General Solution of m x n Rectangular Games

Submitted in partial fulfilment of the requirements of the degree

BACHELOR OF ENGINEERING

IN

Artificial Intelligence and Data Science

By

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(AY 2023-24)

CERTIFICATE

This is to certify that the Mini Project entitled **“General Solution of m x n Rectangular Games”** is a bona fide work of

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submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **“Bachelor of Engineering”** in **“Artificial Intelligence and Data Science Engineering” .**

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Supervisor

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Principal

Mini Project Approval

This Mini Project entitled "**General Solution of m x n Rectangular Games**" by

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is approved for the degree of **Bachelor of Engineering** in **"Artificial Intelligence and Data Science Engineering"**

Examiners

1……………………………………….
(Internal Examiner Name & Sign)

2……………………………………….
(External Examiner name & Sign)

Date:

Place:

Contents

Acknowledgement

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Chapter 1

Introduction

This chapter explains the aim, objectives and scope of the proposed system.

1.1 Introduction

Our topic **General Solution of m x n Rectangular Games** is an integration of DSA, Game Theory and OOPs with Python. We use an amalgamation of concepts from both the subjects to perform arithmetic operations such as matrix manipulation, subtraction, addition & multiplication.

1.2 Motivation

Game theory is a powerful tool for modeling strategic interactions among rational decision-makers. In many real-world scenarios, players face complex decision-making processes, especially in competitive environments. One common problem in game theory is the challenge of finding Nash equilibria.
The procedure we've developed addresses a specific instance of this problem. In this scenario, two players engage in a sequential selection process, where Player A's choices affect Player B's choices, and vice versa.

1.3 Problem Statement & Objectives

- **Problem Statement:** General Solution of m x n Rectangular Games.
- **Objectives:**
    1. The goal is to model and analyze the selection process as players aim to minimize their cumulative loss while making sequential choices.
    2. Design and implement an algorithm for sequential decision-making.
    3. Identify and analyze Nash equilibria, considering Probability Distributions, within the problem context.
    4. Contribute to the field of game theory with a computational framework.

1.4 Organization of the Report

This report consists of three chapters. The first chapter deals with introduction of the topic, problem statement, motivation behind the topic and objectives. The second chapter is the Literature Survey. It includes all the research work done related to this topic. All information related to study of existing systems as well as learning of new tools is mentioned in this chapter. The third chapter is about the proposed system which is used in this project. The block diagram, techniques used, software used screenshots of the project are presented in this chapter. All the documents related to development of this project are mentioned in Reference

Chapter 2

Literature Survey

This chapter explains the concepts used in this project, study of existing system and contribution of this project

2.1 Survey of Existing System

Existing systems or solutions typically refer to established methods and approaches that have been developed in the field of game theory and applied to rectangular games. Here are some of the existing systems and methods that are relevant to this topic:

1. **Nash Equilibrium:**
   One of the fundamental concepts in game theory, Nash equilibrium, is widely applied to rectangular games. Existing systems involve methods to find Nash equilibria, which are points where no player has an incentive to unilaterally deviate from their strategey.
2. **Lemke-Howson Algorithm:**
   The Lemke-Howson algorithm is a specialized algorithm for finding Nash equilibria in non-degenerate two-player games. It can be an integral part of existing systems for solving rectangular games.
3. **Best Response Dynamics:**
   Best Response Dynamics is a dynamic process where players iteratively update their strategies to reach an equilibrium. It's used to explore how players converge to equilibrium and can be a part of the existing systems for game analysis.

2.2 Limitation of existing system

1. **Computational Complexity:** Many methods are computationally intensive, making them impractical for large or complex games, leading to longer solution times.
2. **Specific Game Types:** Existing systems may be tailored to specific game types, limiting their applicability to diverse scenarios.
3. **Common Knowledge:** Assumptions of common knowledge may not hold in all scenarios, limiting the applicability of existing systems.
4. **Multiple Equilibria**: Games with multiple equilibria may lack guidance on selecting the most relevant one.
5. **Real-World Data:** Integrating real-world data and behavioral observations into analysis can be challenging for existing systems.

