

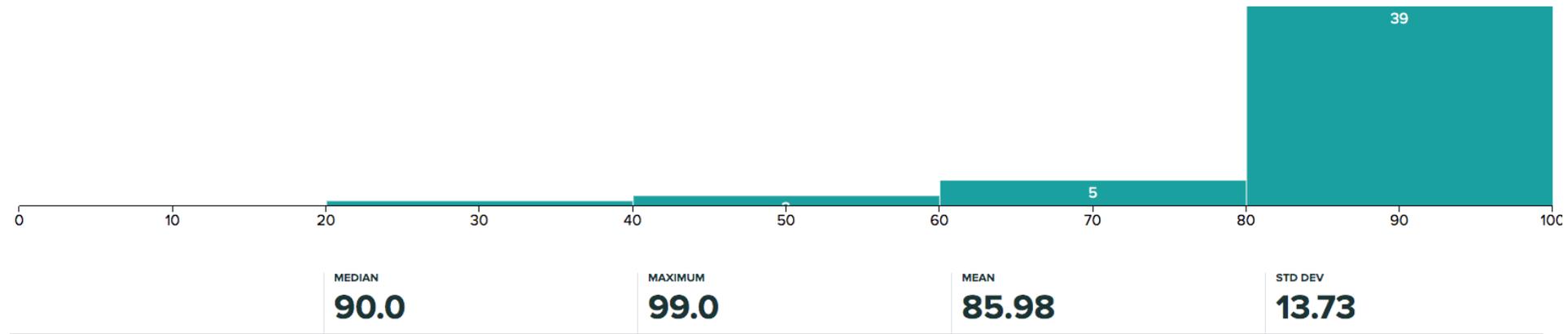
AI



Please fill FCEs

- FCE = Faculty Course Evaluations
- You should have received an email + we will send reminders
- Fill separately for me and Norm
- Super important to help us improve!
- Thank you in advance!

Exam 2 grades are out



What you need to know about concurrency:

- What is concurrency? What is race condition, critical section, deadlock, threads, processes?
- What is the difference between sequential and concurrent programming?
- What is the importance of concurrency (why do we care?)
- How can processes run in one processor vs multiple processors and what is the difference?
- What is the Dining Philosopher's problem? Why does that lead to a deadlock? How can we fix the deadlock?
- Also be able to:
 - Understand and explain the behavior of the Python code where we used threading (with the `inc()` `dec()` functions)
 - Identify race condition, interference and deadlock when given some Python code/function

AI

Overview

- What is AI?
- Games Trees and MiniMax Algorithms
- AI in the world

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

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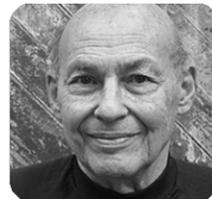
Turing Award recipients in late '60s—early '70s
for contributions to AI



Newell
CMU



Simon
CMU



Minsky
MIT



McCarthy
Stanford

A Cynic's View

- AI is the study of how to get computers to do things that we (humans)
 - are naturally good at: folding laundry, walking up the stairs, understanding language or accents
 - don't fully understand how they work: “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?

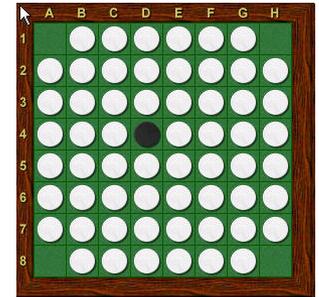
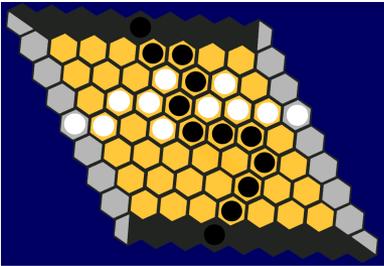
- Thin end of the wedge for AI research
 - Characteristically **human activity**
 - Small so potentially **solvable**
 - Easy to **measure** success or failure
 - Solutions *might* tell us something about **intelligence** in general

Why Study Games?

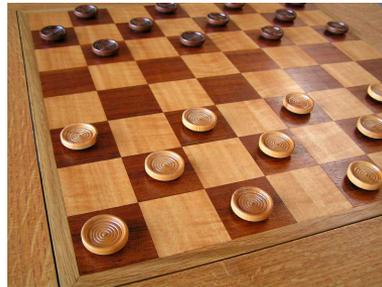
Arthur Samuels, 1960:

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



0	0	0
	0	X
	X	X



Game Properties

- Two players
 - alternating turns

- Perfect information
 - No hidden cards or hidden Chess pieces...

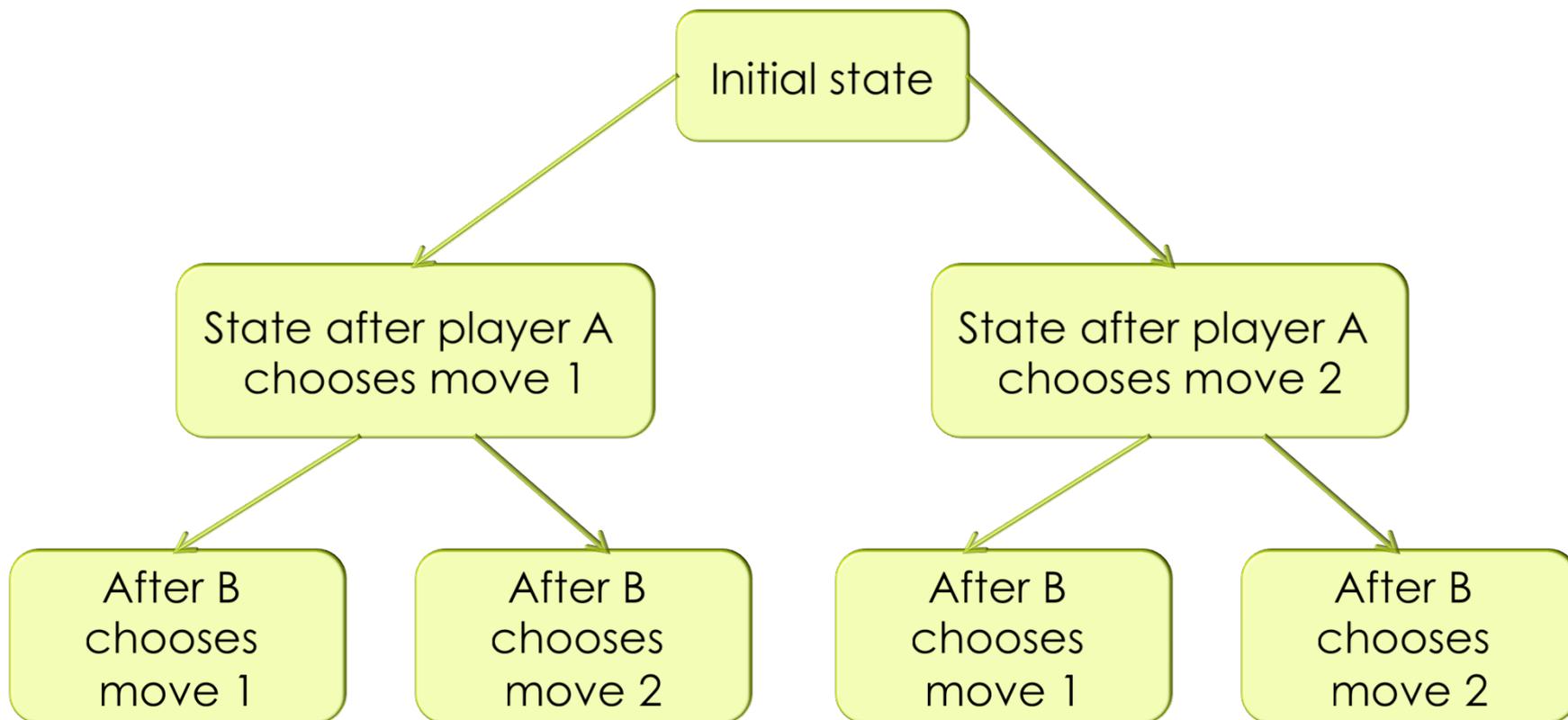
- Finite
 - Game must end in finite number of moves

- 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:



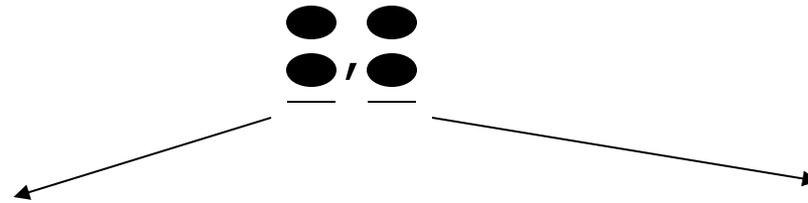
Game of Nim

- 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.
- NIM = Win? (with math)

Playtime!

