A Complete List of Academic and Research Experiences

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1 Academic Courses

In this section, I will list the relevant academic courses I have taken and am currently taking.

- **YSC1216 Calculus (A)**
- **YSC2209 Proof (A)**

  The course was an introduction to mathematical proofs, including the following topics: board presentation of proof, direct proof, proof by contradiction, proof of contrapositive; inductive proof, quantification, LaTeX & git; board presentation of proof, inductive proof, branching proof, nonconstructive existence arguments, AM-GM, fundamental theorem of arithmetic; multidimensional inductive proof, binomial theorem, Cauchy-Schwarz inequality; complete inductive proof, mathematical games, elementary combinatorics; infinite sets, diagonal argument; field axioms, construction of complex numbers, infinite sets, constructive existence arguments, descent theorem, construction of number sets; epsilon-delta argument, construction of the real numbers.

- **YSC1212 Introduction to Computer Science (A+)**

  This class was an introduction to the foundations of computer science taught in the functional programming language OCaml (a statically type-checked programming language with an emphasis on expressiveness and safety). The course culminated in the final project on the following topics:

  - multiplying integers in a tree using an accumulator
  - implementing depth-first and breadth-first traversals
  - indexing strings, arrays, lists, lazy lists, streams, and binary trees
  - computing the width of a binary tree
  - implementing a sieve
  - solving a variant of the knapsack problem

  - implementing an interpreter, a compiler, and a virtual machine for arithmetic expressions

- **YSC2213 Discrete Mathematics (A+)**

  This class introduced the foundations of discrete mathematics, namely combinatorics and graph theory. The class took place in a team problem-solving setting. At the end of the course, I completed the following projects in teams:

  - investigating various Catalan objects
  - investigating various types of self-avoiding lattice paths of length n in $\mathbb{Z}$ and a specialization of the problem in a-by-b lattice.
  - optimizing class schedules at our college
  - investigating the travelling salesman problem

  Textbooks used: *A Walk Through Combinatorics* by Miklós Bóna, *Proofs that Really Count* by Arthur T. Benjamin and Jennifer J. Quinn, *Pearls in Graph Theory* by Nora Hartsfield and Gerhard Ringel, *Algorithm Design* by Jon Kleinberg and Éva Tardos.

- **YSC2232 Linear Algebra (A-)**

  The main topics of this course were vector spaces and linear maps between vector spaces. The topics included the basic theory of vector spaces, including bases, dimension, norms, inner products, and direct sums. We studied the theory of linear maps between vector spaces, culminating in the spectral theorems for real and complex operators and the singular value decomposition. We implemented standard matrix calculations and algorithms using the R programming language.

  Textbooks used: *Linear Algebra Done Right* by S. Axler and *Linear Algebra and Its Applications* by G. Strang.

- **YSC3206 Introduction to Real Analysis (A+)**

  The topics incldued: Real Numbers, Sequences, Series, Complex Numbers, Exponential Trigonometric Functions, Metric and Normed Spaces, Limit and Continuity of Functions, Differentiation, Integration.

- **YSC3237 Introduction to Modern Algebra (A)**

  The topics included: Introduction to Groups, Subgroups & Cyclic Groups, Cosets & Homomorphisms, Quotient Groups, The Isomorphism Theorems, The Fundamental Theorem of Finite Abelian Groups, Group Actions & Enumeration, Conjugation & The Class Equation, The Sylow Theorems, Introduction to Rings, Ideals & Quotient Rings, Factorization, Primality, & Irreducibility, Euclidean, Principal Ideal, and Unique Factorization Domains.

Within the class, we also conducted two exploration projects in groups of two. We investigated topics related to abstract algebra and presented on the respective topics in the video format. The projects were:

1. Classification and Generalization of Plane Isometries.
2. Applications of Polynomial Rings in Algebraic Coding Theory.

Textbooks used: *Contemporary Abstract Algebra* by Gallian, *Algebra* by Artin, *Abstract Algebra* by Dummit and Foote.

- **YSC3236 Functional Programming and Proving (A+)**

  Using the Coq Proof Assistant, we studied an integrated account of specifications, unit tests, implementations, and properties of functional programs, through a variety of examples.

  This course culminated in the final project to formalize an interpreter for arithmetic expressions, a compiler from arithmetic expressions to byte code, and an interpreter for byte code (i.e., a virtual machine), and to prove that for any given arithmetic expression, interpreting this arithmetic expression and compiling this arithmetic expression and then running the resulting byte-code program yield the same result, be it a natural number or an error message.

