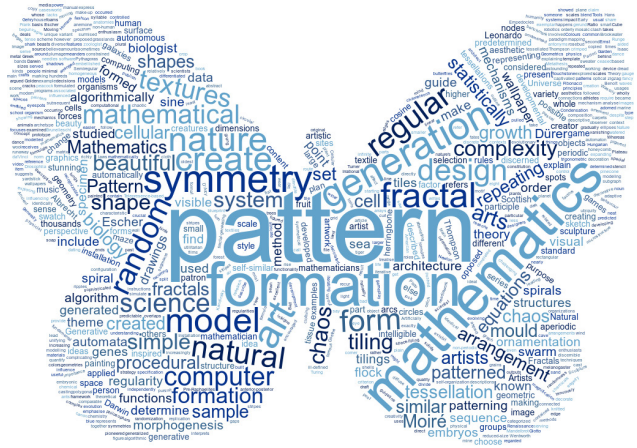
Advanced Mathematical Perspectives 1

Lecture 1: Introduction and Course Summary



Matthew Roughan

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www.maths.adelaide.edu.au/matthew.roughan/notes/AMP1/

School of Mathematical Sciences,
University of Adelaide

THE UNIVERSITY of ADELAIDE

SUB CRUCE LUMEN

ACEMS

AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE FOR MATHEMATICAL AND STATISTICAL FRONTIERS

Section 1

Course Introduction

Who is teaching this course

Course Coordinator: Prof Matthew Roughan
Email: matthew.roughan@adelaide.edu.au
Office: Ingkarni Wardli, Room 6.17

Lecturer (Pure Mathematics): Prof. Finnur Lárusson
Email: finnur.larussonk@adelaide.edu.au
Office: Ingkarni Wardli, Room 6.49

Administrative Enquiries: School of Mathematical Sciences Office,
Level 6, Ingkarni Wardli

Consulting: (Matt Roughan)
Tuesday 2.10 - 3.00 pm (after the workshop)
Wednesday 5.10 - 6.00 pm (after the workshop)

If you wish to see me outside of these hours, then please email me to arrange a time – it is unlikely I will be available to help you if you simply drop by without prior arrangement.

Why am I teaching (my part of) this course?

- Wide range of experience
  - working in industry AT&T, Ericsson
  - working here at university
- Wide range of training
  - Mathematics
  - Computer science
  - Physics
- ACEMS = ARC Centre of Excellence for Math. and Stats. Frontiers
  - Theme leader for "Challenging Data"
- Wide range of research interests
  - centred around Networks
  - focused on computer communications networks (the Internet)
  - bit wider these days: you can see my pubs at

`scholar.google.com.au/citations?user=Mnkm_NsAAAAJ&hl=en&oi=ao`

Overall Structure

- Weeks 1-8: Applied Maths and Statistics (Matt Roughan)
- Weeks 9-11: Pure Mathematics (Finnur Lárusson)
- Week 12: Posters

Most of what I will say today applies to MY part of the course.

Assessment

This is a Project-based course

1. Project 1 (Applied Mathematics and Statistics) 75%
   - Written report: 60%
     - ★ part of the mark will be based on milestones that you have to hand in before the final project is handed up
   - Poster-based oral presentation: 15%

   There are detailed rubrics providing information about how these will be assessed.
2. Project 2 (Pure Mathematics) 25%
   - Finnur Larusson will set detailed assessment criteria
3. There is NO exam!

Hand in your work via MyUni

Assessment

Note

1. Work handed in up to 24 hours late will have 20% subtracted.
2. Work handed in more than 24 hours late will not be accepted, except by prior arrangement for a good reason (see University policies).

This is slightly **more lenient** than the official policy, which is late work will not be accepted at all.

Policy on plagiarism

The University of Adelaide has an official policy on academic honesty and plagiarism, which they are advised to read at

http://www.adelaide.edu.au/policies/230/

Students are encouraged to work together in order to enhance their understanding of the subject matter. To this end they may work together on assignments/practicals. However, you MUST submit your own work.

