Institute of Statistical Research and Training
University of Dhaka

Curriculum and Syllabus

B.S. Honours Program in Applied Statistics

Session : 2017–2018

www.isrt.ac.bd/academics/undergraduate

Institute of Statistical Research and Training

The Institute of Statistical Research and Training (ISRT), University of Dhaka, is the leading institution for training and research in Applied Statistics in Bangladesh. It was founded in 1964 by the Late National Professor Dr. Qazi Motahar Husain, an eminent scientist, academician and a leading proponent of the statistical sciences in this country. The Institute offers a 4-year B.S. (Honours) program that has been designed to produce graduates with strong statistical computing skills, sound knowledge of statistical concepts and the versatility to apply these concepts in areas as diverse as medicine, engineering, economics and the social sciences. The 1-year M.S. program consists of specialized courses in areas ranging from environmental statistics to clinical trials, statistical machine learning and meta analysis and has been designed for students with a keen interest in higher studies and research. In addition, the Institute offers Ph.D. and M.Phil. degree programs. Highly experienced faculty members with a minimum educational qualification of a masters degree, most of whom also have Ph.D. degrees from reputed universities across the world, run these programs.

ISRT boasts an academic environment that is highly competitive and conducive to research. Both students and faculty members benefit from the regular seminars and talks given by researchers from home and abroad on topics of current interest. The Institute has a rich library with well over 15,000 books and is equipped with three state-of-the-art computer labs, cloud computing facilities and high-speed internet access for graduate and undergraduate students. The aim is to provide a learning environment that stimulates intellectual curiosity, critical thinking and independent problem-solving skills. The Journal of Statistical Research (JSR), an international journal which is being published bi-annually by ISRT since 1970, serves as a forum for the exchange of research ideas between statisticians in Bangladesh and abroad. Faculty members conduct research in diverse areas such as biostatistics, spatial statistics, statistical pattern recognition, Bayesian analysis and econometrics and regularly publish in peer-reviewed journals.

Among its other activities, the Institute frequently organizes short courses and training programs for non-statisticians working in government and non-government organizations who find themselves using statistics in their work. In doing so, it has played an active role in promoting and creating awareness about the need for sound statistical practices among people from other disciplines so that they may work more efficiently within their organizations. ISRT also maintains close ties with the Bangladesh Bureau of Statistics and other organizations responsible for the collection and dissemination of statistical data in Bangladesh and is frequently called upon to offer its expertise on statistical issues of national interest. Over the years the Institute has played a significant role in the country's development by producing world class statisticians for academia and industry in addition to providing statistical expertise on issues of national interest. In addition to that the Institute provides statistical consulting service through StatLab primarily for the students and faculty members of the University of Dhaka, with an aim to strengthen research on campus by assisting graduate students and faculty members of other disciplines.

B.S. Honours Program in Applied Statistics

The B.S. honours program in Applied Statistics is an integrated four-year program. A student with high academic attainment in S.S.C. and H.S.C. or equivalent levels with Mathematics as a subject of study is eligible for admission. The regulations for admission of the students and the examinations will be same as those of the B.S. honours courses in the Faculty of Science unless otherwise stated. The program includes courses of both theoretical and applied nature with intensive computing facilities, but more emphasis is given on the applications of the statistical techniques to real life situations arising in medicine, engineering, business, social, environmental and biological sciences. The course is so designed that after successful completion, the graduates are equipped to work efficiently and competently in government and non-government organizations, research organizations, service departments and other related fields.

Structure of the Program

The 4-year B.S. Honours program comprising of four academic sessions, each having a duration of 12 calendar months to be distributed as follows:

26 weeks	for holding classes
4 weeks	preparation for examinations
10 weeks	annual examination and publications of results
12 weeks	vacation and holidays

Each student has to take a total of 140 credits over four academic years. These include 107 credits of theoretical courses, 22 credits of computing courses and 8 credits of oral. For theoretical courses, 23 credits will be from courses of Mathematics, Economics and Computer Science. Detail breakdown on distribution of the courses with credit hours is given later.

The credit is defined as follows:

(i) For theoretical courses, 15 class hours of 50 minutes each = 1 credit.

(ii) For computing courses, 15 class hours of 50 minutes each for lab work + 15 hours for practices = 1 credit.

Assessment System

Evaluation: The performance of a student at each year in a given course will be evaluated by in-course examinations/assignments/ performance evaluation in the class/final examinations. The examination consists of four parts, one at the end of each academic year. Thirty percent marks of the theoretical courses and forty percent marks of the computing courses will be allotted for in-course examinations and attendance.

The marks allocation for theoretical courses will be as follows:

Attendance	:	05
In-course exam	:	25
Final exam	:	70

The marks allocation for computing courses will be as follows:

Attendance/assignment	:	10
In-course exam	:	30
Final exam	:	60

There will be two in-course examinations for each of the theoretical and computing courses. Students in in-course may be evaluated by giving short questions as decided by the course teacher. Each in-course assessment will be of one-hour duration for a theory course and the average of marks from two exams will be considered as the final mark. However, the duration of an in-course assessment is 1.5 hours for a computing course and the sum of two marks will be taken as the final mark.

The duration of theoretical course final examinations will be as follows:

Credit	Duration of Examination
4	4 hours
3	3 hours

The duration of practical course final examinations will be of 4 hours.

Marks distribution for attendance:

Attendance (%)	Marks (%)
90 and above	05
85 to 89	04
80 to 84	03
75 to 79	02
60 to 74	01
Less than 60	00

Grading and Grade Point: Grades and grade points will be awarded on the basis of marks obtained in the written, oral and practical examinations according to the following scheme:

Marks Obtained (%)	Grade	Grade Point
80-100	A+	4.00
75-79	A	3.75
70-74	A-	3.50
65-69	B+	3.25
60-64	B	3.00
55-59	B-	2.75
50-54	C+	2.50
45-49	C	2.25
40-44	D	2.00
less than 40	F	0.00
	I	Incomplete
	W	Withdrawn

Only 'D' or higher grades will be counted as credits earned by a student. Grade point average (GPA) will be calculated as the weighted average of the grade points obtained by a student in all the courses completed in a year. GPA will be calculated according to the following formula:

$$\text{GPA} = \frac{\sum(\text{grade points obtained in a course x total credit for that course})}{\text{total credits taken at a given year}}$$

CGPA = cumulative GPA for different years.

Promotion to the Next Academic Year: A student has to attend courses required for a particular year, appear at the annual examinations and score a minimum specified GPA/CGPA for promotion to the next year. Promotion to the next year will be given if a student scores minimum GPA/CGPA as follows:

Promotion	GPA/CGPA	Grade earned
1^{st} year to 2^{nd} year	2.00	D
2^{nd} year to 3^{rd} year	2.25	C
3^{rd} year to 4^{th} year	2.50	C+

Requirements for the Award of the B.S. (Honours) Degree:

1. Minimum number of required credits must be earned in the maximum period of six academic years starting from the date of 1^{st} year of admission.
2. Must have a CGPA of at least 2.5.
3. A student obtaining an 'F' grade in any course (theory or computing) will not be awarded the degree. A student with an 'F' grade in any course shall be allowed to retake twice/two times either within 3 months of publication of the 4th year results with special fees or with the following batches.

Some policies about the examination system are given below:

1. **In-course Examination**
   (a) No make-up test will be arranged for a student who fails to appear in in-course test/tests. Absence in any in-course test will be counted as zero when calculating the average in in-course test for that course. However, a student can apply to the Director if recommended by the respective course teacher. The Director will place the application before the academic committee only if the particular student has met with an accident or her/his parents have expired or s/he has gone through a surgical procedure or any other such situation which the Academic Committee feels can be considered. The make-up test must be held during the course period.
   (b) Course teachers must announce results within 4 weeks of holding the examinations.
   (c) Marks for in-course assessments must be submitted by concerned course teachers to the Chairman of the Examination Committee and the Controller of Examinations before the final examination.
   (d) Questions for in-course examinations may preferably be of multiple choice (MCQ) types. Students may also be evaluated by giving short questions as decided by the course teacher.

2. **Final Examination**

   (a) The year final examinations will be conducted centrally by the Controller of Examinations as per existing rules.

   (b) Students having 75% or more attendance on average (collegiate) are eligible to appear in the final examination.

   (c) Students having 60-74% attendance are considered to be non-collegiate and will be eligible to sit for the final examination with a penalty (the amount will be fixed by the Dean, faculty of science).

   (d) Students having attendance less than 60% will not be allowed to sit for the final examination but may seek readmission in the program.

   (e) At the beginning of each academic session, an examination committee is to be constituted for that session by the academic committee of the institute. The Chairman of the Examination Committee will act as a course co-ordinator for that session. The examination committee will have a Chairman, two internal members and an external member.

   (f) For theoretical course final examinations, there will be two examiners: the course teacher will be the first examiner and the second examiner will be a faculty from within the department or from any other department of the University of Dhaka relevant to the subject.

   (g) Third Examination: Under the double-examiner system and in case of difference of more than 20% of marks, there will be a third examination. Marks of the nearest two examiners (theory and project report) will be averaged for the final mark.

3. **Time Limits for Completion of Bachelor's Degree**

   A student must complete the courses of her/his studies for a B.S. (Honours) degree in a maximum period of six academic years.

4. **Improvement**

   (a) If a student obtains a grade 'C+' or lower in a course in any year, s/he will be allowed to repeat the term-final examination only once with the following batch for the purpose of grade improvement. However, s/he will not be eligible to get a grade better than 'B+' in such a course. A student failing to improve her/his grade in a course can retain the earlier grade.

   (b) Grade improvement will not be allowed in those courses in which a student obtains a grade better than 'C+'.

(c) For the purpose of grade improvement, a student will be permitted to repeat term final examinations for a maximum of 8 (eight) credits in a specific year.

(d) A student will be allowed to repeat a maximum of 20 (twenty) credits in her/his four years BS Program for grade improvement.

(e) Improvement in the 4^{th} year courses: Students would be allowed to sit for improvement examination in the 4^{th} year courses with the following batch, provided they must do it before the publication of final result by the office of the Controller of Examinations or Issuance of Provisional Certificate by the Controller of Examinations.

5. **Admission to Next Academic Year and Readmission at the Same Year**

   (a) A student should take admission to the next academic year within 2 (two) months after publication date of the results of the current year.

   (b) A student (if applicable) can take readmission 2 (two) times throughout the program either in the same class or in different classes. In both cases, s/he must complete the degree by 6 (six) years from the time of original admission.

   (c) A student (if applicable) may seek readmission and continue studies as a regular student provided s/he has at least 30% attendance in the previous year.

   (d) On readmission (if applicable), the student has to retake all courses and examinations. In case s/he does not get the opportunity to repeat the courses due to late admission, marks of in-course assessment and laboratory performance/ assessments in the previous year may be retained by the student. In this case, s/he must retain in-course marks of all previous year courses but not part of the courses.

6. **Academic Awards**

   A student can earn the following awards on very successful completion of the degree.

   (a) As a recognition of excellent performance, the names of the students may be included in Dean's Honor Award or Dean's Merit Award in an academic year without appearing at any improvement examination. There will be two categories of awards for graduate students:

      i. **Dean's Honor Award**: students with CGPA 3.85 and above (Dean of the faculty of science may change the cutoff).

ii. **Dean's Merit Award**: students with CGPA 4.00.

(b) To be eligible for the ISRT Golden Jubilee award, a student must have a B.S. degree in Applied Statistics with the highest CGPA among the students of her/his class without sitting in any improvement examination and have shown outstanding academic merit throughout her/his work for the degree. Note that the student must have completed the degree in four years.

7. **Other General Regulations**

   For any matter not covered in the above guidelines, existing rules for Integrated Honours Course of Dhaka University will be applicable.