Playing Nim

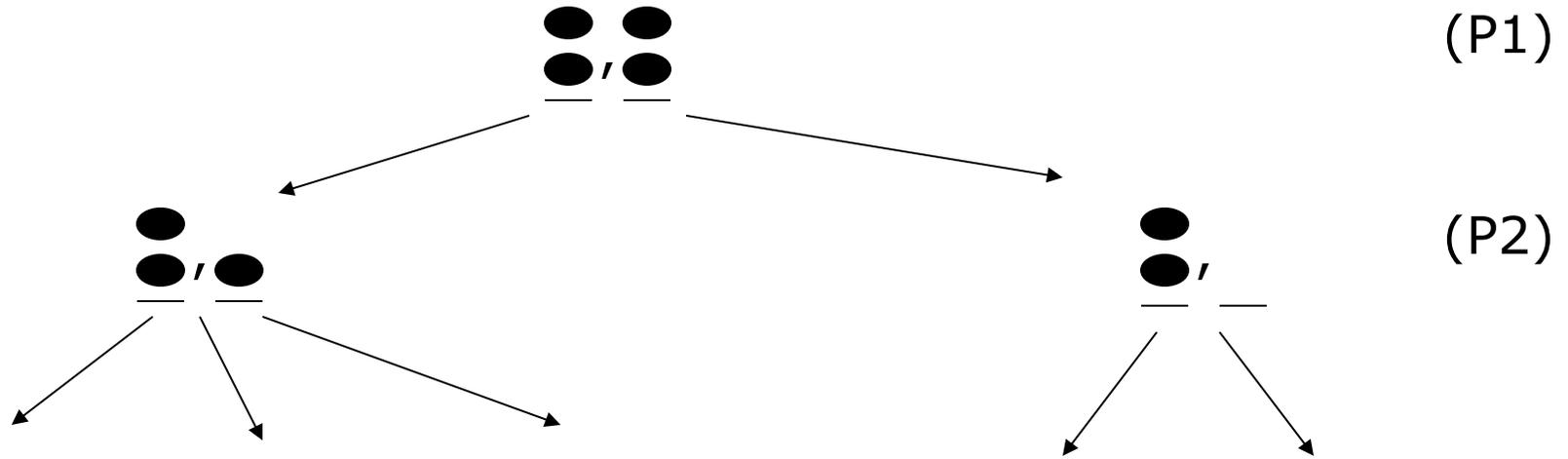
P1 has first move



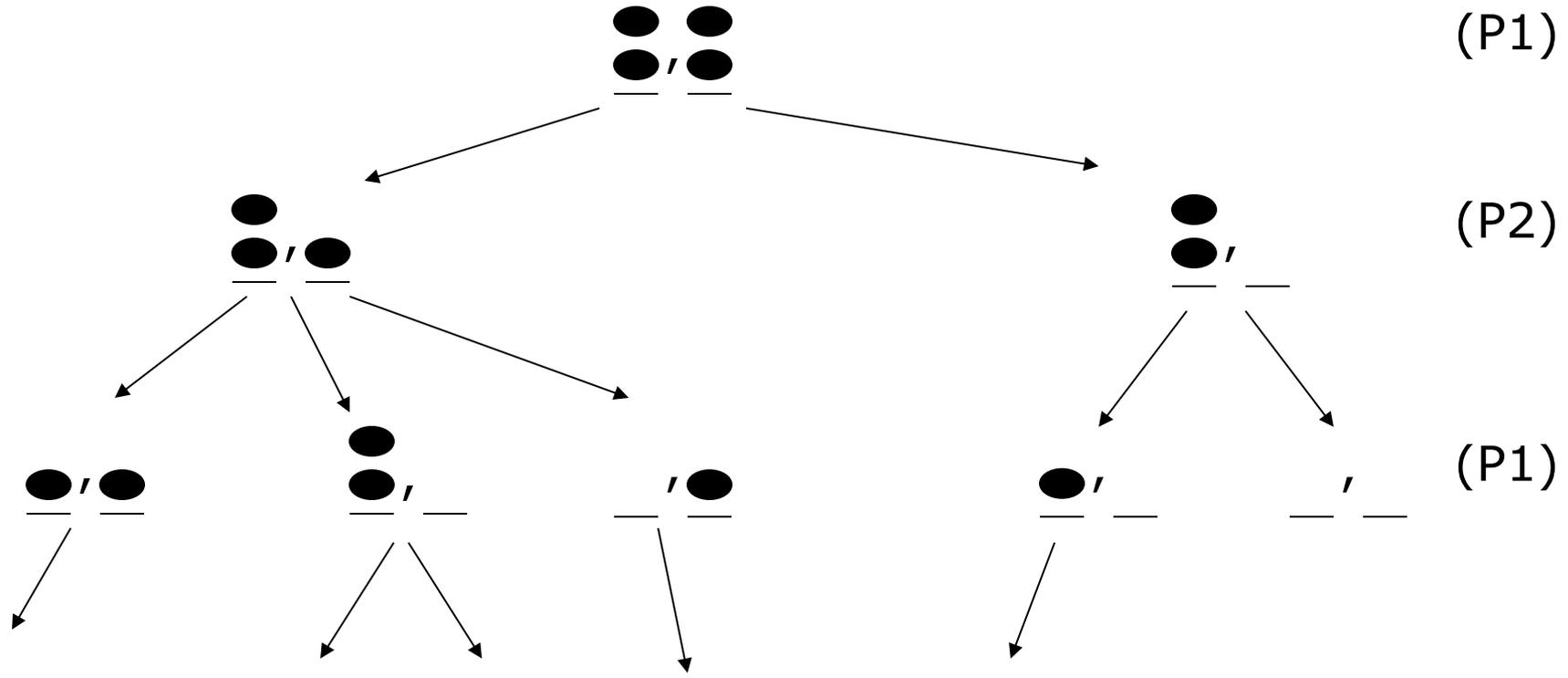
(P1)

Playing Nim

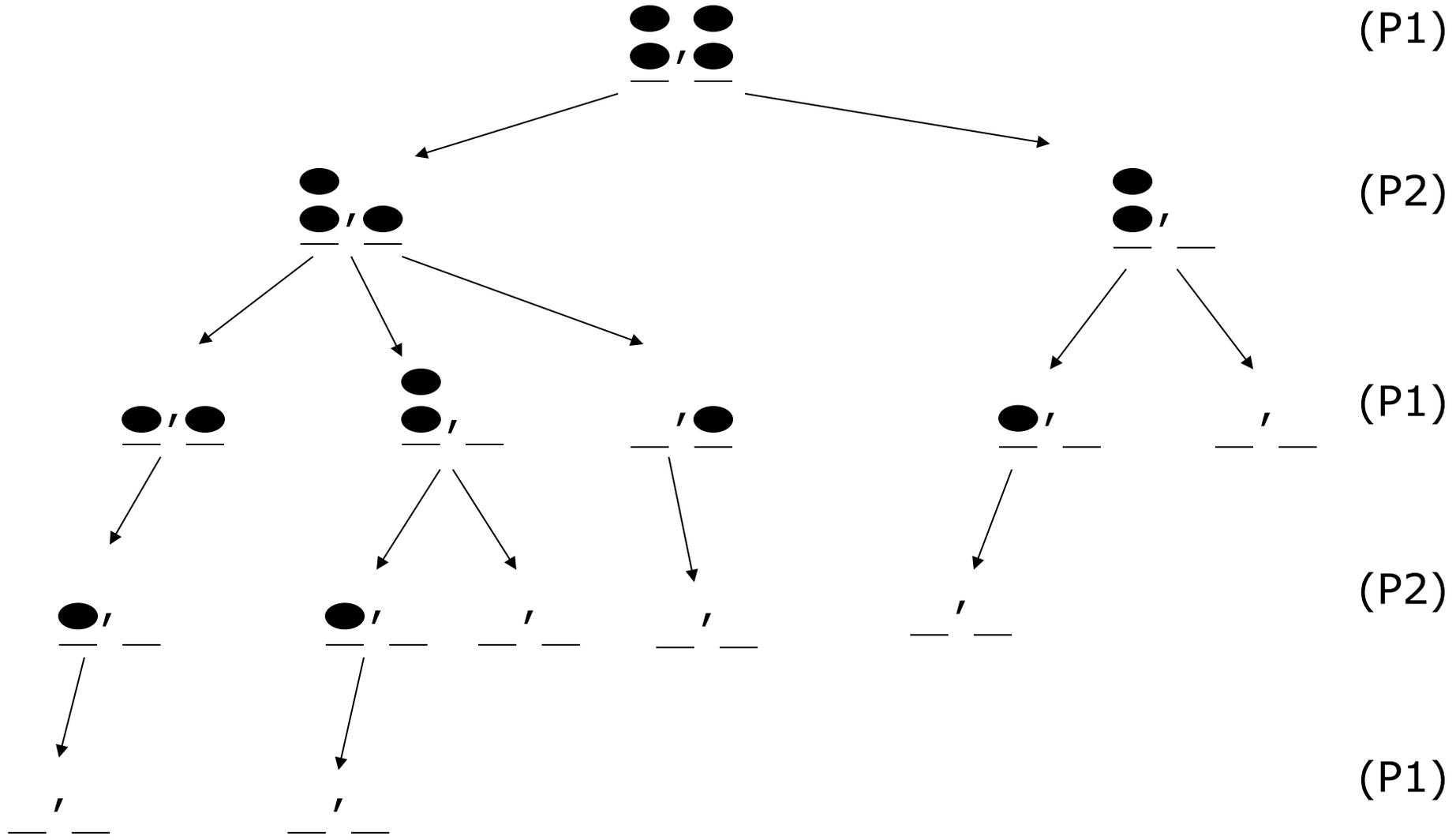
P2 possible moves



Playing Nim P1 moves next



Playing Nim P1 moves next



Evaluation Functions

- We can define the **value** (goodness) of a certain game state (board).
- For example,
 - 1 = Player P1 wins,
 - 1 = Player P2 wins
 - (0 = tie, when ties are possible)

