SYLLABUS

M.S. Program in Applied Statistics
Session: 2016–2017

www.isrt.ac.bd/syllabus
The Master of Science (M.S.) program in Applied Statistics is a one academic year program. The minimum requirement for the admission to this program is the successful completion of the B.S. Honours degree in Applied Statistics. The regulations for the admission and the examinations will be the same as those of the M.S. courses in the Faculty of Science unless otherwise stated. There are two types of course designs available for the M.S. program in Applied Statistics:

- **Group A**: M.S. degree based only on course work.
- **Group B**: M.S. degree based on course work and thesis.

Total credit hours for both the Group A and B is 30. Students of both groups must take 19 credit hours of theoretical courses of which 4 credit hours are compulsory and 15 credit hours are elective. For the elective part, students can choose five 3-credit hours courses from the list of optional courses. The choice of optional courses will depend on the availability of teaching faculties of the institute. In addition, there will be a two credit hours oral comprehensive course. The remaining credit hours are distributed as follows:

- **Group A**
  Students from Group A are required to take three statistical computing courses (AST 530, AST 531, and AST 532) and prepare either a project report or a report from internship (AST 550). The computing courses AST 530 and AST 531 are of 2 credit hours and the comprehensive computing course AST 532 is of 3 credit hours. The project report (AST 550) will carry 2 credit hours of which 40% weight will be allotted for presentation, 10% for supervisor and the remaining 50% will be allotted for report.

- **Group B**
  A selected number of students will be considered for Group B who are required to submit a thesis and defend it (AST 551). The course AST 551 will carry 6 credit hours of which 40% weight will be for thesis presentation and 60% weight for thesis. Students of Group B must take the comprehensive statistical computing course (AST 532), which will carry 3 credit hours. It is expected that all thesis students actively participate in seminars organized by the institute during the academic year.

Each M.S. student (Group A and Group B) will be required to give at least one seminar during the academic year. It is a non-credit course but compulsory. The grade to be assigned will be “Satisfactory” or “Not-Satisfactory”. The internal members of the examination committee will evaluate the performance in the seminars.

The marks allocation for theoretical and computing courses will be as follows:

<table>
<thead>
<tr>
<th>Theoretical</th>
<th>Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance : 65</td>
<td>Attendance/assignment : 10</td>
</tr>
<tr>
<td>In-course exam : 25</td>
<td>In-course exam : 30</td>
</tr>
<tr>
<td>Final exam : 70</td>
<td>Final exam : 60</td>
</tr>
</tbody>
</table>

There will be two in-course examinations for each of the theoretical and computing courses.
## Courses for Group A

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credit Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory Credits</strong></td>
<td></td>
</tr>
<tr>
<td>Theoretical Courses</td>
<td>4</td>
</tr>
<tr>
<td>Statistical Computing Courses</td>
<td>7</td>
</tr>
<tr>
<td>MS Project or Internship</td>
<td>2</td>
</tr>
<tr>
<td>Oral</td>
<td>2</td>
</tr>
<tr>
<td>Seminar</td>
<td>Non-credit</td>
</tr>
<tr>
<td><strong>Elective Credits</strong></td>
<td></td>
</tr>
<tr>
<td>Theoretical Courses</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
</tr>
</tbody>
</table>

## Compulsory Credits for Group A

<table>
<thead>
<tr>
<th>Course ID</th>
<th>Course Title</th>
<th>Credit Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST 501</td>
<td>Applied Bayesian Statistics</td>
<td>4</td>
</tr>
<tr>
<td>AST 530</td>
<td>Statistical Computing I</td>
<td>2</td>
</tr>
<tr>
<td>AST 531</td>
<td>Statistical Computing II</td>
<td>2</td>
</tr>
<tr>
<td>AST 532</td>
<td>Comprehensive Statistical Computing</td>
<td>3</td>
</tr>
<tr>
<td>AST 540</td>
<td>Oral</td>
<td>2</td>
</tr>
<tr>
<td>AST 545</td>
<td>Seminar</td>
<td>Non-credit</td>
</tr>
<tr>
<td>AST 550</td>
<td>MS Project/Internship</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>
### Courses for Group B

