TREES & ADVERSARIAL SEARCH
Lecture-4(Russel & Norvig)

Artificial Intelligence
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Why do we study game playing in the context of AI????

- Abstract nature of games makes them an appealing subject of study
- Game playing is a very interesting meeting point for human and computational intelligence…..Human intelligence vs. Computational intelligence
- Require making decisions even when not possible to calculate an optimal strategy
- Heavy penalty for in-efficiency…game playing has given rise to many ideas on how to make best use of time
- Two person games are more complicated because of the presence of a 'hostile' and essentially unpredictable opponent
- ***Does winning a game absolutely require human intelligence?***

TYPES OF GAMES

- We want to look at games that are
  - Deterministic
  - Finite
  - Discrete
  - Turn-taking
  - Two-player
  - Zero-sum
  - Perfect information
- Zero-sum Game
  - Gains of one player = Losses of the other player
- Discrete
  - Game states and decisions are finite
- Deterministic
  - No chance is involved e.g. no throwing of die
- Games with perfect information
  - Both players can see the states…each decision made sequentially…no simultaneous moves
  - Scrabble does not have perfect information available to the other player
  - Example: Chess, Go, Tic Tac Toe
- Finite
  - Finite number of states and decisions, e.g., tennis is not finite

ADVERSARIAL SEARCH

- How programs play board games
  - Chess
  - Checkers
- One choice leads to another making a tree of choices
  - Minimax search
  - Alpha-Beta pruning

GAMES … SOME DEFINITIONS

- Game can be defined as a kind of search problem
  - Initial State S: Includes board position and identifies the player to move
  - Successor Function Succ: Returns a list of (move, state) pairs each indicating a legal move and resulting state
  - Terminal Test: Test that determines when a game is over.
  - Terminal State T: State where the game has ended
  - Utility Function/ Payoff Function/ Objective Function V: Function that gives a numeric value for the terminal state, e.g.
    - Chess +1, -1, or 0 (win, loss, or draw)
  - Game Tree: Initial state and legal moves for each side define a game tree for the game