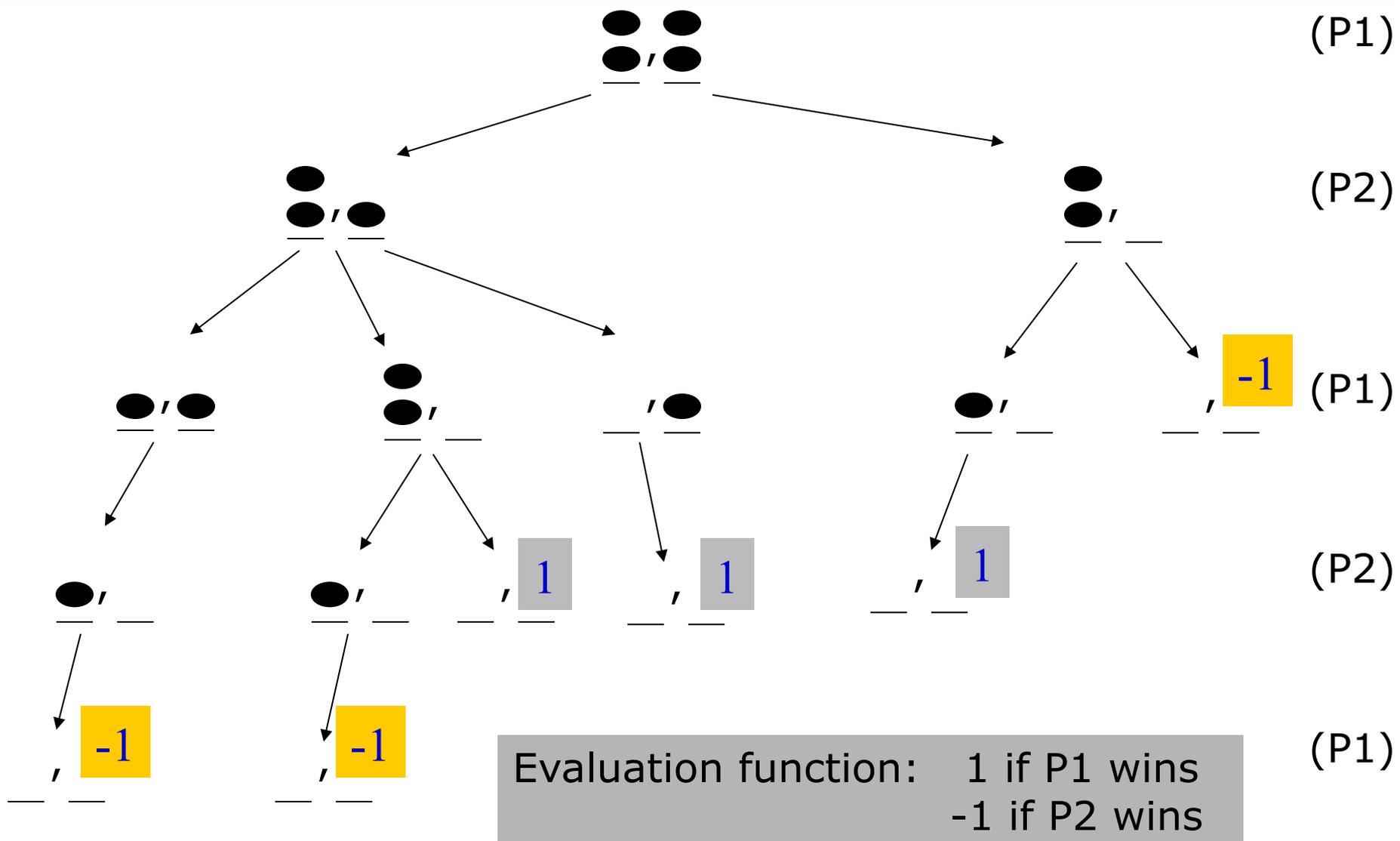
How do we play (win!)?

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

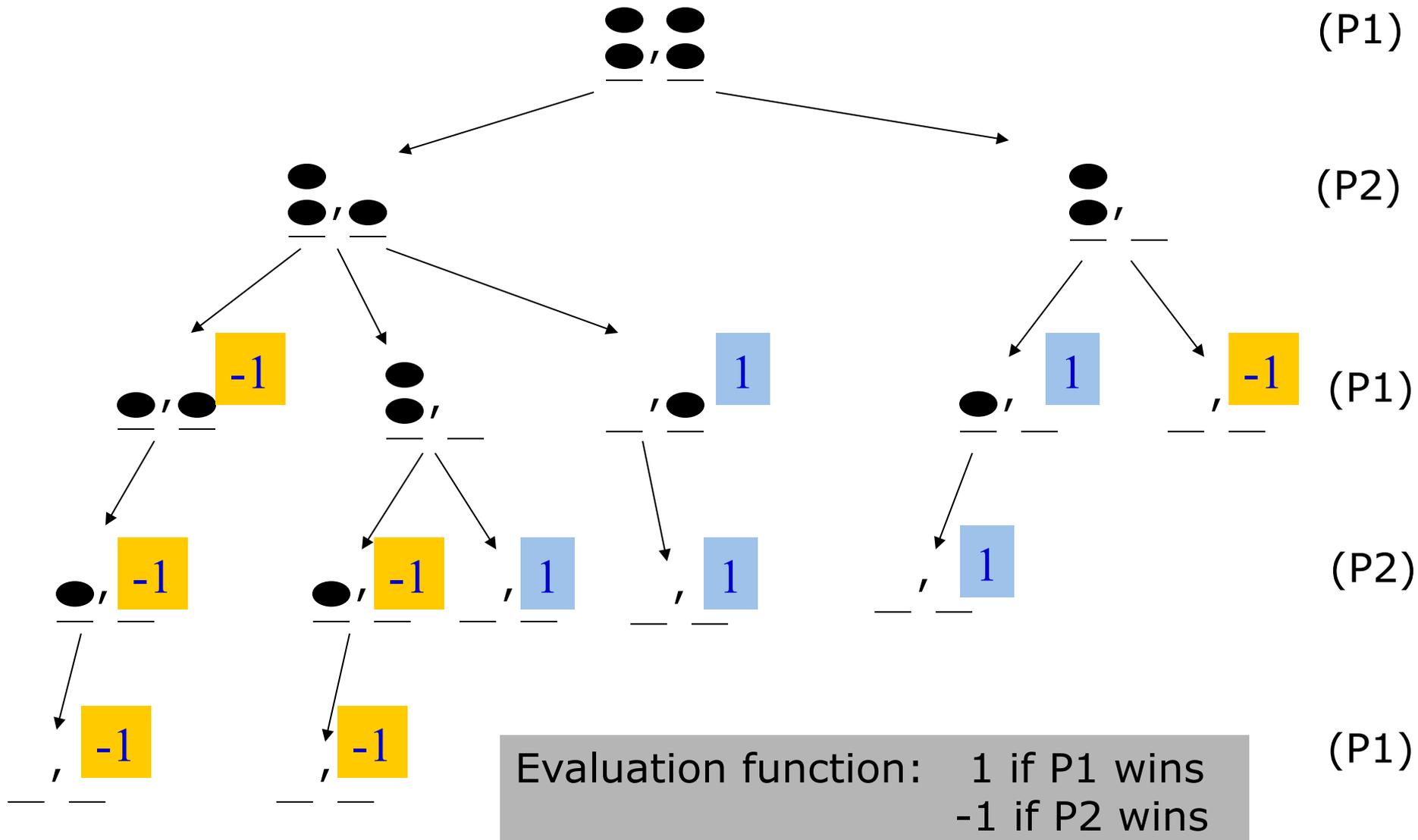
- Start by evaluating the terminal positions, where the game is over (the leaf nodes).

