

# Search in OOXX Games

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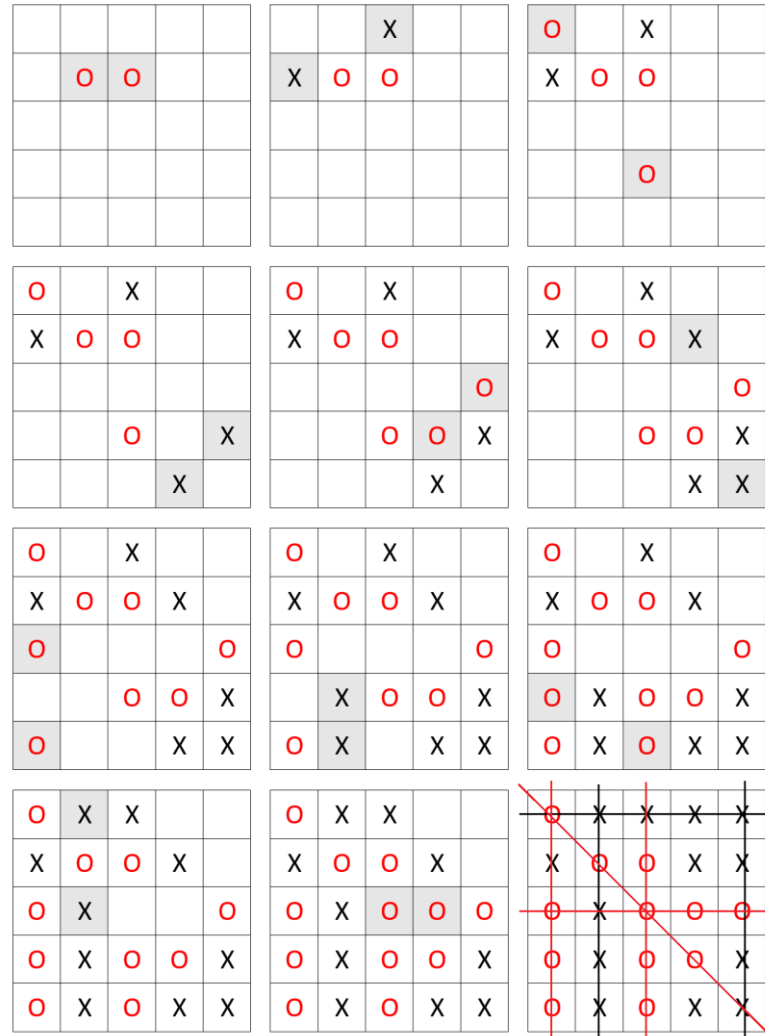
# Introduction to OOXX Games (井井井井字棋)

- OOXX Games (井井井井字棋 or 井<sup>4</sup>字棋)
  - Invented by Adrien Wu (吳聖福) in 2018
- Rules
  - Two players, O and X, alternately place two tokens of their own, on a 5X5 board.
  - O always plays first to put two O's on the board.
  - X always plays second to put two X's on the board.
  - After 11 plays, the game is ended by putting the last 3 X's to make the board full.
  - How to determine the winner
    - One point for a player is achieved if we have at least 4 tokens of this player in each of the 5 rows, 5 columns, and 2 diagonals.
    - The player with more points wins the game.

# An Example of OOX Game

## Result

- O: 4, X: 3 → O wins!



# Problem Definition

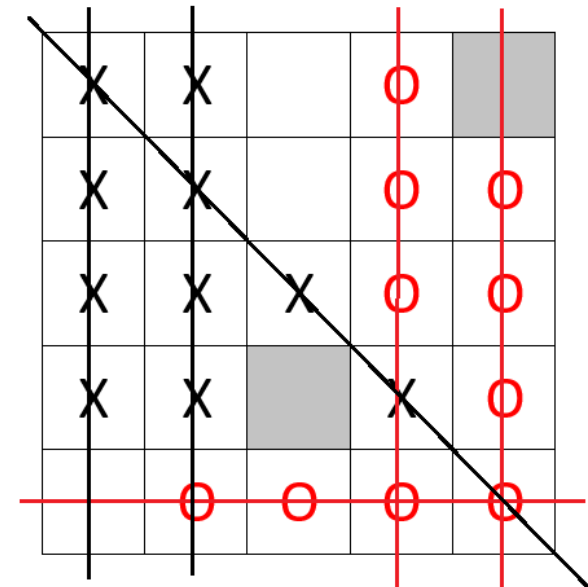
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- Given a half-filled board, determine who is the winner (or a tie) if both adopt the best strategy to play.
- Three possible results
  - O win
  - X win
  - Draw

