AlphaOthello

Due: 6/28 11:59am

Demo: 6/28 2pm

Outline

1. Introduction
2. Othello
3. State Value Function
4. Minimax
5. Alpha-Beta Pruning
6. How To Design Your AI
7. Package
8. Requirements
9. Grading

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Introduction

- Design and implement an AI that can play the boardgame Othello
- Read the current board and output the next move
- Design a state value function to evaluate the score of the board
- Determine the next move with tree search algorithm

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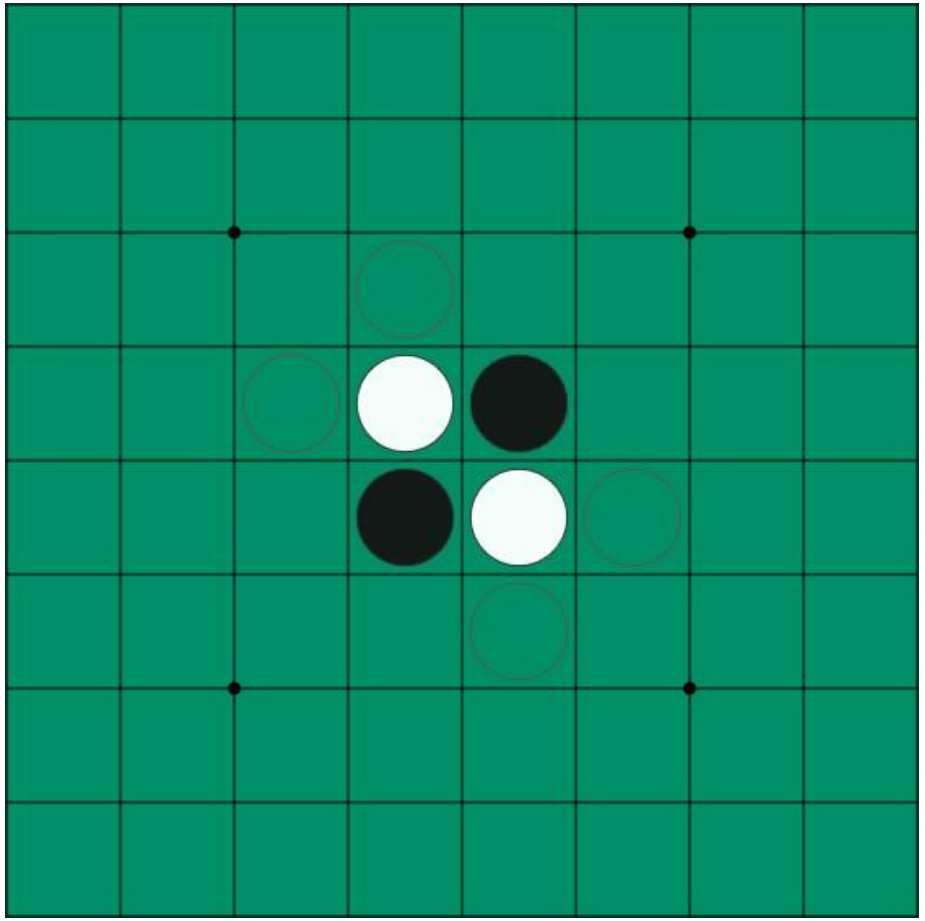
Othello (Reversi)



Source: https://www.eothello.com/
https://www.othelloonline.org/ (Stronger)

Othello Rules

- Use black and white discs and an 8 x 8 board, black plays first
- Starts with initial board (the board on the previous page)
- Player can place disc if the new disc and another same color disc are on a line (horizontal, vertical, diagonal), with one or more contiguous opposite color discs between the two discs of the player
- The opposite color discs between player discs will be flipped
- Player passes if no valid move can be performed
- The game ends when neither player can move
- The one with more discs wins

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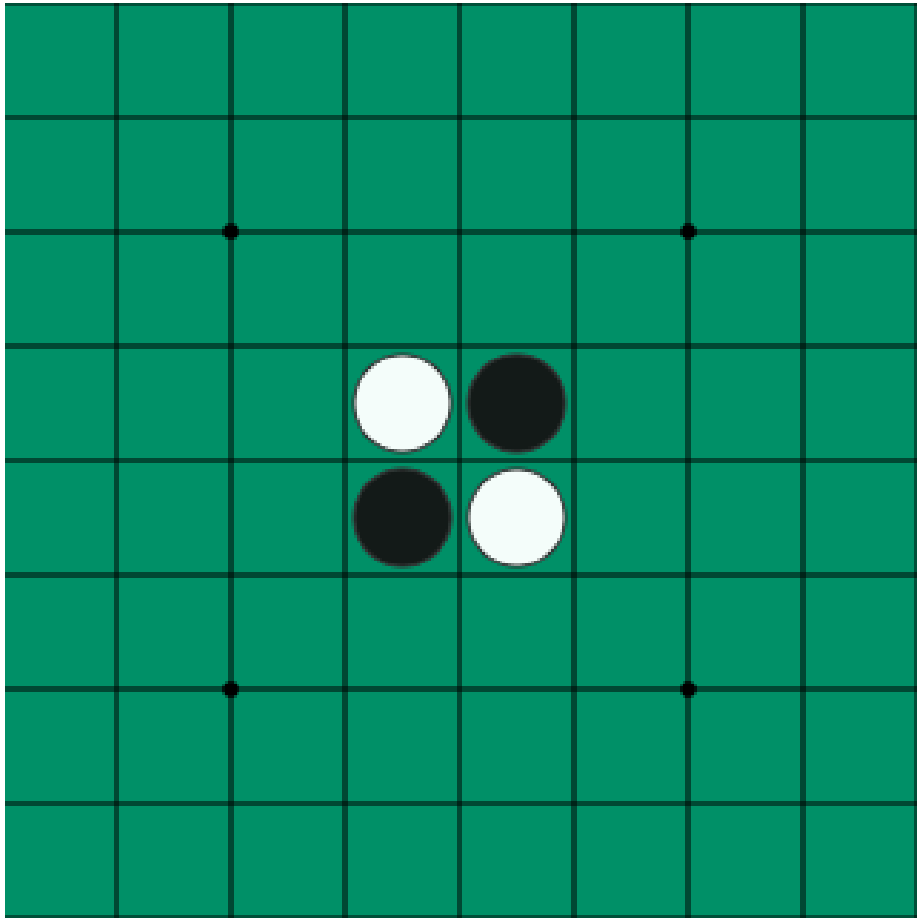
Initial board



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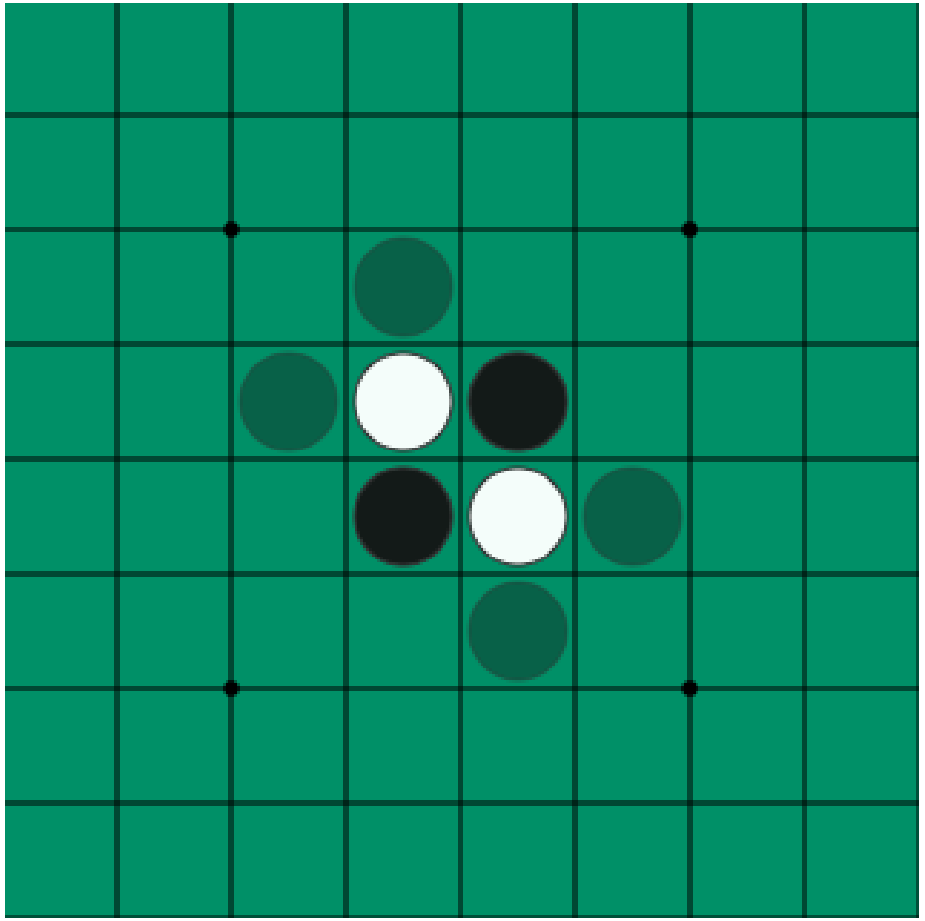
Gray discs are valid moves of black



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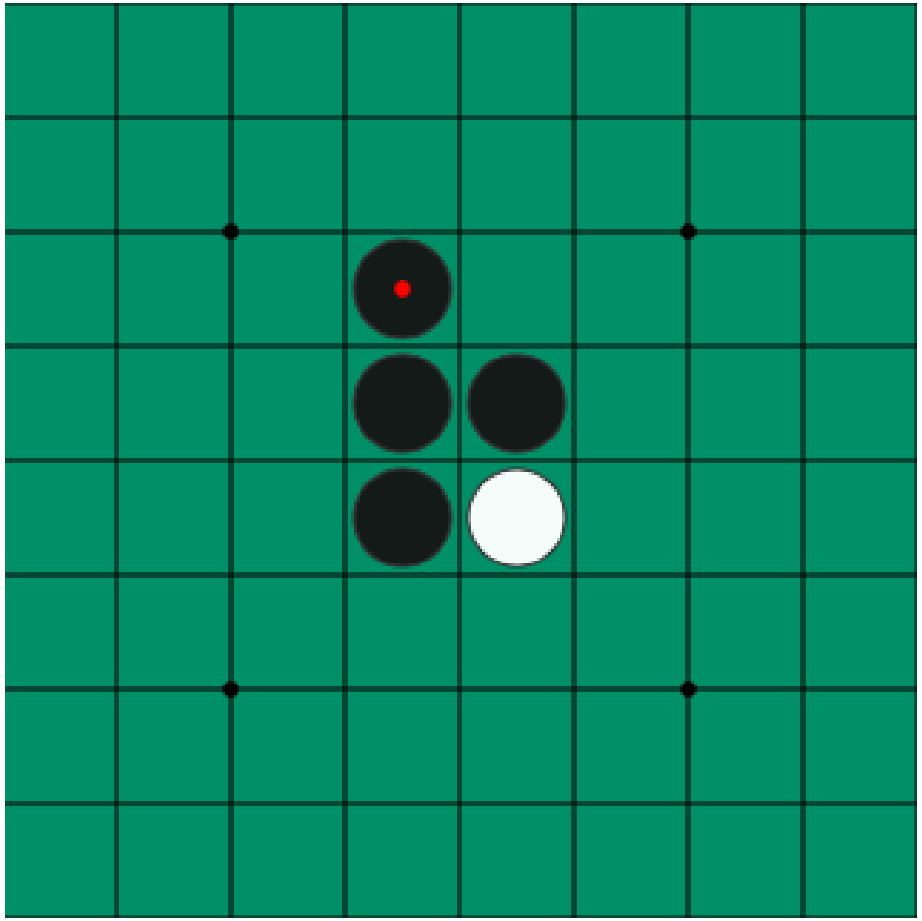
- The one with more discs wins

Black plays (2, 3), one white disc is flipped



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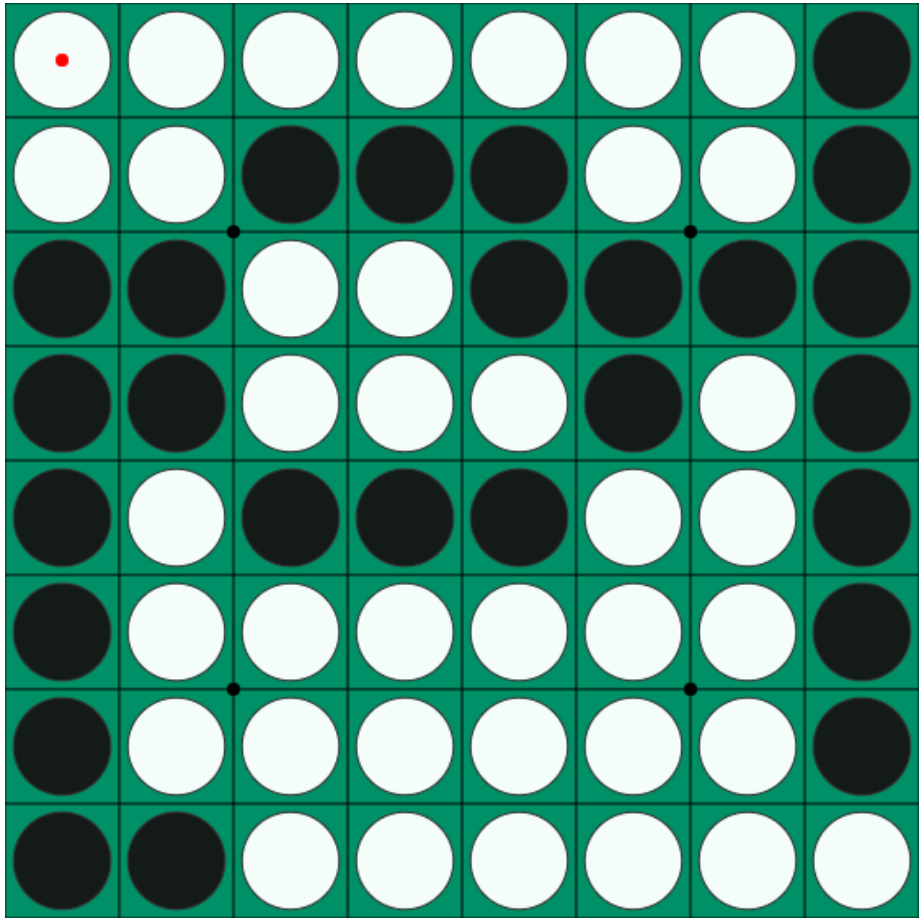
Since neither player can move, game ends



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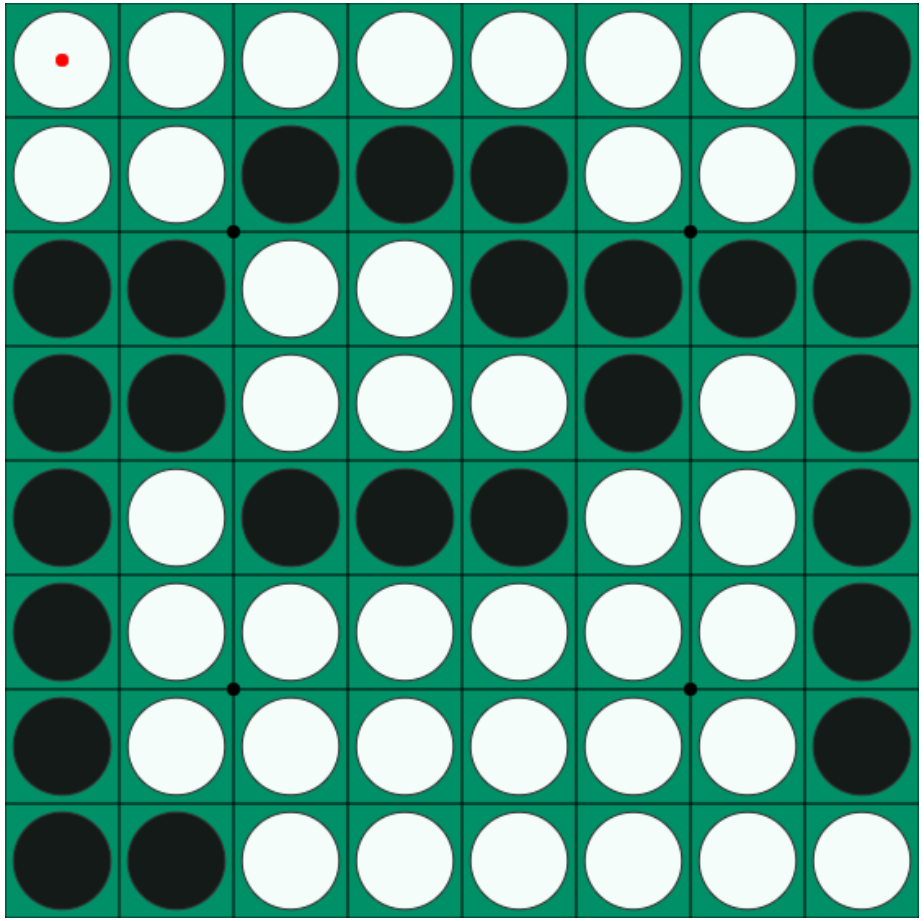
- The one with more discs wins

White wins with more discs



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State Value Function

- The program should decide which move is better
- We can pick the move which leads to the board with highest score
- Thus, we need a function to evaluate the score of the board
- It is the “**state value function**”

State Value Function

- State => the board
- Value => how “good” the board is
- Function => given a board, output the value

