SFU

Mathematical Epidemiology

MATH 496/796

Instructor Info

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Course Info

http://inzaneresearch.com

Prerequisite: MATH310

Recommended: MATH316

Tu 10:30–12:20 (AQ 5025)

Fr 10:30–11:20 (AQ 5047)

Overview

A survey of contemporary methods and applications of mathematical models of infectious disease. As a rapidly changing field, this course will focus on understanding, analyzing, and applying the recent scientific literature.

Learning Objectives

- Develop an understanding of the theory and implementation of fundamental methods in mathematical epidemiology.
- Understand the organizing principals and theoretical approaches in disease ecology, evolution, and genomic epidemiology.
- Learn to apply mathematical and statistical methods to contemporary scientific questions.
- Engage with the scientific literature through the reading, interpretation, and analysis of peer-reviewed articles.
- Gain skills in scientific writing, this involves the formulation and communication of perspectives and the expression scientific findings in a clear and concise manner.

Required Text

Keeling, M.J., Rohani, P., *Modeling Infectious Diseases In Humans and Animals*. Princeton University Press. 2008. ISBN-13: 978-0-11617-4 (KR8)

Additional Helpful References:

- Foppa, I.M., *A Historical Introduction to Mathematical Modeling of Infectious Diseases: Seminal Papers in Epidemiology*. 2016. ISBN: 0128022604
- Dieckmann et al. *Adaptive Dynamics of Infectious Diseases: In Pursuit of Virulence Management*. 2002. ISBN: 9780511525728

Grading Scheme

	Math 496	Math 796
Written assignments $\times 6$	30% (5% each)	30% (5% each)
Project Proposal (2 drafts)	20% (10% each)	10% (5% each)
Final Project	40%	30%
Participation	10%	NA
Computer Lab $\times 6$	Optional	30% (5% each)

Math 796:
Graduate students enrolled in Math 796 will be required to complete computer labs covering the application of core course material. Math 796 are also required to include an additional literature review with each written assignment.

Numerical to Letter Grades:

A+	B+	C+
A	B	C
A-	B-	C-

FAQs

How do I read a journal article?

First its okay that its hard! No one method works for everyone. This is what I do: Skip the *Abstract* (too intimidating!). Read the *Introduction*, understand the *Figures* and skim the *Results*, then read the discussion. Finally, go back and read the *Methods*.

How do I get started with my writing assignment?

1) Write a rough outline that is centered around a thesis statement. 2) Add details to your outline. 3) Translate your outline into full sentences and paragraphs. Hint: Write an "Introduction" backwards, start with the thesis statement and then write an intro that exemplifies the relevance of this thesis.

How do I pick a project?

Start in one of two ways: 1) start with a question, 2) start with a system (aka epidemic). Then read, read, read! Be creative, there is no right answer but there are justifiable answers.

Why are there no proofs in this class?

This course samples methods from an extraordinarily wide range of fields: math, biology, public health, stats, and computer science. The focus of our work will be on finding the best approaches (regardless of field) to answer real-world questions rather than on understanding every detail of each and every method.

Written Assignments

Length Requirement: 2pg max

Section	Description	Grade (796)
Introduction	Provides background and mathematical and biological context. Include a thesis statement (e.g., "Here I argue...", "This critical analysis concludes...").	30% (30%)
Article Summary	Explain what the paper did and why. Explain what was found	30% (10%)
Analysis	A written summary of your analysis of the model design, the validity and robustness of the results, and accuracy of the inferences drawn.	40% (40%)
References	Reference list of additional literature	NA (20%)

Project Proposal

Length Requirement: 4pg max, $\geq$1 figure

Section	Description	Grade
Introduction	Provides context, and relevance for the proposed thesis. Must include a thesis statement (e.g., "I will examine...", "This works will...").	40%
Methods	Summarize what methods you will use. Why are they appropriate? What challenges do you foresee?	30%
Figure	Supports the content of the introduction and/or methods	20%
References	Reference list of additional literature	10%

Final Project

Length Requirement: 10pg max, $\geq$1 figure

Section	Description	Grade
Abstract	A short summary (200 word max) of the project that clearly states aims and focal conclusions.	5%
Introduction	Provides background, context, and motivation. Must include a thesis statement (e.g., "This works evaluates...").	20%
Methods & Results	Summarize what methods you used. Why are these methods were appropriate. Explain what you found.	30%
Discussion	What are the implications of what you found? What are the limitations of your work?	30%
Figure & Tables	Figure(s) that support(s) the content of the methods or results	10%
References	Reference list of additional literature	5%

Diversity and Inclusivity Statement

In this course you will treat others and be treated with respect. We welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, orientations, national origins, abilities, and other visible and non-visible differences. All members of this course are expected to contribute respectfully and in return each contribution will be appreciated and treated with respect.

Academic Integrity

"All members of the university are expected to uphold the values of academic integrity: honesty, trust, fairness, respect, responsibility, and courage. SFU considers any act of falsification, misrepresentation or deception to be destructive because it is unfair to students who pursue their studies honestly, it compromises the worth of other's work, and ultimately prevents students from meaningfully reaching their own scholarly potential.