2.3 Mini Project Contribution

Their project presents a structured methodology for analyzing rectangular games in game theory. It commences with the initialization of variables and matrices, streamlining data representation. The project establishes a logical framework for player strategy logic, facilitating a systematic approach to decision alternation. Within the core loop, losses are computed and matrices are updated iteratively, aiding in the identification of Nash equilibria. Their innovative secondary loop introduces extended logic, enhancing equilibrium calculations. Ultimately, the project presents Nash equilibria, making results accessible and contributing to the field by delivering a well-structured and comprehensive methodology for solving rectangular games.

Chapter 3

Proposed System

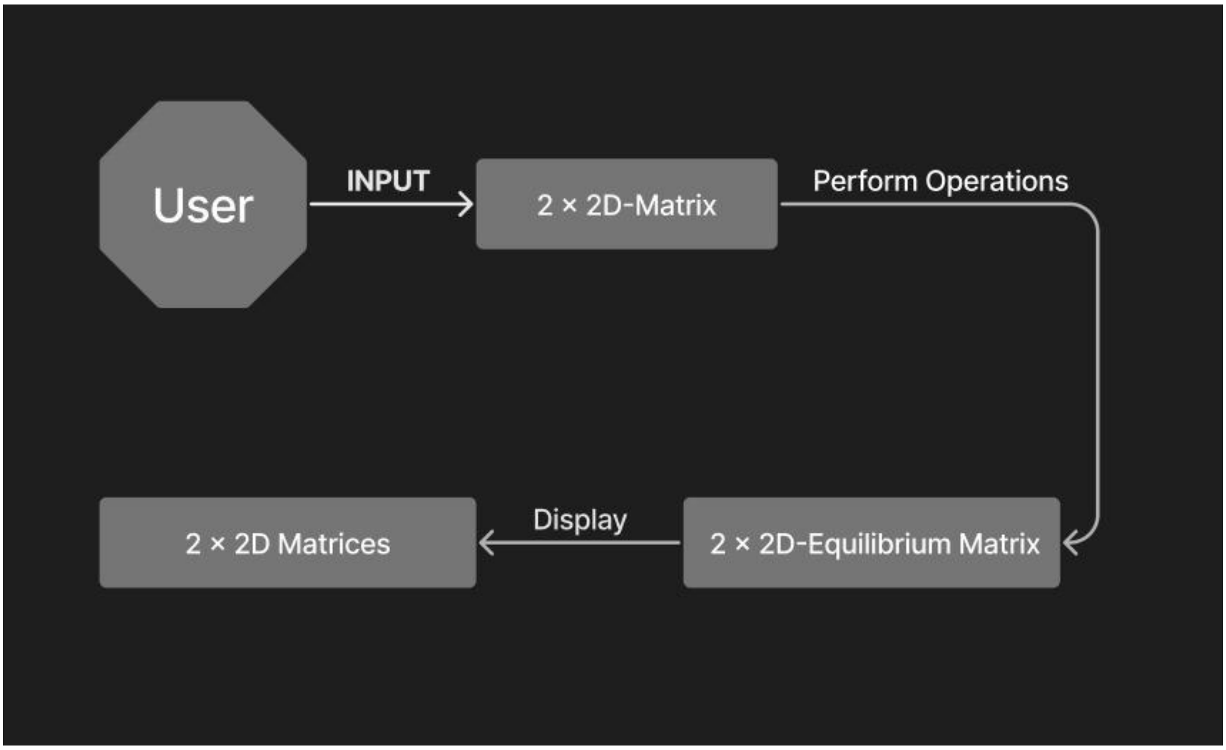
This chapter consists of detailed description about the methodology used, the hardware and software components, the tools used and also the screenshots of the project

3.1 Introduction

The programming language we have used is Python. Python is an object-oriented programming language that emphasizes the creation of classes, objects, and methods for structured program execution. This approach enables the development of clean and organized code by encapsulating data and functionality within objects.

In our project on the "General Solution of m x n Rectangular Games," we extensively apply matrix manipulation and probability distribution concepts. Matrix manipulation plays a pivotal role in structuring the game, involving operations on the payoff matrix and strategy matrices. Meanwhile, probability distribution is central to modeling mixed strategies, where players make decisions based on probability distributions over available choices. This approach enhances the realism of player interactions and contributes to accurate Nash equilibrium calculations. By integrating these concepts, our project offers a comprehensive and systematic framework for analyzing rectangular games, enabling more realistic representations of strategic decision-making processes.

