SM-2302 Software for Mathematicians

Introduction & Getting Started

Drs. Haziq Jamil & Huda Ramli
Mathematical Sciences, Faculty of Science, UBD
`https://github.com/sm2302-aug23`

Semester I 2023/24

Admin

- Lecturer information

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- **IMPORTANT: Read the syllabus.**
- Weekly contact hours
  - Lectures: Tuesdays 2:10–4.00 pm @ ICTC Lab 7
  - Labs: Fridays 2:10–4.00 pm @ ICTC Lab 7
- Be aware of schedule and important deadlines.
- Check Canvas regularly for announcements and course materials.

Module description

> *Mathematical software is what bridges higher mathematics to real world applications. On completing this module, students should be able to use* `MATLAB` *and* `R` *to effectively implement mathematical solutions to real world problems. They should also be able to produce publication-quality mathematical documents using LaTeX. This module provides the computing skills required for an applied mathematics final year project.*

Contents

1. Learning `MATLAB` and `R` languages for mathematical applications.
2. `MATLAB` specific outomes:
   - Basic operations, programming, numerical techniques and root finding.
3. `R` specific outcomes:
   - Logic and types, data frames and matrices, data wrangling, and visualisations.
4. Preparation of report-style documents using LaTeX.
5. Version control and social coding using Git and GitHub.

Assessment

Take note that this module is assessed wholly (100%) by coursework.

Formative assessment

- Lab-based tutorials

Summative assessment

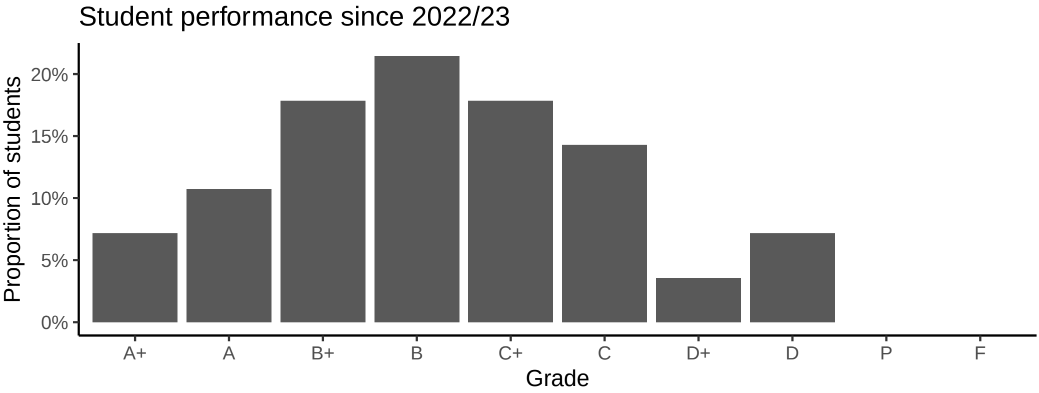
- **[10%]** 2 × online quizzes (R and MATLAB)
- **[5%]** 1 × Canvas discussion (Git & GitHub)
- **[20%]** 2 × mini individual assignments
- **[30%]** 2 × mini group assignments
- **[5%]** 2 × group peer review
- **[30%]** 1 × project assignment with written report

Schedule

Week	Topic	Instructor	Assessment
W01: 31/07 – 06/08	Introduction & Getting Started	HJ	
W02: 07/08 – 13/08	[R] Logic and types	HJ	
W03: 14/08 – 20/08	[R] Matrices and data frames	HJ	Quiz 1
W04: 21/08 – 27/08	[Git] Git and GitHub	HJ	Discussion 1
W05: 28/08 – 03/09	[R] The tidyverse	HJ	Individual 1
W06: 04/09 – 10/09	[R] Visualisations using ggplot	HJ	
W07: 11/09 – 17/09	[MATLAB] Basic operations	NHR	
18/09 – 24/09	Mid-semester Break		
W08: 25/09 – 01/10	[R] Peer review	HJ	Group 1
W09: 02/10 – 08/10	[MATLAB] Programming	NHR	
W10: 09/10 – 15/10	[MATLAB] Numerical techniques	NHR	Quiz 2
W11: 16/10 – 22/10	[MATLAB] Root-finding	NHR	Individual 2
W12: 23/10 – 29/10	[LaTeX] Typesetting reports	NHR	
W13: 30/10 – 05/11	[LaTeX] Beyond reports	NHR	
W14: 06/11 – 12/11	[MATLAB] Peer review / presentations	NHR	Group 2