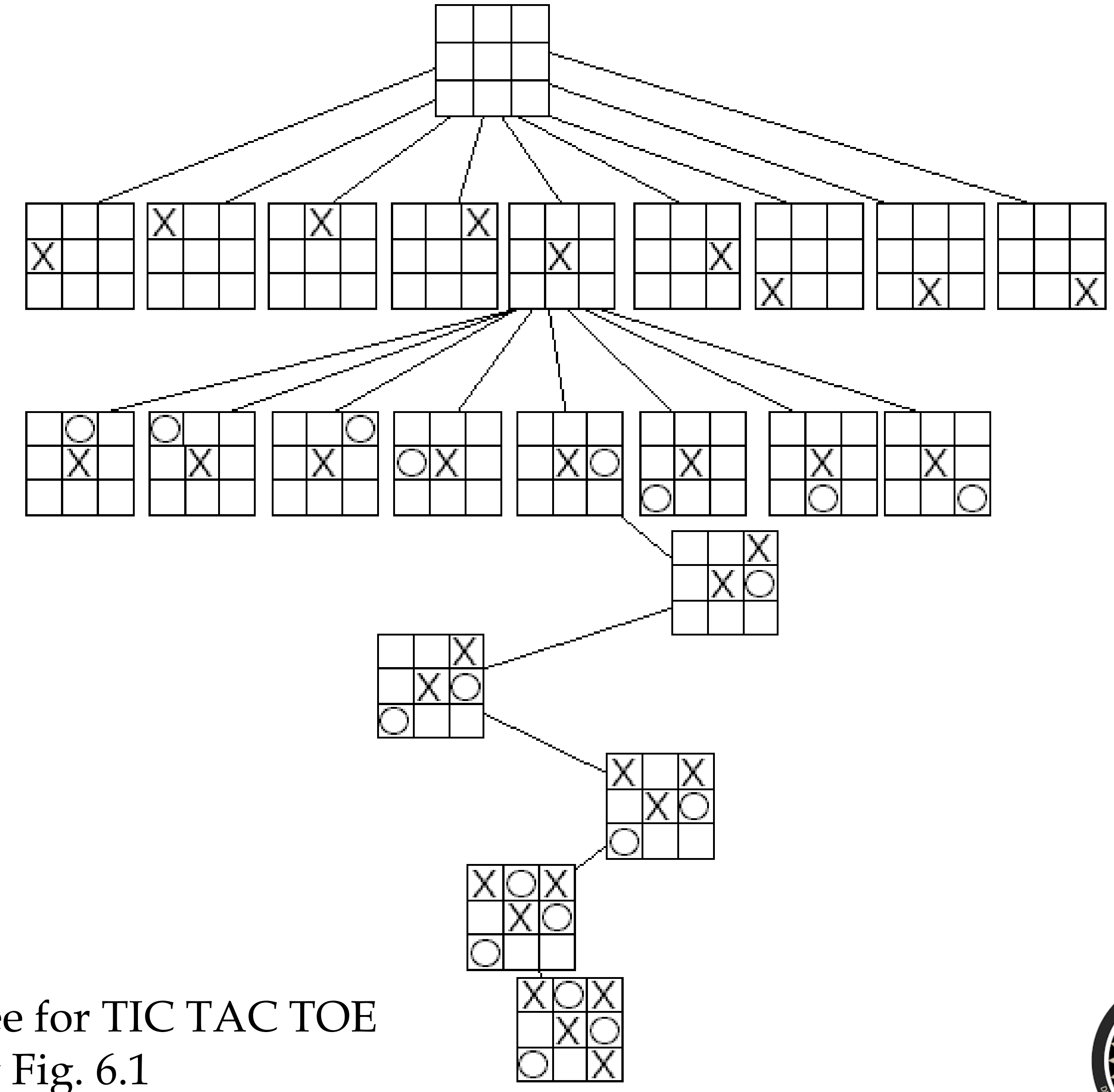
GAME TREE

- Nodes denote board configurations
- Branches indicate how one configuration can be transformed into another by a single legal move
- Ply p of a game tree = Number of levels of the tree including the root
- $p = d+1$
- A *Move* is one player's choice and the other player's reaction

MORE ABOUT GAME TREES…

- Situation analyzer converts all judgments about board situations into numbers
- Positive numbers indicate favor to one player
- Negative numbers indicate favor to the other player
- Process of computing a number that reflects board quality is called static evaluator
- The number computed is called static evaluation score
- Game theoretic value: The value of a terminal that will be reached assuming both players use their optimal strategy

Example of Search Tree



Part of the search tree for TIC TAC TOE
See Russel & Norvig Fig. 6.1

Is Exhaustive Search Possible???

- In chess if the effective branching factor is 16 and depth is 100 then the possibilities are of the order of 100^{120}
- Would British Museum Search be a good idea in this case???