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credit Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory Credits for the Group B</strong></td>
<td></td>
</tr>
<tr>
<td>Theoretical Courses</td>
<td>4</td>
</tr>
<tr>
<td>Statistical Computing Courses</td>
<td>3</td>
</tr>
<tr>
<td>MS Thesis</td>
<td>6</td>
</tr>
<tr>
<td>Oral</td>
<td>2</td>
</tr>
<tr>
<td>Seminar</td>
<td>Non-credit</td>
</tr>
<tr>
<td><strong>Elective Credits</strong></td>
<td></td>
</tr>
<tr>
<td>Theoretical Courses</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
</tr>
</tbody>
</table>

### Compulsory Credits for Group B

<table>
<thead>
<tr>
<th>Course ID</th>
<th>Course Title</th>
<th>Credit Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST 501</td>
<td>Applied Bayesian Statistics</td>
<td>4</td>
</tr>
<tr>
<td>AST 532</td>
<td>Comprehensive Statistical Computing</td>
<td>3</td>
</tr>
<tr>
<td>AST 540</td>
<td>Oral</td>
<td>2</td>
</tr>
<tr>
<td>AST 545</td>
<td>Seminar</td>
<td>Non-credit</td>
</tr>
<tr>
<td>AST 551</td>
<td>MS Thesis</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Course ID</td>
<td>Course Title</td>
<td>Credit Hour</td>
</tr>
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</tr>
<tr>
<td>AST 510</td>
<td>Advanced Survival Analysis</td>
<td>3</td>
</tr>
<tr>
<td>AST 511</td>
<td>Environmental and Spatial Statistics</td>
<td>3</td>
</tr>
<tr>
<td>AST 512</td>
<td>Advanced Time Series Analysis</td>
<td>3</td>
</tr>
<tr>
<td>AST 513</td>
<td>Actuarial Techniques</td>
<td>3</td>
</tr>
<tr>
<td>AST 514</td>
<td>Advanced Operations Research</td>
<td>3</td>
</tr>
<tr>
<td>AST 515</td>
<td>Advanced Econometric Methods</td>
<td>3</td>
</tr>
<tr>
<td>AST 516</td>
<td>Advanced Population Studies</td>
<td>3</td>
</tr>
<tr>
<td>AST 517</td>
<td>Queueing Theory and Stochastic Processes</td>
<td>3</td>
</tr>
<tr>
<td>AST 518</td>
<td>Applied Multivariate Techniques</td>
<td>3</td>
</tr>
<tr>
<td>AST 519</td>
<td>Analysis of Longitudinal Data</td>
<td>3</td>
</tr>
<tr>
<td>AST 520</td>
<td>Adaptive Sampling</td>
<td>3</td>
</tr>
<tr>
<td>AST 521</td>
<td>Optimum Experimental Designs</td>
<td>3</td>
</tr>
<tr>
<td>AST 522</td>
<td>Statistical Signal Processing</td>
<td>3</td>
</tr>
<tr>
<td>AST 523</td>
<td>Meta Analysis</td>
<td>3</td>
</tr>
<tr>
<td>AST 524</td>
<td>Clinical Trials</td>
<td>3</td>
</tr>
</tbody>
</table>
DetaileD Syllabus

AST 501: Applied Bayesian Statistics  

Bayesian thinking: background, benefits and implementations; Bayes theorem, components of Bayes theorem - likelihood, prior and posterior; informative and non-informative priors; proper and improper priors; discrete priors; conjugate priors; semi-conjugate priors; exponential families and conjugate priors; credible interval; Bayesian hypothesis testing; building a predictive model.

Bayesian inference and prediction: single parameter models - binomial model, Poisson model, normal with known variance, normal with known mean; multi-parameter models - concepts of nuisance parameters, normal model with a non-informative, conjugate, and semi-conjugate priors, multinomial model with Dirichlet prior, multivariate normal model; posterior inference for arbitrary functions; methods of prior specification; method of evaluating Bayes estimator.

Summarizing posterior distributions: introduction; approximate methods: numerical integration method, Bayesian central limit theorem; simulation method: direct sampling and rejection sampling, importance sampling; Markov Chain Monte Carlo (MCMC) methods - Gibbs sampler, general properties of the Gibbs sampler, Metropolis algorithm, Metropolis-Hastings (MH) sampling, relationship between Gibbs and MH sampling, MCMC diagnostics - assessing convergence, acceptance rates of the MH algorithm, autocorrelation; evaluating fitted model - sampling from predictive distributions, posterior predictive model checking.

