Paper Code: COMP717
Assignment 1
Due Tuesday, 29 April 2025

Name ....James.....Dunlop..... **ID number....21155697.....**

Instructions:

Please attach this sheet to the front of your assignment.

- This assignment contributes 35% towards your final grade. The total mark is 100.
- This assignment has two parts. Part 1 has base problems; Part 2 has a choice of two options A and B. You **can team up with 1-2 other students** to complete this assignment. If you work as a team, all students should sign this page, and provide a brief note on their contributions to the assignment. **• We encourage you to explore and utilize the capabilities of AI tools like ChatGPT as valuable resources in your learning journey. These tools can be powerful aids when used thoughtfully and ethically. No Full Answer Generation: You must not use AI to generate complete answers or substantial portions of your assignments. Transparency and Attribution: You are required to clearly state in your submission where and how you have used AI tools. Be specific about the prompts you used and the output you received. Critical Evaluation: It is essential to critically evaluate the information provided by AI tools. Remember that AI can sometimes produce inaccurate, biased, or misleading information. Always verify the information with reliable sources. Focus on Learning: The goal of using AI is to enhance your learning, not to replace it.**

  Check Canvas on more details on AI usage policy.
- Submit an electronic copy through Canvas before 11:59 p.m. on Tuesday, 29 April 2025. The submission requirement is specified at the end of each option.

The School of Computer and Mathematical Sciences regards any act of cheating including plagiarism, unauthorised collaboration and theft of another student's work most seriously. Any such act will result in a mark of zero being given for this part of the assessment and may lead to disciplinary action.

Please sign to signify that you understand what this means, and that the assignment is your own work.

Signature: .....JD.....

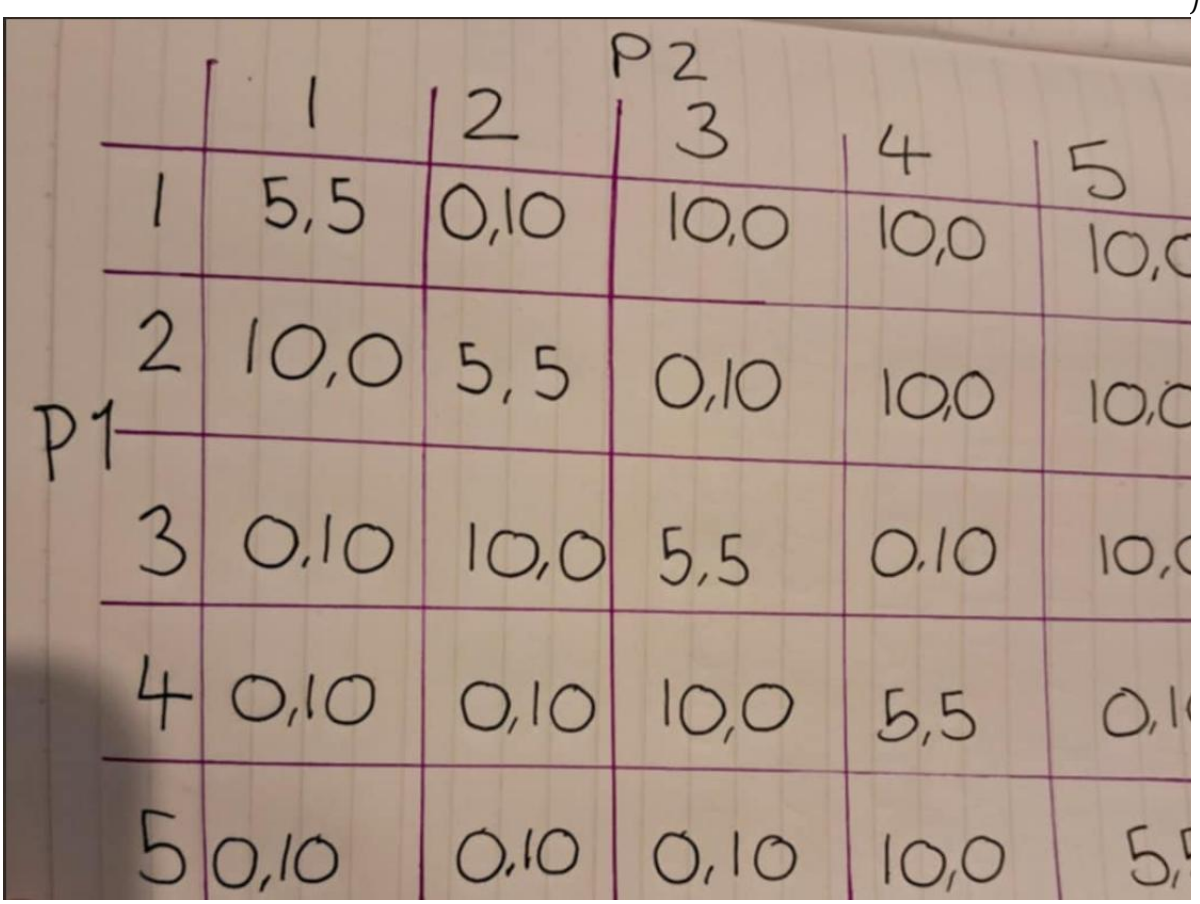
Part 1 Base Problems - 30 Marks

This part contains the set of base problems.

