AI

Overview

- What is AI?
- Games and state-space search
- When can we say a program is intelligent?

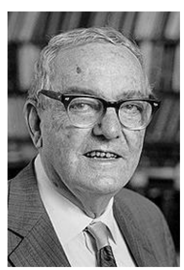
Artificial Intelligence

- Branch of computer science that studies the use of computers to perform computational processes normally associated with human intellect and skill.
- Some areas of AI:

Game playing	Knowledge representation	Robotics
Machine learning	Natural language processing	Music, Speech & Vision

Turing Award recipients in late '60s—early '70s for contributions to AI

Newell
CMU



Simon
CMU

Minsky
MIT

McCarthy
Stanford

A Cynic's View

- AI is the study of how to get computers to do things we don't understand.
  - "thinking", "learning", "creativity", etc.

- When we do understand something, it's no longer AI: it's just programming.
  - *Examples:*
    - speech recognition,
    - computer chess and checkers,
    - robotics, …

Games and Search

A laboratory for artificial intelligence

Why Study Games?

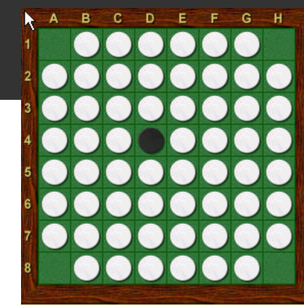
- Thin end of the wedge for AI research
  - Characteristically **human activity**
  - Small so potentially **solvable**
  - Easy to **measure** success or failure
  - Solutions *might* tell us something about **intelligence** in general
  - But are we just “looking under the lamp post”?

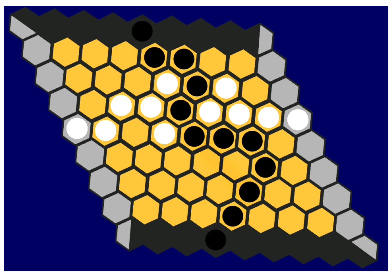
Why Study Games?

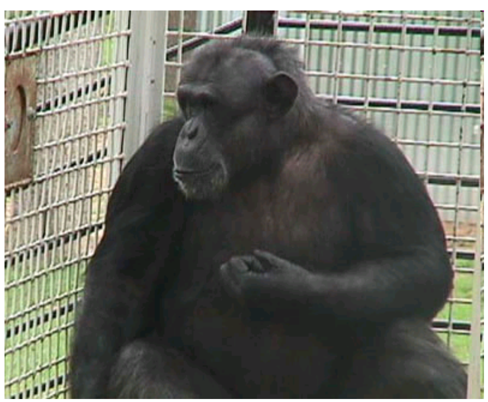
Arthur Samuels, 1960:

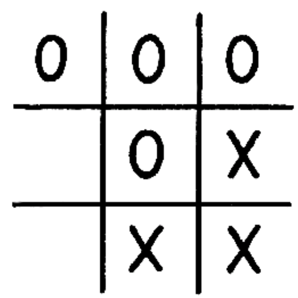
Programming computers to play games is but one stage in the development of an understanding of the methods which must be employed for the *machine simulation of intellectual behavior*. As we progress in this understanding it seems reasonable to assume that these newer techniques will be applied to real-life situations with increasing frequency, and the effort devoted to games . . . will decrease. Perhaps we have not yet reached this turning point, and we may still have much to learn from the study of games. [Emphasis ours]

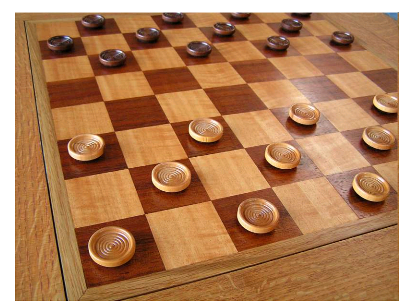
Two-player games









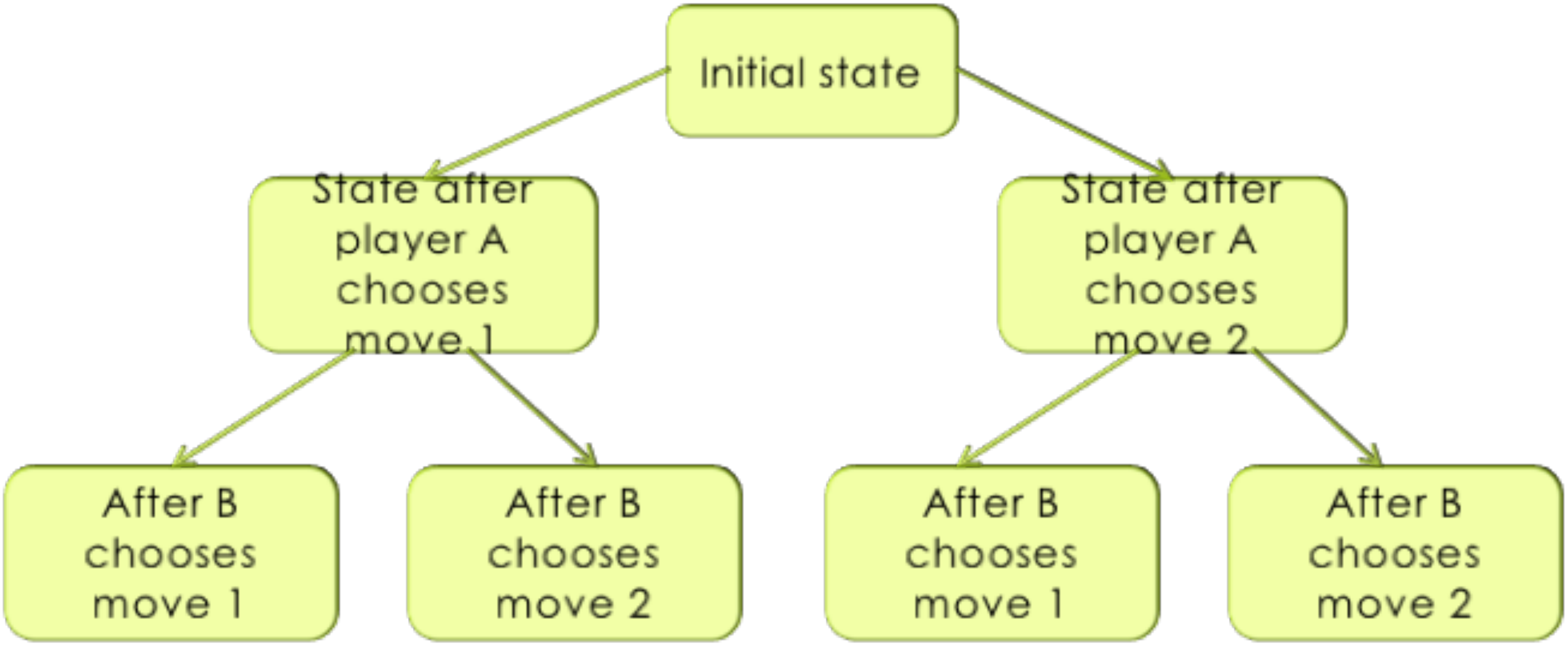


Game Properties

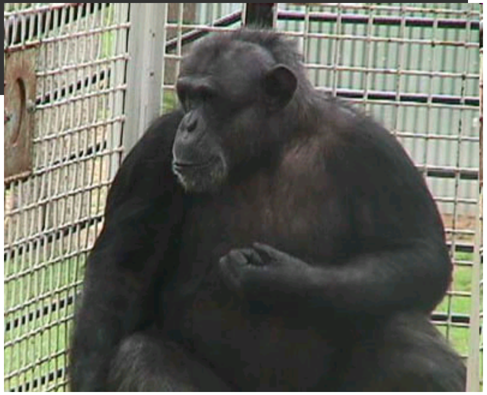
- Two players
  - alternating turns
- Perfect information
  - No hidden cards or hidden Chess pieces…
- Finite
  - Game must end in finite number of moves
- Deterministic
  - no randomness, e.g., dice
- Zero sum
  - Total winnings of all players

Game Tree

- Imagine a two-player game with two possible moves at each point. *A* goes first:

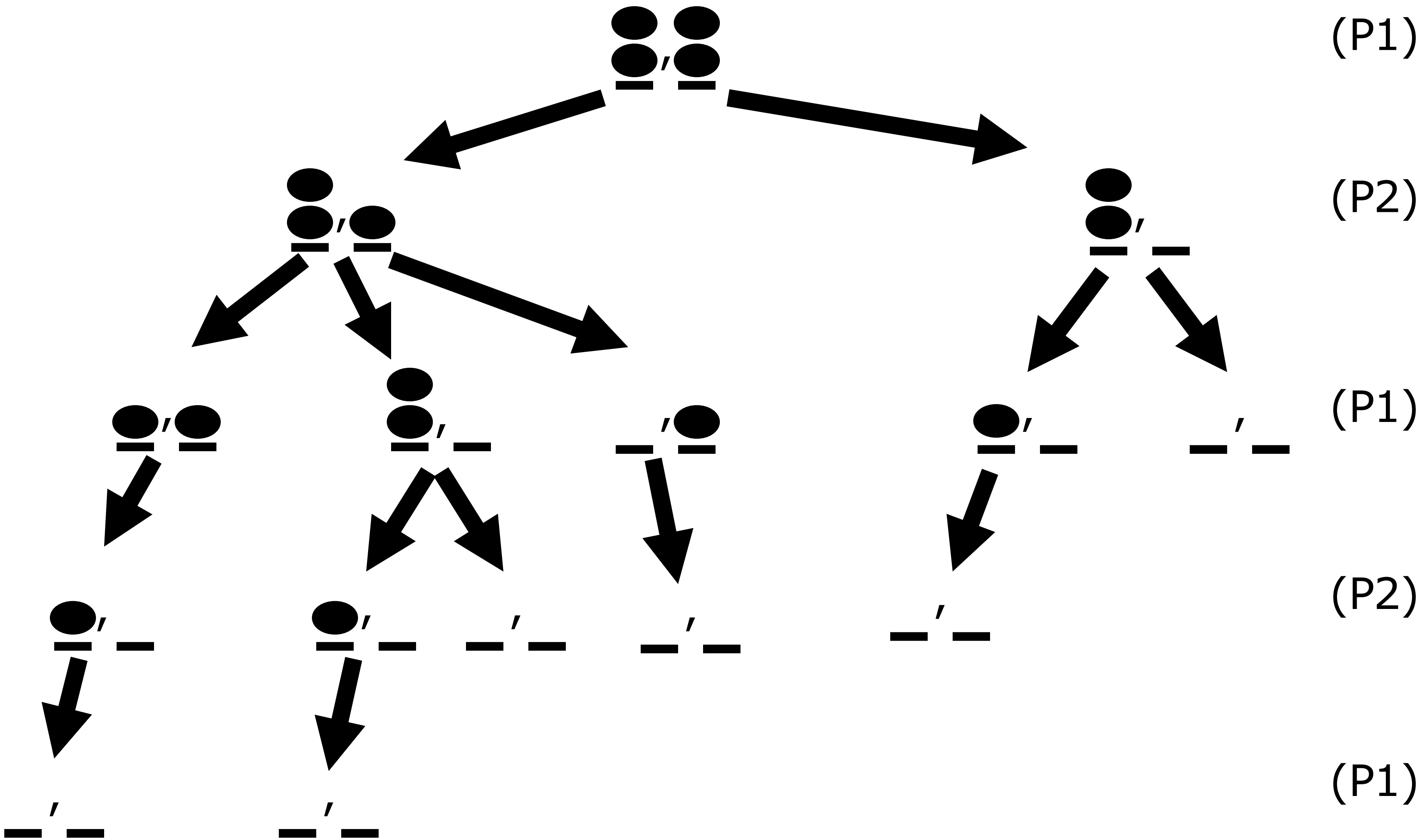


Game of Nim



- Two players
- Some piles of stones
- At each turn, player can remove any number of stones from any single pile
- If it is your turn and there are no stones left, you lose.