Linear model: introduction, classical and Bayesian inference and prediction in the linear models, hierarchical linear models - Bayesian inference and prediction, empirical Bayes estimation; generalized linear model - Bayesian inference and prediction (logit model, probit model, count data model); model selection - Bayesian model comparison.

Nonparametric and Semiparametric Bayesian models.

Text Books

Semiparametric Multiplicative Hazards Regression Model: Introduction, estimation of parameters, inclusion of strata, handling ties, sample size determinations, counting process form of a Cox model, time-dependent covariates, different types of residuals for Cox models, checking proportionality assumption.

Multiple Modes of Failure: Basic characteristics of model specification, likelihood function formulation, nonparametric methods, parametric methods, semiparametric methods for multiplicative hazards model.


Text Books
Review of non-spatial statistics and stochastic process, overview of different types of spatial data; random field and spatial process - geostatistical/point reference process, areal/lattice process and point process; spatial data concern.

Geostatistical data: real data examples, measure of spatial dependence- variogram and covariance, stationarity and isotropic, variograms and covariance functions, fitting the variograms functions; Kriging, linear geostatistical model - formulation, simulation, estimation and prediction, generalized linear geostatistical model - formulation, simulations, estimation and prediction. Areal data: neighborhoods, testing for spatial association, autoregressive models (CAR, SAR), estimation/inference; grids and image analysis, disease mapping. Point pattern data: locations of events versus counts of events, types of spatial patterns, CSR and tests - quadrat and nearest neighbor methods, K-functions and L-functions, point process models- estimation and inference, health event clustering.

Special topics in spatial modeling: Hierarchical models, Bayesian methods for spatial statistics, Bayesian disease mapping, Spatio-temporal modeling, more on stationarity. Use of R and GIS software for with emphasis on analysis of real data from the environmental, geological and agricultural sciences.

Text Books


Text Books
Theory of interest in continuous time. Forces of interest and discount (constant and varying). Present and accumulated value calculations using non-level interest rates. Continuous annuities; valuation of continuous streams of payment, including the case in which interest conversion period differs from the payment period; continuous varying annuities. Bonds and related securities.
Principles of actuarial modeling. Familiarity with actuarial models: survival models, credibility models, risk theory models, ruin theory models, etc and their applications.

Text Books
Special Types of Linear Programming Problems: Transportation problem, Transshipment problem, Assignment problem, Multidimensional problems.


Dynamic Programming: Characteristics of dynamic programming problems, Deterministic dynamic programming, Probabilistic dynamic programming.

Non-linear Programming: Sample application, Graphical illustration of non-linear programming problems, Types of non-linear programming problems, One-variable unconstrained optimization, Multivariate unconstrained optimization, Karush-Kuhn Tucker (KKT) conditions for constrained optimization, Quadratic programming, Separable Programming, Convex programming, Non-convex programming.

Inventory Models: The ABC inventory system, A generalized inventory model, Deterministic models, Probabilistic models, Just-in-time manufacturing system;

Text Books

Three-Stage Least Squares Estimation: The Three-Stage Least Squares Estimator (3SLS), Comparison between GMM 3SLS and Traditional 3SLS.


Text Books

Estimation of population parameters from incomplete data. Estimation of mortality from census. Survivorship ratio. Estimate of infant and child mortality by indirect techniques such as Brass, Sullivan, Trussell and Feeney. Estimation of adult mortality from information on widowhood and orphanhood. Estimation of fertility by indirect techniques such as Brass, Hill, Coale-Trussell, relational Gompertz and reduced Gompertz model.

Population and Development: Inter-relation between population and development as envisaged value. Various population theories such as demographic transition theory. Emerging theories of population. Micro-economic theory of population. Recent contribution of East-islam, Becker, Caldwell etc.

Morbidity: Morbidity differentials and trends in Bangladesh. Health expectancy and burden of disease.


Text Books
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, a more general queueing models: M/G/1, M/G/m, G/M/1 queueing systems and analysis.


Reliability theory: structure functions, minimal path and minimal cut sets, reliability of systems of independent components, bounds on the reliability function, system life as a function of component lives, expected system lifetime, systems with repair.

