

MODULE TITLE	Bayesian statistics, Philosophy and Practice		CREDIT VALUE	15
MODULE CODE	MTH3041		MODULE CONVENER	Prof Daniel Williamson (Coordinator)
DURATION: TERM	1	2	3	
DURATION: WEEKS	11	0	0	
Number of Students Taking Module (anticipated)		25		

#### DESCRIPTION - summary of the module content

Since the 1980s, computational advances and novel algorithms have seen Bayesian methods explode in popularity, today underpinning modern techniques in data analytics, pattern recognition and machine learning as well as numerous inferential procedures used across science, social science and the humanities.

This module will introduce Bayesian statistical inference, describing the differences between it and classical approaches to statistics. It will develop the ideas of subjective probability theory for decision-making and explore the place subjectivity has in scientific reasoning. It will develop Bayesian methods for data analysis and introduce modern Bayesian simulation based techniques for inference. As well as underpinning a philosophical understanding of Bayesian reasoning with theory, we will use software currently used for Bayesian inference in the lab, allowing you to apply techniques discussed in the course to real data.

Pre-requisite: MTH2006 Statistical Modelling and Inference or equivalent

#### AIMS - intentions of the module

This module will cover the Bayesian approach to modelling, data analysis and statistical inference. The module describes the underpinning philosophies behind the Bayesian approach, looking at subjective probability theory, subjectivity in science as well as the notion and handling of prior knowledge, and the theory of decision making under uncertainty. We then move to Bayesian modelling and inference looking at parameter estimation in simple models and then hierarchical models. Finally, we explore simulation-based inference in Bayesian analyses and develop important algorithms for Bayesian simulation by Markov Chain Monte Carlo (MCMC) such the Gibbs sampler and the Metropolis-Hastings algorithm. This module is an excellent precursor to MTH3012.

#### INTENDED LEARNING OUTCOMES (ILOs) (see assessment section below for how ILOs will be assessed)

On successful completion of this module *you should be able to*:

##### Module Specific Skills and Knowledge

1. Show understanding of the subjective approach to probabilistic reasoning;
2. Demonstrate an awareness of Bayesian approaches to statistical modelling and inference and an ability to apply them in practice;
3. Demonstrate understanding of the value of simulation-based inference and knowledge of techniques such as MCMC and the theories underpinning them;
4. Demonstrate the ability to apply statistical inference in decision-making;
5. Utilise appropriate software and a suitable computer language for Bayesian modelling and inference from data.

##### Discipline Specific Skills and Knowledge

6. Demonstrate understanding, appreciation of and aptitude in the quantification of uncertainty using advanced mathematical modelling;

##### Personal and Key Transferable / Employment Skills and Knowledge

7. Show advanced Bayesian data analysis skills and be able to communicate associated reasoning and interpretations effectively in writing;
8. Apply relevant computer software competently;
9. Use learning resources appropriately;
10. Exemplify self-management and time-management skills.

#### SYLLABUS PLAN - summary of the structure and academic content of the module

**Introduction:** Bayesian vs Classical statistics, Nature of probability and uncertainty, Subjectivism.

**Decision Theory:** Bayes' rule, Bayes' risk, Decision trees, Sequential Decision making, Utility.

**Bayesian inference:** Conjugate models, Prior and Posterior predictive distributions, Posterior summaries and simulation, Objective and subjective priors, Nuisance parameters, Hierarchical models, Bayesian regression.

**Bayesian Computation:** Monte Carlo, Inverse CDF, Rejection Sampling, Markov Chain Monte Carlo (MCMC), The Gibbs sampler, Metropolis Hastings, Diagnostics.

#### LEARNING AND TEACHING

##### LEARNING ACTIVITIES AND TEACHING METHODS (given in hours of study time)

<b>Scheduled Learning &amp; Teaching Activities</b>	<b>33.00</b>	<b>Guided Independent Study</b>	<b>117.00</b>	<b>Placement / Study Abroad</b>	<b>0.00</b>
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##### DETAILS OF LEARNING ACTIVITIES AND TEACHING METHODS

Category	Hours of study time	Description
Scheduled learning and teaching activities	33	Lectures/practical classes
Guided independent study	33	Post-lecture study and reading
Guided independent study	40	Formative and summative coursework preparation and attempting un-assessed problems
Guided independent study	44	Exam revision/preparation

#### ASSESSMENT

##### FORMATIVE ASSESSMENT - for feedback and development purposes; does not count towards module grade

Form of Assessment	Size of Assessment (e.g. duration/length)	ILOs Assessed	Feedback Method
Coursework - practical and theoretical exercises	15 hours	All	Verbal in class, written feedback on script and oral feedback in office hour

#### SUMMATIVE ASSESSMENT (% of credit)

Coursework	20	Written Exams	80	Practical Exams
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#### DETAILS OF SUMMATIVE ASSESSMENT

Form of Assessment	% of Credit	Size of Assessment (e.g. duration/length)	ILOs Assessed	Feedback Method
Written exam – closed book	80	2 hours	1-8, 9, 10	Written/verbal on request
Coursework - practical and theoretical exercises	20	15 hours	All	Written feedback on script and oral feedback in office hour

#### DETAILS OF RE-ASSESSMENT (where required by referral or deferral)

Original Form of Assessment	Form of Re-assessment	ILOs Re-assessed	Time Scale for Re-assessment
All Summative Assessment	Written Exam (100%)	1-7, 9, 10	August Ref/Def Period

#### RE-ASSESSMENT NOTES

### RESOURCES

**INDICATIVE LEARNING RESOURCES - The following list is offered as an indication of the type & level of information that you are expected to consult. Further guidance will be provided by the Module Convener**

**Basic reading:**

**ELE:** <http://vle.exeter.ac.uk/>

**Web based and Electronic Resources:**

**Other Resources:**

Lindley, D. V. "Making Decisions"

De Groot, M. H. "Optimal Statistical Decisions".

Sivia, D. S. "Data Analysis, A Bayesian Tutorial".

**Reading list for this module:**

Type	Author	Title	Edition	Publisher	Year	ISBN	Search
Set	A Gelman	Bayesian Data Analysis	3rd	CRC Press	2013	9781439840955	<a href="#">[Library]</a>

<b>CREDIT VALUE</b>	15	<b>ECTS VALUE</b>	7.5
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<b>PRE-REQUISITE MODULES</b>	MTH2006
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<b>CO-REQUISITE MODULES</b>	
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<b>NQF LEVEL (FHEQ)</b>	6	<b>AVAILABLE AS DISTANCE LEARNING</b>	No
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<b>ORIGIN DATE</b>	Tuesday 10 July 2018	<b>LAST REVISION DATE</b>	Thursday 16 December 2021
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<b>KEY WORDS SEARCH</b>	Bayesian; Bayes; Statistics; Data, Big Data; Analysis; Decision Theory; Inference; Mathematics; Probability.
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