Playing Nim
P1 has first move



Evaluation Functions

- We can define the **value** (goodness) of a certain game state (board).

- For example,

  1 = Player A wins,

  -1 = Player B wins

  (0 = tie, when ties are possible)

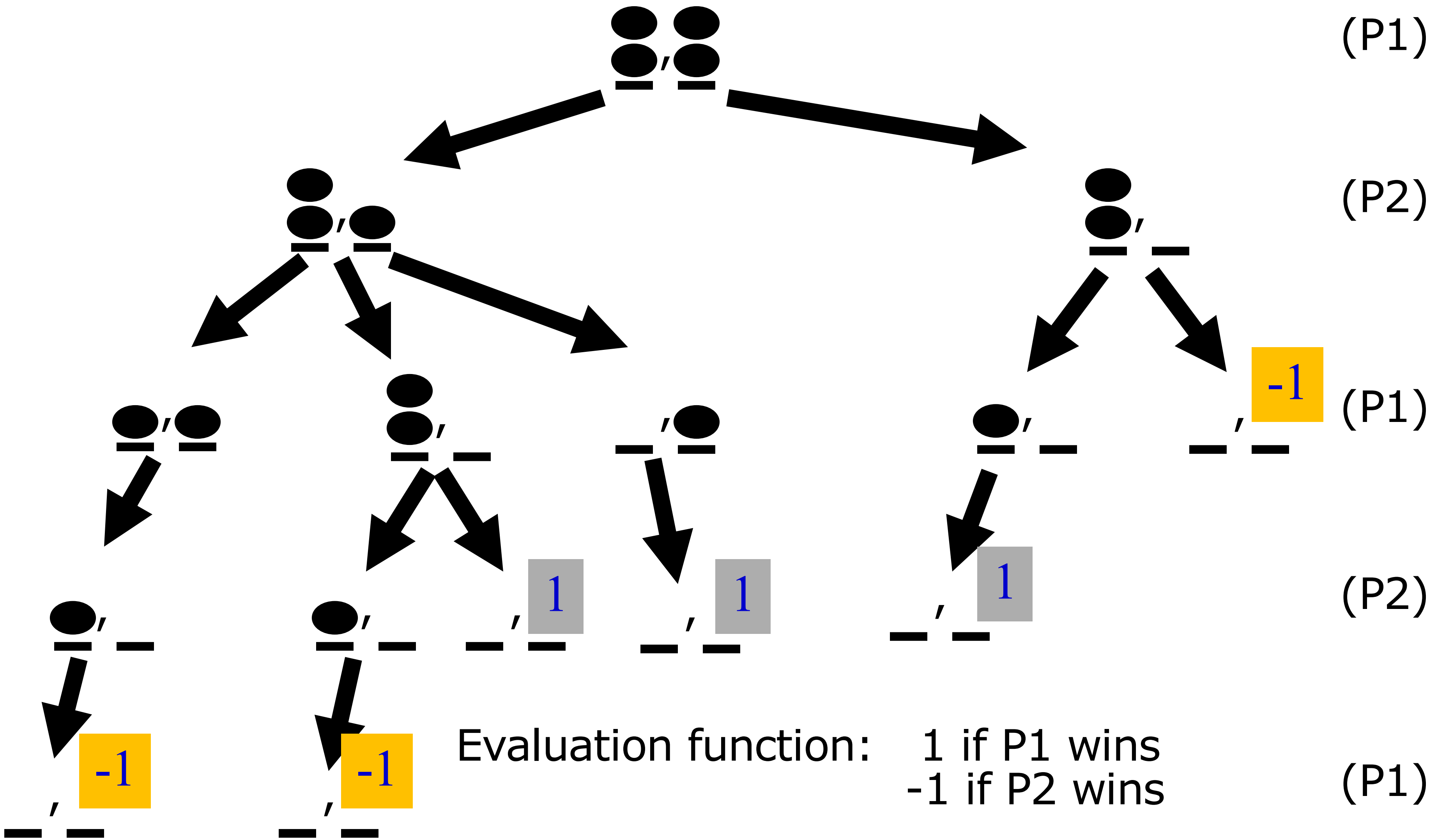
How do we play?

- Traverse the "game tree".
  - Enumerate all possible moves at each node.

- Start by evaluating the terminal positions, where the game is over.

- Propagate the values up the tree, assuming
  we pick the best move for us and
  our opponent picks the best move for her.

Playing Nim with Minimax



Evaluation function: 1 if P1 wins
-1 if P2 wins

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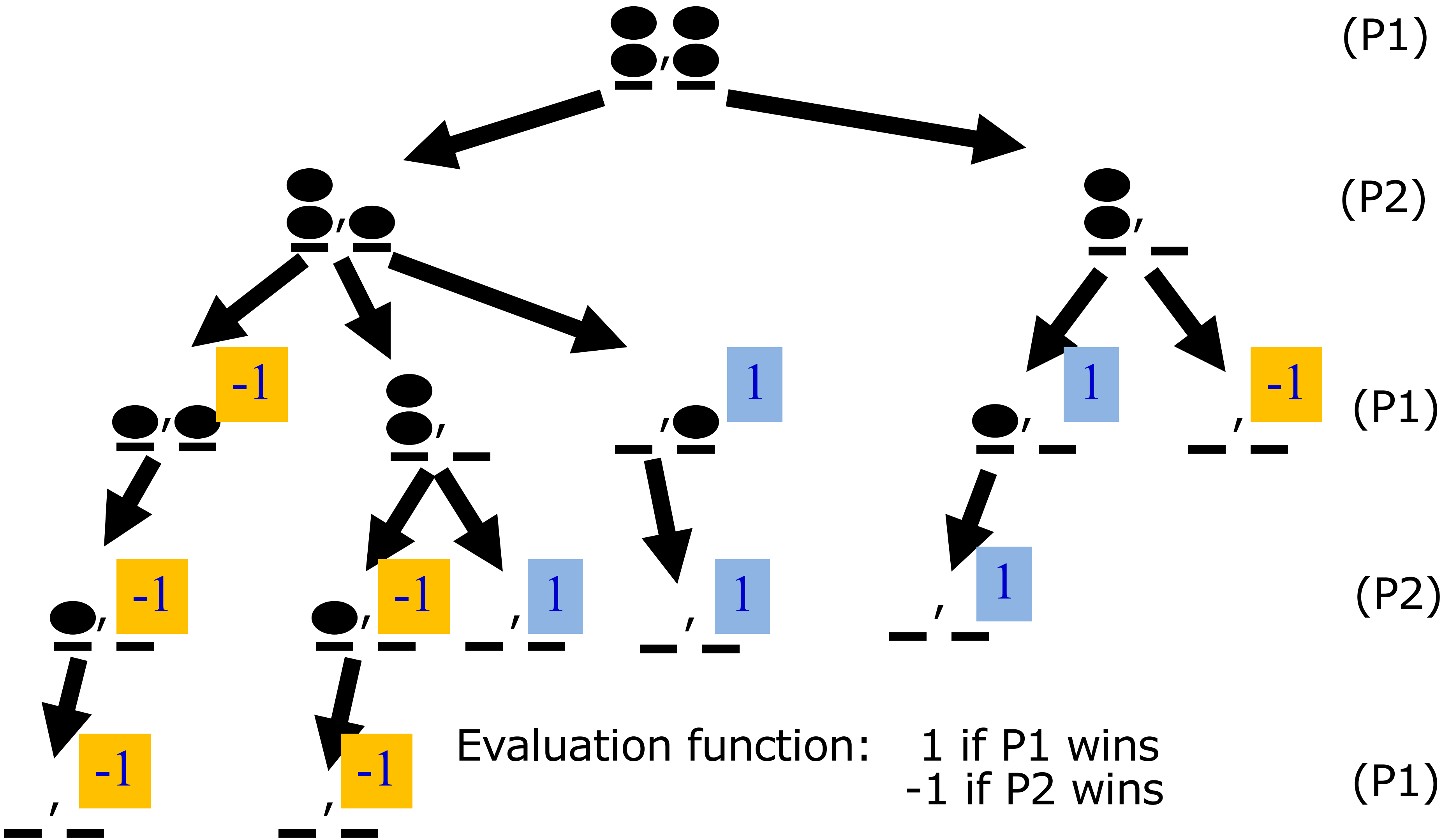