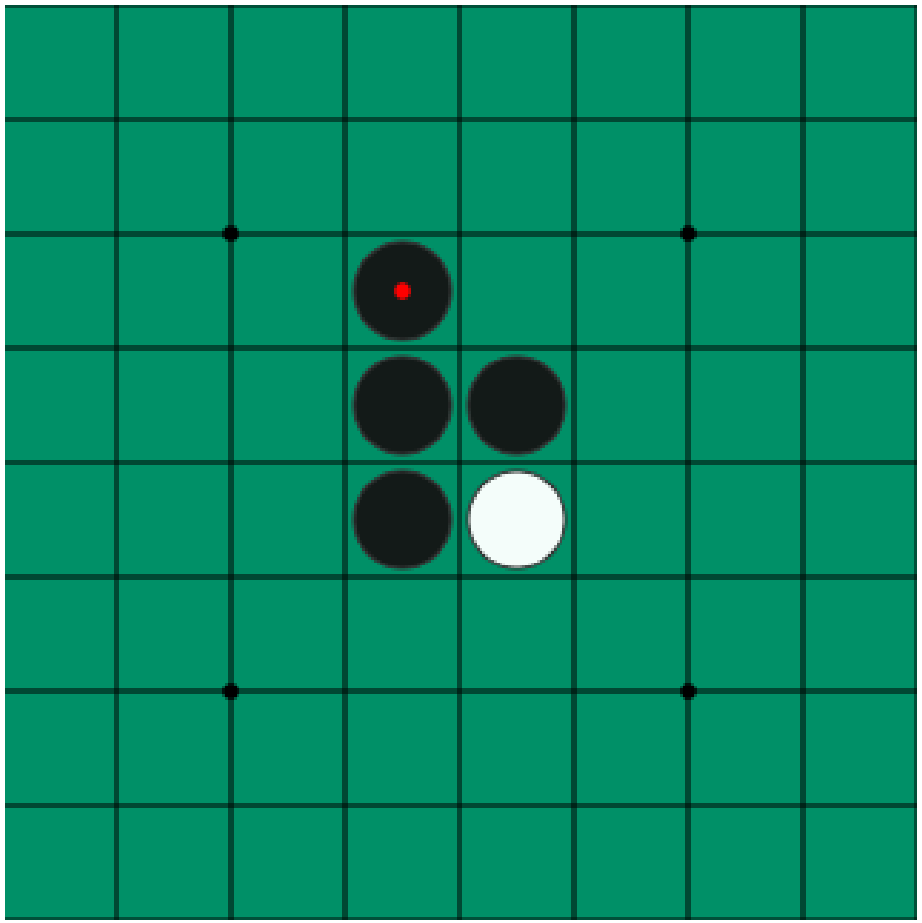
Simple Example

- According to the Othello rule, we win if we have more discs than the opponent when the game ends

- Thus, we can define a simple value function:

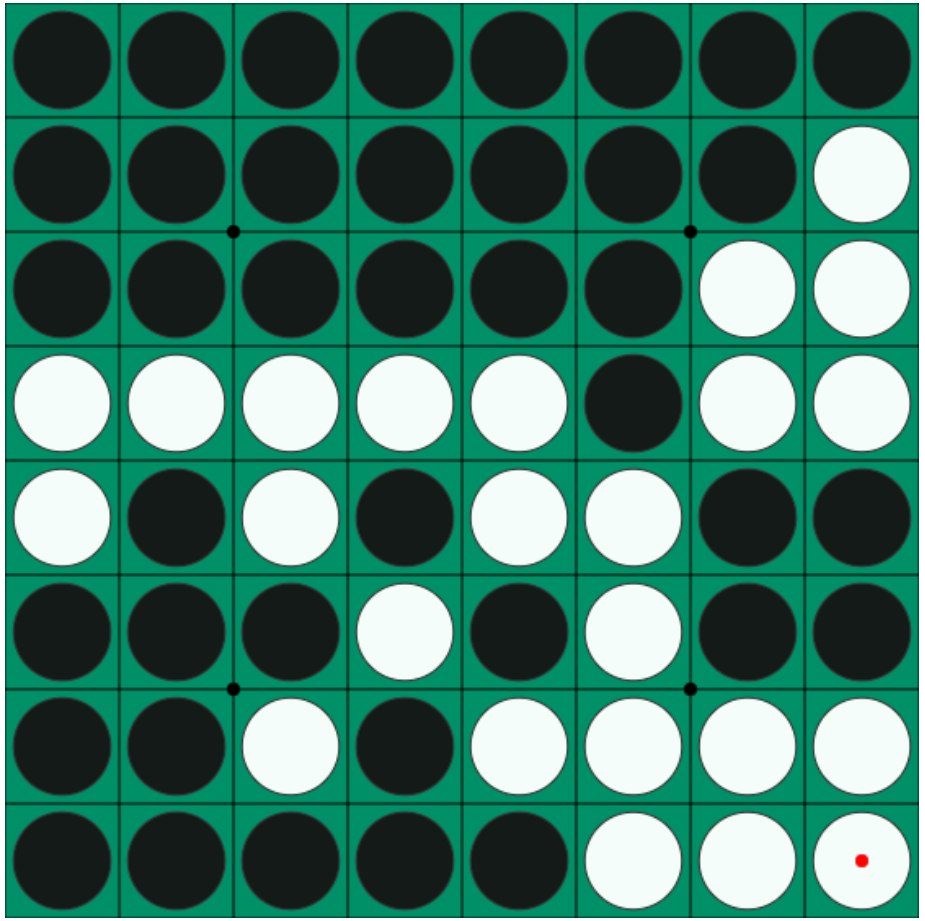
- Value = # of player's discs – # of opponent's discs

Suppose we play as black, value = 4 – 1 = 3



Source: https://www.eothello.com/

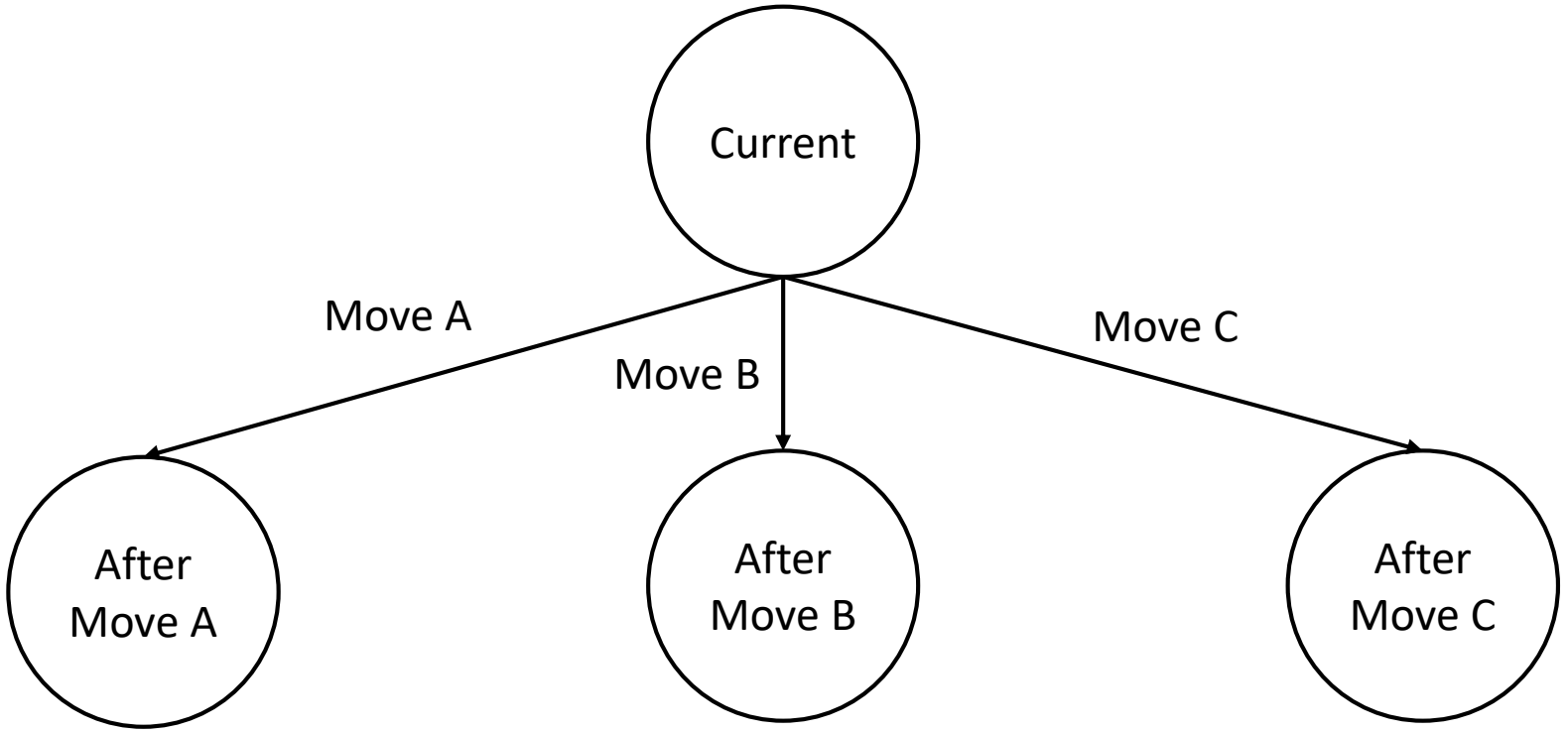
Another example, value = 40 – 24 = 16



Source: https://www.eothello.com/

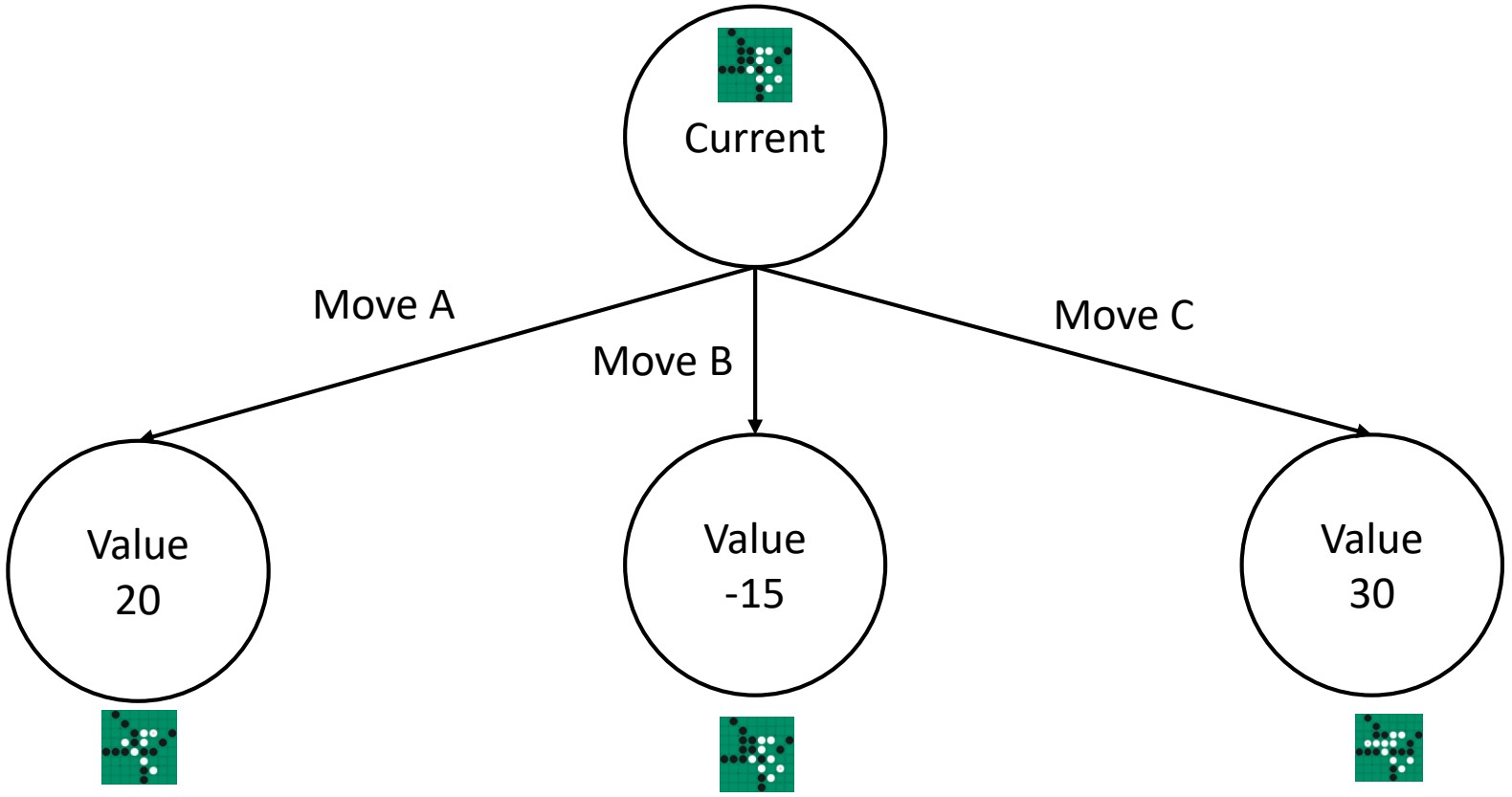
Use value function to pick the next move

- Suppose we have three valid moves, A, B, and C:



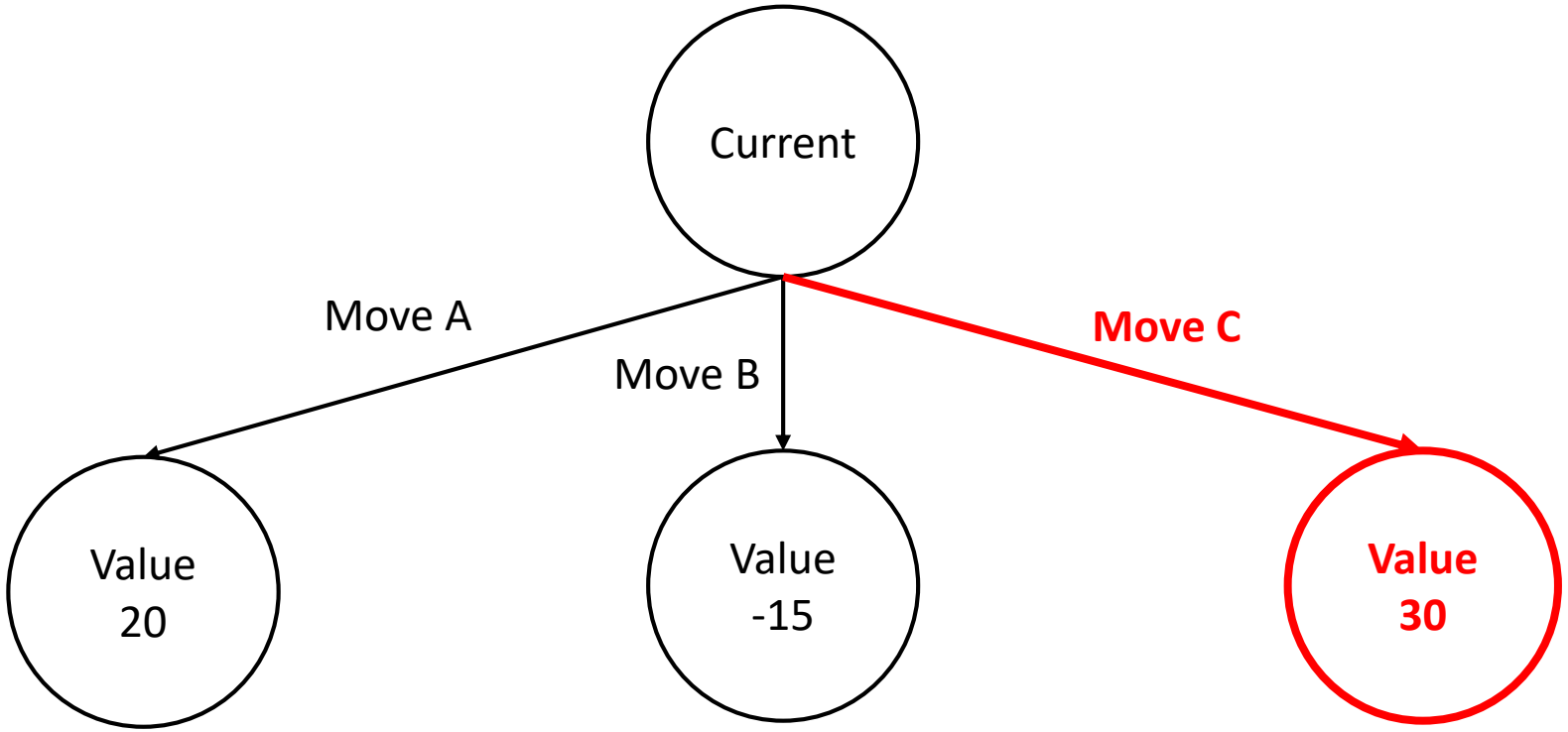
Use value function to pick the next move

- After evaluating the state values, we have 20, -15, and 30



Use value function to pick the next move

- We pick move C to be our next step since it leads to the highest value



Stronger Value Functions

- The value function in the previous example is too simple
- It is nearly impossible to beat the baselines by using it
- In this mini project, you must design a stronger value function to evaluate how “good” the board is

Features You Can Utilize

- Disc count
- Valid move count
- Disc position
- Game status (win, lose, skipped turn)
- Try to figure out more features by yourself

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Minimax

- In the previous example, we only look forward for one step
- However, the opponent will try its best to defeat you
- Greedy choice (next highest value) is not always the best
- We should look forward for more steps and simulate how the opponent thinks to make the best choice with least risk

