THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE

Pattern Analysis

Course Introduction

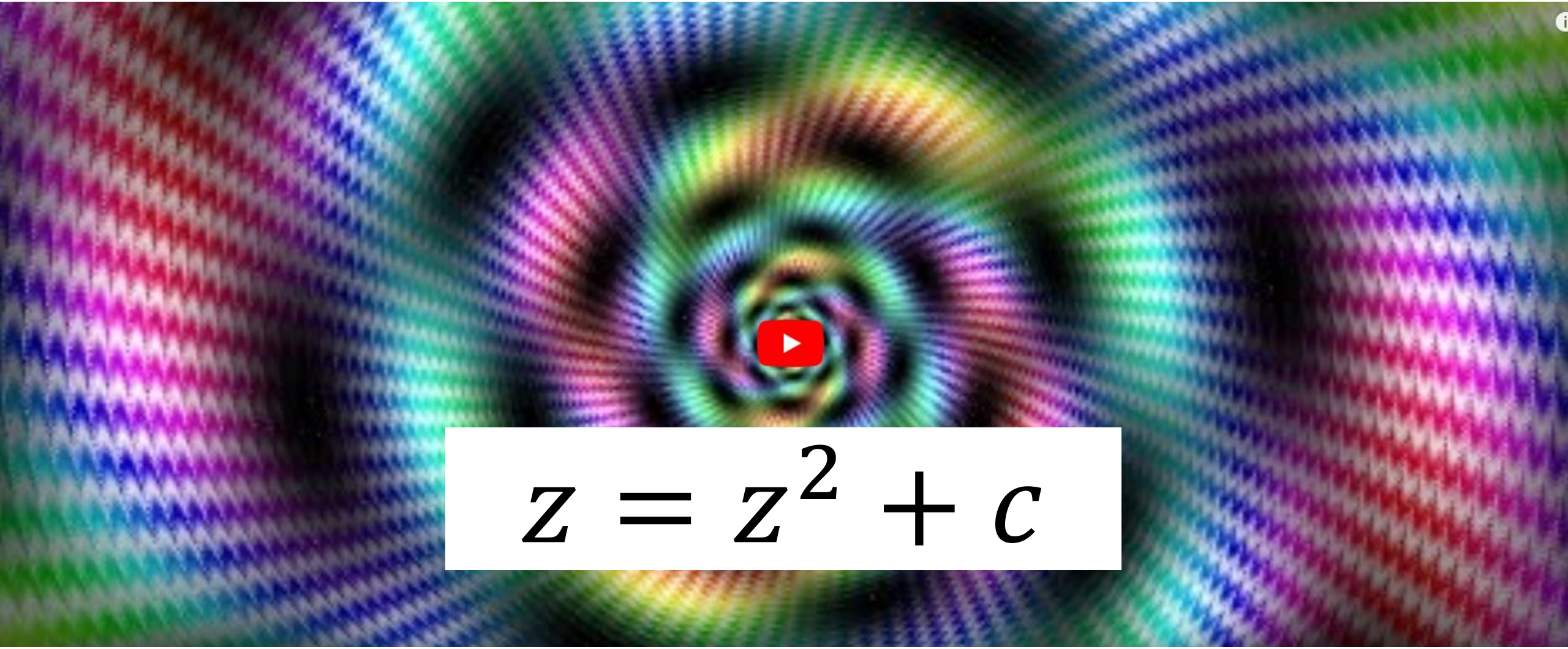
Shekhar “Shakes” Chandra, Ph.D

ARC Future Fellow

shekhar.chandra@uq.edu.au

V1.33

> “A mathematician, like a painter or a poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made with ideas.”
>
> **Godfrey H. Hardy (link)**
> (1877-1947)



This course is about patterns and how to find/make them!

https://www.youtube.com/@standupmaths

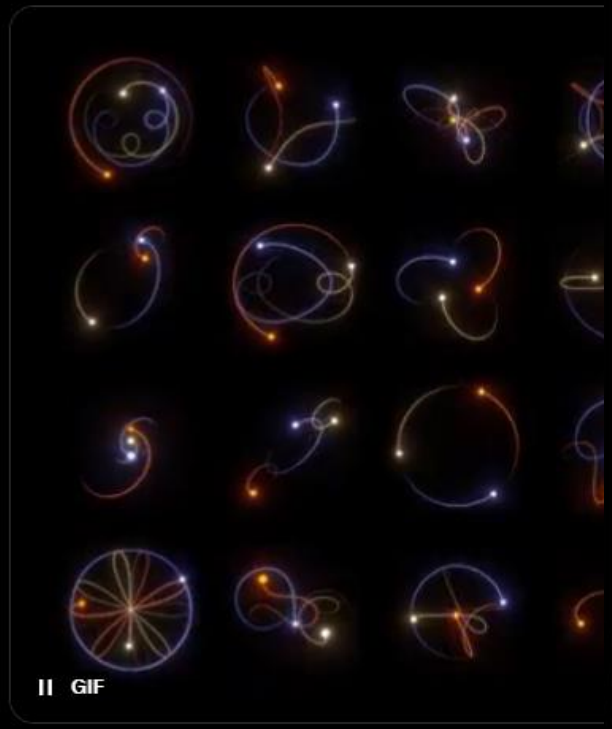
Fractals!

We will lear

Massimo
@Rainmaker1973

In 1890, Henri Poincaré proved the non-existenc
integral of a three-body problem and the sensiti
conditions of its trajectories. Yet, stable solution

[read more: buff.ly/44bpaAl]



Last edited 2:48 AM · Jun 20, 2023 · **1.6M** Views

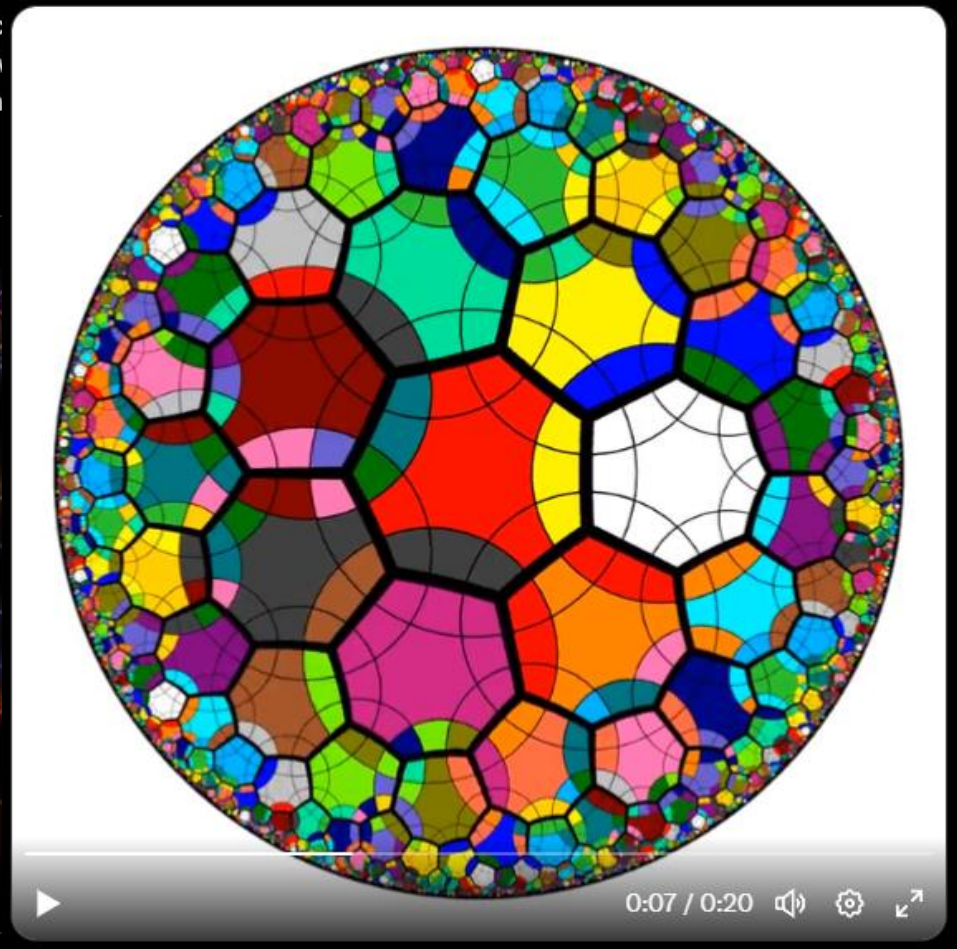
Cliff Pickover
@pickover

Mathematics.