Students are required to have, and may be required to demonstrate, a complete understanding of their submitted work. Failure to demonstrate a complete understanding of a submitted assignment may be interpreted as evidence of plagiarism.

This applies to computer code as well!

Expectations

- The tasks assigned will not all be possible to complete in the allocated sessions
- Time in workshops is to allow you to ask questions and get help
- For this to be useful, you should keep up with the work, and prepare in advance
- You need to budget time to spend on the work outside of the allocated sessions

Course materials

There is no textbook as such, for this course.

- Required materials will be available via MyUni.
- I have additional books that I am willing to lend to students
- However, as an *advanced* course, your are expected to show personal initiative, *i.e.*, you will go beyond the material presented and do some of your own research towards your projects.

Section 2

Feedback from last year, and changes this year

Feedback from Last Year

Which aspects of this course need improvement?

- The assignments
- Starting with, or having a greater time dedicated to, pure mathematics. Removing the requirement of programming for pure maths inclined students. Teaching mathematics, not computer science and engineering.
- I think we needed a bit more explanation of the concepts because most of the people that I talked to found they didn't have enough base knowledge to fully understand the information.
- I think the weighting of the tasks is too high, especially for a course specific to an advanced degree which requires you to achieve a minimum 5.0 GPA. This then leads to small mistakes being very significant in your final result.

(Negative) Feedback from Last Year

Which aspects of this course need improvement?

- Maybe the pure math component where we go through how to write a project should be at the start of the course.
- Maybe just knowing what the point of the course was? It wasn't until about week 6 that I actually started to understand what the purpose of the course was, but that being said it was definitely an incredible course!
- Sometimes lectures werent online
- Practicals, all were rubbish. Workshops had no point to attend.
- WHY DID WE MAKE A POSTER IN UNIVERSITY?!
- I think the course itself may need to be a bit more transparent in its structure.
- There were a number of organisational issues throughout the course. All sessions were listed on the timetable as a Workshop, making it unclear what to expect without a schedule that was provided during a lecture, and the room they were all held in was changed at the last minute, causing me to miss the first week of sessions. Also, Echo360 recordings either did not work or were not made, so missed lectures could not be caught up.

Course Philosophy

We aren't focused (in this course) on teaching you a "topic" of mathematics, though we will do a little of that. The main things we are trying to teach are things that will help turn you into a successful mathematician:

1. How maths fits together as a field
2. Specific "attributes" of good working mathematicians

How maths fits together as a field

Our School is divided into 3 disciplines

- Pure Mathematics: focus at this uni is Geometry
- Statistics: focus biostatistics, ...
- Applied Mathematics: 2 sub-disciplines
  - Dynamics: focus on continuous, deterministic systems, *e.g.*, fluid dynamics, maths biology, ...
  - SMORG (Stochastic Modelling and Operations Research Group): focus on discrete, random systems, *e.g.*, networks, ecology, ...

We want, in this course, to give you at least a flavour of all four of these.

- I will cover Applied (Dynamics and SMORG) and Stats (75%)
- Finnur will cover Pure (25%)

Student attributes

You can see the Uni's graduate attributes on the web, but I think more in terms of the AMSI Industry working groups findings regarding what they *NEED* in mathematicians working in industry and finance and almost anywhere you are likely to get a job

- logical/critical thinking
- practical ability to do problem structuring and solving, often beginning with messy data, or a messy problem description
- data analysis skills, ability to work effectively with data
- communication skills
- ability to code/program
- ability to work collaboratively, in multi-disciplinary teams

We also want to develop your foundational research skills in the mathematical sciences.

Student attributes

This course aims to help give you some of the skills you *NEED* in mathematicians working in industry and finance and almost anywhere you are likely to get a job

- logical/critical thinking
  all of mathematics does this anyway
- practical ability to do problem structuring and solving, often beginning with messy data, or a messy problem description
  I will not give you a well-defined problem to work on
- data analysis skills, ability to work effectively with data
  AMP will get you started working on data
- communication skills
  Report writing, and oral presentation skills!!!
- ability to code/program
  Programming is key for a modern mathematician. You won't get a job without it.
- ability to work collaboratively, in multi-disciplinary teams
  AMP II and III

Programming

- This course will require computer programming
  - The expectation is that you are a 1st year computing subject in parallel with this course, and are hence learning Matlab or equivalent
  - This course will use Matlab by default
  - If you want to use a programming language other than Matlab, I may allow it, if you can justify it clearly
- There is fair bit of programming – why?
  - beyond the need for programming skills to get a job
  - it's a way to make your ideas concrete
  - it's a way to work with bigger data and models than you could do by hand – we can see further into a topic this way
  - one of the main uses for mathematics is to make computation better!