Structure of the Courses

Distribution of courses, credits, marks and detailed syllabus are as follows:

Courses for the FIRST Year

Course ID	Course Title	Credit
AST 101	Elements of Applied Statistics	4
AST 102	Elements of Probability	4
AST 103	Programming with C/C++	3
AST 104	Basic Mathematics	3
AST 105	Calculus	4
AST 106	Principles of Economics	4
AST 107	Linear Algebra	3
AST 130	Statistical Computing I	2
AST 131	Statistical Computing II	2
AST 140	Oral I	2
Total		31

Courses for the SECOND Year

Course ID	Course Title	Credit
AST 201	Sampling Distributions and Simulation	4
AST 202	Actuarial Statistics	3
AST 203	Statistical Inference I	3
AST 204	Design and Analysis of Experiments I	3
AST 205	Introduction to Demography	3
AST 206	Sampling Methods I	4
AST 207	Mathematical Methods	3
AST 230	Statistical computing III: R and Matlab	2
AST 231	Statistical Computing IV	2
AST 232	Statistical Computing V	2
AST 240	Oral II	2
Total		31

Courses for the THIRD Year

Course ID	Course Title	Credit
AST 301	Design and Analysis of Experiments II	4
AST 302	Sampling Methods II	3
AST 303	Linear Regression Analysis	4
AST 304	Epidemiology	3
AST 305	Population Studies	3
AST 306	Statistical Inference II	3
AST 307	Multivariate Statistics I	3
AST 308	Industrial Statistics and Operations Research	4
AST 309	Mathematical Analysis	3
AST 330	Statistical computing VI: SPSS, Stata and SAS	2
AST 331	Statistical Computing VII	2
AST 332	Statistical Computing VIII	2
AST 340	Oral III	2
Total		38

Courses for the FOURTH Year

Course ID	Course Title	Credit
AST 401	Advanced Probability and Stochastic Processes	4
AST 402	Statistical Inference III	3
AST 403	Multivariate Statistics II	4
AST 404	Econometric Methods	4
AST 405	Lifetime Data Analysis	4
AST 406	Research Methodology and Social Statistics	4
AST 407	Analysis of Time Series	3
AST 408	Generalized Linear Models	3
AST 430	Statistical Computing IX	2
AST 431	Statistical Computing X	2
AST 432	Statistical Computing XI	2
AST 440	Oral IV	2
AST 450	B.S. Project	3
Total		40

Detailed Syllabus - First Year

AST 101: Elements of Applied Statistics	Credit 4

Introduction

Statistics is about extracting meaning from data. This course will introduce techniques to collect, present, summarize data in order to visualize the relationships in data and systematic techniques for understanding the relationships using mathematics.

Objectives

The main objective of this course is to acquaint the students with the methods of obtaining and analyzing data in order to make better decisions in an uncertain and dynamic phenomenon. Emphasis will be given mainly on basic statistical methods and techniques.

Contents

Introduction to statistics: meaning of statistics; scopes and limitations; concepts of descriptive and inferential statistics; basic concepts: data, sources of data - primary and secondary data; population, sample, parameter, statistic; variables and types of variable: qualitative, quantitative discrete and continuous; scales of measurements; classification of variable by scales of measurements.

Organization and presentation of data: graphical presentation for qualitative and quantitative data; sorting data, grouping qualitative and quantitative data: construction of frequency distribution and relative frequency distribution; graphical presentation of frequency distribution- histogram, frequency polygon, ogive.

Concept of distribution: location, scale (spread) and shape, illustration with stem-and-leaf diagram; descriptive measures of data; measures of location; measures of dispersion; moments and their interrelationship; measures of skewness and kurtosis; three- and five-number summary; box-plot and modified box-plot.

Description of bivariate data: bivariate frequency distribution; graphical presentation of bivariate data; contingency table; concept of association between two variables; percentage table and interpretation of cell frequencies; measures of association for nominal and ordinal variables; measures of association for interval or ratio variables; correlation; relationship between two variables: simple linear regression; basic issues in inferential statistics.

Text Books

1. Newbold P (2004). Statistics for Business and Economics, 3^{rd} *edition.* Prentice-Hall.
2. Weiss N (2007). Introductory Statistics, 7^{th} *edition.* Addison Wesley.

AST 102: ELEMENTS OF PROBABILITY — **Credit 4**

Introduction

This is an introductory course on probability theory. This course attempts to provide basic concepts of set theory, experiment and sample space, and different approaches of defining probability. It discusses useful laws of probability, conditional probability, Bayes rule, random variables and their distributions, and functions of random valuables. It also covers discussions on certain operators like mathematical expectation and generating function with properties and applications, and thorough discussions on commonly used probability distributions such as Binomial, Hyper geometric, Negative Binomial, Poisson, Normal, Exponential and Gamma distributions.

Objectives

To provide basic concepts of sets, counting techniques, and acquaint students with necessary skills for solving probability related problems using appropriate laws. To introduce the notions of random vaiables. To develop ability to find probability distribution of random variables and of their functions. To introduce operators like generating functions, expectation, etc. for studying the characteristics of distributions. To make familiar with basic probability distributions with possible areas of applications. To prepare the students for learning advance courses where probability theory has a prominent role.

Contents

Combinatorial analysis: basic principles of counting, permutations, combinations; axioms of probability: sample space and events, axioms of probability, sample spaces having equally likely outcomes, probability as a measure of belief; conditional probability and independence: conditional probabilities, Bayes formula, independent events.

Random variables: introduction, discrete random variables, expectation, expectation of a function of a random variable, variance, Bernoulli and binomial random variables, Poisson random variable, other discrete random variables (geometric, negative binomial, hypergeometric); expected value of a sums of random variables; properties of cumulative distribution function; continuous random variables: expectation and variance of continuous random variable, normal random variable, normal approximation to binomial distribution, exponential random variables.

Jointly distributed random variables: joint distribution functions, independent random variables, sums of independent random variables, conditional distributions (discrete and continuous cases); properties of expectation: expectation of sums of random variables, covariance, variance of sums, correlations, conditional expectation, moment generating functions, probability generating function.

Text Book

1. Ross SM (2009). A First Course in Probability, 8^{th} *edition.* Prentice-Hall.

AST 103: Programming with C/C++ | **Credit 3**

Introduction

Programming with C/C++ course mainly focuses the programming language C and the introductory part of Python. The course introduces machine level language, origin of C and application of C programming in statistics. Fundamental discussion on python program and its association with statistics have also been described in this course.

Objectives

This module covers introductory ideas how to connect C programming with statistics through flowchart and programing code execution using compilation, link and run. To understand how to analyses descriptive statistics and data analysis using C programming.

Contents

Introduction to programming: algorithm, flowchart, code (program); levels of programming: machine level, assembly level and high level language; execution of code: translator, compiler, interpreter, assembler; steps of execution: compilation, link, run.

An overview of C: the origins of the C language, compilers versus interpreters; variables, constants, operators, and expressions: data types, declaration of variables, assignment statements, constants, operators, expressions; program control statements: C statements, conditional statements, loop statements, labels; functions: the return statement, function arguments, arguments to main(), returning pointers, pointers to functions; arrays: single-dimension arrays, passing single dimension arrays to functions, two- and multi-dimensional arrays, arrays and pointers, allocated arrays, array initialization;

Applications of C programming in data analysis: frequency distributions, data summary, e.g. mean, median, maximum, minimum, matrix operations, calculation of different rates, fitting simple linear regression and sorting a vector.

Introduction to Python: data input, display of statistical data.

Text Books

1. Dietel PJ and Deitel HM (2010). C How to Program, 7^{th} *edition.* Pearson.
2. Thomas H (2016). An Introduction to Statistics with Python: With Applications in the Life Sciences. Springer.

AST 104: Basic Mathematics	**Credit 3**

Introduction

Basic Algebra and Differential Equation is the fundament of deriving statistical theories. Sound mathematical knowledge is pre-requisite to understand the basic concept of statistics. This course aims to introduce the number theories which are essential and widely used in the field of statistics.

Objectives

To learn and understand the theory of numbers and differential equation in details. To improve the basic mathematical knowledge and to be competent in using the methods.

Contents

Basic Algebra

Theory of numbers: unique factorization theorem; congruencies; Euler's phi-function; inequalities: order properties of real numbers; Weierstrass', Chebysev's and Cauchy's inequalities; inequalities involving means; complex numbers: field properties; geometric representation of complex numbers; operations of complex numbers; summation of algebraic and trigonometric finite series; theory of equations: relations between roots and coefficients; symmetric functions of roots; Descartes rule of signs; rational roots; Newton's method.

Beta and gamma function and their properties; incomplete beta and gamma function; Dirichlet's theorem; Liouville's extension of Dirichlet's theorem.

Differential Equations

Formulation of simple applied problems in terms of differential equations; equations of the first order and their solutions; singular solutions; geometric applications; linear equations with constant coefficients; method of undermined coefficients; variation of parameters and inverse differential operators; simple cases of linear equations with variable coefficients.

Text Books

1. Ayres F (1995). Theory and Problems of Modern Algebra. McGraw-Hill.
2. Ross SL (1980). Introduction to Ordinary Differential Equations, 4^{th} *edition.* Wiley.

AST 105: Calculus | **Credit 4**

Introduction

The course starts by reviewing the properties of different functions and their graphs, limits, continuity and differentiability. The derivative is used to solve related rates problems and the maximization-minimization problems which have a wide application in different field of science and technology. This course also includes the techniques of integration, and use this to determine areas, lengths, surface area and volumes; multivariable calculus; including partial derivatives, multiple integrals, and their applications.

Objectives

This is a fast-paced course emphasizing computational ability and geometric understanding of calculus. The objective is to provide students with practical mathematical skills necessary for advanced studies in all areas of statistics.

Contents

Part A: Differential Calculus

Real numbers and function; limit and continuity of functions of one variable; derivative of a function of one variable; geometric interpretation of the derivative; differentiation formulas; the chain rule; implicit differentiation; derivatives from parametric equations; higher order derivatives; Leibnitiz's theorem; increasing and decreasing functions; extrema of functions; concavity; Rolle's mean value theorems; applications of the theory of extrema, velocity and acceleration related rates; differentials, Lagrange multiplier.

Indeterminate forms; infinite limits; tangent; normal; curvature; asymptote; curve tracing; areas; functions of several variables; limit and continuity; partial derivatives; chain rule; total differentials; Jacobian extrema.

Part B: Integral Calculus

The anti derivatives (indefinite integral); elementary integration formulas; integration by parts; integration by substitution; integration of rational functions; the definite integral; fundamental theorem of calculus; properties of definite integrals; evaluation of definite integrals; simple reduction formulas.

Arc lengths; volumes and surfaces of solids of revolution; multiple integrals; evaluation of double and triple integrals by iteration; area, volume and mass by double and triple integration.

Text Books

1. Anton H (1995). Calculus with Analytic Geometry, 5^{th} *edition.* Wiley.
2. Stewart J (2006). Calculus: Early Transcendentals (Stewart's Calculus Series).

AST 106: PRINCIPLES OF ECONOMICS **Credit 4**

Introduction

This course provides an introduction to a broad range of economic concepts, description of theories and analytical techniques. It considers both microeconomics: the supply and demand based choices made by individual units (households and firms), and macroeconomics: the broader analysis of the economy. The use of supply and demand models will be the fundamental tools and the trade-offs and choices will be considered through comparison of costs and benefits measures. Production and market structure will be analyzed at the firm level as well. Macroeconomic issues concerning the interaction of goods and services markets, labor supply and economic resources at an aggregate level (region or country level) will be discussed.

Objectives

On successful completion of this course, students will be able to: explain how microeconomic models can be used to consider fundamental economic choices of households and firms; describe how macroeconomic models can be used to analyze the economy as a whole; interpret economic models, diagrams and tables and use them to analyze economic environment; illustrate how government policy influences microeconomic choices and macroeconomic upshots.

Contents

Definition and scope of economics; theory of demand and supply; demand schedule; supply schedule; equilibrium of demand and supply; elasticity of demand and supply: measurement of elasticity; price elasticity of demand and supply.