Question 1. *Normal Form Game (15 marks) Here is a* **simplified version** *of the game "Win marks if U can!".*

- *There are two players.*
- *Each player names (chooses) an integer between 1 and 5.*
- *The player who names the integer closest to two thirds of the average gets a reward of 10, the other players get nothing. (E.g., if player 1 names 3 and player 2 names 5, the average is 4 and 2/3 of that is 8/3 which is closer to 3, hence player 1 gets 10 and player 2 gets 0.) • If there is a tie (i.e., choosing the same number), each player gets reward of 5.*

(a) Represent this game in Normal Form. *(5 marks)*



P1 \ P2	1	2	3	4	5
1	5,5	0,10	10,0	10,0	10,0
2	10,0	5,5	0,10	10,0	10,0
3	0,10	10,0	5,5	0,10	10,0
4	0,10	0,10	10,0	5,5	0,1
5	0,10	0,10	0,10	10,0	5,5

(6 marks)

(b) Answer the following questions

- *When player 2 chooses 4, what are the best responses for player 1?*
  - The best responses for player 1 is 2 & 3
- *When player 1 chooses 3, what are the best responses for player 2?*
  - the best responses for player 2 is 2 & 4

- *When player 2 chooses 2, what are the best responses for player 1?*
    - the best responses for player 1 is 1 & 3

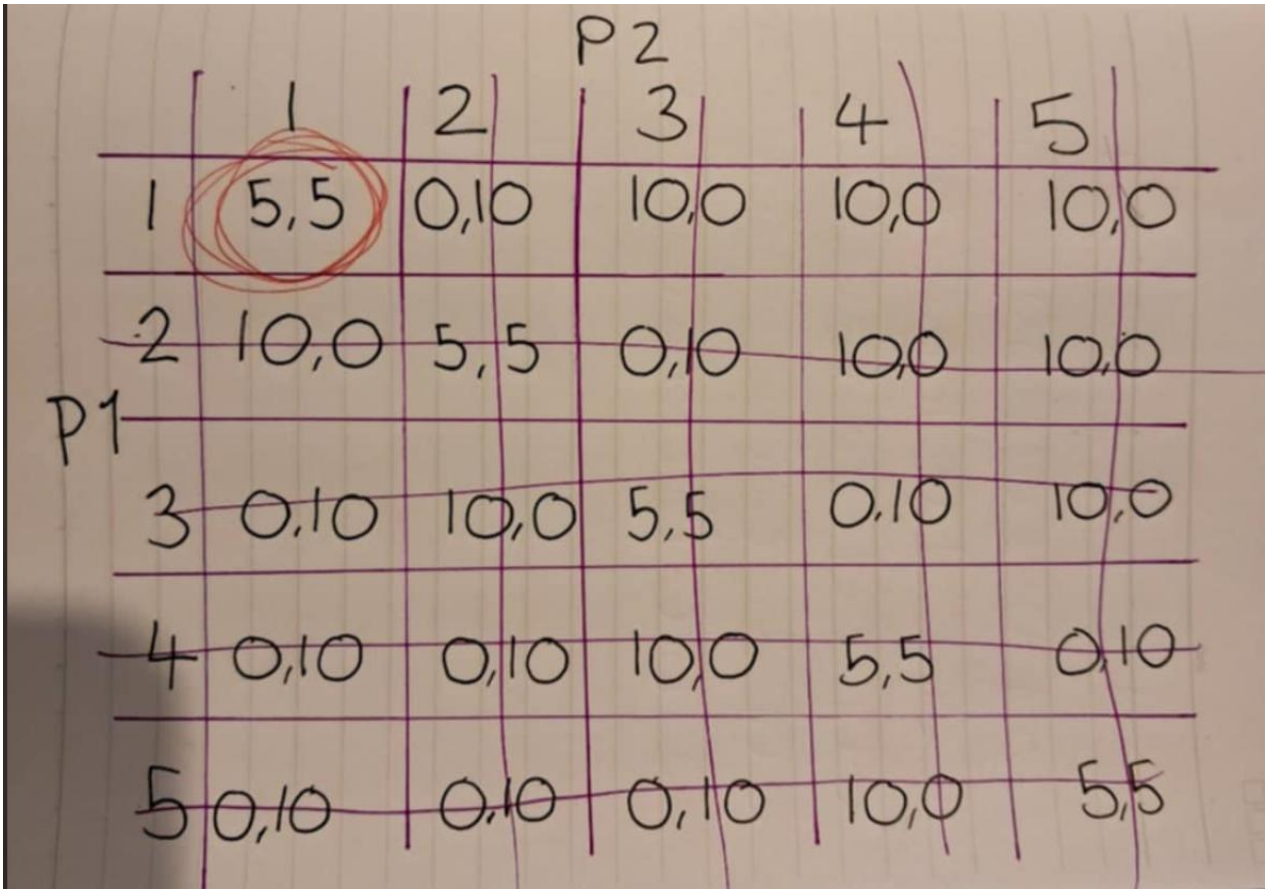
- *When player 1 chooses 1, what are the best responses for player 2?*
    - the best responses for player 2 is 1

- *For player 1, is the strategy of choosing 4 strictly or very weakly dominated by another strategy? If so, which ones?*
    - Choosing 4 is weakly dominated as because choosing 2 is more strictly dominant.