Rubik's Cube for Higher-Dimensional Aliens.

Poincaré disk model. 24-color puzzle based on the regular {7,3} tiling.
Info: roice3.org/magictile

By @roice713, used with permission.



8:39 AM · May 4, 2023 · **60.9K** Views

Science girl
@gunsnrosesgirl3

Subscribe

Dalan Hargrave is a master in the fields of goldsmithing and lapidary and has honed his craft to perfection.

With his exceptional skill and expertise, he has elevated gemstones to the realm of art. This is a 44.64CT Amethyst

📹IG dalanhargrave

From **Levandov**

We will learn AI!

Andrew Carr
@andrew_n_carr

Someone on Reddit is using stable diffusion to take selfies throughout time - here they are with the Trojan horse

2:21 PM · Dec 10, 2022

4,772 Retweets **380** Quote Tweets **93.9K** Likes

hardmaru
@hardmaru

"English football team in tears hugging a giant teddy bear, in a stadium, after losing the World Cup."

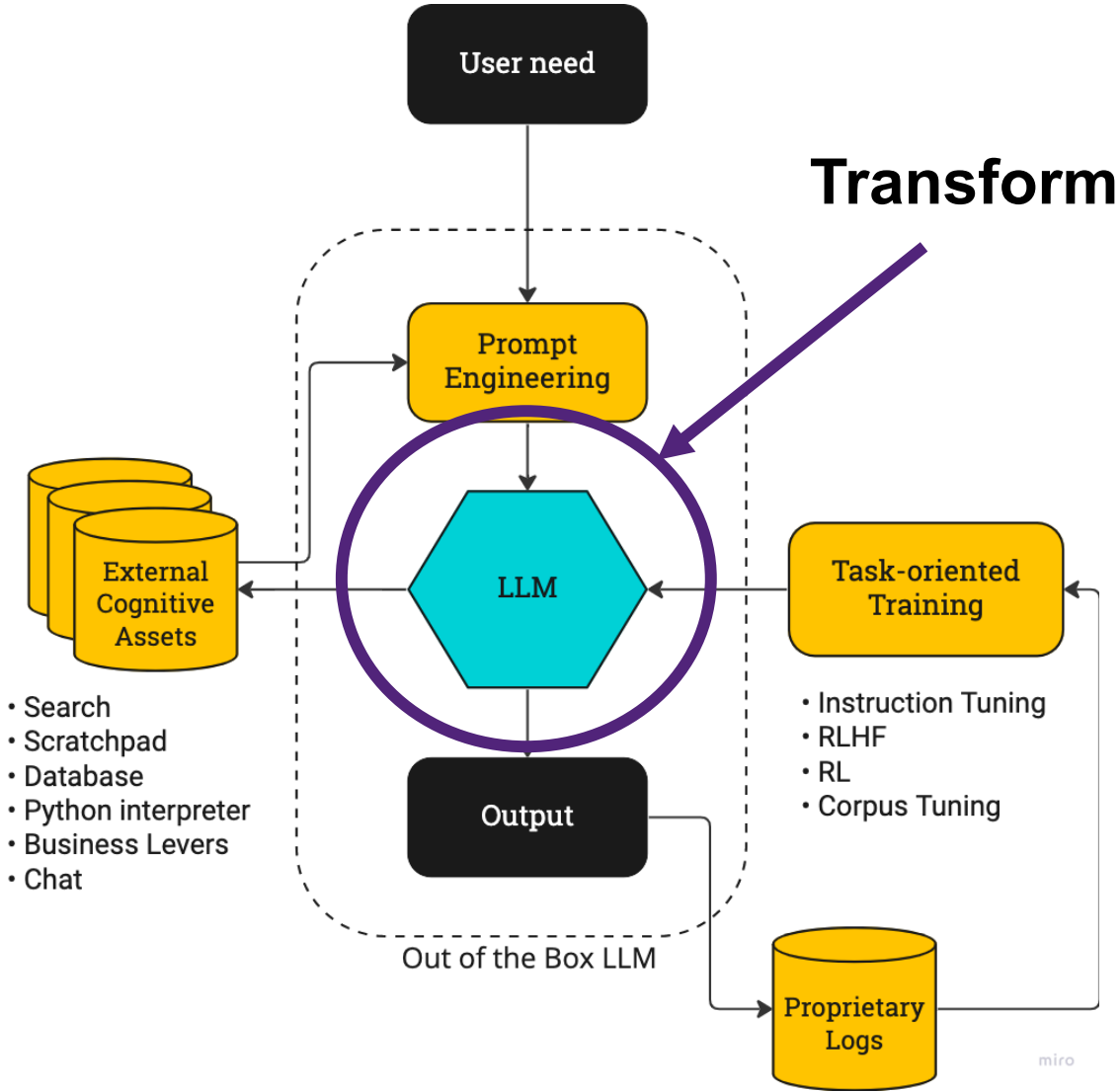
#StableDiffusion2 #StableDiffusion

Stable Diffusion

10:28 AM · Dec 11, 2022

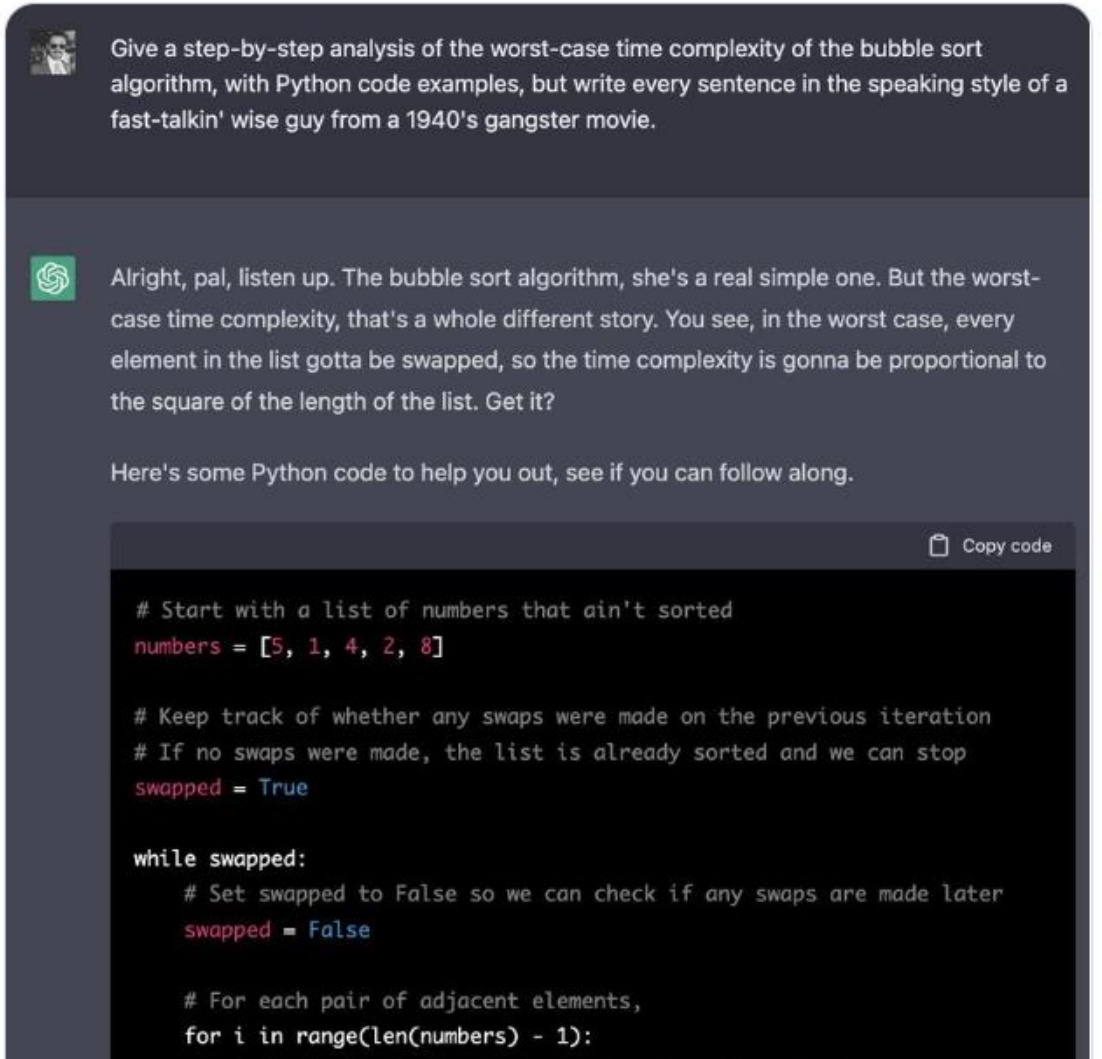
11 Retweets **2** Quote Tweets **134** Likes

