscedasticity. Fitting of Regression models with random coefficients, Mixed estimation. Regression analysis in presence of instrumental variables, Fitting of Distributed lag models, three stage least squares method and full information maximum likelihood methods.

Suggested Readings

Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. John Wiley and Sons, New York.

Baltagi, B.H. (1999). *Econometrics*. Springer-Verlag, Berlin.

Hoel, P.G. and Jessen, R.J. (1977). *Basic Statistics for Business and Economics*. John Wiley and Sons, New York.

Johnston, J. (1984). *Econometric Methods*. McGraw Hill, New York.

Klein, L.R. (1975). *A Textbook of Econometrics*. Prentice Hall of India, New Delhi.

Koutsoyiannis, A. (1992). *Theory of Econometrics*. Macmillan, Hongkong.

Maddala, G.S. (1977). *Econometrics*. McGraw Hill, Auckland.

Theil, H. (1971). *Principles of Econometrics*. John Wiley and Sons, New York.

3. Bio-Statistics

3.1 Major* 31 Credits

(L+P)

1. Probability Theory** (2+0)
2. Statistical Methods** (3+1)
3. Design of Experiments** (2+1)
4. Sampling Techniques** (2+1)
5. Statistical Genetics** (2+1)
6. Applied Multivariate Methods** (2+1)
7. Statistical Inference** (2+1)
8. Mathematical Methods (3+0)
9. Demographic Techniques in Bio-Statistics (2+1)
10. Survival Models in Bio-Statistics (2+1)
11. Econometric and Operational Research (2+1)
12. Data Analysis in Animal Sciences (1+1)
13. Stochastic Processes (2+0)
14. Statistical Methods in Population Studies (2+1)
15. Non-linear Statistical Modeling (2+1)
16. Seminar (0+1)

3.2 Supporting Cours 10 Credits

To be decided by the Students Advisory Committee

3.3 Thesis and Viva-Voce 15 Credits

* The Broad Subject Matter Committee (BSMC) recommended that 31 credits may be taken by a student from the major discipline in view of students coming to this programme from different streams of agriculture and basic sciences.

** Similarly the BSMC recommended that Courses 1-7 as listed above are essential and may be treated as core-courses. Remaining major courses to the extent of 10 credits can be taken as optional as decided by the Students Advisory Committee.

3. Bio-Statistics

1. Probability Theory

(2+0)

Probability — classical and frequency definitions, Axiomatic approach — laws of probability: addition and multiplication theorems, conditional probability. Elements of measure theory. Bayes' theorem. Random variable — discrete and continuous. Mathematical expectation and its laws. Moments, coefficient of skewness and kurtosis. Distribution, characteristic and moment generating functions, Inversion and uniqueness theorems for characteristic functions. Derived distributions. Chebychev's and Kolmogorov's inequalities. Modes of stochastic convergence. Weak and strong laws of large numbers, Central limit theorems. Discrete probability distributions — Bernoulli, binomial, Poisson, negative binomial, geometric. Uniform, hypergeometric, multinomial. Continuous probability distributions — rectangular, Cauchy, normal.

Suggested Readings

- Cramer, H. (1946). *Mathematical Methods of Statistics*. Princeton University Press, Princeton, New Jersey.
- Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.
- Feller, W. (1972). *An Introduction to Probability Theory and its Applications*. Vol. I. John Wiley and Sons, New York.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1977). *An Outline of Statistical Theory*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1983). *Fundamentals of Statistics*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Hoel, P.G. (1971). *Introduction to Mathematical Statistics*. John Wiley and Sons, New York.
- Hogg, R.V. and Craig, T.T. (1978). *Introduction to Mathematical Statistics*. MacMillan, New York.
- Johnson, N.L. and Kotz, S. (1990). *Continuous Univariate Distributions*. Vol. 1 and II. Houghton Mifflin Company, Boston.
- Johnson, N.L. and Kotz, S. (1990). *Multivariate Distributions*. Houghton Mifflin Company, Boston.

- Johnson, N.L. and Kotz, S. (1990). Discrete Univariate Distributions. Houghton Mifflin Company, Boston.
- Kendall, N.G. and Stuart, A. (1960). Advanced Theory of Statistics. Vol I. Charles Griffen and Co. Ltd., London.
- Marek, F. (1963). Probability Theory and Mathematical Statistics. John Wiley and Sons, New York.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (1974). Introduction to Theory of Statistics. McGraw Hill Book Co., New York.
- Parzen, E. (1972). Modern Probability Theory and its Applications. Wiley Eastern Ltd., New Delhi.
- Rohatgi, V.K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd., New Delhi.
- Snedecor, G.W. and Cochran, W.G. (1989). Statistical Methods. Iowa State University Press, Ames, Iowa.
- Weatherburn, C.E. (1947). A First Course in Mathematical Statistics. Cambridge University Press, London.
- Wilks, S.S. (1962). Mathematical Statistics. John Wiley and Sons, New York.

2. Statistical Methods

(3+1)

Descriptive statistics — Stem and leaf displays, Box plot. Continuous probability distributions - exponential, gamma, beta, Weibull, lognormal, logistic. Characteristic property of normal distribution. Distribution of quadratic forms. Cochran theorem. Central and non-central t , χ^2 and F distributions, their applications and tests of significance based on them: Bartlett's test of homogeneity of variances, Large sample tests, Tests for correlation coefficient, regression coefficient etc. Concept of characterization of distributions. Transformation of variables and their distribution functions. Correlation, Regression analysis, Partial and multiple correlation and regression, Regression diagnostics - residuals, multicollinearity, testing adequacy of fit and validation in regression analysis. Sampling distribution of correlation and regression coefficients. Concept of random vectors and moments and their distributions. General Gauss Markoff set up, Gauss-Markoff's theorem, Theory of linear estimation, Test of hypothesis in linear models. Aitken's transformation, Weighted least squares. Truncated and compound distributions, Pearsonian distributions. Bivariate normal distribution — conditional and marginal. Correlation ratio, intra-class correlation. Index numbers, Elements of time series and Arima modelling.

Practical

Frequency distribution, Computation of measures of central tendency and dispersion, Computation of moments, skewness and kurtosis. Fitting of binomial, Poisson, negative binomial and normal distribution. Problem based on large sample tests, Chi-square, t and F-distribution. Simple, multiple and partial correlation coefficient, Correlation ratio and intra-class correlation, Computation of regression coefficients and regression equations. Regression diagnostics. Fitting of truncated distribution, Pearsonian curves. Analysis of categorical data and log-linear models. Analysis of time series data and ARIMA modeling.

Suggested Readings

- Agresti, A. (1990). *Categorical Data Analysis*. John Wiley & Sons, New York.
- Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. John Wiley and Sons, New York.
- Chatterjee, S. and Price, B. (1977). *Regression Analysis by Example*. John Wiley and Sons, New York.
- Christensen, R. (1990). *Log Linear Models*. Springer Text in Statistics, Springer-Verlag, New York.
- Cramer, H. (1946). *Mathematical Methods of Statistics*. Princeton University Press, Princeton, New Jersey.
- David, H.A. (1981). *Order Statistics*. John Wiley and Sons, New York.
- Draper, N.R. and Smith, H. (1981). *Applied Regression Analysis*. Wiley Eastern Ltd., New Delhi.
- Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.
- Elderton, W.P. and Johnson, N.L. (). *Systems of Frequency Curves*. Cambridge University Press, Cambridge.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1977). *An Outline of Statistical Theory*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1983). *Fundamentals of Statistics*. Vol.1. The World Press Pvt. Ltd., Calcutta.
- Hoel, P.G. (1971). *Introduction to Mathematical Statistics*. John Wiley and Sons, New York.

- Hogg, R.V. and Craig, T.T. (1978). Introduction to Mathematical Statistics. MacMillan, New York.
- Johnson, N.L. and Kotz, S. (1990). Continuous Univariate Distributions. Vol. I and II. Houghton Mifflin Company, Boston.
- Johnson, N.L. and Kotz, S. (1990). Multivariate Distributions. Houghton Mifflin Company, Boston.
- Johnson, R.A. and Wichern, D.W. (1988). Applied Multivariate Statistical Analysis. Prentice Hall, London.
- Kendall, N.G. and Stuart, A. (1960). Advanced Theory of Statistics. Vol I. Charles Griffen and Co. Ltd., London.
- Little, R.C., Freund, R.J. and Spector, P.C. (1991). SAS System for Linear Models. SAS Institute Inc. USA.
- Montgomery, D.C. and Peck, E.A. (1982). Introduction to Linear Regression Analysis. John Wiley and Sons, New York.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (1974). Introduction to Theory of Statistics. McGraw Hill Book Co., New York.
- Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.
- Rohatgi, V.K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd., New Delhi.
- Searle, S.R. (1971). Linear Models. John Wiley and Sons, New York.
- Snedecor, G.W. and Cochran, W.G. (1989). Statistical Methods. Iowa State University Press, Ames, Iowa.
- Weatherburn, C.E. (1947). A First Course in Mathematical Statistics. Cambridge University Press, London.
- Wilks, S.S. (1962). *Mathematical Statistics*. John Wiley and Sons, New York.