Minimax

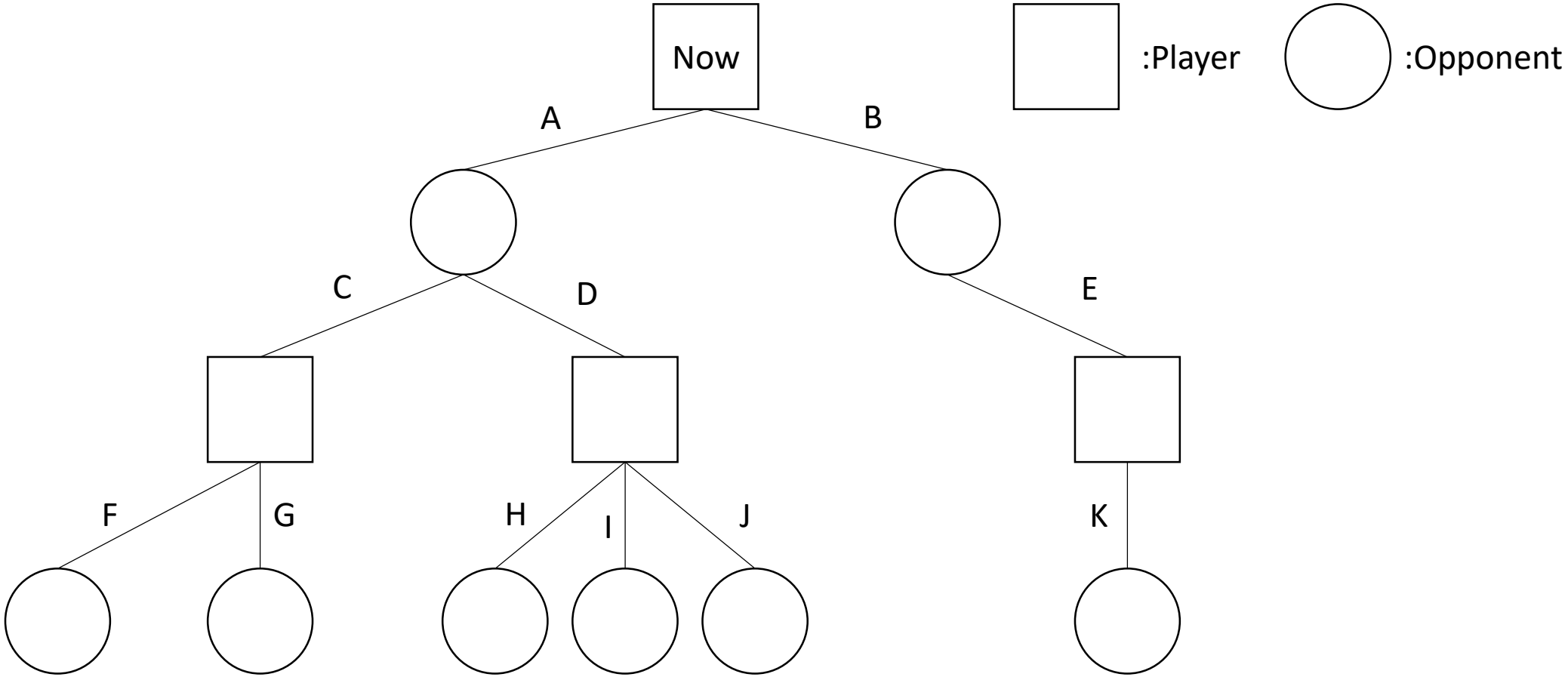
- Player tries its best to win
  - Player picks the move with the highest score
- Opponent tries its best to defeat the player
  - Opponent picks the move with the lowest “player’s value function” score
  - That is, opponent tends to give the player the worst board
- The Minimax algorithm is based on this player-opponent interaction

Minimax Pseudocode

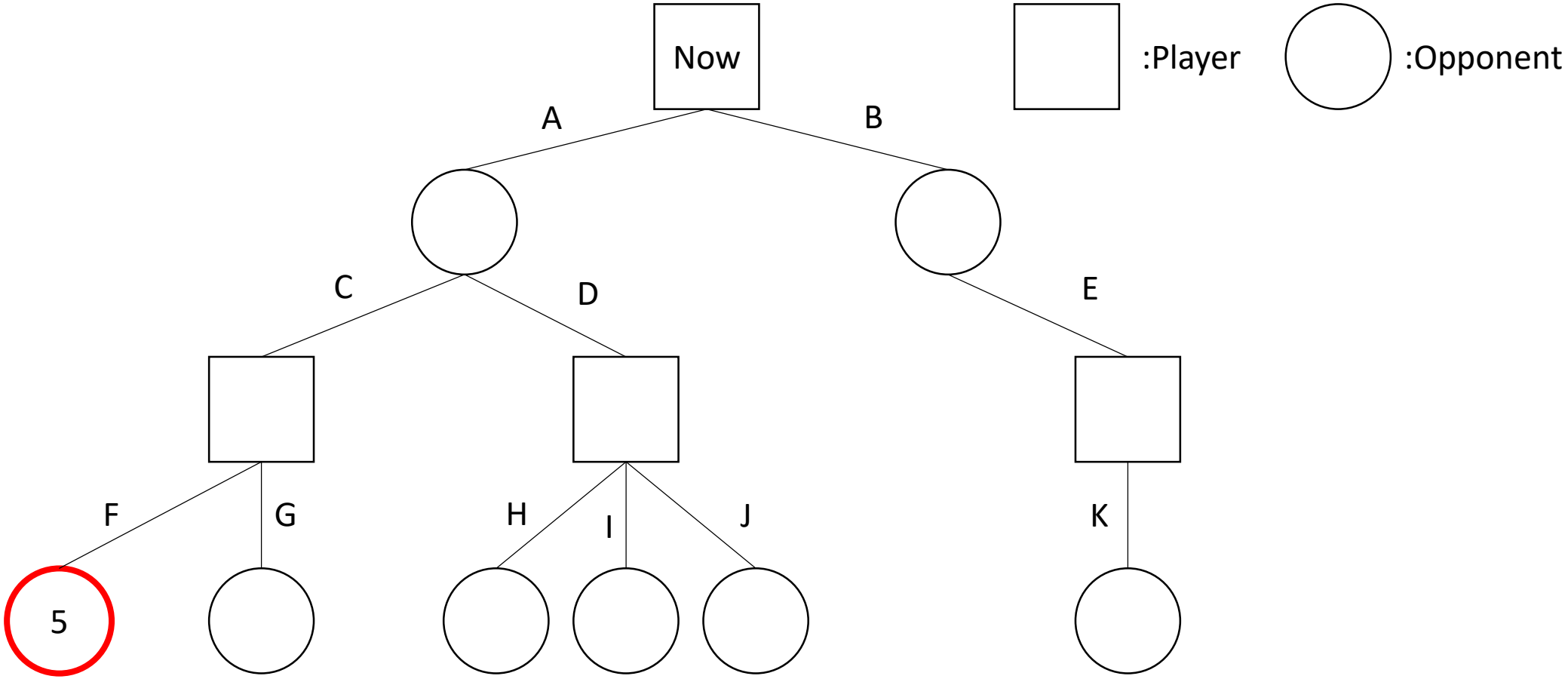
```
function minimax(node, depth, maximizingPlayer) is
    if depth = 0 or node is a terminal node then
        return the heuristic value of node
    if maximizingPlayer then
        value := −∞
        for each child of node do
            value := max(value, minimax(child, depth − 1, FALSE))
        return value
    else (* minimizing player *)
        value := +∞
        for each child of node do
            value := min(value, minimax(child, depth − 1, TRUE))
        return value
```

Source: https://en.wikipedia.org/wiki/Minimax

Example



Evaluate score at leaves



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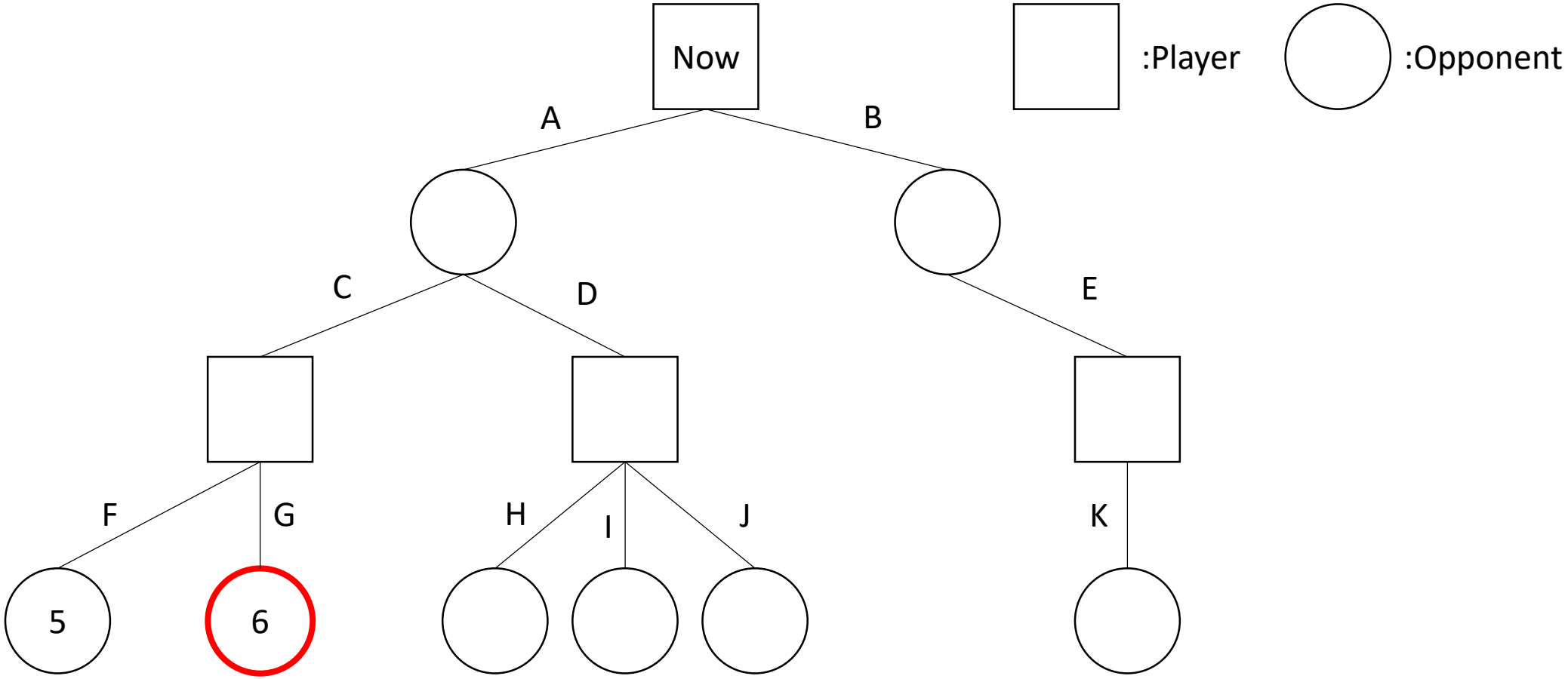
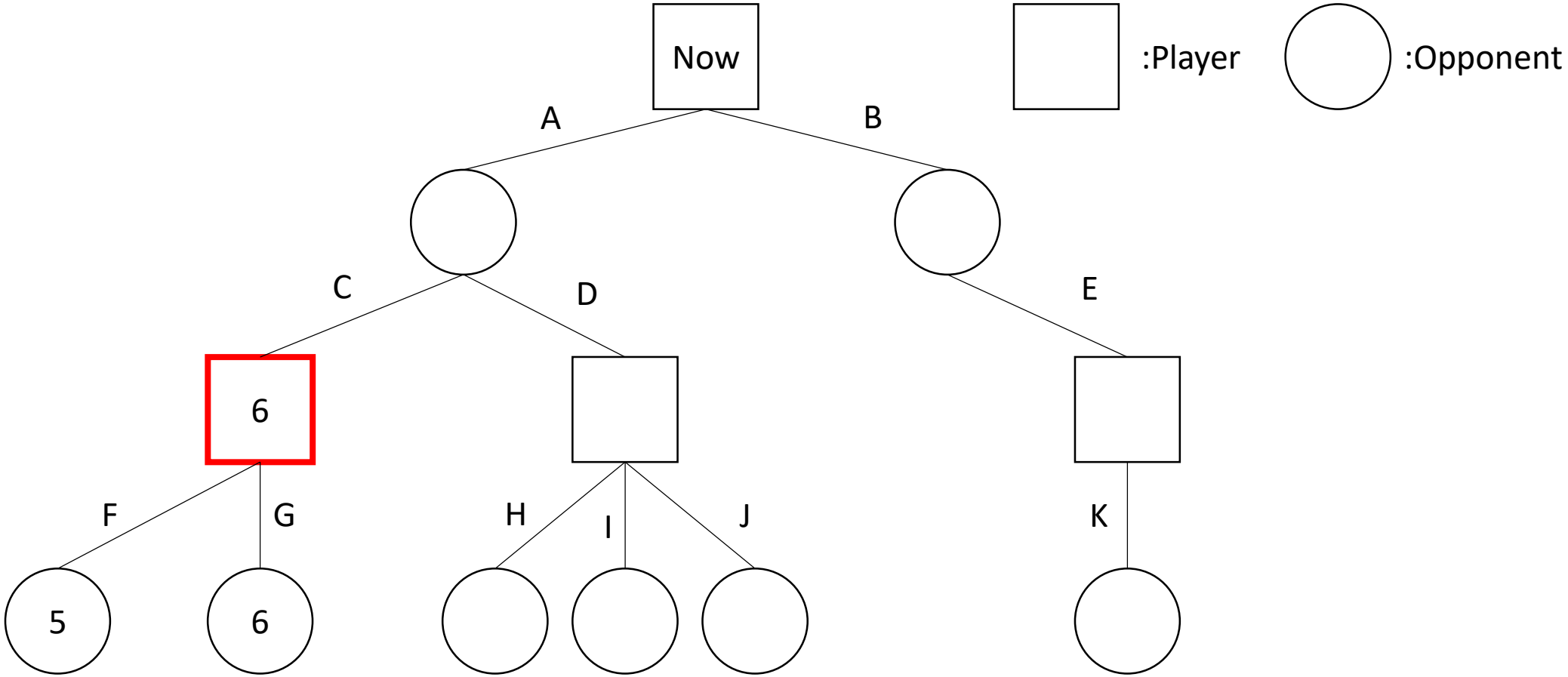


Player picks the largest score



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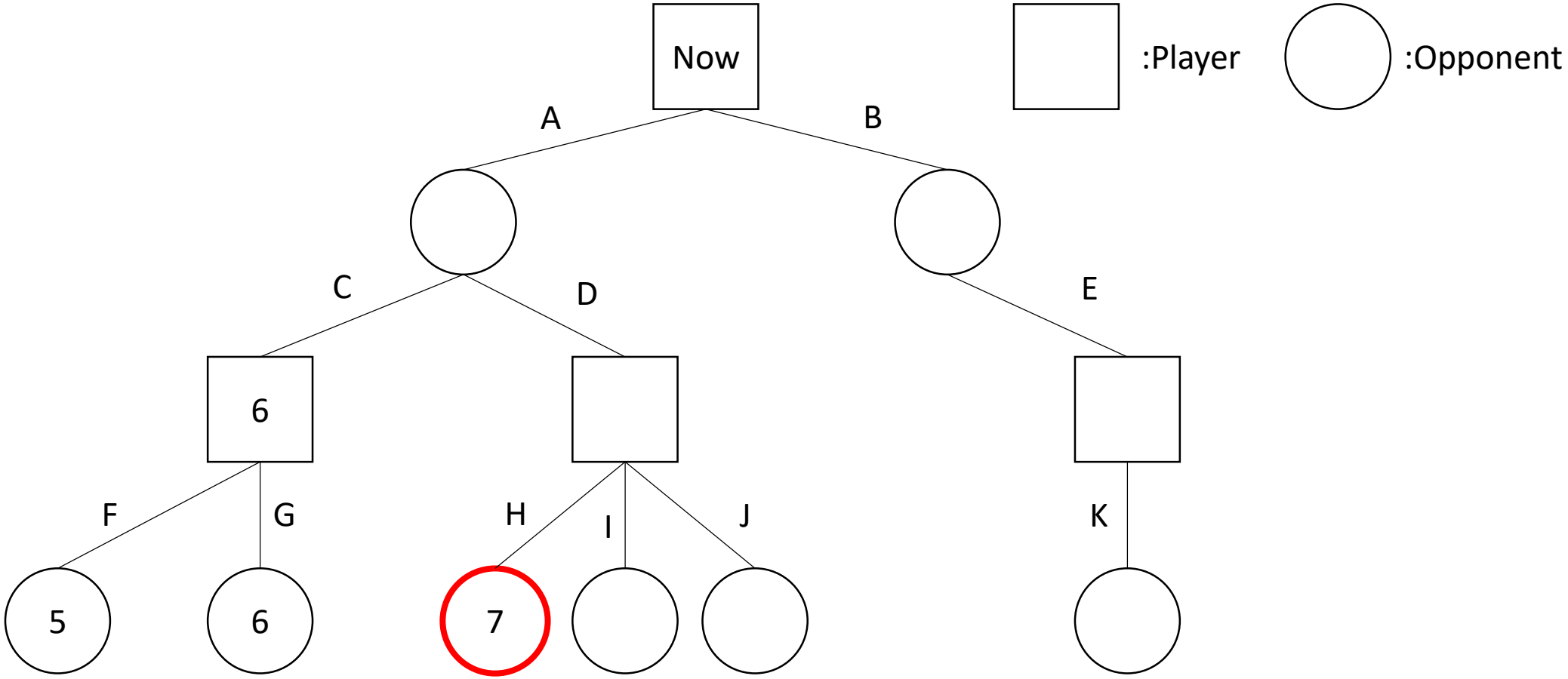