ChatGPT



Riley Goodside
@goodside

OpenAI's new ChatGPT explains the worst-case time complexity of the bubble sort algorithm, with Python code examples, in the style of a fast-talkin' wise guy from a 1940's gangster movie:



Deep Learning Revolution!

Artificial Neural Networks revitalising Artificial Intelligence (AI)!

Deep Neural Networks is the main driver.

Takes days to train, runs in milliseconds regardless of task!

Graphics Cards

If you use any Google, Facebook, Microsoft and Amazon products, you are already using it!

TensorFlow

PyTorch

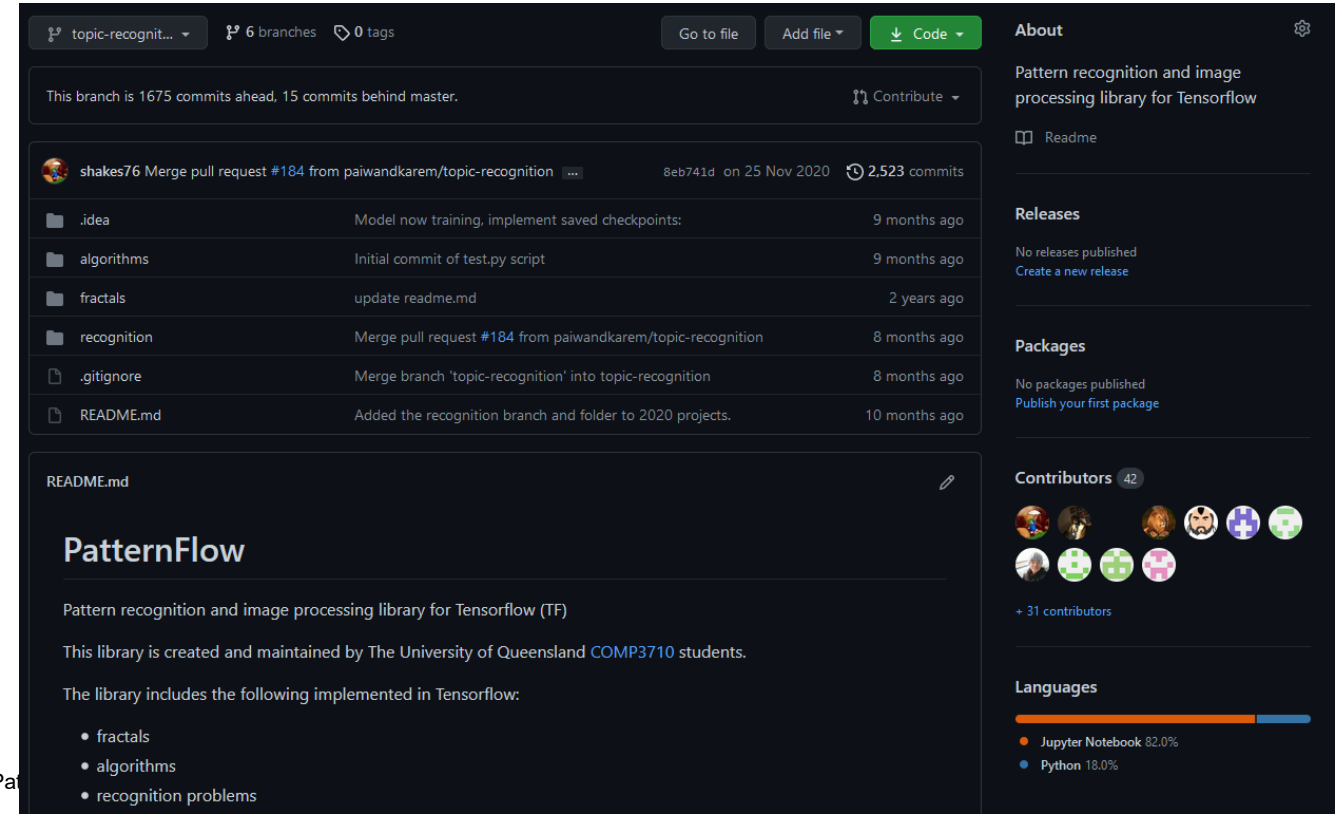
- Numpy-like
- Parallel processing under the hood
- Scales to different hardware auto-magically
- Open Source
- Used by industry

TensorFlow

PyTorch

PatternFlow

GitHub



Your Contribution!

Course Coordinators and Teaching Staff

Dr Shekhar “Shakes” Chandra
Level 5, Room 549,
General Purpose South Building [78]
Tel: 3365 8359
Fax: 3365 4999
shekhar.chandra@uq.edu.au
Webpage

Interests: Image processing, **fractals**, discrete geometry, medical image analysis, **pattern recognition, deep learning**, MRI, shape modelling and scientific visualization

I will always endeavor to make myself available after each contact/lecture at the venue or on ZOOM. This will be the most convenient time.

Getting Help

Post questions on Eds
You should be signed up already!

All lecturers and most tutors are monitoring this forum!

This is the preferred method of asking questions outside teaching activities

If it is a private matter or related to a personal issue

Dr Shekhar “Shakes” Chandra
shekhar.chandra@uq.edu.au

Getting Help

Think carefully before using email

- Can you get the info via the ECP?
- Can you ask the tutors at a tutorial session?
- Is it on blackboard?
- Have you checked the Ed answers?

Please keep communication concise and polite

Let us know if there are problems

- During tutorials, before and after lectures

Assumed/Helpful Background

We will be covering material assuming you are familiar with:

- Linear algebra – vectors, matrices, SVD and vector spaces
- Basic Calculus – Chain rule, differentiation

You **must** be comfortable with:

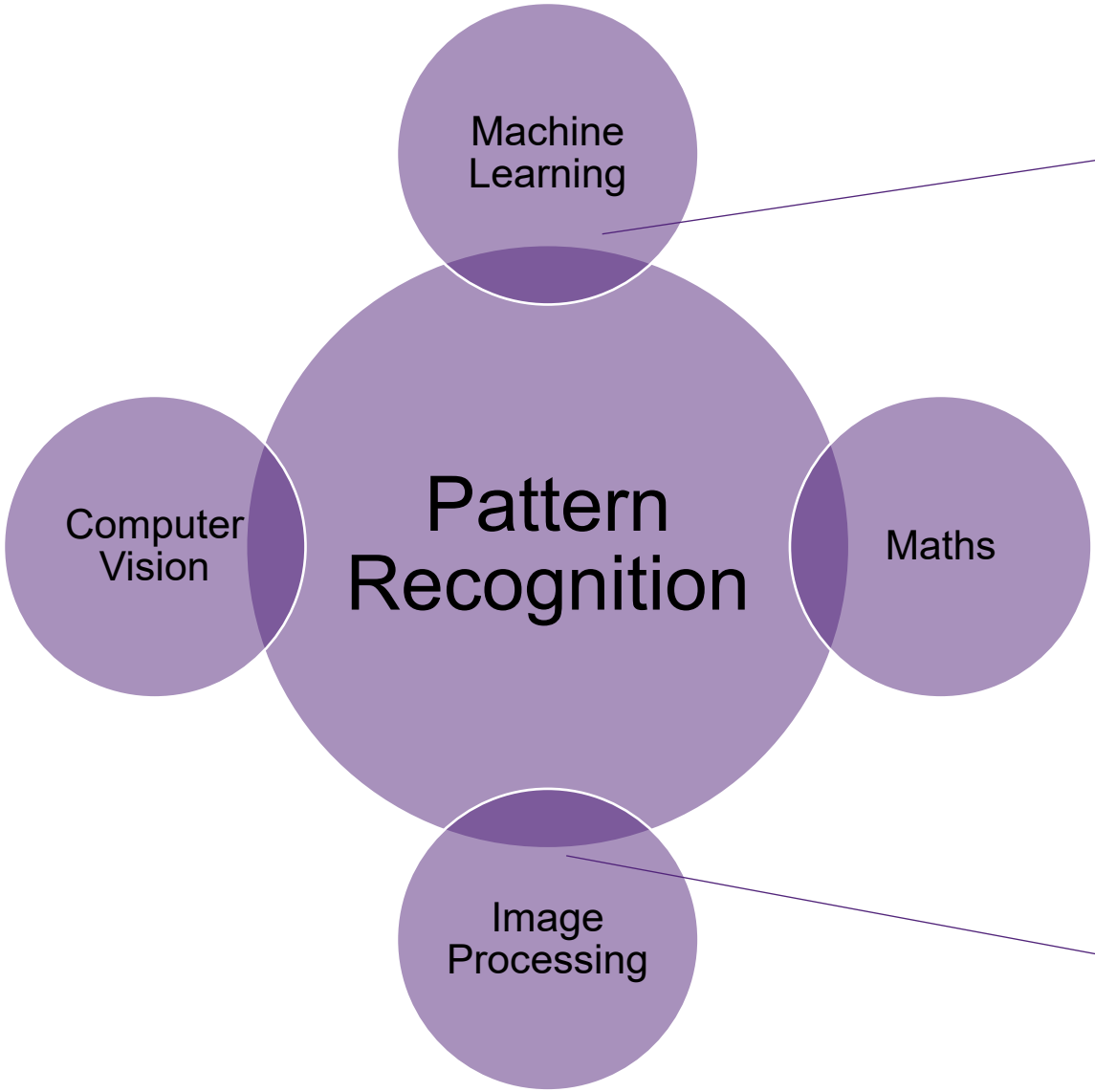
- Python programming – dictionaries, lists, recursion, numpy and matplotlib

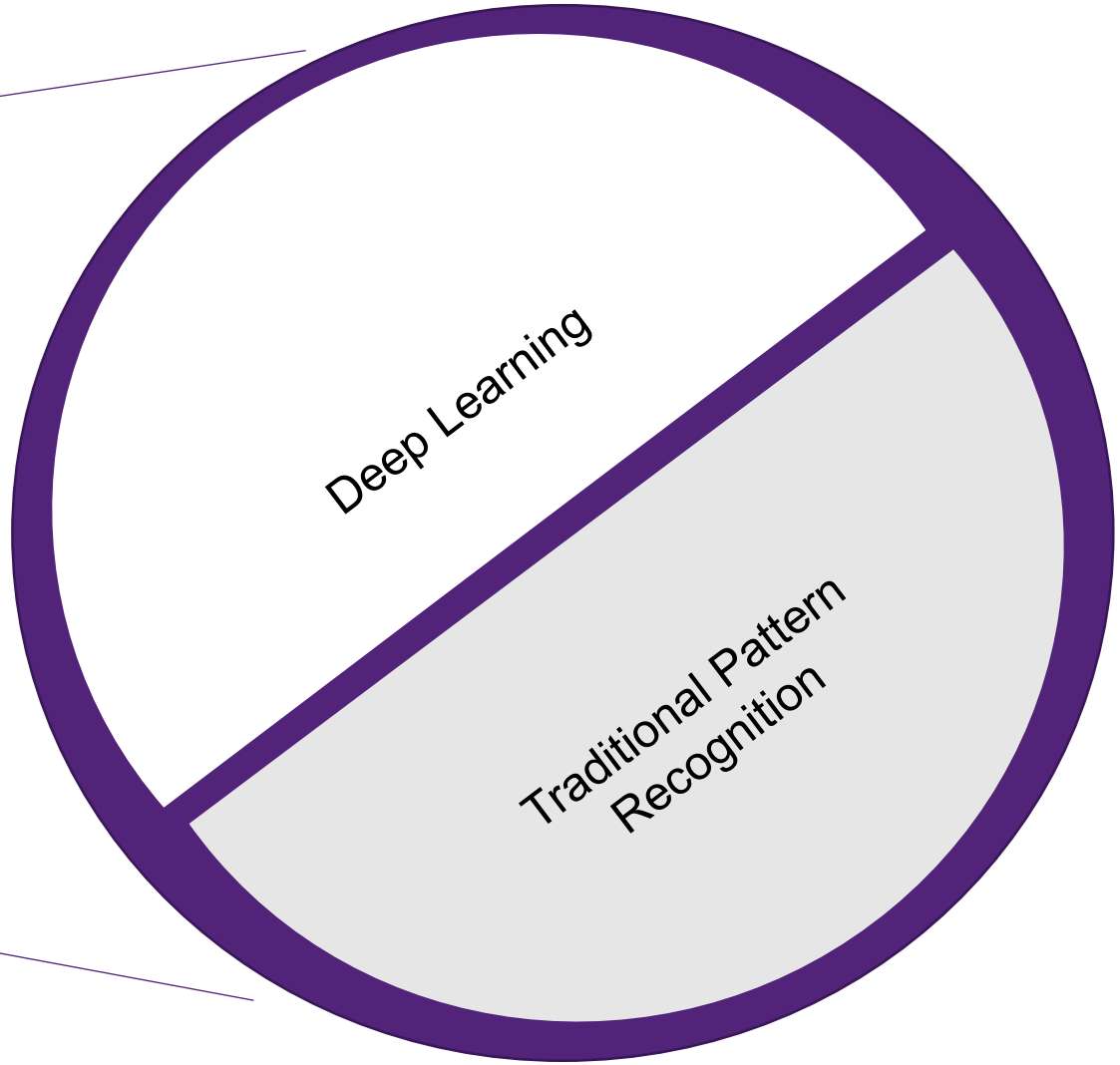
We will NOT be teaching you Python programming

Good to know any one or more of the following:

- MATH1052 – Vector Calculus
- MATH2302 – Graphs and topology (Basic only)
- COMP3506 – Data structures like trees etc.
- Basic object-oriented programming concepts

If you don't know any of the above, please read up on and catch up.