3.2 Architecture



- Here, we take input from the user in form of a 2D matrix.
- Perform certain operation while alternating between the 2 matrices.
- After finding Nash Equilibria, storing the probability distribution in 2 x 2D matrices.
- Then displaying the outputs in the form of 2 x 2D matrices.

3.3 Algorithm and Process Design

1. Formulating the Problem statement:
   By reading our problem statement we can understand that we have to use matrices to store input (payoff matrix) and display outputs (probability distributions) using game theory algorithms.
2. Understanding the framework and requirements:

   The framework goes as follows:

   - Taking the Payoff matrices of 2 players as input from the user.
   - Converting the players strategies into matrices and alternating between the 2 players to calculate loss.
   - Updating the probability distribution matrices of both players.
   - Iterating until Nash equilibria is found.
   - Developed GUI to show user the output i.e. the probability distribution matrix of both the players.
3. Identifying tools/technology to be used:

   Tools that were used to create the solution:

   - Python programming language
   - Visual Studio Code editor(VS code).
4. Finalizing the features to be included:
   - Matrix Manipulation
   - Addition\Subtraction
   - Probability Distribution
5. Development:

   We were able to develop an algorithm taking inspiration from Lemke-Howson Algorithm and Best Response Dynamic Algorithm that helps find the Nash equilibria of 3 x 3 game for 2 players.
6. Testing:

   Tested against various matrices of order 3 x 3 .
7. Evaluation:

   We were able to successfully implement our problem statement.