- *For player 2, is the strategy of choosing 1 strictly or very weakly dominated by another strategy? If so, which ones?*
    - *1 is strictly dominant as it has more dominant rows except 2.*

(c) What is the Nash equilibrium of this game? *(4 marks)*

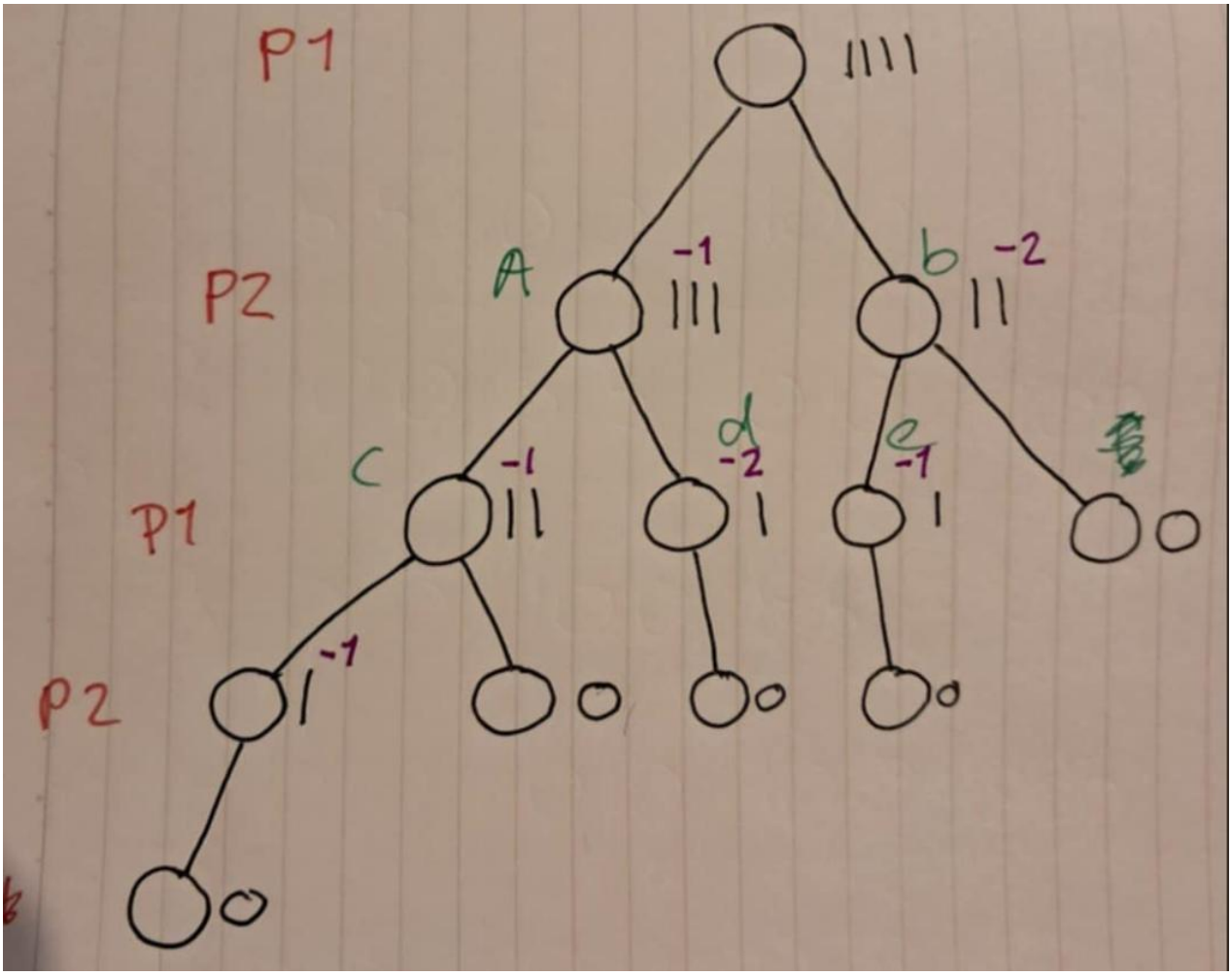
Find this out by applying the concept of dominated strategies to rule out a succession of inferior strategies until only one choice remains.