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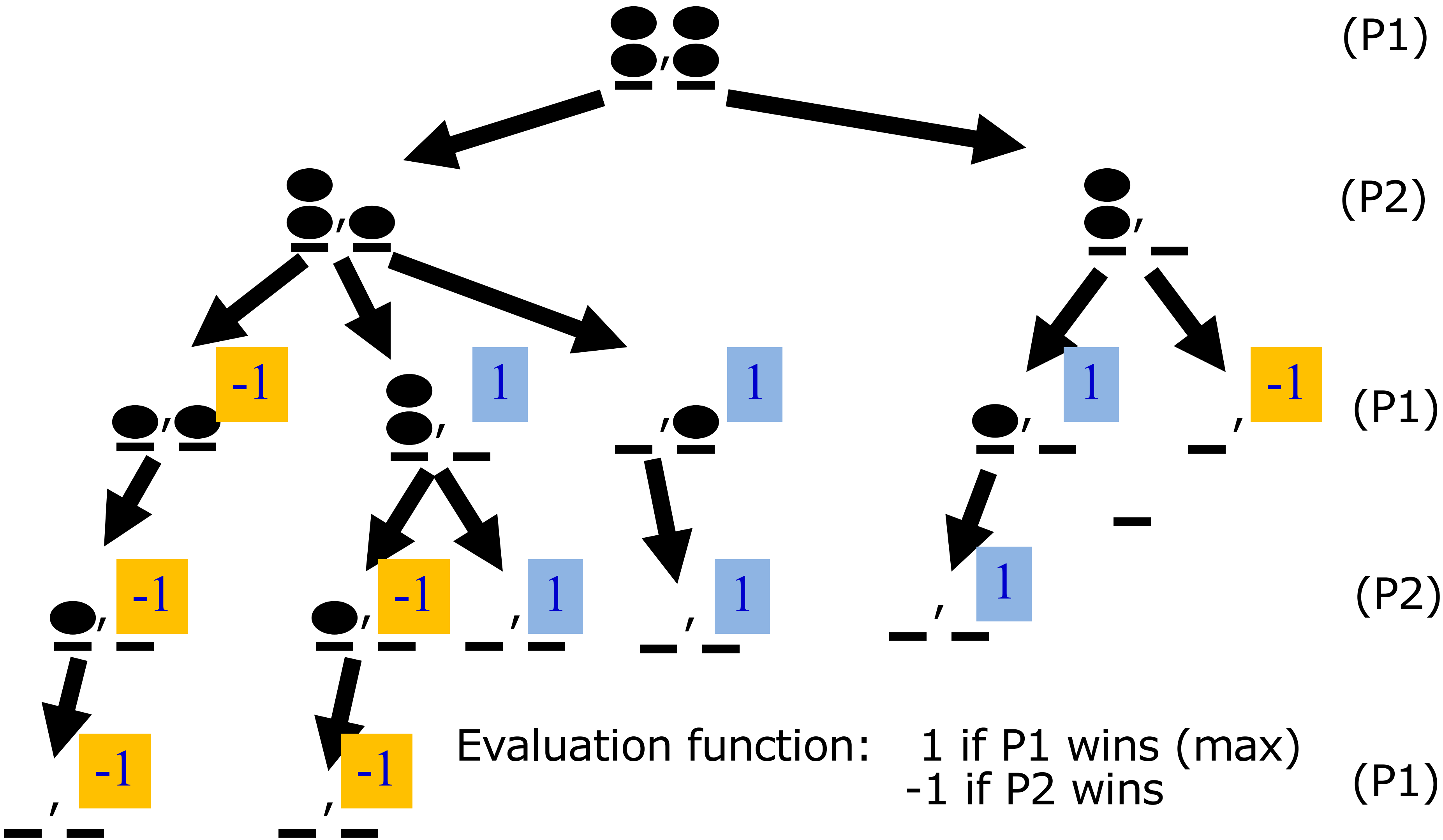
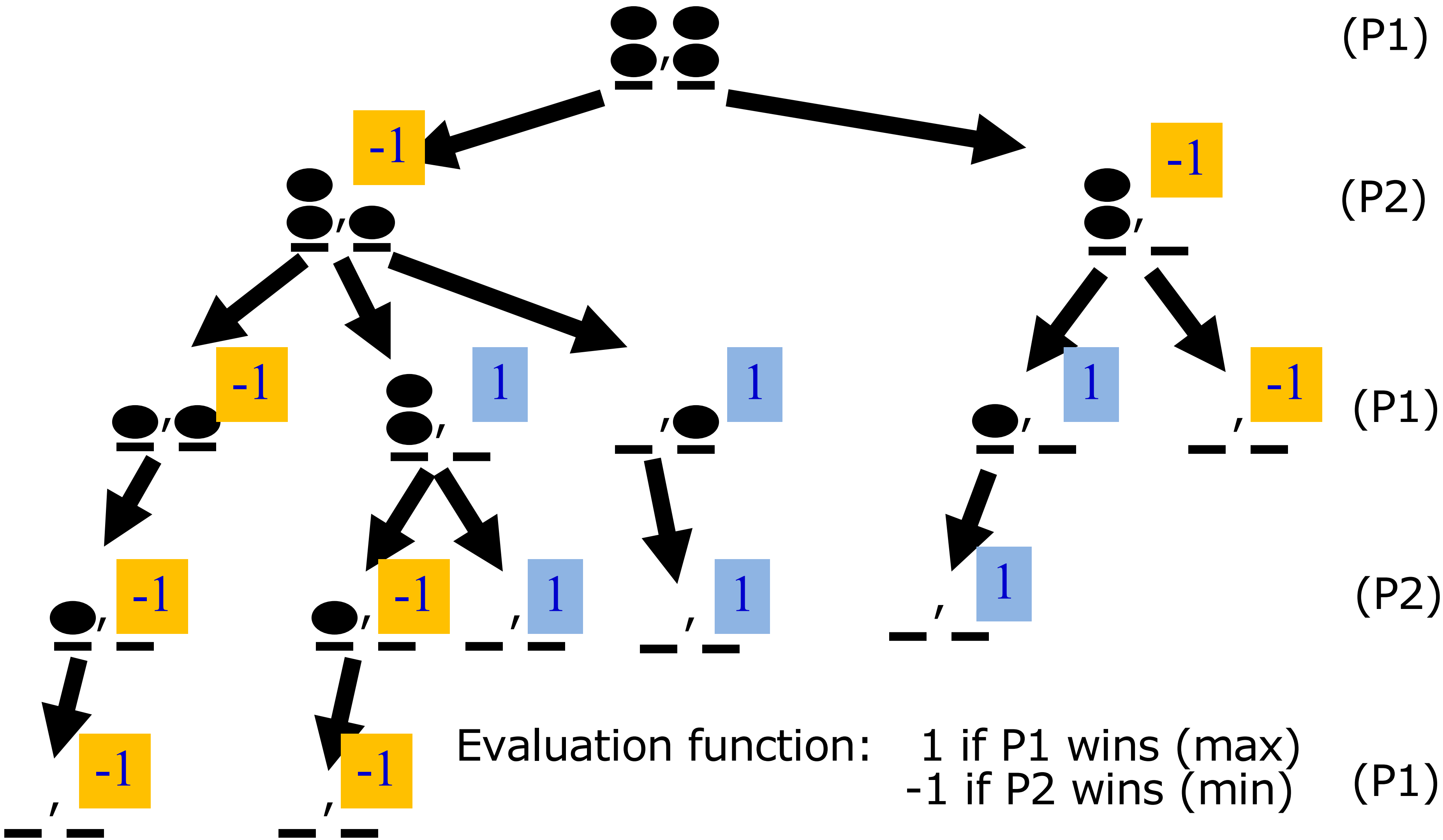


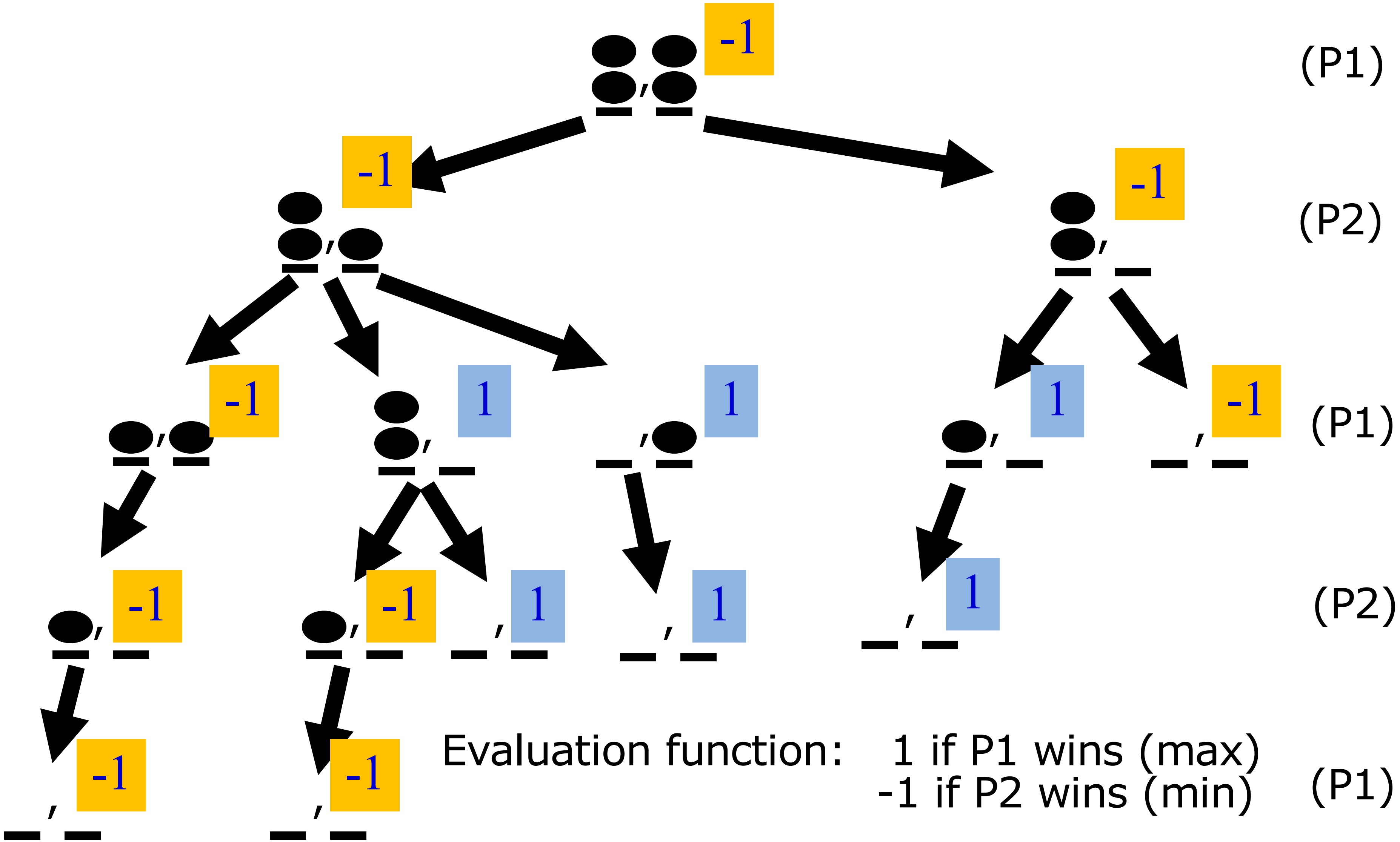
Evaluation function: 1 if P1 wins (max)
-1 if P2 wins

Playing Nim with Minimax



Evaluation function: 1 if P1 wins (max)
-1 if P2 wins (min)

Playing Nim with Minimax



Evaluation function: 1 if P1 wins (max)
-1 if P2 wins (min)

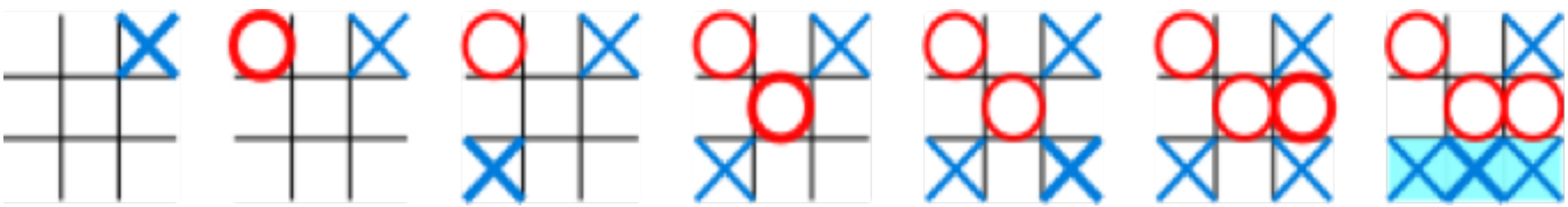
How do we play?

