FINAL YEAR PROJECT

2023/2024

SEMINAR PROCEEDINGS

Department of Computational and Theoretical Sciences,
Kulliyyah of Science,
International Islamic University Malaysia

FINAL YEAR PROJECT 2023/2024 SEMINAR PROCEEDINGS

Published by
Department of Computational & Theoretical Sciences,
International Islamic University Malaysia,
Jalan Sultan Ahmad Shah,Bandar Indera Mahkota,
25200 Kuantan, Pahang Darul Makmur,Malaysia.
Website: https://www.iium.edu.my/kulliyyah/kos/computational-theoretical-sciences

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FINAL YEAR PROJECT COORDINATOR'S FOREWORD

I am honored to present this book, which comprises exemplary final year projects completed by our students. As the coordinator, I'm proud to publish this valuable reference highlighting their talent and innovation. Within these pages, readers will encounter a collection of remarkable projects that underscore the talent, perseverance, and innovation of our students.

The primary aim of this book is to document the exceptional projects undertaken by our students and to provide a valuable resource for future students, faculty members, and researchers alike. I wish to extend my sincere appreciation to all the students who have contributed to this endeavor. Your unwavering dedication to your final year projects, commitment to excellence, and passion for your respective fields have left an indelible impression.

I am confident that the projects featured in this book will serve as a source of inspiration for future students and will lay the groundwork for their own innovative pursuits. Lastly, I would like to express my gratitude to the entire department for their steadfast support in bringing this publication to fruition. Your collective efforts in fostering a collaborative and enriching learning environment have played a pivotal role in achieving this significant milestone.

Dr Hafizah Bahaludin
Coordinator of Final Year Project

EDITOR'S FOREWORD

Welcome to the third issue of the Final Year Project Seminar Proceedings. This time around, the Academic Session 2023/2024, we showcase a book consisting of 11 papers of Mathematical Sciences undergraduate students' final year projects.

The papers in this book cover a whole range of field of interests – Operational Research, Pure Mathematics, Financial Mathematics, Computational Mathematics and Statistics. We would like to take this opportunity to record our congratulations and appreciations to the final year students for their dedications and efforts in their research work.

We are very happy that this third issue finally materialised. This book is the continuation compilation of the final year projects and it is hopeful that this will be a valuable resource references for future students of Mathematical Sciences degree programme of the Department of Computational and Theoretical Sciences, Kulliyyah of Science.

Assoc. Prof. Dr Mimi Hafizah Abdullah
Editor

ABOUT
FINAL YEAR PROJECT

SMS 3401
FINAL YEAR PROJECT I

4 Credit Hours
Seminars
Proposal Submission
Proposal Presentation

SMS 4802
FINAL YEAR PROJECT II

8 Credit Hours
Poster Presentation
Dissertation Submission
Final Year Project Presentation

PRESENTING

COLLECTION OF FINAL YEAR PROJECTS

THE UNSOLVABILITY OF THE GENERAL QUINTIC: THE METHODS BY VLADIMIR ARNOLD AND GALOIS THEORY AND THEIR RELATIONSHIP

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Abstract: One well-known proof of the Abel-Ruffini Theorem is the Galois theory approach developed in the 19th century by Évariste Galois. A more recent proof was presented by Vladimir Arnold which was first published in 1974. Arnold's proof is not as well-known and the connections between his method and Galois theory is left mostly unexplored. This study aims to show both proofs and find relations between them. The Abel-Ruffini Theorem will then be proved using both methods combined. Lastly, the structure of the general formula of polynomials solvable by radicals up to degree 5 will be studied. This study utilises properties of commutators, commutator subgroups, and radical field extensions as well as the Fundamental Theorem of Galois Theory. The two proofs are shown together with comparisons made. The similarities between them stems from how the Galois group of a polynomial is equivalent to the set of all permutations of the solutions of a polynomial in the complex plane in Arnold's method. Another similarity is that successive radical field extensions from the field $\mathbb{Q}$ correspond to successive radical nesting of rational numbers. From these relations, both methods are combined, and the proof is rephrased using concepts from both methods. Finally, the maximum level of radical nesting for a general formula of an nth-degree polynomial corresponds to the longest maximal chain of S_n for $n \leq 4$. This may be true for solvable quintic polynomials but for the group F_{20} instead whose longest maximal chain is of length 3. This study implies a strong relationship between Galois theory and complex analysis with topology. Problems in Galois theory could be solved using topology and vice versa.

***Keywords*:** Abel-Ruffini theorem, Galois theory, Vladimir Arnold, radical field extensions, commutators

INTRODUCTION

This study focuses on two proofs of the unsolvability of the general quintic equation, known as the Abel-Ruffini Theorem. One of the proofs utilises Galois theory by studying a polynomial's Galois group and splitting field structures. This proof, which was formalised by Évariste Galois in the 19th century, is well-known and taught to many students. A more recent proof was made by Vladimir Arnold which he presented and taught to high school students in Moscow in 1963. His proof uses concepts from group theory and complex analysis with some topology. This proof was then first published as a book in 1974 by one of his students, V.B. Alekseev (2004). Since then, this proof has been documented a few times, but it is still mostly unexplored. The two proofs of the Abel-Ruffini Theorem seem different on the surface, but there may be some similarities in their methods. This study aims to present both proofs together and find relations between them. Furthermore, this study aims to summarise the proof of the Abel-Ruffini Theorem using both Galois theory and Arnold's method. Finally, this study investigates the radical structure of the general formulas for solvable polynomials from degree 2 to 5.

There are plenty of studies focused on Galois theory. There are papers on giving the criteria to determine the Galois groups of certain polynomials (Kappe & Warren, 1989). There are also studies on how to solve solvable quintic polynomials using various methods (Dummit, 1991; Kulkarni, 2006; Lazard, 1997). A paper by Zhang (2020) describes all the possible Galois groups of polynomials up to degree 6. Meanwhile, there has been little publications on Arnold's proof. The first one was published by Alekseev in 1974 and later republished in English in 2004. The first journal article on the proof was written by Żołądek (2000) which is a concise statement of the proof using similar methods as Alekseev. Some simplifications of the proof have been made since then, including one by Ramond (2022) which is a more elementary explanation of the proof than Alekseev's original explanation.

The methods used in this study are the commutators, commutator subgroups, radical field extensions, and the Fundamental Theorem of Galois Theory. With these concepts, it is shown that taking a composition of commutator subgroups is equivalent to the definition of a solvable in group in Galois theory. Next, this study shows that making successive radical field extensions is the same as making higher levels of radical nesting of a

general formula for the solutions of polynomials. Lastly, by studying the subgroup structure of solvable groups can indicate how many levels of radical nesting there can be in a general formula of polynomials from degree 2 to 5.

METHODOLOGY

The methods used in this study are the commutators and the commutator subgroups. A commutator of two elements in a group G is defined as $[g,h] = ghg^{-1}h^{-1}$ for all $g,h \in G$. The commutator subgroup of a group G is a group generated by all the commutators in G: $[G,G] = \langle [g,h] : g,h \in G \rangle$. The properties of these subgroups help to show that taking a composition of commutator subgroups in Arnold's method is equivalent to the definition of a solvable group in Galois theory. Next, we use the definition of a radical field extension which shows why taking a composition of commutator subgroups require having more levels of radical nesting in a general formula of a polynomial's solutions. Lastly, the Fundamental Theorem of Galois Theory is used throughout this study. Since the commutator subgroups in Arnold's proof is equivalent to a solvable group in Galois theory, those commutator subgroups are part of the polynomial's Galois group. The Fundamental Theorem gives a one-to-one correspondence between the Galois group and the splitting field which is directly related to radical nesting of the rational numbers.

RESULTS AND DISCUSSION

The set of permutations of the solutions in the complex plane forms a group. Arnold's proof involves taking a composition of commutator subgroups of this group. If this composition eventually results in the trivial group, then the original group is called solvable (Alekseev, 2004). This definition is equivalent to the definition of a solvable group typically used in Galois theory. That is, a group is solvable if there exists a subnormal series such that each quotient group is abelian. Thus, we have the following result.

Theorem *A group G is solvable if either of the following statements is true.*

1. *There exists a sequence of subgroups*
$$G = G_m \geq G_{m-1} \geq \cdots \geq G_1 \geq G_0 = 1$$
such that G_k is normal in G_{k+1} and G_{k+1}/G_k is abelian for $k = 0, \ldots, m-1$.
2. *There exists a sequence of subgroups*
$$G^{(0)} = G, G^{(1)} = [G,G], \ldots, G^{(i+1)} = \left[G^{(i)}, G^{(i)}\right] \text{ for } i = 1, 2, \ldots$$

such that $G^{(n)} = 1$ for some positive integer n.

Due to this equivalency, it implies that the set of permutations of the solutions in the complex plane is the same as the Galois group of the polynomial. This is because the context of a solvable group in Galois theory is used to refer to the Galois group of a polynomial.

Next, we explore the similarities from Galois theory with Arnold's proof. In Galois theory, finding the Galois group usually involves making field extensions from the base field of the polynomial to find all the solutions, more specifically, radical field extensions. If the splitting field of a polynomial is constructed solely using radical field extensions, then the solutions of the polynomial can be said to be expressible or solvable in radicals. In Arnold's proof, if the commutator subgroup generated is nontrivial, then another level of radical nesting is needed to express the solutions of a polynomial.

Theorem *There is a correspondence from k simple radical field extensions of $\mathbb{Q}$ and algebraic expressions with k levels of nesting of radicals.*

Finally, we found that the subgroup structure of the largest solvable group for irreducible polynomials of degree $n \leq 4$ corresponds with the maximum level of nesting of radicals in their general formulas. The sequence of maximal subgroups of a group G is called a *maximal chain.* The maximal chain has length k if there are k maximal subgroups in the sequence (not including the group G). The maximum length of the maximal chain of S_n is the same as the level of nested radicals in a general formula for polynomials of degree $n \leq 4$.

Theorem *Let $f(x)$ be an irreducible separable polynomial of degree $n \leq 4$ with Galois group* $\mathrm{Gal}(f) \leq S_n$. *If the longest maximal chain in S_n has length k, then the number of levels of radical nesting for the solutions of $f(x)$ is at most k.*

From this, we conjecture the following for solvable irreducible quintic polynomials whose largest possible Galois group is F_{20}.

Conjecture *Let $f(x)$ be an irreducible and separable quintic polynomial with rational coefficients. Suppose* $\mathrm{Gal}(f) \leq F_{20}$, *that is, $f(x)$ is solvable by radicals. Then the maximum number of levels of nested radicals of the general formula for the solutions of $f(x)$ is* 3.

CONCLUSIONS

The results show that there is a strong connection between Galois theory and complex analysis with topology. Problems in Galois theory, such as the inverse Galois problem, may be solved using topology. Further studies should be made to confirm the conjecture to investigate the radical structure of the general formula for solvable quintics. Furthermore, Arnold's original proof should be considered when making connections to Galois theory to investigate any deeper relations.

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THE UNSOLVABILITY OF THE GENERAL QUINTIC: THE METHODS BY VLADIMIR ARNOLD AND GALOIS THEORY AND THEIR RELATIONSHIP

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ABSTRACT

The general quintic equation $ax^5+bx^4+cx^3+dx^2+ex+f=0$ is well-known to be not solvable by radicals. The proof of this theorem using Galois theory is taught widely. A more recent proof by Vladimir Arnold using basic group theory and complex analysis is less well-known. This study investigates the relationship between the two methods and aims to explain Arnold's proof using Galois theory. This study uses properties of the symmetric group and This correspondence can be beneficial to expose students to multiple methods of proof and a more solid understanding of abstract algebra and complex analysis.

Introduction

The proof of the unsolvability of the general quintic by radicals by Evariste Galois in the 19th century was one of the highest achievements in modern mathematics. Russian mathematician Vladimir Arnold discovered another proof around 1963 which involves basic group theory, complex analysis, and topology.

Problem Statement

Vladimir Arnold's proof of the unsolvability of the quintic is less widely taught. It can be simplified to be more elementary compared to the traditional Galois theory approach. The study aims to present both proofs, explore connections between them, and explain Arnold's proof in terms of Galois theory.

Objectives

1. To present the Galois theory proof and Arnold's proof of the unsolvability of the quintic.
2. To find relations between Galois theory and Arnold's proof.
3. To explain Vladimir Arnold's proof of the Abel-Ruffini theorem using Galois theory.

Methodology

- Symmetric group: The set of all permutations on n elements.
- Commutators: An element in a group G of the form $xyx^{-1}y^{-1}$.
- Commutator subgroup: The group generated by commutators.
- Solvable group:

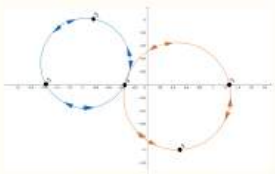
1. The derived series of the group terminates at the trivial group
2. The subnormal series of the group has abelian quotient groups.

Galois Theory Proof

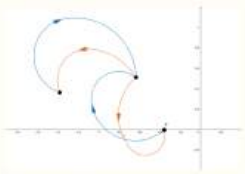
A polynomial is solvable by radicals if and only if its Galois group is solvable. The group S_5 is not solvable. There exists a polynomial, e.g. x^5-8x+2, whose Galois group is S_5, so it is not solvable in radicals. Since there exists such a quintic, then no general quintic formula exists.

Vladimir Arnold's Proof

If the roots are not invariant under k levels of commutators, then the formula needs at least k levels of roots. If the roots are invariant at some finite level of commutators, the roots are solvable in radicals. However, a fifth-degree polynomial's roots are never invariant under any level of commutators. Hence, there is no formula of finite radicals to solve for the roots of a fifth-degree polynomial.



Permutation of the roots



Formula following a closed path

Results

Two equivalent definitions of a solvable group:

- The definition used in Galois theory is the one based on the subnormal series. The definition used by Arnold is based on the derived series. These two definitions are equivalent, showing a common bridge between the two methods.

A nested radical requires a field extension:

- An expression invariant under a nontrivial commutator requires another nested radical to properly express the roots. Adjoining a radical is the basic step of extending a field in Galois theory.

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Ramond, P. (2022). Abel-Ruffini's Theorem: Complex but Not Complicated. *The American Mathematical Monthly, 129*(3), 231–245. https://doi.org/10.1080/00029890.2022.2010494

DEVELOPMENT OF PYTHON PARALLEL SCIENTIFIC COMPUTING MODULE FOR EDUCATIONAL PURPOSES

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Abstract: In this project, a Python parallel scientific module namely "pcl.py", has been developed as an alternative to the pre-existing C++ parallel computing library used in teaching the subject for the undergraduate course. The C++ library is originally provided by George Em Karniadakis and Robert M. Kirby II, from their book published in 2003, entitled "Parallel Scientific Computing in C++ and MPI". The resulted module encompasses six main functions of parallel algorithms, including Thomas Algorithms, Parallel Jacobi Method, Parallel Gaussian Elimination, Parallel Pre-conditioned Conjugate Gradient, Cyclic Reduction, and Parallel Power Method. The functions have been tested on solving second-order ordinary and partial differential equations and the numerical solutions are up to the expected accuracy when compared to the known exact solutions. Nevertheless, the parallel executions have taken longer time than the corresponding serial counter parts which indicates high ratio of MPI communications over computational workloads. This study demonstrated another case to show that the parallel speed up can be achieved when such ratio is reduced much lower. Finally, the numerical solutions from the tested functions are displayed in 2D and 3D plot to show the easiness of using Python in data visualization, over C++.

***Keywords*:** Parallel scientific computing, mpi4py, python, Thomas algorithms, parallel Jacobi method, parallel Gaussian elimination, parallel pre-conditioned conjugate gradient, cyclic reduction, parallel power method.

INTRODUCTION

This project focus on the development of python parallel scientific computing module for educational purposes. Parallel scientific computing can be carried out in a compiled language such as C++ with the Message Passing Interface (MPI). However, C++ is difficult to learn, especially for beginners who have no basic understanding of programming (Ateeq et al., 2014). Many students get overwhelmed by the complexity of the syntax and wide range of paradigms. A difficult concept such as dynamic memory allocation and pointers require strenuous efforts to master. The difficulties get even worse and more daunting when one ventures into the realm of parallel programming, where the rules of the paradigms are getting more complex compared with traditional programming. Therefore, this project aims to create a Python parallel scientific computing module based on the pre-existing C++ library. Apart from that, this project aims to utilize the MPI binding for Python; mpi4py in performing the parallel computing. Finally, the Python parallel scientific computing module is then tested on solving a second order ODE problem using 6 functions which are Thomas Algorithms, Parallel Jacobi Method, Parallel Gaussian Elimination, Parallel Pre-conditioned Conjugate Gradient, Cyclic Reduction, and Parallel Power Method. The Python module is developed by manually rewriting the C++ source codes into Python scripts. During the testing process, when compared to the known precise solutions, the numerical solutions obtained from testing the functions on second-order ordinary and partial differential equations show that they are accurate to an expected degree. However, compared to their serial counterparts, the parallel executions have taken longer, indicating a high ratio of MPI communications over computing demands. This study provided another example of how a considerably smaller reduction in this ratio might result in an increase in parallel speed. Lastly, to demonstrate how much easier it is to use Python for data visualization than C++, the numerical solutions from the tested functions are shown in two and three dimensions.