Question 2. *Extensive Form Game (15 marks) Consider a variant of the* **Take-away game** *discussed in the lecture:*

- *There is a pile of 4 chips on the table.*
- *Two players take turns to remove 1 or 2 chips from the table, with player 1 starting first.*
- *The player removing the last chip(s) wins the game, and get a reward of 1; and the opponent gets a reward of -1.*

(a) Represent this game in Extensive Form. (Note that players have more than 1 decision node and a strategy is a selection of an action at each decision node. If some node has just 1 action, then that action will be chosen as part of the strategy.) (4 marks)



(b) List all the pure strategies of the two players. (4 marks)

Note that you may first find the number of decision nodes for each player, and label the nodes in an order.

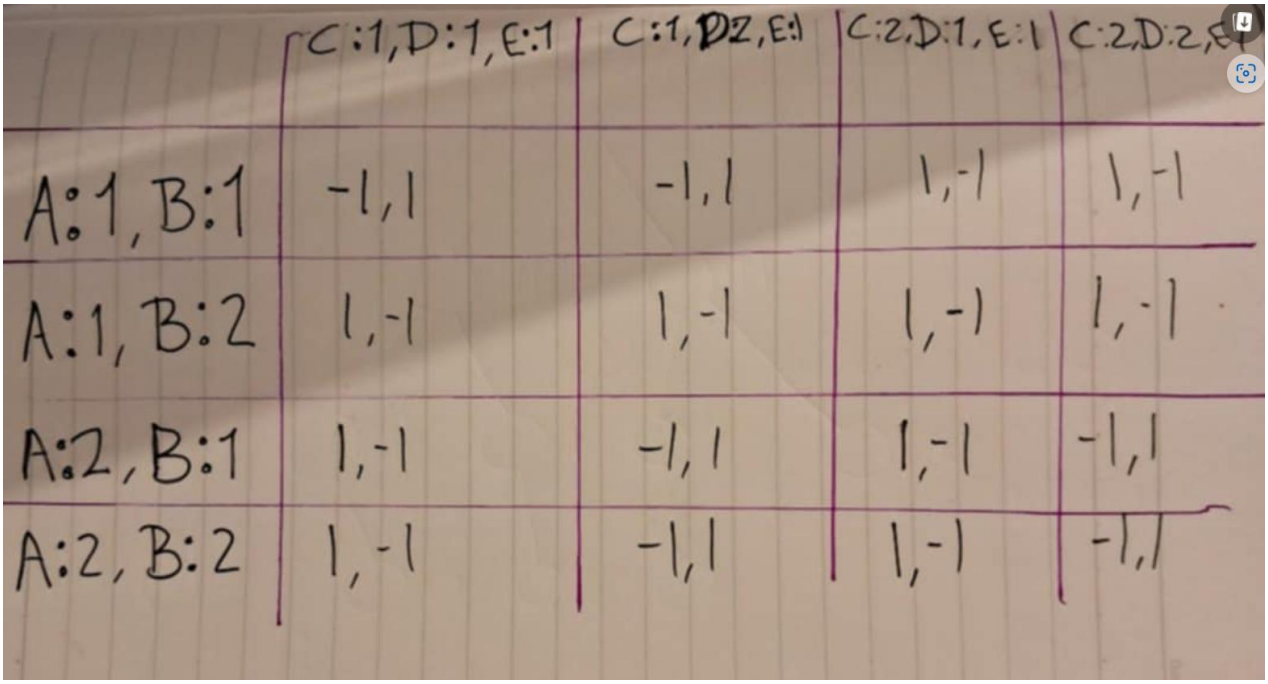
Player 1

- 1) A:Take 1, B:Take 1
- 2) A: Take 1, B Take 2

- 3) A: Take 2, B:Take 1
- 4) ATake 2, B: Take 2
-

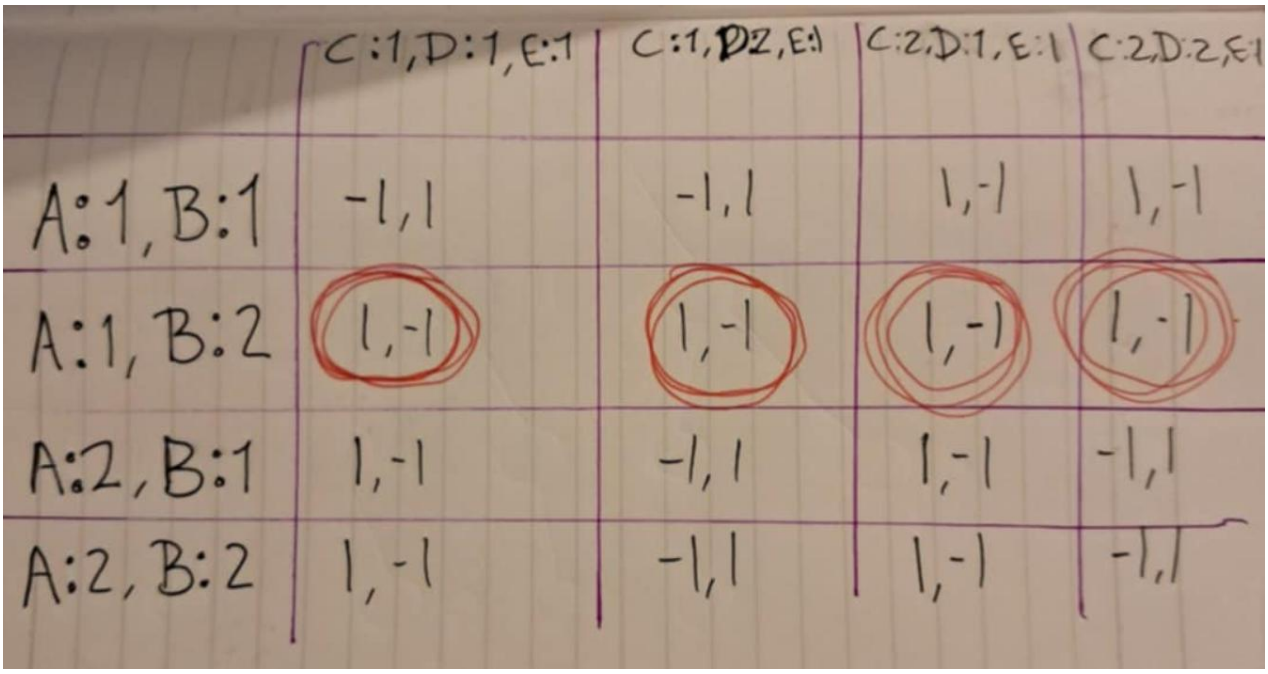
  Player 2
- 1) C: Take 1, D: Take 1, E: Take 1
- 2) C: Take 1, D: Take 2, E: Take 1
- 3) C: Take 2, D: Take 1, E: Take 1