## Examples of Best Strategy (1/3)

### ○ Next play by O

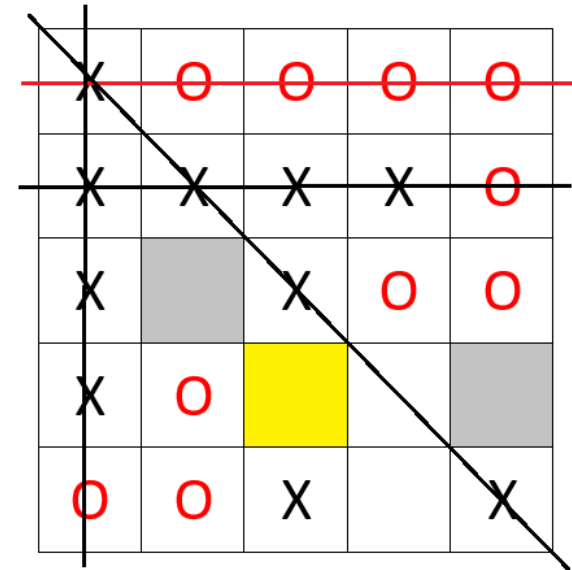
- Both O and X have a score of 3
- O cannot score any more → No way for O to win
- The best bet for O is to take the gray positions, which leads to a tie.
- If O didn't choose the gray positions, X will win.
- So the best strategy for O is the above two gray positions.



## Examples of Best Strategy (2/3)

### ○ Next play by O

- The best bet for O to score 3 is to take the gray positions
- X can get an addition score by take the yellow position.
- No matter how O play, s/he will lose the game.
- So the best strategy for O is actually any two positions (since s/he will lost the game anyway).



## Examples of Best Strategy (3/3)

### ○ Next play by X

- If X takes the gray positions (which leads to the board in the previous slide), s/he will win.
- If X takes the positions marked with \*, s/he will win too.
- So the best strategy for X is not unique.

X	O	O	O	O
X	X	X	X	O
X		X	O	O
X	O	*		
O	O			*

## Hint: How to Determine the Result?

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- Given a current half-filled board, search for the next possible board and record its result.
- Suppose the current board is O's move, s/he will adopt the best strategy to determine the result of the current board:
  - If any of the next boards is "O win" → "O win"
  - Else if any of the next boards is "Draw" → "Draw"
  - Else → "X win"