Brownian motion and stationary processes: Brownian motion, hitting times, maximum variable, variations on Brownian motion, Brownian motion with drift, geometric Brownian motion, pricing stock options, white noise, Gaussian processes, stationary and weakly stationary processes, harmonic analysis of weakly stationary processes.

Text Books
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 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, Multidimensional scaling.

Text Books
Longitudinal data: concepts, examples, objectives of analysis, problems related to one sample and multiple samples, sources of correlation in longitudinal data, exploring longitudinal data.

Linear model for longitudinal data: introduction, notation and distributional assumptions, simple descriptive methods of analysis, modelling the mean, modelling the covariance, estimation and statistical inference.

ANOVA for longitudinal data: fundamental model, one sample model, sphericity condition; multiple samples models.

Linear mixed effects models: introduction, random effects covariance structure, prediction of random effects, residual analysis and diagnostics.

Extension of GLM for longitudinal data: review of univariate generalized linear models, quasi-likelihood, marginal models, random effects models, transition models, comparison between these approaches; the GEE methods: methodology, hypothesis tests using wald statistics, assessing model adequacy; GEE1 and GEE2. Generalized Linear Mixed Models (GLMM): introduction, estimation procedures: Laplace transformation; Penalized Quasi-Likelihood (PQL); Marginal Quasi Likelihood (MQL); Numerical integration: Gaussian quadrature, Adaptive Gaussian quadrature, Monte Carlo Integration; Markov Chain Monte Carlo sampling; comparison between these methods

Statistical analysis with missing data: missing data, missing data pattern, missing data mechanism, imputation procedures, mean imputation, hot deck imputation. estimation of sampling variance in the presence of non-response, likelihood based estimation and tests for both complete and incomplete cases, regression models with missing covariate values, applications for longitudinal data.

Text Books

Design and Model unbiased estimators; Fixed and Stochastic population sampling theory.
Adaptive sampling designs; Detectability in adaptive sampling; constant and unequal detectabilities for adaptive design.
Adaptive cluster sampling; Initial random sample with and without replacement; Initial unequal probability sampling; Expected sample size and cost; Comparative efficiencies of adaptive and conventional sampling.
Systematic and strip adaptive cluster sampling; Stratified adaptive cluster sampling; Adaptive allocation in stratified sampling; Sample sizes based on observations in each strata and from previous strata; Comparison of systematic and stratified adaptive sampling with conventional sampling procedures; Adaptive cluster sampling based on order statistics.
Multivariate aspects of adaptive sampling; Multivariate conditions for adding neighbour-hoods; Design-unbiased estimation for multivariate approach;

Text Books
Optimum design theory: continuous and exact designs, the general equivalence theorem, algorithms for continuous designs and general equivalence theorem, function optimization and continuous design.

Criteria of optimality: A-, D-, and E-optimality; $D_A$-optimality, $D_S$-optimality, c-optimality, linear optimality; compound design criteria.

$D$-optimum designs: properties of $D$-optimum designs, sequential construction of optimum designs, polynomial regression in variable, second-order model with several variables.

Algorithms for constructing of exact $D$-optimum designs: the exact design problem, basic formulae for exchange algorithm, sequential algorithms, non-sequential algorithms, the KL and BLKL exchange algorithms.

Experiments with both qualitative and quantitative factors, blocking response surface designs, mixture experiments, non-linear models, Bayesian optimum designs, model checking and designs for discriminating between models, compound design criteria, generalized linear models.

**Text Books**

Introduction to signals: Signals and their classification; real world analog signals: audio, video, biomedical (EEG, ECG, MRI, PET, CT, US), SAR, microarray, etc; digital representation of analog signals; role of transformation in signal processing. Orthogonal representation of signals. Review of exponential Fourier Series and its properties.

Signal estimation theory: Estimation of signal parameters using ML, EM algorithm, minimum variance unbiased estimators (Rao-Blackwell theorem, CRLB, BLUE), Bayesian estimators (MAP, MMSE, MAE), linear Bayesian estimators.

Signal detection theory: Detection of DC signals in Gaussian noise: detection criteria (Bayes risk, Probability of error, Neyman-Pearson), LRT; detection of known signals in Gaussian noise: matched filter and its performance, minimum distance receiver; detection of random signals in Gaussian noise: the estimator correlator.