Demand and consumer behavior; utility theory; equi-marginal principle; indifference curve analysis: consumers surplus; individual and market demand; derivation of demand curve; theory of production: production function; total, average and marginal product; law of diminishing returns; factors of production; pricing of factors of production; division of labor; localization of industries; returns to scale; law of variable proportion; isoquants; Cob-Douglas and CES production function; theory of cost; fixed and variable cost; total and marginal costs; least cost rule; opportunity cost.

Market structure: perfect and imperfect competition; pricing under monopoly, oligopoly and monopolistic competition; short-run and long-run equilibrium analysis; income and wealth: factor incomes vs. personal incomes, role of government, wealth; fundamentals of wage determination, the supply of labor, determinants of supply, empirical findings, wage differentials; basic concepts of interest and capital, prices and rentals on investments, rates of return and interest rates, present value of assets, real vs. nominal interest rates.

Key concepts of macroeconomics: objectives and instruments of macroeconomics; measuring economic success, tools of macroeconomic policy; real vs. nominal GDP, "Deflating" GDP by a price index; consumption, investment, NDP, GNP, price indexes and inflation; consumption and saving: consumption function, saving function; investment: determinants of investment, revenues; theories of economic growth: four wheels of growth, human and natural resources, capital; theories of economic growth: classical dynamics of Smith and Malthus, neoclassical growth model.

Index number: characteristics, problems in the construction, classification; methods: unweighted, weighted: Laspeyre's, Paasche's, Dorbish and Bowley's, Fisher's, Marshall and Edgeworth's, Kelly's and the chain index numbers; test of accuracy, base shifting, splicing, deflating of index numbers; application of consumer price index number.

Text Books

1. Samuelson PA and Nordhaus WD (2009). Economics, 19^{th} *edition.* McGraw Hill.
2. Mankiw NG (2015). Principles of Economics, 7^{th} *edition.* Cengage Learning.
3. Dowling ET (2011). Introduction to Mathematical Economics, 3^{rd} *edition.* McGraw-Hill Education.
4. Newbold P, Carlson W and Thorne B (2012). Statistics for Business and Economics, 8^{th} *edition.* Pearson

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AST 107: Linear Algebra | **Credit 3**

Introduction

Linear algebra can be used in pretty much any application that deals with more than random variable at a time than dealing with a random vector. Particularly, linear algebra will be heavily used in multivariate statistics course(s). Some matrix algebra will also be very convenient for potential studies in Markov chains and stochastic processes. Linear regression is a very common use of linear algebra as well.

Objectives

Solve systems of linear equations using various methods including Gaussian and Gauss-Jordan elimination and inverse matrices. Perform matrix algebra, determinants and their properties. Understand real vector spaces and subspaces and apply their properties. Understand linear independence and dependence. Find basis and dimension of a vector space. Find eigenvalues and eigenvectors and use them in applications. Diagonalize, and orthogonally diagonalize symmetric matrices. Evaluate the dot product, norm, angle between vectors, and orthogonality of two vectors in R_n. Compute inner products on a real vector space and compute angle and orthogonality in inner product spaces. Create orthogonal and orthonormal bases: Gram-Schmidt process and use bases and orthonormal bases to solve application problems.

Contents

Matrices, vectors and their operations: basic definitions and different types of matrices, matrix operations (addition, multiplication), trace of a matrix, determinant and adjoint of a square matrix, properties of determinants, inverse of matrix, properties of inverse, Kronecker product and related operations.

System of linear equations: Gaussian elimination, Gauss-Jordan elimination, homogeneous linear systems, null spaces and the general solution of linear systems, rank and linear systems, generalized inverse of a matrix, generalized inverses and linear systems.

Vector spaces and subspaces: vector addition and scalar multiplication, linear spaces and subspaces, intersection and sum of subspaces, linear independence and dependence, basis and dimension, inner product, norms and orthogonality, orthogonal projections, Gram-Schmidt orthogonalization.

Eigenvalues and eigenvectors: eigenvalue equation, characteristic polynomial and its roots, Eigenspaces and multiplicities, diagonalizable matrices, computation of eigenvalues and eigenvectors.

Singular value and Jordan decompositions: singular value decomposition, SVD and linear systems, computing the SVD, Jordan canonical form.

Quadratic forms: matrices in quadratic forms, positive and nonnegative definite matrices, congruence and Sylvester's law of inertia, nonnegative definite matrices and minors, some inequalities related to quadratic forms, simultaneous diagonalization and the generalized eigenvalue problem.

Text Books

1. Anton H and Rorres C (2013). Elementary Linear Algebra, 11^{th} edition. Wiley.
2. Banarjee S and Roy A (2014). Linear Algebra and Matrix Analysis for Statistics. Chapman and Hall.
3. Anton H and Rorres C (2005). Elementary Linear Algebra, 4^{th} *edition.* Wiley.

AST 130: Statistical Computing I **Credit 2**

Introduction
This course introduces Microsoft Excel as a tool for statistical analysis of data.

Objectives
It will give an extensive training to the students so that they learn how to manage and analyze data in excel.

Contents
Computing problems related to Elements of Applied Statistics.

AST 131: STATISTICAL COMPUTING II **Credit 2**

Introduction
This course consists of programming with C/C++ and linear algebra. It covers the practical applications of descriptive statistics and data analysis using C programming. In addition, matrices and vectors operations, eigenvalues, eigenvectors, Jordan decompositions have also been covered in linear algebra part.

Objectives
The module will be supported by the statistical software code blocks, which forms the basis of weekly lab sessions. Students will develop a strategic understanding of statistics and the use of associated software.

Contents
Computing problems related to Programming with C/C++ and Linear Algebra.

AST 140: ORAL I **Credit 2**

Each student must be examined by a committee of selected members at the end of the academic year.

Detailed Syllabus - Second Year

AST 201: Sampling Distributions and Simulation

Credit 4

Introduction

This course introduces theory of probability and sampling distribution for describing the behavior of random processes, and the concept of simulation of random processes. It also concentrates on the use of sampling distribution in statistical inference. The objective of this course is to familiar various probability distributions and sampling distributions. It includes deriving the properties of distributions, interrelationship between them and focus on their applications for exploratory analysis regarding selection of appropriate distributions for explaining the random behavior based on data and statistical inference.

Objectives

Upon completion of the course, students should get acquainted with the main concepts and uses of probability and sampling distributions in the theory of statistical inference. Student should understand the common simulation techniques. Furthermore, student should use simulation for understanding the properties of the distributions. In this course, students should know how to use the statistical software R to cover the topics.

Contents

Generating function techniques: moment generating function, cumulant generating function, probability generating function, characteristic function; finding distributions of functions of random variables: change of variable technique, distribution function technique and moment-generating function technique; probability integral transformation; statistic and sampling distribution; law of large numbers; central limit theorem; exact distribution of sample mean; chi-square distribution and its properties; F-distribution and its properties; t-distribution and its properties; non-central chi-square, F and t distributions: definition and derivation; concept of order statistics, distributions of single order statistics and joint distribution of two or more order statistics.

Brief review of some discrete distributions; continuous probability distribution and their properties: uniform, normal, exponential, gamma, beta, log-normal, Cauchy; definition of truncated distribution; definition of compound and mixture distribution; family of distributions: Pearsonian distribution.

Concepts of simulation and its uses in statistics; random number generations: congruential generators, seeding; random variate generations: inversion method (direct method), rejection method (indirect method); simulating discrete random variables; simulating normal random variables: rejection with exponential envelope, Box-Muller algorithm; Monte-Carlo integration: hit-and-miss method, improved Monte-Carlo integration; variance reduction: antithetic sampling, importance sampling, control variates.

Text Books

1. Robinson E (1985). Probability Theory and Applications. Springer Science & Business Media.
2. Wadsworth GP and Bryan JG (1960). Introduction to Probability and Random Variables. McGraw-Hill.
3. Zehna PW (1970). Probability Distributions and Statistics. Allyn and Bacon.
4. Jones O, Maillardet R and Robinson A (2009). Introduction to Scientific Programming and Simulation using R. Chapman & Hall/CRC.
5. Arnold BC, Balakrishnan N and Nagaraja HN (2008). A First Course in Order Statistics. Society for Industrial and Applied Mathematics.

AST 202: ACTUARIAL STATISTICS **Credit 3**

Introduction

This course aims at providing an introduction to principles of actuarial science and mathematics involved in it. Topics include role of insurance in economy, different instruments involved in actuarial computations including interest and discount rates, pricing and valuation of actuarial products including annuities, amortization schedules, sinking funds, life assurances and premiums, among others.

Objectives

The course will enable understanding of the fundamental concepts of actuarial science and appreciate its role in economy. It will build a concrete knowledge of underlying theories behind actuarial computations. Finally, it will help to understand how statistical and mathematical models are used in pricing and valuing actuarial products and their real life applications.

Contents

The meaning of actuarial science; role of insurance in the economy; role of an actuary.

Fundamentals of theory of interest: definition of simple interest and compound interest and their comparisons; accumulated value factors and present value factors; effective and nominal rates of interest and their interrelationship; effective and nominal rates of discount; relation between interest and discount; equations of value and use of the time diagram in solutions of problems in interest; problems involving unknown length of investment and unknown rate of interest; annuity; different types of annuities certain; present and accumulated values of immediate annuity and annuity due; present value of deferred annuities and variable annuities; capital redemption policies; amortization schedules and sinking funds.

Actuarial mathematics: discrete life annuity and its applications; present values of different life annuities; life assurance; present values of various life assurances in terms of commutation functions; related problems; premiums; different types of premiums; net premiums; office premiums; prospective policy values.

The basic deterministic model: cash flows; an analogy with currencies; discount functions; calculating the discount function; interest and discount rates; constant interest; values and actuarial equivalence; regular pattern cash flows; balances and reserves; basic concepts; relationship between balances and reserves.

Stochastic interest-rate models: stochastic interest-rate models I; basic model for one stochastic interest rate; independent interest rates; stochastic interest-rate models II; dependent annual interest rates; modelling the force of interest; what one can do with these models.

Text Books

1. Kellison SG (1991). The Theory of Interest, 2^{nd} *edition.* McGraw-Hill/Irwin.
2. Promislow SD (2011). Fundamentals of Actuarial Mathematics, 2^{nd} *edition.* John Wiley & Sons.

AST 203: Statistical Inference I | **Credit 3**

Introduction

This course deals with fundamental concepts and techniques of statistical inference including estimation and tests of simple and composite hypotheses. A brief revision will also be given of some basic topics in probability theory as well as random variables.

Objectives

The aim of the course is to provide a thorough theoretical grounding in statistical inference. The primary objective is to provide an introduction to mathematical statistics necessary for the subsequent study of specialized courses in statistics, biostatistics, actuarial science and econometrics. The impact that statistics has made and will continue to make in virtually all fields of scientific and other human endeavours is considered.

Contents

Basic Concepts: Fundamental ideas of statistical inference; parametric and nonparametric inference; estimators, statistics, parameters; sampling distributions and their uses in inference; point estimation, interval estimation and test of hypotheses; theory and reality.

Point estimation of parameters and fitting of probability distributions: descriptive statistics; exploratory data analysis; least squares estimation; moments based estimation; maximum likelihood estimation; uses of graphical tools for assessing goodness of fit; asymptotic distributions of maximum likelihood estimators.

Interval estimation: methods for constructing confidence interval - pivotal quantity method, Wald- type method, likelihood ratio based method; confidence intervals for means; confidence intervals for the difference of two means; confidence intervals for proportions; interpretation of confidence intervals.

Testing hypotheses and assessing goodness of fit: heuristics of hypothesis testing; errors in hypothesis testing, statistical significance and power; exact tests and approximate tests; tests about one population mean, test about the equality of two population (independent and paired) means; test about the equality of more than two population means; test about proportions; likelihood ratio test; statistical tests applied to categorical data: Fisher's exact test, chi-square test of homogeneity and independence; chi-square goodness of fit tests.