- 4) C: Take 2, D: Take 2, E: Take 1
-

(c) *Represent this game in normal form.* *(3 marks)*
(Each row or column is a pure strategy for the respective player).



	C:1, D:1, E:1	C:1, D:2, E:1	C:2, D:1, E:1	C:2, D:2, E:1
A:1, B:1	-1, 1	-1, 1	1, -1	1, -1
A:1, B:2	1, -1	1, -1	1, -1	1, -1
A:2, B:1	1, -1	-1, 1	1, -1	-1, 1
A:2, B:2	1, -1	-1, 1	1, -1	-1, 1

(d) *Find all of the pure strategy Nash Equilibria of this game in the normal form.* *(4 marks)*
Indicate if an equilibrium is subgame perfect.



	C:1,D:1,E:1	C:1,D:2,E:1	C:2,D:1,E:1	C:2,D:2,E:1
A:1,B:1	-1,1	-1,1	1,-1	1,-1
A:1,B:2	1,-1	1,-1	1,-1	1,-1
A:2,B:1	1,-1	-1,1	1,-1	-1,1
A:2,B:2	1,-1	-1,1	1,-1	-1,1

Pure strategy

- A:1,B:2 vs C:1,D:1,E:1
- A:1,B:2 vs C:1,D:2,E:1
- A:1,B:2 vs C:2,D:1,E:1
- A:1,B:2 vs C:2,D:2,E:1

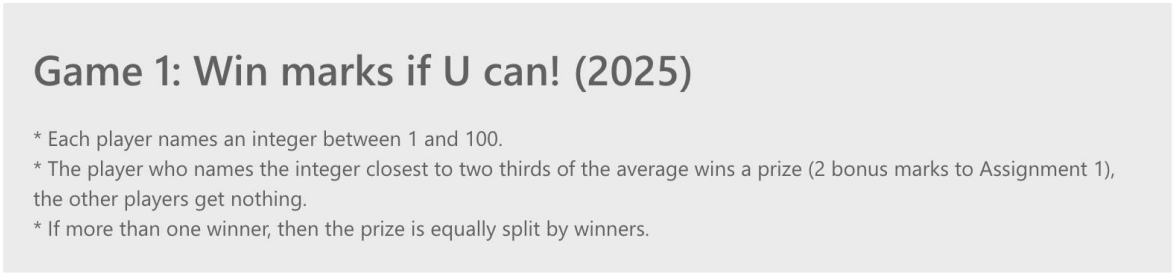
Subgame Perfect Equilibrum

- A:1,B:2 vs C:2,D:1,E:1

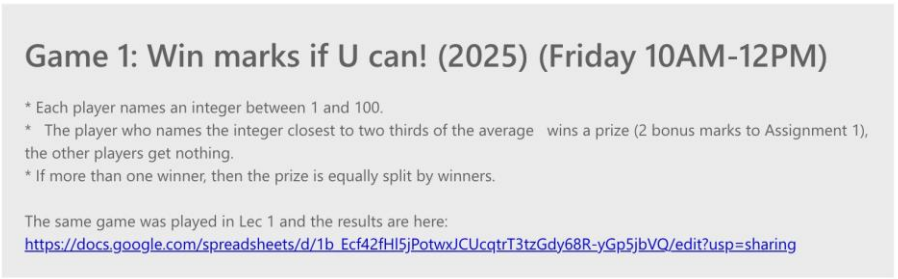
Part 2 Option A: 70 Marks - Knowledge and Rational Agents

The aim of this assignment is for you to gain a better understanding of knowledge and rationality in building intelligent agents.