- What is the rule to compute the value of nonterminal node?
  - If it is our turn (P1) then we pick the maximum outcome from the children.
  - If it is the opponent's turn (P2) then we pick the minimum outcome from the children.
- This process is known as the Minimax algorithm.
- We play the move that gives us the maximum at the root.

Tic Tac Toe

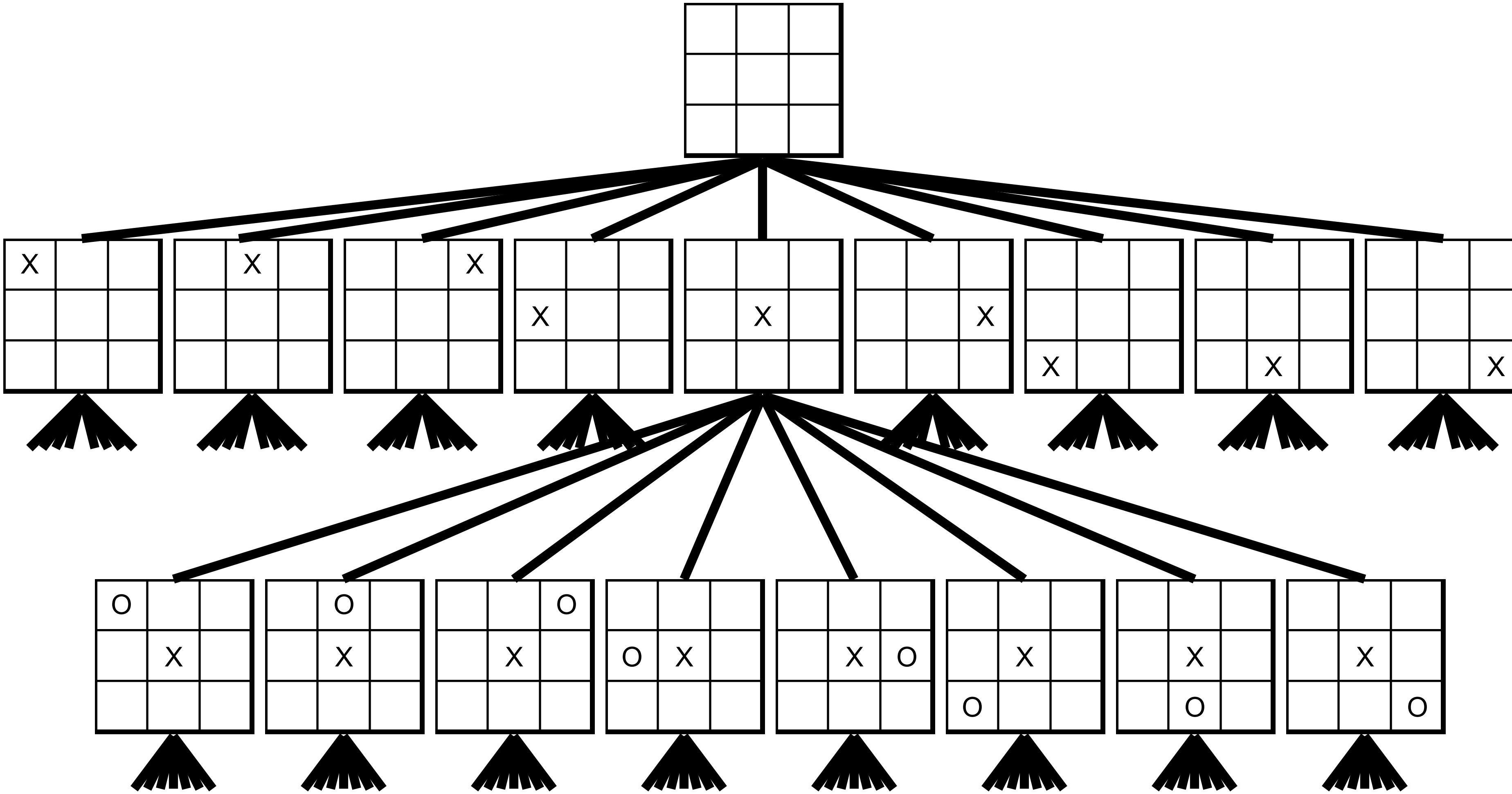
A pencil and paper game for two players, *X* and *O*, who take turns marking the spaces in a 3×3 grid. The player who succeeds in placing three of their marks in a horizontal, vertical, or diagonal row wins the game.

The following example game is won by the first player, X:



Source: Wikipedia

Tic Tac Toe Game Tree

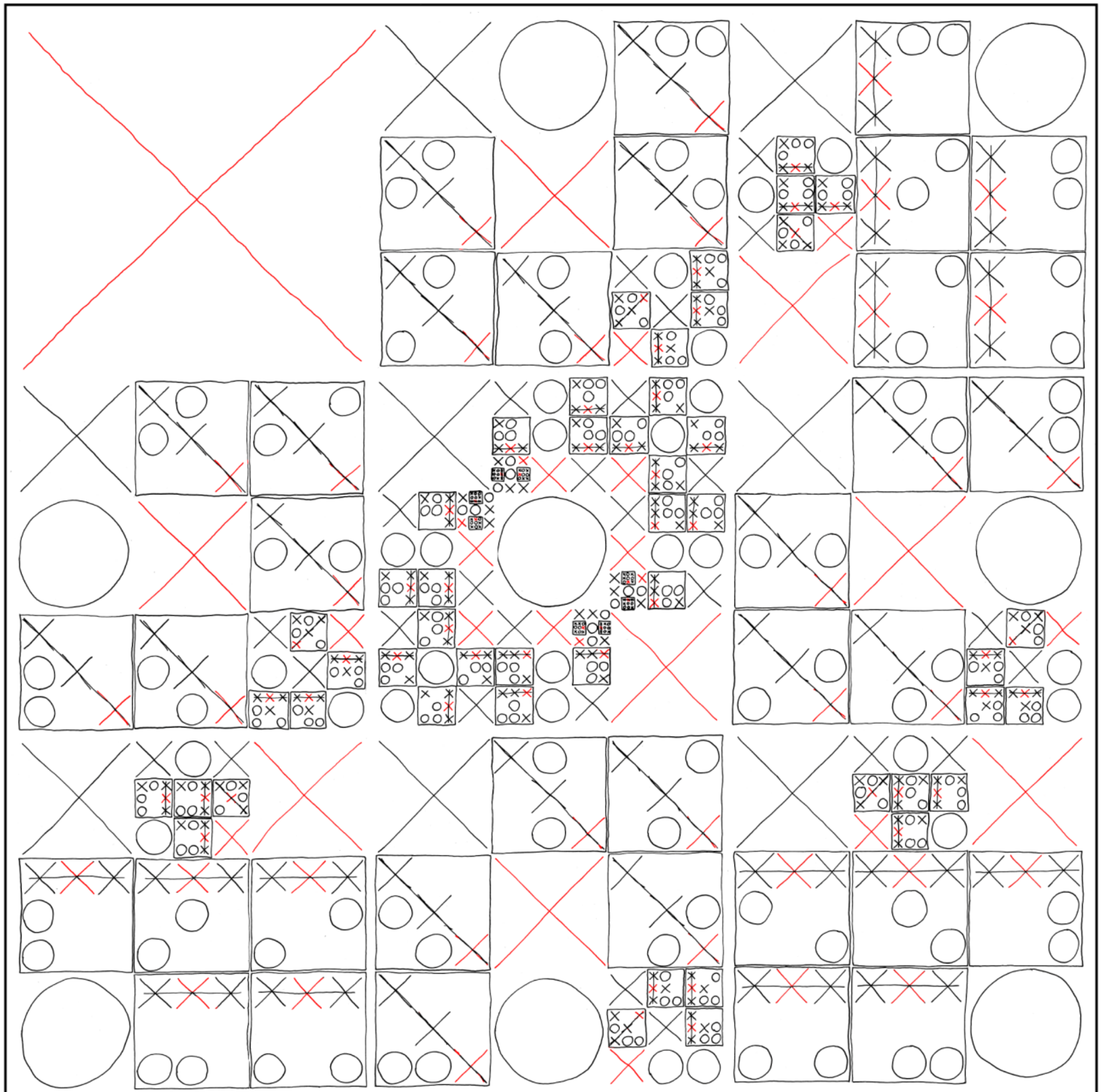


For the Enthusiast

- If you are interested in optimal strategies see the next 9 slides.