METHODOLOGY

The Python scripts is written manually based on the pre-existing C++ source code. Since most of the functions already existed in the numpy built-in package, only 6 functions is written in the Python module. Five out of six functions are methods for solving linear systems and the remaining is for solving eigenvalue problems. The functions for solving linear system are Thomas algorithm, parallel Jacobi method, preconditioned conjugate gradient method, and parallel gaussian elimination. The function to solve eigenvalue problem is parallel power method. All of the functions to solve linear system in parallel basically takes several parameters which are the matrix A, vector b, the communicator and the size of the rank used.

Rewriting C++ source codes to python scripts manually requires a very deep understanding of the existing C++ codes itself. The most challenging part is to deal with C++ source codes that contain pointers. Since Python does not have pointers, it requires very good logical programming skills to ensure that the code can be written in python without any issues. In C++ source code, the concept of dynamic memory allocation is used in defining the matrices as well as vectors. However, in Python, we may use numpy built-in library to carry out such tasks and it is more convenient compared with C++. Another challenge is to apply mpi4py in the Python script as most of the function call form mpi4py have different parameters with MPI in C++. Therefore, the official documentation of mpi4py need to be read carefully to ensure that every function calls can be executed properly. Figure 1 below shows the workflow of the project.

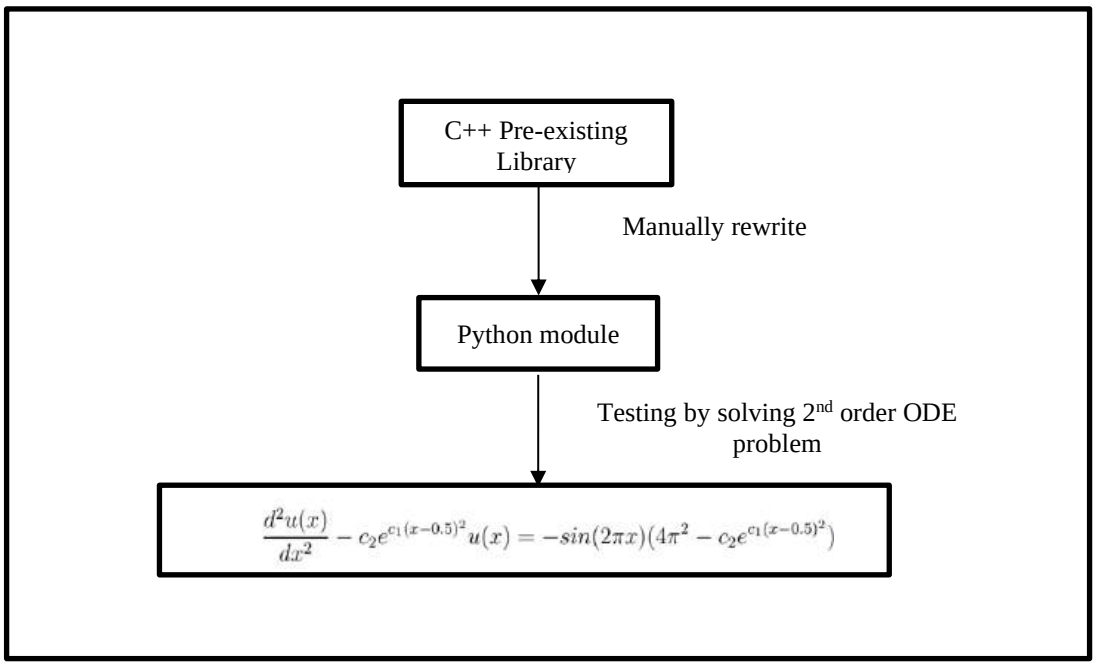

Figure 1. Flowchart on the process of developing the python module.

RESULTS AND DISCUSSION

In performing parallel numerical computations, time execution will be the benchmark as using more than one processor may speed up the computation processes. The table below shows the time execution for each algorithms for serial and parallel with 2 processors.

Table 1. The time execution for each method for serial and parallel.

Method	Time execution (seconds)	
	Serial	Parallel
Thomas Algorithm	0.001	0.016
Jacobi	0.028	27.35
Gaussian Elimination	0.010	0.109
Cyclic Reduction	0.001	0.134
PCGM	0.016	0.114
Power Method	0.012	2.754

From Table 1, it can be observed that the time execution increases as the number of processors used increases. Increasing the number of processors in parallel computing doesn't guarantee a linear increase in computation speed due to the high ratio of communication costs per workload. Consider an embarrassingly parallel problem where the communication cost is very low, for example the computation of photon statistics of an ideal cavity QED laser model based on Quantum Trajectory Algorithm. It can be seen that the time execution has been reduced to almost half when the number of processors is increased twice.

Table 2. Time execution for the computation of photon statistics of an ideal cavity QED laser model based on Quantum Trajectory Algorithm.

Number of Processor	Time execution (seconds)
1	7198.60980
2	4568.49411

CONCLUSION

In conclusion, the python package has been successfully developed according to the project objectives . The testing on second-order ODE problems, coupled with the inherent efficiency derived from C++ algorithms, establishes pcl.py as a reliable and performant tool for solving linear systems and eigenvalue problems. In the future, the project might possibly be improved in terms of the algorithm structure, so that the computation processes will increase.

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DEVELOPMENT OF PYTHON PARALLEL SCIENTIFIC COMPUTING MODULE FOR EDUCATIONAL PURPOSES

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1 ABSTRACT

In this project, a Python module called pcl.py consists of 7 functions used in parallel computing course is successfully created.

2 PROBLEM STATEMENT

Python is getting popular in scientific computations realm. Thus, how to convert the previously C++ parallel computing code into Python module?

3 PROJECT OBJECTIVES

1. To **apply mpi4py** as an alternative to MPI in C++ to carry out parallel computations.
2. To **create a Python module** to be used in the parallel scientific computing course.

4 INTRODUCTION

- The current syllabus of parallel computing course use C++ as a programming platform mainly based on (Karniadikis, 2005).
- New course outline that **utilize Python** as a programming platform may assist the student to better comprehend the course content.
- Python has **lots of built-in packages** for parallel computing, numerical computations and data visualisation (Ateeq et al, 2014).

5 METHODOLOGY

- The Python module is created by **manually rewriting the C++ code exactly back into Python scripts** .
- Mainly, **7 user-defined functions** of parallel algorithms is created in a single Python scripts.
- Then, the python module is tested for solving a very large tridiagonal symmetric positive-definite linear systems.

6 RESULT

[1] List of the user-defined functions inside the module

```
Python 3.7.2 (tags/v3.7.2:9a3ffc0492, Dec 23 2018, 23:09:28) [MSC v.1916 64 bit
(AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import os
>>> import pcl # (this is the library that I am working on) #
>>> print(dir(pcl))
['Gauss_Elim', 'Jacobi_P', 'MPI', 'QR_method', 'SecularEq', 'SolveSecularEq', 'T
DQREigensolver', 'Thomas', '__builtins__', '__cached__', '__doc__', '__file__',
'__loader__', '__name__', '__package__', '__spec__', 'cyc_red', 'np', 'pcgm', 'p
ower_method']
```

[2] Sample Demo from Textbook on solving linear elliptic PDE

$$\frac{\partial^2 u}{\partial x^2}(x,y) + \frac{\partial^2 u}{\partial y^2}(x,y) = 0,$$

for (x, y) in the set $R = \{(x, y) \mid 0 < x < 0.5,\ 0 < y < 0.5\}$. The boundary conditions are

$$u(0, y) = 0,\ \ u(x, 0) = 0,\ \ u(x, 0.5) = 200x, \text{ and } u(0.5, y) = 200y.$$

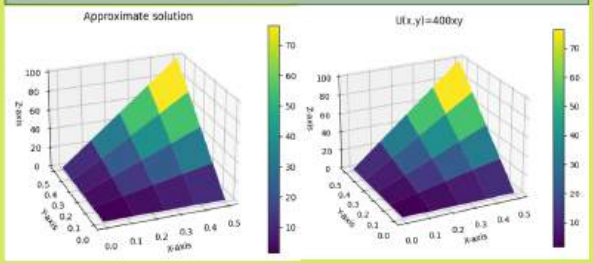
[3] Demo on how to use the module to large linear system

```
import matplotlib.pyplot as plt
from pcl import *
import time
comm=MPI.COMM_WORLD       # define communicator
size_rank=comm.Get_size() # define size of rank
rank=comm.Get_rank()      # define identity of rank
Matrix_A = np.array([[ 4, -1,  0, -1,  0,  0,  0,  0,  0],
                     [-1,  4, -1,  0, -1,  0,  0,  0,  0],
                     [ 0, -1,  4,  0,  0, -1,  0,  0,  0],
                     [-1,  0,  0,  4, -1,  0, -1,  0,  0],
                     [ 0, -1,  0, -1,  4, -1,  0, -1,  0],
                     [ 0,  0, -1,  0, -1,  4,  0,  0, -1],
                     [ 0,  0,  0, -1,  0,  0,  4, -1,  0],
                     [ 0,  0,  0,  0, -1,  0, -1,  4, -1],
                     [ 0,  0,  0,  0,  0, -1,  0, -1,  4]])
Vector_b = np.array([[25],[50],[150],[0],[0],[50],[0],[0],[25]],dtype=np.double)
comm.Barrier()
time_start = MPI.Wtime()
Vector_x = pcgm(comm , rank, size_rank, Matrix_A, Vector_b, 1e-14)
comm.Barrier()
time_end = MPI.Wtime()
if rank == 0:
    print(Vector_x,"\n")
    print("|Ax-b| \n")
    print(abs(np.matmul(Matrix_A,Vector_x) Vector_b),"\n")
    print(f'The elapsed time is {time_end - time_start} seconds')
```

[4] The output

```
|Ax-b|                    |actual-result|
[[0.00000000e+00]          [[0.00000000e+00]
 [0.00000000e+00]           [0.00000000e+00]
 [2.84217094e-14]           [7.10542736e-15]
 [7.10542736e-15]           [1.77635684e-15]
 [1.42108547e-14]           [3.55271368e-15]
 [1.42108547e-14]           [0.00000000e+00]
 [3.55271368e-15]           [0.00000000e+00]
 [7.10542736e-15]           [1.77635684e-15]
 [0.00000000e+00]]          [0.00000000e+00]]
```

[5] 3d Ploting using Matplotlib in Python



CONCLUSION

- Parallel computing in python is easier than C++.
- mpi4py is a good alternative to MPI in C++.
- Data ploting and Sciecntific computattion is easier to be performed in python compared to C++.

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A STUDY ON FTSE BURSA MALAYSIA KLCI USING MINIMUM SPANNING TREE AND DEGREE CENTRALITY DURING STATE ELECTIONS

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Abstract: A financial network comprises nodes that are connected by links to represent the correlation between the stocks. Many researchers have been using the financial network to show the intercorrelation between stocks, especially during major events such as the global financial crisis. Even so, there are too little researchers conducted to observe the consequences of state elections that were held on 12th August 2023 towards the Malaysian Market. Therefore, this paper aims to construct a financial network of the top 30 companies listed in FTSE Bursa Malaysia KLCI. The study analyzed the data one month before and one month after the state elections where it covers from 11th July 2023 until 13th September 2023. The state elections involved six states which were Selangor, Kelantan, Terengganu, Negeri Sembilan, Kedah and Penang. A minimum spanning tree (MST) technique is used to visualize the structure of financial markets. Other than that, the degree centrality method is used to compute the number of connections of the stock where it represents the level of influence of a stock. The findings showed that there are significant differences towards the financial network structure in terms of the main clusters, and the most influential stocks. Before the state elections, there were five main clusters that were formed with one domain node and after the state elections, the clusters group decreased to four with three domain nodes. For future studies, it might be possible to include all stocks that are listed in Bursa Malaysia and adopt a longer period such as covering all state elections that have happened. The results might be more precise since it can exhibit extensive effects within broader industries and more extended periods.

***Keywords*:** Financial network, minimum spanning tree, degree centrality, state election

INTRODUCTION

The relationship between the stocks will help the investors to identify the problems or the difficulties that will be faced by a certain stock market during a certain time. A financial network that consists of the nodes that represent the companies and the edges that represent the relationships between the stocks make it easier for the investors and researchers to analyze the financial markets. In previous research, there are several ways to investigate financial networks. This study use the MST technique where it is known to simplify the financial network by having nodes and edges. The visualization will help the investors to analyze the changes in the relationship between the stocks. The relationship between the stocks can be identified by looking at the correlation of the stocks that leads the investors to understand the relationship in the financial network. With this understanding, we can identify which stock plays the most important role during the state elections. There are several studies that utilize this technique to construct and investigate a financial network which are Bahaludin et al., (2019), Mahamood et al., (2019b), (2019a), and Yee & Salleh, (2018). For a deeper understanding of the financial network, degree centrality method is used to identify the most influential stocks during the period of the study. Degree centrality helps to calculate the number of connections of a stocks. There are studies that investigated the changes in the financial market by using the degree centrality technique (Bahaludin et al., 2019; Mahamood et al., 2019b, 2019a; Yee & Salleh, 2018). In Malaysian Market, there are a lot of studies investing a financial network using MST have been carried out on the general elections. However, there are few studies that investigate the financial network during state elections. Hence, this paper aims to construct a financial network of top 30 companies listed in FSTE Bursa Malaysia KLCI in the duration of one month before and after the state elections.

METHODOLOGY

MINIMAL SPANNING TREE

Firstly, cross-correlation matrices based on the log return of closing prices are calculated. The correlation coefficient, C_{ij}, between the stocks *i* and j is given by,

$$C_{ij} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sqrt{\left(\langle r_i^2 \rangle - \langle r_i \rangle^2\right)\left(\langle r_j^2 \rangle - \langle r_j \rangle^2\right)}} \tag{1}$$

where, r_i is the vector of the log-returns.

The log-returns can be computed as $r_i(t) = \ln P_i(t+1) - \ln P_i(t)$ and $P_i(t)$ is the price of stock *i* on date *t*. Correlation coefficients obtained within the range of $-1 \le C_{ij} \le 1$ indicates that -1 means inversely correlated and 1 means perfectly correlated between stocks. The correlation coefficient between stocks *i* and j will form the symmetric $N \times N$ matrix. Secondly, correlation coefficients are transformed into a distance matrix. However, correlation coefficients cannot be considered as a distance between two stocks because they do not satisfy the properties of Euclidean metric which are,

$$\begin{cases} d_{ij} \ge 0 \\ d_{ij} = d_{ji} \\ d_{ij} \le d_{ix} + d_{xj} \end{cases} \tag{2}$$

Thus, the distance between stock *i* and stock j can be calculated as follows:

$$d_{ij} = \sqrt{2\left(1 - C_{ij}\right)} \tag{3}$$

Thirdly, financial networks are constructed using the minimum spanning tree based on the distance matrix via a Kruskal algorithm. There are several steps listed in Kruskal algorithm which are, 1) sort the distance between two stocks in ascending order, 2) choose a pair of stocks with the smallest distance and connect them with an edge, 3) choose a second small distance, 4) connect the nearest pair and ignore the pair if it forms a cycle in the network, and 5) repeat the steps until all the stocks are connected in a unique network.

DEGREE CENTRALITY

Centrality measures are employed for further analysis of the financial network. This study uses the degree centrality method to analyzed the financial network deeper. Degree centrality represents the total number of stocks that is connected to a stock i. The calculation of degree centrality is as follows:

$$C_{Degree}(i) = \frac{\sum_{j}^{N} A_{ij}}{N-1} \tag{4}$$

where $A_{ij} = 1$ if the stock i and j is connected and 0 otherwise.