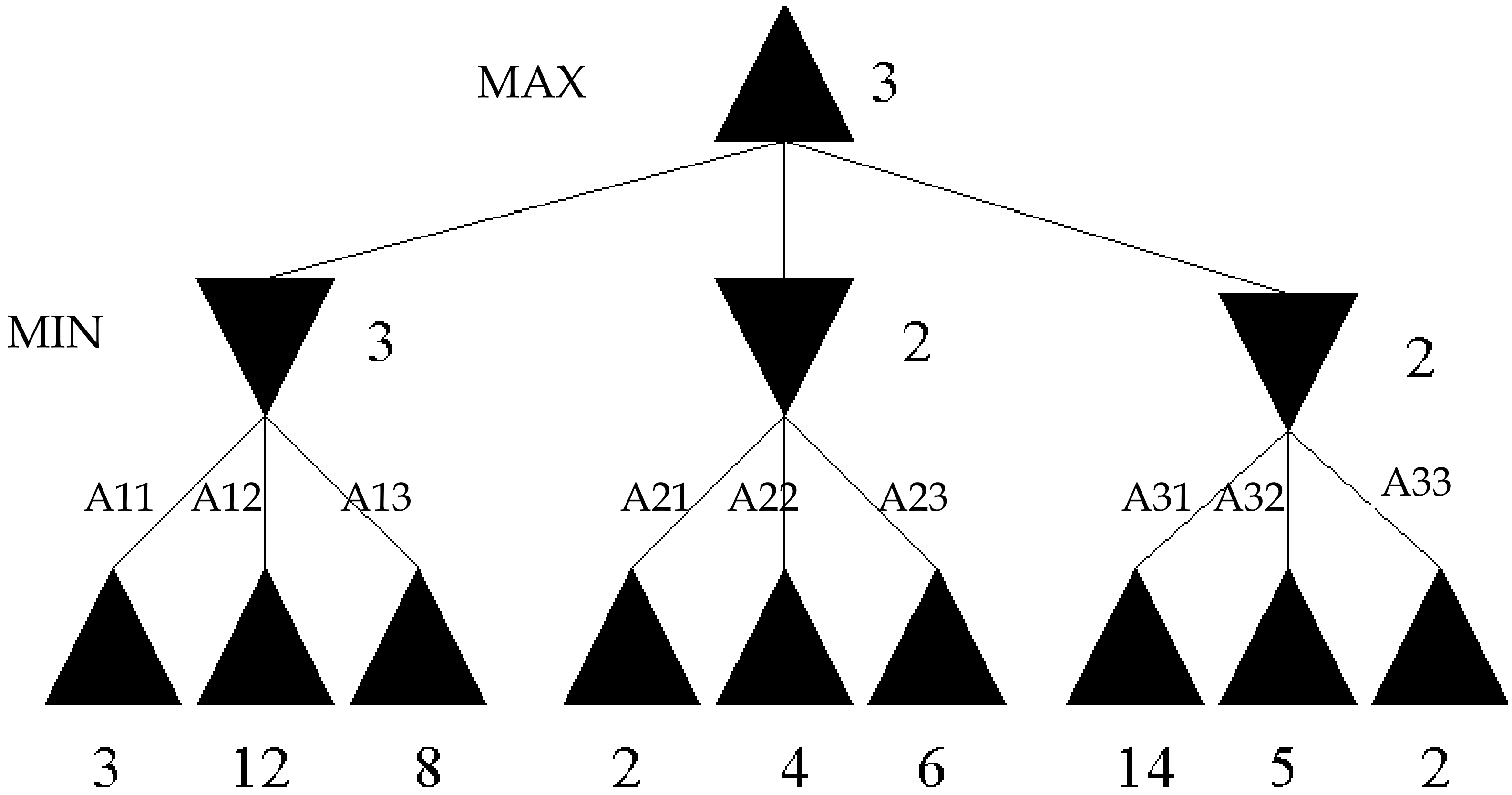
Minimax Procedure

- Opponents in a game are MAX and MIN
- MAX or maximizer is the player trying to win and maximize his/her advantange
- MIN or minimizer is the opponent attempting to minimize max's score
- We have a zero sum game
- MIN uses the same information and tries to move to a state that is worst for MAX

ALGORITHM

- When limit of search is reached, compute static value of current position relative to appropriate player
- If level is minimizing level use minimax on children of current position and report minimum of result
- If level is maximizing level use minimax on children of current position and report maximum of result