Text Books

1. Hogg RV, Tanis EA and Zimmerman DL (2015). Probability and Statistical Inference, 9^{th} *edition*. Pearson.
2. Hogg RV, McKean J and Craig AT (2010). Introduction to Mathematical Statistics, 7^{th} *edition*. Pearson.

AST 204: Design and Analysis of Experiments I	**Credit 3**

Introduction

This course covers methodological and practical issues to design and analysis of experiments. Topics covered will include an introduction to design of experiments, completely randomised design, randomised complete block design, Latin square design and balanced incomplete block design.

Objectives

The course will help to understand the methodological issues of experimental design. Students will develop an understanding to write hypotheses that can be tested using experiments. Finally, it will build a base to analyse and interpret data obtain from experiments.

Contents

Introduction to design of experiments: strategy of experimentation; some typical examples of experimental design; basic principles; guidelines for designing experiments.

Experiments with a single factor: the analysis of variance; analysis of fixed effects model; estimation of model parameters; unbalanced data; model adequacy checking; regression model, comparisons among treatment means, graphical comparisons of means, contrasts, orthogonal contrasts, multiple testing, Scheffe's method, comparing pairs of treatment means, comparing treatment means with a control; Determining sample size; operating characteristic curve, specifying standard deviation increase, confidence interval estimation method; discovering dispersion effects; regression approach to analysis of variance; least squares estimation of the model parameters, general regression significance test; nonparametric methods in analysis of variance; the Kruskal-Wallis test.

Randomized blocks, Latin squares, and related designs: the randomized complete block designs (RCBD); statistical analysis of RCBD, model adequacy checking; estimating model parameters; Latin square design; Graeco-Latin square design; balanced incomplete block design (BIBD); statistical analysis of BIBD; least squares estimation of BIBD; recovery of intra-block information in the BIBD.

Text Book

1. Montgomery DC (2001). Design and Analysis of Experiments, 5^{th} *edition*. Wiley.

AST 205: Introduction to Demography **Credit 3**

Introduction

Demographic data contains valuable information about a countrys socio-economic development, population growth and trend as well as the overall public health scenario. Thus Demographic data comprises significant importance both in statistics and public health arena. This course focuses on defining the demographic life events and explains the statistical analysis procedures.

Objectives

The course is intended to introduce the basic ideas of demography and state the importance of demographic studies. It helps to understand well-known demographic theories and different measures of demographic events. Students will perceive and analyze current demographic situation of Bangladesh.

Contents

Basic concept of demography; role and importance of demographic/population studies; sources of demographic data: census, vital registration system, sample surveys, population registers and other sources especially in Bangladesh.

Errors in demographic data: types of errors and methods of testing the accuracy of demographic data; quality checking and adjustment of population data; post enumeration check (PEC) and detection of errors and deficiencies in data and the needed adjustments and corrections.

Fertility: basic measures of fertility; crude birth rate, age specific fertility rates (ASFR), general fertility rate (GFR), total fertility rate (TFR), gross reproduction rate (GRR) and net reproduction rate (NRR), child-woman ratio; concept of fecundity and its relationship with fertility.

Demographic theory: transition theory and the present situation in Bangladesh; Malthus' theory and its criticism. Mortality: basic measures of mortality: crude death rate (CDR), age specific death rates (ASDR), infant mortality rate, child mortality rate, neo-natal mortality rate; standardized death rate its need and use; direct and indirect standardization of rates; commonly used ratios: sex ratio, child-woman ratio, dependency ratio, density of population.

Fertility and mortality in Bangladesh since 1951: reduction in fertility and mortality in Bangladesh in recent years; role of socio-economic development on fertility and mortality.

Nuptiality: marriage, types of marriage, age of marriage, age at marriage and its effect on fertility, celibacy, widowhood, divorce and separation, their effect on fertility and population growth.

Migration: definition, internal and international migration; sources of migration data; factors affecting both internal and international migration, laws of migration; impact of migration on origin and destination, its effect on population growth, age and sex structure, labor supply, employment and unemployment, wage levels, and other socio-economic effects; migration of Bangladeshis abroad and its impact on overall economic development of the country.

Text Books

1. Siegel JS and Swanson DA (2004). The Methods and Materials of Demography, 2^{nd} *edition.* Emerald.
2. Shryock HS, Siegel JS and Larmon EA (1975). The Methods and Materials of Demography, volume I and II. U.S. Department of Commerce Publication.

AST 206: SAMPLING METHODS I **Credit 4**

Introduction

This course introduces basic sampling techniques used in sample survey along with estimation procedures. This course covers simple random sampling, systematic sampling, stratified random sampling, and cluster sampling. It also covers some special sampling designs.

Objectives

To make students familiar with different sampling techniques so that they can determine required sample size and choose appropriate sampling techniques for a real life survey situation.

Contents

Introduction: concept of sampling, and definition of related terms; role of sampling theory, requirements of a good sampling design, steps in a sample survey, probability and nonproba- bility sampling, selection (draw-to-draw) and inclusion probability, sampling weight, with and without replacement sampling, characteristics of estimate: bias, mean square error and variance (precision), errors in sample survey and census, sample size determination: basics and complex scenarios.

Simple random sampling (SRS): sample selection, estimation: mean, total, proportion, ratio of two quantities, unbiasedness and variances/standard errors (SEs) of the estimators, estimators of the SEs, confidence interval (normal approximation); finite population correction, estimation over subpopulation, computation: inclusion probabilities and sampling weights.

Systematic sampling: motivation, use and challenges, sample selection, different estimators and their unbiasedness and variances, estimator of the variances, comparison with SRS, sampling from population with linear trend or periodic variation.

Stratified random sampling: concept, reasoning and needs in heterogeneous population, number and formation of strata, sample selection, estimators (total, mean, proportion), variances of the estimators, estimators for the variances, different allocation techniques, comparison with SRS, design effect and its uses, poststratification, quota sampling.

Auxiliary information in estimation: ratio estimators (total, mean), different properties: un- biasedness, variance (approximate), estimated variance, confidence interval, comparison with mean per unit estimates, conditions for best linear unbiased ratio estimator, application in stratified sampling, unbiased ratio-type estimates; product estimator; regression estimator: lin- ear regression estimate and its properties (unbiasedness, variance and estimated variance) under preassigned b and estimated b, comparison with mean per unit estimate, application in stratified sampling, relative merits and demerits.

Cluster sampling: motivation and reasoning, formation and size of clusters; cluster sampling with equal sized clusters: estimators and their various properties (unbiasedness, variance and estimated variance), comparison with SRS and systematic sampling, optimum cluster size, strat- ification in cluster sampling: estimation and comparison with simpler sampling designs.

Special sampling designs: capture-recapture sampling: implementation, Peterson and Chapman estimators for population size and their variances, Hypergeometric and Multinomial models for estimating population abundance; ranked set sampling: sample selection and estimation.

Text Books

1. Cochran WG (1977). Sampling Techniques, 3^{rd} *edition.* Wiley.
2. Lohr SL (1998). Sampling: Design and Analysis. Duxbury.
3. Levy PS and and Lemeshow S (2008). Sampling of Populations: Methods and Applications, 4^{th} *edition.* Wiley.
4. Rao PSRS (2000). Sampling Methodologies with Applications, 1^{st} *edition.* Chapman & Hall/CRC.
5. Thompson SK (2012). Sampling, 3^{rd} *edition.* Wiley.

AST 207: MATHEMATICAL METHODS **Credit 3**

Introduction

This course presents mathematical and elements of scientific computing approach for solving mathematical problems that arises mainly in science and engineering applications. It deals with the theory and application of numerical approximation technique as well as their computer implementation. Mathematical methods, mainly Fourier analysis and Laplace transform, provide a foundation for further studies in disciplines in which Mathematics and Statistics may play important roles.

Objectives

The course wants to develop an understanding of the core idea and concepts of numerical methods. It will enable applying rigorous analytic, highly numerate approach and developing scientific computer programs. Students will also develop the ability to apply Fourier series and Fourier Integrals to significant applied problems especially in telecommunication that are closely related to Laplace transform.

Contents

Interpolation and inverse interpolation: uses of Newton's forward and backward interpolation formula; Lagrange's formula; numerical integration: Simpson's rule;

Weddle's rule; trapezoidal rule; Gauss's quadratic formulae and proper examples from the applications to econometrics, meteorology and biomedicine; Euler's formula of summation and quadrature.

Solution of numerical algebraic and transcendental equations; equations in one unknown; finding approximate values of the roots; finding roots by repeated application of location theorem; method of interpolation or of false position; solution by repeated plotting on a large scale; Newton-Raphson method; Newton-Raphson method for simultaneous equations.

Fourier series: periodic function; Fourier series process of determining the Fourier coefficients; Dirichlet conditions; odd and even functions; half range Fourier sine or cosine series; Parseval's identity; differentiation and integration of Fourier series.

Laplace transform: introduction; definition of integral transformation; definition of Laplace transform; Laplace transform of some elementary functions; sufficient conditions for the existence of Laplace transform; some important properties of Laplace transform; initial and final value theorem; Laplace transforms of some special functions.

Inverse Laplace transform: definition of inverse Laplace transform; Lerch's theorem; some important properties of the inverse Laplace transform; partial function decompositions; definition of convolution; convolution theorem; Heaviside's expansion formula; evaluation of integrals; application of Laplace transform.

Introduction to Taylor's and Laurent series.

Text Books

1. Burden RJ and Faires JD (2010). Numerical Analysis, 9^{th} *edition.* Brooks Cole.
2. Kreyszig E (2011). Advanced Engineering Mathematics, 10^{th} *edition.* Wiley.
3. Jeffrey A (2001). Advanced Engineering Mathematics. Academic Press.

AST 230: STATISTICAL COMPUTING III: **R** AND **Matlab**

Credit 2

Introduction

Any scientific task without the knowledge of software is difficult to imagine and complete in the current scenario. R is a free software that is capable of handling mathematical and statistical manipulations. It has its own programming language as well as built in functions to perform any specialized task. Students intend to learn the basics of R software in this course, along with MATLAB/Octave.

Objectives

To be able to learn and apply the basics of R, like creating objects, writing functions, reading/creating dataframes, reading external data sets, basic programming (looping and if-conditioning), create plots, and also, perform exploratory data analysis. To be able to learn and apply the basic features of MATLAB, including creating objects, basic mathematical operations, creating functions, statistical graphics, and also, basic programming.

Contents

Introduction to R

History and overview of R programming language, R objects, matrices, lists, data frames, reading and writing data files, subsetting R objects, vectorized operations, control structures, functions (both in-built and custom), different loop functions, simulation, calling C function from R.

Exploratory data analysis: managing data frames with dplyr package, exploratory graphs, summary statistics, different plotting systems (base, ggplot2, lattice).

Application of R in optimizing non-linear functions using Newton-Raphson iterative procedure, numerical integration and differentiation.

Introduction to Matlab/Octave

Introduction; basic features; command window; mathematical operations in command window; array operation; matrix operations; logical operations; script m-files; function m-files; data input and output; statistical graphics: common plots in statistics, three dimensional plot, color maps, mash, and surface plots.

Programming and exploratory data analysis with Matlab/Octave.

Text Books

1. Peng RD (2015). R Programming for Data Science. Leanpub.
2. Peng RD (2015). Exploratory Data Analysis with R. Leanpub.
3. Quarteroni A, Saleri F and Gervasio P (2010). Scientific Computing with MATLAB and Octave, 3^{rd} *edition.* Springer.
4. Kabacoff RI (2010). R in Action. Manning.

AST 231: Statistical Computing IV

Credit 2

Introduction

This course is designed to introduce computational methods and algorithms which will be helpful for understanding theoretical concepts and practical applications of probability and sampling distributions, and statistical inference including point and interval estimation and test of hypotheses.