## Hint: How to Speed Up Computation?

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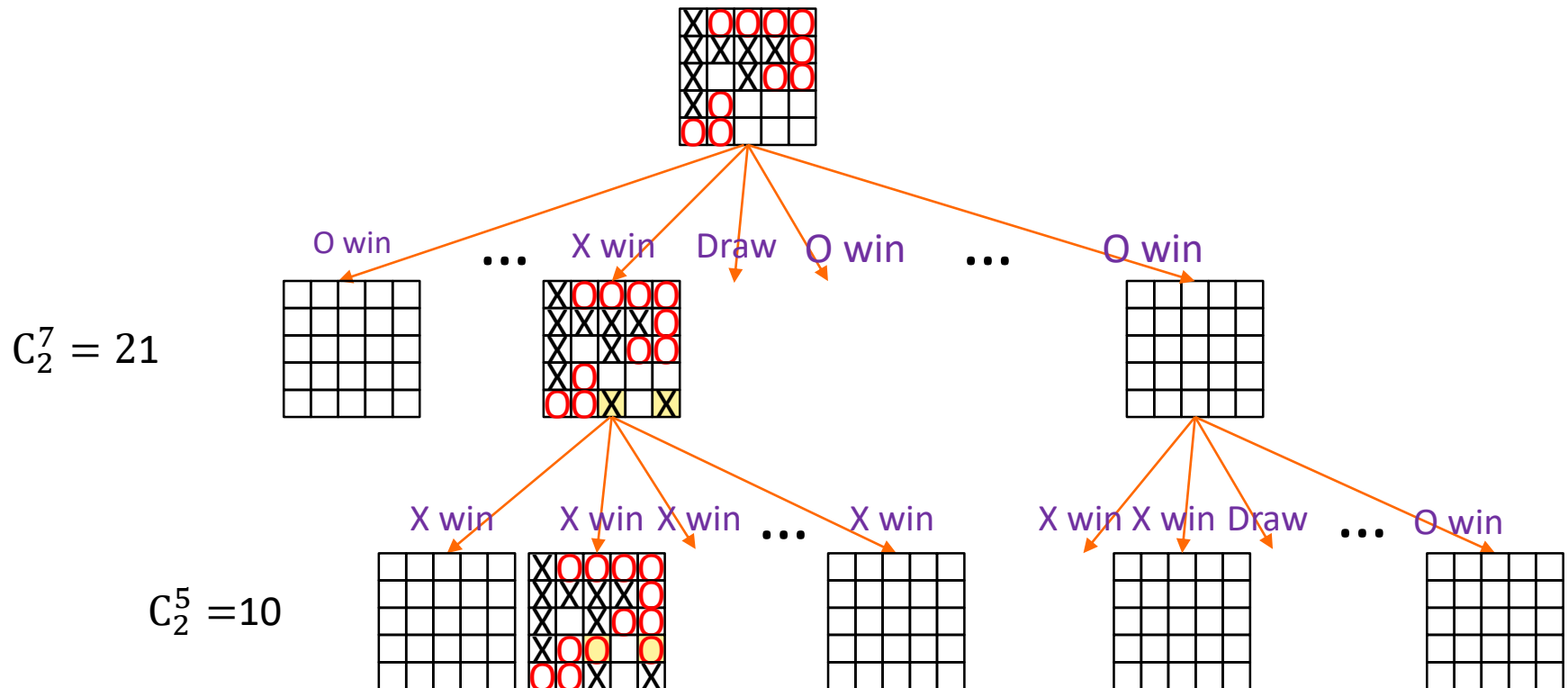
- During the search, it is likely that you run into a board that has been computed before.
- You can use `<unordered_map>` to record the result of a given board, so you can easily retrieve it later.

## Hint: How to Save Memory?

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- Each board has 25 elements, and each element has 3 states (O, X, and empty)
  - ➔ Use 2 bits for each element
  - ➔ Use a long long (64 bits) for a board to save it to an unordered map