Past student feedback

- *Fun and applied module*
- *Challenging if not have coding experience*
- *Useful for FYP and other modules*
- *Intensive and lots of work involved*



Use of AI, collaboration, sharing and code reuse

- All graded assignments must be your own individual work, *except* for the group assignments (these are expected to be collaborative in nature). **Otherwise, NO CODE SHARING among peers**.
- We are aware that the internet is a great resource. You may make use of any of these resources, but **you must explicitly cite where you obtained any code you have used directly, or gained inspiration from**.
- Any recycled code that is discovered and is not explicitly cited will be treated as plagiarism, regardless of source.
- The use of AI tools (including but not limited to ChatGPT) to produce solutions to any assignments is **prohibited**, and if caught using will be treated as plagiarism.

Plagiarism

Penalties for plagiarism

- A written, formal reprimand kept in Faculty records; and/or
- Resubmission of assignment; and/or
- Reduced assignment marks; and/or
- Fail grade for assignment.

Admin

Purpose of mathematical software

Getting started

Purpose of mathematical software

> *Software is essential for modelling, analysing and calculating numeric, symbolic, or geometric data.*

Generally speaking, mathematical software is very focused:

1. **Software calculator**: Performs simple mathematical operations.
2. **Computer algebra systems**: Designed to solve classical algebra equations and problems in human readable notation.
3. **Statistics**: Statistical analysis of data.
4. **Optimisation**: Selecting a best solution from a set of alternatives.
5. **Numerical analysis**: Numerical approximations for the problems of mathematical analysis.
6. etc.

Remark

While mathematical software produces useful solutions, they very often do not explain why the solutions are what they are.

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- We might attempt to brute force the answer by writing a software loop.
- Can we prove this theorem by software?

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- Can we prove this theorem by software?

```
INPUT n
  i := 2
  count := 0
  WHILE i <= n
    rem := n % i
    IF rem not equal to 0
      i := i + 1
      count := count + 1
    END IF
  END WHILE
OUTPUT count
```

Software affords us insight

Let $\pi(x)$ be the prime counting function defined to be the number of primes less than or equal to x, for any $x \in \mathbb{R}$. Can we intuit a good approximation of $\pi(x)$?

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A different (but related) question: How far apart are the prime numbers?

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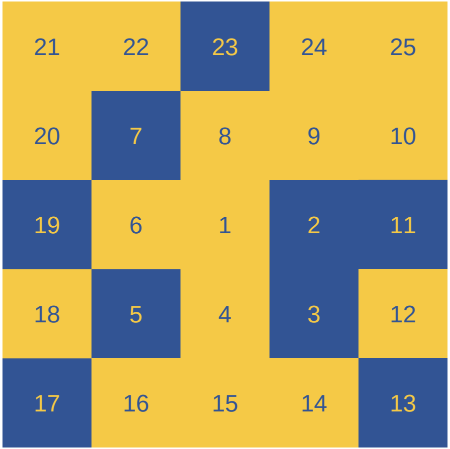
A different (but related) question: How far apart are the prime numbers?

Define the *density* of primes as $\pi(x)/x$. This gives an idea of the distribution of primes up to x. It would be interesting to map this out.

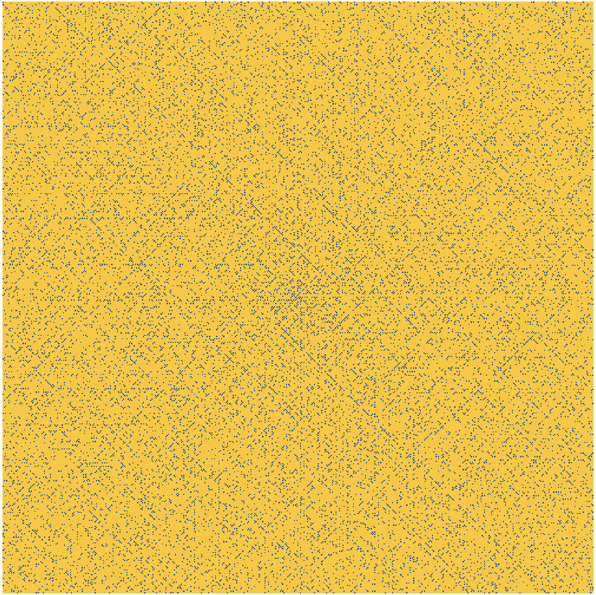
Source code from
`https://github.com/johnistan/ulam-spirals-R`