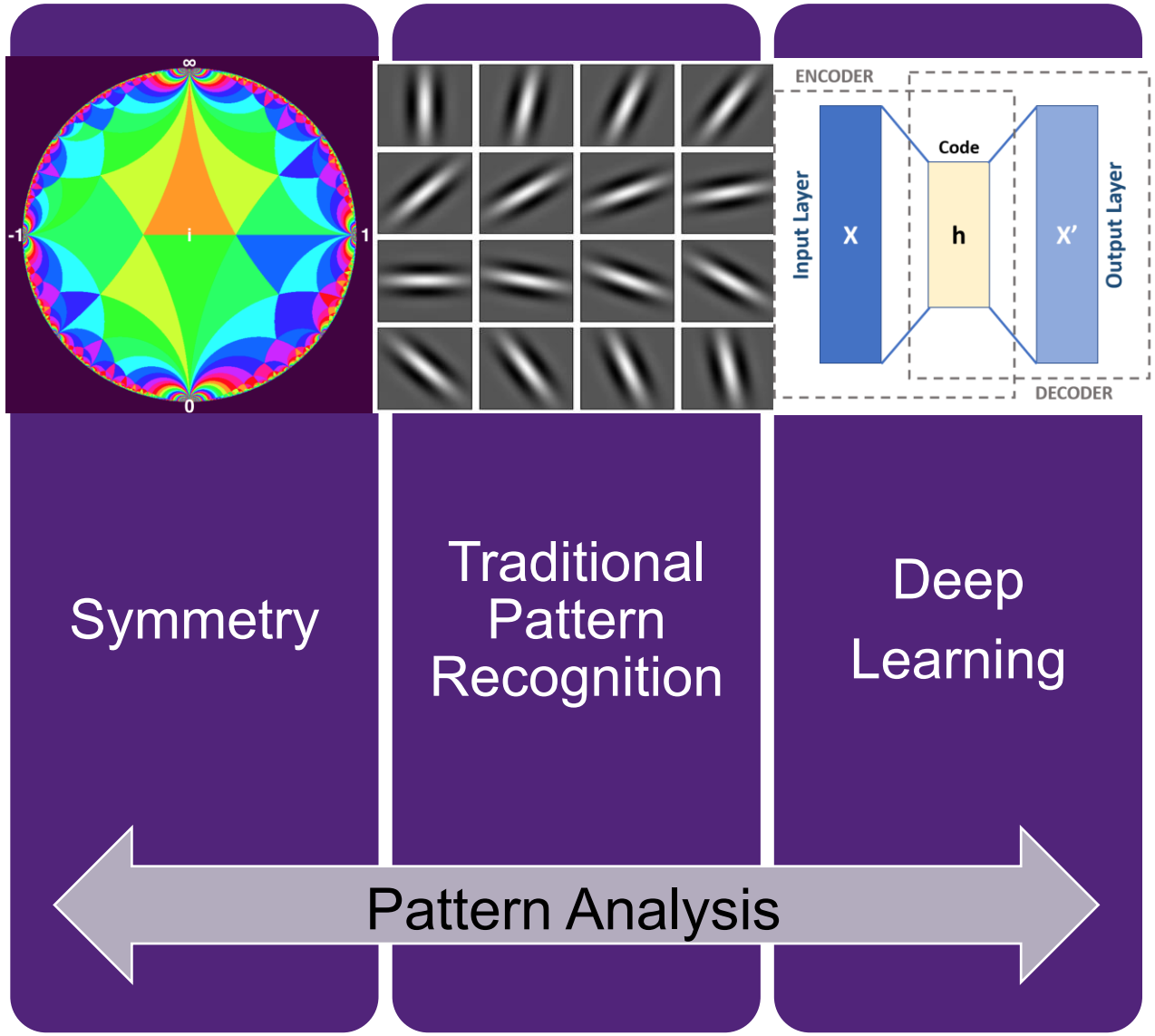

Machine Learning
Computer Vision
Pattern Recognition
Maths
Image Processing


Deep Learning
Traditional Pattern Recognition

Course Structure

- Symmetry and Self Similarity
  - Group Theory
  - Fractal Geometry
- Traditional Pattern Recognition
  - Features and Measures
  - Transform Domains
    - Fourier Transform
    - Radon Transform
    - Wavelet Transforms
    - Dimensionality Reduction
  - Random Forests
- Deep Learning
  - Neural Networks
  - Convolutional Neural Networks (CNNs)
  - Transformers

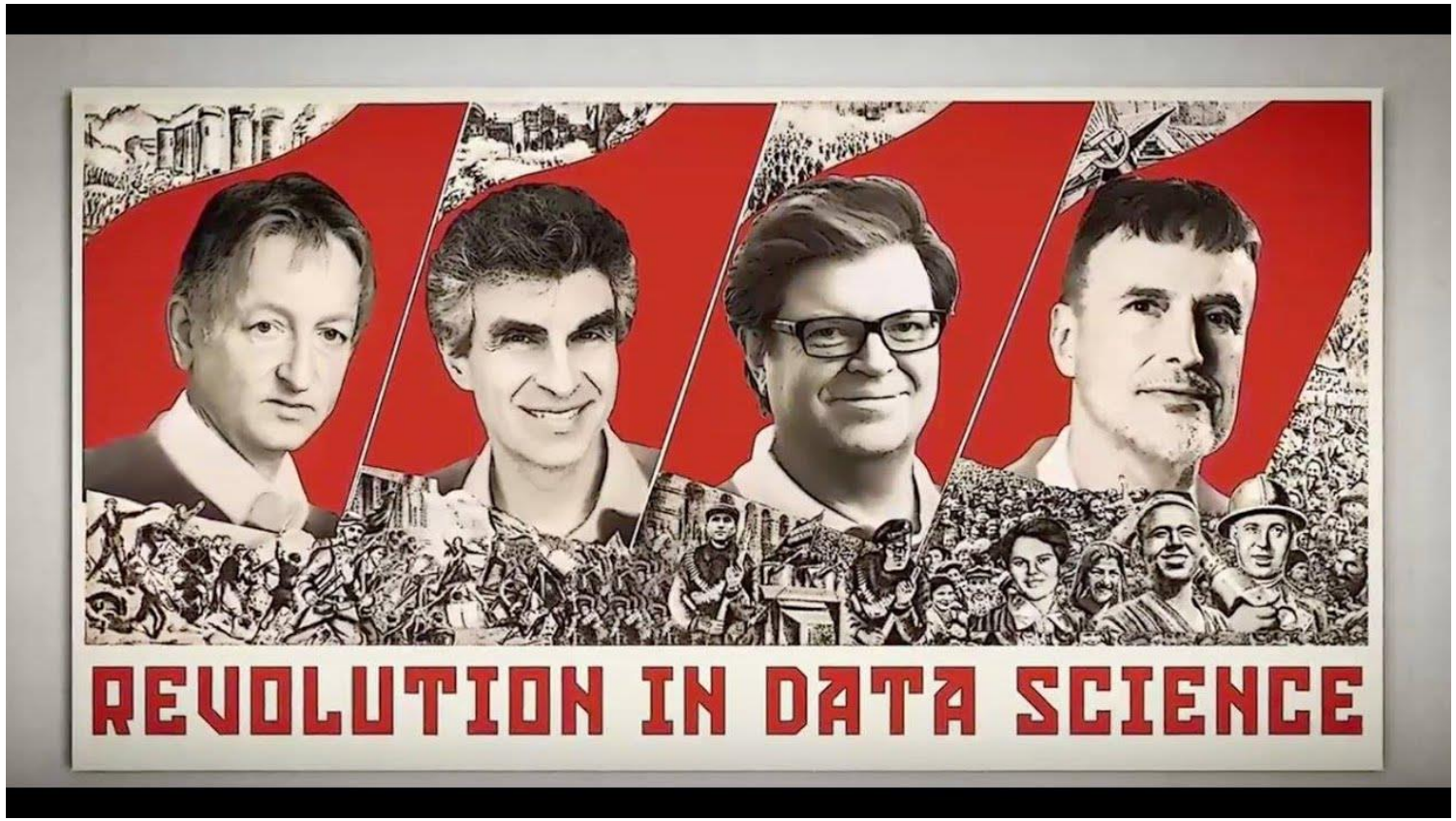
Click on Images for Sources



Course Structure

- Symmetry and Self Similarity
  - Group Theory
  - Fractal Geometry
- Traditional Pattern Recognition
  - Features and Measures
  - Transform Domains
    - Fourier Transform
    - Wavelet Transforms
    - Dimensionality Reduction
  - Random Forests
- Deep Learning
  - Convolution and Neural Networks
  - Convolutional Neural Networks (CNNs)
  - Transformers
  - Large Language Models (LLMs)