RESULTS AND DISCUSSION

Figure 1 represent the network of top 30 companies listed in FTSE Bursa Malaysia KLCI one month before state elections. In general, Figure 1 clearly shows that five main clusters were formed which are dominated by Sime Darby (SIME), Hong Leong (HLBB), AmBank (AMMB), Genting (GENT), and CIMB Group (CIMB). Based on the figure, the shortest distance is between GENT and GENM which is 0.55302. Other than that, largest cluster consist of SIME, SIPL, IOIB, TLMM, MISC, MXSC, PETR, and IHHH. The figure also shows that the stocks with the largest size of node is GENM. This indicates that GENM is the most influential stock in the network before the state elections. Meanwhile, Figure 2 represent the network of top 30 companies listed in FTSE Bursa Malaysia KLCI one month after state elections. In general, the main clusters decreased from five before the state elections to four clusters after the state elections. As depicted in the figure, the clusters are dominated by IOIB, PGAS, AXIA, and CIMB. It is also shown that the shortest distance RHBC – AXIA. Other than that, the largest group consists of CIMB, GENT, GENM, TLMM, MBBM, AMB, HLBB, PUBM, PETR, CELC, MRDI, and QRES. The figure shows that the stocks with the largest size of node increased from one to three which are CIMB, RHBC, and SIPL. This indicates that they are the most influential stocks in the network after the state elections.

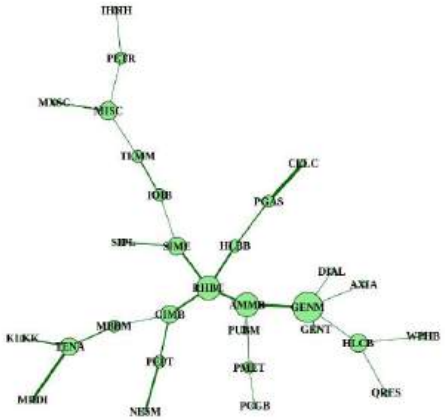

Figure 1. Financial network before state elections.

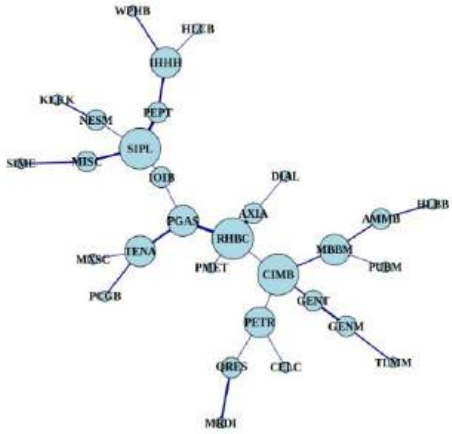

Figure 2. Financial network after state elections.

CONCLUSIONS

This paper shows the correlation between the top 30 companies listed in FTSE Bursa Malaysia KLCI. The correlations were analysed by using MST technique and degree centrality method. These methods help to identify the most influential stock by constructing the financial network. The results shows that GENM is the most influential stock before the state elections and SIPL, CIMB, and RHBC are the most influential stocks after the state elections. Above all, this paper helps the investors to get the overview of the situation of the financial network before and after the state elections. It also helps the investors to make a better investment strategy based on their priority.

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A STUDY ON FTSE BURSA MALAYSIA KLCI USING MINIMUM SPANNING TREE AND DEGREE CENTRALITY DURING STATE ELECTIONS

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COMPUTATIONAL AND THEORETICAL SCIENCES

ABSTRACT

This paper investigate the **impact of state elections** towards the financial market. The data that was analyzed is from the **top 30 companies listed in FTSE Bursa Malaysia KLCI.** Minimum spanning tree and degree centrality methods are used to construct the financial network. It also help to identify which stocks are the most influential stocks before and after the state elections. This paper finds that state elections have impacts towards financial market in terms of **structure and most influential stock**

INTRODUCTION

- **State elections** was held on 12th August 2023. The state elections causes the stock markets to fluctuate.
- **Minimum spanning tree** is used to visualize the financial network before and after the state elections.
- **Degree centrality** technique is used to determine the most influential stock
- Duration of the study is **one month before and one month** after the state selection (from 11th July until 13th September)

PROLEM STATEMENT

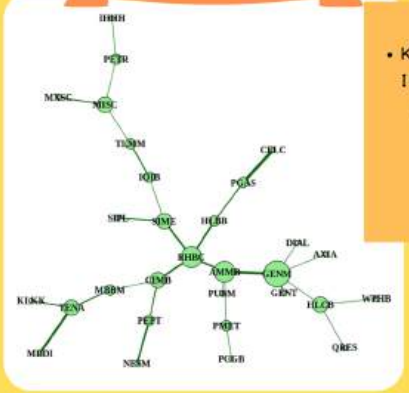
The **uncertain relationship** between the stocks before and after is due to the state elections.

By Bilal Ahmad Memon (2020), **elections give impact towards the financial market**

OBJECTIVES

- **To construct** two financial networks of FTSE Bursa Malaysia KLCI **before and after the state elections** respectively.
- **To identify** the most influential stocks in the financial network before and after the state elections.

BEFORE STATE ELECTIONS



- KEY PLAYERS (MOST INFLUENTIAL)
  - GENM (Genting Malaysia)

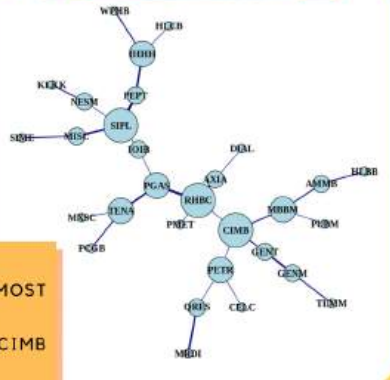
METHODOLOGY

1. Data collection and data cleaning.
2. Compute the correlation coefficient.
3. Calculate the distance matrix.
4. Construct MST using Kruskal's Algorithm
5. Compute the degree centrality.
6. Information extraction (Degree Centrality)

DATA

1. Malaysian state elections.
   a. 12th August 2023
2. **One month before** state elections
   a. 11th July 2023
3. **One month after** state elections
   a. 13th September 2023
4. Companies
   a. **Top 30 companies** listed in FTSE Bursa Malaysia KLCI.
5. Sources
   a. Investing.com
   b. Yahoo Finance

AFTER STATE ELECTIONS



- KEY PLAYERS (MOST INFLUENTIAL)
  - CIMB (CIMB Group)
  - RHBC (RHB Bank)
  - SIPL (Sime Darby Plantation)

CONCLUSION

- The results indicates that a structural changes in the financial networks are due to the state elections.
- The results can help the investors acknowledge the situation of the financial market in the duration of state elections thus give them the more informed and prudent judgement for investement strategy

REFERENCES

Memon, B. A., Yao, H., & Tahir, R. (2020). General election effect on the network topology of Pakistan's stock market: network-based study of a political event. Financial Innovation, 6(1). https://doi.org/10.1186/s40854-019-0165-x

LAMINAR FLOW OF NEWTONIAN FLUID IN A LID-DRIVEN CAVITY WITH SOLID CIRCULAR BLOCK

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Abstract: This paper investigates the characteristics of two-dimensional laminar flow of a Newtonian fluid inside a lid-driven cavity that consists of a solid circular block and how the size of the solid circular block affects the velocity profiles of the Newtonian fluid. The fluid flow is driven by the top lid that moves to the right while the other lids remain stationary. By solving the Navier-Stokes equation using finite element method and automated solution technique (FEniCS), the velocity profile of the fluid flow can be observed. The study finds that, when the size of circular block increases, the velocity of the Newtonian fluid decreases.

***Keywords*:** Laminar flow, newtonian fluid, lid-driven cavity, circular block, automated solution technique (FeniCS)

INTRODUCTION

This study investigates the laminar flow of Newtonian fluid in a lid-driven cavity containing solid circular block and observes the effects of the size of the solid circular block towards the velocity profile of the fluid flow. A study by Gangawane et al. (2019) stated that a flow is indeed a laminar flow if the Reynolds number, Re, is in the range of $1 \leq \mathrm{Re} \leq 1000$. Billah et al. (2011) concluded that the size of circular block has a substantial impact towards fluid flow. Navier-Stokes equation will be employed and solved by using finite element method and automated solution technique, FEniCS. It was shown that the flow of Newtonian fluid in a lid-driven cavity with solid circular block is indeed a laminar flow and that when the size of the circular block increases, the velocity of the fluid decreases.

METHODOLOGY

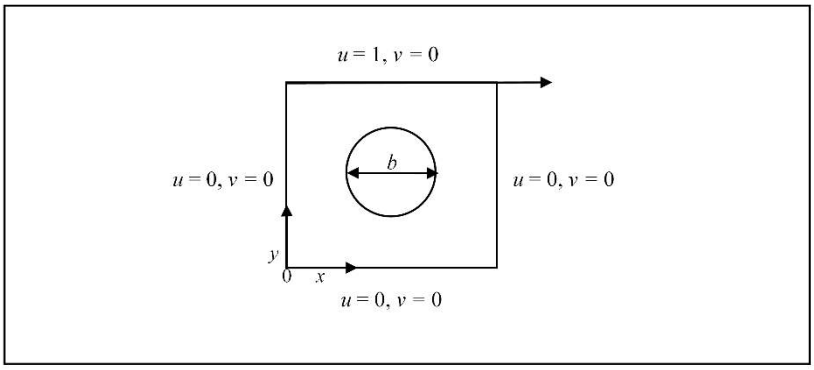


Figure 1. Configuration with Boundary Conditions.

Continuity equation

$$\nabla \cdot \mathbf{u} = 0 \tag{1}$$

Momentum equation

$$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = -\nabla p + \mu \nabla^2 \mathbf{u} \tag{2}$$

where ρ = 1 g/cm^3 is density of fluid, **u** = (u,v) = 1 m/s is velocity of lid, p is pressure, μ = 1.002 kg/(m-s) is dynamic viscosity of fluid, *b* = 0.2 m, 0.3 m, 0.4 m, 0.5 m is diameter of circular block (Billah et al., 2011; Patterson & Morris, 1994; Zhu et al., 2019).

In pre-processing step, firstly we import necessary FEniCS libraries, then we generate meshing domain and build a finite element function space with two elements: a scalar element with order one for pressure and a vector element with order two for velocity. Next, we define the trial and test functions and specify the boundary conditions according to Figure 1. İn the processing step, we will transform the continuity and momentum equation, (1) and (2), into their variational form or weak form by multiplying them with the test functions and integrate over domain.

Continuity equation weak form

$$\int \nabla \cdot \mathbf{u}(q)\, dx = 0 \tag{3}$$

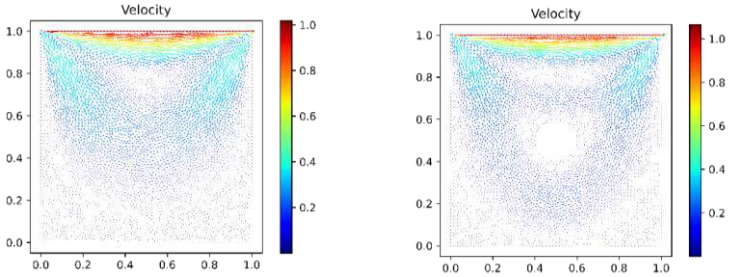
Momentum equation weak form

$$\int \rho(\mathbf{u} \cdot \nabla)\mathbf{u} \cdot v\, dx + \int \nabla p \cdot v\, dx + \mu \int (\nabla \mathbf{u} \cdot \nabla v)\, dx = 0 \tag{4}$$

In post-processing step, after the solver successfully runs without errors, we plot the result using matplotlib and obtain the velocity profile of our Newtonian fluid.

RESULTS AND DISCUSSION

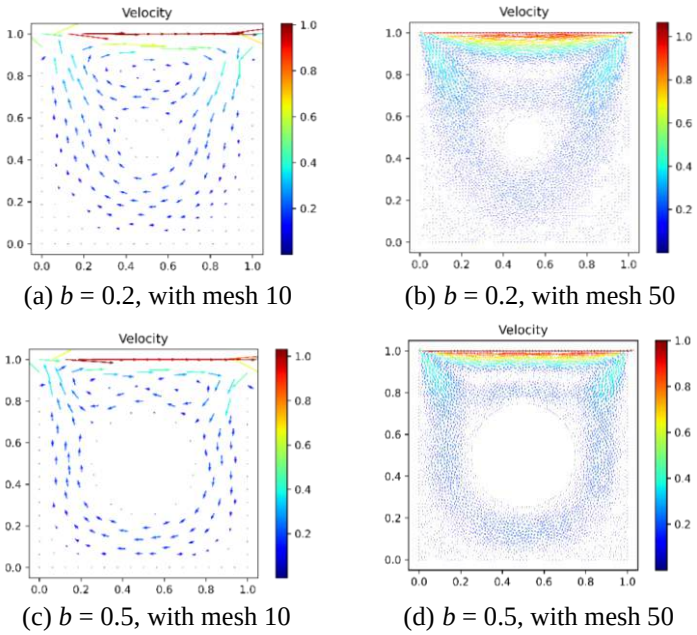
This study considers regular water as the fluid material in the cavity while it is at room temperature. By using the parameters, we calculate the Reynolds number, Re. We get the value of Reynolds number, Re, within the range of $1 \leq \text{Re} \leq 1000$. This proves that the flow is a laminar flow as per stated by Gangawane et al. (2019).



(a) Without solid circular block (b) With solid circular block

Figure 2. Velocity Profiles ith and without Solid Circular Block.

From Figure 2 (a), it shows that the vector arrow in light blue colour at top right and top left of the cavity is longer than those in Figure 2 (b). The size of vector arrow in light blue and yellow region at the top of the cavity also reduces when a solid circular block was added in the cavity. This demonstrates that when the solid circular block is absent, the fluid's velocity is faster than when the solid circular block is present.



(a) b = 0.2, with mesh 10 (b) b = 0.2, with mesh 50

(c) b = 0.5, with mesh 10 (d) b = 0.5, with mesh 50

Figure 3. Velocity Profiles with Different Sizes of Circular Block.

Based on Figure 3, when the diameter of the solid circular block increase from 0.2 m to 0.5 m, the velocity of the fluid decreases. It was shown that the light blue and yellow region at the top of the cavity decreases when the size of the solid circular block increases. This situation proves that when the solid circular block becomes bigger, the fluid's velocity reduces.

CONCLUSIONS

Numerical investigation of laminar flow in a lid-driven cavity with solid circular block was conducted by solving Navier-Stokes equations using finite element method and automated solution technique (FEniCS). It was shown that the flow of Newtonian fluid in a lid-driven cavity with solid circular block is indeed a laminar flow. It was observed that the size of the circular block visibly influences the velocity of the flow. As a result, it can be concluded that the insertion of circular blocks can be employed to adjust fluid flow velocity in a lid-driven cavity.

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LAMINAR FLOW OF NEWTONIAN FLUID IN LID-DRIVEN CAVITY WITH SOLID CIRCULAR BLOCK

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ABSTRACT

This paper investigates the characteristics of laminar flow of a Newtonian fluid inside a lid-driven cavity that consists of a solid circular block and how the size of the solid circular block affects the velocity profiles of the Newtonian fluid. By solving the Navier-Stokes equation using finite element method and automated solution technique, FEniCS, the velocity profile of the fluid flow can be observed. The study finds that, when the size of circular block increases, the velocity of the Newtonian fluid decreases. This research aims to provide information regarding the effects of various block sizes on fluid velocity that will contribute to greater knowledge of fluid behaviour and its relevance to practical applications.

MATHEMATICAL MODELLING

Continuity Equation:

$$\nabla \cdot \mathbf{u} = 0 \quad (1)$$

Momentum Equation:

$$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = -\nabla p + \mu \nabla^2 \mathbf{u} \quad (2)$$

where ρ is density, u = (u, v) is velocity, p is pressure, and μ is dynamic viscosity

OBJECTIVES

1. To investigate the laminar flow of Newtonian fluid in a lid-driven cavity containing solid circular block.
2. To analyse the effect of the size of solid circular block towards the velocity of Newtonian fluid.

METHODOLOGY

PRE-PROCESSING

- Import libraries
- Generate meshing domain
- Build finite element function space
- Define trial and test functions
- Define parameters

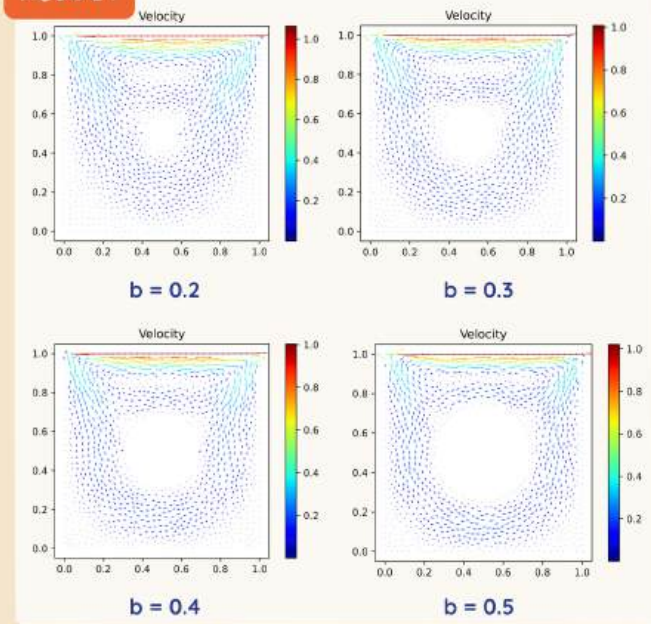
PROCESSING

- Transform continuity and momentum equation into variational form
- Solve the equations

POST-PROCESSING

- Plot result
- Obtain velocity profile

RESULT



CONCLUSION

- The flow is indeed laminar flow because the Reynolds number is < 1000
- The fluid velocity decreases when the size of the circular block increases

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FITTING EPIDEMIOLOGICAL SEIRD MODEL TO COVID-19 DATA USING PYMOO LIBRARY

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Abstract: This study employs a modified SEIRD model to analyze COVID-19 cases from 25th January 2020 – 25th September 2020 in Malaysia. İn order to accurately fit the model to the data, sixteen model parameters are optimized to obtain the least square error objective. Two optimization algorithms, Nelder-Mead (NM) and Pattern-Searh (PS) have been chosen under Pymoo libary and the error are furthermore quantified based on the Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). These measurements indicate that Pymoo a reliable Python optimization package as the fitting errors surpass the accuracy produced by the other packages reported from the citations.