21	22	23	24	25
20	7	8	9	10
19	6	1	2	11
18	5	4	3	12
17	16	15	14	13

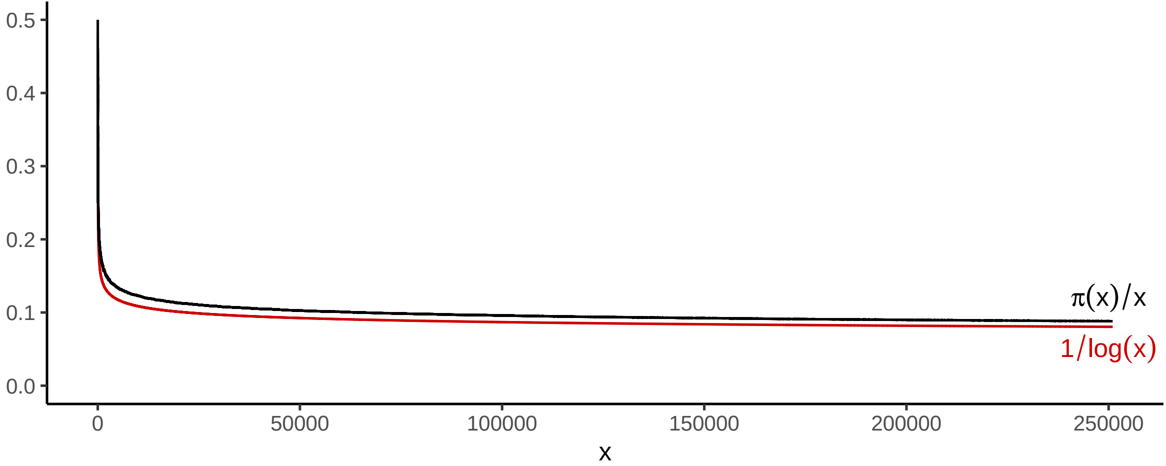
Ulam's spiral

- Prominent diagonal, horizontal and vertical lines containing large number of primes.
- Not unsurprising, as these correspond to certain prime-generating polynomials such as $x^2 - x + 41$ (Euler's).
- Nonetheless, connected to many unsolved areas of mathematics!
  - Riemann Hypothesis
  - Goldbach's conjecture
  - Twin prime conjecture
  - Legendre's conjecture



Does the density converge?

As $x \to \infty$, the prime density $\pi(x)/x$ diminishes at a slow rate. Reminiscent of an inverse logarithmic decrease!



The prime number theorem

- The *asymptotic* law of distribution of prime numbers states that

$$\lim_{x\to\infty} \frac{\pi(x)/x}{1/\log(x)} = \frac{\pi(x)}{x/\log(x)} = 1$$

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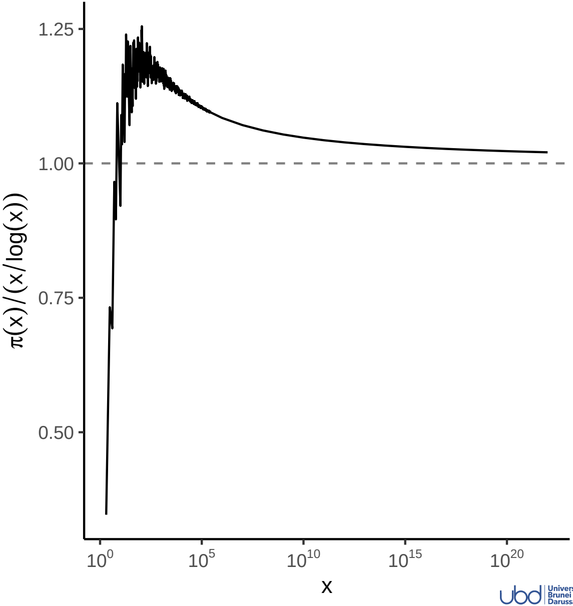
$$\lim_{x\to\infty} \frac{\pi(x)/x}{1/\log(x)} = \frac{\pi(x)}{x/\log(x)} = 1$$