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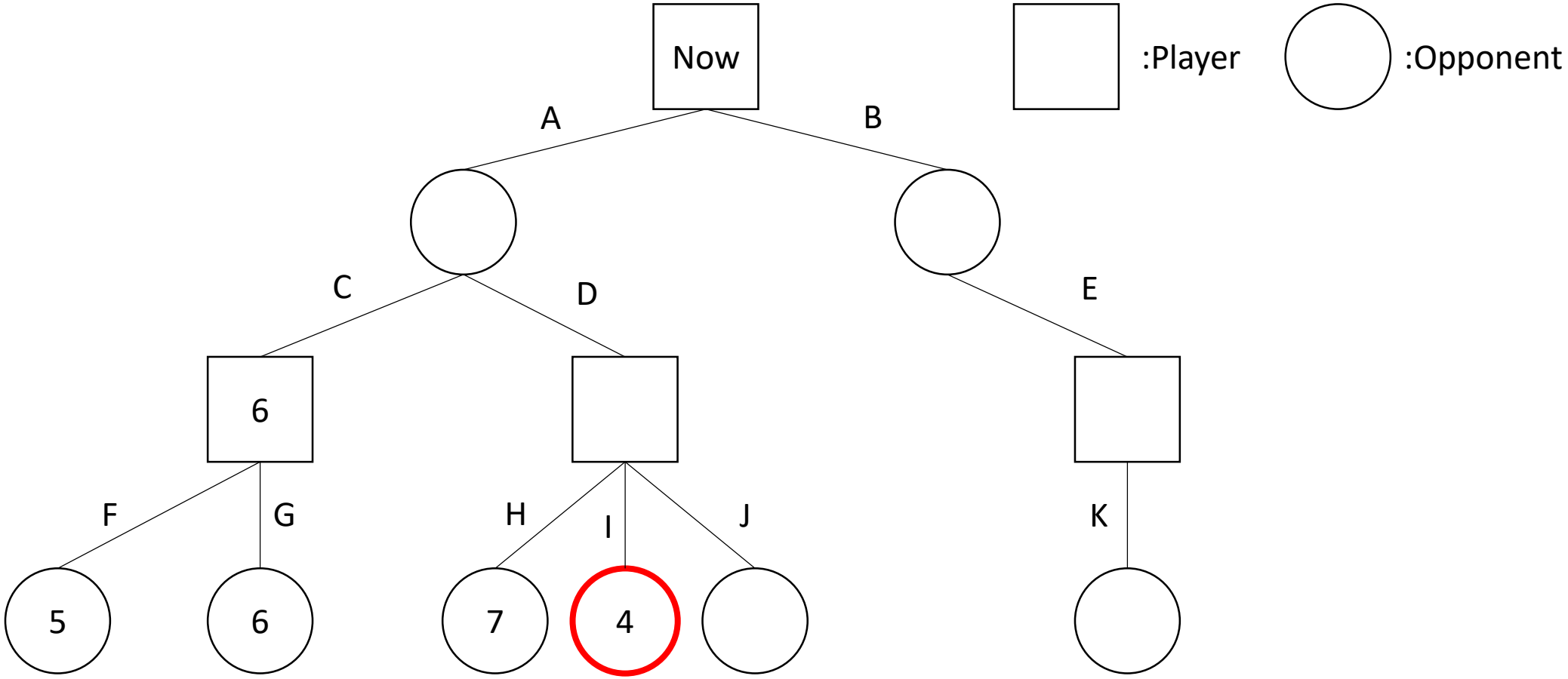

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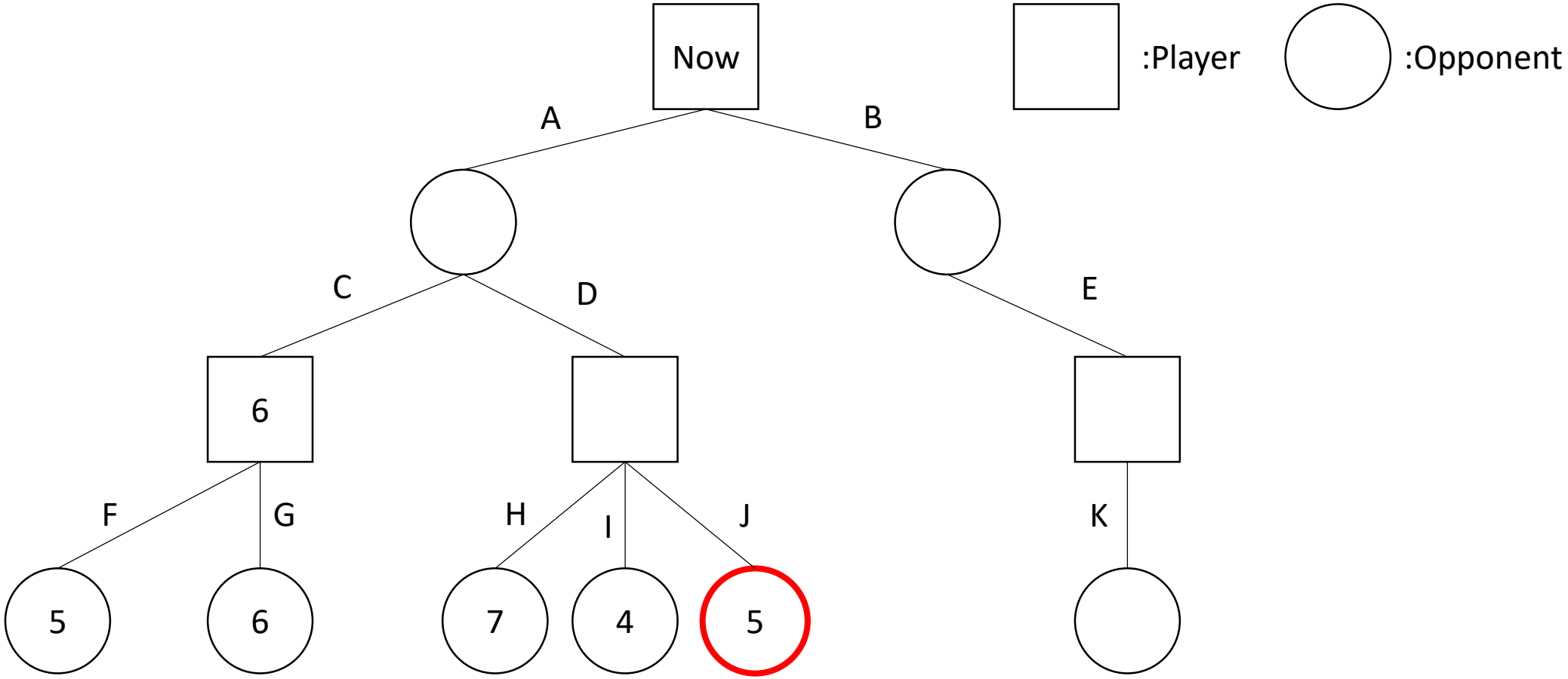

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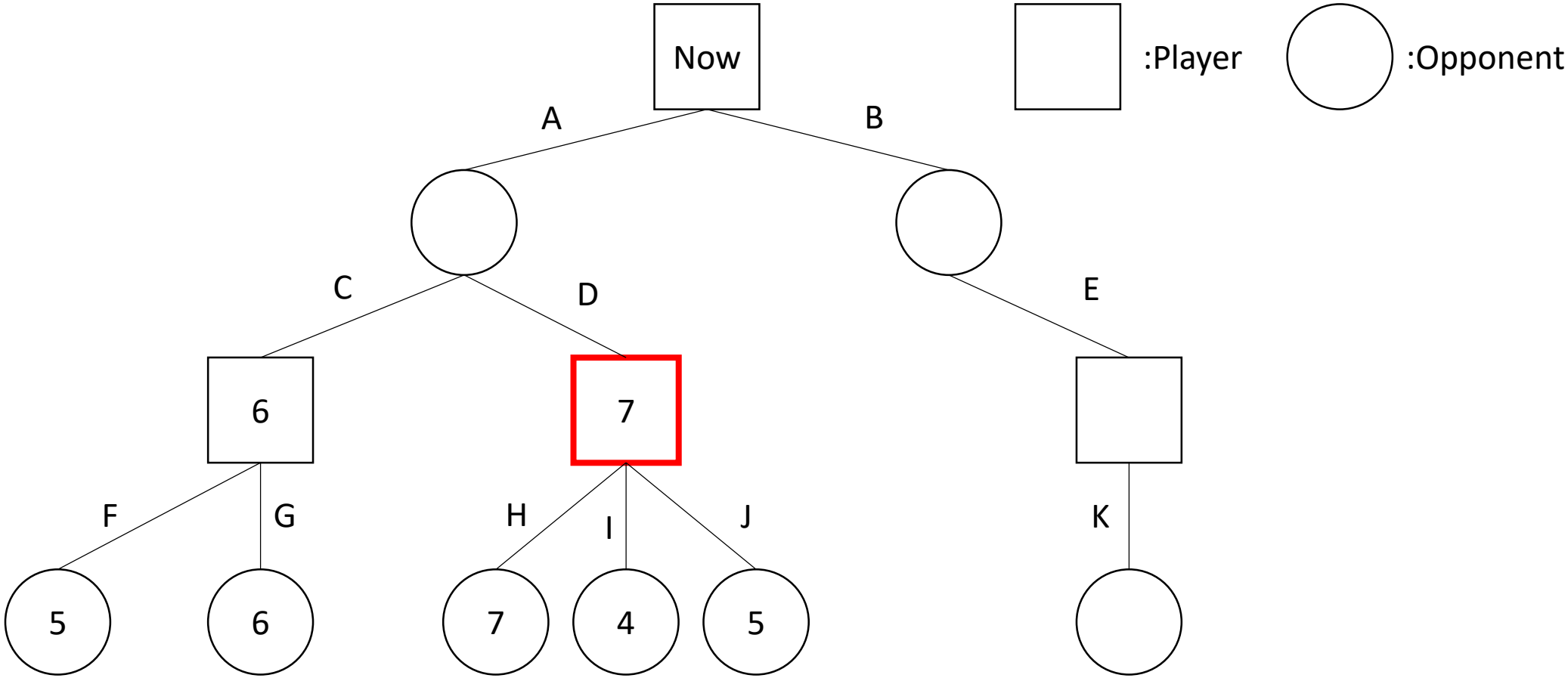
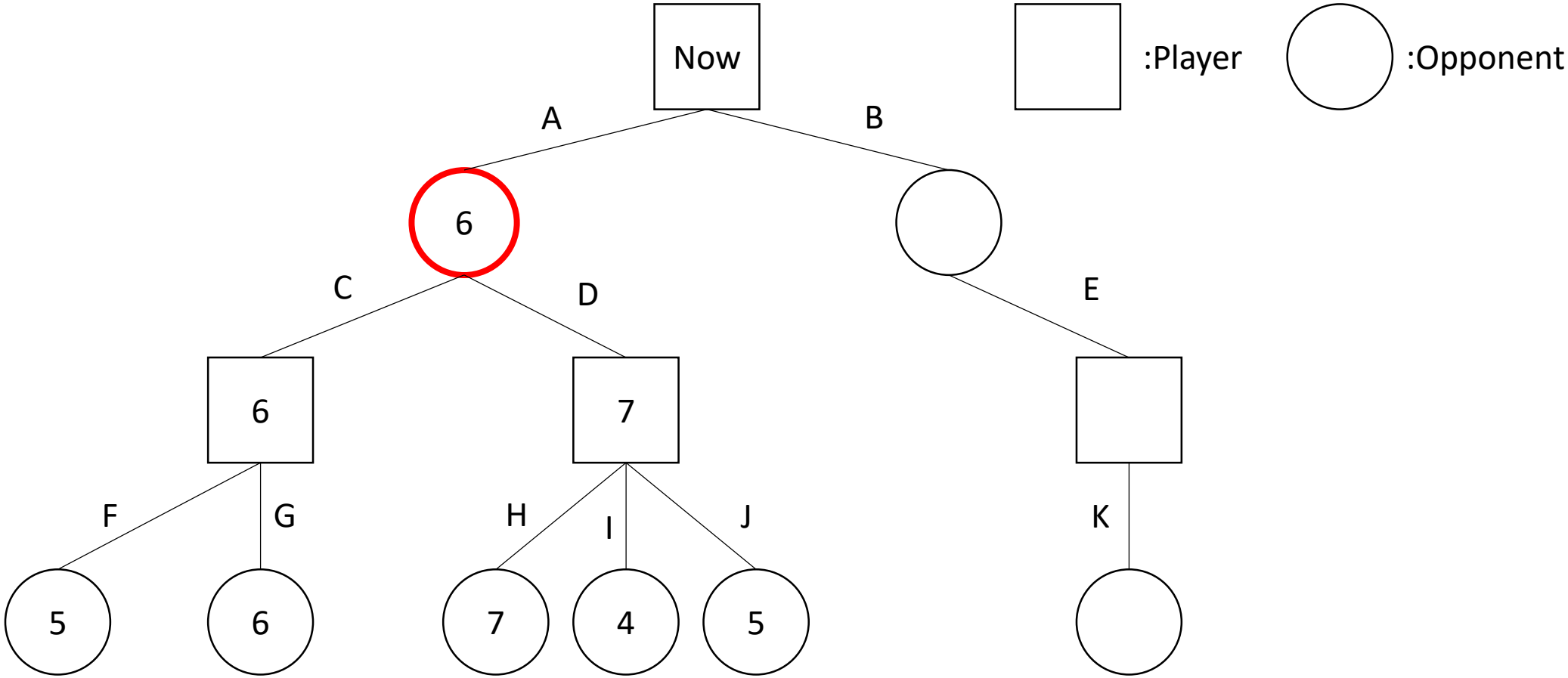
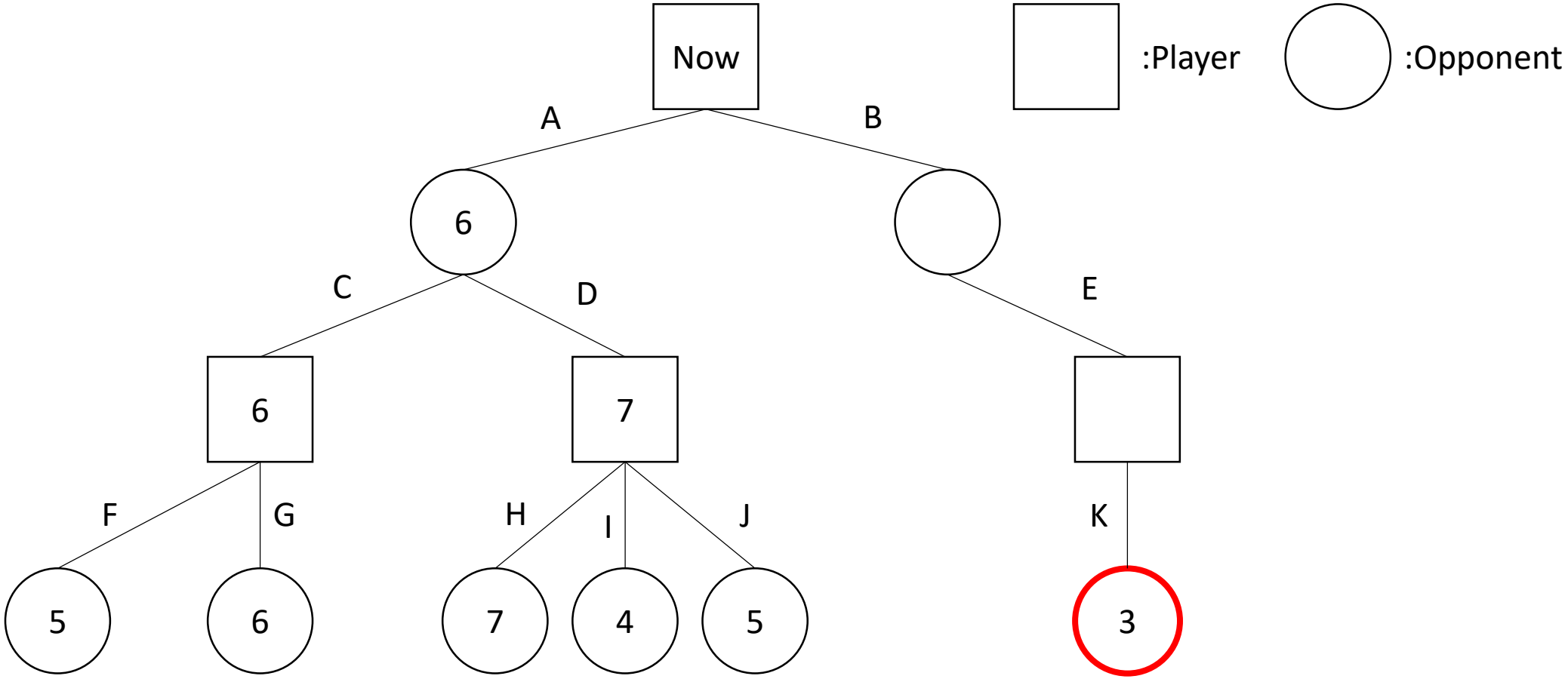