***Keywords*:** Pymoo, SEIRD, optimization, Nelder-Mead, pattern-search

INTRODUCTION

Python has emerged as the most popular programming language for academic particularly in the data science and optimization. There are several optimization libraries available in Python such as Lmfit, Scipy and Pymoo. Pymoo is a relatively new framework, but it provides more extensive number of algorithms compare to the other optimization packages which include not only single but multiple objectives state of art algorithms (Blank, 2020; Blank & Deb, 2020; Petrović et al., 2021).

This study aims to explore the Pymoo's framework since Pymoo requires the knowledge of defining class, to be able to utilize it and subsequently to optimize the SEIRD model by first applying the Nelder-Mead and then reoptimizing it with the Pattern-Search technique. The model is a system of nonlinear ordinary differential equations consist of sixteen parameters that should be optimized to achieve the objective that is the least square error between the numerical solutions and the collected data.

METHODOLOGY

Optimization is maximizing or minimizing functions within a specified set, representing a range of choices under specific conditions. In this study, the optimization problem can be defined as:

$$minimize \quad \sum_{i=1}^{N} (y_i - u_i)^2 \tag{1}$$

subjected to the SEIRD equations with the parameters

$$p_j^L \leq p_j \leq p_i^U \qquad j = 1,2,\dots,16$$

where

$$p_j^L = [0,0,\dots,0,1,0.07,0]$$

$$p_j^U = [1,1,\dots,1,30,30,30,5,0.5,1]$$

where, y_i is the i-th COVID-19 case, u_i is the corresponding numerical solution from the SEIRD model, N is the total number of considered cases, p_j is the j-th parameter that need to be optimized while p_j^L and p_j^U are the lower and upper limit respectively for the p_j. The actual definitions for the parameters and their limits will be explained next.

The SEIRD model is given as follows:

$$\frac{dS}{dt} = -\frac{\beta_I(t)SI}{N} - \frac{\beta_E(t)SE}{N} + \delta(t)R \quad (2)$$

$$\frac{dE}{dt} = \frac{\beta_I(t)SI}{N} - \frac{\beta_E(t)SE}{N} + \sigma E \quad (3)$$

$$\frac{dI}{dt} = \sigma E - \gamma(t)I - \mu(t)I \quad (4)$$

$$\frac{dR}{dt} = \gamma(t)I - \delta(t)R \quad (5)$$

$$\frac{dD}{dt} = \mu(t)I \quad (6)$$

In the SEIRD model for COVID-19 analysis in Malaysia, sixteen parameters capture key aspects of disease transminssion and progression. These include infection rate (β), incubation rate (σ), recovery rate (γ), death rate (μ) and reinfection rate (δ). These parameters represent probabilities of transitions between susceptible (S), exposed (E), infected (I), recovered (R) and deceased (D) states. Each parameter influences population trajectories, enabling accurate modelling of COVID-19 transmission.

RESULTS AND DISCUSSION

To comprehensively evaluate the model's performance, Table 1 provides an overview of the error values for each compartment, infected (I), recovered (R) and death (D), as well as the overall error. This analysis encompasses two optimization techniques, Nelder-Mead algorithm and combination of Nelder-Mead and Pattern-Search algorithms. The table offers a comparative insight into the RMSE and MAE values across different compartments and optimization methods.

Table 1 Error Values of the Model

	RMSE		**MAE**	
	NM	NM & PS	NM	NM & PS
I	330.860	311.337	260.281	250.901
R	314.761	266.186	228.340	185.051
D	25.307	23.869	16.398	17.796
Overall Error				
NM	264.0601		168.3398	
NM & PS	236.8930		151.2490	

Furthermore, Figure 1 visually captures the fitted curves for the *I*, *R* and *D* populations, covering the period from 25th January 2020 to 25th September 2020. The blue dashed line represents the actual data, while the yellow and green curves denote the outcome achieve using the Nelder-Mead technique and the combined Nelder-Mead and Pattern-Search techniques respectively.

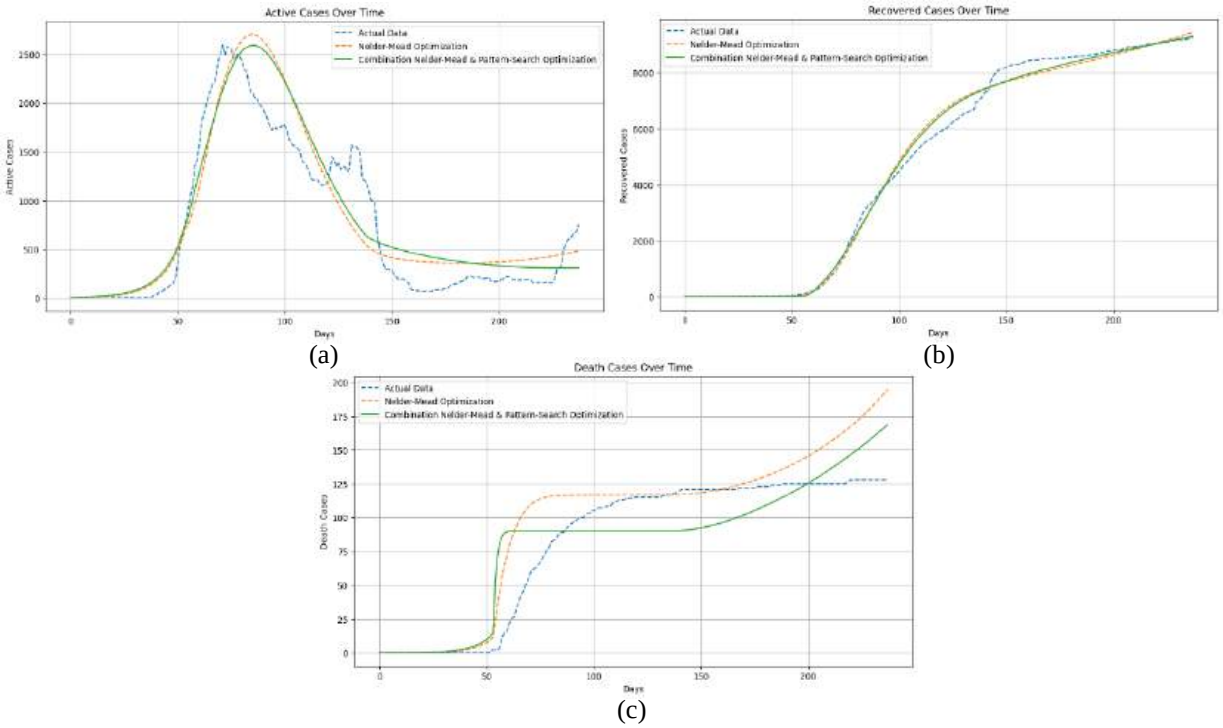

Figure 1. Fitted curves for *I*, *R*, and *D*.

The optimization results from both the NM algorithm and combination of NM and PS algorithms exhibit similar output, with the combination method showing lower error values. Therefore, the optimized values obtain through the combination of algorithms closely match the actual data of COVID-19 cases in Malaysia.

A comparison with another study by Zulkarnain et al., (2023), which utilize only NM algorithm in LmFit for parameters optimization, reveals that Pymoo yields lower RMSE values. In their study, the RMSE value is 346.102, while by applying Pymoo, the RMSE value is 264.060. It is evident that optimization in Pymoo is significantly better than LmfFit, even though both packages are offered by Python.

CONCLUSIONS

Pymoo shines among Python optimization libraries for its diverse algorithms. İt delivers high accuracy, proven by lower error values in model comparisons. Plus, it boasts a wider range of techiniques compared to others. Overall, Pymoo excels at optimizing parameters for more accurate outputs, making it reliable for further model fitting and other applications.

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FITTING EPIDEMIOLOGICAL SEIRD MODEL TO COVID-19 DATA USING PYMOO LIBRARY

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ABSTRACT

The Susceptible-Exposed-Infected-Recovered-Death (SEIRD) model is used to model the trend of Coronavirus disease 2019 (COVID-19). Two algoriths are combined to optimize the COVID-19 data and it impoved the accuracy compared to previous published works.

INTRODUCTION

Pymoo, Python's Multi-objective Optimization package, is a recent addition to optimization tools. This research aims to optimize and fit an epidemiological model for COVID-19 cases in Malaysia using Pymoo and subsequently compare the model's accuracy with other existing studies.

OBJECTIVES

- To attain a comprehensive understanding of utilizing the Pymoo library.
- To compute the optimized parameters for the SEIRD model using the Nelder-Mead algorithm.
- To apply the combination of Nelder-Mead (NM) and Pattern-Search (PS) techniques to further reduce the root mean square error (RMSE).

PROBLEM STATEMENT

SIRD model [2]
- fitting SIRD model
- use 2 optimizations, Nelder-Mead & Pattern-Search

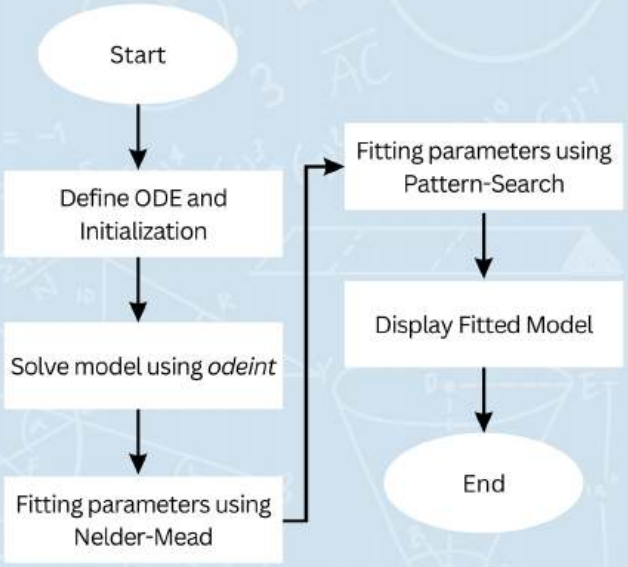
+

SEIRD model [1]
- fitting SEIRD model
- use 1 optimization only Nelder-Mead

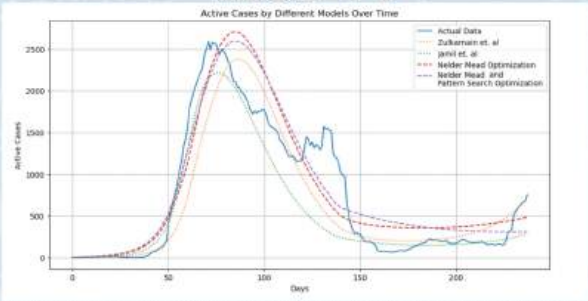
Improve fitting the models using 2 optimization algorithm, Nelder-Mead and Pattern-Search

METHODOLOGY

Flowchart for fitting SEIRD model



RESULT 1



RESULT 2

No.	Model	RMSE
1.	Jamil et.al (2021)	789.346
2.	Zulkarnain et.al (2023)	346.102
3.	Present (NM only)	264.060
4.	Present (NM & PS)	236.893

CONCLUSION

This study used the SEIRD model to analyze COVID-19 trends and employed Pymoo for optimization. By integrating two algorithms, we significantly improved the accuracy of COVID-19 data compared to previous studies. Our findings not only showcase the effectiveness of Pymoo in optimizing epidemiological models but also underscore the importance of such optimization in boosting prediction accuracy. When compared to existing studies, our research further solidifies the advancements made, providing valuable insights into the field of COVID-19 modeling and optimization.

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A PORTFOLIO MANAGEMENT OF SELECTED STOCKS FROM INDUSTRIAL PRODUCTS AND SERVICES, TECHNOLOGY AND TELECOMMUNICATION AND MEDIA OF BURSA MALAYSIA SECTORS

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Abstract: This study aims to investigate and analyse the portfolio management of selected stocks from Industrial products and services, Technology and Telecommunication and Media of Bursa Malaysia sectors. The purpose of this research is to provide guidelines and references for investors to analyze and help to choose more suitable portfolios for investment. In this research, nine stocks are selected, which are PCHEM, SUNWAY, PMETAL, VITROX, MYEG, GREATEC, AXIATA, CDB and MAXIS. By calculating the various data from 1st April 2023 to 30th September 2023 of these stocks, five different types of investment portfolios are studied. In this study, Excel software is used to calculate specific data such as correlation, covariance matrix, weight of each stock, expected return and risk. The findings show that SUNWAY has the highest return at 0.21% and AXIATA has the lowest return at -0.14%. Meanwhile, MYEG has the greatest risk at 2.36%, while VITROX has the lowest risk at 1.11%. For the different type of portfolios, portfolio having the combination of the lowest risk stocks which are SUNWAY, VIROX and CDB is the best performing portfolio, with a reasonable expected return of 0.04% and the lowest level of risk of 0.68%. This research might contribute to the additional scientific literature on portfolio management from the perspective of stocks in Bursa Malaysia. Also, the results and findings may provide guidelines and references for investors to minimize risk and optimize return.

***Keywords*:** Portfolio management, expected return, risk, correlation, covariance matrix, weight

INTRODUCTION

This research concentrates on analysing and comparing the risk and return of stocks in a portfolio from industrial products and services, technology and telecommunication and media of Bursa Malaysia sectors by using data obtained from yahoo finance. The data collected is limited from April to September 2023. However, the complexity of today's financial market may pose challenges to investors in selecting high-quality investments. Nonetheless, calculating and analysing each stock effectively can help assess its risk and performance. As a result, investors can select a portfolio that suits their personal risk preferences (Lyu, 2021). Thus, this study attempts to provide a guide to calculate risk and return of an investment. Various methods have been used to calculate expected returns and analyse risk on stock markets around the world, including CAPM, risk analysis techniques, and value at risk (Dinh, 2021). Lyu (2021) has investigated portfolio management of stocks of eight Australian companies using expected return, standard deviation, correlation matrix, and covariance matrix, as well as the Capital Asset Pricing Model to analyze the data. Additionally, Dinh (2021) has studied the relationship between risks and the expected return of a portfolio in the Vietnam stock market by applying the standard deviation, variance, coefficient of variation methods and matrix function to measure risks. Therefore, this study applies the correlation of coefficient, covariance matrix model, and weight of selected stocks so as to achieve the lowest risk of a portfolio and also the expected return of an investment. In this study, portfolio having a combination of 3 stocks with the lowest risk which are SUNWAY, VIROX and CDB is found to be the best investment for investor to choose if minimizing risk is the primary concern.

METHODOLOGY

This research uses data from Bursa Malaysia and Yahoo Finance between 1st April 2023 to 30th September 2023. The 3 stocks in each 3 selected sectors are chosen based on its highest market capitalization in that particular market sector. The first selected sector is from the industrial product and services which consists of PCHEM, SUNWAY, PMETAL. The second selected sector is from the technology sector which consists of VITROX, MYEG, GREATEC. The third selected sector is from the telecommunication and media which consists of AXIATA, CDB and MAXIS. In this research, the historical adjusted closing prices for each selected stock is collected. Besides, the Excel software is used to calculate specific data. For the calculation of risk and return of each stock, return is calculated using logarithmic return while risk is measured by standard deviation. Meanwhile, to come out with this risk and return of a portfolio of stock, the weights of each stock, the correlation and covariances need to be calculated. Methodology of calculating and analysing risk and return for each stock and each portfolio is referred from Capinski and Zastawniak (2011).