- **MA4207 Mathematical Logic (IP)**

  This is an introductory mathematical course in logic. It gives a mathematical treatment of basic ideas and results of logic, such as the definition of truth, the definition of proof and Godel's completeness theorem. The objectives are to present the important concepts and theorems of logic and to explain their significance and their relationship to other mathematical work. Major topics include: Sentential logic, structures and assignments, elementary equivalence, homomorphisms of structures, definability, substitutions, logical axioms, deducibility, deduction and generalization theorems, soundness, completeness and compactness theorems, and prenex formulas.

  Textbook used: *A Mathematical Introduction to Logic* by Enderton.

- **YSC2229 Introductory Data Structures and Algorithms (IP)**

  This course covers algorithm-and-data-structure basic design techniques and tools, as well as their runtime analysis. Besides, we also study some algorithms that are widely used, such as, divide and conquer, dynamic programming, greedy algorithms, graph algorithms, linear programming, randomized algorithm, etc. We also discuss a few types of data structures, particularly dynamic data structures and their access time analysis: hashing, randomized binary search trees, and an access-time analysis called amortized analysis. The programming languages used for this course are Python and C/C++.

  Textbook used: *Introduction to Algorithms* by Cormen et al.

- **MA3288 Advanced Undergraduate Research Opportunities Programme in Science (UROPS) in Mathematics I (IP)**

  This is a research module on the topic of Topological Data Analysis (TDA). The aim of the project is to investigate the effectiveness of applying methods in the emerging field of TDA to solve problems that involve natural language data. We will study the state-of-the-art method of persistent homology and several notable applications in computational analysis of natural language. In particular, we hope to investigate how effective the topological approach is compared to the traditional regression-based tools and why, which is still an open problem (Savle et al., 2019). In this project, we study the mathematical foundations of the state-of-the-art methods in topological data analysis as well as the existing semantic space models. Further, we aim to investigate the effectiveness of these methods as well as to propose and possibly implement some improvements.

  Topics to be studied include: point-set topology, algebraic topology, persistence, homology, simplicial complex, the persistence algorithms, semantic space models.

  Some references used so far: *Topology for Computing* by Zomorodian, *Topology and Data* by Gunnar Carlsson, *Elementary Applied Topology* by Robert Ghrist, *Algebraic topology* by Allen Hatcher.

- **YIR3317G Independent Reading and Research (IP)**

  This is a research module on the topic of infinite group theory. The topics will include: free groups and finitely presented groups, group theoretical classes and closure operations; Abelian groups; decomposition of groups: series; calculus of commutators; introduction to soluble groups; introduction to nilpotent groups; introduction to braid groups - constructed together in class; application of braid groups. This independent reading and research module will culminate into a series of individual presentations as well as proof-based problem solving assignments.

  Texbook used: *A Course in the Theory of Groups* by Robinson.

2 Research Experiences

- (Jan 2020 – present) ***Peer Tutor,* YSC2209 Proof *and* YSC2232 Linear Algebra.**

  As a peer tutor, I assist the instructors and provide academic guidance for students in the core modules in Mathematics, YSC2209 Proof and YSC2232 Linear Algebra.

- (Jan 2020 – present) ***Persistent Homology of Semantic Spaces.***

Supervisor: Fei Han, Department of Mathematics, National University of Singapore.

This is a research module on the topic of Topological Data Analysis (TDA). The aim of the project is to investigate the effectiveness of applying methods in the emerging field of TDA to solve problems that involve natural language data. We will study the state-of-the-art method of persistent homology and several notable applications in computational analysis of natural language. In particular, we hope to investigate how effective the topological approach is compared to the traditional regression-based tools and why, which is still an open problem (Savle et al., 2019). In this project, we study the mathematical foundations of the state-of-the-art methods in topological data analysis as well as the existing semantic space models. Further, we aim to investigate the effectiveness of these methods as well as to propose and possibly implement some improvements.

Topics to be studied include: point-set topology, algebraic topology, persistence, homology, simplicial complex, the persistence algorithms, semantic space models.

- (Jan 2020 – present) ***Regional Cultural Politics of PRC's New Media Technologies in Xinjiang.***
  Supervisor: Shao-Ling Ma, Yale-NUS College.

  As a paid research assistant, I will be responsible for collecting, organizing, and annotating a bibliography of resources related to the ongoing crisis in Xinjiang, PRC. This is part of an ongoing, larger interdisciplinary project studying various notions of material, labor practices grounding the often-overhyped and misunderstood issue of the PRC's digital ascent. The first part of the project requires that the student analyze and make notes on the databases and websites on the Xinjiang crisis, and supplement their understanding with academic articles on the following areas 1) critical computational/algorithmic studies; 2) scholarship on racial capitalism and digital surveillance (most of which, but not all, are from outside of China studies); 3) histories of internal colonialism in Xinjiang. The second part of the project entails research on Chinese social media websites and apps (Weibo; WeChat; TikTok; Kuaishou, etc) on both official statements and popular sentiments on Xinjiang and its Uyghur minorities, and study them from the perspectives of new media and performance.