3. Design of Experiments (2+1)

Basic principles of Design of experiments, uniformity trials, Fairfield Smith's law, Shape and size of plots and blocks. Elements of linear estimation. Analysis of variance and covariance. Completely randomized, Randomized block and Latin square designs. Mutually orthogonal latin squares. Missing

plot techniques. General properties and analysis of block designs. Balanced incomplete block (BIB) designs. General properties and analysis with and without recovery of information. Construction of BIB designs, Youden square designs, Lattice designs. Repeated measurement designs. Groups of experiments. Factorial experiments, Confounding in symmetrical factorial (in particular 2^n and 3^n series) experiments, Split plot and Strip-plot designs. Concepts of association scheme, Partially balanced incomplete block (PBIB) designs with two associate classes. Properties, analysis and construction. Lattice designs. Applications of covariance analysis. Analysis of clinical trial experiments. Planning and designing of experiments. Preparation of layout plans and field visits related to applications of these designs.

Practical

Determination of size and shape of plots and blocks from uniformity trials data. Analysis of data generated from completely randomized design, randomized complete block design, BIB design, lattice design, PBIB designs, latin square design, Youden square design, 2^n , 3^n factorial experiments without and with confounding, split and strip plot designs, repeated measurement design. Analysis of covariance. Analysis of Groups of experiments. Missing plot techniques. Analysis of clinical trial experiments. Sampling in field experiments.

Suggested Readings

- Chakraborti, M.C. (1962). Mathematics of Design and Analysis of Experiments. Asia Publishing House, Bombay.
- Cochran, W.G. and Cox, D.R. (1987). Experimental Designs. John Wiley and Sons, New York.
- Cox, D.R. (1958). Planning of Experiments. John Wiley and Sons, New York.
- Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments. Wiley Eastern Ltd., New Delhi.
- Dean, A.M. and Voss, D. (1999). Design and Analysis of Experiments. Springer Texts in Statistics, Springer-Verlag, New York.
- Dey, A (1986). Theory of Block Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. (1986). Orthogonal Fractional Factorial Designs. Wiley Eastern Ltd., New Delhi.
- Dey, A. and Mukerjee, R. (1999). Fractional Factorial Plans. John Wiley and Sons, New York.

- Federer, W.T. (1963). *Experimental Designs*. Oxford and IBH Publishing Co., London.
- Fisher, R.A. (1953). *Design and Analysis of Experiments*. Oliver and Boyd, London.
- Fisher, R.A. (1958). *The Genetical Theory of Natural Selection*. Dover Publication, New York.
- Garcia, D., A. and Phillips, D.T. (1995). *Principles of Experimental Design and Analysis*. Chapman and Hall, London.
- Hall, M. Jr. (1986). *Combinatorial Theory*. John Wiley and Sons, New York.
- Hicks, C.R. (1964). *Fundamental Concepts in the Design of Experiments*. Hort, Rinchart and Winton, New York.
- John, J.A. and Quenouille, M.H. (1977). *Experiments: Design and Analysis*. Charles and Griffin Co. Ltd., London.
- John, J.A., Wolock, F.W. and David, H.A. (1972). *Cyclic Designs*. National Bureau of Standards, Applied Math. Series, 62, Washington, D.C.
- John, P.W.M. (1971). *Statistical Design and Analysis of Experiments*. Macmillan, New York.
- Kempthorne, O. (1976). *Design and Analysis of Experiments*. John Wiley and Sons, New York.
- Khuri, A.I. and Cornell, J.A. (1989). *Response Surface Designs and Analysis*. Marcel and Dekker, New York.
- Little, R.C., Freund, R.J. and Spector, P.C. (1991). *SAS System for Linear Models*. SAS Institute Inc. USA.
- Mead, R. (1988). *The Design of Experiments*. Cambridge University Press, Cambridge.
- Meinert, C.L. (1986). *Clinical Trials: Design, Conduct and Analysis*. Oxford University Press, New York.
- Nigam, A.K. and Gupta, V.K. (1979). *Hand Book on Analysis of Agricultural Experiments*. IASRI Publication, New Delhi.
- Nigam, A.K., Puri, P.D. and Gupta, V.K. (1988). *Characterization and Analysis of Block Designs*. Wiley Eastern Ltd., New Delhi.

- Ogawa, J. (1974). *Statistical Theory of the Analysis of Experimental Designs*. Marcel and Dekker, New York.
- Pearce, S.C. (1983). *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley and Sons, New York.
- Raghavarao, D. (1971). *Construction and Combinatorial Problems in Design of Experiments*. John Wiley and Sons, New York.
- Rao, C.R. (1965). *Linear Statistical Inference and its applications*. John Wiley and Sons, New York.
- Scheffe, H. (1959). *The Analysis of Variance*. John Wiley and Sons, New York.
- Searle, S.R. (1971). *Linear Models*. John Wiley and Sons, New York.
- Shah, K.R. and Sinha, B.K. (1989). *Theory of Optimal Designs*. Lecture notes in Statistics, Vol. 54, Springer-Verlag, New York.
- Street, A.P. and Street, D.J. (1987). *Combinatorics of Experimental Designs*. Oxford Science Pub., Clarendon Press, Oxford.

4. Sampling Techniques

(2+1)

Probability sampling. Sample space, Sampling designs. Simple random sampling, estimation of proportions, confidence-interval, determination of sample size, inverse sampling. Sampling with varying probabilities. Stratified sampling, Ratio and regression methods of estimation, Cluster sampling, Multi-stage sampling with equal probability. Double sampling. Systematic sampling. Non-sampling errors — sources and classification, Imperfect frames, Non-response in surveys, Imputation methods, Randomized response techniques, Response errors — interpenetrating sub-sampling. Multiple frames. Ordered and unordered estimators, Sampling strategies due to Horvitz and Thompson, Midzuno-Sen, Rao-Hartley-Cochran and PPS systematic sampling. pPS Sampling schemes. Planning of a survey for animal husbandry statistics, methods of data collection, questionnaire versus schedule, problem of sampling frame, choice of sampling design. Statistics of livestock and livestock products, fisheries statistics, Role of different organizations engaged in data collection in India.

Practical

Determination of sample size and selection of sample. Simple random sampling, Inverse sampling, Sampling with varying probabilities, Stratified sampling. Ratio and regression methods of estimation. Cluster, systematic, double, multi-stage sampling. Imputation methods. Randomized response techniques.

Suggested Readings

Cochran, W.G. (1977). Sampling Techniques. John Wiley and Sons, New York.

Kish, L. (1965). Survey Sampling. John Wiley and Sons, New York.

Murthy, M.N. (1977). Sampling Theory and Methods. Statistical Publishing Society, Calcutta.

Sarndal, C.E., Swensson, B. and Wretman, J. (1992). Model Assisted Survey Sampling. Springer-Verlag, New York.

Singh., D., Singh, P. and Kumar, P. (1979). Hand Book of Sampling Theory. IASRI Publication, New Delhi.

Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Application. Iowa State University Press, Ames, Iowa and Indian Society of Agricultural Statistics, New Delhi.

5. Statistical Genetics (2+1)

Physical basis of inheritance. Classical and modern techniques such as DNA sequencing. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, Combined estimation, disturbed segregation. Gene and genotypic frequencies, Random mating and Hardy-Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, forces affecting gene frequency — selection, mutation and migration, equilibrium between forces in large populations, polymorphism. Theory of path co-efficient. Regular system of inbreeding. Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Correlation between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals improvement programmes. Correlated response to selection. Restricted selection index. Inbreeding and cross-breeding, Changes in mean and variance. Mating designs including diallel crosses.

Practical

Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation. Detection and estimation of linkage parameter by different procedures. Estimation of genotypic and gene frequency from a given data. Hardy-Weinberg law. , Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic

correlation coefficient. Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits. Mating designs. Construction of selection index including phenotypic index, restricted selection index. Correlated response to selection.

Suggested Readings

Bailey, N.T.J. (1961). *The Mathematical Theory of Genetic Linkage*. Clarendon Press, Oxford.

Balding, D.J., Bishop, M. and Cannings, C. (2001). *Hand Book of Statistical Genetics*. John Wiley and Sons, New York.

Crow, J.F. and Kimura, M. (1970). *An Introduction of Population Genetics Theory*. Harper and Row, New York.

Dahlberg, G. (1948). *Mathematical Methods for Population Genetics*. Inter Science Publications, New York.

East, E.M. and Jones, D.F. (1919). *Inbreeding and Outbreeding*. J B Lippincott Co, London and Philadelphia.

Falconer, D.S. (1985). *Introduction to Quantitative Genetics*. English Language Book, Longman, Essex, England.

Fisher, R.A. (1949). *The Theory of Inbreeding*. Oliver and Boyd, Edinburgh.

Fisher, R.A. (1950). *Statistical Methods for Research Workers*. Oliver and Boyd, Edinburgh.

Fisher, R.A. (1958). *The Genetical Theory of Natural Selection*. Dover Publication, New York.

Haldane, J.B.S. (1932). *The Causes of Evolution*. Harper and Bros., London.

Jain, J.P. (1982). *Statistical Techniques in Quantitative Genetics*. Tata McGraw Hill, New Delhi.

Kempthorne, O. (1957). *An Introduction to Genetic Statistics*. The Iowa State University Press, Ames, Iowa.

Lerner, I.M. (1950). *Population Genetics and Animal Improvement*. The University Press, Cambridge.