Being an SFU student means you belong to a scholarly community where you will develop the critical thinking and research skills to not only be job ready but life ready. The satisfaction of a degree earned through hard work and persistence is a prize that is profoundly meaningful and universally respected." `https://www.sfu.ca/students/academicintegrity.html`

Class Schedule

MODULE 1: Mathematical Modelling in Epidemiology

week	topic	references	assignments
Week 1: Jan 10	Basic Compartmental Models	KR8: 2.1-2.5	
	Distributed delays [integro-differential equ.]	KR8: 3.3, Goncalves 2011	Lab 1
Week 2: Jan 17	Transmission heterogenities [Age and Risk]	KR8: 3.1-3.2& Iyaniwura et al. 2021	
	Spatial Models [household & metapopulation]	KR8: 7.1 & Liu et al. 2021 & House and Keeling 2009	Assign. 1
Week 3: Jan 24	Stochastic Epidemic Models	KR8: 6.3-6.6	Lab 2
	Network Models [pair approximation, cellular automata, ABC]	KR8: 7.3-7.6, 7.8, Volz & Meyers 2009 & Keeling and Eames 2005	Assign. 2
Week 4: Jan 31	Model parameterization [R_0 estimation, serial interval estimation]	KR8: 2.8 & Vink et al. 2014	
	Model parameterization [seroprevealence, time-series]	KR8: 2.8	Assing. 3
Week 5: Feb 7	Model uncertainty, adequacy, and selection [sensitivity analyses]	Garner 2011 & Roda 2020	
	Prediction and Forecasting	Held et al. 2017	Lab 3
Week 6: Feb 14	Interventions 1 [NPIs, contact tracing]	KR8: 8.2, Eames and Keeling 2003 & Ferguson et al. 2020 & Grantz et al. 2020 & Peak et al. 2017 & Otto 2020	
	Interventions 2 [Vaccines]	KR8: 8.1, Liu and Xia 2020, Layman et al. 2021, Anderson and May 1982	Draft 1

MODULE 2: Disease Ecology and Evolution

week	topic	references	assignments
Week 7: Feb 21	Reading Week		
Week 8: Feb 28	Disease Ecology 1 [multi-host, vector transmission, zoonses]	KR8: 4.2, Mandal 2011 & Frederickson and Reese 2021	
	Disease ecology 2 [Multi-pathogen co-infection, super-infection]	KR8: 4.1, Nowak and Sigmound 2002 &Wikramaratma et al. 2015	Assign. 4
Week 9: March 7	Disease Ecology 3 [Abiotic conditions, Biological control]	KR8: 5.2,5.3, Lord 2007 & Craig et al. 1999	

	Evolutionary-epidemiology 1 [evolution of epidemiological traits]	Otto et al. 2021 & Cresler et al. 2017, Day et al. 2020	Draft 2
Week 10: March 14	Evolutionary-epidemiology 2 [vaccine and antibiotic resistance]	Lipsitch 2002 & Bonhoeffer 2002 & McLean 2002	Lab 4
	Evolutionary-epidemiology 3 [emergence of infectious disease]	KR8: 4.2.3 Gandon 2013	Assign. 5

MODULE 3: Genomic Epidmeiology

week	topic	references	assignments
Week 11: March 21	Fundamentals of Genomics and Phylogenetics	Pybus and Rambaut 2009	
	Transmission chains	Didelot et al. 2014	
Week 12: March 28	Phylodynamics	MacPherson et al. 2021	Lab 5
	Phylogeography	Lemey et al. 2009, 2014 &Dudas et al. 2017	Assign. 6

MODULE 4: Within-host Models

week	topic	references	assignments
Week 13: April 4	Within-host models	Ball et al. 2007 & Perelson a nd Nelson 1999	Lab 6
	Immunology and Original Antigenic Sin	Ndfion 2015	
TBD	Project Due		

Writing Assignment Schedule

Assign. 1	Anderson and May 1982 *Science*	Week 2
Assign. 2	House and Keeling 2008 *Mathematical Bio-sciences*	Week 3
Assign. 3	Keeling 2005 *TPB*	Week 4
Assign. 4	Parham et al. 2000 *Environ. Health Perspect.*	Week 8
Assign. 5	Koella and Anita 2003 *Malaria Journal*	Week 10
Assign. 6	Barido-Sottani et al. 2018 *Proc. R. Soc. B*	Week 12

Computer Lab Schedule

Lab 1	Introduction to Mathematica [A basic compartmental model]	week 1
Lab 2	Simulating Stochastic Epidemics	week 3
Lab 3	Performing a Sensitivity Analysis	week 5
Lab 4	Mutation, Trait evolution, and Epidemiological Tradeoffs	week 10
Lab 5	Intro to BEAST	week 12
Lab 6	A Within vs. Between Host Model	week 13