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

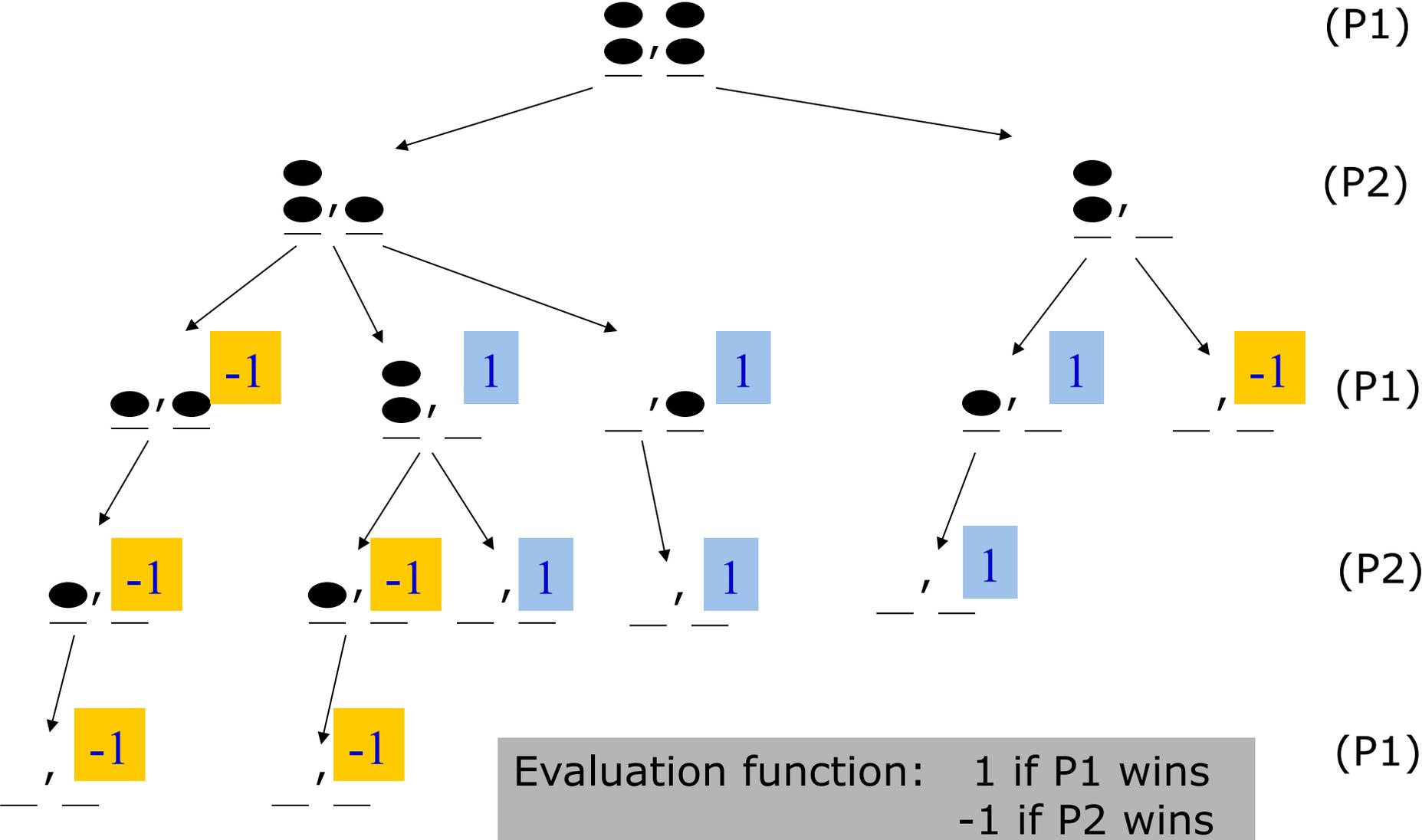
Playing Nim with Minimax



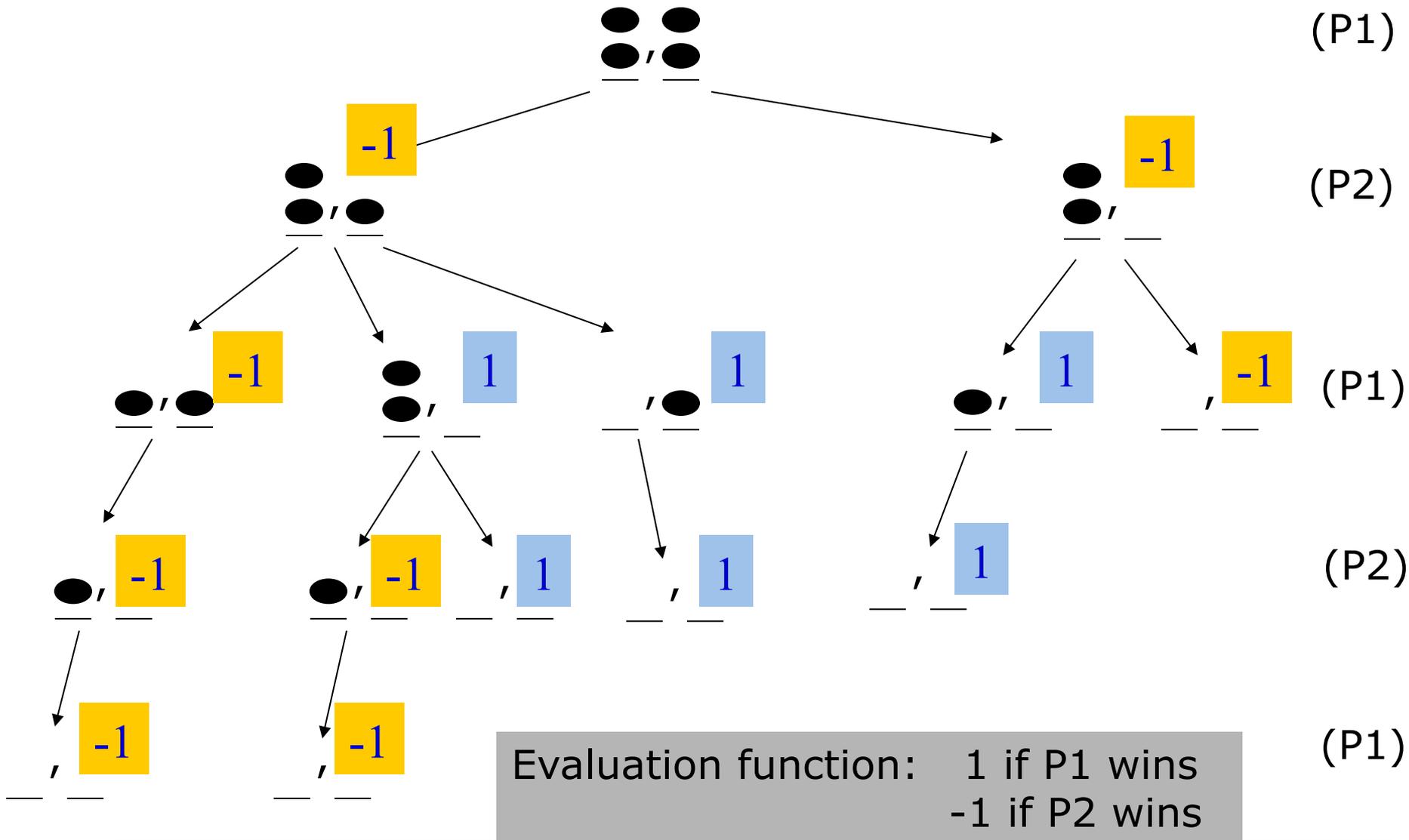
Playing Nim with Minimax



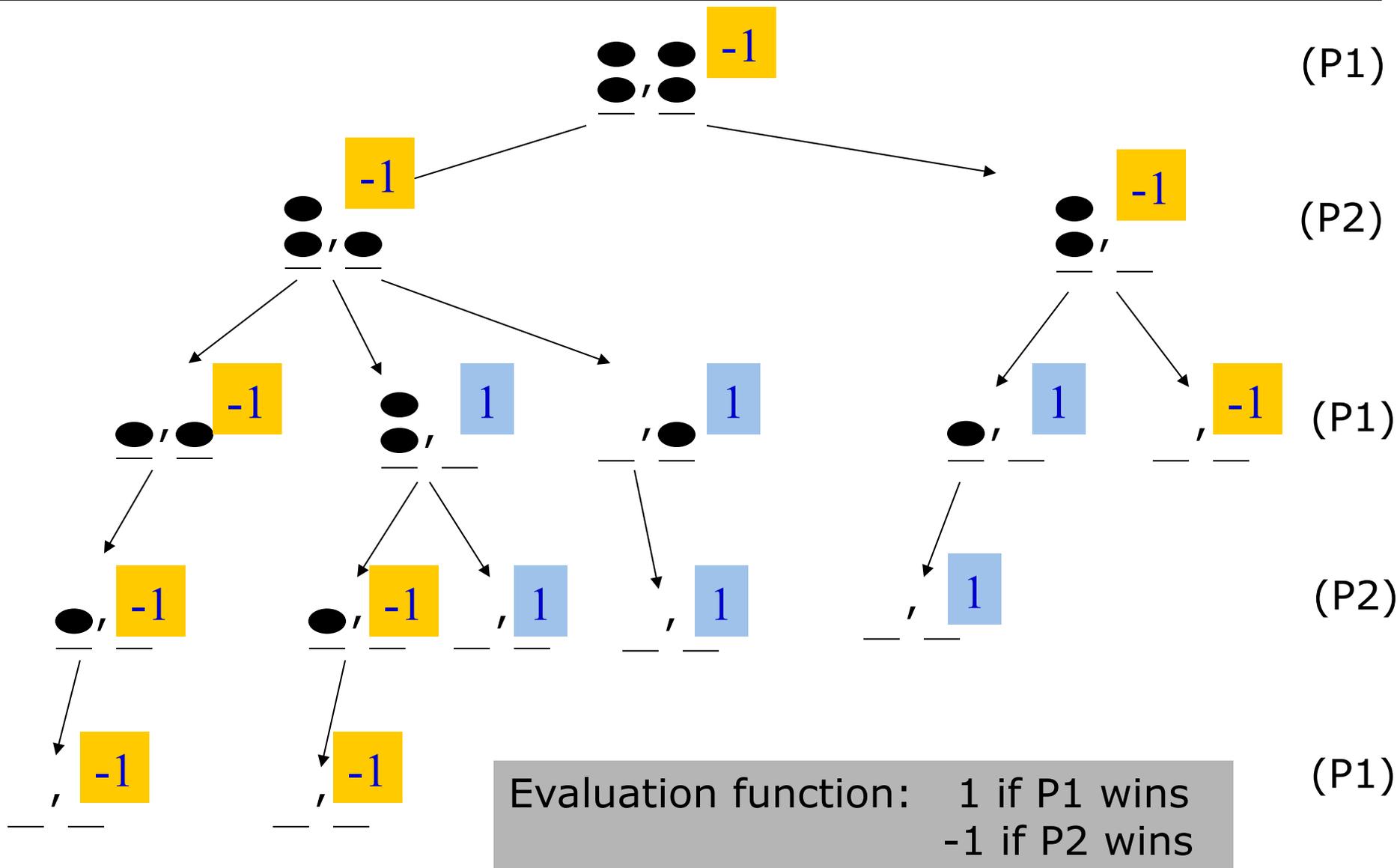
Playing Nim with Minimax



Playing Nim with Minimax



Playing Nim with Minimax



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.

MiniMax Algorithms

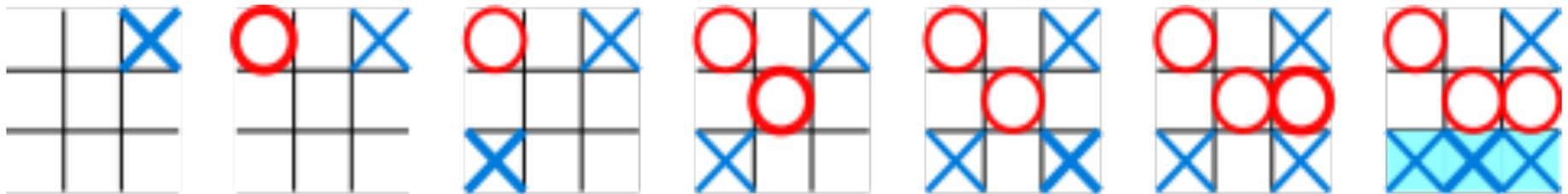
- Player P1 (us) maximize goodness.
- Player P2 (opponent) minimizes goodness
- At a leaf (a terminal position) A wins, loses, or draws.
 - Assign a score: 1 for win; 0 for draw; -1 for lose.
- At max layers, take node score as maximum of the
 - child node scores
- At min layers, take nodes score as minimum of the
 - child node scores