Objectives

To teach students how to write computer codes for simulating data from different probability distributions and use these data to illustrate theoretical concepts related to sampling distributions and statistical inference. To introduce students to computational methods required for fitting probability distributions, conducting point and interval estimation, and performing test of hypotheses using real life datasets.

Contents

Simulation, fitting of probability distributions, point and interval estimation, test of hypotheses.

AST 232: Statistical Computing V | Credit 2

Introduction
This course has two parts. First, students will apply their theoretical knowledge on Design and Analysis of Experiments to analyse practical data from completely randomized, randomized block and Latin square designs. Second, students will analyse practical data from simple random sampling, stratified random sampling, systematic sampling and cluster sampling using their theoretical knowledge on Sampling Methods.

Objectives
The successful completion of the course will enable students to design and analyze an experiment. It will also help them to plan and implement a sample survey.

Contents
Design of experiments (completly randomized, randomized block, Latin square design), sampling methods (simple random, stratified, systematic and cluster sampling).

AST 240: Oral II | Credit 2

Each student must be examined by a committee of selected members at the end of the academic year.

Detailed Syllabus – Third Year

AST 301: Design and Analysis of Experiments II

Credit 4

Introduction

This course deals with the concepts and techniques used in the factorial design. The course examines how to design factorial experiments, carry them out, and analyze the data. Experiments with random factors and nested and split designs are also discussed in this course.

Objectives

On successful completion of this course, the students are expected to: understand the basic ideas of factorial design; design the experiments involving up to 2 and 3 factors with k levels; analyze the data from such experiments; interpret the results of any analysis; and design and analyze the experiments involving random factors.

Contents

Introduction to factorial designs: basic definition and principles; advantage of factorials; two-factor factorial design; statistical analysis of fixed effects model, model adequacy checking, estimating model parameters, choice of sample size, assumption of no interaction in a two-factor model, one observation per cell; general factorial design; fitting response curve and surfaces; blocking in a factorial design.

2^k factorial design: introduction; 2^2 design; 2^3 design; general 2^k design; a single replicate in 2^k factorial design; blocking in a 2^k factorial design; confounding in 2^k factorial design; confounding in 2^k factorial design in two blocks; confounding in 2^k factorial design in four blocks; confounding in 2^k factorial design in 2^p blocks; partial confounding.

Two-level fractional factorial designs: one-half fraction of 2^k design; one-quarter fraction of 2^k design; general 2^{k-p} fractional factorial design; resolution III designs; resolution IV and V designs.

Three-level and mixed-level factorial and fractional factorial designs: 3^k factorial design, confounding in 3^k factorial design, fractional replication of 3^k factorial design, factorials with mixed levels.

Response surface methods: introduction to response surface methodology; method of steepest ascent; analysis of second-order response surface; experimental designs for fitting response surfaces; mixture experiments; robust designs.

Experiments with random factors: random effects model; two-factor factorial with random factors; two-factor mixed model; sample size determination with random effects; rules for expected mean squares; approximate F tests; approximate confidence intervals on variance components; modified large-sample method; maximum likelihood estimation of variance components.

Nested and split-plot designs: two-stage nested designs; statistical analysis, diagnostic checking, variance components; general m-staged nested design; designs with both nested and factorial factors; split-plot design; split-plot designs with more than two factors; split-split-plot design, strip-split-plot design.

Text Books

1. Dean AM and Voss AM (1999). Design and Analysis of Experiments. Springer.
2. Montgomery DC (2001). Design and Analysis of Experiments, 5^{th} *edition.* Wiley.
3. Bailey R (2008). Design of Comparative Experiments. Cambridge.

AST 302: SAMPLING METHODS II | **Credit 3**

Introduction

This course introduces advanced sampling methods used in sample survey. It covers sampling of unequal clusters, two-stage sampling, multistage sampling, methods for estimating variance in complex surveys, and non-sampling errors.

Objectives

To acquaint students with the methodologies associated with the advanced sampling techniques.

Contents

Probability proportional to size (PPS) sampling: motivating examples, with replacement (WR) sampling: cumulative measure of size method and Lahiris method, Hansen-Hurwitz (H-H) es- timator (unbiasedness, variances, estimated variance), comparison with SRS, optimum measure of size, PPS without replacement (WOR) sampling: challenges and solutions, initial probabil- ities, normalizing probabilities, inclusion probabilities and their relation with the sample size, Horvitz-Thompson (H-T) estimator (unbiasedness, variance, estimated variance), different meth- ods of PPSWOR: Brewers method, Durbins method, Des Raj method, Murthys method, Rao- Hartley-Cochran method, Multinomial distribution for PPSWR sampling, H-T estimator in case of PPSWR sampling.

Sub-sampling, sub-sampling of unequal sized clusters: different estimators and their variances, two-stage sampling: design, estimators (total, mean), variances and their unbiased estimators, three stage sampling: design, estimators (total, mean), variances and their estimators, general framework (two-stage and three-stage) for estimating population total, different sampling de- signs at different stages, determination of sample sizes in two and three-stage sampling, optimum sampling and sub-sampling fractions, use of information from pilot survey.

Concept of double sampling and its necessity, application in stratified sampling, and in Ratio and Regression estimators, repeated sampling from the same population: sampling on two and more than two occasions.

Complex survey: definition and challenges involved in complex surveys, approaches of variance estimation (VE), replication methods for VE: random group method, balanced repeated repli- cation (balanced half-sample replication) method, Jackknife method and Bootstrap method, implementation of replication methods in complex sampling designs, post-stratification.

Non-sampling errors: sources of the errors, effects of nonresponse, inference on population pro- portion in presence of nonresponse, types of nonresponse, Call-backs and its effects, Hansen and Hurwitz approach for nonresponse, Politz-Simmons adjustment for bias reduction, mathemat- ical model for errors of measurement, mechanism of nonresponse, imputation and its different techniques.

Special sampling designs: multiplicity, network sampling: design and estimation (multiplicity and Horvitz-Thompson estimators for population total, and their different properties), adaptive sampling: adaptive cluster sampling (ACS) and related concepts used in ACS, Hansen-Hurwitz and Horvitz-Thompson estimators for population total, and their different properties.

Text Books

1. Cochran WG (1977). Sampling Techniques, 3^{rd} *edition.* Wiley.
2. Lohr SL (1998). Sampling: Design and Analysis. Duxbury.
3. Thompson SK (2012). Sampling, 3^{rd} *edition.* Wiley.
4. Kirk MW (2007). Introduction to Variance Estimation, 2^{nd} *edition.*Wiley.

AST 303: Linear Regression Analysis | **Credit 4**

Introduction

This introductory course gives an overview of regression types and details the application of multiple linear regression. This course covers the theory behind regression analysis, multiple linear regression, classical estimation and testing methods, and residual analysis. It also covers the formulation, interpretation and validation of linear regression models, and hands on use of a statistical package (SPSS) to see how the theory can be applied to answer a specific research question.

Objectives

To acquaint students with Least Square methods and concept of linear regression, correlation, and its applications. To approach the material with matrices algebra. To develop the ability to build regression models. To acquaint students with transformations, qualitative variable in the model which broaden the use of linear regression theory. To gain familiarity with the use of modern statistical software packages for building a statistical model.

Contents

Measures of association for quantitative data: correlation and inference concerning correlation; regression and model building, motivating examples, uses of regression.

Simple linear regression model: model for $E(Y|x)$, least squares estimation, assumptions related to errors, maximum likelihood estimation (MLE) of model, sampling distribution of MLEs of the model parameters, inferences concerning the model parameters (confidence intervals and t-test), confidence interval estimate of the $E(Y|x)$ (confidence band).

Model accuracy and diagnostics: goodness of fit test (F-test, coefficient of determination, R^2); prediction and prediction interval for a new Y at specific x, residual analysis: definition, normal probability plot, plots of residuals versus fitted values, residuals versus x, other residual plots, statistical tests on residuals; detection and treatment of outliers; concept of lack of fit and pure error, test for lack of fit, transformations as solution to problems with the model, weighted least squares.

Matrix representation of simple linear regression model, inference and prediction.

Multiple linear regression models: formulation of multiple regression models, estimation of the model parameters: least squares estimation, maximum likelihood estimation, sampling distributions of the MLEs, confidence interval and hypothesis testing for concerning model parameters; model accuracy and diagnostics: goodness of fit test (F test, R^2, adjusted R^2), prediction of a new observation; extra sum of squares principles and its application in testing general linear hypothesis, checking all assumptions concerning model and use of remedy measures when assumptions are not valid, detection and treatment of outliers, influential observations.

Polynomial regression model: introduction; polynomial models in one variable: basic principles, piecewise polynomial fitting; polynomial models in two or more variables; orthogonal polynomials.

Indicator variables: the general concept of an indicator variable, use of the indicator variables in linear regression, models with only indicator variables, idea of regression models with an indicator response variable.

Variable selection and model building: the model building problem, consequences of model mis-specification, criteria for evaluating subset regression models, computational techniques for variable selection.

Validation of regression models: concept, cross validation.

Text Books

1. Weisberg S (2013). Applied Linear Regression, 4^{th} *edition.* Wiley.
2. Montogomery CD and Peck E (1981). Introduction to Linear Regression Analysis. Wiley and Sons.
3. Draper NR and Smith H (1999). Applied Regression Analysis, 3^{rd} *edition.* Wiley.

AST 304: Epidemiology | **Credit 3**

Introduction

This course covers the basic principles and methods of epidemiology, with an emphasis on critical thinking, analytic skills, and application to clinical practice and research. Topics include outcome measures, methods of adjustment, surveillance, quantitative study designs, and sources of data, analysis of exposure-disease relationship and causal inference. The course will provide tools for critically evaluating the literature and skills to practice evidence-based medicine.

Objectives

To become familiar with epidemiologic terminology, outcome measures, and study designs; to appreciate application of epidemiologic methods in the studies of both infectious and chronic diseases and current public health issues.

Contents

Introduction: disease processes, statistical approaches to epidemiological data, study design, binary outcome data, causality.

Measures of disease occurrence: prevalence and incidence, disease rates, hazard function; review of simple random samples, probability, conditional probabilities, and independence of two events.

Measures of disease-exposure association: relative risk, odds ratio, relative hazard, risk, attributable risk.

Study designs: population-based studies, cohort studies, case-control studies, case-cohort studies; Assessing significance of 2×2 tables obtained from chohort designs, case-control designs.

Estimation and inference for measures of assocaition: odds ratio, sampling distribution and confidence interval for odds ratio, relative risk, excess risk, attributable risk.

Confounding and interaction: causal inference, counterfactuals, confounding variables, control of confounding variables by stratification, causal graphs, controllong confounding in causal graphs; Cochran-Mantel-Haenszel test, summary estimates and confidence intervals for odds ratio and relative risk after adjusting for confounding factors.

Interaction: multiplicative and additive interaction, interaction and counterfactuals, test of consistency of association across strata, overall test of association, a test for trend in risk.

Text Books

1. Jewell NP (2003). Statistics for Epidemiology. Chapman and Hall.
2. Kleinbaum DG, Kupper LL and Morgenstern H. (1982). Epidemiologic Research: Principles and Quantitative Methods. Wiley.

AST 305: Population Studies **Credit 3**

Introduction

The course introduces some of the demographic techniques to analyze population data and hence the case of population in Bangladesh.

Objectives

This course is expected to enable the students to achieve understanding of the graduation of population data, use of various life tables, population growth and projection, and the stable and stationary population. In the latter part, the course will shift attention to the case of Bangladesh population focusing the issues such as national policy, growth, trends and factors of demographic variables (e.g., fertility, mortality, morbidity, migration), and relationships with development, population ageing and future prospects.

Contents

Graduation of data: meaning and its need, techniques of graduation, graduation of age distribution; life table: its concept, structure and calculation, complete life table (life table by single year of age) and abridged life table, multiple decrement life tables, working life table, different life table functions and inter-relationships among them, use of life table, etc. Model life tables, Coale and Demeny regional model life tables.

Force of mortality: idea and definition calculation of life table with the help of force of mortality.