XKCD's Optimal Tic-Tac-Toe

MAP FOR X:

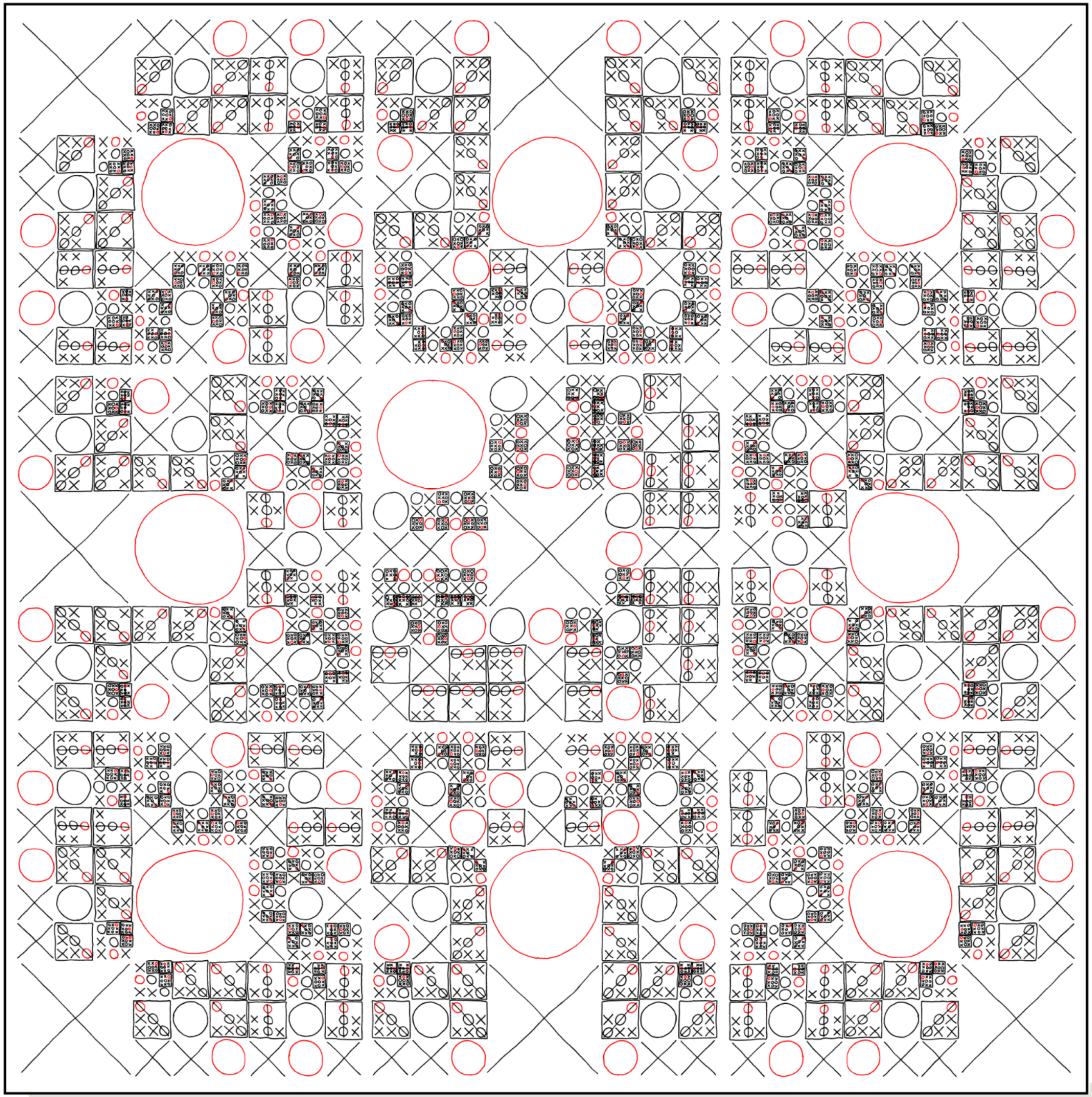


COMPLETE MAP OF OPTIMAL TIC-TAC-TOE MOVES

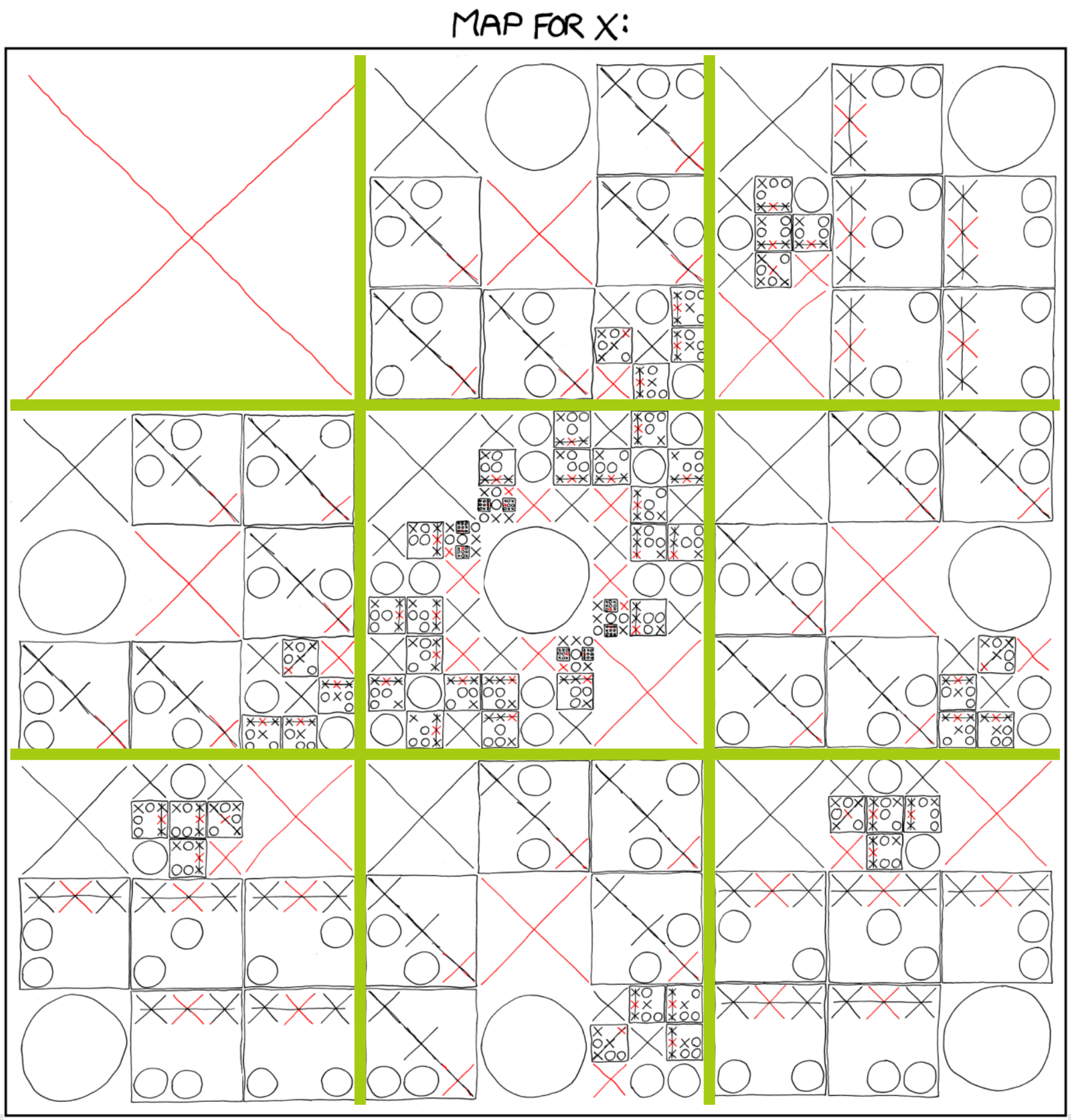
YOUR MOVE IS GIVEN BY THE POSITION OF THE LARGEST RED SYMBOL ON THE GRID. WHEN YOUR OPPONENT PICKS A MOVE, ZOOM IN ON THE REGION OF THE GRID WHERE THEY WENT. REPEAT.

http://xkcd.com/832

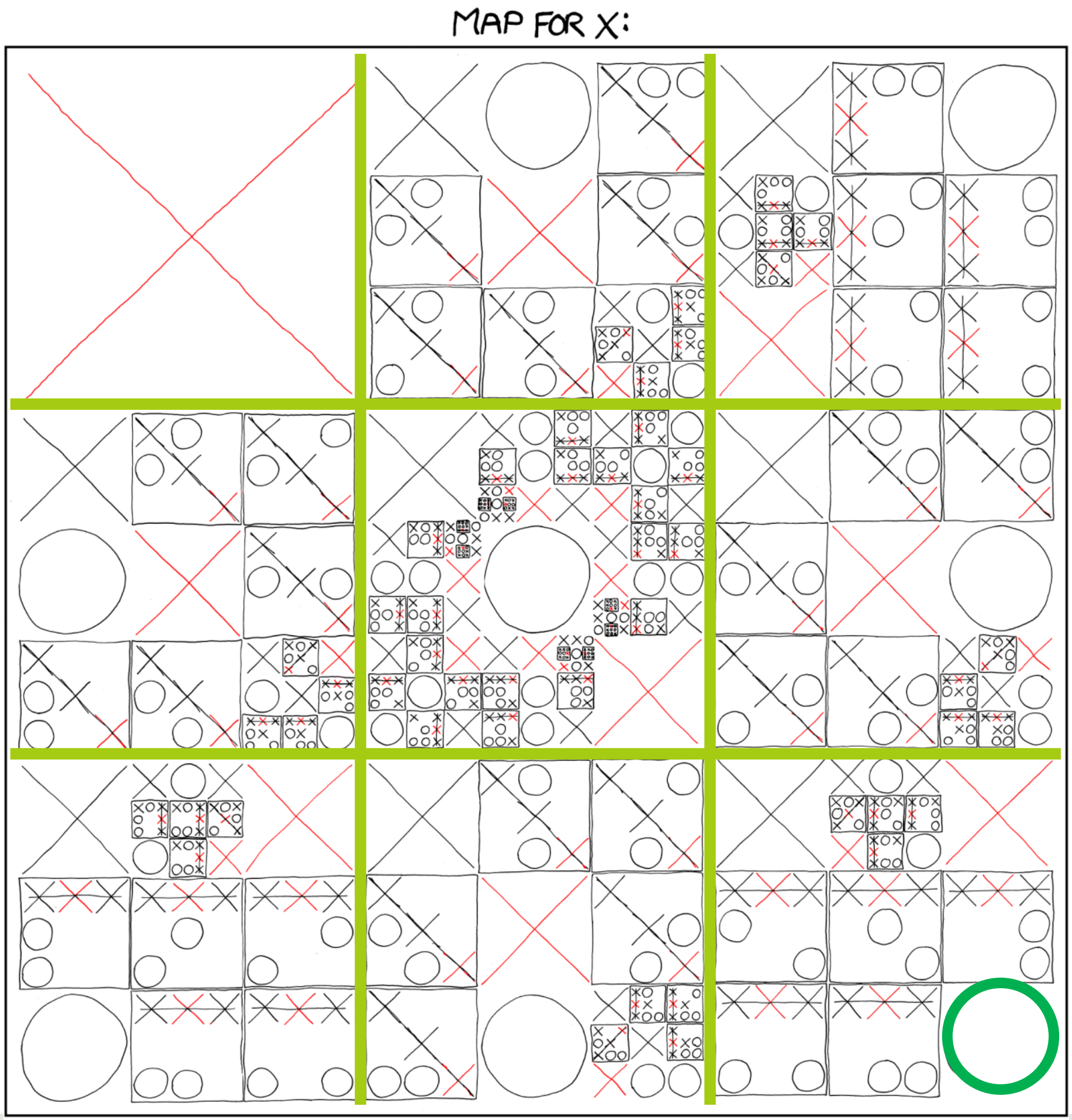
MAP FOR O:



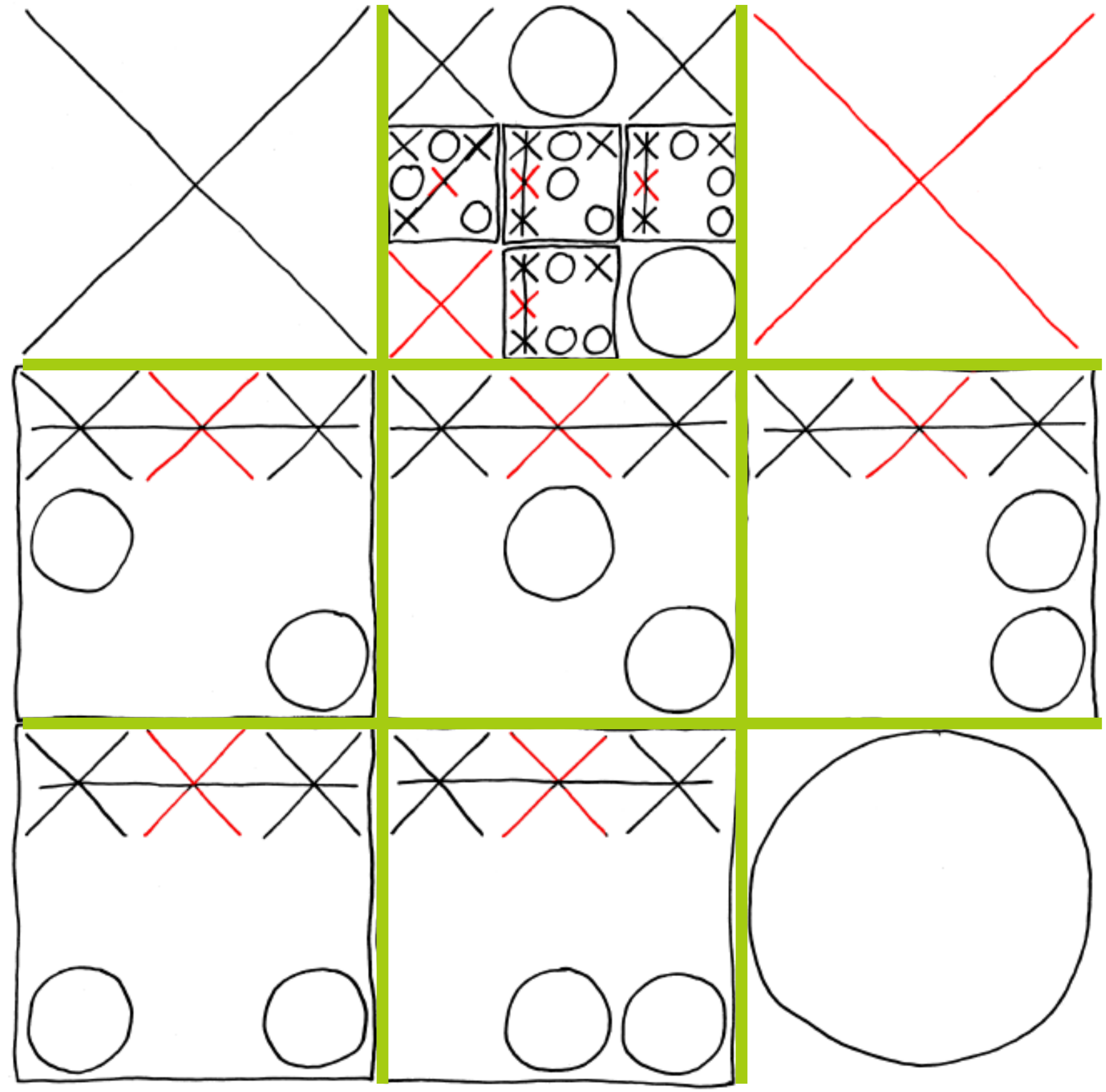
X Move 1



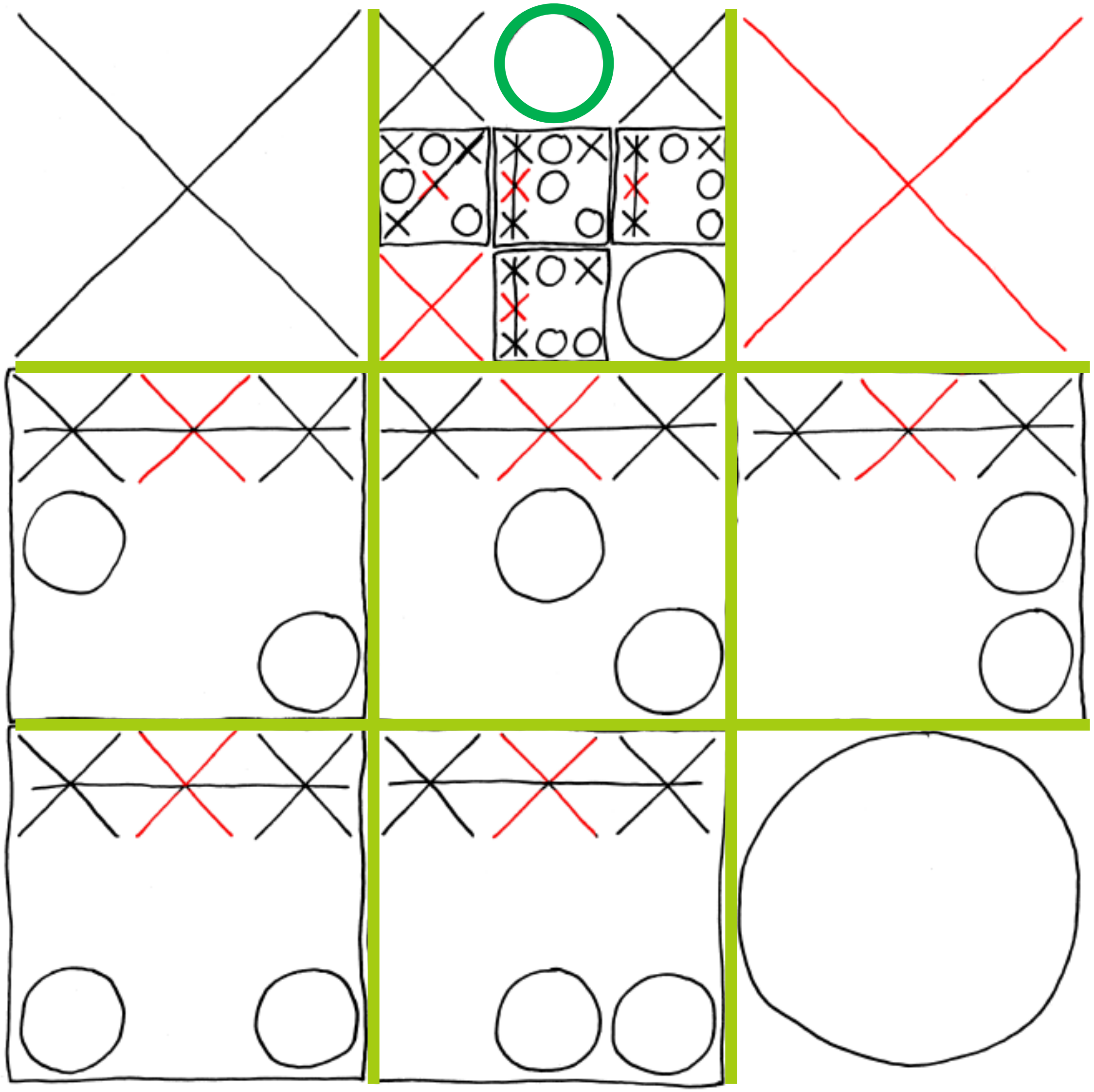
O Move 1 (non-optimal play)