3.4 Details of Hardware & Software

RAM → 16GB DDR5

GPU → 4GB Nvidia RTX3050

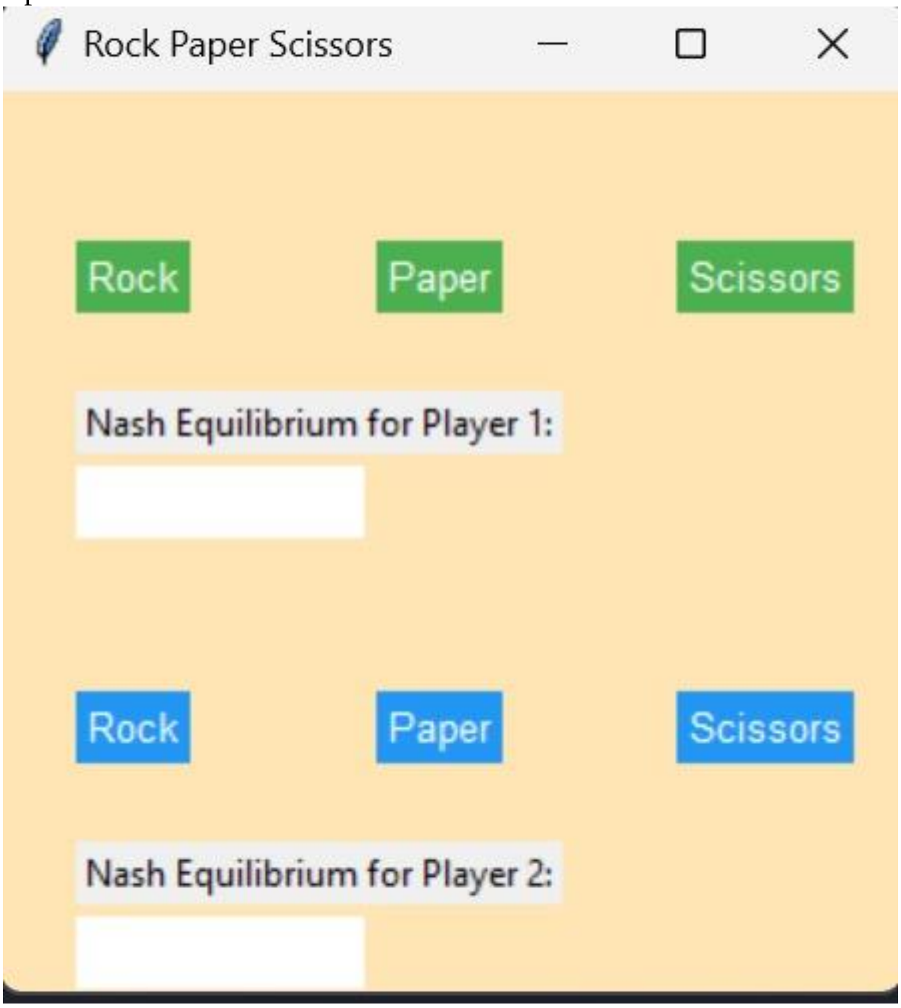
OS → Microsoft 11

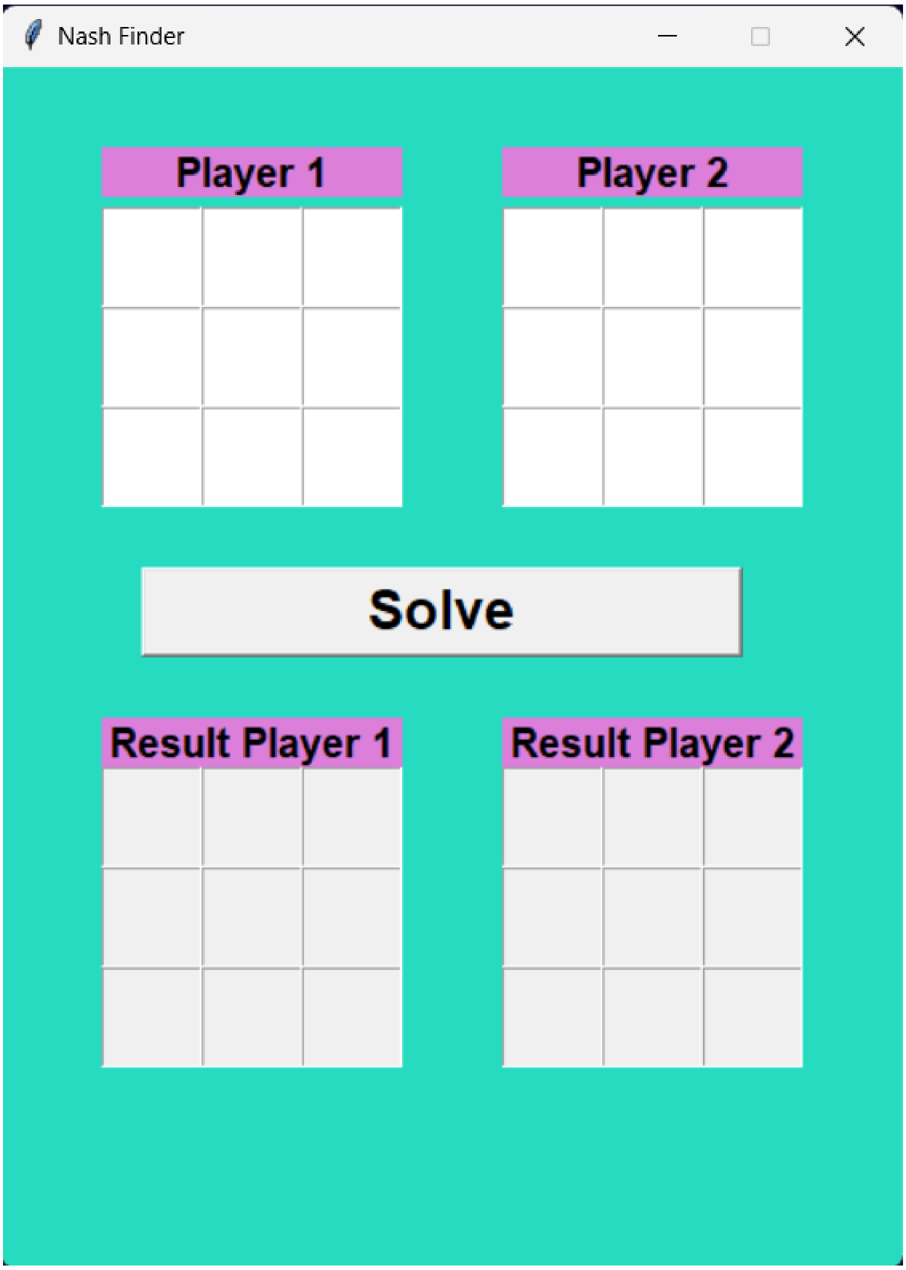
Processor → Ryzen 7 5600H

Memory → 512GB SSD

3.5 Results

Here we take in the two polynomials as input from the user and display it to the user to see if the input is correct or not.