Population growth, techniques to measure it, doubling time concept in demography; population estimates and projections; different techniques of population projection- component method, arithmetic/linear method, geometric method, exponential method, matrix method, etc, need for population projections. Use of Lee-Carter model in population projections.

Stable and stationary population, their characteristics and uses; Lotka's characteristics equation, intrinsic birth and death rates, effect of uniform drop in force of mortality on the growth rate, effects of changes in fertility and mortality on the age distribution of population.

Population in Bangladesh: history of growth of population in Bangladesh; implications of the growth of population in Bangladesh; population policy in Bangladesh; level, trends and determinants in fertility, mortality and migration in Bangladesh; interrelationship between population and development; future prospects of population and population control in Bangladesh; aged and aging of population in Bangladesh.

Text Books

1. Shryock HS, Siegel JS and Larmon EA (1975). The Methods and Materials of Demography, volume I and II. U.S. Department of Commerce Publication.
2. Bogue DJ (1969). Principles of Demography. Wiley.

AST 306: STATISTICAL INFERENCE II | **Credit 3**

Introduction

To infer means to make general statements on the basis of specific observations. This is a task undertaken in almost every quantitative field of research. This course deals with the advanced statistical inferential methods. It emphasizes concepts, methods and theory covering the broad topics of hypothesis testing, data reduction, likelihood inference in exponential families and criteria for comparison of estimators. Successful completion of this course will provide a foundation for understanding probability-based statistical inference material presented in other courses.

Objectives

The objective of this course is to provide a thorough theoretical grounding and working knowledge of statistical inference. It aims to teach fundamental materials which will be of use in specialized courses in statistics such as actuarial science and biostatistics. At the end of this course one should be able to perform hypothesis tests, explain the principles of data reduction, judge the quality of estimators as well as choose appropriate methods of inference to tackle real problems.

Contents

Testing hypotheses: approaches to hypothesis testing- Neyman-Pearson approach, Fisher approach and Jeffreys' approach; error probabilities and the power function; the concept of a best test; best critical region; most powerful test via the Neyman-Pearson lemma; uniformly most powerful (UMP) test via the Neyman-Pearson Lemma; likelihood ratio property; UMP test via maximum likelihood ratio property; unbiased and UMP unbiased tests.

Principle of data reduction: Sufficiency- conditional distribution approach, Neyman factorization theorem; minimal sufficiency- Lehmann-Scheffe approach; information- one-parameter situation, multi-parameters situation; ancillarity- location, scale, and location-scale families, its role in the recovery of information; completeness- complete sufficient statistics, Basu's theorem.

Likelihood based inference in exponential families: formulation; estimation- one parameter case and multi-parameter case; approximate normality of MLEs- estimating variance of MLEs; Wald tests and confidence interval; likelihood ratio test and confidence interval; inference about g(θ)- the delta method applied to MLEs.

Criteria to compare estimators- unbiasedness, variance and mean squared error; best unbiased and linear unbiased estimators; improved unbiased estimator via sufficiency; the Rao-Blackwell theorem; uniformly minimum variance unbiased estimator(UMVUE); the Cramer-Rao inequality and UMVUE; the Lehmann-Scheffe theorems and UMVUE; a generalization of the Cramer-Rao inequality; evaluation of conditional expectations; unbiased estimation under incompleteness; does the Rao-Blackwell theorem lead to UMVUE? consistent estimators; comparison of estimators using decision theoretic approach - loss function and risk function; methods of evaluating interval estimators: size and coverage probability.

Text Books

1. Mukhopadhyay N (2000). Probability and Statistical Inference.
2. Rice J (2007). Mathematical Statistics and Data Analysis.
3. Hogg RV, McKean J and Craig AT (2010). Introduction to Mathematical Statistics.

AST 307: MULTIVARIATE STATISTICS I **Credit 3**

Introduction

The objective of the course is to introduce several useful multivariate techniques, and making strong use of illustrative examples.

Objectives

On successful completion of the course, the students should be able to understand the concept of analyzing multivariate data. They should be familiar with a basic minimum level of matrix competency and with general aspects of handling multivariate data. Specifically, the students will be familiarized with the range of multivariate techniques available; will be able to summarize and interpret multivariate data; will have an understanding of the link between multivariate techniques and corresponding univariate techniques; and will be able to use multivariate techniques appropriately, undertake multivariate hypothesis tests, and draw appropriate conclusions.

Contents

Preliminaries of multivariate analysis: applications of multivariate techniques; the organization of data; data display and pictorial representations; distance.

Random vectors and random sampling: some basics of matrix and vector algebra; positive definite matrices; a square-root matrix; random vectors and matrices; mean vectors and covariance matrices; matrix inequalities and maximization; the geometry of the sample; random sample and expected values of sample means and covariance matrix; generalized variance; sample mean, covariance, and correlation as matrix operations; sample values of linear combinations of variables.

The multivariate normal distribution: the multivariate normal density and its properties; sampling from a multivariate normal distribution and maximum likelihood estimation; sampling distribution and large sample behavior of sample mean vector and sample variance-covariance matrix; assessing the assumption of normality; detecting outliers and data cleaning; transformation to near normality.

Inferences about a mean vector: the plausibility of mean vector as a value for a normal population mean; Hotelling T^2 and likelihood ratio tests; confidence regions and simultaneous comparisons of component means; large sample inference about a population mean vector; inferences about mean vectors when some observations are missing; time dependence in multivariate data.

Comparisons of several multivariate means: paired comparisons and a repeated measures design; comparing mean vectors from two populations; comparison of several multivariate population means (one-way MANOVA); simultaneous confidence intervals for treatment effects; two-way multivariate analysis of variance; profiles analysis; repeated measures designs and growth curves;

Multivariate linear regression models: the classical linear regression model; least squares estimation; inferences about regression model; inferences from the estimated regression function; model checking; multivariate multiple regression; comparing two formulations of the regression model; multiple regression model with time dependent errors.

Text Books

1. Johnson RA and Wichern DW (1999). Applied Multivariate Statistical Analysis, 4^{th} *edition.* Prentice-Hall.
2. Srivastava MS (2002). Methods of Multivariate Statistics. Wiley.

AST 308: Industrial Statistics and Operations Research	Credit 4

Introduction

This course deals with the concepts and techniques used in the industry to maintain the quality of the process. Concepts of different types of control charts and their application in industry are discussed in this course. Basic concepts of acceptance sampling and how to design an acceptance sampling are also discussed. The concept and solution procedure of linear programming problem, duality and sensitivity analysis are discussed. Introduction of game theory, in particular the two person zero sum game are discussed.

Objectives

On successful completion of this course, the student is expected to: understand the basic ideas of control chart techniques; apply and interpret control charts for variables and attributes; design acceptance sampling plan; and find optimal solution using Linear Programming Problem.

Contents

Industrial Statistics

Fundamental concepts of industrial statistics and its purposes; industrial quality control: total quality control; statistical quality control; chance and assignable causes of variation; statistical process control.

Control chart: concept of control chart; statistical basis of the control chart; basic principles; choice of control limits; sample size and sampling frequency; rational subgroups; analysis of patterns on control charts; sensitizing rules for control charts; necessary steps for constructing control charts; types of control charts (control charts with standard given and control charts with no standard given); control charts for attributes: concepts of nonconformity; nonconforming unit; defect; defective unit; p-chart; d-chart; c-chart; u-chart; basic concepts of control charts for variables; statistical basis and interpretation of $\bar{X}$, R and S charts.

Cumulative sum and exponentially weighted moving average control charts: the cumulative sum control chart; basic principles; the tabular or algorithmic cusum for monitoring the process mean; recommendations for cusum design; the standardized cusum; the exponentially weighted moving average control chart for monitoring the process mean; design of an EWMA control chart; robustness of the EWMA to non-normality; the moving average control chart.

Acceptance sampling: basic concepts of acceptance sampling; OC curve and its uses; types of OC curves; properties of OC curves. Single sampling plan: basic concepts of single sampling plan for attributes; construction of type A and type B OC curves under single sampling plan for attributes; specific points on the OC curve (AQL, LTPD); rectifying inspection; AOQ; AOQL; ATI; ASN; designing a single sampling plan; double sampling plan: basic concepts of double sampling plan; OC curve; ASN: AOQ; ATI; designing a double sampling plan; introduction to multiple sampling plan and sequential sampling analysis; acceptance sampling plan by variables: basic concepts of acceptance sampling plan; types of sampling plans; designing a variable sampling plan with a specified OC curve.

Operations Research

Nature and impact of OR approach; phases of OR; concept of linear programming problem (LPP); construction of LPP; solution of LPP: graphical and the simplex method; revised simplex method; big-M method, two phase method; concept of convergence, degeneracy and cycling; duality: dual primal relationship and formulation of dual problems; sensitivity analysis: introduction to sensitivity analysis; game theory: finite and infinite games; zero sum games; two person zero sum games; pay off matrix; maximum and minimum criterion of optimal solution of a game; dominance property; algebraic method for the solution of a game; equivalence of rectangular game matrix and linear programming; application in real life situation using MATLAB/Octave software.

Text Books

1. Montgomery DC (2004). Introduction to Statistical Quality Control. Wiley.
2. Hillier FS, Lieberman GJ, Nag B and Basu P (2001). Introduction to Operations Research, 9^{th} *edition.* McGraw-Hill.

AST 309: MATHEMATICAL ANALYSIS | **Credit 3**

Introduction

The study of mathematical analysis is indispensible for prospective students in different sectors of graduate level, specially, in science, engineering, economics and management sciences. This course contains basic properties of real numbers, sets, intervals; sequences and series of real numbers; different properties of limits, continuity, differentiability and integration of a function; and basic concepts of measure theory and probability measure. Calculus is one of most fundamental courses in mathematical sciences and this is the prerequisite course for mathematical analysis.

Objectives

The course has great value for a student who wishes to go beyond the routine techniques to solve standard problems, and who wants to extend ideas to a new context. It develops the ability to analyze mathematical situations properly and precisely. It also helps the students to learn how to work comfortably with concepts that initially seemed so mysterious.

Contents

The real number system; axioms and completeness and its consequences; Dedekind cut, sets, compact sets; simple operation on them.

Sequence of functions of one and several variables; limit; continuity; continuous functions; uniform continuity; differentiation and integration; infinite series of constants and functions; convergence and divergence; power series: differentiation and integration of power series; Taylor expansion with remainder or in infinite series.

Metric and topological spaces; limit points; open and closed sets; interior and exterior points; boundary points; continuous mapping and Cauchy sequences.

Measure and integrals on abstract sets on real lines; Cramer measurability: fundamental definitions; auxiliary lemma; fundamental theorems; measurable functions; Lebesgue measure on a real line, plane; integrals; Riemann-Steiljes integrals.

Text Book

1. Rudin W (1976). Principles of Mathematical Analysis. McGraw-Hill.

AST 330: Statistical Computing VI: SPSS, Stata, and SAS

Credit 2

Introduction

This is an introductory course of the three popular statistical packages. Students will learn to implement different statistical techniques using these packages.

Objectives

The course aims to develop computing skills of the students. The in-depth knowledge of the course will enable a student to analyse data from various sources.

Contents

SPSS

Introduction to SPSS; data entry, reading SPSS and other data sets, import; defining the variable with labels and value labels; working with date and time variable; data matching across cases and variables; basic data management: transformation of data using different (numeric, arithmetic, statistical, and logical) expressions, operations, and functions; different commands in SPSS: get, save, save outfile, split files, sort cases, compute, recode, if, select if, do if, end if, list, aggregate, sample selection, report; graphical presentation: simple bar graphs, line graphs, graphs for cumulating frequency and pie graphs; exploratory analysis: frequencies, descriptive statistics, multiple response, bivariate analysis - crosstabs.