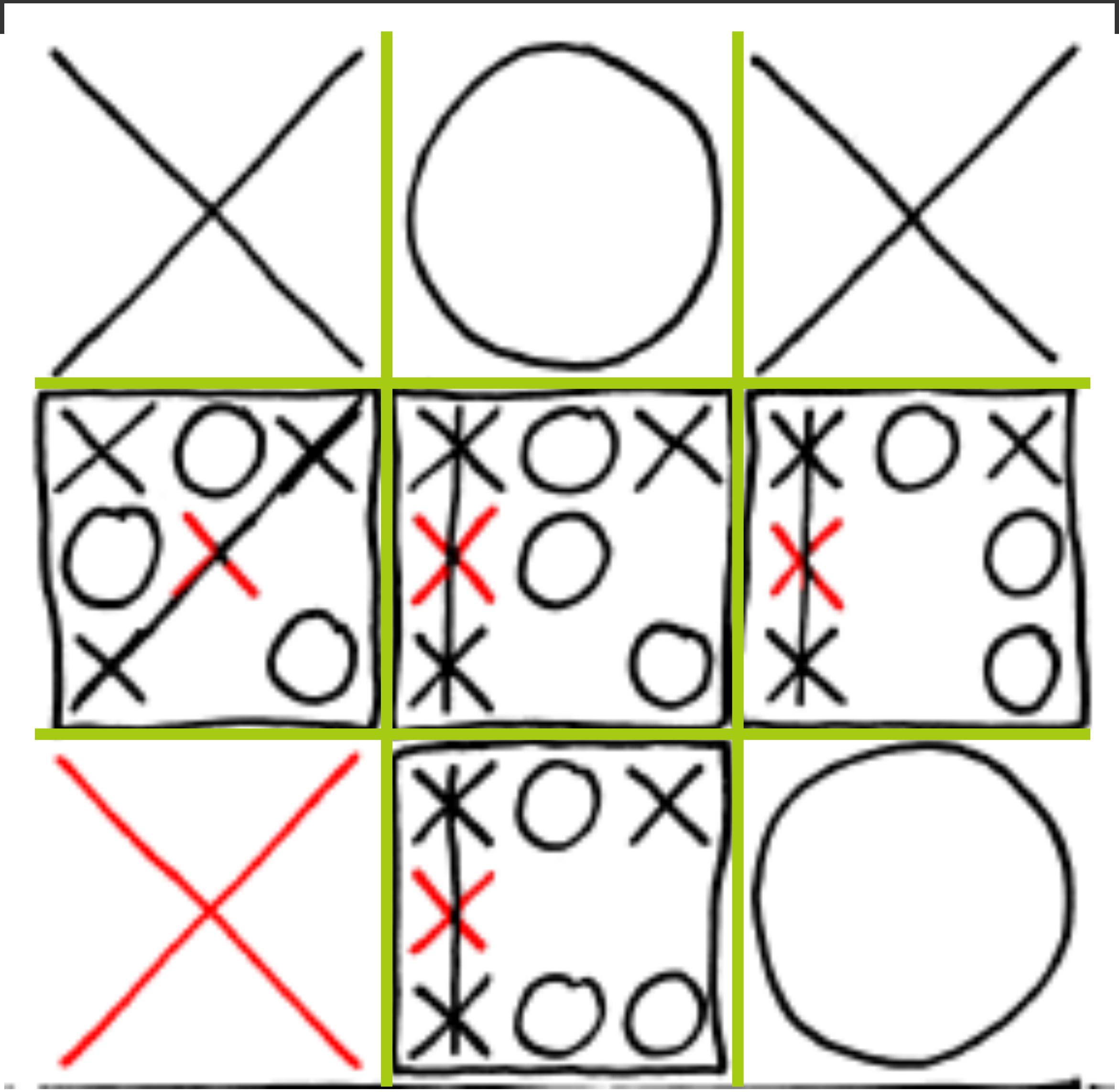
X Move 2



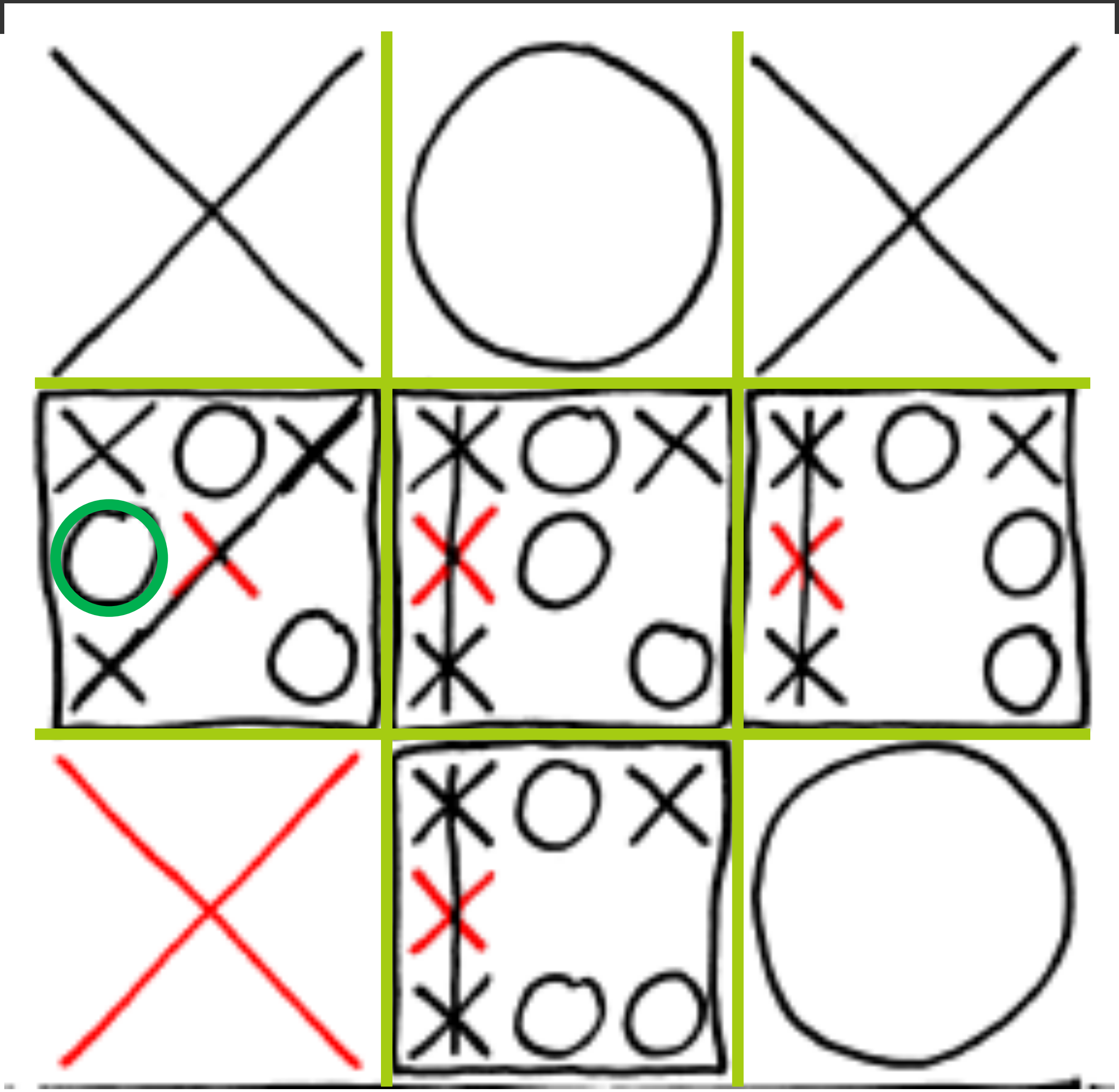
O Move 2



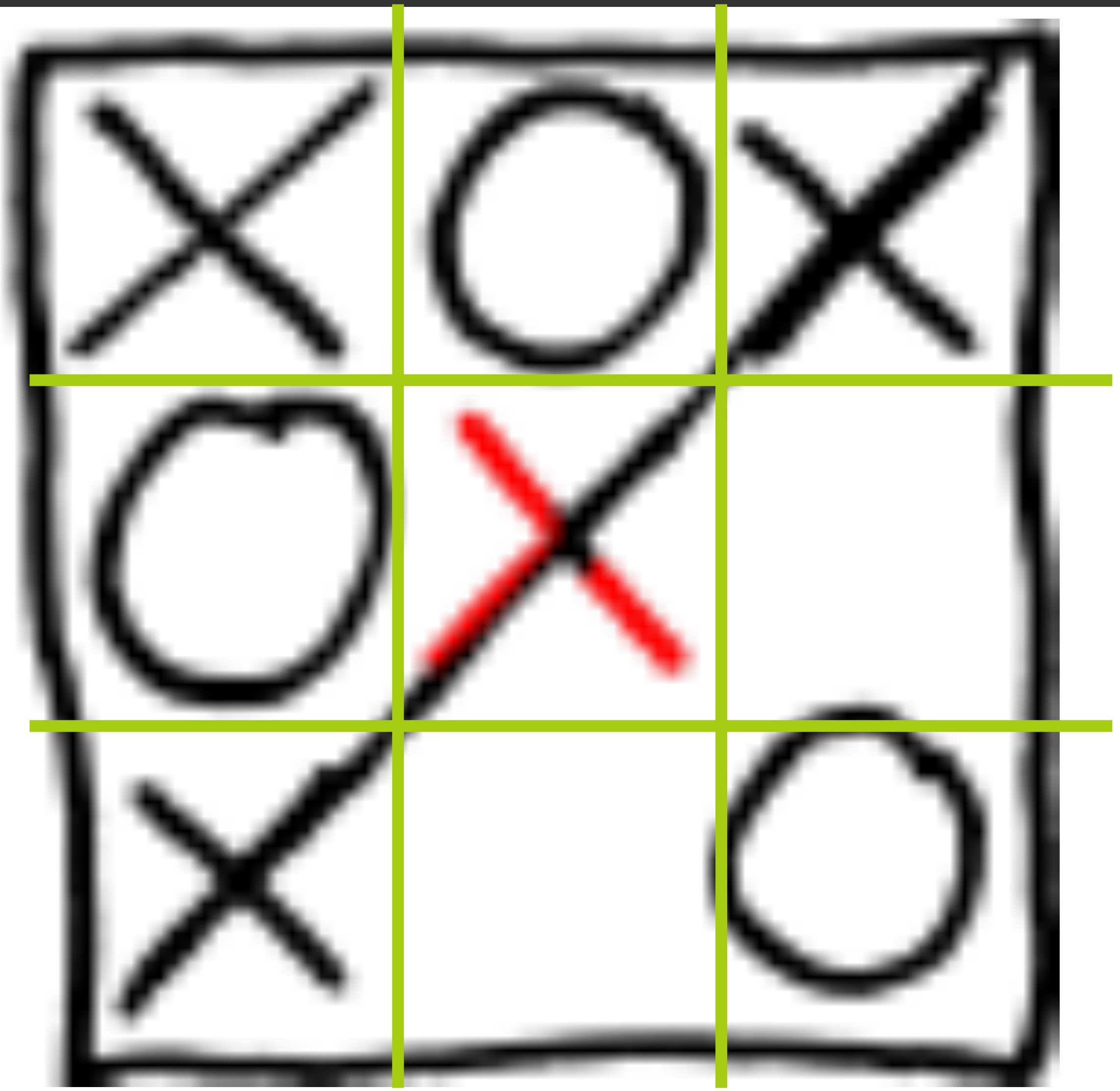
X Move 3



O Move 3



X Move 4 To Win



How Big is the Tic-Tac-Toe Tree?

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    9*8*7*6*5 = 15,120

Tic-Tac-Toe Is Completely Searchable

- Using recursion, can grow the entire game tree with the **current board state** as the root
- fewer than 363,000 nodes, *feasible*
- Furthermore, if board **symmetries** are taken into account, two games are considered the same if **rotating** and/or **reflecting** the board makes one of the games into a copy of the other game.

Some Other *Solved* Games

- Connect Four
- Awari (Oware)
- Checkers (!) which took decades (see *Chinook*)

Chess - Infeasibility

- A complete analysis of a chess game is ***computationally infeasible***

- (What other problem have we seen lately that is computationally infeasible? Hint: in that case, infeasibility was a *desirable feature,* not a problem.)

- But human beings play chess, some very well!
  - *Idea:* computer techniques to deal with combinatorial explosion may reveal something important about intelligence

Game Analysis

- For most games, the number of possible moves and potential outcomes is HUGE.

combinatorial EXPLOSION

Example:

Chess: If there approximately 20 possible moves at each turn, looking ahead 15 moves requires examining about 3.3 x 10^{19} sequences, which would take ***years.***

Managing combinatorial explosion

- An AI technique used to manage the explosion is the use of a *game tree*.
  - A tree is built with a **root node** representing the **current state** of the game.
  - **Child nodes** are generated representing the state of the game for each **possible move**.
  - The tree is propagated down, building **more child nodes** for moves allowed by the **next move**, etc.
  - **Leaves** are terminal (win/lose/draw) states of the game.
  - **Unlike the trees** you've studied before, game trees are not usually computed in their entirety (they are too large!)

Search and heuristics

Coping with combinatorial explosion

Game Tree as Search Space

- We say we ***search*** **the game tree** as we try to compute a winning move
  - In reality AI programs generate a small part of the tree only!
- ***Search space*** or ***solution space***—a powerful general idea in life as in computing

Heuristics

- Human thought is not purely deductive. It often relies on approximations or analogies.
- A heuristic is a “**rule of thumb**” that may not always be correct but usually gives useful results.
- Heuristic algorithms are helpful because they can find a **reasonably good solution** to a problem **without requiring excessive search**.