RESULTS AND DISCUSSION

RESULT 1

Table 1 shows the result of average return and standard deviation for all stocks. Based on the three sectors, we can see that the highest values of return are 0.21% at stock 2 (SUNWAY) in sector 1 which is from industrial product and services. Meanwhile the least values of return of -0.14% at stock 7 (AXIATA) in sector 3 which is from telecommunication and media sector. On the other hand, the maximum amount of standard deviation is at stock 5 (MYEG) in sector 2 which is 2.36%. This means that stock 5 (MYEG) in technology sector has the highest level of risk among the sectors. The minimum amount of standard deviation also in sector technology which is at stock 4 (VITROX) with 1.11%. This means that stock 4 (VITROX) in technology sector has the lowest level of risk among the sectors.

Table 1. Average return and standard deviation of selected stocks.

Sector	Stock	Average return (%)	Standard deviation (%)
Industrial product and services	S1. PCHEM (Petronas Chemicals Group Berhad)	0.02	1.54
	S2. SUNWAY (Sunway Berhad)	0.21	1.29
	S3. PMETAL (Press Metal Aluminium Holdings Berhad)	-0.02	1.54
Technology	S4. VITROX (Vitrox Corporation Berhad)	-0.05	1.11
	S5. MYEG (MY E.G. Services Berhad)	0.04	2.36
	S6. GREATEC (Greatech Technology Berhad)	-0.10	1.77
Telecommunication and Media	S7. AXIATA (Axiata Group Berhad)	-0.14	1.62
	S8. CDB (Celcomdigi Berhad)	0.02	1.24
	S9. Maxis (Maxis Berhad)	-0.002	1.80

RESULT 2

Table 2 shows the result of all 5 portfolios. Based on the result, portfolios 1 and 5 have the highest portfolio return at 0.10%. In contrast, portfolio 2 has the lowest portfolio return of -0.05% among all portfolios. Meanwhile, portfolio 3 has the greatest standard deviation at 0.96% while the least risk is at portfolio 4 where the standard deviation at 0.68%.

Table 2. Expected return and risk of 5 different type of portfolios.

Portfolio	1 Industrial Product & Services Sector	2 Technology Sector	3 Telecommunication and Media Sector	4 Lowest risk stocks from each sector	5 Highest return stocks from each sector
Stock	S1 = PCHEM S2 = SUNWAY S3 = PMETAL	S4 = VITROX S5 = MYEG S6 = GREATEC	S7 = AXIATA S8 = CDB S9 = MAXIS	S2 = SUNWAY S4 = VITROX S8 = CDB	S2 = SUNWAY S5 = MYEG S8 = CDB
Weight (%)	S1 = 24.6791 S2 = 46.7425 S3 = 28.5785	S4 = 64.1626 S5 = 11.5327 S6 = 24.3046	S7 = 25.5160 S8 = 51.2252 S9 = 23.2588	S2 = 26.6360 S4 = 39.4896 S8 = 33.8744	S2 = 42.2468 S5 = 11.4165 S8 = 46.3367
Expected return (%)	0.10	-0.05	-0.03	0.04	0.10
Standard deviation (%)	0.93	0.93	0.96	0.68	0.84

CONCLUSION

We can conclude that portfolio 4 which is the combination of 3 stocks with the lowest risk which consists of SUNWAY, VIROX and CDB is the best performing portfolio, with a reasonable expected return of 0.04% and the lowest level of risk 0.68%. Portfolio 4 is highly recommended if minimizing risk is the primary concern. Portfolio 1 which is from the industrial product and services sector have the highest expected return of 0.10% and the standard deviation of 0.93% which is consider moderate risk for the portfolio. Similarly, portfolio 5 have the highest expected return of 0.10% and the standard deviation of 0.84%. Therefore, those investors aiming for higher returns with moderate risk may find portfolios 1 and 5 are suitable options. Portfolios 2 and 3 are not a suitable option because they have negative expected returns. Hence, by calculating and analyzing each stock effectively, investors can be able to assess its risk and performance. This allows investors to select a portfolio that fits their personal risk preferences. Thus, it is recommended that the study can be further extended by adding more classes of assets. In addition, the data collected is limited from April to September 2023 only. Therefore, the data taken can be extended for a longer time frame instead of analysis for 6 months only.

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A Portfolio Management of Selected Stocks from Industrial Products and Services, Technology and Telecommunication and Media of Bursa Malaysia Sectors

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ABSTRACT

This study aims to investigate and analyse the portfolio management of selected stocks from Industrial products and services, Technology and Telecommunication and Media of Bursa Malaysia sectors. The purpose of this research is to provide guideline and references for investors to analyze and help to choose more suitable portfolios for themselves. Hence, by using the data taken from Bursa Malaysia and Yahoo Finance, Microsoft Excel is used to calculate the data collected.

PROBLEM STATEMENT

The complexity of today's financial market may pose challenges to investors in selecting high-quality investments (Lyu, 2021). Nonetheless, by calculating and analysing each stock effectively can help assess its risk and performance.

INTRODUCTION

- A **portfolio** is **a group of assets** held by an investor, consisting of various asset classes (Bhatt, 2011).
- A **portfolio management** is a process of continually reallocating money into a variety of investment products in order to maximize return while minimizing risk (Jiang, 2017).

OBJECTIVES

- To **investigate the risk and return of each selected stock** from the Industrial products and services, Technology and Telecommunication & Media sectors.
- To **analyse and compare the risk and expected return of portfolios of stocks.**

METHODOLOGY

1. Data

- Bursa Malaysia and Yahoo Finance.
- 1st April 2023 to 30th September 2023.
- Industrial product & services, technology and telecommunication & media sectors.
- Three stocks chosen based on the highest market capitalization in that particular market sector.

2. Calculation of risk and return of each stock

01 RETURN

$$K = \ln\frac{S_i}{S_{i-1}}$$

- Calculated using logarithmic return

02 RISK

$$\sigma_k = \sqrt{\frac{\Sigma(K-\bar{K})^2}{n-1}} = \sqrt{Var\,K}$$

- Measured by standard deviation

- Methodology of calculating and analysing risk and return for each stock and portfolio is from Capinski & Zastawniak (2011).

$$\sigma_k = \sqrt{Var\,K}$$

3. Calculation of risk and expected return of portfolio of stocks

01 COVARIANCE MATRIX

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix}$$

$$c_{ii} = Var(K_i)$$

$$c_{ij} = \rho_{ij}\sigma_i\sigma_j$$

02 CORRELATION

$$\rho_{ij} = \frac{cov(K_iK_j)}{\sigma_i\sigma_j}$$

03 WEIGHT

$$W = \frac{uC^{-1}}{uC^{-1}u^T}$$

04 EXPECTED RETURN

$$\mu_V = mw^T$$

05 RISK

$$\sigma_V^2 = wCw^T$$

$$\sigma_V = \sqrt{wCw^T}$$

RESULTS AND FINDINGS

Table 1: Average return and standard deviation of selected stocks

Sector	Stock	Average return	Standard deviation
Industrial product and services	S1. PCHEM	0.02	1.54
	S2. SUNWAY	0.21	1.29
	S3. PMETAL	-0.02	1.54
Technology	S4. VITROX	-0.05	1.11
	S5. MYEG	0.04	2.36
	S6. GREATEC	-0.10	1.77
Telecommunication and Media	S7. AXIATA	-0.14	1.62
	S8. CDB	0.02	1.24
	S9. Maxis	-0.002	1.80

Among all stocks, **SUNWAY** has the **highest** return at **0.21%**, and **AXIATA** has the **lowest** return of **-0.14%**. On the other hand, **MYEG** has the **greatest** standard deviation at **2.36%**, while **VITROX** has the **lowest** standard deviation of **1.11%** which indicates the **least** amount of risk.

Table 2: Expected return and risk of 5 different portfolios

Portfolio	1 Industrial Product & Services Sector	2 Technology Sector	3 Telecommunication and Media Sector	4 Lowest risk stocks from each sector	5 Highest return stocks from each sector
Stock	S1 = PCHEM S2 = SUNWAY S3 = PMETAL	S4 = VITROX S5 = MYEG S6 = GREATEC	S7 = AXIATA S8 = CDB S9 = MAXIS	S2 = SUNWAY S4 = VITROX S8 = CDB	S2 = SUNWAY S5 = MYEG S8 = CDB
Weight (%)	S1 = 24.6791 S2 = 46.7425 S3 = 28.5785	S4 = 64.1626 S5 = 11.5327 S6 = 24.3046	S7 = 25.5160 S8 = 51.2252 S9 = 23.2588	S2 = 26.6360 S4 = 39.4896 S8 = 33.8744	S2 = 42.2468 S5 = 11.4165 S8 = 46.3367
Expected return (%)	0.10	-0.05	-0.03	0.04	0.10
Standard deviation (%)	0.93	0.93	0.96	0.68	0.84

Portfolio 1 and **5** have the **highest** portfolio return at **0.10%**. In contrast, **portfolio 2** has the **lowest** portfolio return of **-0.05%** among all stocks. Meanwhile, **portfolio 3** has the **greatest** standard deviation at **0.96%** while **portfolio 4** has the **least** standard deviation at **0.68%**.

CONCLUSION

- Portfolio 4 is the best performing portfolio, with expected return of 0.04% and the lowest level of risk 0.68%. As a result of its lower standard deviation, portfolio 4 is highly recommended if minimizing risk is the primary concern.
- Those aiming for higher returns with moderate risk may find portfolio 1 and 5 are suitable options.
- Portfolio 2 and 3 are not suitable option because they have negative expected returns.
- Depending on the investor's preferences and requirements, different portfolios may be prioritized. Hence, by calculating and analyzing each stock effectively, investors can be able to assess its risk and performance.

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A PORTFOLIO MANAGEMENT ON SELECTED STOCKS FROM CONSUMER PRODUCTS AND SERVICES, ENERGY, AND HEALTHCARE OF BURSA MALAYSIA SECTORS

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Abstract: Due to the complexity of today's financial market, a study of risks and returns can help investors address the common challenges that they face in choosing high-quality investment goals. Therefore, professional calculation and analysis can effectively evaluate each stock's risk and return. This study investigates the risks and returns of selected stocks from three out of 13 sectors in Bursa Malaysia, as well as analyses and compares the risks and expected returns of portfolio of stocks. To achieve this objective, nine stocks with the highest market capitalization from three sectors in Bursa Malaysia were selected. The adjusted closing prices were collected from Yahoo Finance for six months from 1st April 2023 until 30th September 2023. Excel software is used to calculate specific data, including correlation, covariance matrix, and weight calculations to compute the risk and expected return of the stocks. As a result, five effective investment portfolios were obtained. Hence, the investors can choose a more suitable portfolio according to their risk preferences. In this study, it is believed that this method is useful for investors who are interested to invest in three stocks. However, if investors want to include more than three stocks in their investment strategy, more considerations or adjustments may be necessary. For example, instead of analysis for 6 months only, the data taken can be extended for a longer time frame.

***Keywords*:** Portfolio management, expected return, risk, correlation, covariance matrix, weight

INTRODUCTION

A portfolio is a collection of assets that investors use to invest to make a profit (Dinh, 2021). Meanwhile, portfolio management is a complex process that attempts to make an investment exercise more return and less risky (Vo et al., 2022). Maximizing returns on an investment is something that investors strive for. Nevertheless, the two primary factors affecting an investment decision are risk and expected return. Therefore, choosing high-quality investment goals is typically challenging for investors due to the complexity of today's financial market. On the other hand, professional measurement and analysis can effectively evaluate the risk and the performance of each stock. This study aims to accomplish two objectives such as to investigate the risks and returns of selected stocks from three out of 13 sectors in Bursa Malaysia and to analyze and compare the risks and expected returns of portfolio of stocks. There are many risks and expected return studies conducted. Markowitz (1952) found two important elements that have always been considered in making investment decisions whereby the higher the risk, the higher the return, and vice versa. During the investment process, investors have the opportunity to gain profits or take risks (Lyu, 2021). Nine stocks with the highest market capitalization from three out of 13 sectors in Bursa Malaysia were selected. The adjusted closing prices were collected from Yahoo Finance for six months from 1st April 2023 until 30th September 2023. Excel software is used to calculate the correlation between two stocks, covariance matrix, and weight calculations to compute the risk and expected return of the stocks. As a result, five effective investment portfolios were obtained. Portfolios having stocks with the highest return from each sector has the highest return with a value of 0.06% and is highly recommended for investment.

METHODOLOGY

The study's methodology involves selecting nine stocks with the highest market capitalization from three out of 13 sectors in Bursa Malaysia such as consumer products and services, energy, and healthcare. In addition, the adjusted closing prices for selected stocks were collected from Yahoo! Finance for six months starting from 1st April until 30th September 2023, and aim to calculate the risk and return of stocks. In this context, the calculation of return is by using logarithmic return. Then, the calculation of risk and expected return of a portfolio of stocks is done through statistical measures like the correlation between two stocks, covariance matrix, and weight to compute risk and expected return (Capinski and Zastawniak, 2011). Moreover, it compares portfolios across sectors based on risk and expected return metrics, highlighting the importance of these measures in a portfolio management and investment decision-making.

RESULTS AND DISCUSSION

RESULT 1

From Table 1, VELESTO has the highest average return with a value of 0.16% and TOPGLOV has the lowest average return at -0.16%. Meanwhile, HARTA has the highest standard deviation of 3.22%. In contrast, NESTLE has the lowest standard deviation at 0.51%.

Table 1. Risk and Return of Nine Stocks from Each Sector.

SECTOR	STOCKS	Average return (%)	Standard deviation (%)
Consumer Products and Services	1. Nestle Malaysia Berhad (NESTLE)	-0.06	0.51
	2. PPB Group Bhd (PPB)	-0.04	0.90
	3. Petronas Dagangan Berhad (PETDAG)	0.05	1.44
Energy	4. Dialog Group Berhad (DIALOG)	-0.08	1.65
	5. Hibiscus Petroleum Berhad (HIBISCS)	0.12	1.99
	6. Velesto Energy Berhad (VELESTO)	0.16	2.68
Health Care	7. IHH Healthcare Berhad (IHH)	0.05	0.92
	8. Hartalega Holdings Berhad (HARTA)	0.04	3.22
	9. Top Glove Corporation (TOPGLOV)	-0.16	3.16

RESULT 2

From Table 2, this study investigates five portfolios which are the portfolio management of three selected stocks from consumer products and services sector, the portfolio management of three selected stocks from energy sector, the portfolio management of three selected stocks from healthcare sector, portfolio management with the lowest risk stocks and portfolio management with the highest return stocks. Portfolio 5 has the highest return with a value of 0.06%. While portfolio 1 and portfolio 4 have the lowest negative returns with a value of -0.04%. On the other hand, portfolio 2 has the highest standard deviation at 1.38% and portfolio 1 has the lowest standard deviation at 0.47%. However, the weight for stock 8 (HARTA) with a value -1.17% means the portfolio involves short selling. As the weight of Stock 8 has a negative value, that means Portfolio 3 includes short selling. This means that for the portfolio to have the lowest risk, short selling has to be involved.

Table 2. Expected Return and Risk of Five Different Types of Portfolios.

Portfolio	**Portfolio 1** Sector 1	**Portfolio 2** Sector 2	**Portfolio 3** Sector 3	**Portfolio 4** Lowest-risk stocks from each sector	**Portfolio 5** Highest return stocks from each sector
Stocks	1. NESTLE	4. DIALOG	7. IHH	1. NESTLE	3. PETDAG
	2. PPB	5. HIBISCS	8. HARTA	4. DIALOG	6. VELESTO
	3. PETDAG	6. VELESTO	9. TOPGLOV	7. IHH	7. IHH
Weight (%)	S1 = 27.16 S2 = 8.51 S3 = 64.33	S4 = 53.12 S5 = 32.45 S6 = 14.43	S7 = 90.74 S8 = -1.17 S9 = 10.43	S1 = 77.98 S4 = 4.25 S7 = 17.77	S3 = 27.16 S6 = 8.56 S7 = 64.33
Expected return (%)	-0.04	0.02	0.03	-0.04	0.06
Standard deviation (%)	0.47	1.38	0.87	0.48	0.76

CONCLUSION

We can conclude that portfolio 4 which is the combination of 3 stocks with the lowest risk which consists of SUNWAY, VIROX and CDB is the best performing portfolio, with a reasonable expected return of 0.04% and the lowest level of risk 0.68%. Portfolio 4 is highly recommended if minimizing risk is the primary concern. Portfolio 1 which is from the industrial product and services sector have the highest expected return of 0.10% and the standard deviation of 0.93% which is consider moderate risk for the portfolio. Similarly, portfolio 5 have the highest expected return of 0.10% and the standard deviation of 0.84%. Therefore, those investors aiming for higher returns with moderate risk may find portfolios 1 and 5 are suitable options. Portfolios 2 and 3 are not a suitable option because they have negative expected returns. Hence, by calculating and analyzing each stock effectively, investors can be able to assess its risk and performance. This allows investors to select a portfolio that fits their personal risk preferences. Thus, it is recommended that the study can be further extended by adding more classes of assets. In addition, the data collected is limited from April to September 2023 only. Therefore, the data taken can be extended for a longer time frame instead of analysis for 6 months only.