# Game Tree

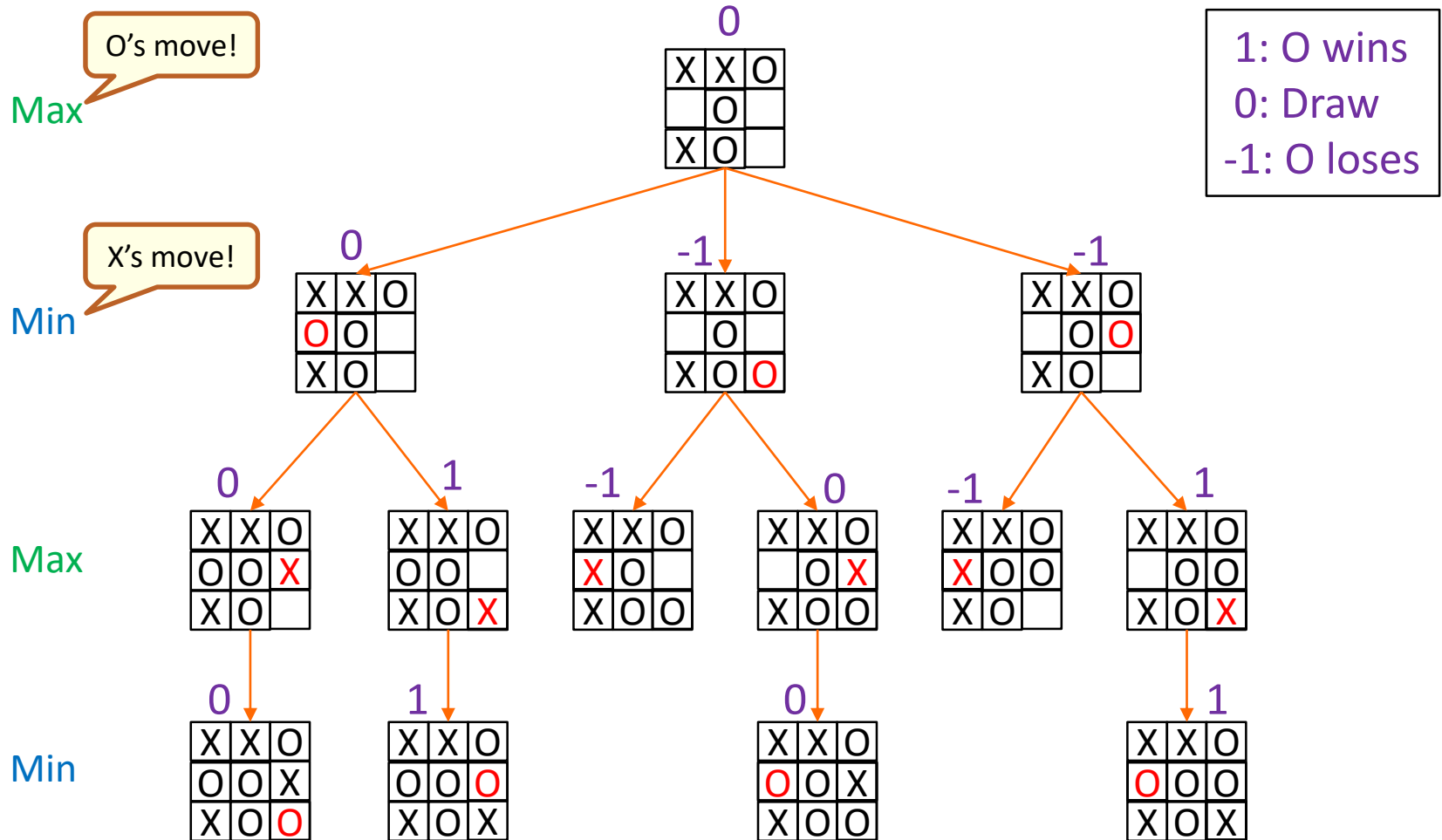


## Hint: How to Speed Up More?

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- Comments from 吳聖福