- (May 2020 – Aug 2020) ***Numerical Exponential Polynomials.***
  Supervisor: David Andrew Smith, Yale-NUS College.

  This project focused on the relative growth of terms in exponential polynomials. In different regions of the complex plane, different terms of an exponential polynomial dominate others. I used analytic and geometric arguments to compare the relative dominance of terms.

For research outputs, please refer to my report and expository notes on Complex Analysis.

- (Jul 2019 – Sep 2019) ***Hybrid Analytical-Numerical Integration.***
  Supervisor: David Andrew Smith, Yale-NUS College.

  This project focused on Julia library for exponential sums and survey of Langer's work. I implemented a Julia library providing for the efficient description and algebra of exponential sums. Exponential sums are exponential polynomials in which each polynomial coefficient is a complex constant. I also surveyed Langer's (1931) paper on the asymptotic locus of zeros of such functions.

  For research outputs, please refer to my report and code.

- (Jun 2019 – Jul 2019) ***Digital Gazetteer Project at Yale Digital Humanities Lab.***
  Supervisor: Catherine DeRose, Yale University.

  In this project worked with my colleagues at the Yale Digital Humanities Lab on the Digital Gazetteer Project. I built the geocoding database for the project and acquired skills in essential tools in Digital Humanities, including text mining and processing, ArcGIS, Augmented Reality using Unity game engine, user design principles. I also attended weekly meetings and various workshops organized by the Yale Digital Humanities Lab and the Yale Library.

- (Sep 2018 – Jun 2019) ***Ecological Modeling Research Cluster.***
  Supervisor: Maurice Cheung, Yale-NUS College.

  In this project, my colleagues and I employed mathematical modeling methods to analyze empirical ecological data using the Python programming language.

- (Jan 2018 – Jun 2018) ***Emotion recognition from electroencephalography (EEG) signals using hybrid deep neural networks.***
  Supervisor: Hongliang Ren, School of Engineering, National University of Singapore.

  I worked full-time as a research intern at Lab of Medical Mechatronics, National University of Singapore (Department of Biomedical Engineering). I worked on an independent project on emotion recognition from electroencephalography (EEG) signals, using hybrid deep neural networks as well as transfer learning. Please refer to the project webpage for more details.

- (Apr 2016 –Dec 2017) ***Application of Machine Learning in Automatic Sentiment Recognition in Human Speech***
  Supervisor: Yin Kwee Ng, Eddie, College of Engineering, Nanyang Technological University.

This project explored the possibility of applying supervised Machine Learning in recognizing sentiments in English utterances on a sentence level. In addition, the project also aimed to examine the effect of combining acoustic and linguistic features on classification accuracy.

With this project, I was among the International Finalists in the most prestigious science competition in China, the Dongrun-Yau Science Award organized by Tsinghua University.

The paper for this research project was published on Dec 27, 2018 as part of the Advances in Intelligent Systems and Computing book series (AISC, volume 887). Please refer to the paper link and the conference interviewfor more details.

- (2015 – 2017) ***Training for the Singapore National Olympiad in Informatics and obtained Bronze medals.***

  The training for the National Olympiad in Informatics helped me establish a solid foundation in competitive programming in C/C++ and developed my algorithm design and problem solving skills.

- (Long-term Personal Passion Project) ***The Panini Machine.***

  Overview

  In this project, I will attempt to use mathematical and computational methods to implement the Sanskrit linguistic system. The Sanskrit language was first formalized by the Indian linguist Panini (and hence the name of this project). My plan is to study the mechanics of Sanskrit and at the same time the relevant technical methods which I have broadly classified into the probabilistic approach and the deterministic approach.

  I think of this project as a convergence of my interests. If we consider each of the disciplines a wooden plank stacked on top of each other, then the current project is my ongoing experiment to locate the "center of gravity" where a balanced state can be achieved.

  Significance

  The significance of this project is two-fold. First, there is an increased interest in ancient Indian thought and traditions. However, many scholars are deterred by the lack of readily translated texts and the difficulties involved in learning Sanskrit. By implementing the grammatical system of Sanskrit, it is hoped that we can contribute to the task of Machine Translation in Sanskrit. The second and more important significance is the potential contribution to the current theories in Natural Language Processing (NLP), and more generally Artificial Intelligence. Most of the methods in NLP make use of probabilistic models to deal with the uncertainties in languages. Unlike most of these

commonly spoken languages, Sanskrit is very peculiar in that it is highly systematic and even deterministic in nature, which could lead to some interesting alternatives to this probabilistic way of thinking.

For more details, see the gitbook documentation.