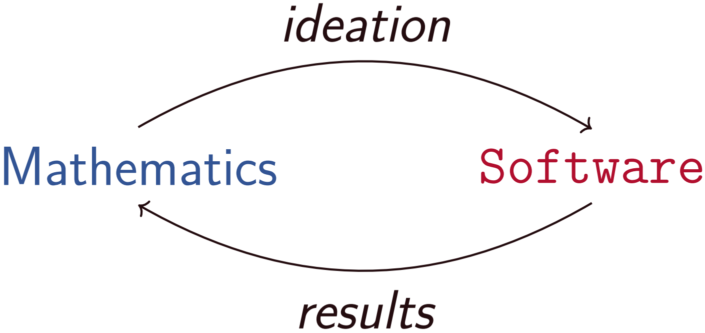
- From this, we have

$$\pi(x) \sim \frac{x}{\log(x)}$$

- We now have an approximation for the prime counting function, which improves as x increases. In particular, $\lim_{x\to\infty} x/\log(x) = \infty$.



Using software



ideation

Mathematics

`Software`

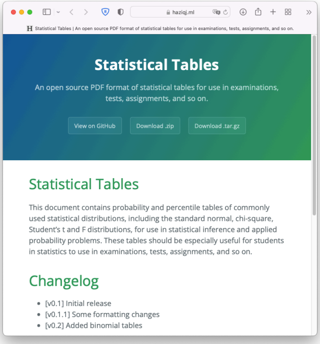
results

Use software as a tool to...

- Explore and visualise ideas
- Confirm ideas numerically
- Communicate results

Beyond this course

Static websites served on GitHub; 3-D plots and animation; Plotting GIS shape files and maps; Reproducible research (`knitr`); Text processing and analysis; Web and social media scraping; Creating R packages; Web APIs; Parallel computing; Optimisation; Mathematical and statistical modelling



H Statistical Tables | An open source PDF format of statistical tables for use in examinations, tests, assignments, and so on.

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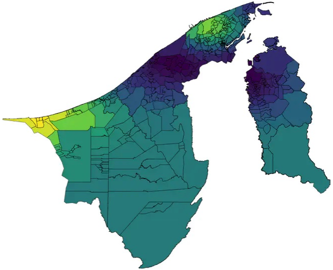
Statistical Tables

This document contains probability and percentile tables of commonly used statistical distributions, including the standard normal, chi-square, Student's t and F distributions, for use in statistical inference and applied probability problems. These tables should be especially useful for students in statistics to use in examinations, tests, assignments, and so on.

Changelog

- [v0.1] Initial release
- [v0.1.1] Some formatting changes
- [v0.2] Added binomial tables



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Purpose of mathematical software

Getting started

- Instructions
- Software overview

Instructions

IMPORTANT

Check Canvas for detailed instructions regarding software installation and sign up procedures.

Important points:

- Use UBD e-mail in most cases to obtain Education Benefits
- Pick a suitable username (one that you won't be embarassed to use in a few years time!)
- Practice safe and secure passwords
- When using Lab PCs, best to create a personal folder and keep all your work files in there.
- Using your own laptops is fine. Mind your cables! Avoid tripping hazards.
- Recommended to use USB drives (make sure they're clean!) or some cloud service (Dropbox, Sharepoint, Google Drive, etc.)

Software overview

1. MATLAB–more details in NHR's sessions.
2. RStudio Desktop
   - RStudio is installed on campus computers.
   - It is free to install on your personal computers–`https://www.rstudio.com/products/rstudio/download/`
   - You may also need to install the `R` language too, depending on your system. Do a Google search for 'R Windows download' or similar.
3. Git, github.com and GitHub Desktop
   - Please sign up for an account at github.com/signup using your UBD e-mail.
   - You will be invited to join the course organization (`sm2302`) in due course.
   - Assignments will be distributed and collected via GitHub.
4. Overleaf.com
   - Please sign up for an account at `https://www.overleaf.com/register`