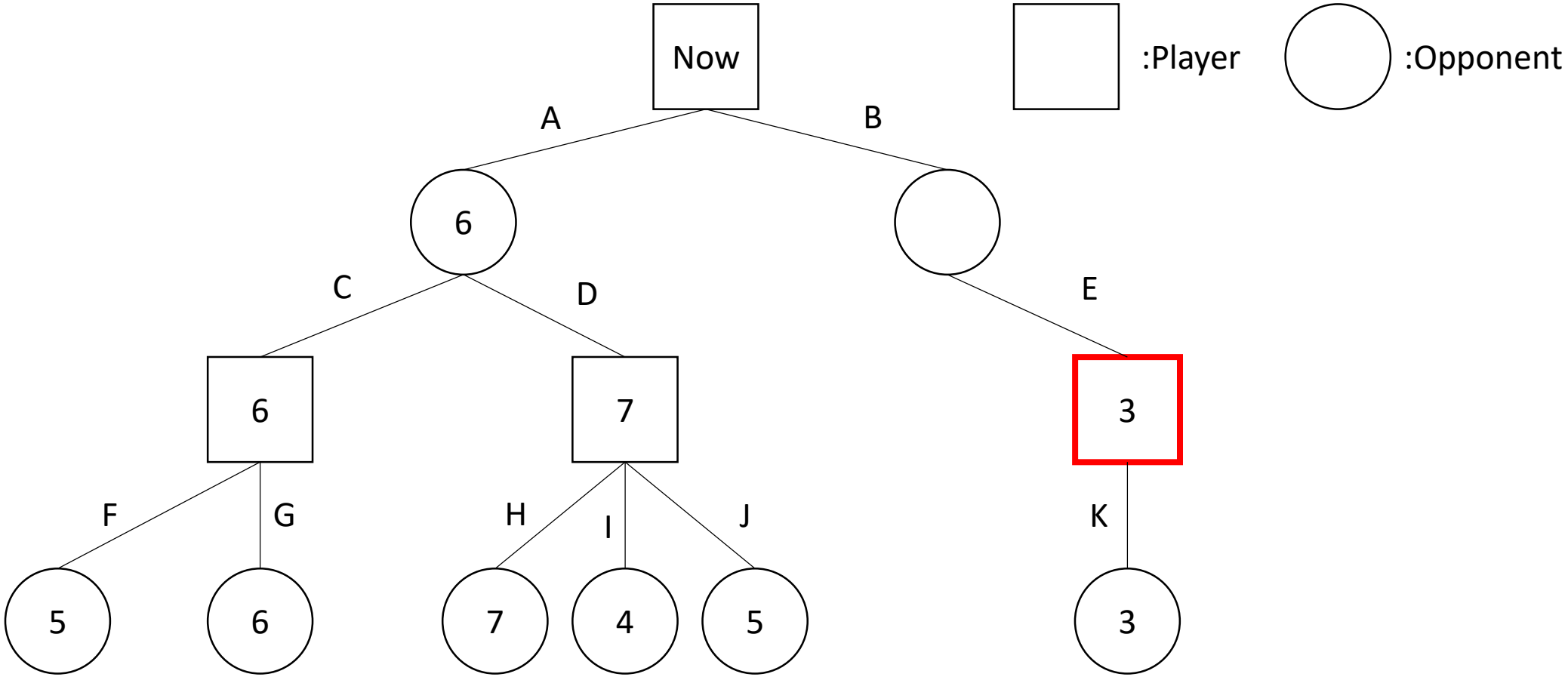
Opponent picks the smallest score



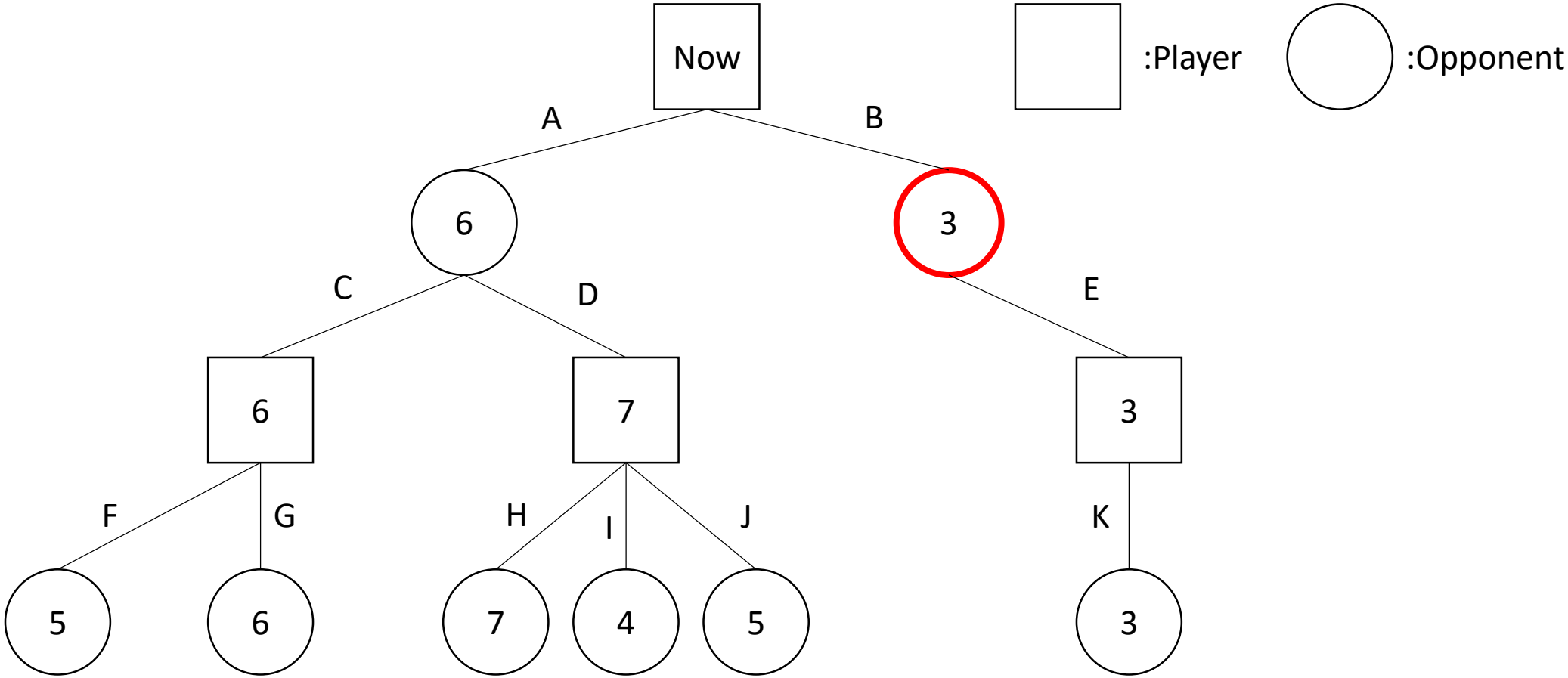
Evaluate score at leaves



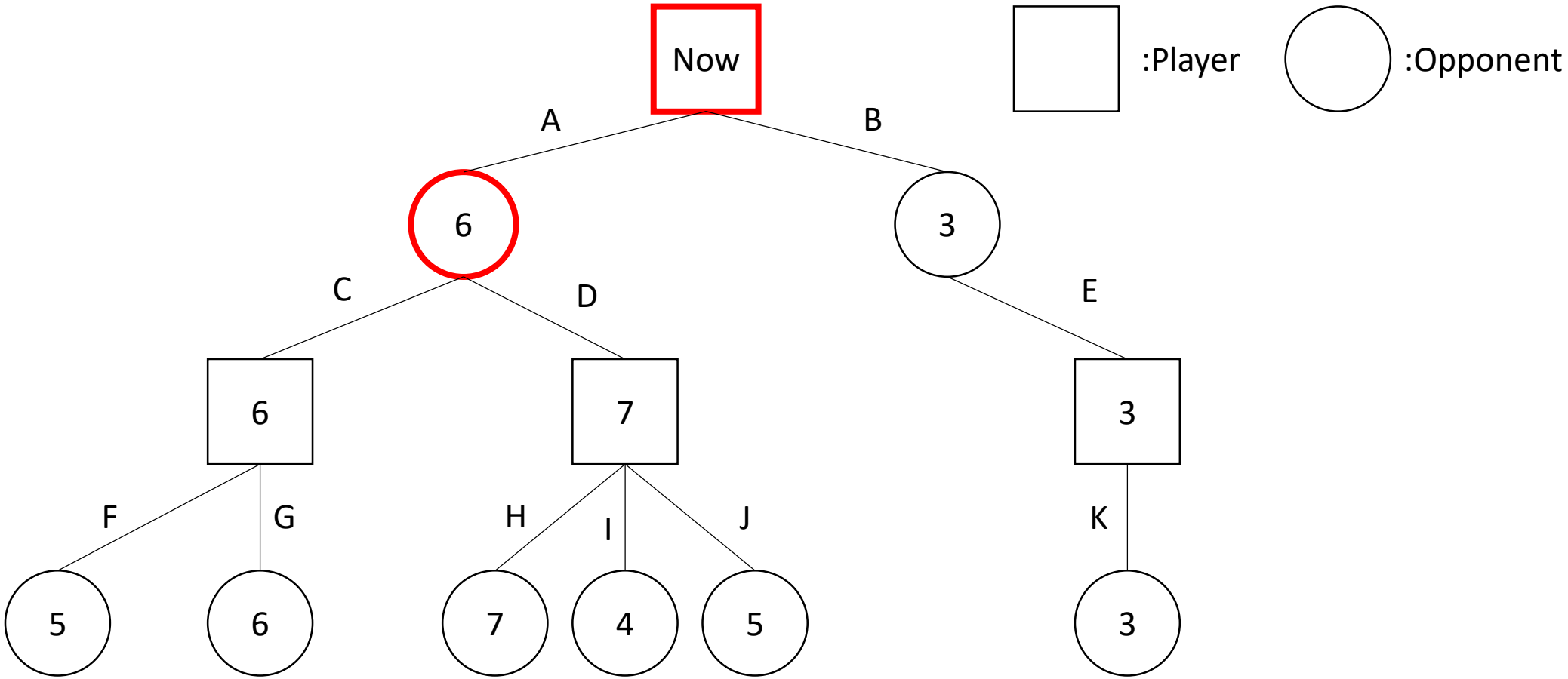
Player picks the largest score



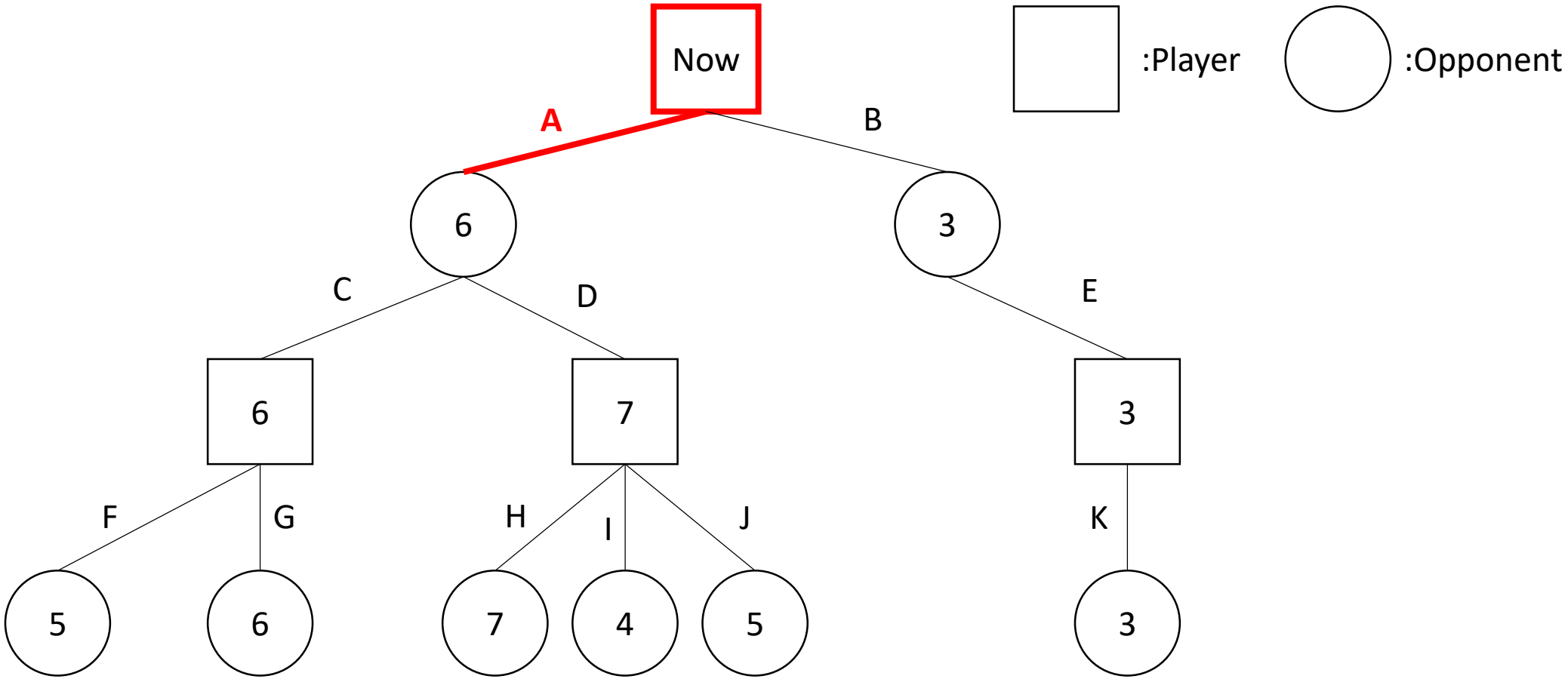
Opponent picks the smallest score



Move A has the largest score



Player picks move A to be the next move



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Alpha-Beta Pruning

- By Minimax, we can simulate our opponent's moves and pick a move with minimum risk and maximum value
- Looking forward for more steps may improve the policy
- However, the size of the search tree may drastically increase with the increase of search depth

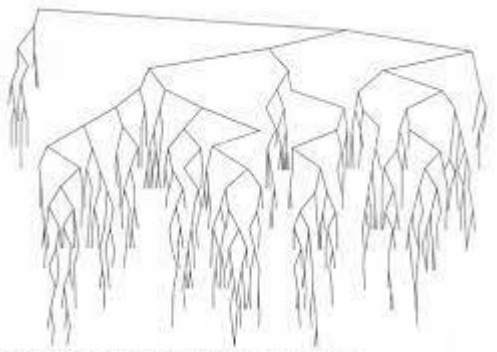
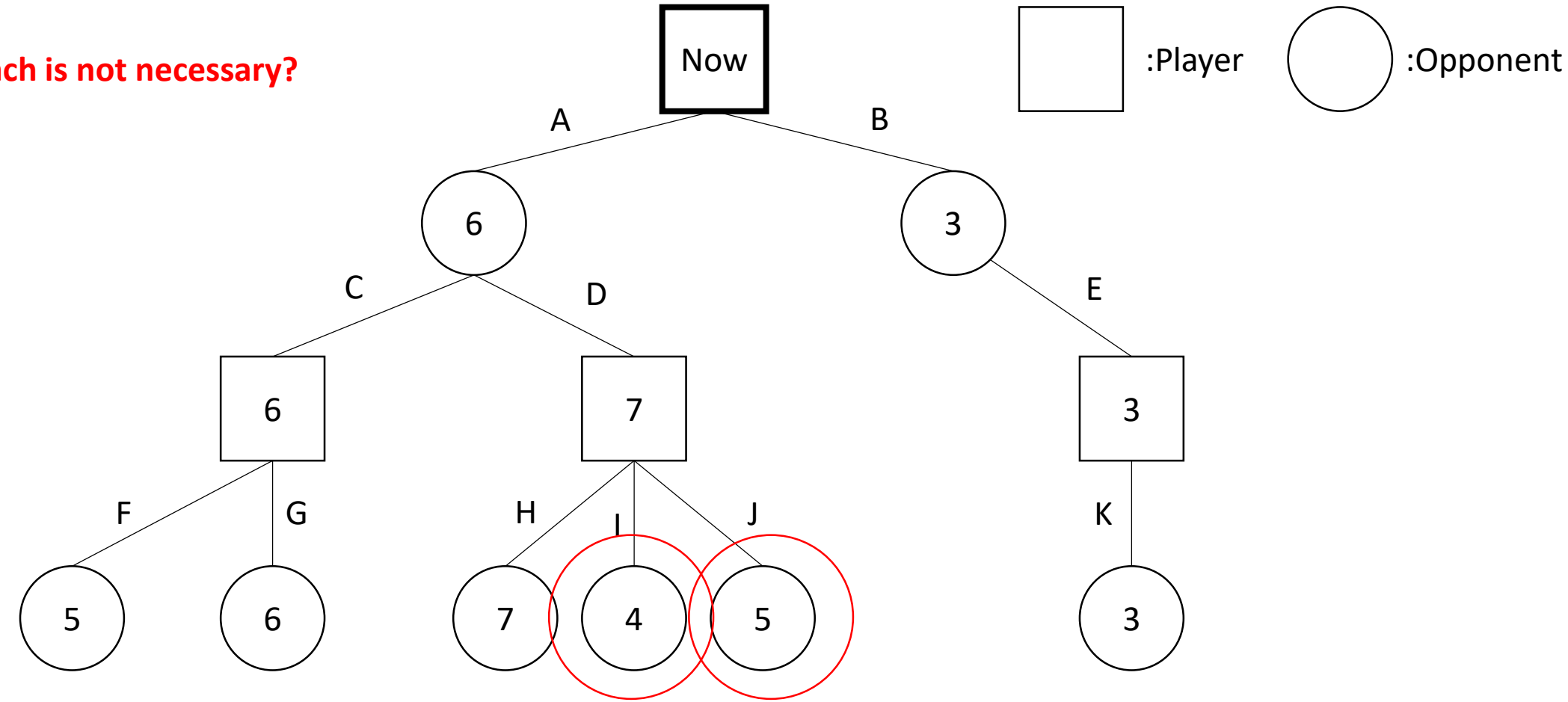


Figure 4.26 A randomly generated binary search tree

Alpha-Beta Pruning

- Since we only have limited time, if we hope to increase search depth, we must optimize the search process
- There are many branches in the minimax process which is not related to the result
- We can try to “prune” these branches to improve efficiency
- The Alpha-Beta Pruning is the improved version of Minimax method which eliminates some unnecessary branches

Which branch is not necessary?