Tic-tac-toe

Tic Tac Toe

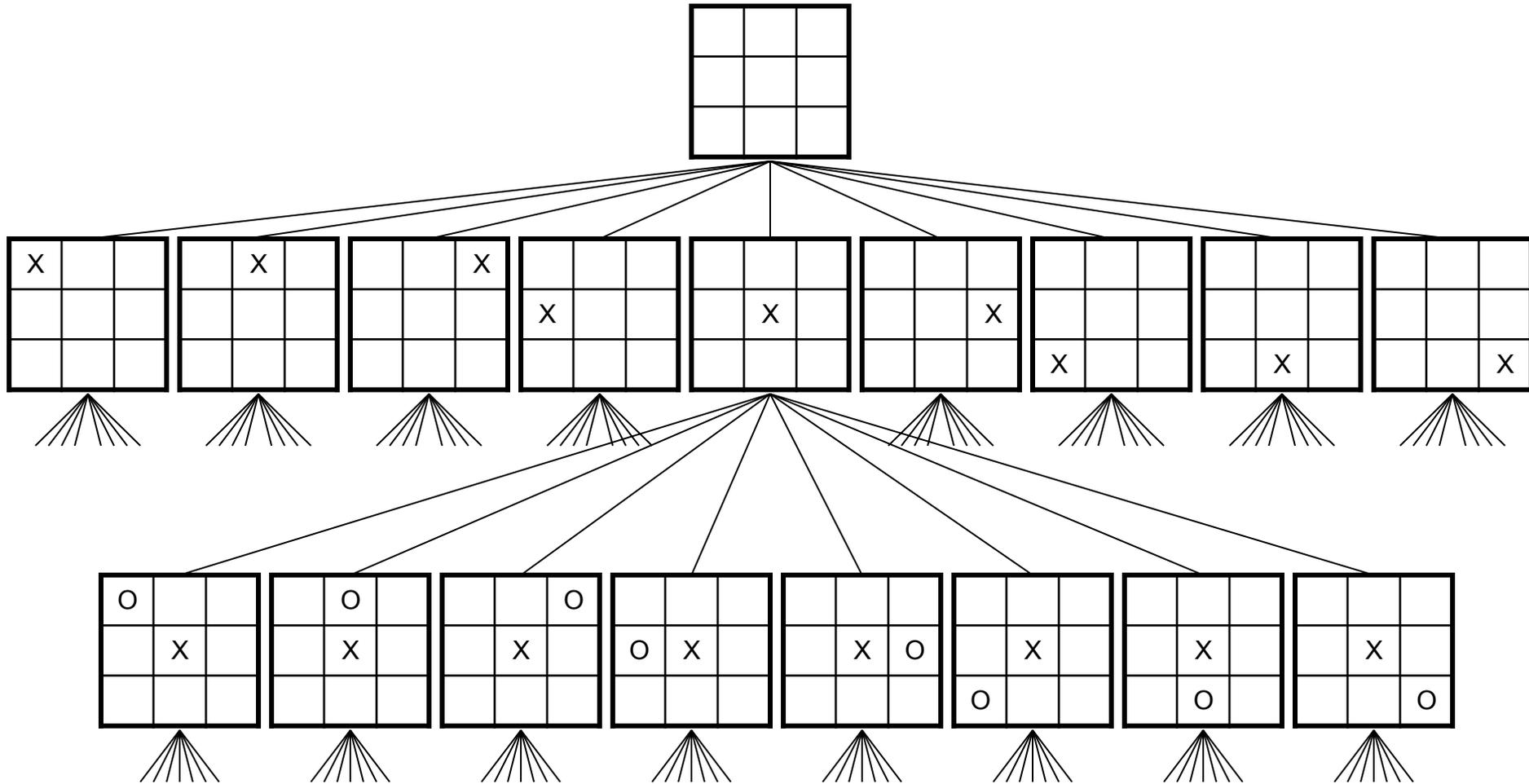
A pencil and paper game for two players, X and O, who take turns marking the spaces in a 3×3 grid. The player who succeeds in placing three of their marks in a horizontal, vertical, or diagonal row wins the game.

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



Source: Wikipedia

Tic Tac Toe Game Tree

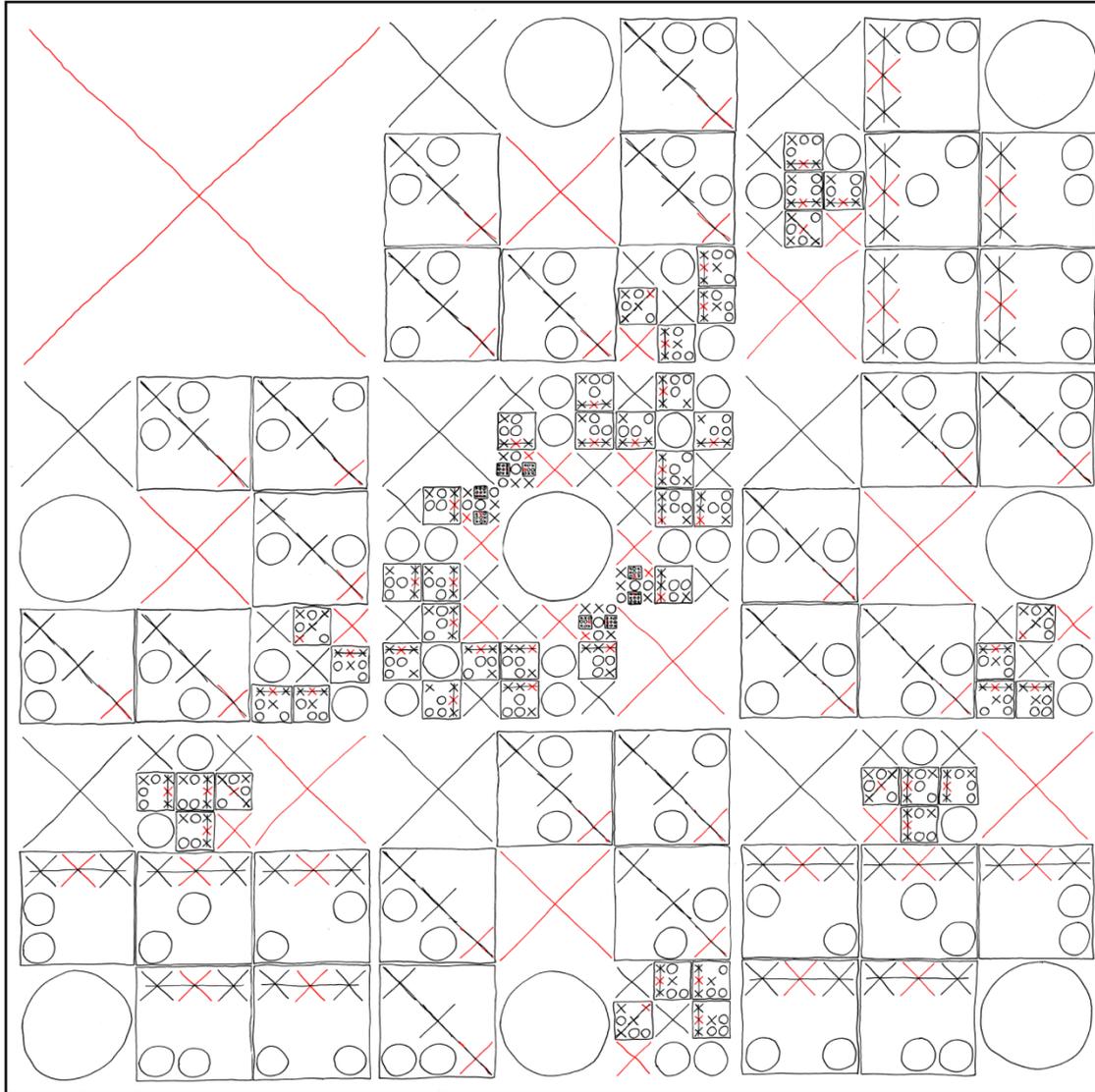


For the Enthusiast

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

XKCD's Optimal Tic-Tac-Toe

MAP FOR X:

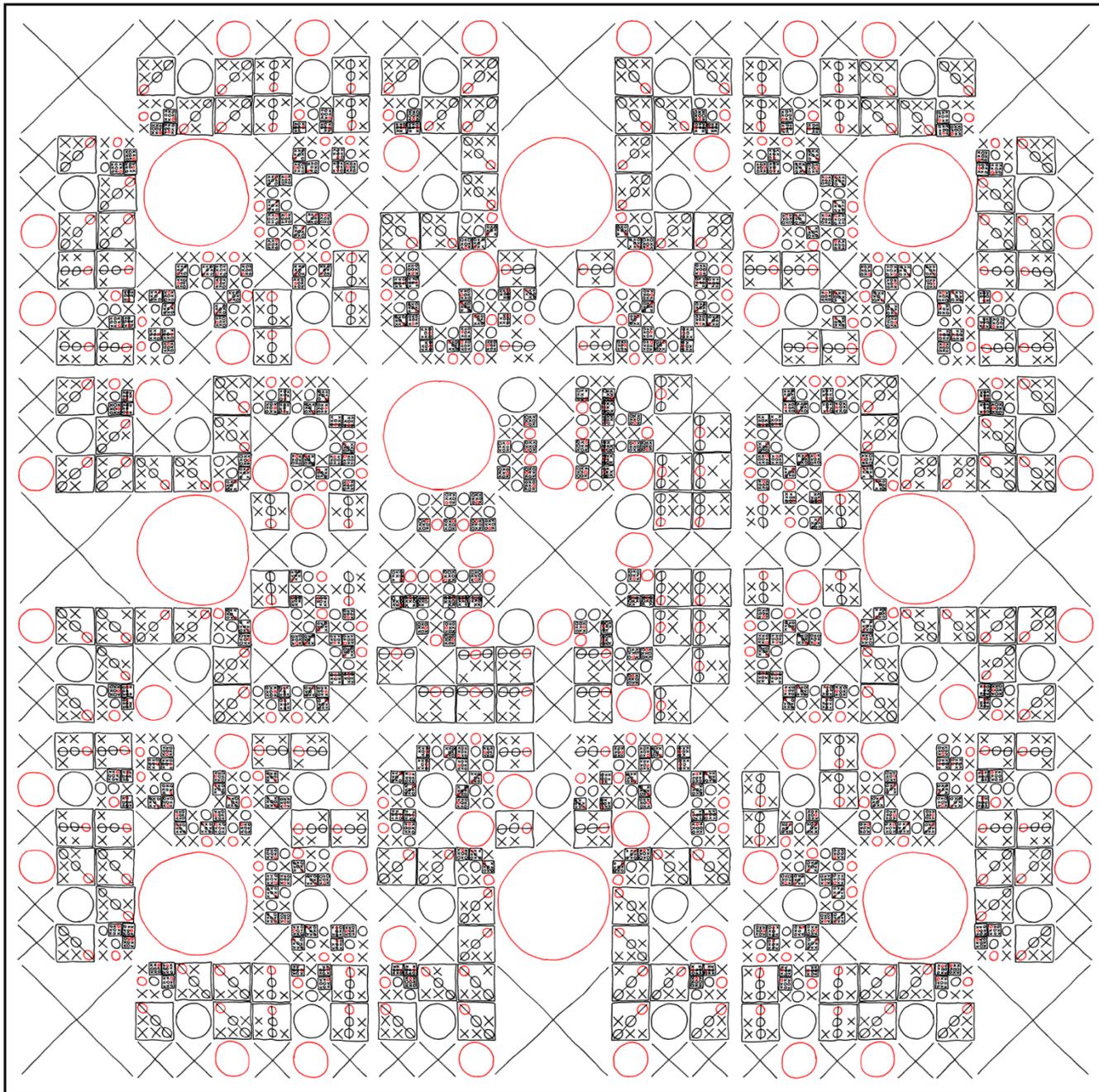


COMPLETE MAP OF OPTIMAL TIC-TAC-TOE MOVES

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.