Lerner, I.M. (1954). *Genetic Homeostasis*. Oliver and Boyd, Edinburgh.

Lerner, I.M. (1958). *The Genetic Theory of Selection*. John Wiley and Sons, New York.

- Li, C.C. (1982). Population Genetics. The University of Chicago Press, Chicago.
- Mather, K. (1949). Biometrical Genetics. Methuen, London.
- Mather, K. (1951). The Measurement of Linkage in Heredity. Methuen and Co., London.
- Mather, K. and Jinks, J.L. (1977). Introduction to Biometrical Genetics. Chapman and Hall, London.
- Mather, K. and Jinks, J.L. (1982). Biometrical Genetics. Chapman and Hall, London.
- Narain, P. (1990). Statistical Genetics. Wiley Eastern Ltd., New Delhi.
- Narain, P., Bhatia, V.K. and Malhotra, P.K. (1979). Handbook of Statistical Genetics. IASRI Publication, New Delhi.
- Pearce, S.C. (1965). Biological Statistics: An Introduction. McGraw Hill, New York.

6. Applied Multivariate Methods (2+1)

Multivariate normal distribution, marginal and conditional distribution, Characterizations, maximum likelihood estimates of mean vector and dispersion matrix. Wishart distribution, Hotelling's T^2 and Mahalanobis' D^2 statistics, Test of hypothesis on means, Multivariate analysis of variance and covariance, Cluster analysis, Classification by linear discriminant function, Canonical correlation, Principal components, Factor analysis. Applications of multivariate analysis techniques.

Practical

Maximum likelihood estimates of mean-vector and dispersion matrix. Testing of hypothesis on means. Multivariate analysis of variance and covariance. Problems on Cluster analysis, Discriminant function, Canonical correlation and Principal component analysis.

Suggested Readings

- Anderson, T.W. (1958). An Introduction to Multivariate Statistical Analysis. John Wiley and Sons, New York.
- Johnson, R.A. and Wichern, D.W. (1988). Applied Multivariate Statistical Analysis. Prentice Hall, London.

Kshirsagar, A.M. (1972). *Multivariate Analysis*. Marcel and Dekker, New York.

Rao, C.R. (1965). *Linear Statistical Inference and its applications*. John Wiley and Sons, New York.

Srivastava, M.S. and Khatri, C.G. (1979). *Introduction to Multivariate Statistics*. Elsevier North Holland Inc.

7. **Statistical Inference** (2+1)

Point estimation, Properties of estimators: unbiasedness, consistency, efficiency and sufficiency. Frechet Cramer-Rao inequality, Rao-Blackwell theorem, completeness and bounded completeness, Basu's theorem. Methods of estimation — Maximum likelihood, least squares, minimum χ^2 , minimum distance, moments, maximum entropy. Testing of hypothesis: Two kinds of errors, Neyman-Pearson lemma, power function, uniformly most powerful tests and their constructions, unbiased tests, likelihood ratio tests, testing of composite hypothesis. Confidence-interval estimation. Non-parametric tests: run, sign, rank, median, Wilcoxon, Mann-Whitney, Kruskal Wallis, Friedmann two way ANOVA by ranks. Sequential analysis: Sequential probability ratio test. Elements of Decision theory and Bayesian inference.

Practical

Consistency and Unbiasedness, Method of estimation - Maximum Likelihood, Minimum and Modified Minimum c^2 , Moments. Confidence Interval Estimation. MP and UMP tests. Type I, Type II Errors and power of test. Non-parametric tests. Sequential Probability Ratio Test.

Suggested Readings

Box, G.E.P. and Tiao, G.C. (1973) *Bayesian Inference in Statistical Analysis*. Addison Wesley, London.

Christensen, R. (1990). *Log Linear Models*. Springer Text in Statistics, Springer-Verlag, New York.

Conover, W.J. (1980). *Practical Nonparametric Statistics*. John Wiley and Sons, New York.

Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*. John Wiley and Sons, New York.

Hogg, R.V. and Craig, T.T. (1978). *Introduction to Mathematical Statistics*. MacMillan, New York.

Kendall, N.G. and Stuart, A. (1960). *Advanced Theory of Statistics*. Vol I. Charles Griffen and Co. Ltd., London.

Lehman, E.L. (1983). Theory of Estimation. John Wiley and Sons, New York.

Lehman, E.L. (1986). Testing of Statistical Hypotheses. John Wiley and Sons, New York.

Mood, A.M., Graybill, F.A. and Boes, D.C. (1974). Introduction to Theory of Statistics. McGraw Hill Book Co., New York.

Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.

Rohatgi, V.K. (1976). An Introduction to Probability Theory and Mathematical Statistics. Wiley Eastern Ltd., New Delhi.

Rohatgi, V.K. (1984). Statistical Inference. John Wiley and Sons, New York.

Siegel, S., Johan, N. and Casellan Jr. (1956). Non-parametric Tests for Behavior Sciences. John Wiley and Sons, New York.

Tiku, M.L., Tan, W.Y. and Balakrishnan, N. (1986). Robust Inference. Marcel and Dekker, New York.

Wald, A. (1947). Sequential Analysis. John Wiley and Sons, New York.

8, Mathematical Methods

(3+0)

Introduction to Matrix Algebra. Characteristic roots and equations. Linear and quadratic forms. Grammmian root. Kronecker and Hadamard product of matrices. Permutation matrices, Full rank factorization, Equations having many solutions, Generalized inverses. Differentiation and integration of matrices. Minimization and Maximization, Rayleigh's theorem. Calculus: Differentiation of functions, successive differentiation, Partial differentiation, Integration by simple methods. Real Analysis: Convergence and Uniform convergence of infinite series, Use of comparison test. D'Alembert's Ratio - test, Cauchy's root test, Raabe's test for convergence of infinite series. Riemann integration, concept of Lebesgue integration, Power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals. Linear Algebra: Groups, fields, rings and vector spaces, linear transformations, Gram Schmidt's orthogonalisation. Galois field — Fermat's theorem and primitive elements. Concepts of Graph theory and its applications. Numerical Analysis: Operators like E, D. Simple interpolation, Divided differences. Numerical differentiation and integration, Euler - Maclaurin summation formula. Solution of Linear Differential equations.

Suggested Readings

- Brand, L. (1955). Advanced Calculus. John Wiley and Sons, New York.
- Chakraborti, M.C. (1962). Mathematics of Design and Analysis of Experiments. Asia Publishing House, Bombay.
- Chatterjee, S.K. (1970). Mathematical Analysis. Oxford and IBH Publishing Co., London.
- Deo, N. (1984). Graph Theory with Application to Engineering and Computer Science. Prentice Hall of India Pvt. Ltd., New Delhi.
- Gibson, G.A. (1954). Advanced Calculus. Macmillan, London.
- Hadley, G. (1969). Linear Algebra. Addison Wesley, London.
- Henrice, P. (1964). Elements of Numerical Analysis. John Wiley and Sons, New York.
- Hildebrand, F.B. (1956). Introduction to Numerical Analysis. Tata McGraw Hill, New Delhi.
- Malik, S.C. and Arora, S. (1991). Mathematical Analysis. Wiley Eastern Ltd., New Delhi.
- Mirsky, L. (1972). Introduction to Linear Algebra. Oxford University Press. London.
- Narayan, S. (1988). Text Book of Matrices. S.Chand & Co. Pvt. Ltd., New Delhi.
- Rao, C.R. (1965). Linear Statistical Inference and its applications. John Wiley and Sons, New York.
- Scarborough, J.B. (1976). Numerical Mathematical Analysis. Oxford and IBH Publishing Co., London.
- Searle, S.R. (1982). Matrix Algebra Useful for Statistics. John Wiley and Sons, New York.

9. Demographic Techniques in Bio-Statistics (2+1)

Introduction to vital statistics, crude and standard mortality and morbidity rates, Description and construction of life tables, abridged life tables, Stationary and stable population, Fertility rates: CBR, GFR, GRR and NRR. Estimation of median effective doses-their relative potency and standard

errors, Application of deterministic and stochastic models in epidemiology, Probit analysis, Confounding with natural mortality and methods of its adjustment, Odds-ratio, Mantel-Henszel estimate and its confidence interval, testing of hypothesis in 2×2 and $2 \times k$ tables, Fundamentals of matched analysis, Logistic regression analysis.

Practical

Problems based on estimation of crude and standard mortality and morbidity rates, construction of life tables. Estimation of CBR, GFR, GRR and NRR. Probit Analysis. Deterministic and stochastic models in epidemiology. Logistic Regression. Odds-ratio tests, Mantel-Henszel estimate and its confidence interval, testing of hypothesis in 2×2 and $2 \times k$ tables.

Suggested Readings

- Cox, D.R. (1957). Demography. Cambridge University Press, Cambridge.
- Altman, D.G. (1991). Practical Statistics for Medical Research. Chapman and Hall, London.
- Anderson, B. (1990). Methodological Errors in Medical Research. Blackwell Scientific, Oxford.
- Armitage, P. and Berry, G. (1987). Statistical Methods in Medical Research. Blackwell Scientific, Oxford.
- Bailey, N.T.J. (1975). The Mathematical Theory of Infectious Diseases and its Applications. Griffin, London.
- Crow, J.F. and Kimura, M. (1970). An Introduction of Population Genetics Theory. Harper and Row, New York.
- Dahlberg, G. (1948). Mathematical Methods for Population Genetics. Inter Science Publications, New York.
- East, E.M. and Jones, D.F. (1919). Inbreeding and Outbreeding. J B Lippincott Co, London and Philadelphia.
- Everitt, B.S. and Dunn, G. (1998). Statistical Analysis of Medical Data. Arnold, London.
- Fleiss, J.L. (1981). Statistical Methods for Rates and Proportions. John Wiley and Sons, New York.
- Lawless, J.F. (1982). Statistical Models and Methods for Lifetime Data. John

Wiley and Sons, New York.

