City University of Hong Kong
Course Syllabus

offered by School of Data Science
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	Bayesian Regression Modelling and Analysis
Course Code:	SDSC8012
Course Duration:	One Semester
Credit Units:	3
Level:	R8
Medium of Instruction:	English
Medium of Assessment:	English
Prerequisites: *(Course Code and Title)*	Nil
Precursors: *(Course Code and Title)*	Nil
Equivalent Courses: *(Course Code and Title)*	Nil
Exclusive Courses: *(Course Code and Title)*	Nil

Part II Course Details

1. Abstract

This course aims to offer students rigorous and comprehensive knowledge of advanced Bayesian regression concepts, theory, and methods. It will develop students' abilities to apply Bayesian regression models to nonstandard and complex data analysis problems. Students will be trained to develop Bayesian models and apply software packages such as MATLAB, R or WinBUGS to fit the developed models and perform Bayesian inference.

2. Course Intended Learning Outcomes (CILOs)

No.	CILOs	Weighting (if applicable)	Discovery-enriched curriculum related learning outcomes		
			A1	*A2*	*A3*
1.	**Explain** and **apply** Bayes theorem, Bayesian decision theory, empirical Bayesian estimation, and types of prior distributions (conjugate, Jeffreys, and reference priors) in the context of Bayesian linear models.	20%	✓	✓	
2.	**Describe** and **implement** Bayesian linear regression models, Bayesian generalized linear models, Bayesian model averaging, and Bayesian variable selection methods.	25%	✓	✓	
3.	**Apply** Markov chain Monte Carlo algorithms and integrated nested Laplace approximations to perform Bayesian regression with the help of software.	15%	✓	✓	
4.	**Describe** and **implement** Gaussian process modelling, and experiment designs for fitting Gaussian process models.	20%	✓	✓	
5.	**Describe** and **implement** Bayesian optimization, and Bayesian quadrature.	20%	✓	✓	
		100%			

A1: *Attitude*
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: *Ability*
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: *Accomplishments*
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

3. Learning and Teaching Activities (LTAs)

LTA	Brief Description	CILO No.					Hours/week (if applicable)
		1	2	3	4	5	
Lectures	Students will engage in formal lectures to gain knowledge about Bayesian regression modelling and analysis.	✓	✓	✓	✓	✓	26 hours/semester
Demonstration of MATLAB/R/ WinBUGS codes	Students will develop an understanding of the MATLAB/R/ WinBUGS codes included in the course materials by following an in-class demonstration and explanation of the codes.	✓	✓	✓	✓	✓	12 hours/semester

4. Assessment Tasks/Activities (ATs)

Assessment Tasks/Activities	CILO No.					Weighting	Remarks
	1	2	3	4	5		
Continuous Assessment: 75 %							
Midterm Students will be assessed via the midterm their understanding of concepts learned in class, textbooks, and reading materials.	✓	✓	✓	✓	✓	25%	
Two assignments Students will work individually or in teams to develop Bayesian regression models and apply the models to analyse data with the help of software.	✓	✓	✓	✓	✓	50%	
Examination: 25 % (duration: 2 hours, if applicable)							
Examination Students will be assessed via the examination their understanding of concepts learned in class, textbooks, and reading materials.	✓	✓	✓	✓	✓	25%	
						100%	

5. Assessment Rubrics

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Coursework	Midterm and assignments	High	Moderate	Basic	Not even reaching marginal levels
2. Examination	Close-book but open-notes exam	High	Moderate	Basic	Not even reaching marginal levels

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Coursework	Midterm and assignments	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Examination	Close-book but open-notes exam	High	Significant	Moderate	Basic	Not even reaching marginal levels

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

- Likelihood, prior distribution, Bayes theorem, Bayesian linear regression model, utility/loss functions, quadratic loss function, zero-one loss function, admissibility, shortest credible intervals, empirical Bayesian estimation, conjugate prior, Jeffreys prior, reference prior, g-prior,
- Bayesian hierarchical linear model, Bayesian spline models, Bayesian model averaging, Bayesian variable selection methods, stochastic search variable selection, Bayesian LASSO, Bayesian generalized linear models, multivariate normal distribution, multivariate t distribution, Wishart and inverse Wishart distributions,
- Gibbs sampling, slice sampling, adaptive Metropolis-Hastings algorithms, integrated nested Laplace approximation, variational Bayesian methods
- Gaussian process regression, covariance functions, reproducing kernel Hilbert space, mean square continuity and differentiability, modelling with derivative information, Latin hypercube designs, maximum entropy sampling, maximin and minimax designs, separability and Cartesian product design
- Bayesian optimization, expected improvement, correlated knowledge gradient, noisy evaluations, multiobjective Bayesian optimization, Bayesian quadrature, Koksma-Hlawka inequality.

2. Reading List

2.1 Compulsory Readings

1.	Denison, D. G., Holmes, C. C., Mallick, B. K., & Smith, A. F. (2002). *Bayesian methods for nonlinear classification and regression* (Vol. 386). John Wiley & Sons.
2.	Vidales, A. (2019). *Machine learning with Matlab: Gaussian process regression, analysis of variance, and Bayesian optimization*. Independently published.
3.	Faraway, J. J., Wang, X., & Ryan, Y. Y. (2018). *Bayesian Regression Modeling with INLA*. Chapman and Hall/CRC.
4.	Santner, T. J., Williams, B. J., Notz, W., & Williams, B. J. (2018). *The design and analysis of computer experiments* (2nd Edition). New York: Springer.
5.	Rasmussen, C. E., & Williams, C. K. (2006). Gaussian Process Regression for Machine Learning. The MIT Press.
6.	O'Hagan, A., & Forster, J. J. (2004). *Kendall's advanced theory of statistics, volume 2B: Bayesian inference* (Vol. 2). Arnold.

2.2 Additional Readings

NIL