# MinMax Rule: Game Tree of Tic-Tac-Toe



# Example: $\alpha$ - $\beta$ Pruning in a Game Tree (1/3)

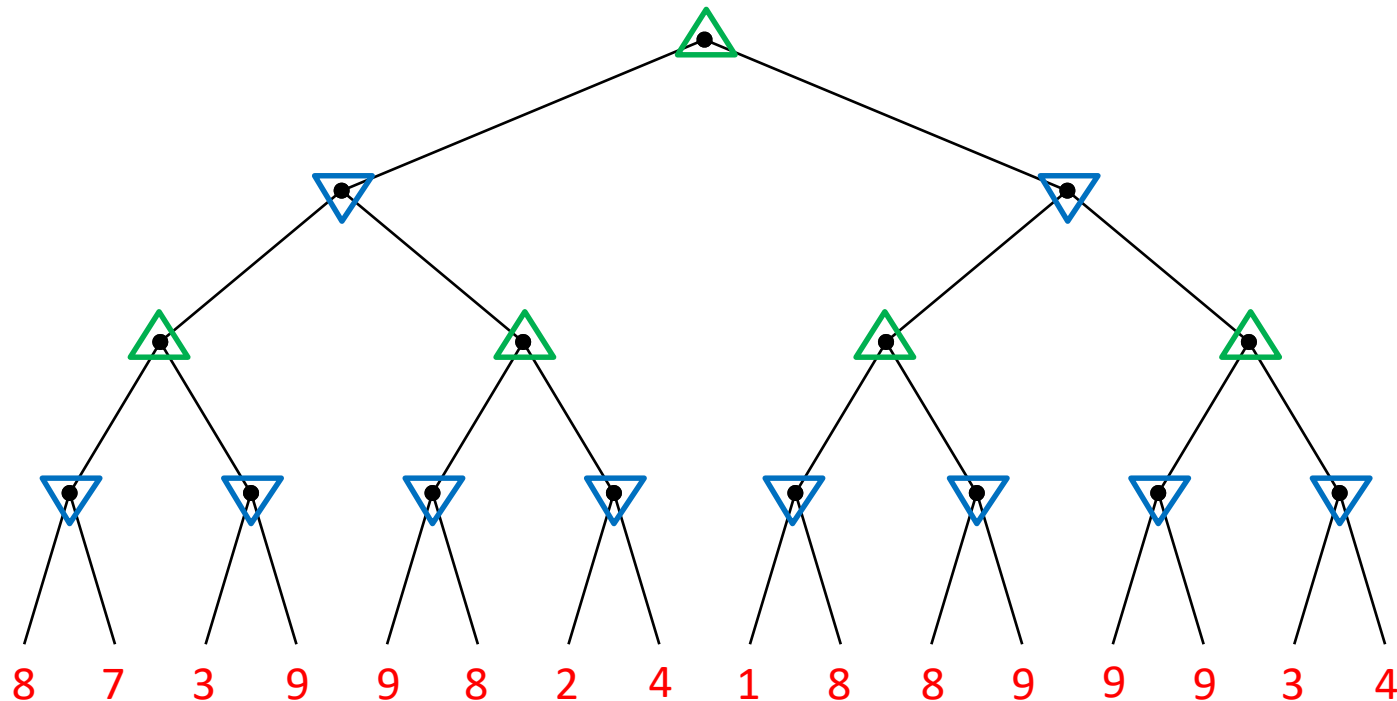
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Max