MINIMAX EXAMPLE



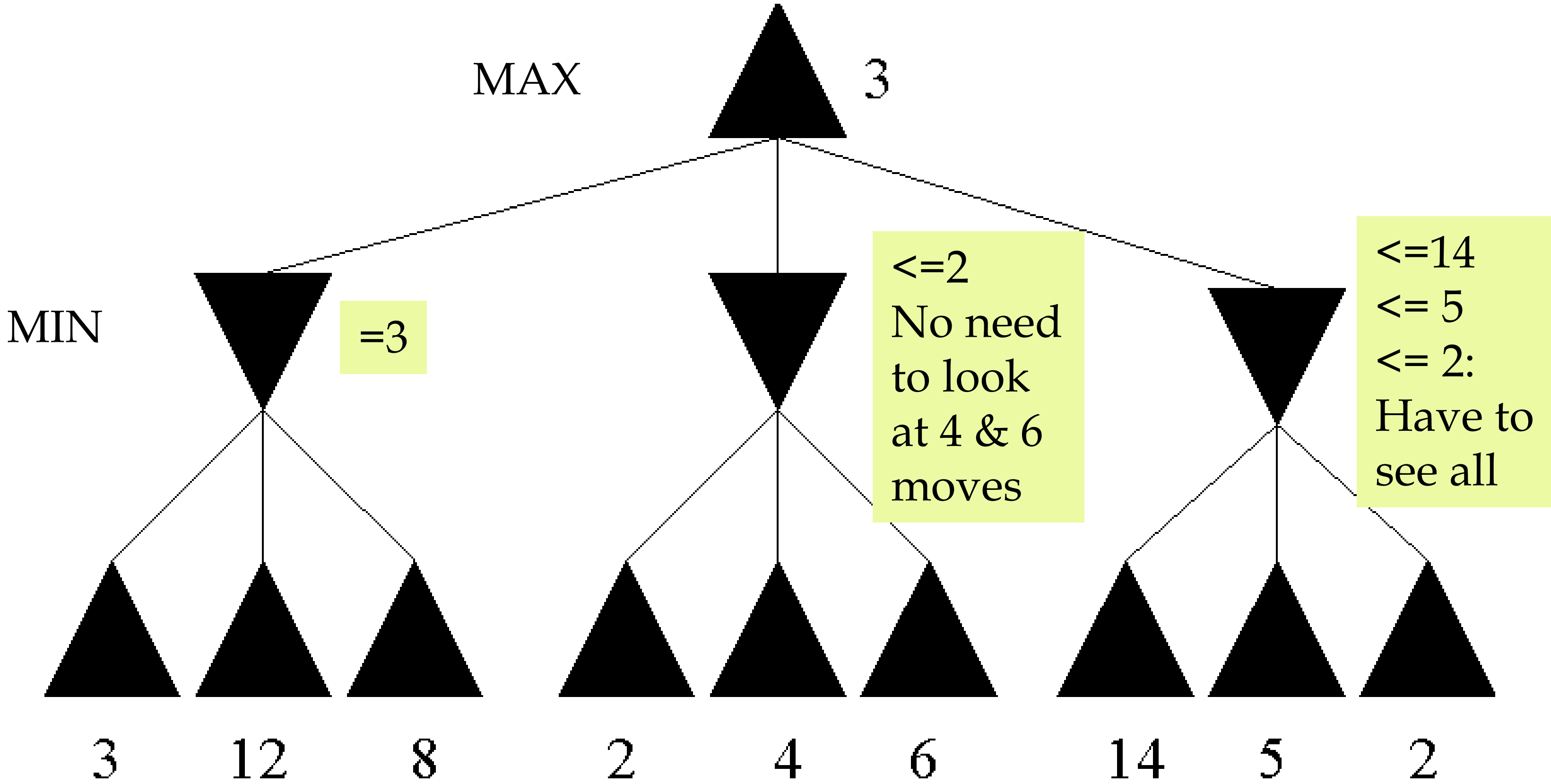
What should be Max's decision ???