Stata

Introduction to Stata: different windows and files, help file and searching for information; data entry, reading both stata and and other format of data file, combining Stata files; exploring data: example commands-browse, edit, list, sort, describe, assert, codebook; data management: creating a new data set specifying subsets of data with in and if qualifiers, generating and replacing variables, using functions based on egen command, converting numeric and string formats, creating new categorical and ordinal variables, reshaping or collapsing data, weighting observations, creating random data and random samples; graphs: example commands- histograms, scatterplots, line plots, connected-line plots, two-way plots, box plots, combining graphs; exploratory data analysis: summary statistics and tables: example commands - summarize, tabstat, table; frequency tables and two-way cross tabulations, multiple tables and multi-way cross tabulations, tables of means, medians and other summary statistics.

SAS

Introduction to SAS: overview of the SAS data step, syntax of SAS procedures, comment statements; reading different format of data set, infile options, creating and reading a permanent data sets, defining the variable: variable type, variable name, variable formats, variable labels, value labels, working with large data sets, data set subsetting, concatenating, merging and updating; working with arrays; restructuring SAS data sets using arrays, describing data: descriptive statistics, frequency distributions, bar graph and plotting data, creating summary data sets with proc means and proc univariate, outputting statistics other than means; analyzing categorical data: questionnaire design and analysis, adding variable and value labels, recoding data, two-way and multiple tables.

Text Books

1. Cody RP and Smith JK (2005). Applied Statistics and the SAS Programming Language, 5^{th} *edition.* Prentice Hall.
2. Norusis MJ (1988). SPSS/PC for the IBM PC/XT/AT.
3. Hamilton LC (2006). Statistics with Stata, Thomson Brooks/Cole.

AST 331: Statistical Computing VII	**Credit 2**

Introduction
The objective of this course is to equip students with linear regression methods and models used in the analysis of factorial experiments with focus on the practical application of the methods. The computer exercises and project will need to use the free R software/language and the commands to produce the desired output and answer the relevant statistical questions. It includes least squares and maximum likelihood estimation, significance of variables, confidence intervals for model parameters, model selection and validation, residual analysis, and prediction.

Objectives
Upon completion of the course, students should understand how to use R to fit linear models used in factorial experiment and observation studies. Student should understand the least squares and maximum likelihood method of estimation and corresponding methods for testing hypothesis, and should be able to understand the overview of linear models for analyzing observational and experimental data with correct interpretation of the output. Also, students should be able to investigate how well a given model fits the data.

Contents
Fitting simple and multiple regression, analysis of factorial experiments.

AST 332: Statistical Computing VIII | Credit 2

Introduction

This computing course is based on the application of some statistical courses. Mainly the real life application of statistical inference, multivariate techniques, linear programming problem and life table models are discussed. In this course, problems related to hypothesis testing and data reduction are discussed. Application of multivariate normal distribution, inference about a mean vector, comparison of several multivariate means and multivariate linear regression models are discussed with real life data. Life table models and population projections are applied on real data sets to understand the solution procedure. The construction and solution procedures of linear programming problem are discussed.

Objectives

On successful completion of this course, the student is expected to: understand the application of hypothesis testing and data reduction; able to formulate and solve linear programming problem; capable to project population and construct life table; competent to compare several multivariate means and apply multivariate linear regression models.

Contents

Inference, multivariate test and regression, cluster analysis, multidimensional scaling, LPP, life table, population pyramid.

AST 340: Oral III | Credit 2

Each student must be examined by a committee of selected members at the end of the academic year.

Detailed Syllabus – Fourth Year

AST 401: Advanced Probability and Stochastic Processes	**Credit 4**

Introduction

This module covers two important parts, one is advanced probability and another is stochastic processes. The module begins with a brief overview of modern probability and convergence of random variable and then moves on to the stochastic process to describe Markov chains, Poisson process, continuous time Markov chain and renewal process.

Objectives

Students will learn how to apply advanced probability in real life problems and how to give prediction using transition probability and gamblers ruin theory. They should understand the applications of stochastic processes in real life situations.

Contents

Modern probability: events as sets, field, sigma field, probability measure, Borel field and extension of probability measure, measure theoretic approach of random variables; probability space.

Convergence of random variables: modes of convergence: almost sure, rth mean, in probability, in distribution, their interrelationship; law of large numbers, strong and weak laws of large numbers, limiting distribution; central limit theorem; law of iterated logarithm; martingale.

Markov chains: introduction, Chapman-Kolmogorov equations, classification of states, limiting probabilities, gamblers ruin problem, mean time spent in transient states, branching processes, time reversible Markov chains, Markov chain Monte Carlo methods, Markov decision processes, hidden Markov chains.

Poisson process: exponential distribution, properties, convolutions of exponential random variables; counting processes, Poisson process, interarrival and waiting time distributions, further properties of Poisson processes, generalizations of the Poisson process, nonhomogeneous Poisson process, compound Poisson process, conditional or mixed Poisson processes.

Continuous-time Markov chains: introduction, continuous-time Markov chains, birth and death processes, transition probability function, limiting probabilities, time reversibility.

Introduction to queueing theory: Classical M/M/1 queue, global and local balance, performance measures, Poisson arrivals see time averages (PASTA) property, M/M/1/S queueing systems, blocking probability, performance measures, multi-server systems M/M/m, performance measures, waiting time distribution of M/M/m, performance measures of M/M/m/m with finite customer population, Erlang loss systems.

Renewal theory and its applications : introduction, distribution of renewals, limit theorems and their applications, renewal reward processes, regenerative processes, semi–Markov processes, Markov renewal processes.

Text Books

1. Grimmett G and Stirzaker D (2001). Probability and Random Processes, 3^{rd} *edition.* Oxford.
2. Ross S (2010). Introduction to Probability Models, 10^{th} *edition.* Elsevier.

AST 402: STATISTICAL INFERENCE III — **Credit 3**

Introduction

A branch of statistics has been developed to draw conclusion in a short time and cost-effective way regarding the population of interest which is ubiquitously known as statistical inference. It facilitates both parametric and nonparametric approaches under the umbrella of classical and Bayesian paradigms.

Objectives

Learning this course students will be able to draw statistical inference both in classical and Bayesian framework. To do so, a broad range of statistical techniques will be taught, particularly covering parametric, nonparametric and semiparametric inferential approaches. Keeping the diversity of demands in current world, this course is designed in such a way that the students can build up their research career in a wide variety of fields such as social science, medical statistics, clinical trials, spatial statistics, multivariate statistics, etc. It is intended that the students, after the successful completion, will have ample skills in handling data to meet the inferential needs.

Contents

Statistical inference: parametric, nonparametric and semiparametric inference.

Approximate and computationally intensive methods for statistical inference: the general problem of inference; likelihood functions; maximum likelihood estimation; optimization techniques-Newton type methods; EM algorithm-simple form, properties, uses in analysing missing data, fitting mixture models and latent variable model; restricted maximum likelihood (REML) method of estimation; Multi-stage maximization; Efficient maximization via profile likelihood; confidence interval and testing hypothesis in these complex cases; Bayesian method of inference: prior and posterior distribution, different types of prior, credible intervals and testing hypothesis; analytical approximations-asymptotic theory, Laplace approximation; numerical integral methods-Newton-Cotes type methods; Monte carlo methods; simulation methods-Markov chain Monte Carlo.

Resampling techniques: bootstrap-confidence intervals, test, parametric bootstrap, advantages and disadvantages of parametric bootstrap; jackknife-confidence interval, test and permutation test.

Nonparametric inference and robustness: introduction, inference concerning cumulative distribution function (cdf), quantiles and statistical functionals: empirical cdf, quantiles, estimating statistical functionals, influence functions, testing statistical hypothesis-one sample settings, two or more sample settings; tolerance limit; empirical density estimation- histograms, kernel, kernel density estimation.

Text Books

1. Casella G and Berger RL (2003). Statistical Inference, 2^{nd} *edition.* Duxbery.
2. Millar RB (2011). Maximum Likelihood Estimation and Inference: With Examples in R, SAS and ADMB. Wiley.
3. Hogg RV, McKean J and Craig AT (2010). Introduction to Mathematical Statistics, 7^{th} *edition.* Pearson.

AST 403: Multivariate Statistics II | **Credit 4**

Introduction

Multivariate analysis skills have been recognized as part of the key requisites for statistical analysts. The complexity of most phenomena in the real world requires an investigator to collect and analyze observations on many different variables instead of a single variable. The desire for statistical techniques to elicit information from multivariate dimensional data thus becomes essential and crucial for data analysts. This course focuses on multivariate methods based on normal theory. It gives students working knowledge on how to analyze data and solve problems involving measurements of p variables on each of n subjects.

Objectives

The objective of this course is to give students experience with multivariate techniques in the analysis of research data. The aim is to teach students how to select appropriate methods of multivariate data analysis and interpret the results. Having successfully completed this course one should be able to demonstrate knowledge and understanding of: the techniques for displaying and summarizing multivariate data; basic properties of the multivariate normal distribution; standard multivariate hypothesis tests.

Contents

Principal components: population principal components, summarizing sample variations by principal components, graphing the principal components, large sample inference.

Factor analysis: the orthogonal factor models, methods of estimation (maximum likelihood estimates and principal factor analysis), selection of loadings and factor (factor rotation, varimax rotation, quartimax rotation, oblimin rotations), factor scores, structural equations models.

Canonical correlation analysis: canonical variates and canonical correlations, sample canonical variates and sample canonical correlations, large sample inference.

Discrimination and classification: separation and classification of two populations, classification of two multivariate normal populations, evaluating classification functions, Fisher's discriminant function, classification with several populations, Fisher's method for discriminating several populations.

Clustering: similarity measures, hierarchical clustering methods, nonhierarchical clustering methods; fuzzy clustering, determination of number of clusters: Gap statistics and its several modifications, several cluster validity indices, cluster's homogeneity test; multidimensional scaling.

Text Books

1. Johnson RA and Wichern DW (1999). Applied Multivariate Statistical Analysis, 4^{th} *edition.* Prentice-Hall.
2. Srivastava MS (2002). Methods of Multivariate Statistics. Wiley.

AST 404: ECONOMETRIC METHODS | **Credit 4**

Introduction

This course covers a range of econometric methods required to conduct empirical economic research and understand applied econometric results. Topics include models for panel data, simultaneous equations models, models with lagged variables, and limited dependent variables.

Objectives

To introduce students to the basic principles of econometric analysis. To gain theoretical understanding of the methods needed for econometric research including their underlying assumptions, advantages and limitations. To understand how to use different econometric tools in real-world economic problems and interpret findings

Contents

Econometric modeling, data and methodology; specification analysis and model building: bias caused by omission of relevant variables, pretest estimation, inclusion of irrelevant variables, model building; testing non-nested hypotheses, encompassing model, comprehensive approach-J test, Cox test; model selection criteria.

Models for panel data: fixed effects: testing significance of group effects, within- and between-groups estimators, fixed time and group effects, unbalanced panels and fixed effects; random effects: GLS, FGLS, testing for random effects, Hausmans specification test.

Simultaneous equations models: illustrative systems of equations, endogeneity and causality; problem of identification: rank and order conditions for identification; limited information estimation methods: OLS, estimation by instrumental variables (IV), Two-Stage Least Squares (2SLS), GMM Estimation, limited information maximum likelihood and the k class of estimators, 2SLS in nonlinear models; system methods of estimation: Three-Stage Least Squares (3SLS). full-information maximum likelihood, GMM estimation, recursive systems and exactly identified equations; comparison of methods-Kleins Model I; specification tests; properties of dynamic models: dynamic models and their multipliers.

Models with lagged variables: lagged effects in a dynamic model, lag and difference operators; simple distributed lag models: finite distributed lag models, infinite lag model: geometric lag model; Autoregressive Distributed Lag (ARDL) models: estimation of the ARDL model, computation of the lag weights in the ARDL model, stability of a dynamic equation, forecasting; Vector Autoregressions (VAR): model forms, estimation, testing procedures, exogeneity, testing for Granger causality, impulse response functions, structural VARs, application: policy analysis with a VAR.