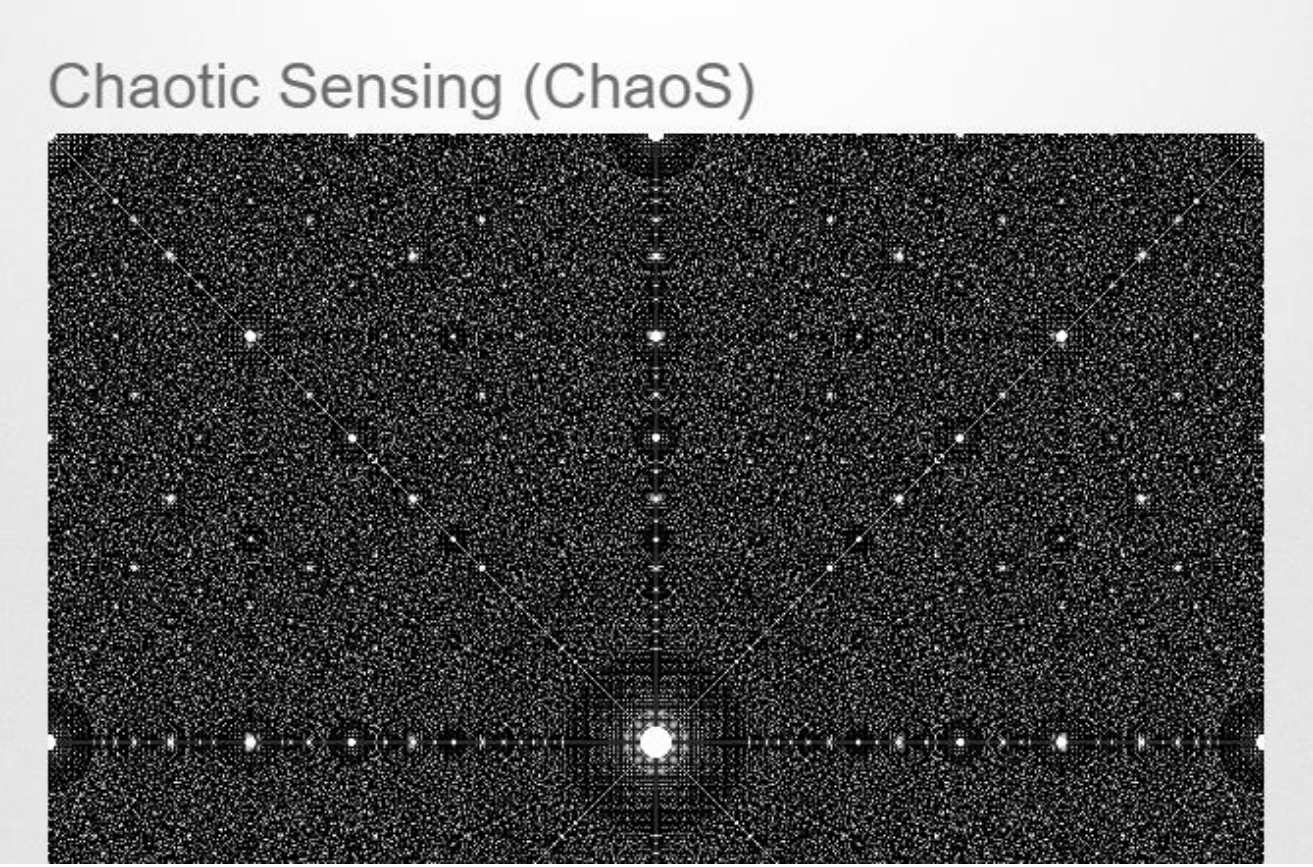
Geometric Deep Learning – Click for Keynote



After this course, you will be a master of geometric deep learning

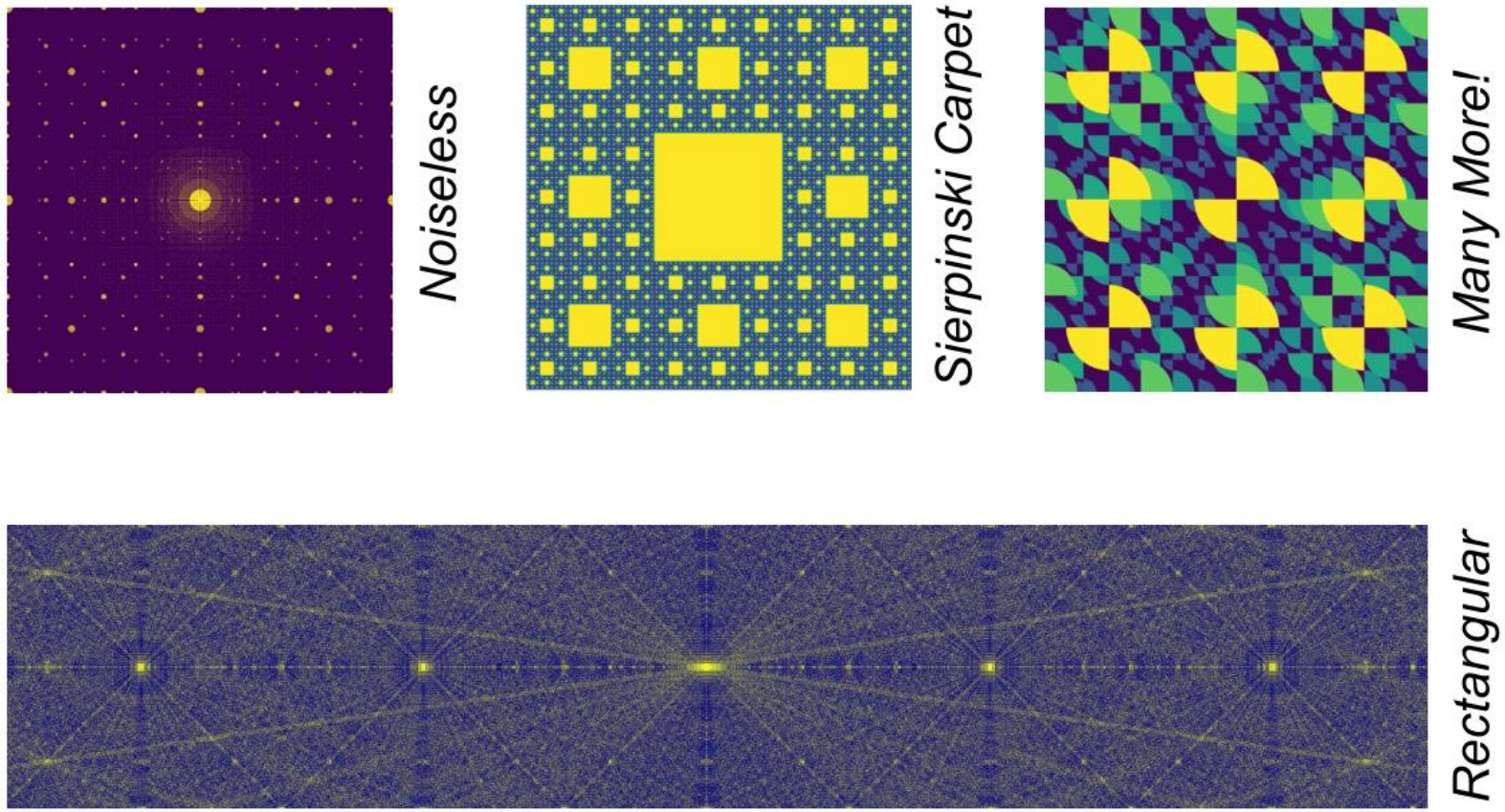
What can we do with this knowledge?