Alpha-Beta Pruning Pseudocode

```
function alphabeta(node, depth, α, β, maximizingPlayer) is
    if depth = 0 or node is a terminal node then
        return the heuristic value of node
    if maximizingPlayer then
        value := −∞
        for each child of node do
            value := max(value, alphabeta(child, depth − 1, α, β, FALSE))
            α := max(α, value)
            if α ≥ β then
                break (* β cutoff *)
        return value
    else
        value := +∞
        for each child of node do
            value := min(value, alphabeta(child, depth − 1, α, β, TRUE))
            β := min(β, value)
            if β ≤ α then
                break (* α cutoff *)
        return value
```

Source: https://en.wikipedia.org/wiki/Alpha%E2%80%93beta_pruning

Alpha-Beta Pruning

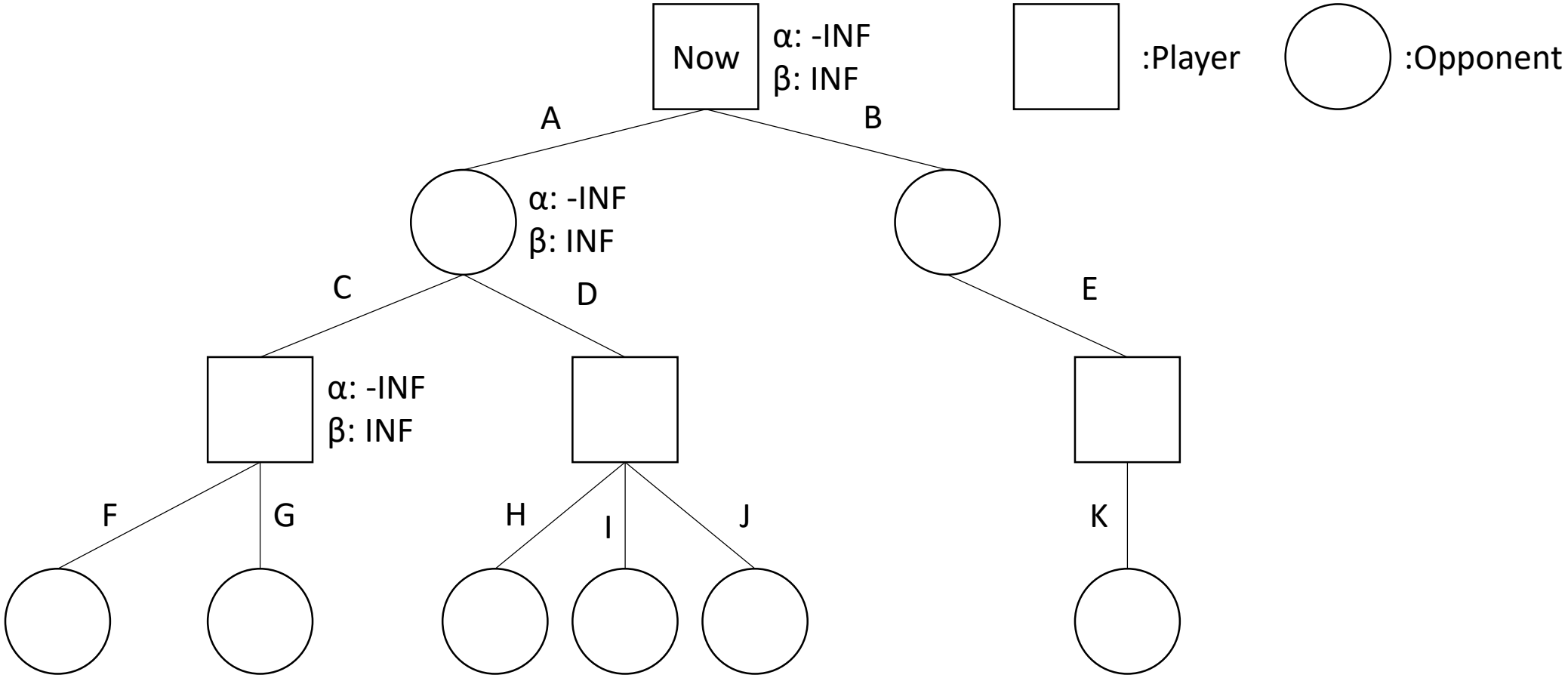
- Alpha: the maximum score that the player is assured of in the current search process

- Beta: the minimum score that the opponent is assured of in the current search process

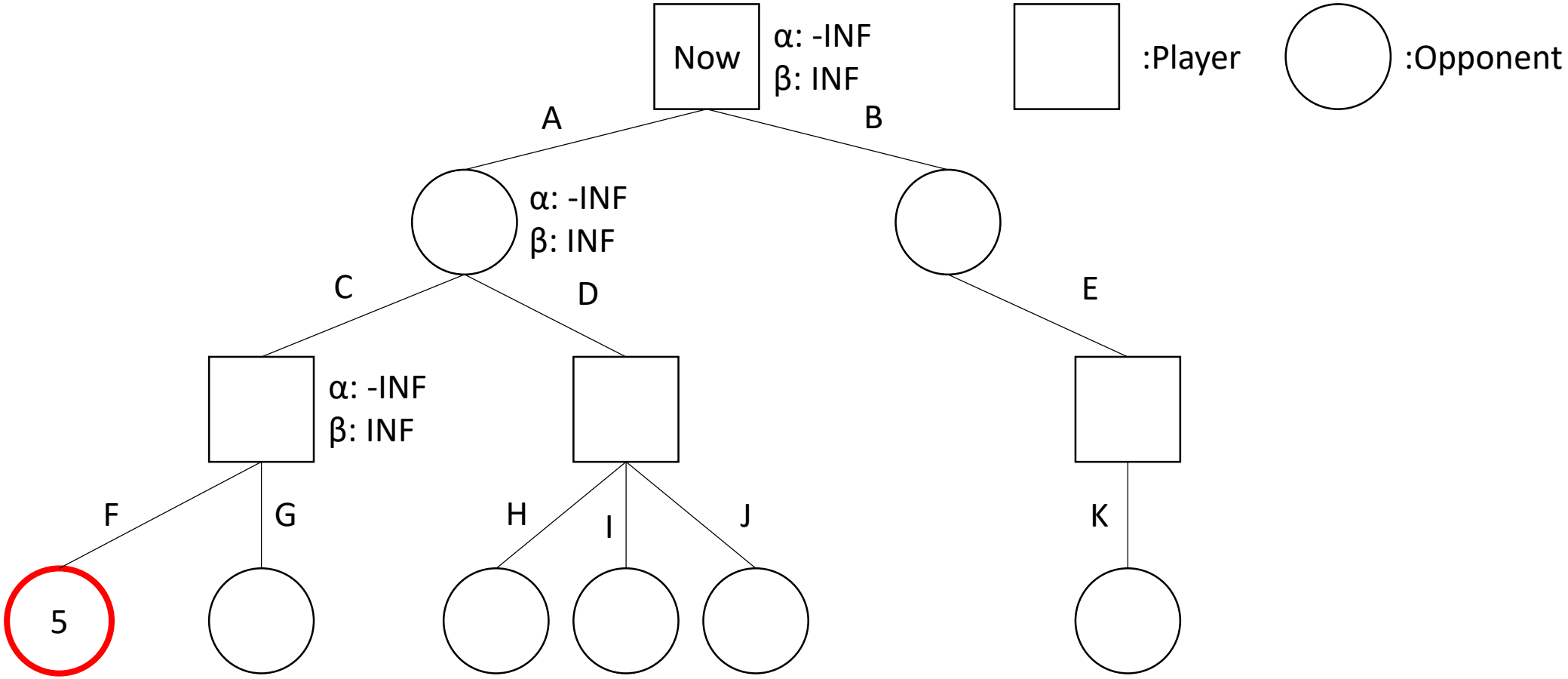
Alpha-Beta Pruning

- If alpha >= beta on a player node, we can stop to search on this branch
- In this situation, the player will return a value >= beta on this branch
- However, the opponent already has a better choice (beta)
- Thus, no matter the later discovered value on this branch, the opponent will not pick this branch
- We can “prune” this branch since it will not affect the result
- We can also stop to search if beta <= alpha on an opponent node

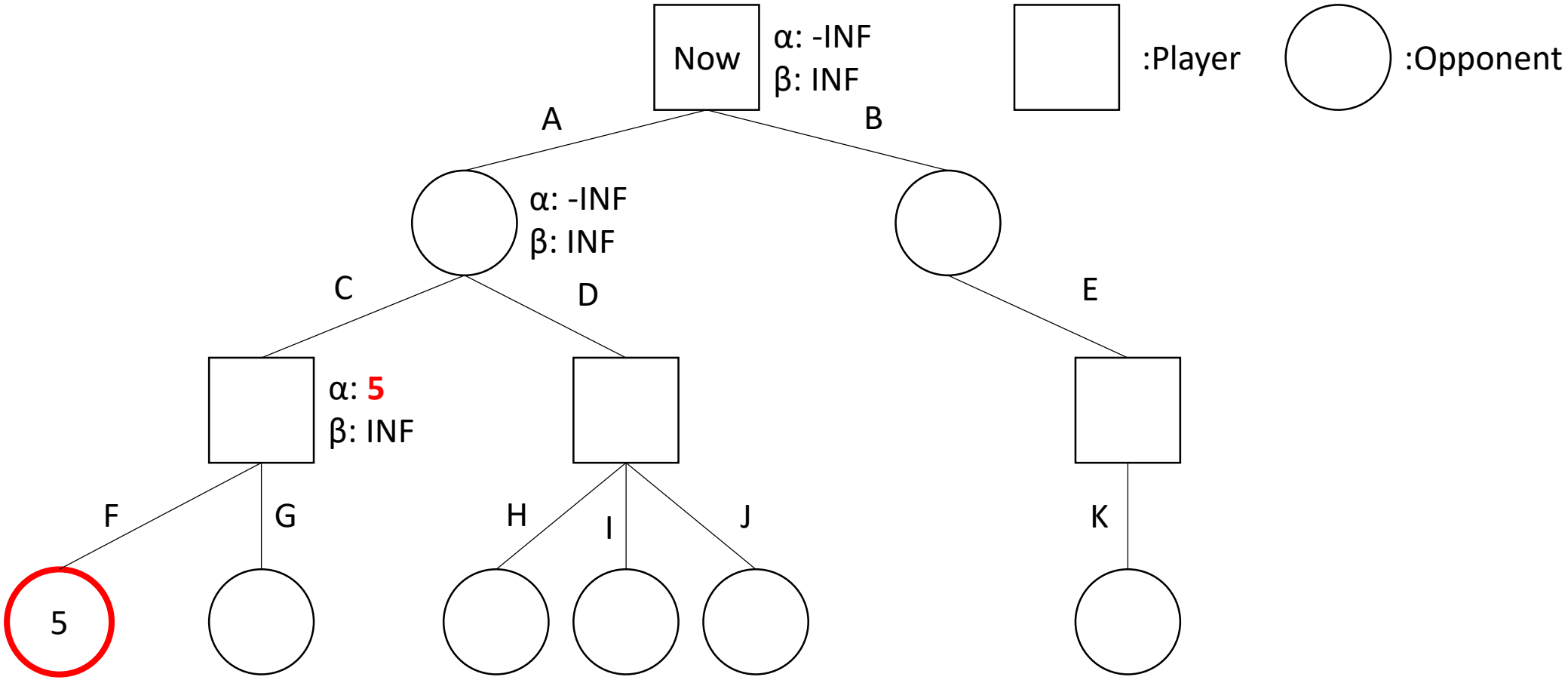
Example


Now
α: -INF
β: INF
:Player
:Opponent
A
B
α: -INF
β: INF
C
D
E
α: -INF
β: INF
F
G
H
I
J
K