Dealing With **Huge** Game Trees

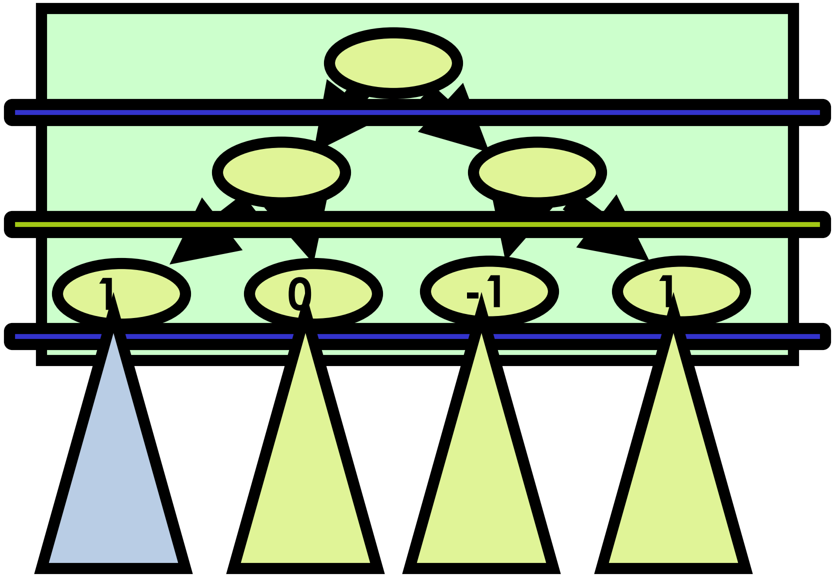
- How does a computer program that plays Chess or Go deal with the huge size of the game trees that can be generated?
  - **Chess**: size of game tree: ~35^{100} (about 10^{150}), beyond hope, even for fastest computers!
  - **Go**: much bigger (one estimate is 10^{360})
- These programs use heuristics to reduce the part of the tree that must be examined

Estimator functions

- Save time by **guessing** search outcomes
  - ***Chess***: Estimate the quality of a situation
    - *Count pieces*
    - *Count pieces, using a weighting scheme*
    - *Count pieces, using a weighting scheme, considering threats*
    - *...*

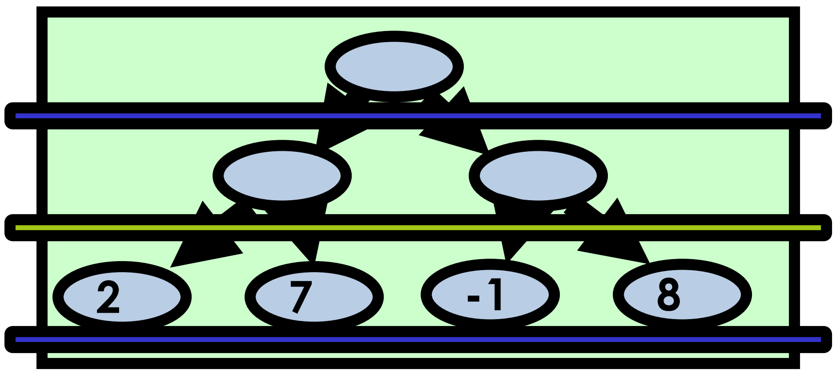
Minimax, in reality

- Rarely do we reach an actual leaf
  - Use **estimator functions** to statically guess outcome of unevaluated subtrees (value of current position)
  - Max



Minimax, bounded search

- Rarely do we reach an actual leaf
  - Use **estimator functions** to statically guess outcome of unevaluated subtrees (value of current position)
  - Max — A moves
    Min — B moves
    Max — **A moves**



Note that minimax works with any real numbers, not just -1, 0, 1.

Minimax, in reality

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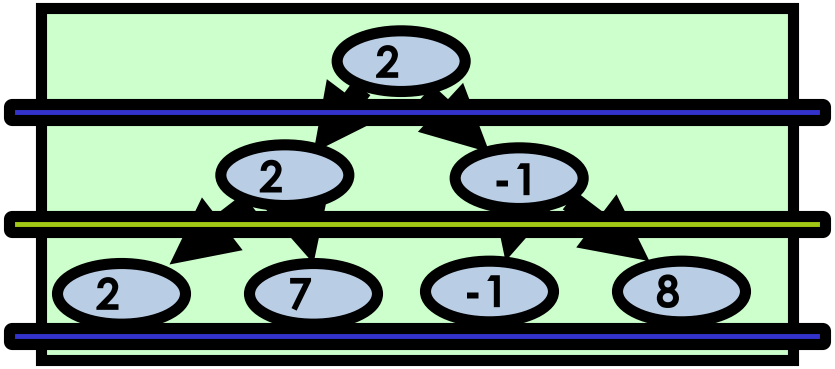
  - Max
    Min
    Max



A moves
B moves
A moves

Minimax, bounded search

- Trade-off: Quality *vs*. Speed
  - **Quality**: deeper search
  - **Speed**: use of estimator functions

- Balancing
  - relative costs of move generation and estimator functions,
  - quality and cost of estimation function

Search and problem solving

not just for games!

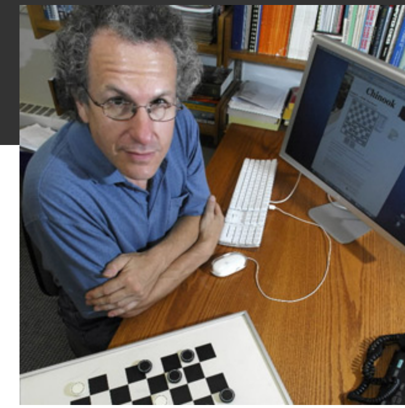
State Space Search

- Searching game trees is a form of *state space search*
- *“Good old-fashioned AI”*: idea that *any* intelligent behavior can be modeled as search in a state space tree
- Successes:
  - Chess, checkers, etc.
  - Route-finding for airline travel planning
  - Layout for integrated circuits in electronics
  - Automated manufacturing processes
  - Symbolic integration
  - Proving theorems

"Deep Blue"

- IBM's "Deep Blue" computer beats Gary Kasparov in a chess match in 1997.
- Heuristics values:
  - The value of each piece. (1 for pawn up to 9 for queen)
  - The amount of control each side has over the board.
  - The safety of the king.
  - The quickness that pieces move into fighting position.
- For more info:
  - http://www.research.ibm.com/deepblue/home/html/b.html
- Is Deep Blue intelligent?

"Chinook"



- Created by computer scientists from the University of Alberta to play checkers (draughts) in 1989.
- In 2007, the team led by Jonathan Schaeffer announced that Chinook could never lose a game. **Checkers had been solved**:

  The best a player playing against Chinook can achieve is a draw.
- Chinook's algorithms featured:
  - a library of opening moves from games played by grandmasters
  - a deep search algorithm
  - a good move evaluation function (based on piece count, kings count, trapped kings, player's turn, "runaway checkers", etc.)
  - an end-game database for all positions with eight pieces or fewer. and other minor factors.
- Is Chinook intelligent?

Philosophical foundations

what is intelligence?

Well, What *Is* Intelligence?

- Many arguments over this, some fierce
  - Alan Turing
  - Roger Penrose (*The Emperor's New Mind*)
  - Hubert Dreyfus
  - Daniel Dennett (*Consciousness Explained*)
  - Alan Newell and Herbert Simon
  - John Searle (the Chinese room argument)
  - Hilary Putnam
  - Many other philosophers and cognitive scientists

Intelligence as Symbol Processing

- Newell & Simon's General Problem Solver (GPS) in 1957
- Idea: *all* intelligent behavior is symbol processing (the *physical symbol system hypothesis*)
- So is computing, ergo, AI should be conquered fairly soon
- "Brain in a box" based on a general problem-solving strategy applicable to mathematics problems, games, etc.
- Challenged by combinatorial explosion

The Imitation Game (Turing Test)

- Proposed by Alan Turing in 1948 as a litmus test for “thinking”.

- A human interrogator communicates with two players via teletype.
  - One player is human, the other a machine.
  - Each tries to convince the interrogator that they are the human.

If the interrogator can’t tell which player is human, the machine must be thinking.

Hypothetical Conversation from Turing's Paper

- **Interrogator:** In the first line of your sonnet which reads "Shall I compare thee to a summer's day," would not "a spring day" do as well or better?
- **Computer:** It wouldn't scan.
- **Interrogator:** How about "a winter's day"? That would scan all right.
- **Computer:** Yes, but nobody wants to be compared to a winter's day.

- **Interrogator:** Would you say Mr. Pickwick reminded you of Christmas?
- **Computer:** In a way.

Dickens character

- **Interrogator:** Yet Christmas is a winter's day, and I do not think Mr. Pickwick would mind the comparison.
- **Computer:** I don't think you're serious. By a winter's day one means a typical winter's day, not a special one like Christmas.

What features of intelligence does this hypothetical conversation exhibit? Is this the same "intelligence" used to play chess?

Eliza

- Mid-60's "trick" program fooled unsuspecting users:

User: Men are all alike.
Eliza: In what way?
User: They're always bugging us about something or other.
Eliza: Can you think of a specific example?

Eliza exposed

- Part of a conversation with a modern-day version:

  User: You are a machine.
  Eliza: You have your mind on machines, it seems.
  User: Clever you!
  Eliza: Are you sure that clever me?

- But this is just a toy—what if someone is really trying?

Loebner Prize

A chatterbot written by someone really trying to win the prize:

JUDGE: What music do you like?

ZOE: I'm not really into music. What's your favorite song?

JUDGE: What is your favorite song?

ZOE: That's very interesting. Tell me more. I don't think I have a favorite. What is your favorite play?

JUDGE: I like Waiting for Godot. What is your favorite play?

ZOE: I like Waiting for Godot, too! I don't think I have a favorite. What is your favorite play?

A chat with a winner

Human: what will the weather be like in san jose for thanksgiving?

Mitsuku: I hope it's sunny in san jose for thanksgiving today.

Human: do you know what the weather will be like on that day?

Mitsuku: I don't know where you live to tell you what the weather will be.

Where do you live and I'll tell you the weather forecast.

Human: san jose california

Mitsuku: I hope it's sunny in san jose california today.

Chatbot at http://mitsuku.com/

AI and Common Sense

- “Common sense” knowledge a huge challenge
- We take ours for granted but how can a computer “have” or “simulate” it?
- *Watson*

“Watson”

- IBM's “Watson" computer beat champions Ken Jennings and Brad Rutter in a 2-game match on Jeopardy! in 2011.
- Watson parsed clues into different keywords and fragments.
- Watson had 4TB of data content but was not connected to the Internet during the game.
- Watson executed thousands of language analysis algorithms *concurrently*. The more algorithms that pointed to the same answer, the more likely Watson would buzz in.
- Is Watson intelligent?

Summary

- Artificial Intelligence
- Games described as (large) decision trees
- Heuristics to guide search
- Would-be definitions of intelligence
- Turing Test