MacMahon, B. and Pugh, T.F. (1970). Epidemiology- Principles and Methods. Little Brown, Boston.

Mann, N. R., Schafer, R E. and Singpurwalla, N.D. (1974). Methods for Statistical Analysis of Reliability and Life Data. John Wiley and Sons, New York.

Sham, P. (1997). Statistics in Human Genetics. Arnold, London.

Woolson, F. R. (1987). Statistical Methods for the Analysis of Biomedical Data. John Wiley and Sons, New York.

10. Survival Models in Bio-Statistics (2+1)

Concept of survival data, definition and associated probability density function, survival function, hazard function, Censoring in survival time, Estimation of survival function by life table analysis, Kaplan and Meirer Method, Some survival and failure time distributions: family of exponential and Weibul models, Analytical and graphical method for choosing best fitted distribution, Parametric and non-parametric tests for comparison of survival functions, Concomitant variables in lifetime distribution models, Cox-proportional *hazard* models, Cox-proportional hazard models with time dependent covariates,

Practical

Estimation of survival functions - life table analysis, Kaplan and Meirer Method. Estimation of survival functions in case of censored observations - life table method, Kaplan and Meirer method. Fitting of survival and failure time distributions: family of exponential and Weibul models (For uncensored and censored observations). Regression and Maximum Likelihood Method of fitting and choosing appropriate distribution to the survival times. Graphical method for choosing best fitted distribution, Parametric and Non-Parametric tests for comparison of survival functions, Parametric tests for comparison of survival functions in the presence of censored survival times, Non parametric tests for comparing survival functions in the presence of uncensored survival times. Concomitant variables in lifetime distribution models. Fitting of Cox-proportional hazard models.

Suggested Readings

Anderson, B. (1990). Methodological Errors in Medical Research. Blackwell Scientific, Oxford.

Armitage, P. and Berry, G. (1987). *Statistical Methods in Medical Research*. Blackwell Scientific, Oxford.

Elandt-Johnson, R. C. and Johnson N. L. (1980). *Survival Models and Data Analysis*. John Wiley and Sons, New York.

Everitt, B.S. and Dunn, G. (1998). *Statistical Analysis of Medical Data*. Arnold, London.

Lee, E.T. (1980). *Statistical Methods for Survival Data Analysis*. Lifetime Learning Publications, Belmont, California.

11. Econometrics and Operations Research

(2+1)

Study of single equation linear regression models, Maximum likelihood and ordinary least squares methods of estimation, Statistical inference in linear regression, Estimation subject to linear restrictions, Use of dummy variables, Multicollinearity and estimation and testing of hypothesis in linear models not of full rank. Generalized least squares method of estimation, Seemingly unrelated regressions, Heteroscedasticity, Auto - correlation, Distributed lag models. Elements of time-series analysis, Components of time-series, Measurement of secular trend — Methods of moving averages and curve fitting, Measurement of seasonal fluctuations, Measurement of cyclical fluctuations—Periodogram analysis, Harmonic analysis, Serial correlation and Correlogram. Elementary linear programming and principles of duality, Elements of queuing theory, waiting time models, Introduction to networks, flow charts, critical path and PERT. Elementary risk analysis.

Practical

Estimation of parameters of linear model through the methods of Ordinary Least Squares (OLS), Test of significance of the estimates. Restricted Ordinary Least Squares Method, Generalized least squares method, Weighted least squares method. Problem on Autocorrelation, Multicollinearity, Dummy variation, Heteroscedasticity. Analysis of time-series data. Serial correlation and Correlogram. Linear Programming Problem. Dual simplex method. Sensitivity analysis. Classical Optimization technique. Flow charts and PERT

Suggested Readings

Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. John Wiley and Sons, New York.

Baltagi, B.H. (1999). *Econometrics*. Springer-Verlag, Berlin.

Belsley, D.A., Kuh, E. and Welsch, R.E. (1980). *Regression Diagnostics:*

Identifying Influential Data and Source of Collinearity. John Wiley and Sons, New York.

Everitt, B.S. (1987). Introduction to Optimization Methods and their Application in Statistics. Chapman Hall, London.

Johnston, J. (1984). Econometric Methods. McGraw Hill, New York:

Klein, L.R. (1975). A Text Book of Econometrics. Prentice Hall of India, New Delhi.

Koutsoyiannis, A. (1992). Theory of Econometrics. Macmillan, Hongkong.

Maddala, G.S. (1977). Econometrics. McGraw Hill, Auckland.

Rao, S.S. (1984). Optimization Theory and Application. Wiley Eastern Ltd., New Delhi.

Rustagi, J.S. (1994). Optimization Techniques in Statistics. Boston Academic Press, Boston.

Taha, H.A. (1999). Operations Research: An Introduction. Prentice Hall of India, New Delhi.

Theil, H. (1971). Principles of Econometrics. John Wiley and Sons, New York.

Zeleny, M. (1974). Linear Multi-objective Programming - Lecture Notes in Economics and Mathematical Systems, Sr.95. Springer - Verlag, Berlin.

12. Data Analysis in Animal Sciences

(1+1)

Use of Software packages for: Summarization and tabulation of data; Descriptive statistics; Graphical representation of data; Fitting and testing the goodness of fit of probability distributions; Testing of hypothesis; t-test, Chi-square test and F-test; Concept of analysis of variance and covariance of data for one-way and multi-classified experiments; Analyzing crossed and nested classified designs; Analysis of mixed models; Estimation of variance components; Testing the significance of contrasts; Correlation and regression including multiple regression; Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data etc.

Practical

Use of software packages for Summarization and tabulation of data, Measures of central tendency, dispersion, skewness and kurtosis, To obtain frequencies

and basic statistics including graphical representation of data, Robust Estimation, Testing linearity and normality assumption, Estimation of trimmed means etc., Cross tabulation of data including its statistics, cell display and table format and means for different sub-classifications, Fitting and testing the goodness of fit of probability distributions, Testing the hypothesis for one sample T-test, two sample T-test, paired T-test, test for large samples - Chi-squares test, F test, One way analysis of variance , contrast and its testing, pairwise comparisons, Multiway classified analysis of variance - cross-classification, nested classification, factorial set up, fixed effect models, random effect models, mixed effect models, estimation of variance components, Generalized linear models - analysis of unbalanced data sets, testing and significance of contrasts, Estimation of variance components in unbalanced data sets - maximum likelihood, ANOVA, REML, MINQUE, Bivariate and partial correlation, Distances - to obtain a distance matrix, dissimilarity measures, similarity measures, Linear regression, Multiple regression, Regression plots, Variable selection, Regression statistics, Fitting of growth models - curve estimation models, examination of residuals, Discriminant analysis - fitting of discriminant functions, identification of important variables, Factor analysis-descriptive statistics and correlation coefficients. different extraction methods, working different factor scores, Principal component analysis - obtaining principal component, spectral composition, Analysis of time series data - fitting of ARIMA models, working out moving averages.

Suggested Readings

- Anderson, C W and Loynes R M (1987) The Teaching of Practical Statistics, Wiley, Chichester.
- Atkinson, A C (1985) Plots Transformations and Regression, Oxford University Press, Oxford.
- Chambers, J M , Cleveland W S , Kleiner, B and Tukey, P A (1983) Graphical Methods for Data Analysis, Wadsworth, Belmont, California.
- Chatfield, C (1983) Statistics for Technology, 3rd Edn., Chapman and Hall, London.
- Chatfield, C (1995) Problem Solving: A statistician's guide, Chapman and Hall, London,
- Chatfield, C and Collins A J (1980) Introduction to Multivariate Analysis, Chapman and Hall, London
- Cleveland, W S (1985) The Elements of Graphing Data, Wadsworth, Belmont, California.
- Ehrenberg, A S C (1982) A Primer in Data Reduction, Wiley, Chichester.