- New sampling methods for imaging using fractals - https://shakes76.github.io/ChaoS/



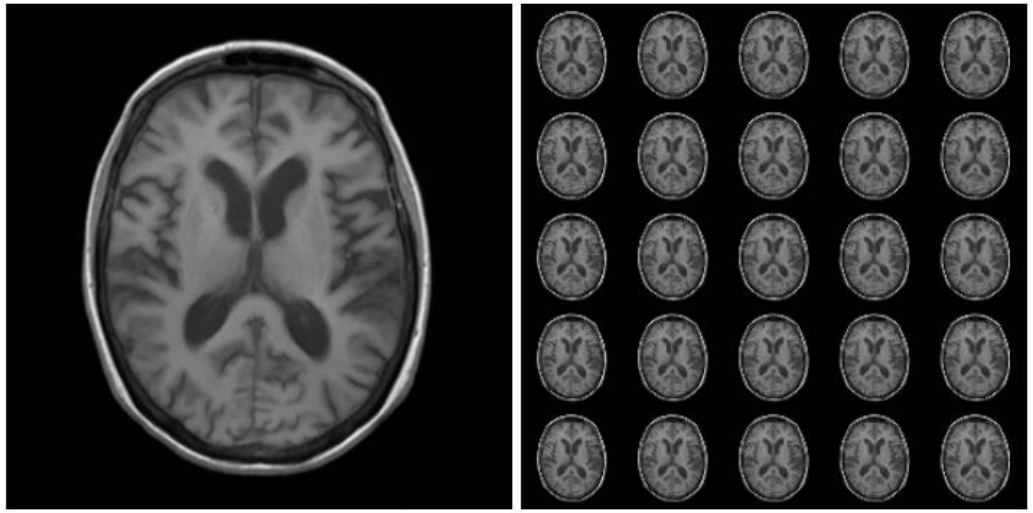
What can we do with this knowledge?

- New transforms for imaging called the Kaleidoscope transform that can produce fractals - https://doi.org/10.1109/LSP.2021.3116510



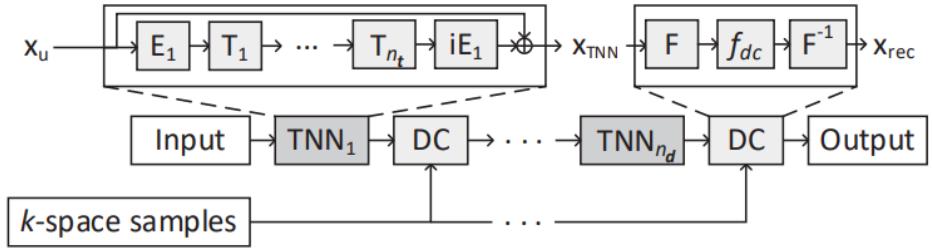
What can we do with this knowledge?

- New ways to represent images using the Kaleidoscope transform for AI methods such as the visual transformer (ViT) https://arxiv.org/abs/2203.12861

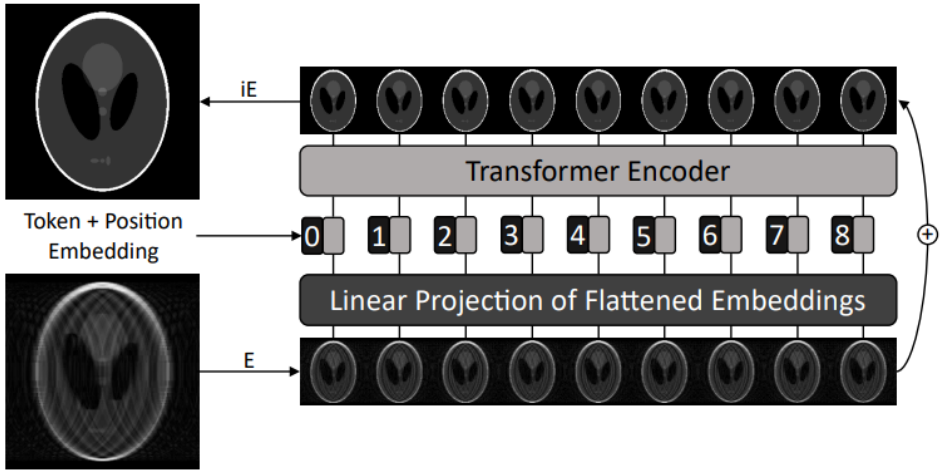


(a) 320 × 320 sample T1-w brain MRI. (b) 64 × 64 Kaleidoscope Embeddings.

Fig. 1: $(\nu = 5, \sigma = 1)$-KT for token embedding: (a) Input Image; (b) Downsampled and concatenated versions of (a).



(a) $\mathbf{E}$ is the token embedding and $i\mathbf{E}$ its inverse, $\mathbf{F}$ is the DFT, n_t are the number of transformer encoder layers per-TNN, n_d are the number of cascaded TNN blocks and f_{dc} is data consistency.



(b) Example of a ViT-based TNN denoiser with KD. Patch, KD and axial tokens are used in this work.

Fig. 2: Architecture for the proposed DcTNN.

Week	Date	Lectures	Pracs	Assessments
1	28/07/2025	Patterns - Symmetry and Self Similarity	Fractals	
2	4/08/2025			
3	11/08/2025			Demo Code Due and Marked Off
4	18/08/2025	Traditional Pattern Recognition		
5	25/08/2025		Pattern Recognition	
6	1/09/2025			
7	8/09/2025	Deep Learning 1 - Convolutional Neural Networks		Demo Code Due and Marked Off
8	15/09/2025 VAEs/Unet			
9	22/09/2025 GANs		**Report**	
Break	29/09/2025	Break		
10	6/10/2025 Symp 1	Deep Learning 2 - Transformers	**Report**	
11	13/10/2025 Symp 2			
12	20/10/2025 Summary			
13	27/10/2025	Course Review Exam Prep		**Pull Request Due**

Course Schedule

Contact Times

Lectures

Check your timetable

3 hours per week (2 hrs Contact style, 1 hour Traditional Lecture style)

Tutorials/Laboratories

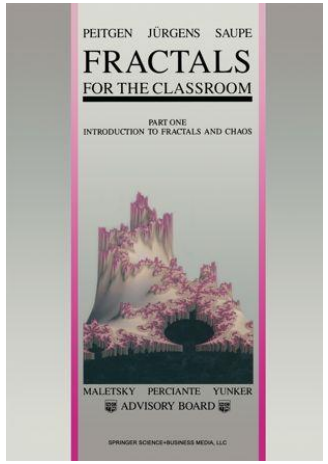
Check your timetable

1 hour tutorial every week (week 2 onwards)

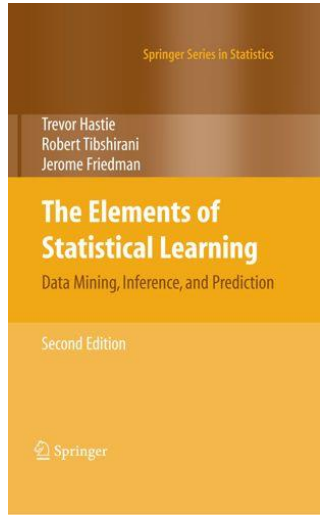
3 hour lab every week (week 2 onwards)

Additional Learning Activities will be announced as needed (for example, additional pracs for marking demos)

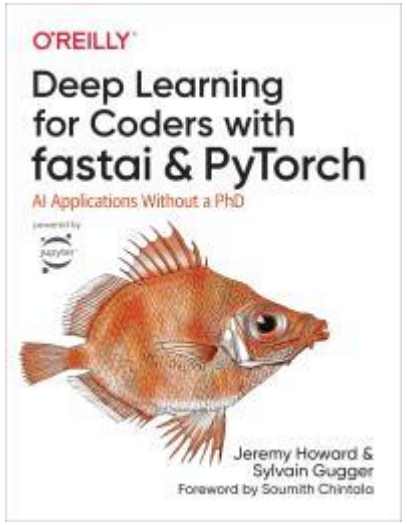
Prescribed & Recommended Texts



Peitgen, Jürgens and Saupe **(1992).**
Fractals for the classroom: Part one introduction to fractals and chaos
Oxford University Press.
[eBook – UQ Library]



Hastie, Friedman and Tibshirani **(2001).**
The Elements of Statistical Learning
Springer Series in Statistics
[eBook – UQ Library]



Gugger, S., & Howard, J. **(2020).**
Deep Learning for Coders With Fastai and PyTorch: AI Applications Without a PhD.
O'Reilly.
[eBook – UQ Library]

Shekhar Chandra **(????)** *Work in Progress*.
Pattern Analysis: A deep learning approach
Provided on Blackboard

Online Resources

- Google's Python Class website
- Shakes' curated YouTube Playlist of the Course Content
- UQ's partnership with the AWS Educate Program – Sign up using your UQ email
- Tensorflow, Keras Tutorials (PyTorch and JAX will also be allowed with limited support)
- Popular Maths and Compute Science YouTube Channels:
  - Computerphile
  - Numberphile
  - 3Blue1Brown
- Stanford Encyclopedia of Philosophy's entry on Geometry
- Shakes' Book – Pattern Analysis (Work in Progress, see BB)

COMP3710 YouTube Playlist

Pattern Analysis

37 videos • 1,228 views • Updated today

Public

A playlist of pattern recognition and analysis videos. Includes patterns and deep learning for my course COMP3710 at the University of Queensland.