Min

Max

Min



## Example: $\alpha$ - $\beta$ Pruning in a Game Tree (2/3)

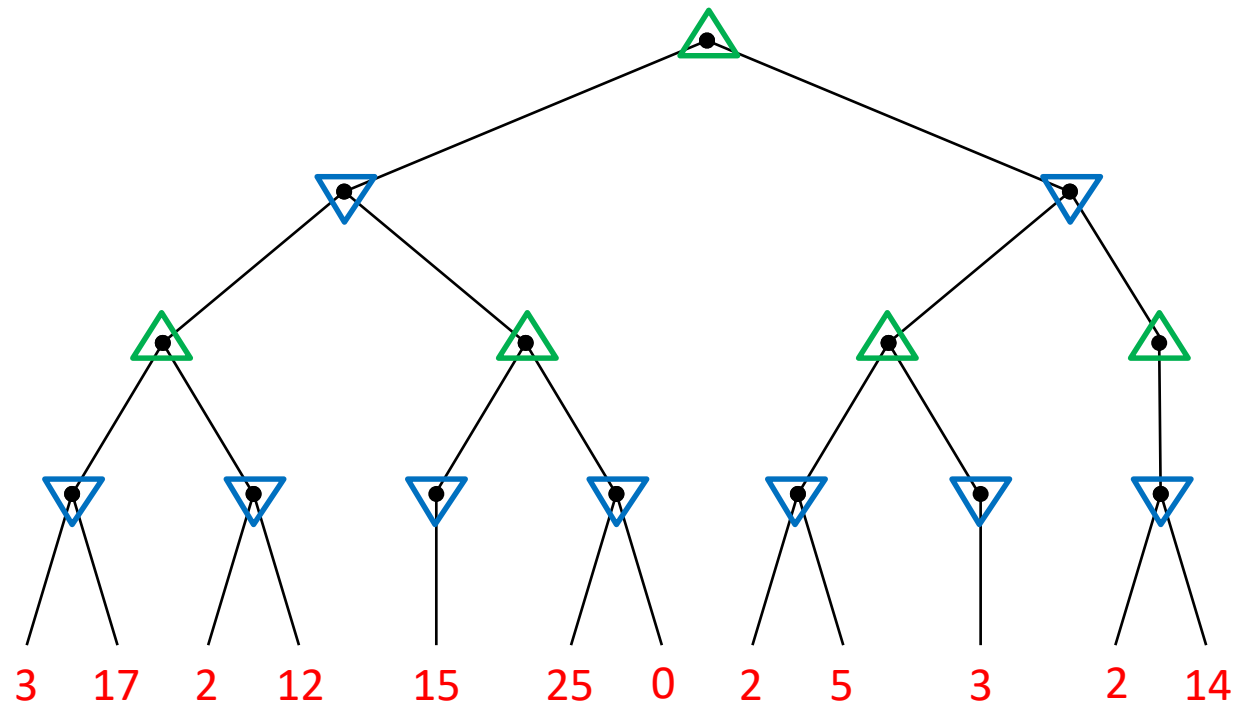
### Source

Max

Min

Max

Min

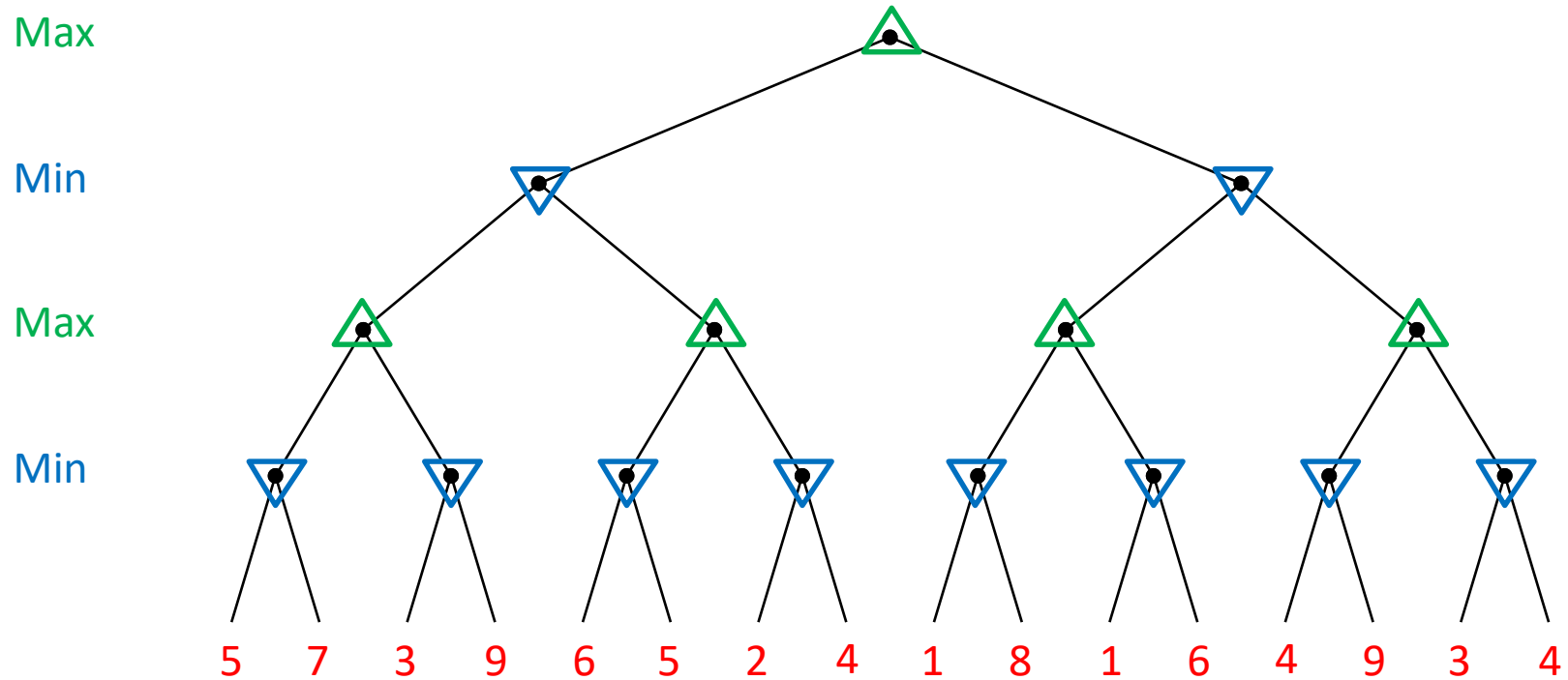






# Exercise 1: $\alpha$ - $\beta$ Pruning in a Game Tree

- Display how the search can be reduced via  $\alpha$ - $\beta$  Pruning



## Exercise 2: $\alpha$ - $\beta$ Pruning in a Game Tree

- Display how the search can be reduced via  $\alpha$ - $\beta$  Pruning