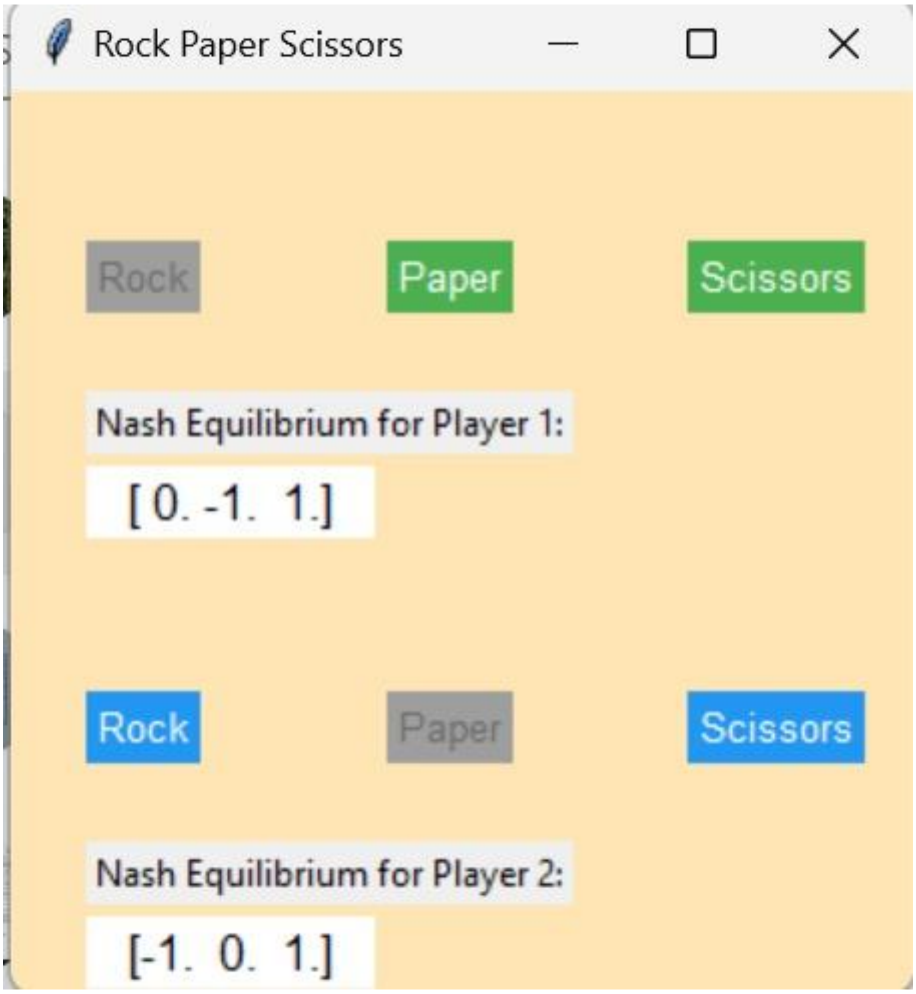
Following Iterations occur as we approach Nash Equillibria:

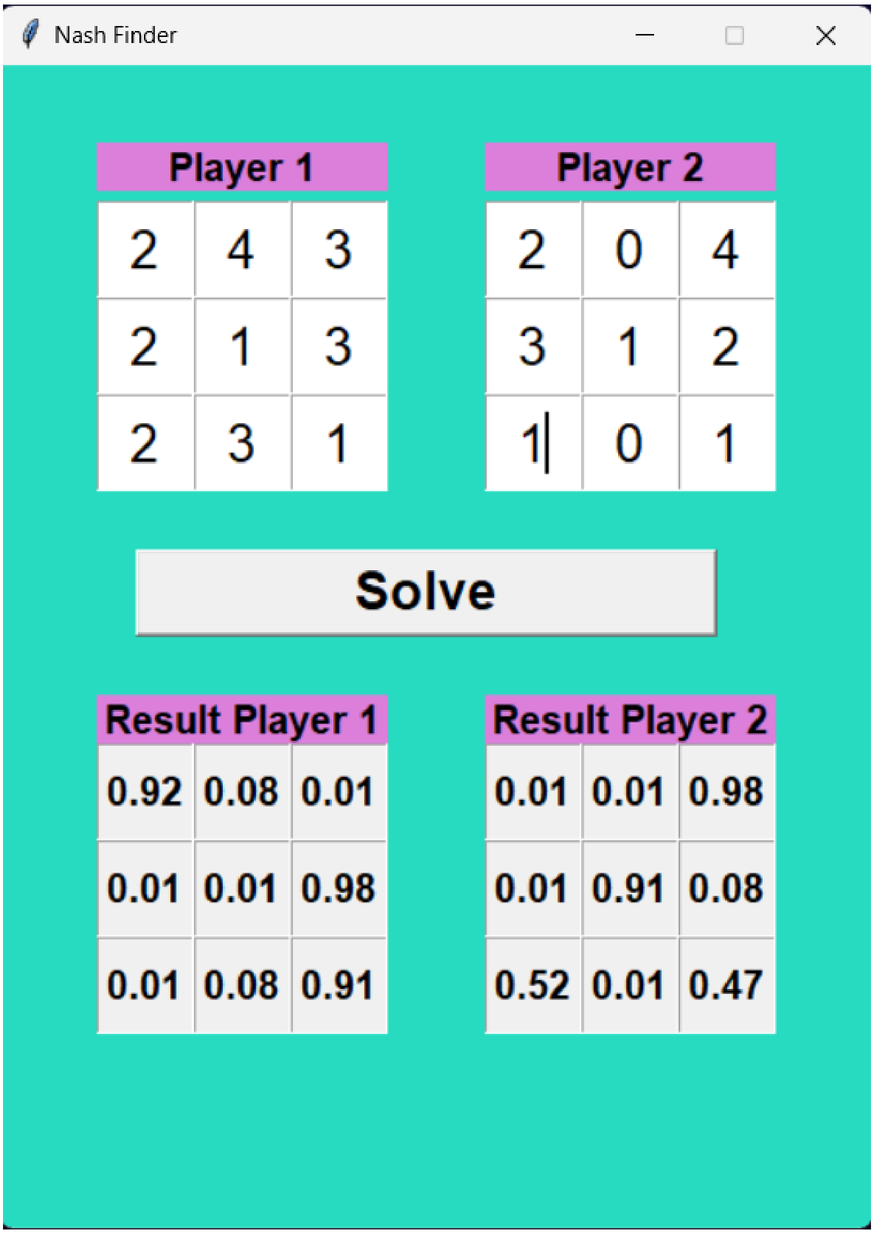
```
Player 1 plays:2.0
Player 2 plays:0.0
Player 1 plays:0.0
Player 2 plays:2.0
Player 1 plays:-1.0
Player 2 plays:2.0
Player 1 plays:0.0
Player 2 plays:1.0
Player 1 plays:-1.0
Player 2 plays:3.0
Player 1 plays:2.0
Player 2 plays:-1.0
Player 1 plays:2.0
Player 2 plays:2.0
Player 1 plays:3.0
Player 2 plays:3.0
Player 1 plays:3.0
Player 2 plays:3.0
Player 1 plays:1.0
```

Following selection ratio was formed on the basis of loss calculation for each player:

```
Player 1:
1.0 1.0 4.0
1.0 4.0 1.0
2.0 1.0 3.0
Player 2:
2.0 4.0 0.0
3.0 2.0 1.0
4.0 1.0 1.0
```

Finally, we get the probability distribution of both the players:


Rock Paper Scissors
Rock
Paper
Scissors
Nash Equilibrium for Player 1:
[0. -1. 1.]
Rock
Paper
Scissors
Nash Equilibrium for Player 2:
[-1. 0. 1.]



3.6 Conclusion and Future Work

Hence, we implemented an algorithm to find the general solution of m x n rectangular games.

Next, we will try to implement the same for orders other than 3 x 3 and explore deeper into the concepts of Game theory.

Reference

Material Type	**Name**	**Link**
Online Document	Operation Research by Hamdy .A. Taha	http://zalamsyah.staff.unja.ac.id/wp-content/uploads/sites/286/2019/11/9-Operations-Research-An-Introduction-10th-Ed.-Hamdy-A-Taha.pdf
Online Document	MS&E246 by Ramesh Johari	https://web.stanford.edu/~rjohari/teaching/notes/246_lecture3_2007.pdf
Youtube video	1. Game theory 101: Best Responses 2. Game Theory 101: Mixed Strategy Nash equilibria	https://www.youtube.com/watch?v=VuDutyTs_r8 https://www.youtube.com/watch?v=fvEQujUcPv4&t=347s