Applications: Scalar quantization, image compression, pattern recognition, histogram equalization, segmentation, application of signal estimation and detection theory to signal communication, signal recovery from various types of linear and nonlinear degradations, copyright protection, enhancement, etc.

Text Books
Introduction to systematic review and meta analysis: motivation, strengths and weakness of meta-analysis, problem formulation (why study meta analysis), systematic review process; Types of results to summarize; overview of effect size; effect size calculation for both continuous and discrete data; Combining effect size from multiple studies; fixed effect and random effects models and their estimation; heterogeneity between studies and its estimation techniques; test of homogeneity in meta analysis; prediction intervals; subgroup analysis, Meta regression: random effect meta regression, baseline risk regression; Publication bias in meta analysis; Power analysis for meta analysis; Effect size rather than P-values; Meta analysis based on direction and P-values, Reporting the results of meta analysis; Introduction to Bayesian approach to meta analysis; Meta analysis for multivariate/longitudinal data; Network meta analysis;

Text Books
Statistical approaches for clinical trials: introduction, comparison between Bayesian and frequentist approaches and adaptivity in clinical trials. Phases of clinical trials, pharmacokinetics (PK) and pharmacodynamics (PD) of a drug, dose-concentration-effect relationship and compartmental models in pharmacokinetic studies.

Phase I studies: Determining the starting dose from preclinical studies. Rule-based designs: 3+3 design, Storer’s up-and-down designs, pharmacologically-guided dose escalation and design using isotonic regression. Model-based designs: continual reassessment method and its variations, escalation with overdose control and PK guided designs.

Phase II studies: Gehan and Simon’s two-stage designs. Seamless phase I/II clinical trials: TriCRM, EffTox and penalised D-optimum designs for optimum dose selection.

Phase III studies: Randomised controlled clinical trial, group sequential design and multi-arm multi-stage trials in connection with confirmatory studies.

Text Books


**AST 530: **Statistical Computing I  
Credit 2

Computing problems related to AST 501: Applied Bayesian Statistics, and AST 523: Meta Analysis

**AST 531: **Statistical Computing II  
Credit 2

Computing problems related to AST 518: Applied Multivariate Techniques, and AST 519: Analysis of Longitudinal Data

**AST 532: **Comprehensive Statistical Computing  
Credit 3

This is a comprehensive statistical computing course, which is compulsory for all the M.S. students. It will cover computing problems related to all the courses studied in the academic year. For this course, 30% weight will be allotted to the in-course examinations, 10% weight will be allotted to the lab-based assignments, and remaining 60% weights for the final examination. Part of the examinations will be held in computer lab.

**AST 540: **Oral  
Credit 2

Each student (Group A and Group B) should be examined orally by a committee of selected members at the end of the academic year.
The internal members of the examination committee will evaluate the performance in the seminars.

Each student should be either in the project report group or in the internship group that the student will decide after discussing with the respective assigned supervisor. Students must submit their project report or internship report within 2 months of completing the final examination. The internal members of the examination committee will evaluate the performance of the students in the seminars and the project report or internship report will be evaluated by two examiners nominated by the examination committee. A supervisor cannot evaluate the project or internship report that s/he has supervised. This course will carry 2 credit hours. For this course, 50% weight of the course will be allotted to report, 10% for supervisor and the remaining 40% will be for seminar presentation.

After three months of the start, each Group B student will submit a three to five page thesis proposal and present his/her proposal, which will be evaluated by the internal members of the examination committee. Written evaluation on the proposal will be provided to the students explaining the possible improvement and in case of “Not satisfactory” proposals, the reasons for “Not satisfactory” performance will be stated in the written evaluation. In case of “Not satisfactory” performance the examination committee may give the student a second opportunity for proposal presentation. Students with “Not-Satisfactory” performance at the end will be transferred to the Group A. The final submission of the thesis will be required within 4 months of the completion of final exam. Thesis will be examined by two external (outside the institute) examiners. Should it be required, the examination committee may consider one internal and one external examiner. Submitted thesis has to be defended at a presentation evaluated by the members of the examination committee. 40% weight will be allotted for thesis defense and remaining 60% for thesis itself.