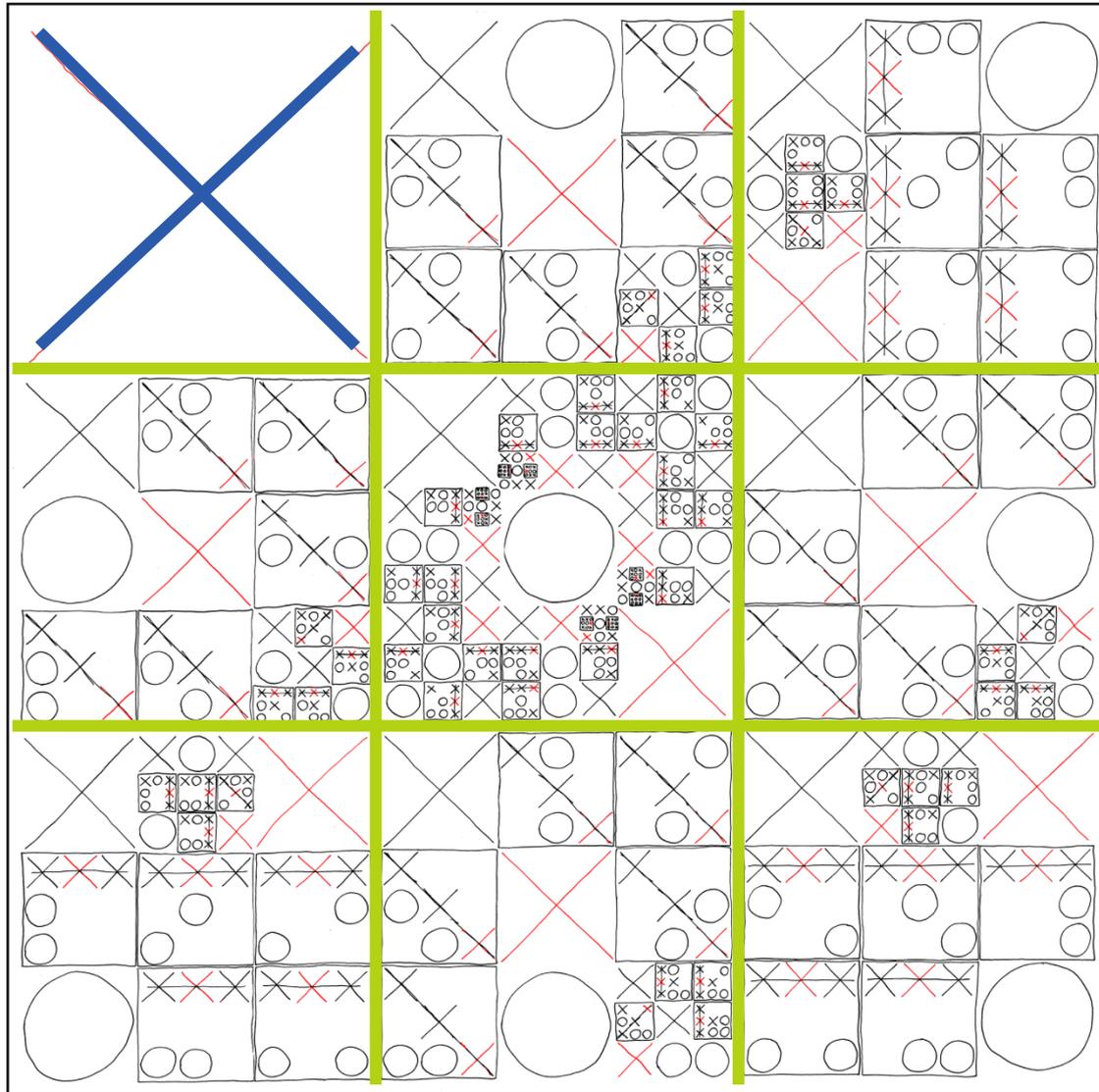
<http://xkcd.com/832>

MAP FOR O:



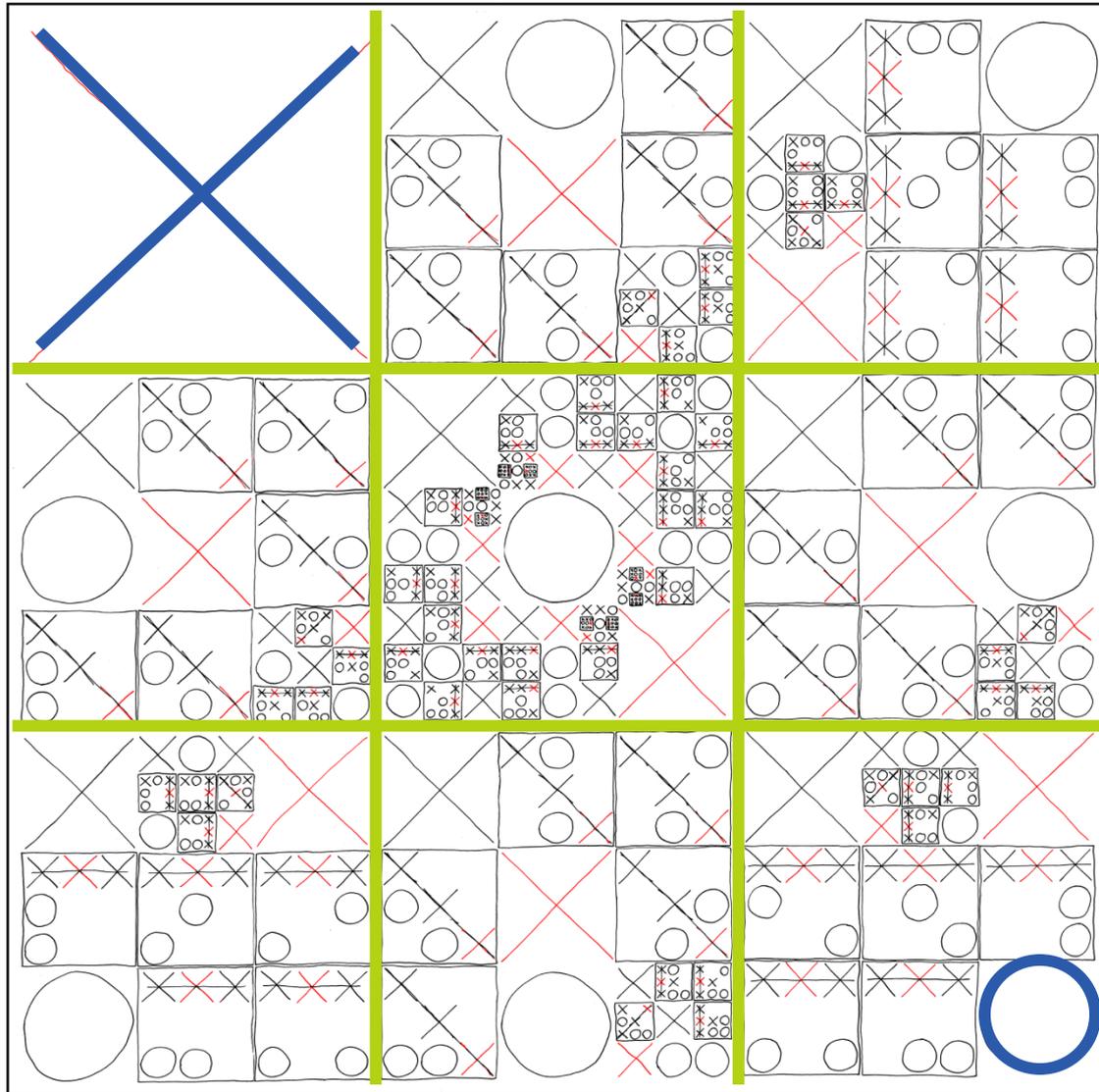
X Move 1

MAP FOR X:



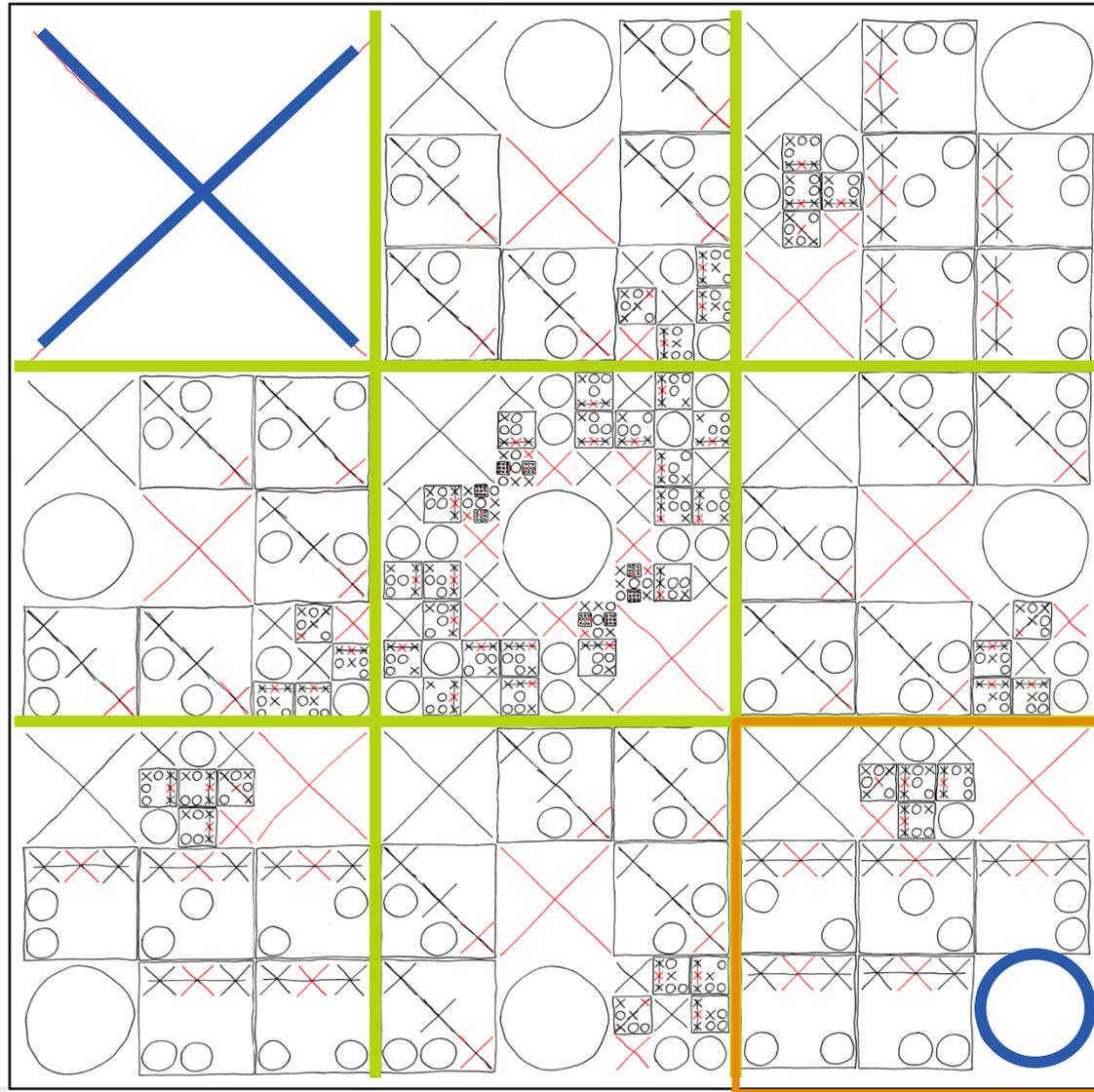
O Move 1 (non-optimal play)