The procedure by which scoring information passes up the game tree is called MINIMAX procedure, because the scores are either minimum or maximum of the scores of the nodes below

About Minimax…

- Minimax procedure can be quite expensive
- Generation of paths or static evaluation can require a lot of computation

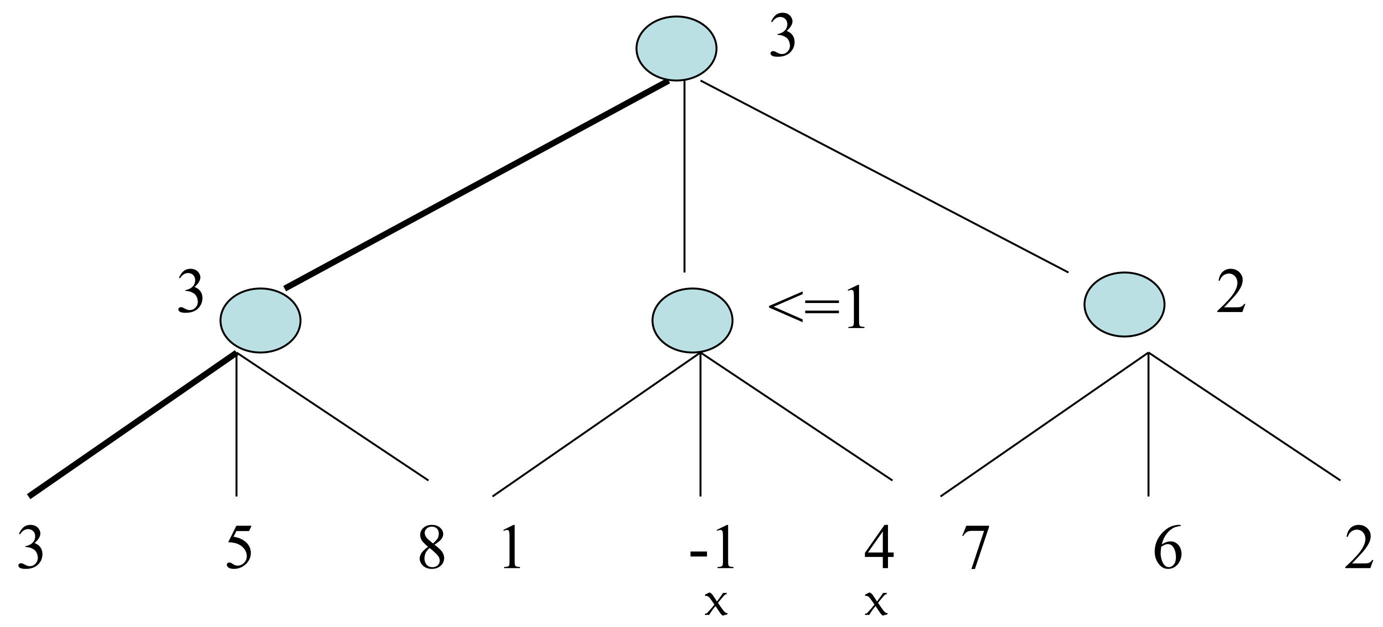
Alpha-Beta Pruning…Example 1



Search at minimizing level terminates when a value < α is found

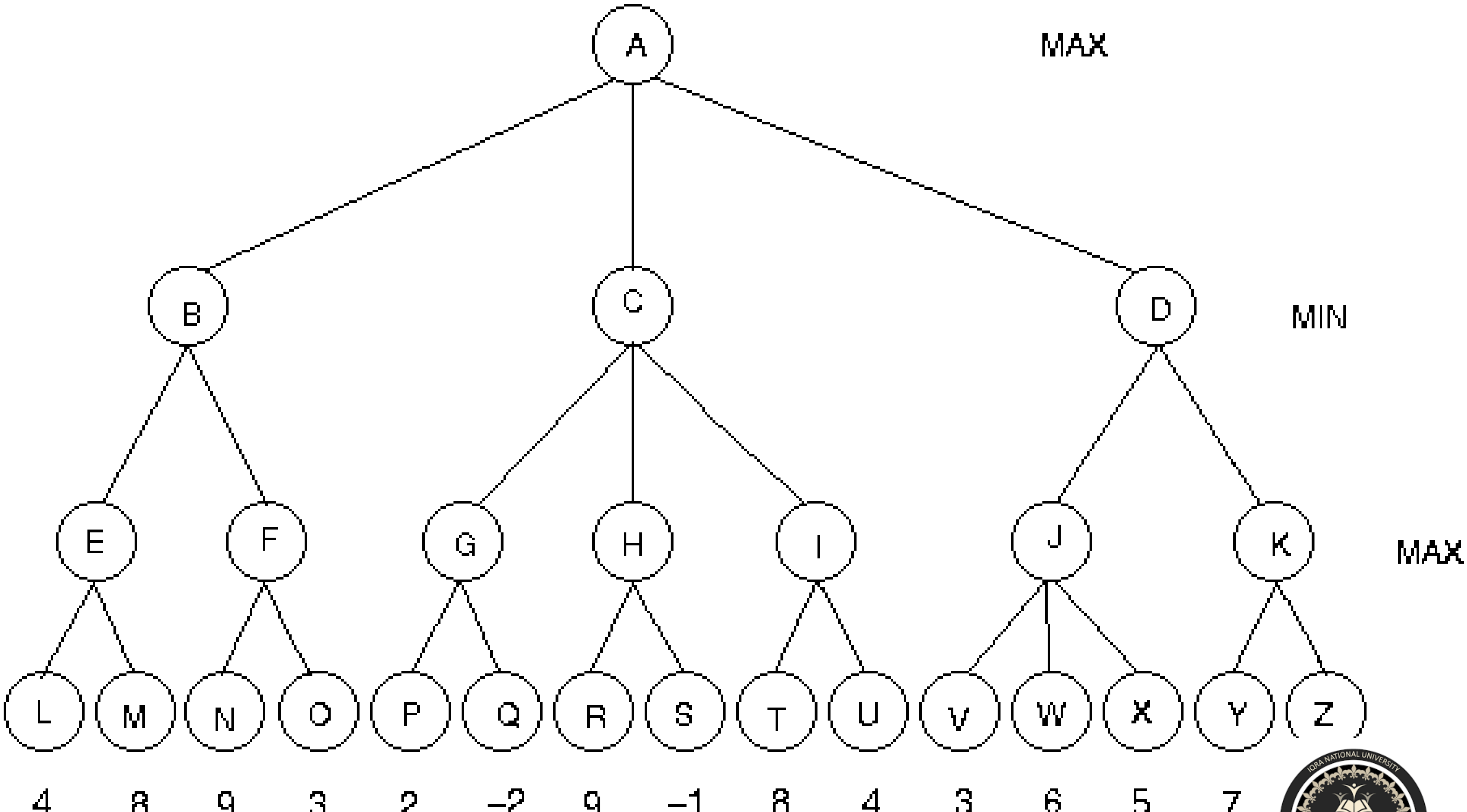
Search at maximizing level terminates when a value > β is found