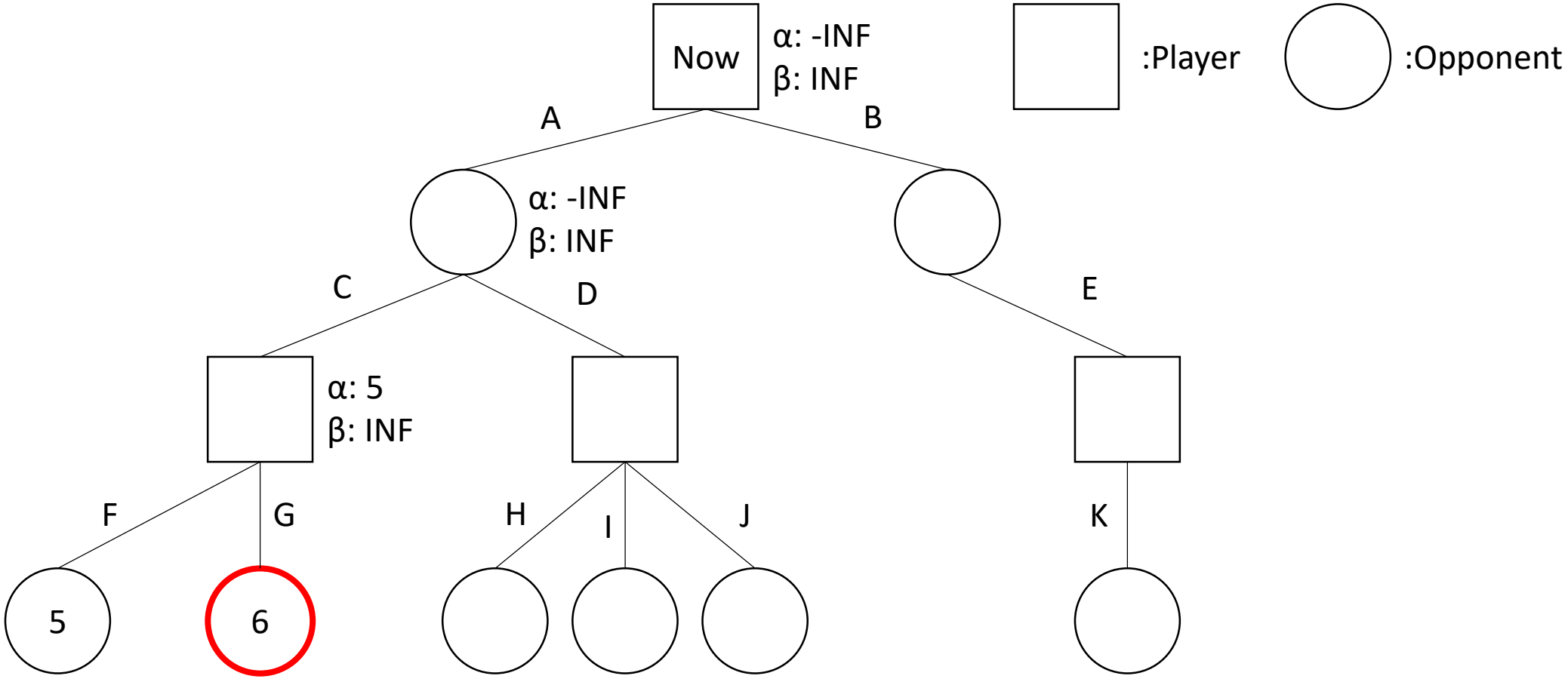
Evaluate score at leaves



Update alpha



Evaluate score at leaves



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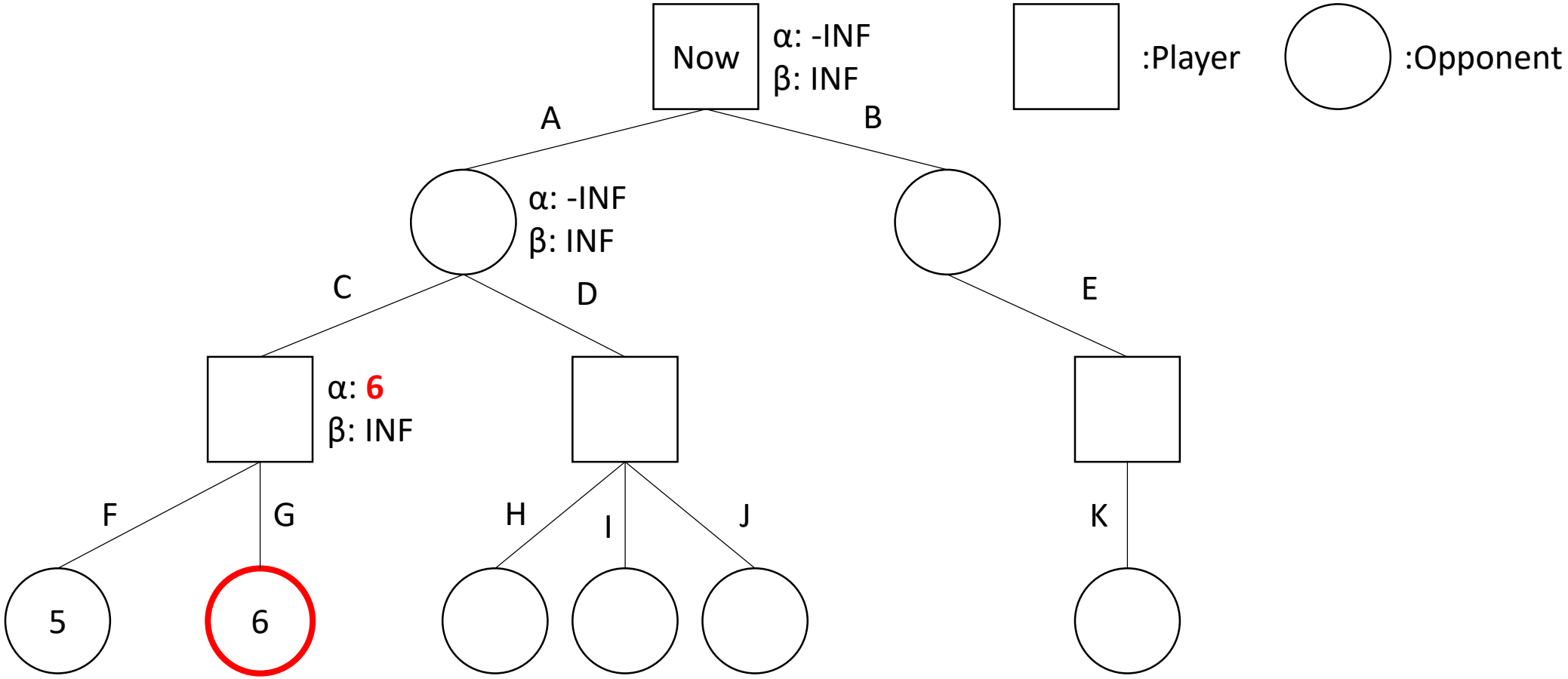
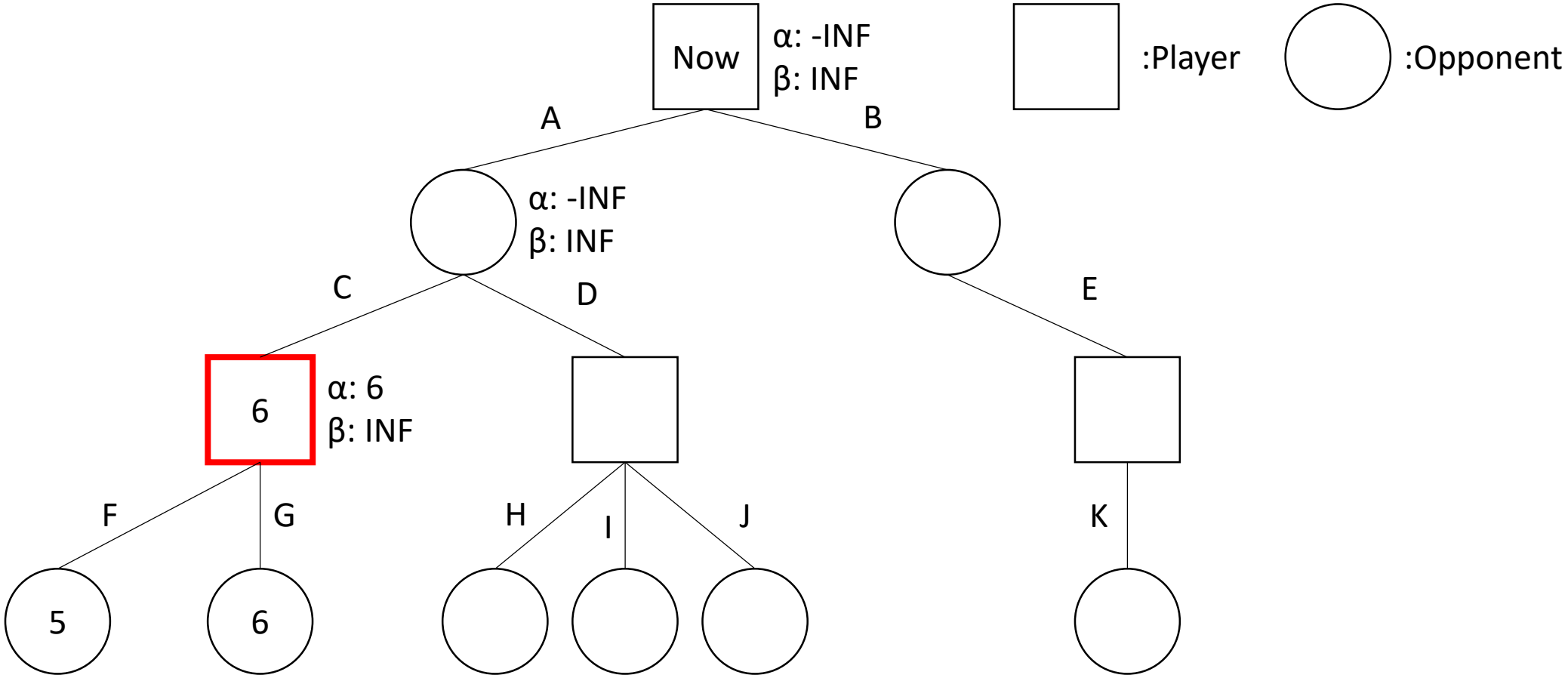
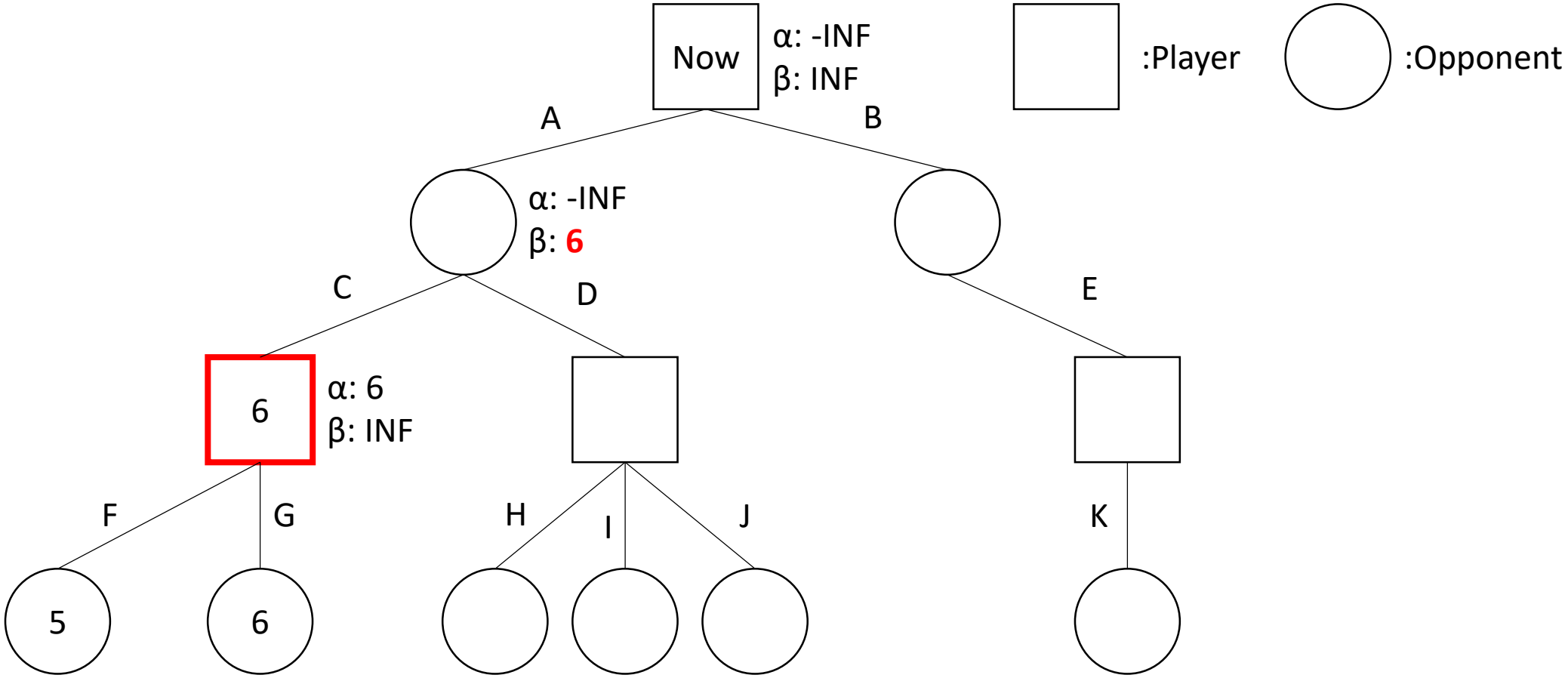


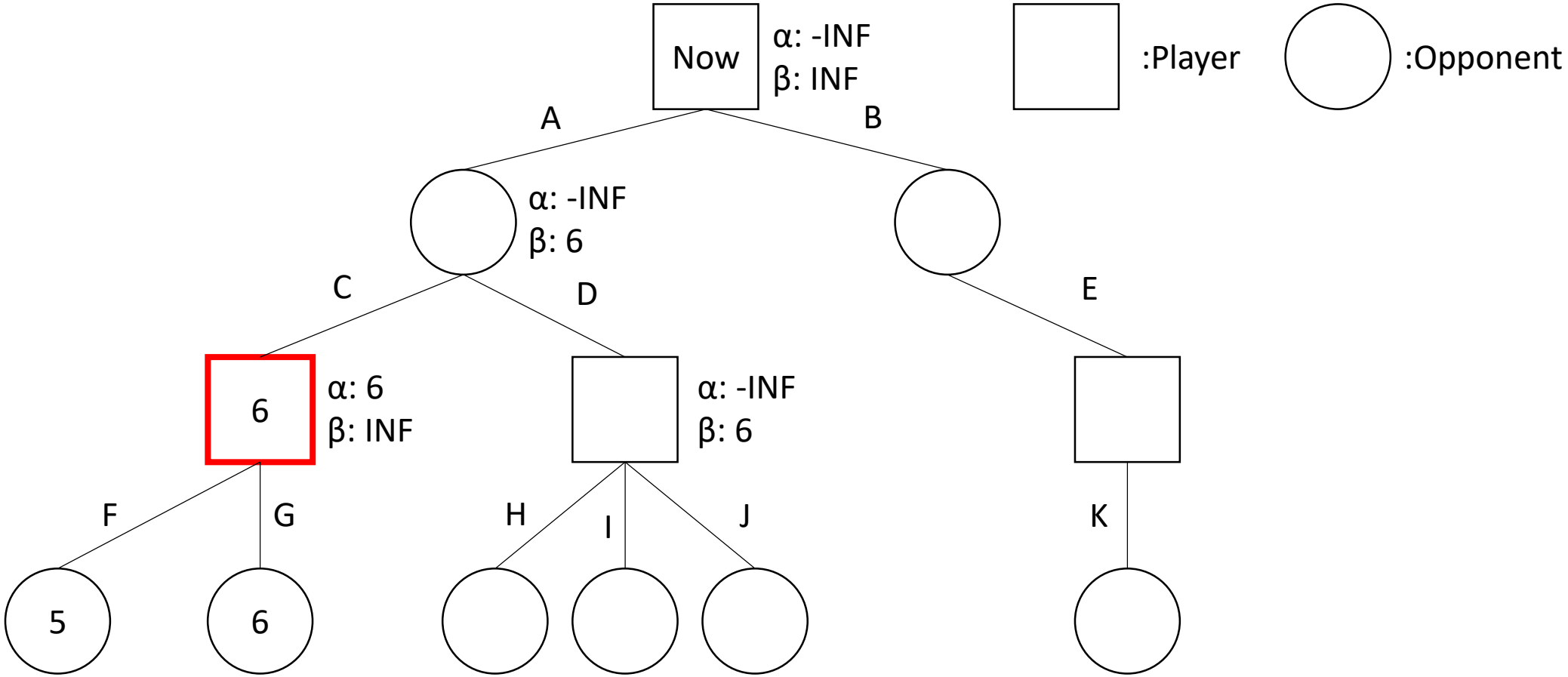
Player picks the largest score



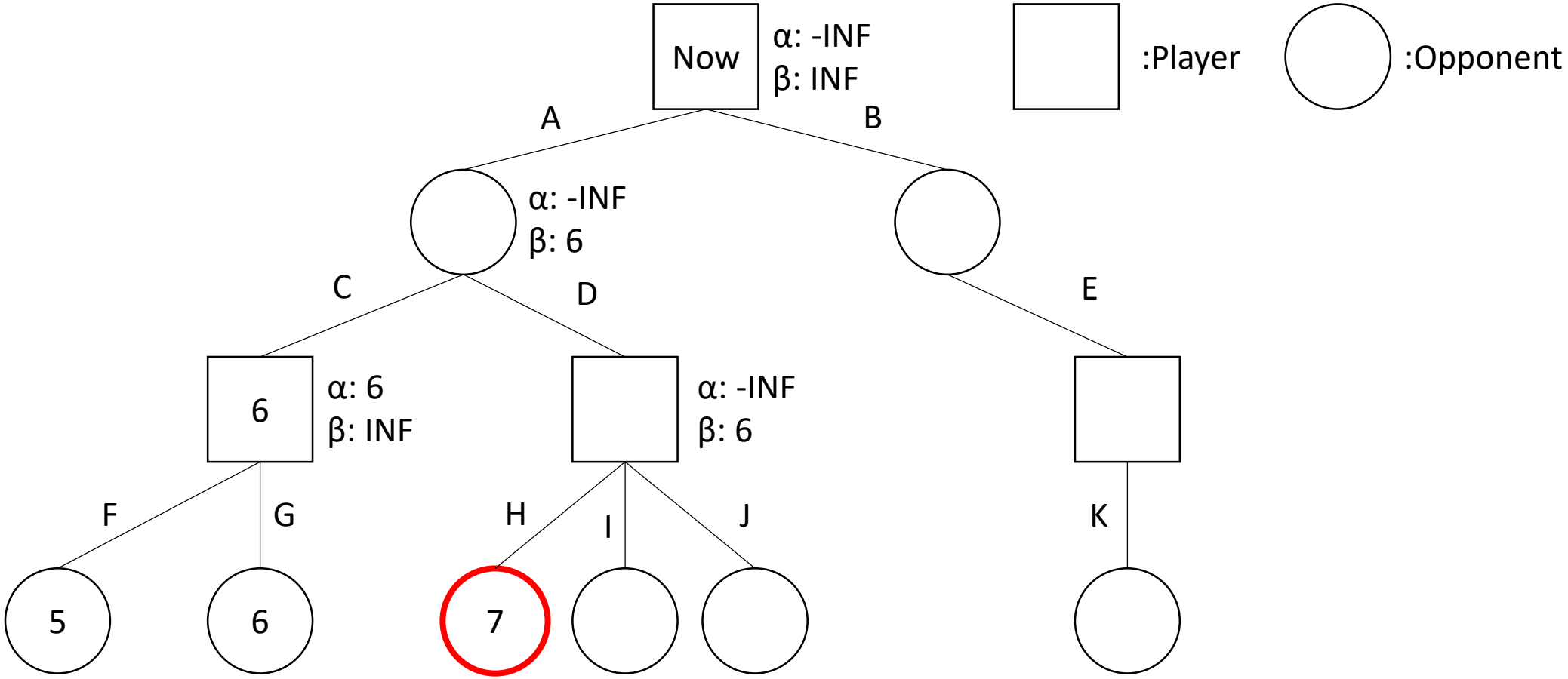
Update beta


Now
α: -INF
β: INF
:Player
:Opponent
A
B
α: -INF
β: 6
C
D
E
6
α: 6
β: INF
F
G
H
I
J
K
5
6