- Erickson, B H and Nosanchuk, T A (1992) Understanding Data 2nd Edn, Open University Press, Milton Keynes.
- Everitt, B S and Dunn, G (1991) Advanced Multivariate Data Analysis, 2nd Edn, Arnold, London.
- Geisser, S (1993) Predictive Inference: An Introduction, Chapman and Hall, New York.
- Miller, R G Jr. (1986) Beyond ANOVA, Basics of Applied Statistics, Wiley, Chichester.
- Ryan, B F and Joiner, B L (1994) MINITAB Handbook, 3rd Edn., Duxbury Press, Belmont, California.
- Snell, E J (1987) Applied Statistics: A Handbook of BMDP Analyses, Chapman and Hall, London.
- Snell, E J and Simpson, H R (1991) Applied Statistics: A Handbook of GENSTAT Analyses, Chapman and Hall, London.
- Sprent P (1993) Applied Non-parametric Statistical Methods, 2nd Edn. Chapman and Hall, London.
- Tufte, E R (1983) The Visual Display of Quantitative Information, Graphics Press, Cheshire, Conn.
- Velleman P F and Hoaglin D C (1981) Application, Basics and Computing of Exploratory Data Analysis, Duxbury Press, Boston, Mass.
- Weisberg, S. (1985) Applied Linear Regression, Wiley, New York .
- Wetherill G B (1982) Elementary Statistical Methods, Chapman and Hall, London .
- Wetherill G B (1986) Regression Analysis with Applications, Chapman and Hall, London

13. Stochastic Processes

(2+0)

Basics of stochastic processes. Random walk models. Markov chains and their applications. Discrete branching processes. Markov processes in continuous time: Poisson process, Random-variable technique. Birth and death processes like pure birth process, linear birth and death process, immigration-birth-death process. Elements of queuing processes^{3/4}queues in series, queuing networks. Applications of queuing theory. Epidemic processes: Simple deterministic and stochastic epidemic model. General epidemic models^{3/4}Kermack and McKendrick's threshold theorem. Recurrent epidemics.

Chain binomial models. Diffusion processes. Diffusion limit of a random walk and discrete branching process. Forward and backward Kolmogorov diffusion equations and their applications.

Suggested Readings

Bailey, N.T.J. (1964). Elements of Stochastic Processes with Applications to the Natural Sciences. Wiley Eastern Ltd., New Delhi.

Bartlett, M.S. (1955). Introduction to Stochastic Processes. Cambridge University Press, Cambridge.

Bharucha-Reid, A.T. (1960). Elements of the Theory of Markov Processes and their Applications. McGraw Hill, New York.

Bhat, U.N. (1972). Elements of Applied Stochastic Processes. Wiley Eastern Ltd., New Delhi.

Cox, D.R. and Miller, H.D. (1965). The Theory of Stochastic Processes. Methuen, London.

Karlin, S. (1966). A First Course in Stochastic Processes. Academic Press, New York.

Lawler, G.F. (1995). Introduction to Stochastic Processes. Chapman and Hall, New York.

Medhi, J. (1982). Stochastic Processes. Wiley Eastern Ltd., New Delhi.

Parzen, E. (1962). Stochastic Processes. Holden-Day, San Francisco.

Prabhu, N.U. (1965). Stochastic Processes. Macmillan, New York.

14. Statistical Methods in Population Studies (2+1)

Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidity, Period and Cohort studies, Application and methods of constructing life table, abridged life tables, Stationary and stable populations, Migration and immigration, Measures of reproduction, total fertility rate, gross reproduction rate, net reproduction rate, replacement index, general fertility models, Stochastic models of fertility and reproduction, Population projections, Epidemiological simulation models.

Practical

Measurement of population growth by various models. Fitting of Lotka's model

(deterministic) and intrinsic rate of growth. Measures of mortality and morbidity. Analysis of data of Cohort studies. Construction of life tables and abridged life tables. Measures of reproduction viz. total fertility rate, gross reproduction rate, net reproduction rate. Measures of Replacement index. General fertility models. Stochastic models of fertility and reproduction. Population projections. Epidemiological simulation models.

Suggested Readings

- Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. John Wiley and Sons, New York.
- Armitage, P. and Berry, G. (1987). *Statistical Methods in Medical Research*. Blackwell Scientific, Oxford.
- Christensen, R. (1990). *Log Linear Models*. Spring Text in Statistics, Springer - Verlag, New York.
- Crow, J.F. and Kimura, M. (1970). *An Introduction of Population Genetics Theory*. Harper and Row, New York.
- Dahlberg, G. (1948). *Mathematical Methods for Population Genetics*. Inter Science Publications, New York.
- Draper, N.R. and Smith, H. (1981). *Applied Regression Analysis*. Wiley Eastern Ltd., New Delhi.
- Fisher, R.A. (1958). *The Genetical Theory of Natural Selection*. Dover Publication, New York.
- Haldane, J.B.S. (1932). *The Causes of Evolution*. Harper and Bros., London.
- Lerner, I.M. (1950). *Population Genetics and Animal Improvement*. The University Press, Cambridge.
- Li, C.C. (1982). *Population Genetics*. The University of Chicago Press, Chicago.
- Lilienfeld, A.M. and Lilienfeld, D.E. (1980). *Foundations of Epidemiology*. Oxford University Press, New York.
- MacMahon, B. and Pugh, T.F. (1970). *Epidemiology- Principles and Methods*. Little Brown, Boston.
- Miettinen, O.S. (1985). *Theoretical Epidemiology: Principles of Occurrence Research in Medicine*. John Wiley and Sons, New York.

Sham, P. (1997). Statistics in Human Genetics. Arnold, London.

15. Non-linear Statistical Modeling (2+1)

Empirical and mechanistic models, Nonlinear growth models like monomolecular, logistic, Gompertz, Richards, Properties of these models, Applications in agriculture and fisheries, Formulation of nonlinear statistical models, Estimation of parameters using iterative procedures like Taylor's. Steepest descent, Levenberg-Marquardt's, Choice of initial values, Examinations of residuals and adequacy of a model, Fitting of nonlinear statistical models using software packages. Compartmental modelling-first and second order input output systems, Dynamics of multivariate systems, Applications in plant growth and animal physiology, Two species system, Non-linear prey-predator models - Lotka-Volterra, Leslie-Gower and Holling-Tanner. Volterra's principle and its applications, Gause competition model, Multi-species modeling.

Practical

Fitting of Non-linear model like Logistic, Gompertz, and Richards. Estimation of parameters using iterative procedures like Taylor's, steepest, descent, choice of initial values. Testing adequacy of model. Compartmental modelling, Non-linear prey-predator model, Gause competition model, Multi-species models.

Suggested Readings

Draper, N.R. and Smith, H. (1981). Applied Regression Analysis. Wiley Eastern Ltd., New Delhi.

France, J. and Thornley, J.H.M. (1984). Mathematical Models in Agriculture. Butterworths, London.

Ratkowsky, D.A. (1983). Nonlinear Regression Modelling: a Unified Practical Approach. Marcel Dekker, New York.

Ratkowsky, D.A. (1990). Handbook of Nonlinear Regression Models. Marcel Dekker, New York.

Seber, G.A.F. and Wild, C.J. (1989). Non-linear Regression. John Wiley, New York.

4. Computer Application

4.1 Major*

31 Credits

(L+P)

1. Introduction to Computer Organization and Architecture**	(2+0)
2. Fundamental of Computer Programming**	(2+1)
3. Data and File Structures**	(2+1)
4. Data Base Management System**	(2+1)
5. Computer Networks**	(2+0)
6. System Analysis and Design**	(1+1)
7. Object Oriented Analysis and Design**	(2+1)
8. Operating System**	(2+1)
9. Discrete Mathematics	(2+0)
10. Numerical Analysis	(2+1)
11. Introduction to Computer Graphics	(1+1)
12. Design and Analysis of Algorithms	(1+1)
13. Software Engineering	(2+0)
14. Management Information System	(1+1)
15. Compiler Construction	(2+1)
16. Data Analysis in Agriculture	(1+1)
17. Simulation and Modeling	(1+1)
18. GIS and Remote Sensing Techniques	(2+1)
19. Recent Trends and Emerging Programming Paradigms	(1+1)
20. Seminar	(0+1)

4.2 Supporting Courses

10 Credits

To be decided by the Students Advisory Committee

4.3 Thesis and Viva-Voce

15 Credits

* The Broad Subject Matter Committee (BSMC) recommended that 31 credits may be taken by a student from the major discipline in view of students coming to this programme from different streams of agriculture and basic sciences.

** Similarly the BSMC recommended that Courses 1-8 as listed above are essential and may be treated as core-courses. Remaining major courses to the extent of 10 credits can be taken as optional as decided by the Students Advisory Committee.

4. Computer Application

1. Introduction to Computer Organization and Architecture (2+0)

Number representations; Boolean algebra; Combinational circuits; Sequential circuits; Organization of CPU; Memory and I/O devices; Machine-level programming. Processor organization; Classification of architectures; Stack machines; Language directed architectures; RISC architecture; pipelining; array processors; MIMD architectures; Data flow machines; Functional description of an operating systems; File/Memory management methods; control of multiple processes.

Suggested Readings

Gear, C.W. (1974). Computer Organization and Programming. McGraw Hill, New York.

Hayes, J.P. Computer Architecture and Organisation, McGraw Hill, New York.

Malvino, A.P. and Brown, J.A. (1999). Digital Computer Electronics. Tata McGraw Hill, New Delhi.

Mano, M. M. (1999). Computer System Architecture. Prentice Hall of India, New Delhi.

Mano, M. M. (1999). Digital Logic and Computer Design. Prentice Hall of India, New Delhi.

2. Fundamental of Computer Programming (2+1)

Definition of computer algorithms; Representations of algorithms; Data types; Use of language supported data structures like arrays and structures; Standard data operations; Control structures; Modular programming techniques; Input-output mechanisms; Stream operations.

Practical

Problems on Data types, Input /Output statements, Control statements, Loops, Arrays, Structures/Unions, Pointers and string processing, Various operations in file management like insert, delete, add and modify a record(s) using suitable techniques.

Suggested Readings

Balaguruswamy, E. (1998). Programming with ANSI C. Tata McGraw Hill, New Delhi.