Alpha Beta Pruning…Example 2

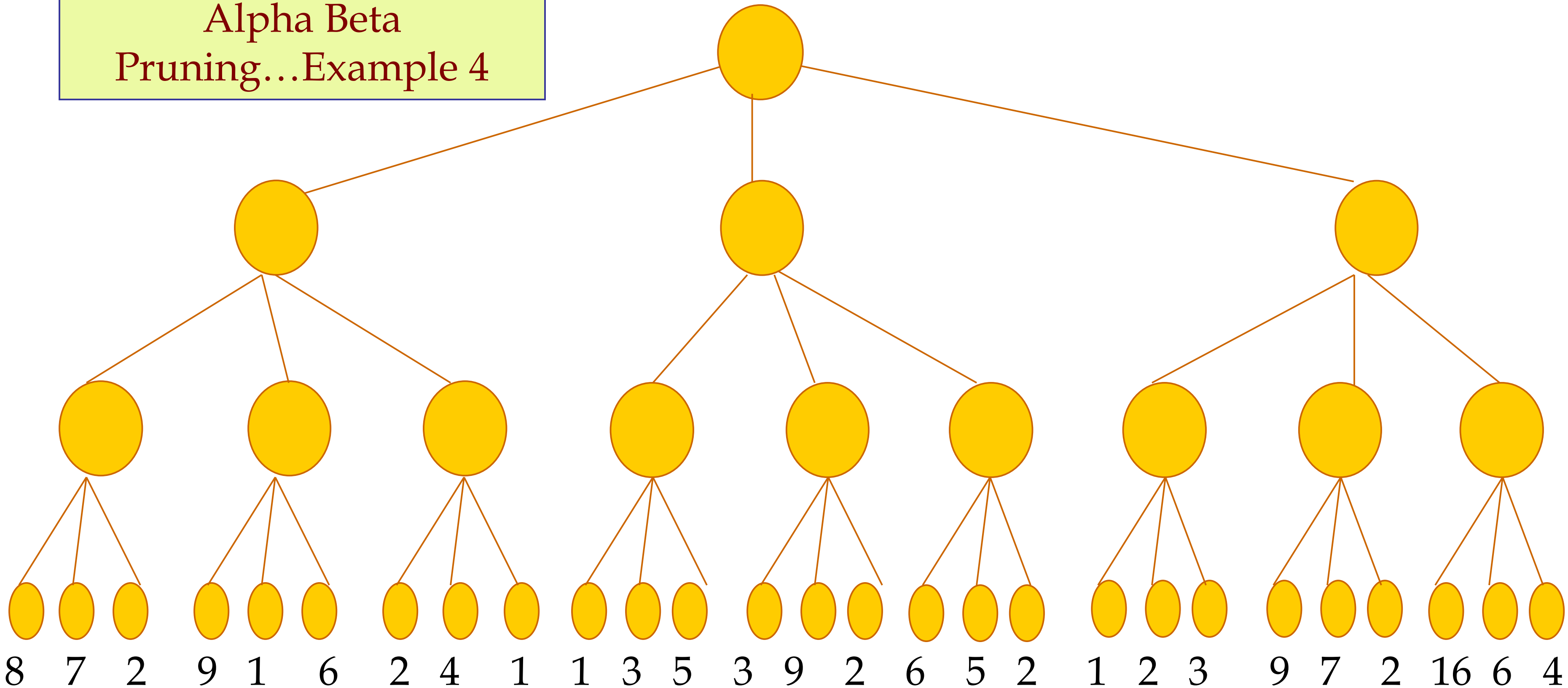


Which branches would be explored???

Alpha Beta Pruning…Example 3



Alpha Beta Pruning…Example 4



α = best choice for max β = best choice for min

Search at minimizing level terminates when a value < α is found

Search at maximizing level terminates when a value > β is found

Alpha Beta Pruning

- Reduces the number of tree branches that must be generated
- Reduces the number of static evaluations that must be made
- Order of branches is most important
- If worst paths examined first then no cutoffs occur
- What is the BEST case for alpha-beta pruning???
- What is the WORST case for alpha-beta pruning???

If you have an idea that is surely bad, do not take time to see how truly awful it is

For an optimally arranged tree, the number of static evaluations required :
when b = branching factor and d= depth

$$S = 2b^{d/2} - 1 \quad \text{for } d \text{ even}$$

$$S = b^{(d+1)/2} + b^{(d-1)/2} - 1$$

Status of Computer Game Players

- Tic-Tac-Toe: Tied for best player in the world (along with every human over the age of 12)
- Othello: Computer better than any human, Champions now refuse to play against a computer
- Checkers: Chinook bested 2nd ranked human player, but lost to the top-ranked player(1992)
- Chess: Deep Blue among the top 100 players, Kasparov also a one time champion…Now Deep Fritz has taken the lead….find out who is the current winner of chess.
- Go: Computer players not even at an amateur ranking
- Connect Four: It's been proven that it is possible for the first player to always win

From: http://sern.ucalgary.ca/courses/CPSC/533/W99/presentations/L2_5A_Boyd_Steward/#sea