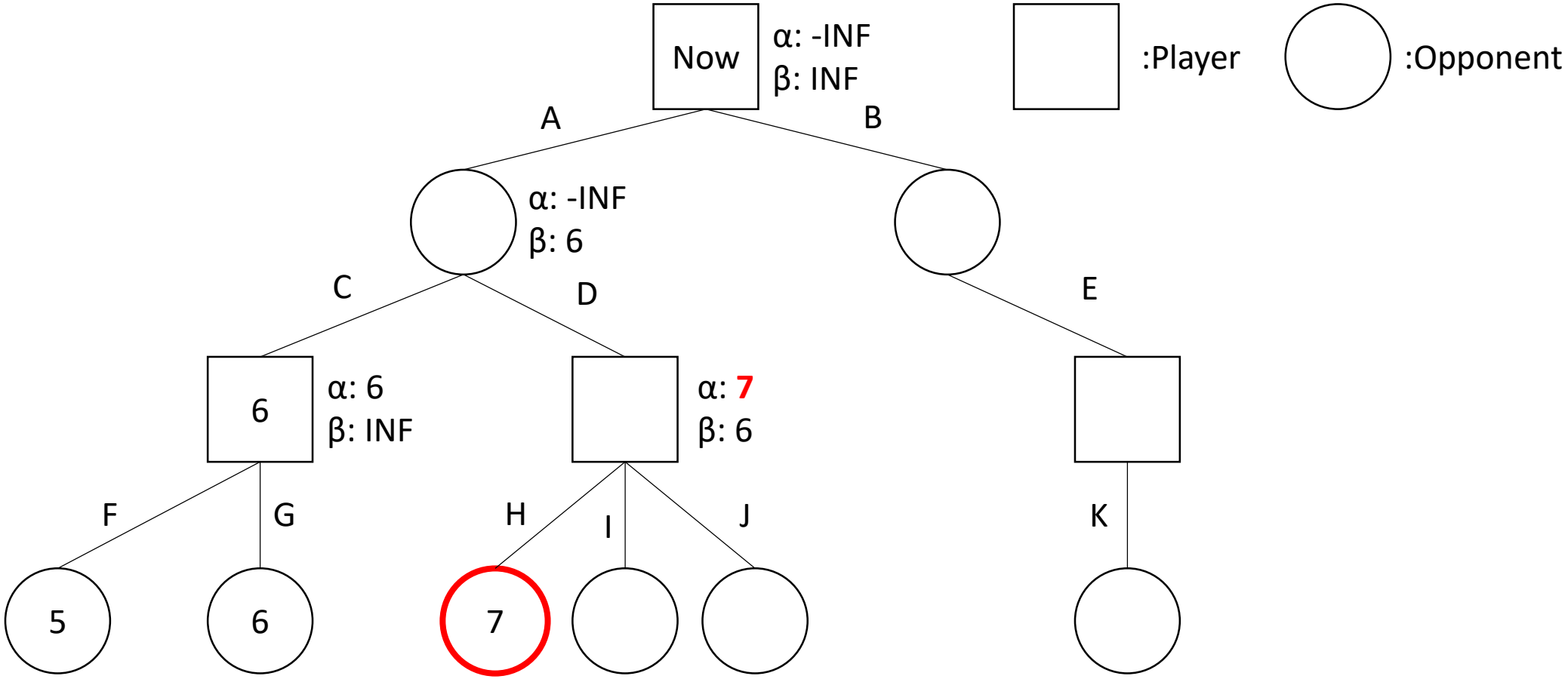
Propagate alpha and beta values



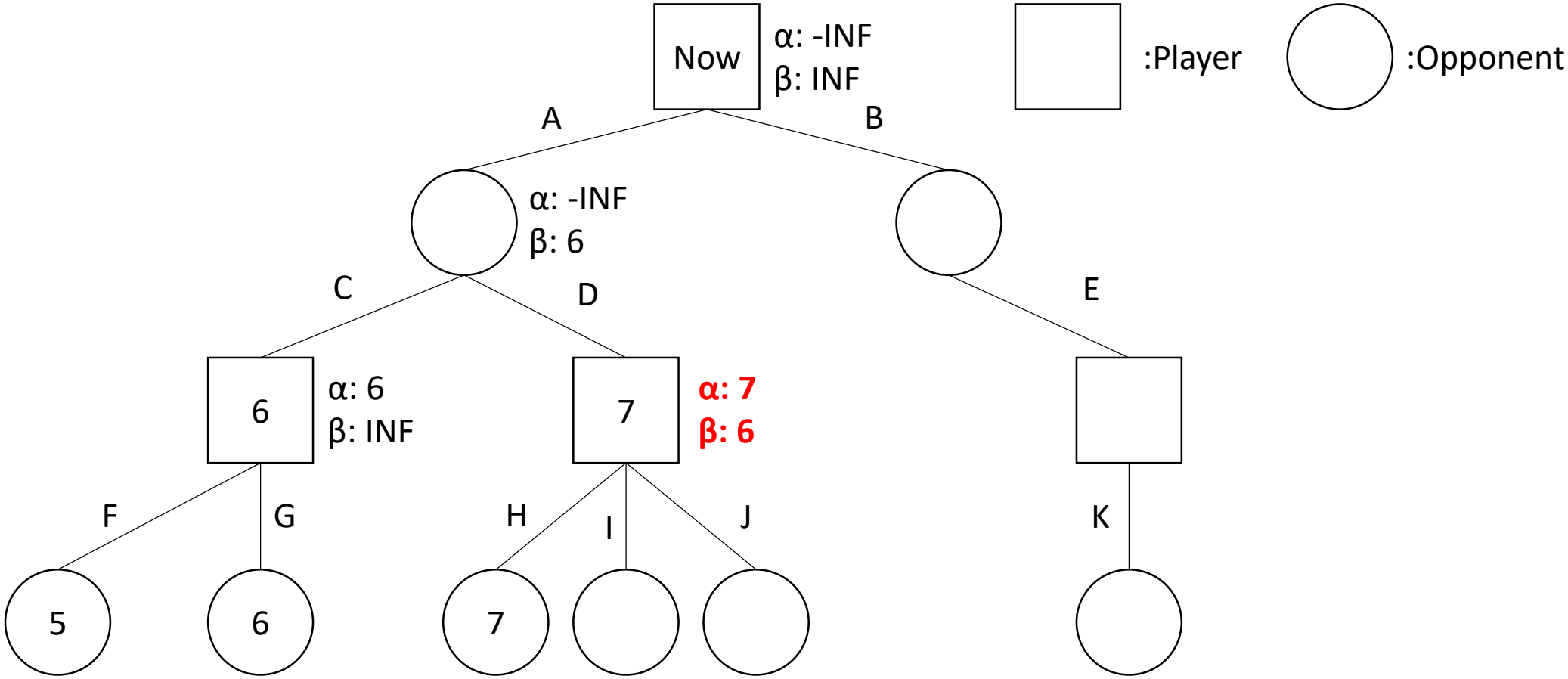
Evaluate score at leaves



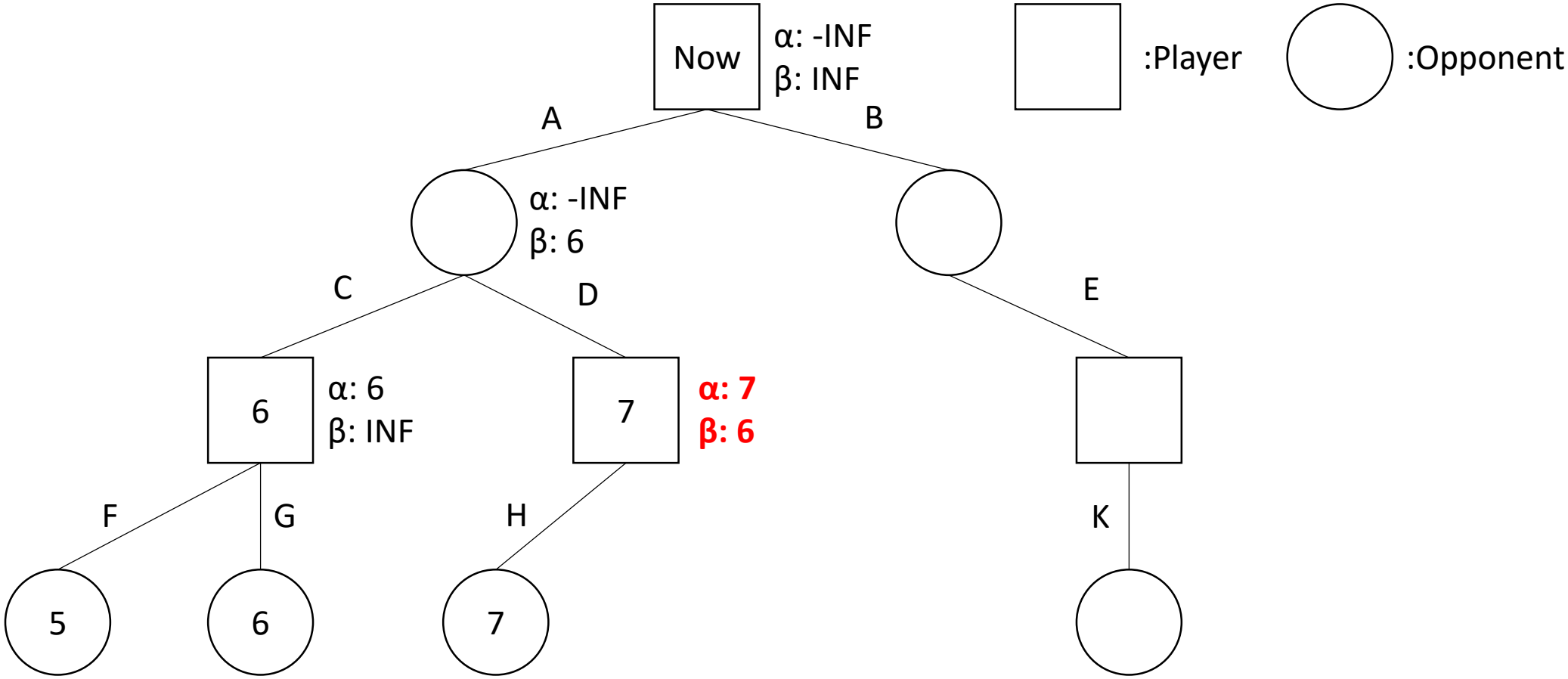
Update alpha



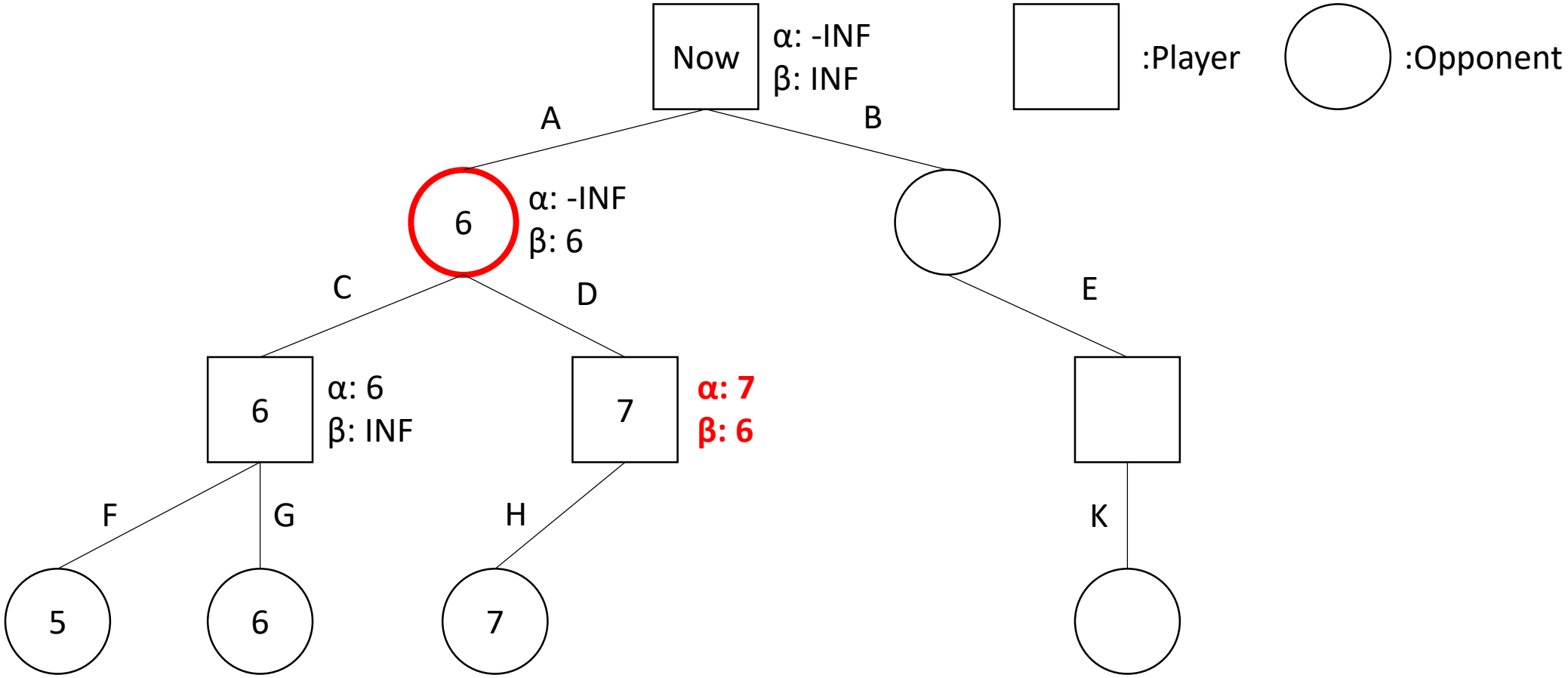
Alpha >= beta in a player node, stop searching



Alpha >= beta in a player node, stop searching



Opponent picks the smallest score



Alpha-Beta Pruning

- In the example above, we use the same search tree as Minimax
- By pruning, we eliminate branches I and J
- However, we still get the same result on branch A
- Alpha-Beta Pruning can effectively speed up the process while maintaining the same result

Outline

1. Introduction
2. Othello
3. State Value Function
4. Minimax
5. Alpha-Beta Pruning
6. How To Design Your AI
7. Package
8. Requirements
9. Grading

How To Design Your AI

- The game runner (main.cpp) executes the AIs of the player and the opponent in turns and communicates with them by files
- Your game AI should read the board status and available moves from the file “state”
- Your game AI should output your move to the file “action”

State file

- The state file consists of four parts:
- Current player (1 or 2)
- Board (8 x 8 matrix)
- Valid move number
- List of valid moves

```
1
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 2 1 0 0 0
0 0 0 1 2 1 0 0
0 0 0 0 0 2 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
4
2 3
3 2
5 4
6 5
```

Action file

- Your AI should output the next move to the “action” file
- You can keep output moves in the time limit (10 seconds)
- Only the last complete output will be considered
  - In the case on the right, (3, 5) will be accepted by the game runner
- You lose if you outputs an invalid move

```
4 2
7 1
3 5
3 5
2 2
2 4
2 4
3 5
3 5
```

How To Design Your AI

- You can refer to the “player_random.cpp” in the “src” folder of the package we provided
- Design your state value function to evaluate the board
- Implement the Alpha-Beta Pruning method and use your value function in the search process
- Run Alpha-Beta Pruning and decide which move to output

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Package Directory Structure

- Mini Project 3
  - baseline
    - windows
      - baseline<i>.exe, i := {1, 2, 3, 4, 5}
    - linux
      - baseline<i>, i := {1, 2, 3, 4, 5}
    - mac
      - baseline<i>, i := {1, 2, 3, 4, 5}
  - src
    - main.cpp
    - makefile
    - player_<description>.cpp, description := {random, infinite, partial, invalid}
  - Mini Project 3 Introduction.pptx
  - Mini Project 3 Spec.pdf

Baseline

- The baseline folder contains executables of the baselines
- If you use Windows, use the baselines in the windows folder
- If you use Linux, use the baselines in the linux folder
- If you use Mac, use the baselines in the mac folder
- We will use these baselines to test the performance of your program
- Test your program against these baselines and try to defeat them

Baseline

- baseline1 => pure random
- baseline2 => minimax with basic value function
- baseline3 => deeper minimax with basic value function
- baseline4 => alpha beta pruning with advanced value function
- baseline5 => deeper alpha beta pruning with advanced value function

Src

- The src folder contains the main program, a makefile and some provided example programs

- The main.cpp is the game runner, do not modify it
  - However, you can refer to it when implementing game simulation of minimax

- The makefile helps you compile your code
  - You can also compile by hand, make sure you set the flags -Wall and -Wextra

Src

- The example programs are some situations you might face while testing your program
- player_random.cpp => the pure random AI
  - You can refer to this one and write your own code
- player_infinite.cpp => only the last move you output in your turn will be considered
- player_invalid.cpp => you lose if you output an invalid move
- player_partial.cpp => moves in incomplete format will not be considered

How To Compile Your Code

- To compile all programs:
- Type make when your working directory is ‘src’

- To compile <program_name>.cpp:
- Type make <program_name> when your working directory is ‘src’

- To clean the executables:
- Type make clean when your working directory is ‘src’

How To Test Your Code

- If you use Windows, type the command below in cmd:
- main.exe <AI1>.exe <AI2>.exe

- If you use Linux / Max, type the command below in terminal:
- ./main ./<AI1> ./<AI2>

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Requirements - Code

- Design and implement an AI that can play the boardgame Othello
- Your AI should read the board from file and write next move to file
- Design a value function to evaluate the score of the board
- Enhance the policy of your AI with Alpha-Beta Pruning

Requirements - Code

- If you are not satisfied by the Alpha-Beta Pruning algorithm, you can try some more advanced methods. However, make sure you can explain how Minimax and Alpha-Beta Pruning works during demo

- If you cannot complete the Alpha-Beta Pruning algorithm, implementing the basic Minimax algorithm also gives you some score

Requirements - Code

- You will lose immediately if your program outputs an invalid move
- Time limit for each move is 10 seconds, and the memory limit is 4GB
- You can keep output moves in the limited time. Only the last successful output move is used by the game runner
- Please refer to the spec for more detailed rules

Requirements - Submission

- Please use C++ and write your program in a single file
- Your program should be named as <student_id>_project3.cpp
- Your program will be compiled in a GNU / Linux environment by:
- g++ -O2 -std=c++14 -Wall -Wextra <student_id>_project3.cpp
- Please make sure your program can be compiled by the command above with no error

Requirements - Report and Demo

- You should write a report to elaborate on how you design your AI
- The report is not directly graded, but is your only available reference through the TA demo (You cannot refer to your code in demo)
- You must attend the demo and answer the questions from TA
- The demo date and method will be announced soon

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Grading

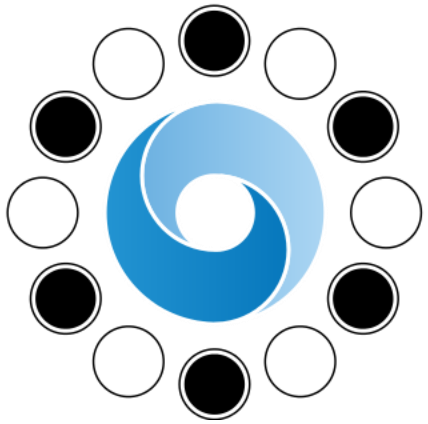
- The project accounts for 9 points of your total grade
- Beat every baseline => +5 points (1 point for each baseline)
- Implement Tree search (Minimax) => +2 points
- Design of your state value function => +1 point
- Implement Alpha-Beta Pruning => +1 point

Grading Bonus

- (Bonus) Uses version control software => +1 point
- Include a screenshot with more than 3 commits in your report

- (Bonus) Class ranking => At most +3 points
- You can attend the class ranking if you beat all baselines
- Your AI will play against other AIs of your classmates and gain bonus score according to your ranking

Develop four own AI!



AlphaOthello