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FINAL YEAR PROJECT EXHIBITION

A Portfolio Management of Selected Stocks from Consumer Products and Services, Energy, and Healthcare of Bursa Malaysia Sectors

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ABSTRACT

This study investigates the risks and returns of selected stocks from three sectors, as well as analyzes and compares the risks and expected returns of portfolio consisting of these stocks. Excel software is used to calculate specific data, including correlation, covariance matrix, and weight calculations to compute the risk and return of the stocks. Thus, five effective investment portfolios are obtained including a portfolio of three selected stocks from each sector, along with portfolio with the lowest-risk stocks and portfolio with the highest-return stocks.

INTRODUCTION

Portfolio means a collection of assets that investors use to invest in an effort to make a profit (Dinh, 2021). Hence, maximizing returns on investment is something that investors strive for. Nevertheless, the two primary factors affecting an investment decision are risk and expected return. During the investment process, investors have the opportunity to gain profits or take risks (Lyu, 2021). Furthermore, as market conditions change, investment portfolios may change accordingly.

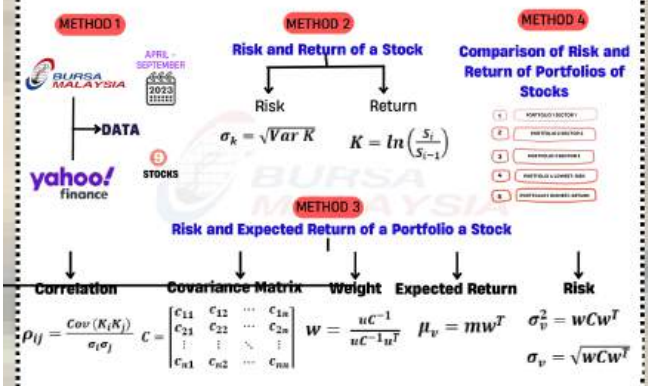
OBJECTIVES

The objectives of this study are: -

- To investigate the risk and return of each selected stock from consumer products and services, energy and healthcare sectors
- To analyse and compare the risk and expected return of a portfolio of stocks.

METHODOLODY

The calculation of risk and return below are referred from Capinski, M., & Zastawniak (2011)



CONCLUSION

In conclusion, this final year project studies portfolio management related to financial markets that play a vital role in balancing returns and minimizing risk. Moreover, this final project studies the risk and return of a portfolio. Thus, this is a study with evidence from the Malaysian market aiming to investigate the risk and return of each selected stock from consumer products and services, energy and healthcare sectors and to analyse and compare the risk and return of stocks in a different type of portfolio.

PROBLEM STATEMENT

Choosing high-quality investment goals is typically challenging for investors due to the complexity of today's financial market. On the other hand, professional measurement and analysis can effectively evaluate the risk and the performance of each stock. Hence, investors can choose a more suitable portfolio suited to their own risk preferences. Thus, this study attempts to provide a guide in determining the risk and return of an investment in stocks.

RESULTS

Table 1 : Risk and return of stocks from three sectors

SECTORS	STOCKS	AVERAGE RETURN %	STANDARD DEVIATION %
CONSUMER PRODUCTS AND SERVICES	NESTLE	-0.06	0.51
	PPB	-0.04	0.90
	PETDAG	0.05	1.44
ENERGY	DIALOG	-0.08	1.65
	HIBISCS	0.12	1.99
	VELESTO	0.16	2.68
HEALTHCARE	IHH	0.05	0.92
	HARTA	0.04	3.22
	TOP GLOV	-0.16	3.16

VELESTO has the highest average return with a value of 0.16% and TOPGLOV has the lowest average return at -0.16%. Meanwhile, HARTA has the highest standard deviation at 3.22%. In contrast, NESTLE has the lowest standard deviation at 0.51%.

Table 2 : Five types of portfolios including a portfolio of comprising of three sectors, portfolio with the lowest-risk stocks and portfolio with the highest-return stocks

PORTFOLIO	PORTFOLIO 1 CONSUMER PRODUCT AND SERVICES	PORTFOLIO 2 ENERGY	PORTFOLIO 3 HEALTHCARE	PORTFOLIO 4 COMBINATION OF STOCKS	PORTFOLIO 5 COMBINATION OF STOCKS
STOCKS	S1. NESTLE	S4. DIALOG	S7. IHH	S1. NESTLE	S3.PETDAG
	S2. PPB	S5. HIBISCS	S8 .HARTA	S4. DIALOG	S6. VELESTO
	S3. PETDAG	S6. VELESTO	S9. TOPGLOV	S7. IHH	S7. IHH
WEIGHT	S1 = 77.37% S2 = 11.23% S3 = 11.40%	S4 = 53.32% S5 = 32.45% S6 = 14.43%	S7 = 90.74% S8 = -1.17% S9 = 10.43%	S1 = 77.98% S4 = 4.25% S7 = 17.77%	S3 = 27.16% S6 = 8.51% S7 = 64.33%
EXPECTED RETURN %	-0.04	0.02	0.03	-0.04	0.06
STANDARD DEVIATION %	0.47	1.38	0.87	0.48	0.76

Portfolio 5 has the highest return with a value of 0.06%. While, Portfolio 1 and 4 have the lowest return at -0.04%. However, Portfolio 2 has the highest standard deviation at 1.38% and Portfolio 1 has the lowest standard deviation with a value of 0.47%.

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ANALYZING FTSE BURSA MALAYSIA KLCI USING MINIMUM SPANNING TREE AND BETWEENNESS CENTRALITY DURING STATE ELECTIONS

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Abstract: This study investigates the impact of the Malaysian state elections held on 12 August 2023, across Selangor, Kelantan, Terengganu, Negeri Sembilan, Kedah, and Penang, on FTSE Bursa Malaysia KLCI. While previous research has established a link between election uncertainty and increased market volatility, this study would like to explore deeper how elections affect stock correlations. Using the methodology of minimum spanning tree (MST) and betweenness centrality, the research constructs financial networks to identify companies that act as mediators. The focus is on the one month before and one month after state elections, aiming to offer investors valuable insight into stock market stability during this politically important period. The study produced a noteworthy finding: RHBC maintained its dominance before and after the elections, but the level of dominance was decreasing. However, this study has the limitation of data since the state election was just held so recently. Thus, to provide more reliable results, we propose that the data period be extended for future research.

***Keywords*:** Financial networks, minimum spanning tree, betweenness centrality, FTSE Bursa Malaysia KLCI, state elections

INTRODUCTION

During state elections, it is difficult to study the complex network of relationships between companies. To navigate this complexity, the construction of financial networks becomes indispensable. By using methods such as minimum spanning tree, it becomes possible to filter out the important connections from the noise. Yee and Salleh (2018) discovered the convincing stock in the market through an examination of stock behaviours. Therefore, drawing inspiration from the work of Yee and Salleh (2018), this study aims to explore how the Malaysian market acts one month before and one month after state elections. The utilization of top 30 largest companies from FTSE Bursa Malaysia KLCI data has been applied to this study and resulted RHBC maintained as the most dominant company before and after the election, but the level of dominance was decreasing. The level of dominancy has been discovered by using the extent of minimum spanning tree, betweenness centrality. Betweenness centrality measures the dominancy of a company by exploring the shortest path between nodes. It evaluates whether a stock plays a role as an intermediate between many stocks. The higher the value of betweenness centrality, the more important is the stock since it controls the flow of information between many nodes.

METHODOLOGY

MINIMUM SPANNING TREE

The first step of constructing minimum spanning tree network is to calculate the correlation matrices, *C*. Let $C = \rho_{ij}$ be the correlation of $N \times N$ matrix, where *N* is the number of stocks. ρ_{ij} is the correlation coefficient between stocks *i* and *j*, calculated using Pearson's correlation coefficient formula,

$$\rho_{ij} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sqrt{\left(\langle r_i^2 \rangle - \langle r_i \rangle^2\right)\left(\langle r_j^2 \rangle - \langle r_j \rangle^2\right)}} \quad (1)$$

where the rate of returns of adjusted closing prices is $r_i(t) = \ln P_i(t+1) - \ln P_i(t)$ and $P_i(t)$ is the price of stock i on date t.

Correlation is measured in the scale 1 to -1. The value of correlation 1 indicates correlation as perfectly correlated and -1 as negatively correlated. The correlation coefficient, ρ_{ij} need to be constructed into distance first to transform the correlation matrix to distance matrix. The distance between two stocks i and j can be computed by using the equation,

$$d_{ij} = \sqrt{2\left(1 - C_{ij}\right)} \quad (2)$$

where d_{ij} should satisfy the three basic properties of Euclidean matrix which are,

$$\begin{cases} d_{ij} \geq 0, \\ d_{ij} = d_{ji} \\ d_{ij} \leq d_{ik} + d_{kj} \end{cases} \quad (3)$$

Lastly, to construct the minimum spanning tree financial network, Kruskal's algorithm must be applied. Firstly, two vertices of the two stocks with the smallest distance will connect to an edge. Then, the next edges are added to the spanning in ascending order until all vertices are connected. The vertices will be ignored if its connection forms a cycle. The vertices and edges represent the stocks and the distance between two stocks respectively.

BETWEENNESS CENTRALITY

The betweenness centrality can be evaluated using the following equation (4)

$$C_{Betweenness}(i) = \sum_{j<k} \frac{g_{jk}(i)}{g_{jk}}, \quad i \neq k \neq j \quad (4)$$

where g_{jk} is the total number of shortest path from node j to k and $g_{jk}(i)$ is the number of paths that pass through i.

RESULTS AND DISCUSSION

Based on Figure 1 and Figure 2, RHBC continues to play an important role during both times, but following the election, its centrality value drops from 0.7365 to 0.6108. In addition, following the state election, there are 13 instead of 14, a decrease in the number of companies with zero values, which indicates less mediating effect. This suggests a shift in the dynamics of the network, with no change in the overall connection structure following the state elections and RHBC remaining significant but playing a less mediating role.

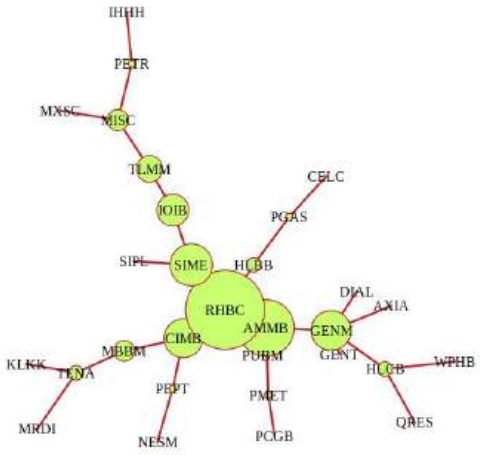

Figure 1. Before state elections.

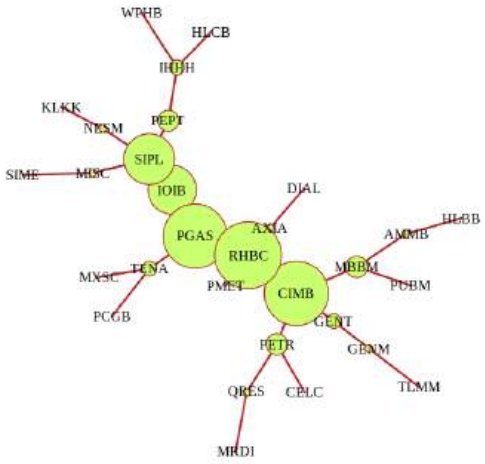

Figure 2. After state elections.

CONCLUSIONS

To sum up, this research offers an in-depth study of the stock prices of the FTSE Bursa Malaysia KLCI one month before and one month after state elections. This study employs innovative methods like minimum spanning tree (MST) and betweenness centrality to understand the complex relationship between companies and state elections. Constructing financial networks offer an alternative viewpoint on the interdependence of companies included in the FTSE Bursa Malaysia KLCI. This provides investors, traders, and market participants important information on creating their strategies for investing during the intensity of the state election.

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A STUDY ON

FTSE BURSA MALAYSIA KLCI USING MINIMUM SPANNING TREE AND BETWEENNESS CENTRALITY DURING STATE ELECTIONS

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1 ABSTRACT

This study investigates the stock price dynamics of the FTSE Bursa Malaysia KLCI in the months before and after the state elections, using the minimum spanning tree (MST) and betweenness centrality approach. The main objective is to **build financial networks** that include companies listed in the FTSE Bursa Malaysia KLCI. In doing so, this study aims to shed light on the complex **relationships** among these companies and their susceptibility to **changes in the political and economic landscape during Malaysian state election periods.**

2 INTRODUCTION

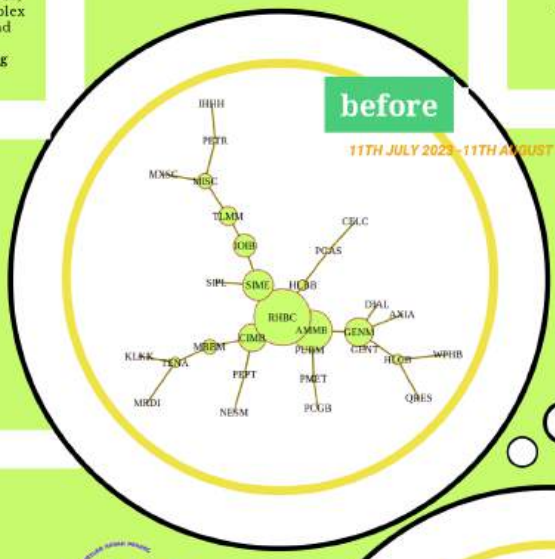
- Difficult to study complex networks during state elections.
- Construct a MINIMUM SPANNING TREE to illustrate

3 PROBLEM STATEMENT

- Focus should shift toward understanding how state elections impact stock correlations.
- Uncertain relationship between stocks before and after state elections

4 OBJECTIVES

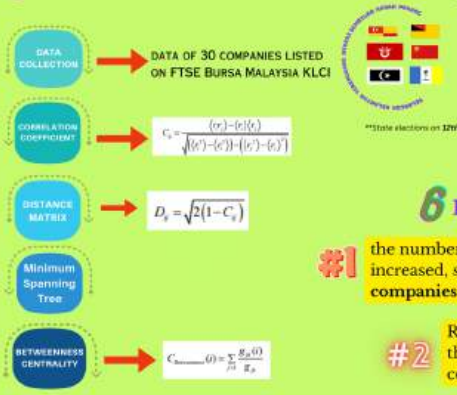
- To construct financial networks of the companies for FTSE Bursa Malaysia.
- To identify the companies that act as mediators for the financial network.



OUTCOME:

- The result indicates structural changes in the stock market due to state elections.
- Help investors, offering valuable insights to estimate stoxk market stability.

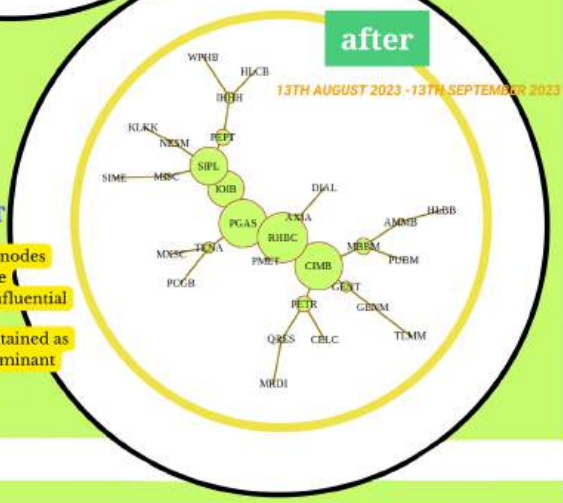
5 METHODOLOGY



6 RESULT

#1 the number of bigger nodes increased, shows **more companies** become influential

#2 RHBC maintained as the most dominant company



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MULTIPLE LINEAR REGRESSION OF CTS STUDENTS' PERFORMANCE IN INTRODUCTION TO STATISTICS (SMS 2309) COURSE

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Abstract: This study aims to investigate students' performance enrolled in the Introduction to Statistics (SMS 2309) course in the Computational and Theoretical Sciences (CTS). There is still an ongoing issue with statistical reasoning becoming increasingly essential. The goal of this research is to determine the factors that contribute to the performance of CTS students in subject SMS 2309 in terms of their Continuous Assessment Marks (CAM). R software is used in the study along with survey distribution and Multiple Linear Regression. According to the results, there is a substantial association; the F-statistic is below 0.05, at 0.0048. This emphasizes how important the components that have been found are in students' performance. For future research, it is recommended to add more variables, increase the sample size, allocate sufficient time, and explore data from different institutions. In conclusion, these suggestions guide future researchers in enhancing this study, contributing to a holistic understanding of factors influencing students' performance in statistics education.