All students attended the lectures and workshops were given the opportunity to play a game named "Win marks if U can!". Every student was offered 4 chances to play this game and its variants. All the participants were presented an online form for the first game:



The same game was played during the workshops with extra information about the first game:

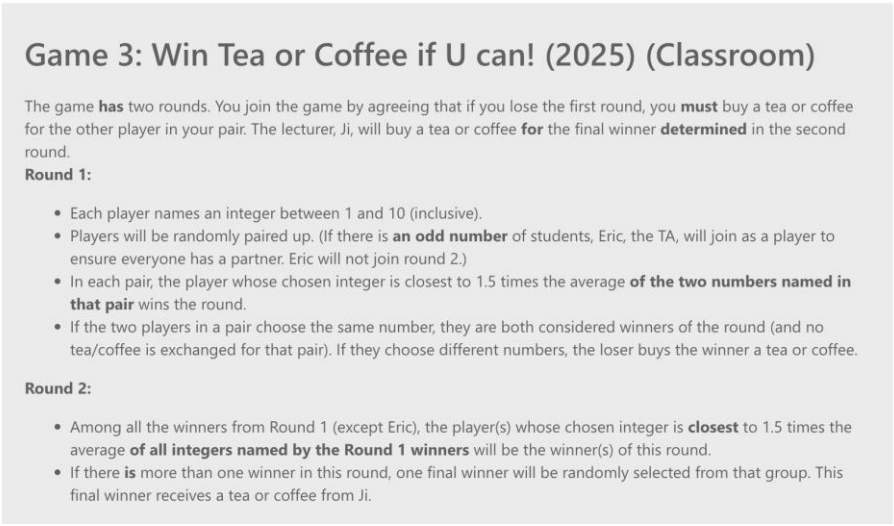


In this game (call it V100), we have the key game ingredients:

- Players: students
- Actions: an integer number between 1 and 100
- Payoff: a share of 2 marks for winners; 0 for others.

In week 3: we explained the methods for rational decision making and mentioned the beauty contest game (which can be seen as a variant of this game). During workshop 3: a game variant (call it V10A) was played in all workshops. The key differences to V100 are that: the action space and the number of players are both smaller; the reward does not include marks.

In week 5, we offer the chance to play a redesigned game (call it V10B):



Game 3: Win Tea or Coffee if U can! (2025) (Classroom)

The game **has** two rounds. You join the game by agreeing that if you lose the first round, you **must** buy a tea or coffee for the other player in your pair. The lecturer, Ji, will buy a tea or coffee **for** the final winner **determined** in the second round.

Round 1:

- Each player names an integer between 1 and 10 (inclusive).
- Players will be randomly paired up. (If there is **an odd number** of students, Eric, the TA, will join as a player to ensure everyone has a partner. Eric will not join round 2.)
- In each pair, the player whose chosen integer is closest to 1.5 times the average **of the two numbers named in that pair** wins the round.
- If the two players in a pair choose the same number, they are both considered winners of the round (and no tea/coffee is exchanged for that pair). If they choose different numbers, the loser buys the winner a tea or coffee.

Round 2:

- Among all the winners from Round 1 (except Eric), the player(s) whose chosen integer is **closest** to 1.5 times the average **of all integers named by the Round 1 winners** will be the winner(s) of this round.
- If there **is** more than one winner in this round, one final winner will be randomly selected from that group. This final winner receives a tea or coffee from Ji.

Your tasks are as follows.

Task 1 (50 Marks)

The game and its variants have been played for a few times. You'll look at the sessions of this year and 2024. Here are more details. The data files are available under the assignment folder.

• Year 2025: Game 1, Game 1 workshops, and Game 3 are recorded. The data file is Data2025.xlsx. The name and student IDs were replaced by pseudo IDs of letters followed by a number. If a student played in two sessions, his/her pseudo IDs will be the same, so this allows to model the strategy change. • Year 2024: 5 sessions played. The data file is Data2024.xlsx. The name and student IDs were replaced by pseudo IDs of letters followed by a number. If a student played in two sessions, his/her pseudo IDs will be the same, so this allows to model the strategy change.

Your task is to study these two years' data files and write a report of 4 pages maximum. Your report shall address four aspects listed below.

(a) Rationality and Knowledge (10 marks)

Discuss what is rationality and why a player's knowledge about other players' rationality is important.

Discuss if the winners win by rational thinking, pure luck, or a combination of both. You shall utilise the data files to support your argument.

(b) Nash equilibrium (10 marks)

Find the pure strategy Nash equilibrium of the variants (V100, V10A and V10B), assuming the perfect rationality of all players.