Limited dependent variable: truncated distributions, moments of truncated distributions, truncated regression model; censored data: censored normal distribution, censored regression (Tobit) model, estimation, issues in specification; censoring and truncation in models for counts, application: censoring in the Tobit and Poisson regression models.

Text Books

1. Greene WH (2011). Econometric Analysis, 7^{th} *edition.* Prentice Hall.
2. Gujarati DN (2010). Basic Econometrics, 5^{th} *edition.* McGraw-Hill.
3. Wooldridge JM (2010). Introductory Econometrics: A Modern Approach, 5^{th} *edition.* Cengage Learning.

AST 405: LIFETIME DATA ANALYSIS | **Credit 4**

Introduction

This course deals with the analysis of survival or failure-time data, which are commonly encountered in scientific investigations. It is being extensively used in medicine, clinical trials, biological and epidemiological studies, engineering, finance and social sciences. This course provides an opportunity for students to learn statistical lifetime probability distributions that are useful for modelling lifetime data. Topics includes lifetime distributions, non-parametric approaches, parametric models and their estimation, accelerated failure time regression models, proportional hazard regression models.

Objectives

The primary focus of the course is to make students to be familiar with the situation where censored data appear and to be able to analyze such data by implementing an appropriate methods and models. Secondly, to introduces students statistical theory and methodology for the analysis of lifetime data from complete and censored samples with emphasis on statistical lifetime distributions, types of censoring, graphical techniques, non-parametric/parametric estimation, and lifetime regression models and related topics.

Contents

Basic concepts and models: lifetime distributions-continuous models, discrete models, a general formulation; some important models-exponential, Weibull, log-normal, log-logistic, gamma distributions, log-location-scale models, inverse Gaussian distributions models, mixture; regression models.

Observation schemes, censoring, and likelihood: right censoring and maximum likelihood; other forms of incomplete data; truncation and selection effects; information and design issues.

Nonparametric and graphical procedures: nonparametric estimation of survivor function and quantiles; descriptive and diagnostic plots; estimation of hazard or density functions; methods of truncated and interval censored data; life tables.

Inference procedures for parametric models: inference procedures for exponential distributions; gamma distributions; inverse Gaussian distributions; grouped, interval censored, or truncated data; mixture models; threshold parameters; prediction intervals.

Inference procedure for log-location-scale distributions: inference for location-scale distributions; Weibull and extreme-value distributions; log-normal and log-logistic distributions; comparison of distributions; models with additional shape parameters; planning experiment for life tests.

Parametric regression models: introduction to log-location-scale regression models, proportional hazards regression models; graphical methods and model assessment; inference for log-location-scale models; extensions of log-location-scale models; hazard based models.

Brief introduction to Cox's proportional hazards model; partial likelihood function, estimation and interpretation of model parameters.

Text Books

1. Lawless J (2003). Statistical Models and Methods for Lifetime Data, 2^{nd} *edition.* Wiley.
2. Kalbfleisch J and Prentice R (2003). The Statistical Analysis of Failure Time Data, 2^{nd} *edition.* Wiley.

AST 406: RESEARCH METHODOLOGY AND SOCIAL STATISTICS

Credit 4

Introduction

This course covers two important parts, one is research methodology and another is social statistics. Research methodology part includes theoretical concept of conducting research, from problem identification to report writing. This part also discusses monitoring and evaluation techniques of intervention programs. Social statistics part includes measurement of national income, poverty and inequality, and psychometric measures.

Objectives

Students will learn how to plan and conduct a survey research. Students will be able to determine appropriate sample size, prepare survey instruments, control both sampling and non-sampling errors, write a study proposal, write a research report, and how to monitor and evaluate development programs. The students will also learn to measure national income, poverty indices, and different psychometric measures.

Contents

Research Methodology

Concept, aims and objectives of research; types of research; steps involved in research: qualitative and quantitative; selection and formulation of research problems; proposal writing; examining the designs of some known researches. Questionnaire, check lists, FGD guidelines etc; preparation of questionnaires; preparation of manuals for interviewer; enumerators' training, monitoring and supervision for controlling the quality of data; how to avoid non-response. Report writing; content and organizations of the report; heading and subheadings; techniques of writing conclusion, summary, recommendations, footnotes references, appendix, etc; examining some local and international reports.

Concept of monitoring and evaluation (M & E): objectives, usefulness and scope of M & E; views of different schools on M & E; performance monitoring versus performance evaluation. Baseline, ongoing and end line evaluation; impact evaluation; M & E of ongoing programs (activities, inputs, outputs, effect); follow-up for remedies, and post-programs evaluation. Monitoring and evaluation plan and data sources: indicators for monitoring and evaluation; identification of indicators and characteristics of ideal indicators; factors influencing indicator selection.

Social Statistics

National income: concepts and methods of measurement; social accounting matrix; theoretical distribution of income and wealth: Pareto and Lognormal distribution of income ; concept, meaning, measurement of positive and normative measures of inequality; Lorenz curve; Gini coefficient; Atkinson's index, Theil's index, Herfindahl index, Human development index etc; desirable properties of a measures of inequality.

Poverty: concept, definition, and issues of poverty; approach for drawing poverty line income; measurement of different poverty indices; Foster, Greer and Thorlock's general class of poverty measure.

Introduction to psychometrics: measurement in psychology and education; intelligent and achievement tests; test scores; equivalence of scores; Z-score and T-score; intelligent quotient.

Definition, nature and importance of anthropology; role and functions of family.

Social inequality: inequality by sex, age, rank, caste, race, class, power, rule and social connections.

Text Books

1. Blankenberg F (1993). Introduction into the Planning, Monitoring and Evaluation System, April, Dhaka.
2. Atkinson AB (1978). The Economics of Inequality. Clarendon.
3. Sen A (1978). On Economic Inequality. Clarendon.
4. Sen A (1982). Poverty and Famines: An Essay on Entitlement and Deprivation. Clarendon.
5. Rahman MPk (1994). Poverty Issues in Rural Bangladesh. University Press Limited, Dhaka.
6. Elifson KW, Runyon R and Haber A (1981). Fundamentals of Social Statistics. Addison-Wiley.

AST 407: ANALYSIS OF TIME SERIES **Credit 3**

Introduction

This is an introductory course of time series theory. The objective of this course is to equip students with various classical time series models, deriving their properties, inference methods and forecasting techniques for analyzing time series data. From computational point of view, it aims to demonstrate the theory with real datasets. Conclusions and proofs are given for some basic formulas and models; these enable the students to understand the principles of time series theory.

Objectives

Upon completion of the course, students should get acquainted with the main concepts of time series theory and methods of analysis. Student should understand the differences between cross-sections and time series, and should be able to understand the fundamental advantage and necessity of appropriate forecasting method in particular environment. In this course, students should know how to use the statistical software R to analyze time series data.

Contents

Introduction and examples of time series; simple descriptive techniques: time series plots, trend, seasonal effects, sample autocorrelation, correlogram, filtering.

Probability models: stochastic processes, stationarity, second-order stationarity, white noise model, random walks, moving average (MA) processes, autoregressive (AR) processes, ARMA processes, seasonal ARMA processes, the general linear process; properties, estimation and model building, diagnostic checking.

Forecasting: naive procedures, exponential smoothing, Holt-Winters, Box-Jenkins forecasting, linear prediction, forecasting from probability models.

Non-stationary time series: non-stationarity in variance-logarithmic and power transformations; non-stationarity in mean; deterministic trends; integrated time series; ARIMA and seasonal ARIMA models; modelling seasonality and trend with ARIMA models.

Stationary processes in the frequency domain: the spectral density function, the periodogram, spectral analysis.

Concept of state-space models: dynamic linear models and the Kalman filter.

Text Books

1. Brockwell PJ and Davis RA (2002). Introduction to Time Series and Forecasting
2. Chatfield C (2003). The Analysis of Time Series, 6^{th} *edition.* Chapman & Hall.
3. Shumway RH and Stoffer DS (2011). Time Series Analysis and Its Applications: With R Examples. Springer.

AST 408: Generalized Linear Models **Credit 3**

Introduction

This course deals with different statistical models for the analysis of quantitative and qualitative data, of the types usually encountered in research.

Objectives

To introduce to the students about the statistical methods including the general linear model for quantitative responses (including multiple regression, analysis of variance and analysis of covariance), binomial regression models for binary data (including logistic regression and probit models), and models for count data (including Poisson regression and negative binomial models). All of these techniques are covered as special cases of the Generalized Linear Model, which provides a central unifying statistical framework for the entire course.

Contents

Generalized linear models: exponential family of distributions; estimation: method of maximum likelihood, method of least squares, estimation of generalized linear models; inference: sampling distribution for scores, sampling distribution for maximum likelihood estimators, confidence intervals for model parameters, adequacy of a model, sampling distribution for log-likelihood statistic, log-likelihood ratio statistic (deviance), assessing goodness of fit, hypothesis testing; multiple regression: maximum likelihood estimation, log-likelihood ratio statistic.

Models for binary responses: probability distributions, generalized linear models, dose response models, general logistic regression, maximum likelihood estimation and log-likelihood ratio statistic, other criteria for goodness of fit, least square methods; multinomial distributions; nominal logistic regression models; ordinal logistic regression models.

Models for count data, Poisson regression and log-linear models: probability distributions, maximum likelihood estimation, hypothesis testing and goodness of fit.

Text Books

1. Dobson, A J and Barnett, A G. (2008). An Introduction to Generalized Linear Models, 3^{rd} *edition.* Chapman & Hall.
2. McCullagh, P. and Nelder, J A. (1989). Generalized Linear Models, 2^{nd} *edition.* CRC Press.

AST 430: Statistical Computing IX

Credit 2

Introduction

A course designed to give hands-on experience of different inferential procedure. Students will learn to apply different multivariate techniques to solve real-life problems.

Objectives

The course aims to learn from a set of data derived from an almost infinitely complex world the most important features so these can be presented clearly to others.

Contents

Inference, principal component analysis, factor analysis, discriminant analysis, canonical correlation analysis.

AST 431: Statistical Computing X

Credit 2

Introduction

Computing course on time series modeling and econometric modeling.

Objectives

To be able to simulate time series objects and explore its various features. To be able to fit time series models like ARIMA using Box-Jenkins methodology, and check diagnostically the validity of the assumptions' of the model used. Also, compare different models based on criteria like AIC, BIC etc. To be able to forecast time series using a valid model for real-life data, and assess the predictability of the model. To be able to fit valid regression models for econometric data, and test for multicollinearity, heteroscedasticity, autocorrelation, and also, compare between compatible models. To be able to fit dynamic regression models and simultaneous equation models to various real-life econometric data.

Contents

Fitting time series models such as ARMA, ARIMA, etc., fitting econometric models.

AST 432: Statistical Computing XI — Credit 2

Introduction

This course deals with the applications of methods related to topics on generalized linear models and lifetime data analysis to real data from diverse areas such as medicine, biological science, engineering and social science. In addition, this course covers the use of statistical software, packages of each models for computing results from real data.

Objectives

The primary focus of the computing course is to make students to be familiar with the real data, and to be able to analyze such data by implementing an appropriate methods and models. Secondly, to be familiar with the statistical software and packages for computing the results from real data. Finally, to be able to interpret the results.

Contents

Fitting survival models, logistic, log-linear models.

AST 440: Oral IV — Credit 2

Each student must be examined by a committee of selected members at the end of the academic year.

AST 450: B.S. Project — Credit 3

Each student will be required to prepare a project report and present the report in a seminar. For the project work, each student will be assigned to a teacher at the beginning of the academic year. The project report submission and presentation should be made before the commencement of final examination. The 50% weight of the course will be allotted to project work, 10% weight for supervisor and the remaining 40% weight will be for seminar presentation. The internal members of the examination committee will evaluate the performance in the seminars and the report will be evaluated by two internal examiners nominated by the examination committee. A supervisor cannot evaluate the project report s/he has supervised.