Shakes Chandra

SORT

Mandelbrot Zoom 10^227 [1080x1920]

tthsqe12

Get started with Google Colaboratory (Coding TensorFlow)

TensorFlow

Getting Started with TensorFlow in Google Colaboratory (Coding TensorFlow)

TensorFlow

Build a deep neural network in 4 mins with TensorFlow in Colab

TensorFlow

Edward Frenkel -- Symmetry and Unification

World Science U

Edward Frenkel -- Galois Groups

World Science U

Assessment

Category	Assessment task	Weight	Due date
Computer Code, Practical/ Demonstration	Fractals In-person	10%	11/08/2025 - 22/08/2025 This course uses Demos that are allocated 3–5-week blocks of scheduled practical sessions in order to complete them with 2 of those weeks allocated to getting marked. Marking is to be done before the end of the final block in the scheduled practical times where possible.
Computer Code, Practical/ Demonstration	Pattern Recognition In-person	20%	8/09/2025 - 19/09/2025 This course uses Demos that are allocated 3–5-week blocks of scheduled practical sessions in order to complete them with 2 of those weeks allocated to getting marked. Marking is to be done before the end of the final block in the scheduled practical times where possible.
Computer Code, Paper/ Report/ Annotation, Project	Pattern Analysis Project Hurdle	40%	31/10/2025 4:00 pm Assessment during scheduled lab session + Submission items This course uses allocated 5-week block of scheduled practical sessions in order to complete the project.
Examination	Final Exam Hurdle Identity Verified In-person	30%	End of Semester Exam Period 8/11/2025 - 22/11/2025

Note the grade hurdles. Please check the ECP link above
These include exams and report assessment marks

Hurdles

3 (Marginal Fail)	47 - 49	Demonstrated evidence of developing achievement of course learning outcomes **Course grade description:** A Grade of 3 will be awarded for an overall mark below 50% but greater than or equal to 47%, while also not meeting the requirements for higher grades.
4 (Pass)	50 - 64	Demonstrated evidence of functional achievement of course learning outcomes. **Course grade description:** A Grade of 4 will be awarded for: - an overall mark below 65% but greater than or equal to 50% - a mark of at least 40% on the project assessment - a mark of at least 40% on the final exam
5 (Credit)	65 - 74	Demonstrated evidence of proficient achievement of course learning outcomes. **Course grade description:** A Grade of 5 will be awarded for: - achieving all the hurdles for a grade of 4 - an overall mark below 75% but greater than or equal to 65% - passed the project assessment - passed the final exam
6 (Distinction)	75 - 84	Demonstrated evidence of advanced achievement of course learning outcomes. **Course grade description:** A Grade of 6 will be awarded for: - achieving all the hurdles for a grade of 5 - an overall mark below 85% but greater than or equal to 75% - a mark of at least 60% on the project assessment
7 (High Distinction)	85 - 100	Demonstrated evidence of exceptional achievement of course learning outcomes. **Course grade description:** A Grade of 7 will be awarded for: - achieving all the hurdles for a grade of 6 - an overall mark of 85% or greater - a mark of at least 80% on the project assessment

Note the grade hurdles. Please check the ECP link above
These include exams and report assessment marks

Lab Demos

Tasks for each **Lab Demo are required to be done and demo'd by due date**.

Tasks for demos are designed to be done within the allocated number of sessions as per the course schedule. Tutors will be at prac sessions to help!

The Demonstration assessments themselves are to be completed within the allocated prac sessions for the demo with a tutor.

No marks will be awarded after the due date, so show up and complete the demo, preferably early!

Tutors will mark off what has been completed and award marks based on tasks completed. They will also test your knowledge with questions and may deduct marks based on your response(s).

Ensure proper shoes and no food or drink in labs, as well as social distancing.

Please complete the necessary OH&S online form if you plan on attending on campus.

Tutorials (Not Assessed Directly)

Tutorials will cover the theoretical material of the course as short answer questions.

Tutorials are NOT compulsory, though the content presented in them will be ***directly* related to all exams within the course**.

There will be a worksheet for each main module of the course.

Each worksheet will be designed to be completed within roughly two tutorial (2 x 1hr) sessions.

Project/Report

This is the most important assessment task in the course (30% of the grade). It will simulate a real-world example of what a deep learning/pattern analysis project would be like when working with a team of developers/researchers.

You will be required to complete a recognition problem on real cutting-edge data using state-of-the-art models (re-use, not (re)implemented yourself) and release it open source via GitHub.

Your project will be integrated into our existing open-source project using a Pull Request.

You are required to submit Git pull request to the PatternFlow open-source project by the due date.

Thus, the requirements for the report are multi-part as highlighted below and will be covered in demos 1 and 2:

- You will need Introduction to Version Control with Git short course on edX (link TBA).
- You will need Version Control for Teams using Git on edX (link TBA).

Workload

COMP3710 has 7 hours contact per week

- 3 Lecture, 1 Tutorial and 3 Practical
- Tutorials and Practicals begin in week 2

UQ policy assumes that

- 1 hr contact ~ 1 additional hr non-contact

  ∴ **you need to commit a total of <u>10-12 hrs/week</u> for the course**

- Practicals are designed to be completed with lab times
- The report may require more time, but again labs will be dedicated to this

Shakes' Teaching Style

Lectures will be made up of:

1. Lecture Notes – **Notes in formal teaching style**. To be released before the lectures and will be readable without lecture recording.
2. Instructional Material – **Demonstrations**, explanations or other instructional material that will be described in the lecture. These may include **Jupyter notebooks, animations, demos, active learning** etc.
3. Any **slides used during lectures will be uploaded** to Blackboard.
4. **Mathemagics!** Special segments within lectures to help you appreciate maths and (hopefully) keep you awake!

What to expect from Shakes

- Deliver interesting lectures: theory, examples, expert guest lecturers, notes posted on Blackboard
- To make course content meaningful and accessible
- Provide professional development for you through content taught
- Instruct you in proper software engineering and algorithmic design
- Post helpful content on Blackboard
- Answer ALL questions respectfully
- Respond to queries in reasonable time
- Provide feedback in reasonable time
- Guidelines for exam

What I expect from you

- Attend and participate in lectures, tutes, pracs
- Set out calculations clearly, with diagrams, units, interpretation
- Make sure you understand the fundamentals: keep up
- Ask questions if you:
  - don’t understand
  - can’t see/hear
  - suspect/find an error
- Attempt all the assessments, having a go is the first step
- Complete all assessment on time
- Attend and complete demos using the sessions allocated for it
- Use email sparingly, use Ed instead
- All communication to be courteous and polite
- If you have a problem,
  - let me know **early** and propose a solution if possible

Conclusion

- We will cover the mathematical theory of patterns - groups
- We will look at fractals and learn the Tensorflow/PyTorch (or equivalent) framework in the process
- Then explore traditional pattern recognition to explore how it was done before the deep learning revolution
- Complete the course by learning about convolutional neural networks
- We hope you will find the area(s) you're interested in and that you will know who to approach if you are interested in research!

What's Next?

What are patterns and how can we scientifically quantify them? In the next few lectures we will cover the mathematics of patterns – groups!

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE

Thank you

Dr Shekhar “Shakes” Chandra | Senior Lecturer
School of Information Technology and Electrical Engineering
shekhar.chandra@uq.edu.au
+61 7 3365 8359

@shakes76
shekhar-s-chandra