In reality, not all players are rational in this game. Discuss the relationship between the winning numbers and Nash equilibrium across different games, with regard to the players' rationality and the knowledge about other players' rationality.

(c) Player Classification (15 marks)

For 2025 sessions, give a classification of players in terms of different levels of rationality and their knowledge about other's rationality.

- Step 1: Create a spreadsheet by merging all the data in the seperate sheets. Each role shall contain collected data for a player (e.g., including time stamps, chosen number across different games, the

reason given in different games, etc). The spreadsheet needs to be submitted as part of the submission. The first column should be the PID.

- Step 2: Give a classification scheme and record the classification result in the second column of the spreadsheet from step 1.
  A good classification scheme shall cover at least 3 classes. For each class, you give a clear criteria, so that each player can be classified into one of the classes. To support your scheme, you shall utilise the data given for the players (but be minded that the players do not necessarily articulate their reasons very clearly in the reason column).

(d) Game 3 Mechanism Analysis (15 marks)

Game 3 aims to enhance students' understanding of Nash equilibrium and mechanism design. Furthermore, it aligns with our goals of fostering classroom interactivity and facilitating new connections among students during their learning journey. Discuss how the game has achieved these objectives and suggest further improvements to its mechanism.

Task 2 (20 Marks)

Game theory serves as an important framework for understanding and designing intelligent systems, particularly as AI agents become more autonomous and interactive. Its application spans a wide range of AI domains, from coordinating multi-agent systems to training sophisticated reinforcement learning agents and enhancing the capabilities of adversarial networks.

Write a short report (up to 2 pages) on game theory's applications in AI.

Submission

You can team up with a classmate to work on this assignment. You are required to provide:

(1) Your solution to Base Problems, and

(2) Your report for Task 1 (Limited to 4 A4 pages, 12 points Times New Roman; clearly indicate (a)-(d)).

(3) Your report for Task 2 (Limited to 2 A4 pages, 12 points Times New Roman).

(4) The spreadsheet from Task 1 (c).

We prefer the answers and reports are included in a single PDF file (file name format AI2025A1XY.pdf, where X,Y are your student ID(s)). The submission is via Canvas.

Part 2 Option B: 70 Marks - Multi - Game Playing Agent

The aim of this assignment is for you to better understand computer game playing by implementing a multi - game playing agent with the minimax algorithm and alpha-beta pruning.

Task 1 (50 Marks)

The agent will need to play multiple games, including the Tic-Tac-Toe, the game of Nim with 4 heaps in configuration of (1,3,5,7), and the game of Tiger vs Dogs. The detailed description will be given at the end of this option. In case that AI tools have been used in the implementation, you must describe the prompts used and your own understanding and contribution to the implementation. In particular, you will need to:

(a) Implement the minimax algorithm and alpha-beta pruning: (20 marks)

- (i) using complete tree search. (Call them $Minimax_{complete}$,$AB_{complete}$) You may use Depth-first search (DFS).

- (ii) using depth limited tree search and an evaluation function.(Call them $Minimax_{limited}$,$AB_{limited}$)
  For depth limited tree search, you just need to introduce a depth variable and when it decreases to 0, either the evaluation value or the terminal value is returned. For Tic-Tac-Toe game, you can use the evaluation function in the workshop 2. For Nim and Tiger vs Dogs, you need to come up with your own evaluation function.

A Pseudocode can be found at https://en.wikipedia.org/wiki/Minimax,https://en.wikipedia.org/wiki/Alpha%E2%80%93beta_pruning

You need to

- Report on the details of your program design (data structures, and functions).
- Provide an evaluation of the players you've developed. Let two algorithms compete against each other and report on the performance difference, e.g., win-draw-lose rate, and resource consumption. A random player (selecting moves randomly) is needed to serve as baseline.

(b) Implement an intuitive user interface (10 marks)

This allows the human player to know the game state/actions to play. In the start of games, the human player should be able to choose who plays first and which version of the algorithm to use (in the case of depth limited, allowing to set the search depth).

Report on the program design and some sample plays.

(c) Scalability Study (20 marks)

Your agent is resource bounded, so the response of the player will be slower if the game gets larger. Design and conduct experiments to study the scalability of your game playing agent by using scaled up versions of Tic-Tac-Toe and Nim.

Specifically, here are some important aspects to consider: •

Game complexity.

In Tic-Tac-Toe, you can scale up by increasing the number in (m,n,k)-game. In Nim, you can scale up by increasing the number of heaps X and size of each heap Y.
E.g., one question on scalability will be: what is the maximal size of the game variant that your agent (running in your hardware) can handle (producing a response in a reasonable amount of time, say 10 or 100 seconds?)

- Algorithm efficiency.
  You can compare minimax, alpha-beta pruning (more efficient than minimax), and varying the limit of search depth.

Report on your experiment design and results. Your hardware and software configurations should also be noted as they are very relevant to the results.

Task 2 (20 Marks)

Implement a game player for a game of your own interest. Here are the requirements.