***Keywords*:** Students' performance, multiple linear regression, R software

INTRODUCTION

Statistics anxiety, characterized by fear when exposed to statistical information or problems, poses a persistent challenge for students in higher education, hindering their performance in statistical courses (Onwuegbuzie and Wilson, 2003; Macher et al., 2011). Despite the growing importance of statistical reasoning, students often grapple with apprehension in statistical education settings (Garfield, 1995; Onwuegbuzie, 2004; Zeidner, 1991). This study addresses the ongoing issue of students' statistical performance, focusing on the Continuous Assessment Marks (CAM) of students from the CTS Department in the Introduction to Statistics (SMS 2309) course. The methodology employed in this study involves the utilization of Multiple Linear Regression (MLR), a powerful statistical tool, to explore the factors influencing CTS students' academic success in SMS 2309. MLR enables researchers to predict outcomes based on multiple variables, allowing for a more accurate understanding of the influencing factors (Pandis, 2016). The analysis will delve into CAM performance, aiming to identify elements that correlate with success in SMS 2309.

The objective of this study is to determine the factors contributing to the performance of CTS students in SMS 2309, specifically focusing on CAM. By doing so, the research aims to shed light on the relationship between these factors and academic success in the Introduction to Statistics course. This exploration is crucial for devising strategies to alleviate statistics anxiety and enhance the learning experience for students in the CTS Department.

METHODOLOGY

This study employs a non-experimental and explanatory research design to develop a predictive model for students' performance in the Introduction to Statistics course (SMS 2309) using Multiple Linear Regression (MLR). The research encompasses four key steps: research design, sample selection, data collection, and data analysis. The non-experimental approach involves utilizing stepwise regression to systematically evaluate the relationship between independent factors (gender, attendance percentage, previous statistics subject score during SPM level, and students' perception) and the dependent variable, which is the students' Continuous Assessment Marks (CAM) in SMS 2309.

The sample comprises students from the CTS Department at IIUM Kuantan Campus who have taken the Introduction to Statistics course. Surveys were administered to collect data on 18 variables, including gender, attendance percentage, previous statistics subject score during SPM level, and various aspects of students' perceptions. The collected data were analyzed using the MLR model in R software, aiming to predict students' performance in SMS 2309 based on the identified parameters. Model evaluation involves assessing R-squared and Adjusted R-squared to measure the explanatory power of the model. Residual analysis is conducted to ensure the model's fit to the data, considering normality, independence, and the presence of outliers.

RESULTS AND DISCUSSION

MULTIPLE LINEAR REGRESSION MODEL

The Multiple Linear Regression model can be stated as follows:

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \epsilon_i \quad (1)$$

where β_0, β_1, β_2, …, β_n are parameters, X_1, X_2, …, X_n are known constant, ϵ_i are independent $N(\mu, \sigma^2)$ and i = 1, …, n. The estimated regression function from this analysis can be written as

$$\hat{Y} = 27.160 + 4.072X_5 + 1.920X_{10} - 3.934\,X_{17} + \epsilon_i \quad (2)$$

The hypothesis statement for Partial F-test are:

$H_0 : \beta_1 = \beta_2 = \ldots = \beta_k = 0$ (no linear relationship)
H_1 : at least one $\beta_i \neq 0$ (at least one independent variable affects Y)

Table below shows that only attendance percentage, X_5, learning and teaching methods encouraged participation, X_{10}, submission on assessment was timely, X_{17}, and feedback on assessment was helpful, X_{18} are statistically significant. The small standard error values give a precision estimation.

Table 1. Coefficients of performance of students (Y) and significant predictor variables (X).

	Estimate	Standard Error	t Stat	p-value	VIF
Intercept	27.15963	7.255786	3.743168	0.000357	
X_5	4.07174	1.627025	2.502568	0.014537	1.117599
X_{10}	1.91996	1.120600	1.713335	0.090838	2.292567
X_{17}	-3.93437	1.486451	-2.64682	0.009922	3.561194

REGRESSION MODEL ASSUMPTION CHECKING

After obtaining the estimation model, we ensured the validation of model assumptions prior to proceeding with further analysis. To assess the normality assumption, we conducted the Shapiro-Wilk test.

The hypothesis statement as follows:

H_0 : The residual is normally distributed
H_1 : The residual is not normally distributed

Table 2. Shapiro-Wilk Normality Test.

Shapiro-Wilk Normality Test	
W	0.9799
P-value	0.2507

For our dataset, the results of the Shapiro-Wilk test indicated a p-value of 0.2507. As this p-value is above the significance level of 0.05, we do not reject the null hypothesis. Therefore, there is insufficient evidence to conclude that the residuals deviate significantly from a normal distribution.

CONCLUSIONS

The results, highlighted by a significant F-statistic of 0.004848017 (less than 0.05), underscore the relevance of our investigation. It became evident that certain factors play a crucial role in determining students' Continuous Assessment Marks (CAM) in SMS 2309. It shows a strong connection between how well students perform in Introduction to Statistics (SMS 2309) with several factors: (1) attendance percentage, X_5, (2) learning and teaching methods, X_{10}, (3) students' perception about submission on assessment was timely, X_{17} and (4) students' opinions about the feedback on assessment was helpful, X_{18}. This study is valuable for everyone involved in education because it gives a deeper understanding of how different student factors are related. The insights from this research can serve as a useful framework for improving student achievement in the subject of Introduction to Statistics for CTS students' in IIUM Kuantan Campus, benefiting both students and the higher institution's top management.

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MULTIPLE LINEAR REGRESSION ON CTS STUDENTS' PERFORMANCE IN INTRODUCTION TO STATISTICS (SMS2309) COURSE

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ABSTRACT

This study explores factors influencing the performance of Computational and Theoretical Sciences students in Introduction to Statistics at IIUM. It employs Multiple Linear Regression, a widely used method for predicting students' academic performance, to establish a strong prediction model using R software. The findings contribute valuable insights and recommendations for enhancing the teaching and learning environment.

INTRODUCTION

This research is aim to figure out the most influenced factor that affect the students performance in Introduction to Statistics (SMS2309). In this research, we had established a variety of factors, ranging from students themselves, learning materials, curricular and classroom settings which have led to the performance of students in SMS2309. In order to analyze the factor, this study have done the multiple linear regression via R software and others method to obtain the best result.

PROBLEM STATEMENT

The issue of the quality of students' statistical performance is still an ongoing issue in scholarly investigations of statistics education. In general, this body of research contrasts the expanding importance of statistical reasoning in higher education with the continuing apprehension that university students have when taking statistical courses. Therefore, this study will delve into the performance of students, specifically those from the CTS Department, in the subject Introduction to Statistics (SMS2309)

OBJECTIVE

The objective of this study is:
To determine the factors that contribute to the performance of CTS students in subject SMS 2309 in terms of their continuous assessment mark.

METHODOLOGY

- **Multiple Linear Regression model :**

$$Y=\beta_0 + \beta_i\beta_{i1} + \beta_i\beta_{i2} + \ldots + \beta_{p-1}\beta_{i,p-1} + \varepsilon_i$$

- **Variance Inflation Factor**

$$VIF_i = \frac{1}{1-R^2_i}$$

- **Stepwise Regression**
  - Partial F-test :

$$SSR\left(X_j \mid all\ variables\ except\ X_j\right) = SSR(all\ variables) - SSR\left(all\ variables\ except\ X_j\right)$$

- **Shapiro-Wilk Normality test :**

H_0 : The residual is normally distributed

H_1 : The residual is not normally distributed

RESULT

- **MULTIPLE LINEAR REGRESSION MODEL :**

$$Y=27.160 + 4.072X_5 + 1.920X_{10} - 3.934X_{17} + 3.568X_{18}$$

- **THE VIF VALUES :**

	F	K	R	S
VIF	1.117599	2.292567	3.561194	3.393620

- **THE REGRESSION OUTPUT FROM EXCEL :**

Regression Statistics	
Multiple R	0.424921689
R Square	0.180558442
Adjusted R Square	0.136264303
Standard Error	5.589481564
Observations	79

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	509.4184	127.3546	4.076351	0.004848017
Residual	74	2311.931	31.2423		
Total	78	2821.349			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	27.15963099	7.255786	3.743168	0.000357	12.702161	41.6171
F	4.071740247	1.627025	2.502568	0.014537	0.829822267	7.313658
K	1.919962902	1.1206	1.713335	0.090838	-0.3128806	4.152806
R	-3.934367053	1.486451	-2.64682	0.009922	-6.89618455	-0.97255
S	3.567521749	1.431751	2.491719	0.014953	0.714695581	6.420348

- **THE SHAPIRO-WILK NORMALITY TEST :**

W	0.97999
P-value	0.2507

CONCLUSION

In conclusion, from the VIF values, it can assume that no serious multicollinearity exist as the VIF values are less than 5. Next, the regression analysis shows it is statistically significant in predicting the dependent variable, based on the low p-value in the ANOVA table from Excel. Moreover, based on the Shapiro-Wilk test results, this research do not have strong evidence to reject the null hypothesis. Therefore, with this information, this study is expected to contribute to helping the department to distinguish the factors in order to have excellent students in statistics.

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CLASSIFYING PLATONIC SOLID INTO THEIR ALGEBRAIC GROUP

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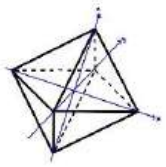
Abstract: Platonic solids are solids that occur when combining all similar 2-dimensional polygon to form a solid. This solid was first time mentioned by Plato. Thus these solids were named after him. In Euclid 13th book, Elements, he successfully determined the exact number of solids that qualify to be Platonic Solids which are tetrahedron, cube, octahedron, dodecahedron and icosahedron. In group theory, the symmetry group of an object is the group of all transformations under which the object remains unchanged. In this project, the goals are to identify the groups, up to isomorphism, that isomorphic to the symmetry group of platonic solids. By using Group theory and defining their symmetries, it is possible to show and classifying into their respective algebraic group. And number of rotational symmetries that can be made by each solid is isomorphic with certain symmetric group, S_n and alternating group, A_n. By studying transformation of a geometry that make the system invariant, it can help physicist develop more theory on finding symmetry of higher dimensional system.

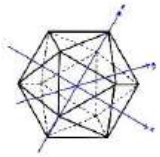
***Keywords*:** Group theory, Symmetric group

INTRODUCTION

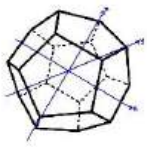
Platonic Solid is a three-dimensional geometry solid where all of their surfaces have the same shape of polygons, and then we added all the 2-Dimensional polygon to construct a three-dimensional structure. There are five solids that belong to Platonic solid which are are Tetrahedron, Cube, Octahedron, Icosahedron and Dodecahedron. The existence of platonic solid already proven by Euclid in his 13^{th} book, *Elements*.



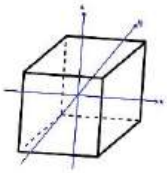
Octahedron



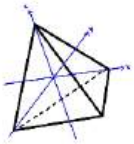
Icosahedron



Dodecahedron



Cube



Tetrahedron

Heather (1956) explore and recount Euclid's *Elements* to show the truthiness of Euclid's work. Foster (1990) proposed of a theorem that group of symmetry G of dodecahedron isomorph with A_5 and also equal with icosahedron. Morandi (2004) also already show that symmetric group of all platonic solid are isomorphic with algebraic group such as A_4, S_4 and A_5 by using Maple software. In this research, methods that will be using are Group theory and rotational symmetry. Then, both will be combined to find and list all the possible permutation of the solid. By the end of the research, it can be found that each solid has their own respective algebraic group.

METHODOLOGY

I. Group theory
Group theory will be used to find the permutations when the solid rotate. In group theory, symmetric group has been introduced by mathematician to study set of finite elements. By knowing the number of elements inside the set, permutations that can be made by the elements inside the set is $n!$ where n can be any positive integers.

II. Reflectional symmetry
To find the platonic solid's algebraic group, it can be shown by finding total rotation that can be made by the solid. Rotation that can be made by the solid while preserving its original structure are when we rotating the solid by making an axis through opposite faces, opposite edges and opposite vertices. To show how the elements can be permuted, each solids can be labelled as f_n for faces and v_n for vertices where *n* is the number of faces and vertices in the respective solid.

III. Combining group theory and reflectional symmetry
By combining both methods, the rotation that can be made by each solids will be proven by group theory. The aim of rotational symmetry is to make sure the solid preserve its original structure when rotating the solid by specific angle and the rotation depends on the axis of rotation. Because different axis will determine its order of permutation.

RESULTS AND DISCUSSION

Table 1.

Platonic solid	Faces	Edges	Vertices	Total rotational symmetry	Algebraic Group
Tetrahedron	8	3	-	12	A_4
Cube	9	6	8	24	S_4
Octahedron	8	6	9	24	S_4
Icosahedron	20	15	24	60	A_5
Dodecahedron	24	15	20	60	A_5

By applying the method, it can be proven that both Heather (1976) and Morandi (2004) works were true. By making an axis through opposite vertices, edges and faces, the summation of all the rotations of each solids are isomorphic with any their correspondence algebraic group. For tetrahedron, when making an axis from vertices to it opposite edges, it will be having 8 rotations and by opposite edges, 3 rotations that preserve its original shape. By summating all the rotation and include its identity, total rotational symmetry that can be made by the solid is 12 and has the same value as alternating group of order 4, A_4.

For a cube, total rotation that can be made by opposite faces, edges and vertices are 9, 6 and 8 respectively. For octahedron, rotation that can be made on each respective opposite faces, edges and vertices and 8, 6 and 9. Total rotational symemtry of each solid are 24 and have the same number of permutation as symmetric group of order 4, S_4 which is 24 as well. For dodecaedron and icosahedron, from Foster (1990) finding, both of the solids are belong to A_5 where the solids will be having 60 total rotational symmetry. By summating all the rotational symmetry, dodecahedron will have 24 rotations on opposite faces, 15 rotations on opposite edges and 20 rotation on opposite vertices. Icosahedron also have the same rotation by opposide edges which are 15 rotations but for opposite faces and opposite vertices will be have 20 and 24 rotations respectively. Both of the solids have 60 rotational symemtries that can be made and it prove Foster's work.

CONCLUSIONS

From the result, it can be shown that all the platonic solids have its own and correspondence to an algebraic group. For tetrahedron, it is isomorphic with A_4,cube and octahedron isomorphic with S_4 and dodecahedron and icosahedron are isomorph with A_5. All the rotation that can be made must preserve the shape original structure and the rotation will having the vertices of each solids commute with each other. By combining both methods, it is possible to show and find all the solids respective algebraic group. Also, it is possible to find all the permutation that can be made by the solids as the stronger proof that the solid is rotating and preserve its original structure. To list all the permutations of vertices are hard because of considering all the possible permutation and permutation might be different depends on point of view of the axis. Group theory is a tool that can be used to study geometry when the structure exists in symmetric form. It is also possible to study the symmetry of higher dimensional mathematical structure and mathematicians can have more abstract idea to understand them.

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TITLE : CLASSIFYING PLATONIC SOLID INTO THEIR ALGEBRAIC GROUP

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ABSTRACT

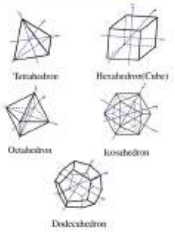
Platonic solids are solids that occur when combining all similar 2-dimensional polygon to form a solid. This solid was first time mentioned by Plato in his dialogue, Timaeus. Thus these solids named after him. In Euclid 13th book, Elements, he successfully determined the exact number of solids that qualify to be Platonic solids which are tetrahedron, cube, octahedron, dodecahedron and icosahedron. In group theory, the symmetry group of an object is the group of all transformations under which the object remains unchanged. We want to identify the groups, up to isomorphism, that isomorphic to the symmetry group of platonic solids. Hence, this research focuses on studying the properties and symmetries of platonic solids by applying group theory and using symmetric group properties.

Introduction

Euclid proved the existence of Platonic solids in his 13th book, *Elements*. Since the emergence of modern mathematics, tons of advanced and interesting mathematical tools can be used to study the properties of geometrical structures. Since Platonic solids hold the value of uniqueness due to their symmetry nature, it is believed that they can be studied through Group theory. By using Group theory, we want show the symmetry of the Platonic solid through permutation of solid's vertices and classify them according to their symmetric group.

Problem Statement

Platonic solid is a three – dimensional structure. Platonic solid is a special form of solid because there are only five solid that belong to platonic solid. All of their faces consists of same polygons. Hence, this research focus on studying the properties and symmetries of Platonic solid because of their uniqueness. We want to identify the groups, up to isomorphism, that isomorphic to symmetry group of platonic solid.