Organisation: Applied and Statistics

We have 3 sessions per week, each of which will have a short lecture, followed by a workshop component.

- *hence they can't be effectively recorded!!!*
- hence you must attend (whenever possible)
- a role will be recorded

A planned schedule of topics and activities is available at MyUni.

Why Posters?

- Don't think of a poster as trivial – good posters are MUCH harder to do than you think
- Posters are a serious means of communication
  - technical conferences use them!
  - we use them to get people interested in what we do
  - they are a good (semi-permanent) reminder of work
- Oral communication skills are vital!
  - You will stand up, next to your poster, and explain it to me
  - 2-3 minute, "elevator pitch"
    https://en.wikipedia.org/wiki/Elevator_pitch
  - *This is arguably the most useful skill you will ever learn*

Practicals/workshops

- One comment was made about the usefulness of the workshop/practicals
- The goal is to teach you techniques that will become part of what you use for your reports
- I have tried to reorganise this year though, to make them more useful

Section 3

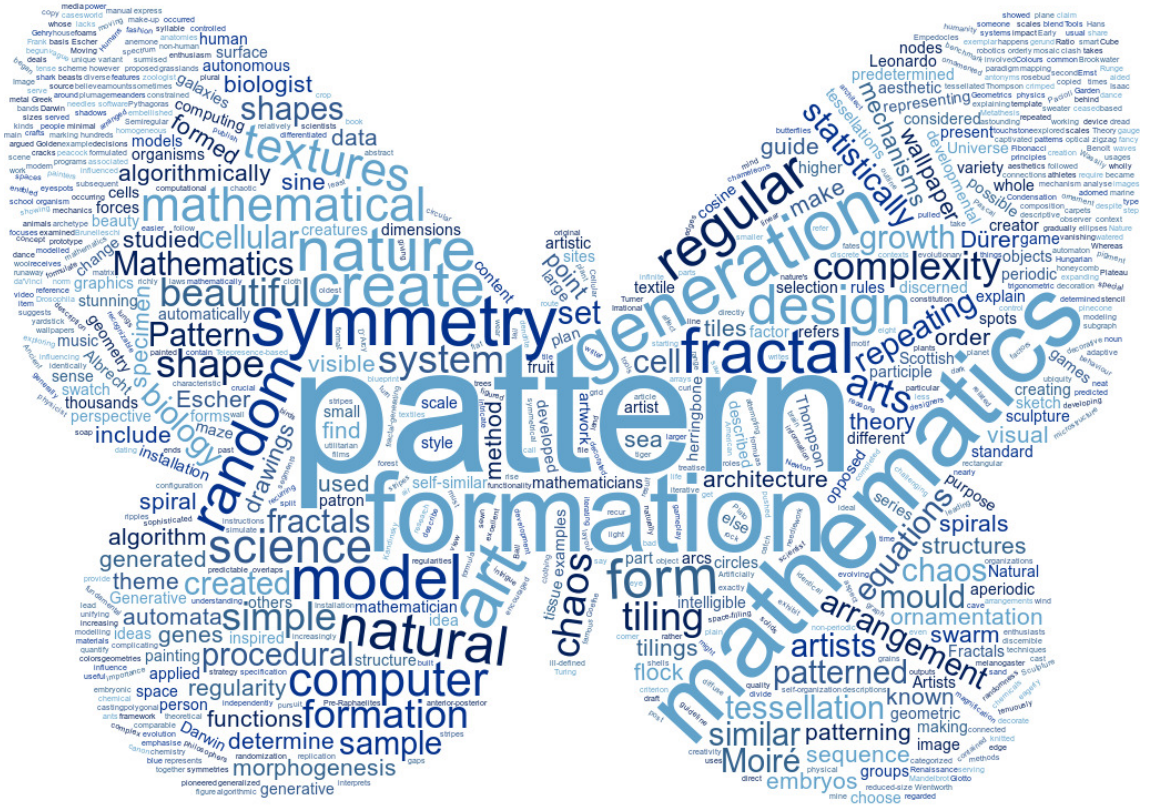
Course Theme

Theme

- AMP 1 theme changes from year to year to keep it fresh
- Aims in choosing it
  - Cover all of the sub-disciplines
  - Give you a hint of something deeper about mathematics
  - Draw (primarily) on your existing mathematical knowledge
  - Hit the teaching goals (I have already described)
  - Have some fun!
- This is interesting stuff, probably outside of your experience of mathematics. Don't panic!

This year's theme

- **Pattern Formation**
- I could have called it
  - Mathematical models in 2D
  - Mathematical eye-candy
  - Procedural generation
  - Mathematical art
  - Generative art
  - Texture modelling
  - Modelling patterns
  - Natural geometry
  - Algorithmic art
  - Data-driven art
  - Generative design
  - Maze generation



Pattern Formation — What's that?

> Mathematics is the science of patterns, and nature exploits just about every pattern that there is.
>
> *Ian Stewart, Nature's Numbers, 1995*

- Patterns are literally EVERYWHERE
- We (humans) are built to see them
  - to recognise faces
  - to spot danger or food
  - to understand language
  - our brain literally gets a hit of endorphins when (we think) we see a pattern
    - ★ it's thought to contribute to gambling addiction
      www.scientificamerican.com/article/how-the-brain-gets-addicted-to-gambling/
