STRATHMORE UNIVERSITY
Institute of Mathematical Sciences

2024/2025
2ST YEAR, SEMIMESTER II

COURSE OUTLINE:

DSA 8505: Bayesian Analysis

STATEMENT ABOUT ACADEMIC HONESTY AND INTEGRITY

Upon registering as bona fide students at Strathmore University , all students pledge to adhere to the institution's policies and regulations. Upholding academic honesty and integrity is of utmost importance to guarantee the validity, reliability, and credibility of the learning process.

Strathmore University unequivocally opposes any type of academic dishonesty, encompassing actions such as plagiarism, cheating, and engaging in other deceptive practices during assessments. The university insists that students consistently complete their own assignments and generate their academic work, except in cases where group assignments are explicitly assigned. Any manifestation of academic dishonesty is considered a breach of conduct according to Strathmore University's Rules and Regulations.

COURSE INFORMATION

COURSE CODE : DSA 8505:
COURSE TITLE: Bayesian Analysis

CREDIT HOURS: 4 hours per week

COURSE PURPOSE:

The aims of this module are to provide an introduction to the Bayesian approach to inference, including hierarchical modelling and the software Win BUGS.

LEARNING OUTCOMES

On completing the course students will, through assessment activities, show evidence of their ability to:

1. Make appropriate inferences within a Bayesian framework
2. Apply the basic concepts of Bayesian inference, including posterior conditioning, credible intervals, prior distributions, and the likelihood principle
3. Apply the theory to the statistical modelling and analysis of practical problems involving Bayesian methods, and to interpret results and draw conclusions in context;
4. Describe the impact of prior assumptions to modelling outcomes, and the use of MCMC methods for posterior simulation;
5. Apply numerical methods for making inferences in more complex problems with a suitable statistical software package

COURSE DESCRIPTION:
Motivation behind Bayesian inference; connections with the classical approach. Subjective interpretation of probability. Types of prior distributions, and the use of Bayes theorem in updating information. Estimation and loss functions. Bayesian inference, Bayesian point and interval estimation. Hypothesis testing, Bayes Factor, and Bayesian model averaging. Principles of data analysis and modern statistical modelling. Exploratory data analysis. Single parameter Bayesian modelling, informative priors, non-informative priors, posterior and predictive distributions, conjugate distributions, introduction to sensitivity analysis. Likelihood-based and Bayesian inference of binomial, ordinal, and Poisson regression models, and the relation of these models to item response theory and other psychometric models. Latent variable interpretations of categorical variables, computational techniques of estimating posterior distributions on model parameters, and Bayesian and likelihood approaches to case analyses and goodness-of-fit criterion. Bayesian hierarchical models, model checking and selection, missing data, introduction to stochastic simulation by Markov Chain Monte Carlo using a higher level statistical language such as R or MATLAB. The concepts of linear models from Bayesian and classical viewpoints. Bayesian regression and General Linear Models using MCMC methods. Application of Bayesian methods to practical problems using the packages R and Win BUGS. Case studies from a variety of fields.

PRE-REQUISITES:
DSA 8405:

MODE OF DELIVERY:
The following methods of delivery will be used in this course: lectures, seminars, practical data analysis sessions, consulting workshops/clinics, group discussion, and case studies

EFFECTIVE DATE: 28th November 2025

LECTURER INFORMATION:

Lecturer's name	Dr Jacob Ong'ala
Email	jongala@strathmore.edu
Phone	0710945685

Course Resources:
Core Reading Materials:

1. Bon, J. J., Bretherton, A., Buchhorn, K., Cramb, S., Drovandi, C., Hassan, C., ... & Wang, X. (2022). Being Bayesian in the 2020s: Opportunities and challenges in the practice of modern applied Bayesian statistics. *arXiv preprint arXiv:2211.10029*. Retrieved from `https://arxiv.org/abs/2211.10029`

2. Oganisian, A., & Roy, J. A. (2020). A Practical Introduction to Bayesian Estimation of Causal Effects: Parametric and Nonparametric Approaches. *arXiv preprint arXiv:2004.07375*. Retrieved from `https://arxiv.org/abs/2004.07375`

3. Chivers, T. (2024). Everything is Predictable: How Bayesian Statistics Explain the World. *Journal of Risk and Uncertainty, 59*(3), 345-348. Retrieved from `https://link.springer.com/article/10.1057/s11369-024-00371-5`

Recommended Reading Materials:

1. Abdul Fattah, E., Van Niekerk, J., & Rue, H. (2024). INLA$^+$: Approximate Bayesian inference for non-sparse models using HPC. *Statistics and Computing, 35*(17). Retrieved from `https://link.springer.com/article/10.1007/s11222-024-10545-y`

2. Astfalck, L., Bird, C., & Williamson, D. (2024). Generalised Bayes Linear Inference. *arXiv preprint arXiv:2405.14145*. Retrieved from `https://arxiv.org/abs/2405.14145`

COURSE SCHEDULE

Topic 1: Introduction to Bayesian Inference

- Motivation behind Bayesian inference and connections with the classical approach.
- Subjective interpretation of probability.
- Introduction to Bayes' theorem and its use in updating information.
- Practical examples comparing Bayesian and frequentist approaches.

Topic 2: Prior Distributions and Bayes Theorem

- Types of prior distributions: informative, non-informative, and improper priors.
- The role of prior distributions in Bayesian inference.
- Examples of using Bayes' theorem for updating prior beliefs.
- Discussion of the concept of conjugate priors and their benefits.

Topic 3: Estimation and Loss Functions

- Bayesian estimation and the role of loss functions (e.g., squared error loss, absolute loss).
- Bayesian point and interval estimation.
- Comparison with classical estimation techniques.
- Case studies on estimating population parameters using Bayesian methods.

Topic 4: Bayesian Hypothesis Testing and Model Averaging

- Hypothesis testing using Bayesian methods.
- Introduction to Bayes Factors for model comparison.
- Bayesian model averaging and its importance in model uncertainty.
- Applications to real-world hypothesis testing problems.
- Sensitivity analysis and its importance in Bayesian modelling.

Topic 5: Bayesian Inference in Regression Models

- Bayesian inference for binomial, ordinal, and Poisson regression models.
- Connections with item response theory and psychometric models.
- Latent variable interpretations of categorical variables.
- Introduction to goodness-of-fit criteria in Bayesian models.

Topic 6: Bayesian Hierarchical Models and Missing Data

- Understanding Bayesian hierarchical models.
- Model checking and model selection techniques.
- Addressing missing data in Bayesian frameworks.
- Case studies demonstrating hierarchical Bayesian modelling.

Topic 7: Stochastic Simulation and Markov Chain Monte Carlo (MCMC)

- Introduction to stochastic simulation methods.
- Understanding Markov Chain Monte Carlo (MCMC) techniques.
- Practical implementation using R or MATLAB.
- Applications to Bayesian regression and General Linear Models.

Topic 8: Applications of Bayesian Methods

- Bayesian regression models using MCMC methods.
- Application of Bayesian methods to real-world problems in various fields.
- Practical data analysis using R and WinBUGS.
- Case studies showcasing Bayesian methods in practice.

ASSESSMENT AND EVALUATION STRATEGIES:

	Assignments	Weight
1	Course Work Assessment	40%
2	End of Semester Written Examination	60%

DATE REVISED: 19th Dec 2024

AUTHORISATION:
This course is authorized for use by:

Prof. Jacob Ong'ala	----------	----------
Lecturer	Signature of Lecturer	Date