Gottfried, B.(1999). Programming with C, Schaume Outline Series. Tata McGraw Hill, New Delhi.

Kanetkar, Y.(1999). Let Us C. BPB Publications, New Delhi.

Kanetkar, Y.(1999). Exploring C. BPB Publications, New Delhi.

Karnighan, B. W. and Ritchie, D. (2000). The C Programming Language. Prentice Hall of India, New Delhi.

Sethi, R. (1996). Programming Language Concepts. Addison Wesley, New York.

Tondo, C.I. and Gimpel, S.E. (1991). The C Answer Book. Prentice Hall of India, New Delhi.

3. Data and File Structures (2+1)

Representation of character, string and their manipulation; Linear list structure; Stacks; Queues; Dequeues; Representation and processing of linear linked lists; Multiple linked structures; Tree Structures; Representation of tree structures and different tree traversal algorithms; Sorting and searching. Basic file Organization (sequential indexed, index sequential, direct, multi-ring); Hybrid file organizations (simple, tree structured, multi-level indexing, index sequential, hierarchical structures, complex ring organizations, virtual storage, phaniform files); Techniques of file system evaluation (cost benefits, usage).

Practical

Implementation of various types of structures - linked lists, doubly linked lists, circular linked lists, queue, dequeue, stack and tree, String processing, Searching and sorting techniques, Creation, updation, deletion, indexing, validity checking for various file organisations, Evaluation of different file organisations, Case studies.

Suggested Readings

Aho, A.V., Hopcroft, J.E. and Ullman, J.D. (1983). Data Structures and Algorithms. Addison Wesley, Reading, Massachusetts.

Clay Brook G. Bill (1983). File Management Techniques. John Wiley and Sons, New York.

Hans, D. G. (1986). File Systems, Design and Implementation. Prentice Hall, New York.

- Harbron, T.R. (), File System Structures and Algorithms, Prentice Hall, New York.
- Horowitz, E. and Sahani, S. (1983). Fundamentals of Data Structures. Galgotia Publishers, New Delhi.
- Johnson, L.F. and Cooper, R.H. (1986). File Techniques for Database Organisation in COBOL. Prentice Hall, New York.
- Knuth, D.E. (1968). Art of Computer Programming, Vol. I. Fundamental Algorithms. Addison Wesley, Reading, Massachusettes.
- Knuth, D.E. (1973). Art of Computer Programming, Vol. III. Sorting and searching. Addison Wesley, Reading, Massachusettes.
- Langsam, Y. Augenstein, M.J. and Tanenbum, A. S. (1999). Data Structures Using C and C++. Prentice Hall of India, New Delhi.
- Livadas, Panes E. (1990). File Structures Theory and Practice. Prentice Hall, New Jersey.
- Tremblay, J.P. and Sorenson, P.G.(1976). An Introduction to Data Structures with Applications. McGraw Hill, New York.
- Weiss, M.A. (1994). Data Structures and Algorithm Analysis in C++, Benjamin/Cummings Publishing Co.,
- Wiederhold, (1988). File Organisation for Database Design. McGraw Hill, New York.

4. Data Base Management System (2+1)

DBMS architecture; Data models; Relational model; relational database design, normal forms; Integrity; Views and security; Concurrency control; Reliability; Query processing; Deductive databases; Relational Data Base Management System Package.

Practical

E-R diagram construction, SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints, forms, reports, triggers, creating procedures/functions and buttons, Normalization of database, Development of a database application.

Suggested Readings

- Date, C.J. (2000). Introduction to Database System. Addison Wesley, Reading, Massachusetts.

- Desai, B. C. (2000). Introduction to Database Systems. Galgotia Publications, New Delhi.
- Silberschartz, A., Korth, H. F. and Sudarshan, S. (1997). Database Systems Concepts. Tata McGraw Hill, India.
- Ullman, J.D. (1998). Principles of Database System. Galgotia Publishers, New Delhi.

5. Computer Networks (2+0)

Network topology and its analysis; OSI Reference model; Network protocols; Design issues at physical layer; data-link level protocols and their performances; Routing algorithms and control techniques at Network level; Design issues at transport level.

Suggested Readings

- Arick, M.R. (1994). The TCP/IP Companion - A Guide for Common User. Shroff Publishers and Distributors Pvt. Ltd., Mumbai.
- Freer, J. (1990). Computer Communication and Networks. Affiliated East West Press, New Delhi.
- Hayes, J. (2001). Modelling and Analysis of Computer Communication Networks. Khanna Publishers, New Delhi.
- Tanenbaum, A.S.(1999). Computer Networks. Prentice Hall of India, New Delhi.

6. System Analysis and Design (1+1)

Systems development cycles; Information requirement definition; System analysis, methods; Tools techniques for system analysis; 4GL Environments; Conversion and implementation; Audit.

Practical

Study of various systems from development point of view, Requirements analysis and designing and documentation of various systems.

Suggested Readings

- Awad, E. M. (1993). System Analysis and Design. Galgotia Publishers, New Delhi.
- Edwards, P. (). System Analysis and Design. McGraw Hill, New York.
- Hawryszkiewycz, I.T. (). Introduction to System Analysis and Design, Prentice

Hall of India, New Delhi.

Kerzner, H. (1998). Project Management: A System Approach to Planning, Scheduling and Controlling. CBS Pub. and Distributors, New Delhi.

7. Object Oriented Analysis and Design (2+1)

Procedural abstraction, command and functional procedures; Data encapsulation - concepts of modules and interfaces; Data abstraction and types; Introduction to object orientation; History and evolution of object oriented languages; Abstract data types, classes, objects, object/message paradigm; Overloading, dynamic binding, parametric polymorphism; Inheritance: class and object inheritance, inheritance and dynamic binding, multiple inheritance; Object identity, facets of identity, operations with identity; Object oriented programming languages; Object oriented software design; Generic and reusable classes; Object oriented databases-design, query languages, capabilities and limitations.

Practical

Case studies using object oriented analysis and design (OOAD), Creation of various types of classes - overloading, inheritance, data abstraction, polymorphism, Database design and its implementation using OOAD.

Suggested Readings

Bergin, J. (1994). Data Abstraction: The Object-Oriented Approach Using C++. McGraw Hill, New York.

Holzner, S. (1997). The Visual C++ Programming Language. Prentice Hall of India, New Delhi.

Johnsonbaugh, R. and Kalin, M. (1995). Object Oriented Programming in C++. Prentice Hall, New Jersey.

Khoshafian, S. and Abnous, R. (1995). Object Orientation Concepts, Languages, Databases, User Interfaces. John Wiley and Sons, New York.

Sengupta, S. and Korobkin, C.P. (1994). C++ Object Oriented Data Structures. Springer-Verlag, New York.

Stronstblp, B. (2000). The C++ Programming Language. Addison Wesley, New York.

8. Operating System (2+1)

Languages of operating system development; Process synchronization; Concurrent processes; Problem of mutual exclusion; Deadlock and prevention;

Race conditions; Semaphore classes Monitors Semaphores for process synchronization; race conditions; Operating and count semaphores; Process allocation; Memory management; Multi-programming with fixed and variable number of tasks; Continuous allocation; Paging, demand paging, page fault; Virtual memory; Fragmentation; Segmented memory management, shared segments; Segmented and demand paged management, Overlays and swapping, Thrashing, Processor management Different techniques of job scheduling, task scheduling, round robin policy etc.; Multi processor system, Master slave scheduling; Homogeneous scheduling; Device management system; Dedicated share and virtual devices; Spooling channels; Multiplexer and selector, control units; Traffic controllers and device handlers; Information management memory techniques; Input-Output file protection; Distributed operating system; A case study of OS Design and implementation.

Practical

Problems using system calls for process management, signaling, file management, directory management, protection, Critical section problem, Solution to mutual exclusion by Peterson method, Producer consumer problem with fatal race conditions, Comparison of various CPU scheduling algorithms, Paging, segmentation and demand paging, Implementation of an operating system.

Suggested Readings

Bach, M.J. (1998). Design of the UNIX Operating System, Prentice Hall of India, New Delhi.

Deitel, H.M. (1990). An Introduction to Operating System. Addison Wesley, London

Kernighan, B.W. and Pike, R. (1996). The UNIX Programming Environment, Prentice Hall of India, New Delhi.

Peterson, J. and Silberschatz, A. (1991). Operating System. Addison Wesley, Reading, Massachusetts.

Tanenbaum, A.S. (2000). Modern Operating Systems. Prentice Hall of India, New Delhi.

9. Discrete Mathematics (2+0)

Sets: Set theory, subsets, operations on sets, set cardinality and counting; Functions: Bijective functions, pigeon-hole principle, Boolean functions, permutation functions, Boolean algebra, recursion relations; Number Theory: Binary arithmetic, exponentiation, induction, sequences, big-oh notation, GCD,

Euclidean algorithm, partially ordered sets, congruence and equivalence relation, encryption scheme, Fibonacci sequence, linear homogenous recurrence relations with constant coefficients; Graph Theory: Graphs, trees, LAN, Eulerian cycles, Hamiltonian cycles, graph coloring, graph algorithms; Mathematical Logic: Propositional calculus, proposition, logic connectives and compound statements, conjunction, disjunction, truth tables, duality, tautologies and fallacies; Algebraic Systems: Subsemigroups, subgroups and cosets, homomorphisms, application of groups to counting, ring, integral domain and field.