Objectives

In this project, we would like to :
1. Investigate the symmetries of the platonic solid.
2. Identify the groups, up to isomorphism, that isomorphic to symmetry group of platonic solid.

Result

Platonic solid	Faces	Edges	Vertices	Total rotational symmetry	Algebraic Group
Tetrahedron	8	3	-	12	A_4
Cube	9	6	8	24	S_4
Octahedron	8	6	9	24	S_4
Icosahedron	20	15	24	60	A_5
Dodecahedron	24	15	20	60	A_5

Table above show all the rotational symmetry of platonic solid and their correspondent algebraic group

Methodology

1. Representing permutation elements
First, represent all the solids with labelling all their edges as e_n, vertices as v_n and faces as f_n.
Then put every vertices, v_n, to their respective faces. For tetrahedron, octahedron and icosahedron, $f_n = [v_i, v_j, v_k]$, for cube, $f_n = [v_i, v_j, v_k, v_l]$ and for dodecahedron is $f_n = [v_i, v_j, v_k, v_l, v_n]$.
2. Symmetrical Rotation
Find all possible transformation that preserve the original structure by making an axis through 2 opposite vertices, edges and faces, and show how all vertices of the solid permute with each other.
The transformation can be shown by rotating the solid by $\frac{\pi}{2}, \frac{\pi}{3}, \frac{\pi}{4}$ *and* $\frac{\pi}{5}$ depends on the solid. All the symmetries will form a group.
3. Classifying into an algebraic group
For every product of the transformation, it can be labelled as g_n, where $g_n \in G$, G is the all possible permutation and $g_n = \{v_1, v_2, v_3, \dots, v_n\}$. We let $g_1 = I$ where I is the identity and also equals to f_n. Then after collect all the permutation that occur, total symmetries of solids will isomorph to an algebraic group.

Conclusion

To conclude, we can show that Platonic solid is symmetrical by using Group theory through finding their respective rotational symmetries. Then, it is also possible to find their correlate algebra group. For tetrahedron, it's isomorph to A_4. Hexahedron(Cube) and octahedron isomorph with S_4. Dodecahedron and Icosahedron isomorph with A_5.

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A STUDY ON VARIATIONAL ANALYSIS: THE DISCRETE SYSTEM IN CUBIC-QUINTIC NON-LINEAR SCHRÖDINGER EQUATION

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Abstract: A system that experiences sudden state changes at specific times is said to be discrete. The majority of systems that are studied in operations research and management science, such as transportation or communication studies, are under the application of discrete systems. This study investigates the analytical study of the static soliton for Cubic-Quintic Discrete Nonlinear Schrödinger Equation (DNLSE) in discrete system. Subsequently, static soliton, that is often used to characterize specific self-action regime in a continuous one-dimensional problem, is defined as a self-reinforcing wave packet that keeps its form and velocity while it travels in a medium. Moreover, it is well-known that the NLSE is a known integrable equation of partial differential equation. Therefore, the variational approximation method is applied to convert partial differential equations into ordinary differential equations, thus, to derive the equations for soliton parameters evolution during the interaction process. The method is used for qualitative study of Discrete NLSE and classify self-action modes. The diffraction of narrow (in grating scale) wave beams weakens in discrete media is demonstrated, leading to the "collapse" of the one-dimensional wave field with power exceeding the critical value. As a result, the central fiber gains the ability to self-channel radiation.

***Keywords*:** Discrete stationary soliton, cubic-quintic nonlinear Schrödinger equation, variational approximation method, wave scattering process

INTRODUCTION

The Nonlinear Schrödinger Equation (NLSE) is a partial differential equation that governs the dynamics of certain wave phenomena in many physical systems, and it exhibits a strong connection with wave particles, especially soliton wave. Soliton is a class of solitary wave solutions that can manifest in diverse nonlinear partial differential equations (Litvak et al., 2018). Additionally, static soliton is type of soliton that remains stationary in space and time. It is a localized, stable solution of a nonlinear wave equation that does not propagate or change shape over time. Static solitons can be found in a variety of physical systems, including optics, fluid dynamics, and quantum physics.

The Discrete Nonlinear Schrödinger Equation (DNLSE) is an extension form of the NLSE in the discrete system. It is a fundamental equation within the framework of the nonlinear lattice dynamics model. In order to solve the DNLSE problem, the Variational Approximation (VA) method is utilized to study the propagation of the solitons. It works by reducing the Partial Differential Equation to an Ordinary Differential Equation which explains the scattering process of solitons solution. The main equation for this research, the cubic-quintic DNLSE is employed for a set of evenly spaced lossless light guides in the form:

$$\frac{i\partial\psi_n}{\partial_z}+\psi_{n+1}+\psi_{n-1}+\left|\psi_n\right|^2\psi_n+\left|\psi_n\right|^4\psi_n=0 \tag{1}$$

where the first term indicates the soliton propagation, second and third term are the vector dispersion. Then, the last two terms describe the nonlinearity of the soliton (Balakin et al., 2016). As the main equation go through the procedure of VA method, two coupled equations are obtained in which characterize the soliton behaviour in discrete system. With different value of power, the numerical simulation will describe the self-action structures of wave beams such as periodic variations in beam width during propagation, collapse, and stationary soliton.

METHODOLOGY

In 1983, Anderson employed a VA method that utilized trial functions to illustrate the fundamental features of pulse development as determined by the nonlinear Schrödinger equation. This method can describe the primary features of the pulse evolution as found by the NLSE since it gives explicit mathematical equations for the pulse compression or decompression factor, the maximum pulse amplitude, and the induced frequency chirp. Nevertheless, the values will still be approximate but with high accuracy (Anderson, 1983).

Referring to Umarov et al., (2013), the selection of the trial function which also the first step of the approach is crucial to the effectiveness of the VA method. By substituting the chosen trial function into Lagrangian density, we calculate the effective Lagrangian with spatial integration of the Lagrangian density. Then, the average Lagrangian is obtained by solving Euler-Lagrangian equations in order to obtain the equation for the parameters. As a result, the two coupled equation of width and center of mass positions are then interpreted into numerical simulation in order to observe the scattering process of the discrete solitons in self-action mode.

RESULTS AND DISCUSSION

In the context of solving discrete soliton, it is important to employ the variational approach to provide an approximate depiction of the evolution of the wave-field. Throughout the VA method, the soliton scattering mechanism is described by two coupled equations for width and centre of mass position.

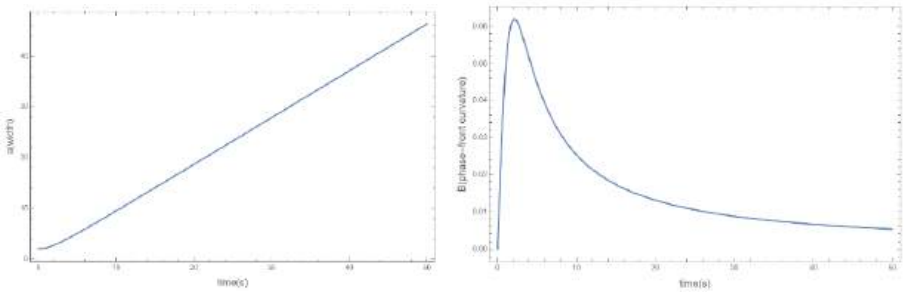
$$\frac{\partial a}{\partial z} = 4\beta a\, \mathrm{e}^{-\frac{1}{4a^2}-\beta^2 a^2} \tag{2}$$

$$\frac{\partial \beta}{\partial z} = \frac{-P}{2\sqrt{2\pi}a^3} - \frac{2P^2}{3\sqrt{3}a^4\pi} + \frac{1-4\beta^2a^4}{2a^2}\frac{2}{a^2}\exp\left(-\frac{1}{4a^2}-\beta^2a^2\right) \tag{3}$$

Then, by setting the $\beta = 0$ and $\frac{d\beta}{dz} = 0$, the power of the wave beam propagation, *P* is acquired

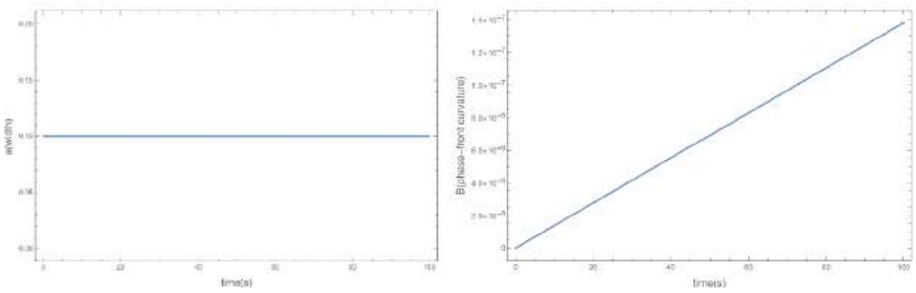
$$P = \frac{1}{8}\left(-3a\sqrt{\frac{3\pi}{2}} + \sqrt{9a^2 + 64\sqrt{3}\mathrm{e}^{-\frac{1}{4a^2}-a^2}}\sqrt{\frac{3\pi}{2}}\right). \tag{4}$$

The power is a key parameter in understanding the behavior of the wave beam, particularly in relation to phenomena such as self-action, collapse, and self-focusing. With the different values of *P*, the numerical simulation of coupled equation *a* and β , elaborate the scattering process of static soliton wave in discrete cubic-quintic NLSE.



a) b)

Figure 1. a) the spreading out of the soliton as it propagates through a medium when $a = 2$ and $P = 0.04257$. b) the collapsing of the wave in which the soliton's wavefront curvature decreases with increasing time when the power exceeding the critical value.



a) b)

Figure 2. a) The width of a soliton is unchanged with time when $a = 0.1$ and $P = 6.8931 \times 10^{-10}$.

b) The soliton's wave front curvature is increasing as the time passes.

CONCLUSIONS

The research developed a variational analysis for qualitative study, specifically on the discrete soliton in the cubic-quintic NLSE and classify self-action mode. The behaviour of the scattering process of discrete soliton waves in the static DNLSE is successfully analysed using the VA method. The process involves an analytical examination, a numerical analysis of the parameters obtained, and an investigation of the outcomes of the VA method. It is found that the collapsing of the wave in which the soliton's wavefront curvature decreases with increasing time when the power exceeding the critical value. The width *a*, of the soliton is increasing when $P = 0.04257$ and constant when $P = 6.8931 \times 10^{-10}$.

Nonlinear waves and discrete solitons have found diverse and innovative applications, from physics to engineering. Moreover, discrete solitons have been exploited in innovative research aimed at creating metamaterials with electromagnetic wave modification capabilities. Advanced technologies including lenses, cloaking devices, and other optical devices with special qualities are built on upon these materials. Researchers are also looking into the possibilities of nonlinear waves in energy transport and storage systems. This includes developing materials and technologies that use solitons for extremely efficient energy transmission and storage, notably in superconductors and waveguides.

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A STUDY ON VARIATIONAL ANALYSIS:

THE DISCRETE SYSTEM IN CUBIC-QUINTIC NON-LINEAR SCHRÖDINGER EQUATION

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ABSTRACT

- The study focuses on analysis of discrete solitons for Cubic-Quintic Nonlinear Schrodinger Equation (NLSE).
- To convert partial differential equations into ordinary differential equations, the variational approximation approach is employed.
- The approach classifies self-action modes and qualitatively studies discrete NLSE.
- The weakening of narrow wave beam diffraction in discrete media causes the one-dimensional wave field to "collapse" with power over the critical threshold.

INTRODUCTION

- Solitons are independent wave packets that maintain their shape and amplitude during propagation due to vector dispersion and the nonlinearity effect. This phenomena can be explained through NLSE below.

$$i\psi_t + \frac{1}{2}\psi_{xx} + F(|\psi|^2)\psi = 0$$

soliton propagation — vector dispersion — nonlinearity

$$i\frac{\partial \psi_n}{\partial_z} + \psi_{n+1} + \psi_{n-1} + |\psi_n|^2\psi_n + |\psi_n|^4\psi_n = 0$$

- This work is studying the soliton scattering in Discrete Cubic-Quintic Nonlinear Schrödinger Equation.
- A system that experiences sudden state changes at specific times is said to be discrete.
- The majority of systems in operations research & management science, such as transportation or communication studies, are under the application of discrete systems.

OBJECTIVE

1. To provide closed form approximation for the Cubic Quintic DNLSE using Variational approximation method.
2. To investigate the behavior of the discrete soliton of Cubic Quintic DNLSE in self-action modes with different value of powers.

CONCLUSION

The study focus on the soliton scattering of Discrete Cubic-Quintic Nonlinear Schrödinger Equation in self-action mode. The closed form of the ODE from discrete cubic quintic NLSE is described using Variational Approximation method. The results obtain are the coupled equation of the width and center of mass position of the soliton. With different value of power, the numerical simulation will describe the self-action structures of wave beams such as periodic variations in beam width during propagation, collapse, and stationary soliton.

PROBLEM STATEMENT

The NLSE is typically considered a non-integrable equation, leading to the absence of an analytical solution. The utilization of the Variational Approximation (VA) method is motivated by the need to convert partial differential equations into ordinary differential equations. Hence, the equation can be analytically solved to characterize the behaviors of solitons.

METHODOLOGY: VARIATIONAL APPROXIMATION METHOD

1. Choose an appropriate trial function with time dependent parameters.
2. Substitute the chosen ansatz into Lagrangian-density of the equation.
3. Calculate the effective Lagrangian with spatial integration of the Lagrangian density.
4. Get the average Lagrangian and use it to solve Euler-Lagrangian equations in order to obtain the equation for the parameters.
5. Two coupled equations for the width and center of mass position are obtained to describe the soliton scattering process.

ANALYTICAL RESULT

Applying Poisson's formula for summation to a continuous argument function F(x)

$$\sum_{n=-\infty}^{\infty} F(n) = \int_{-\infty}^{\infty} F(x) \sum_{n=-\infty}^{\infty} \exp(2\pi i n x)dx,$$

transform Lagrangian into a form which is more convenient for the approach

$$L = \sum_{n=-\infty}^{\infty} \int_{-\infty}^{\infty} [\frac{i}{2}(\psi\frac{\partial\psi^*}{\partial z} - \psi^*\frac{\partial\psi}{\partial z}) - \psi(x+1)\psi^* - \psi^*(x+1)\psi - \frac{1}{2}|\psi_n|^4 - \frac{1}{3}|\psi_n|^6]$$

Integrating the Lagrangian, result obtain

$$L = \frac{d\beta}{dz}Pa^2\sum_{n=-\infty}^{\infty}(1-2\pi^2n^2a^2)e^{-\pi^2n^2a^2} - 2P\sqrt{\pi}e^{\frac{1}{4a^2}-\beta^2a^2}\sum_{n=-\infty}^{\infty}\cos\pi n\, e^{-\pi^2n^2a^2-2\pi n\beta a^2} - \sqrt{\frac{\pi}{2}}\frac{P^2}{2a^2}\sum_{n=-\infty}^{\infty}e^{-\pi^2n^2a^2/2} - \frac{P^3}{3\sqrt{3a^2\pi}}\sum_{n=-\infty}^{\infty}e^{-\pi^2n^2a^2/3}$$

in order to describe the processes, n = 0. So the result,

$$L_z = \frac{d\beta}{dz}\frac{Pa^2}{2} - 2P\exp\left(-\frac{1}{4a^2} - \beta^2a^2\right) - \frac{Pa^2}{2}\sqrt{\frac{1}{2\pi}} - \frac{P^3}{3\sqrt{3a^2\pi}}$$

Using the Euler equation

$$\frac{d}{dz}\frac{\partial\mathcal{L}_c}{\partial q_z} - \frac{\partial\mathcal{L}_c}{\partial q} = 0$$

where q is the parameter of the (a,β) system, the ODE of the a and β are obtained. Resulting to two coupled equation where a(z) and β(z) characterize the wave-packet width and phase-front curvature.

$$\frac{\partial a}{\partial z} = 4\beta a\, e^{-\frac{1}{4a^2}-\beta^2a^2}$$

$$\frac{\partial\beta}{\partial z} = \frac{-P}{2\sqrt{2\pi}a^3} - \frac{2P^2}{3\sqrt{3}a^4\pi} + \frac{1-4\beta^2a^4}{2a^3}\frac{2}{a^3}\exp\left(-\frac{1}{4a^2} - \beta^2a^2\right)$$

In the case of a collimated wave beam, β = 0 and dβ/dz = 0,

$$P = \frac{2\sqrt{2\pi}}{a}\exp\left(\frac{-1}{4a^2}\right)$$

with different value of P, the numerical simulation of coupled equation a and z, will show the scattering process of soliton in discrete cubic quintic NLSE.

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e ISBN 978-629-97106-2-2