- But what causes the patterns in the first place?

Why care what causes patterns?

Questions:

1. Why do we see the same patterns again and again in different contexts: stripes on a zebra, ripples on a sand dune, fingerprints?
2. Some patterns in nature look designed – *e.g.*, the Giant's causeway, honeycomb, stones on the Norwegian tundra – are they?
3. Zebras have slightly different stripe patterns – why? Would a cloned Zebra be the same? (also see Tigers, Leopards, Cows, Giraffes, ...)
4. If we wanted to avoid making patterns how would we do that? Why?
   - what about computers (which are deterministic) that need to generate random events, *e.g.*, in computer games
   - what about cryptography (crypt-analysts exploit patterns)
5. Are crop circles made by aliens?

Pattern Formation Applications

1. Cryptography and steganography
2. Computer games
   1. texture generation
   2. procedural generation: *e.g.*, Elite Dangerous, No Man's Sky, ...
   3. CGI (anti-aliasing, ...)
3. Noise removal (fixing images or music)
4. Bio-mimetic algorithms
   1. ant optimisation
   2. flocking and autonomous vehicles
   3. genetic algorithms

   If we understand how biology does something, it can lead to new ideas for us to do similar things.
5. Micro and nano-structure engineering: self-organising circuits, ...

Memes

> What is a pattern, anyway? We usually think of it as something that repeats again and again. The math of symmetry can describe what this repetition may look like ... But our intuitions about symmetry can be deceptive. In general, shape and form in nature arise not from the "building up" of symmetry, but from the breaking of perfect symmetry — that is, from the disintegration of complete, boring uniformity, where everything looks the same, everywhere.
>
> *Philip Ball, Patterns in Nature, 2016 [Bal16]*

- order from randomness
  - emergence of large-scale structure from small interactions
- randomness from order
  - symmetry breaking through instability
- interesting patterns arise at the edge of chaos , where symmetry and uniformity start to break down

Takeaways

- Course Admin
  - lots of details you need to know
- Theme: Pattern formation
  - we'll start on this for real next week

Further reading I

Philip Ball, *Patterns in nature: Why the natural world looks the way it does*, University of Chicago Press, 2016.

D'Arcy Wentworth Thompson, *On growth and form*, Cambridge University Press, 1945, `https://archive.org/details/ongrowthform00thom`.