Suggested Readings

Abertson, M.O. and Hutchinson, J.P. (1988). Discrete Mathematics with Algorithms. John Wiley and Sons, New York.

Deo, N. (1984). Graph Theory with Application to Engineering and Computer Science. Prentice Hall of India, New Delhi.

Knuth, D.E. (1968). Art of Computer Programming, Vol. I. Fundamental Algorithms. Addison Wesley, Reading, Massachusettes.

Tremblay, J.P. and Manohar, R.P. (1975). Discrete Mathematical Structures with Applications to Computer Science. McGraw Hill, New York.

10. Numerical Analysis

(2+1)

Introduction to complex variables; Matrix algebra; Numerical solutions of linear equations; Iterative techniques and their analysis; Linear Difference equations; Propagation of Round-off errors and the techniques to minimize it; Interpolation and approximation by polynomials; Numerical differentiation and integration; Exposure to mathematical software packages.

Practical

Matrix Algebra - pivoting of matrices, matrix inversion, rank of a matrix, Eigen values and eigen vectors - power method for least eigen value, Jacobi's method, Householder method, Solution of linear system of equation - Gaussian elimination method, Jacobi iteration method, Gauss-Seidel iteration method, Linear difference equations - Solution of difference equations by relaxation method, Solution of differential equations by difference equations method, Transformation of differential equations into difference equations, Propagation of round-off errors - evaluation of round-off errors due to arithmetic operations, impact due to propagation of round-off errors, round-off errors minimization techniques, Interpolation - Newton interpolation formulae, Lagrange's interpolation formulae, Aitken-Neville iterated interpolation scheme, Newton's divided difference interpolation formulae, Hermite

interpolation formula, spline interpolation, Numerical integration - trapezoidal rule, Simpson's rule, Gauss-Legendre open quadrature, Numerical differentiation - derivatives from Newton-Gregory forward polynomial, Derivatives from spline interpolating polynomials.

Suggested Readings

Atkinson, Kendall E.(1978). An Introduction to Numerical Analysis. John Wiley and Sons, New York.

Henrici, P.(1964). Elements of Numerical Analysis. John Wiley and Sons, New York.

Jain M.K., Iyengar, S.R.K. and Jain, R.K.(1985). Numerical Methods for Scientific and Engineering Computation. Wiley Eastern Ltd., New Delhi.

Kendall E. Atkinson.(1978). An Introduction to Numerical Analysis. John Wiley and Sons, New York.

Kennedy, W. J. and Gentle, J.E. (1980). Statistical Computing. Marcel and Dekker, New York.

Krishnamurthi, E.V. and Sen, S.K.(1986). Computer - Based Numerical Algorithms. East West Publishing, New Delhi.

Kuo, S.S.(1965). Computer Applications of Numerical Methods. Addison Wesley, Reading, Massachusetts.

Yakowitz, S. and Szidarovszky, F. (1986). An Introduction to Numerical Computation. MacMillan, New York.

11. Introduction to Computer Graphics

(1+1)

Basic raster graphics algorithms for drawing 2D primitives; Graphics hardware; Geometrical transformations; Viewing in 3D; Visible-surface determination; Illumination and shading; Representing curves and surfaces; Image manipulation and storage.

Practical

Development of algorithms for drawing geometrical figures, rotation, charts and their implementation, pixel handling on screen, Use primitive transformations and/or their combinations, Display of False Colour Composite (FCC), Forier transformation, removal of noise/errors of satellite data and its storage.

Suggested Readings

Hearn, D. and Baker, M.P. (1986). Computer Graphics. Prentice and Hall of India, New Delhi.

Marshall, G. (1983). Programming with Graphics. Granada Publishing, London.

Newman, W. M. and Sproull, R. F. (1981). Principles of Interactive Computer Graphics. McGraw Hill, New York.

Prince, D. M. (1979). Interactive Graphics for Computer Aided Design (CAD). Addison Wesley, New York.

12. Design and Analysis of Algorithms (1+1)

Sorting algorithms; Searching algorithms; String processing; Graph and geometric algorithms; Most exploited paradigms of problem-solving; analysis of algorithms; Computation of lower/upper-bound for the complexity of algorithms; Definition of non-deterministic polynomial algorithms and the proofs of establishing NP-completeness of some problems.

Practical

Sorting and searching using different techniques and comparing complexity functions of the algorithms, Problems on string processing, Operations on tree.

Suggested Readings

Aho, A.V., Hopcroft, J.E. and Ullman, J.D. (1974). Design and Analysis of Computer Algorithms. Addison Wesley, Reading, Massachusetts.

Aho, A.V., Hopcroft, J.E. and Ullman, J.D. (1983). Data Structures and Algorithms. Addison Wesley, Reading, Massachusetts.

Baase, S. (1978). Computer Algorithms: Introduction to Design and Analysis. Addison Wesley, Reading, Massachusetts.

Horowitz, E. and Sahani, S. (1977). Algorithms: Design and Analysis. Computer Science Press, Potomac Md.

Knuth, D.E. (1968). Art of Computer Programming, Vol. I. Fundamental Algorithms. Addison Wesley, Reading, Massachusetts.

Knuth, D.E. (1969). Art of Computer Programming, Vol. II. Semi Numerical Algorithms. Addison Wesley, Reading, Massachusetts.

Knuth, D.E. (1973). Art of Computer Programming, Vol. III. Sorting and searching. Addison Wesley, Reading, **Massachusetts**.

13. Software Engineering (2+0)

Software crisis; software cycle; Project planning; requirements analysis; Software design and implementation; Testing; Configuration management; software maintenance; Specifications and verification; Systems delivery/release; CASE.

Suggested Readings

Fairley. R. (1999). Software Engineering Concepts. Tata McGraw Hill, New Delhi.

Shooman, M.L. (1983). Software Engineering, McGraw-Hill, New York.

Sommerville, I. (1989). Software Engineering. Addison Wesley, Reading, Massachusetts.

14. Management Information System (1+1)

Basic management principles; Objectives of MIS; System concepts of MIS; Planning, design and implementation of MIS; Decision making with MIS; Data information and communication of MIS; Information systems in agriculture; Development of a MIS; Accounting and Financial management; Project management-project scheduling CPM and PERT.

Practical

Examination of case histories of various MIS from development point of view, Information management needs of agriculture research and education, agri-business, agricultural production and distribution etc., Development of a decision support system, Study of accounting and financial management systems, Application of CPM and PERT techniques.

Suggested Readings

Balaguru, T., Manikandan, P. and Kalla. J.C. (1996). Management Information System for Agricultural Research. National Academy of Agricultural Research and Management, Hyderabad.

Davis, G. B. and Olson, M.H. (1985). Management Information Systems. McGraw Hill, New York.

Kanter, J. (1987). Management Information System. Prentice and Hall, New Delhi.

Kerzner, H. (1998). Project Management: A System Approach to Planning, Scheduling and Controlling. CBS Pub. and Distributors, New Delhi.

Murdick, R.G., Ross, J.E. and Claggett, J.R. (1988). Information System for Modern Management. Prentice and Hall, New Delhi.

Taha, H.A. (1999). Operations Research: An Introduction. Prentice Hall of India, New Delhi.

15. Compiler Construction (2+1)

Compilers and translators; Formal Language; structure of compiler; Lexical analysis; Symbol tables; semantic analysis; Languages of compiler development; Properties of context free grammars; Transformational grammars; Right Linear grammar; Implementing finite state machines; Push down machines; Syntax directed translation; Top down parsing; LL(k)-Grammar; Bottom up parsing; Error handling; LR grammars and their properties; Error handling in LR(k) language; Intermediate languages; Code optimization; Machine code generation; Machine dependent optimization.

Practical

Program for - magic squares, FSM for unsigned constant, context free grammar, shift reduce parsing, operator precedence parsing, recursive decent parsing, predictive parser, simple LR parser, postfix form for intermediate code, compile compilers. Design - a lexical analyser for regular expression, a finite state machine for reserved word.

Suggested Readings

Aho, A.V. and Ullman, J.D. (1993). Principles of Compiler Design Theory, Narosa Publishing House, New Delhi.

Lewis, P.M., Rosenkrantz, D.J. and Streams, R.E. (1978). Compiler Design Theory, Addison Wesley, Reading, Massachusetts,

Treernblay, J.P. and Sorenson, P.G. (1985). The theory and Practice of Compiler Writing, McGraw Hill Book Company, New York

16. Data Analysis in Agriculture (1+1)

Use of Software packages for: Summarization and tabulation of data; Descriptive statistics; Graphical representation of data; Fitting and testing the goodness of fit of probability distributions; Testing of hypothesis; t-test, Chi-square test and F-test; Concept of analysis of variance and covariance of data for one-way and multi-classified experiments; Analyzing crossed and

nested classified designs; Analysis of mixed models; Estimation of variance components; Testing the significance of contrasts; Correlation and regression including multiple regression; Discriminant function; Factor analysis; Principle component analysis; Analysis of time series data etc.