- Describe the game clearly, including the players, actions, game dynamics, terminal conditions and goals.
- Provide an evaluation.

Games

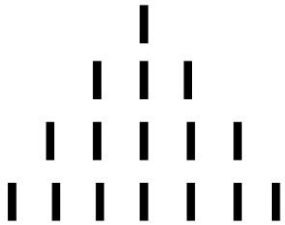
(1) Tic-Tac-Toe

Tic-Tac-Toe is played on a three-by-three grid by two players, who alternately place the marks X and O in one of the nine spaces in the grid. The We call the first player Xplayer, and the second player Oplayer. The player who succeeds in placing three of their marks in a horizontal, vertical, or diagonal row is the winner. Tic-tac-toe is an instance of an (m,n,k)-game, where two players alternate taking turns on an $m \times n$ board until one of them gets k in a row.

Here is a sample play from https://en.wikipedia.org/wiki/Tic-tac-toe

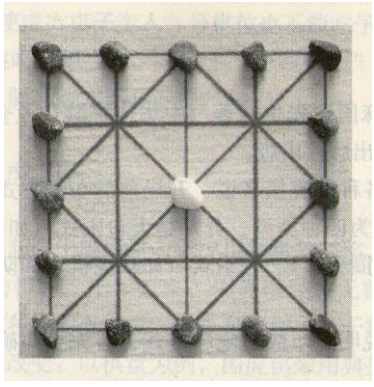
(2) Nim (1,3,5,7)

Nim (1,3,5,7) is a game played on 4 heaps (rows) with 1, 3, 5 and 7 sticks on each heap by two players who alternately remove 1 or more sticks in the same row. The player who removes the last sticks loses the game, and the other player wins the game. This game can be scaled up with more heaps and sticks.



(3) Tiger vs Dogs

Here is a very ancient game originated from China: Tiger vs. Dogs.



In the above 5 × 5 board, there are one tiger (represented by a white stone in the center) and 16 dogs (represented by black stones in the perimeter).

The tiger is controlled by the tiger player and the dogs are controlled by the dog player. The tiger player goes first and then they take turns. Each player can go one step along the line to an adjacent position that is not occupied.

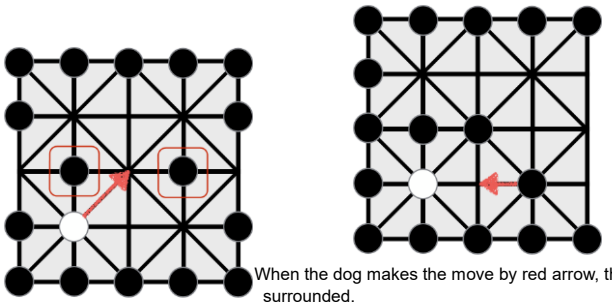
When the tiger enters a position such that the following condition hold “two dogs are adjacent to this position such that they three are in the same line, and also these two dogs have no adjacent dogs in the same

line", then these two dogs are killed by the tiger. If 6 dogs are killed, then the tiger player wins and the dog player loses.

When the dogs surrounded the tiger such that there is no unoccupied adjacent position for the tiger to move, then the tiger player loses and the dog player wins.

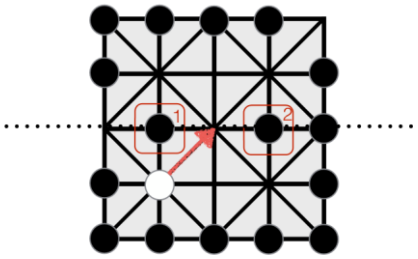
To help you to understand this game, here are a few examples:

Example:



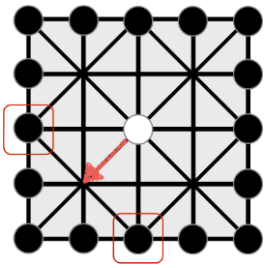
When the dog makes the move by red arrow, the tiger is surrounded.

Example:



When the tiger makes the move by red arrow, the marked two dogs are not killed because there is a dog in the same line that dogs are killed.

Example:



When the tiger makes the move by red arrow, the marked two dogs are killed.

Example:

When the tiger makes the move by red arrow, the marked two dogs are killed.

Submission

You can team up with a classmate to work on this assignment. You are required to provide:

(1) Your solution to Base Problems, and

(2) Your report for Task 1 (Limited to 4 A4 pages, 12 points Times New Roman),

(3) Your report for Task 2 (Limited to 2 A4 pages, 12 points Times New Roman).

(4) The source code and the compiled program of your game playing agent (with notes on what library it may depends on and instructions on how to run it). There is no restriction on your programming language. Note that the you can use some code already exists but you need to clearly state in your report and emphasise particularly your own original contribution.

(5) You are required to do a demo of your program at one of the workshop sessions during week 8.

We prefer the answers and reports are included in a single PDF file (file name format AI2025A1XY.pdf, where X,Y are your student ID(s)). The submission is via Canvas.