Practical

Use of software packages for Summarization and tabulation of data, Measures of central tendency, dispersion, skewness and kurtosis, To obtain frequencies and basic statistics including graphical representation of data, Robust Estimation, Testing linearity and normality assumption, Estimation of trimmed means etc., Cross tabulation of data including its statistics, cell display and table format and means for different sub-classifications, Fitting and testing the goodness of fit of probability distributions, Testing the hypothesis for one sample T-test, two sample T-test, paired T-test, test for large samples - Chi-squares test, F test, One way analysis of variance , contrast and its testing, pairwise comparisons, Multiway classified analysis of variance - cross-classification, nested classification, factorial set up; fixed effect models, random effect models, mixed effect models, estimation of variance components, Generalized linear models - analysis of unbalanced data sets, testing and significance of contrasts, Estimation of variance components in unbalanced data sets - maximum likelihood, ANOVA, REML, MINQUE, Bivariate and partial correlation, Distances - to obtain a distance matrix, dissimilarity measures, similarity measures, Linear regression, Multiple regression, Regression plots, Variable selection, Regression statistics, Fitting of growth models - curve estimation models, examination of residuals, Discriminant analysis - fitting of discriminant functions, identification of important variables, Factor analysis-descriptive statistics and correlation coefficients. different extraction methods, working different factor scores, Principal component analysis - obtaining principal component, spectral composition, Analysis of time series data - fitting of ARIMA models, working out moving averages.

Suggested Readings

Anderson, C W and Loynes R M (1987) The Teaching of Practical Statistics, Wiley, Chichester.

Atkinson, A C (1985) Plots Transformations and Regression, Oxford University Press, Oxford.

Chambers, J M , Cleveland W S , Kleiner, B and Tukey, P A (1983) Graphical Methods for Data Analysis, Wadsworth, Belmont, California.

Chatfield, C (1983) Statistics for Technology, 3rd Edn., Chapman and Hall, London.

- Chatfield, C (1995) *Problem Solving: A statistician's guide*, Chapman and Hall, London.
- Chatfield, C and Collins A J (1980) *Introduction to Multivariate Analysis*, Chapman and Hall, London
- Cleveland, W S (1985) *The Elements of Graphing Data*, Wadsworth, Belmont, California.
- Ehrenberg, A S C (1982) *A Primer in Data Reduction*, Wiley, Chichester.
- Erickson, B H and Nosanchuk, T A (1992) *Understanding Data 2nd Edn*, Open University Press, Milton Keynes.
- Everitt, B S and Dunn, G (1991) *Advanced Multivariate Data Analysis, 2nd Edn*, Arnold, London.
- Geisser, S (1993) *Predictive Inference: An Introduction*, Chapman and Hall, New York.
- Miller, R G Jr. (1986) *Beyond ANOVA, Basics of Applied Statistics*, Wiley, Chichester
- Ryan, B F and Joiner, B L (1994) *MINITAB Handbook, 3rd Edn.*, Duxbury Press, Belmont, California.
- Snell, E J (1987) *Applied Statistics: A Handbook of BMDP Analyses*, Chapman and Hall, London.
- Snell, E J and Simpson, H R (1991) *Applied Statistics: A Handbook of GENSTAT Analyses*, Chapman and Hall, London.
- Sprent P (1993) *Applied Nonparametric Statistical Methods, 2nd Edn.* Chapman and Hall, London.
- Tufte, E R (1983) *The Visual Display of Quantitative Information*, Graphics Press, Cheshire, Conn..
- Velleman P F and Hoaglin D C (1981) *Application, Basics and Computing of Exploratory Data Analysis*, Duxbury Press, Boston, Mass.
- Weisberg, S. (1985) *Applied Linear Regression*, Wiley, New York .
- Wetherill G B (1982) *Elementary Statistical Methods*, Chapman and Hall, London .

Wetherill G B (1986) Regression Analysis with Applications, Chapman and Hall, London

17. Simulation and Modeling

(1+1)

Uses and purposes of simulation; Classification of models; Generation and testing of random numbers, Simulation of stochastic events and processes, Design of simulation experiments, Analysis of data generated by simulation experiments, Discrete event simulation; Verification and validation of simulation models, Simulation languages, Simulation of agricultural problems and systems,

Practical

Generation of random numbers, testing randomness of generated random numbers, Generation of random variates following Normal, Beta, Gamma, Exponential, Chi-square, Student's-t, F, Weibull, Binomial, Poisson distributions with the given parameters, Discrete event simulation, Simulation from specific models applicable in agriculture.

Suggested Readings

Brately, P., Fox, B.L. and Schrage, L.E. (1987). A Guide to Simulation. Springer Verlag, New York.

Deo, N. (1987). System Simulation with Digital Computer. Prentice and Hall of India, New Delhi.

Kennedy, W. J. and Gentle, J.E. (1980). Statistical Computing. Marcel and Dekker, New York.

Kleijnen, J. P. C., (1974). Statistical Techniques in Simulation - (In two parts). Marcel and Dekker, New York.

Knuth, D.E. (1968). Art of Computer Programming, Vol. I. Fundamental Algorithms. Addison Wesley, Reading, Massachusetts.

Payer, T. A. and Hill, M. (1982). Introduction to Simulation. McGraw Hill. New York

Press, W. H., Flannery, B. P., Teukolsky, S. A., and Vetterling, W. T., (1986). Numerical Recipes: The Art of Scientific Computing. Cambridge University Press, Cambridge.

Ripley, B.D. (1987). Stochastic Simulation. John Wiley and Sons, New York.

Shannon, R. E. (1975). *System Simulation - the Art of Science*. Prentice Hall, New York.

Taha, H.A. (1999). *Operations Research: An Introduction*. Prentice Hall of India, New Delhi.

18. GIS and Remote Sensing Techniques (2+1)

Introduction to Geographical Information System (GIS); Introduction- maps and spatial information, components of a GIS; GIS Internals - data representation- raster and vector data structures and analysis techniques; Digital Elevation Models; Data input, verification, storage and output; Spatial modelling- manual and automatic digitizing process; Data errors in GIS; Classification methods-multivariate analysis and classification; Spatial interpolation; Current and potential uses of GIS in agricultural planning; Software components used in GIS; GIS in India. Physics of remote sensing, atmospheric effects and remote sensing sensors; Spectral signatures of earth surface features, spectral characteristics of vegetation, soil and water; Data acquisition system, satellite image acquisition; Data collections: pre-processing and data storage; Visual and digital image interpretation; Digital image processing.

Practical

Digitization of a map with the help of a digitizer, Map editing, Geo-referencing and map projections, Creation of attribute database and linking with spatial data, General analysis of the data with the help software, Applications of digital elevation models using GIS, Spatial interpolations using GIS, Visual interpretations of remote sensing data, Geometric corrections of remote sensing digital data, Methods for improving quality of digital data, Techniques of image classifications.

Suggested Readings

Curran, P.J. (1985). *Principles of Remote Sensing*. Longman Inc., New York.

Burrough, P.A. (1986). *Principles of Geographic Information System for Land Resources Assessment*. Oxford University Press, Oxford.

Jensen, J.R. (1996). *Introductory Digital Image Processing*. Prentice Hall, New Jersey.

Lillesand, T.M. and Kiefer, R.W. (1987). *Remote Sensing and Image Interpretation*. John Wiley and Sons, New York.

Peuquet, D. J. and Marble, D. F. (1990). *Introductory Readings in Geographic Information System*. Taylor and Francis, London.

19. Recent Trends and Emerging Programming Paradigms

(1+1)

Latest trends in programming on the emerging technologies relating to software development.

Practical

Designing of the Information Systems using object oriented analysis & design techniques and representation of them using object diagrams, Development of independent components for numerical algorithms (Interpolation, Solutions of simultaneous equations, Numerical integration) using DCERPC (Distributed Computed Environment Remote Procedure Call) compliant languages, Designing of a dynamic website for research organization/university.

Suggested Readings

Naughton, P., and Schildt, H. (2001). The Complete Reference, Java 2. Tata McGraw Hill, New Delhi.

Haefel-Monson, Richard. Enterprise JavaBeans, 2nd Edition, O'Reilly & Associates, Inc. USA

Ayers, D. Bergsten, H. et al. Professional Java Server Programming, Wrox Press Ltd.

List of participants in meeting cum workshop organized on the Broad Subject Matter Areas (BSMA) of Statistical Sciences held at IASRI, New Delhi-110012 on 4th Oct., 1999.

1. Dr. S.D. Sharma, Director, IASRI, New Delhi.
2. Dr. N.L. Maurya, ADG(Acdn.), ICAR, New Delhi.
3. Dr. P. K. Malhotra, Head, Division of Computer Application, IASRI, New Delhi.
4. Dr. G Nageswara Rao, Head Dept. of Statistics, ANGRAU, Hyderabad.
5. Dr. S.P. Dhall, Assoc. Professor, Dept. of Basic Sciences, DYSUHF, Solan.
6. Dr. V. K. Gupta, National Fellow, IASRI, New Delhi.
7. Sh. Mahesh Kumar, Prof. (Agril. Statistics), IASRI, New Delhi.
8. Dr. Prajneshu, Prof. (Agril. Statistics, IASRI, New Delhi.
9. Dr. R. C. Goyal, Principal Scientist, IASRI, New Delhi.
10. Dr. V. K. Bhatia Senior Scientist, IASRI, New Delhi.
11. Sh. Sanjeev Kumar, Scientist, IASRI, New Delhi.