MAP FOR X:

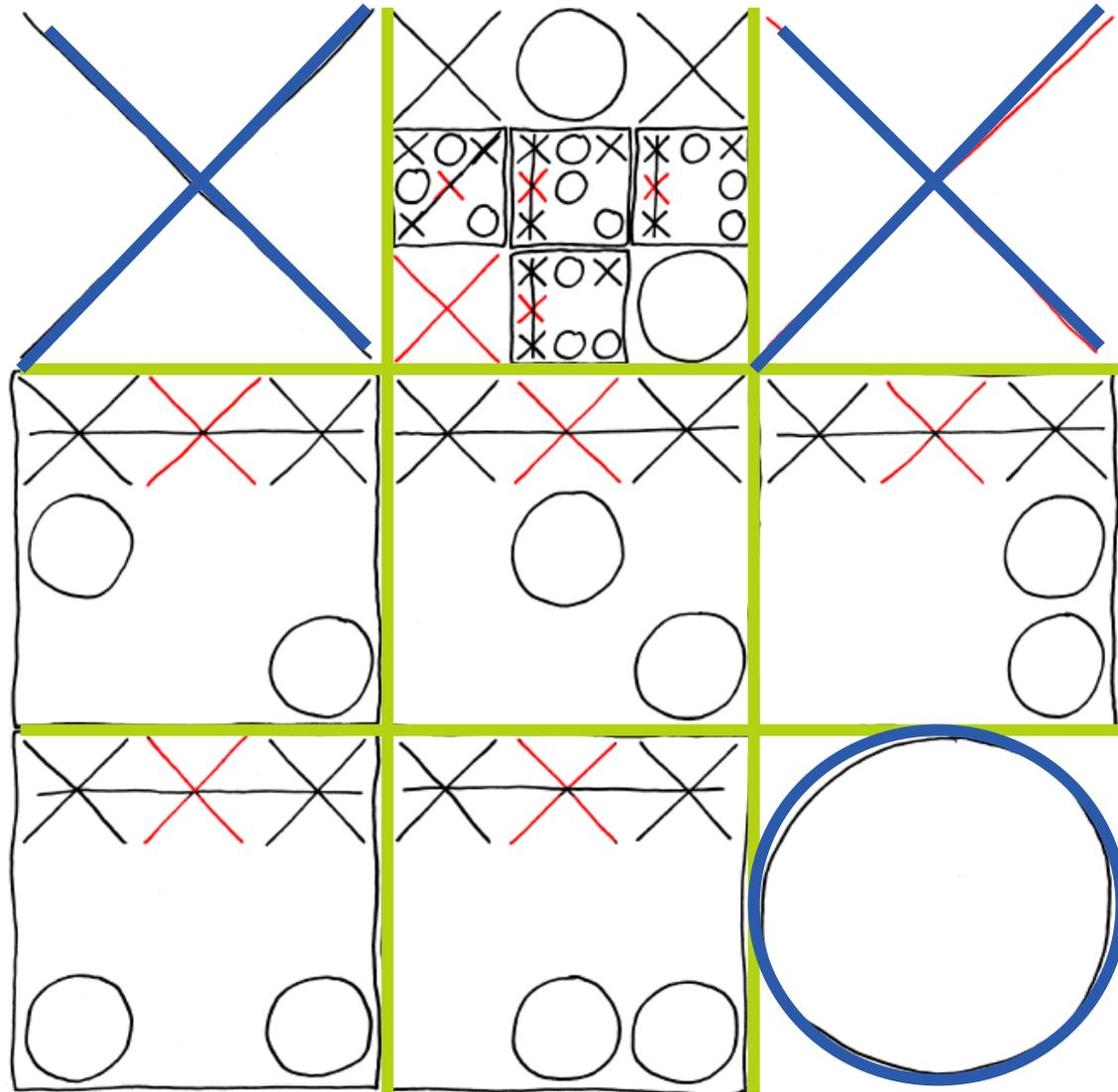


O Move 1 (non-optimal play)

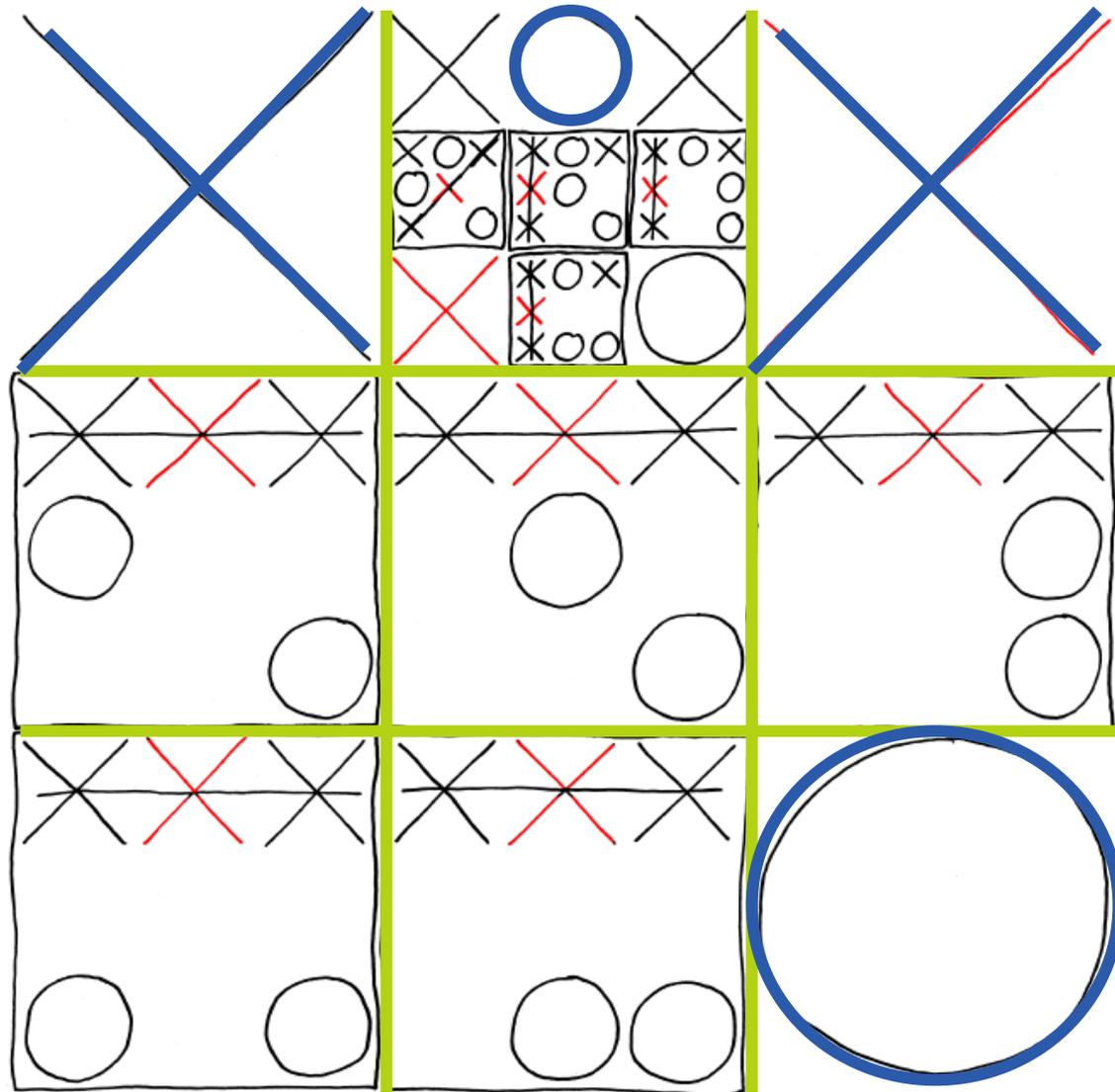
MAP FOR X:



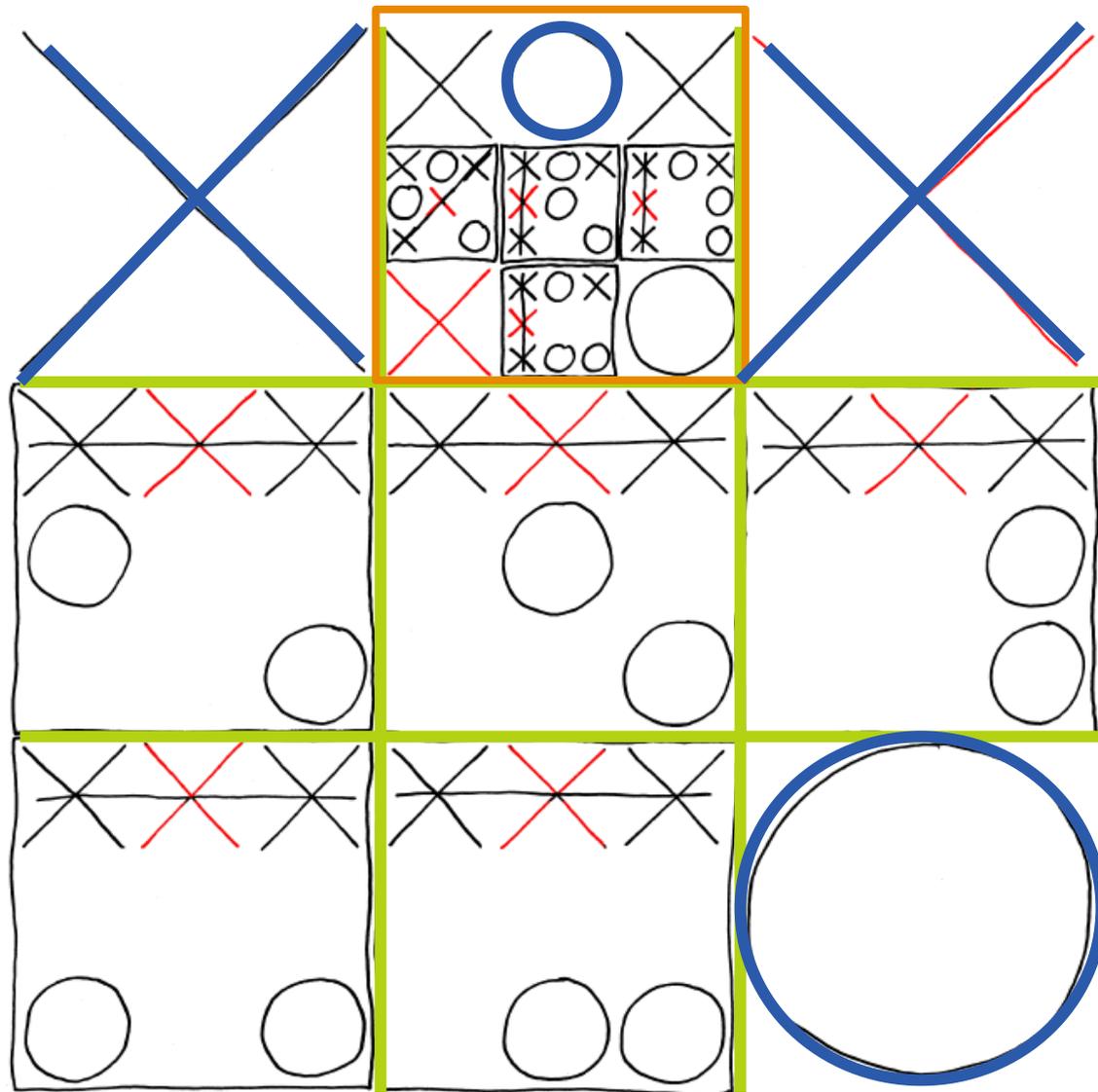
X Move 2



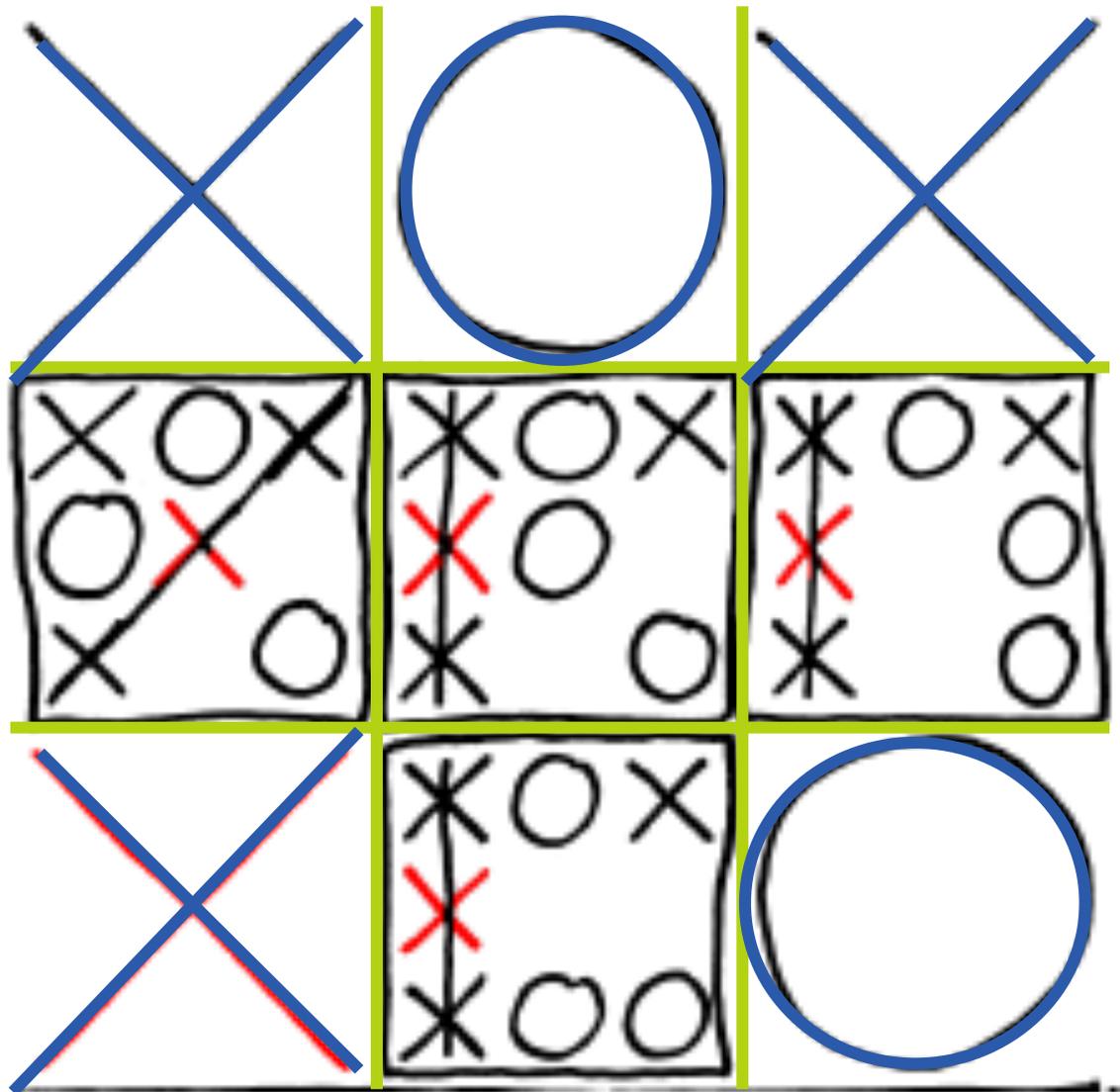
O Move 2



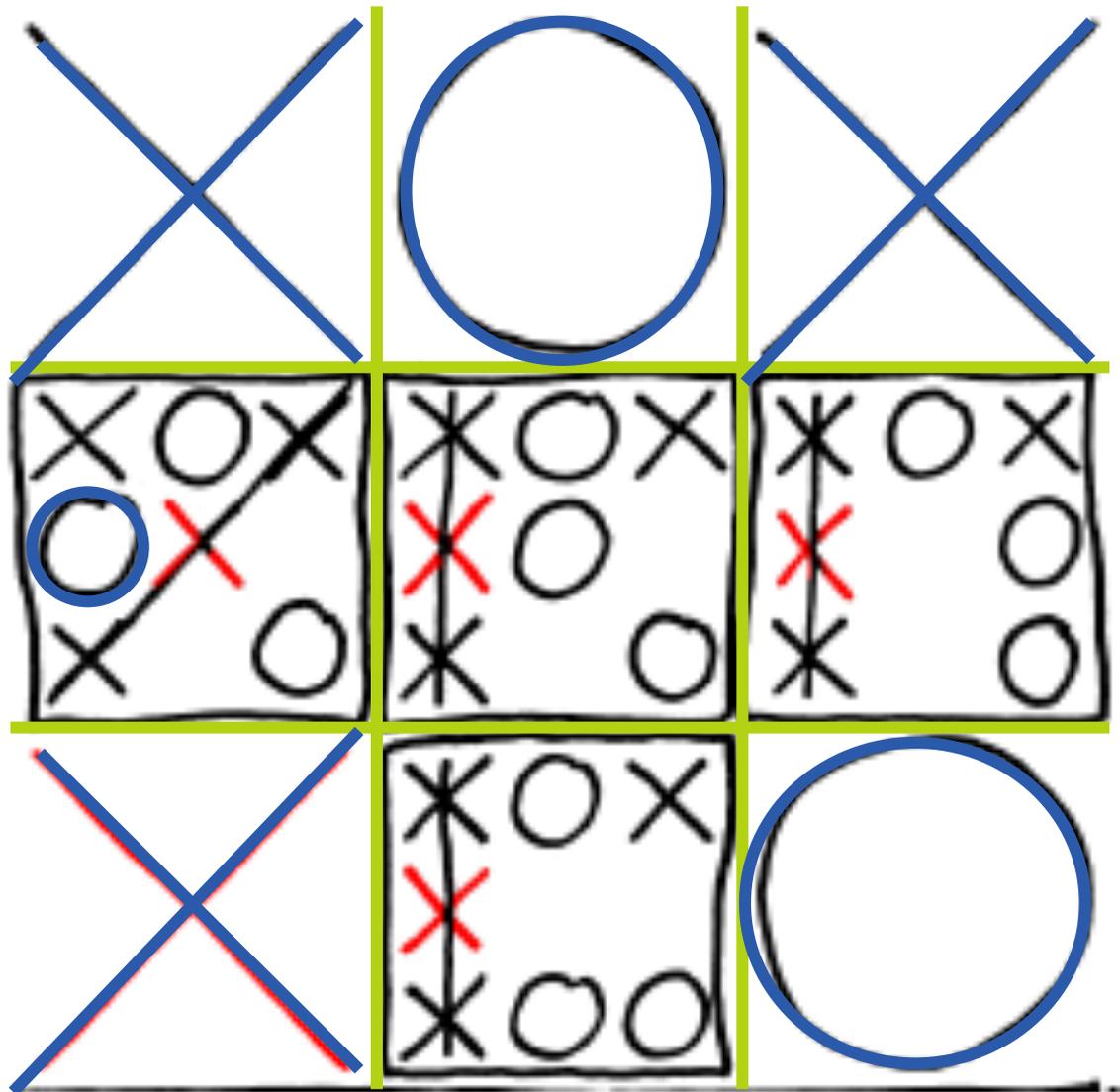
O Move 2



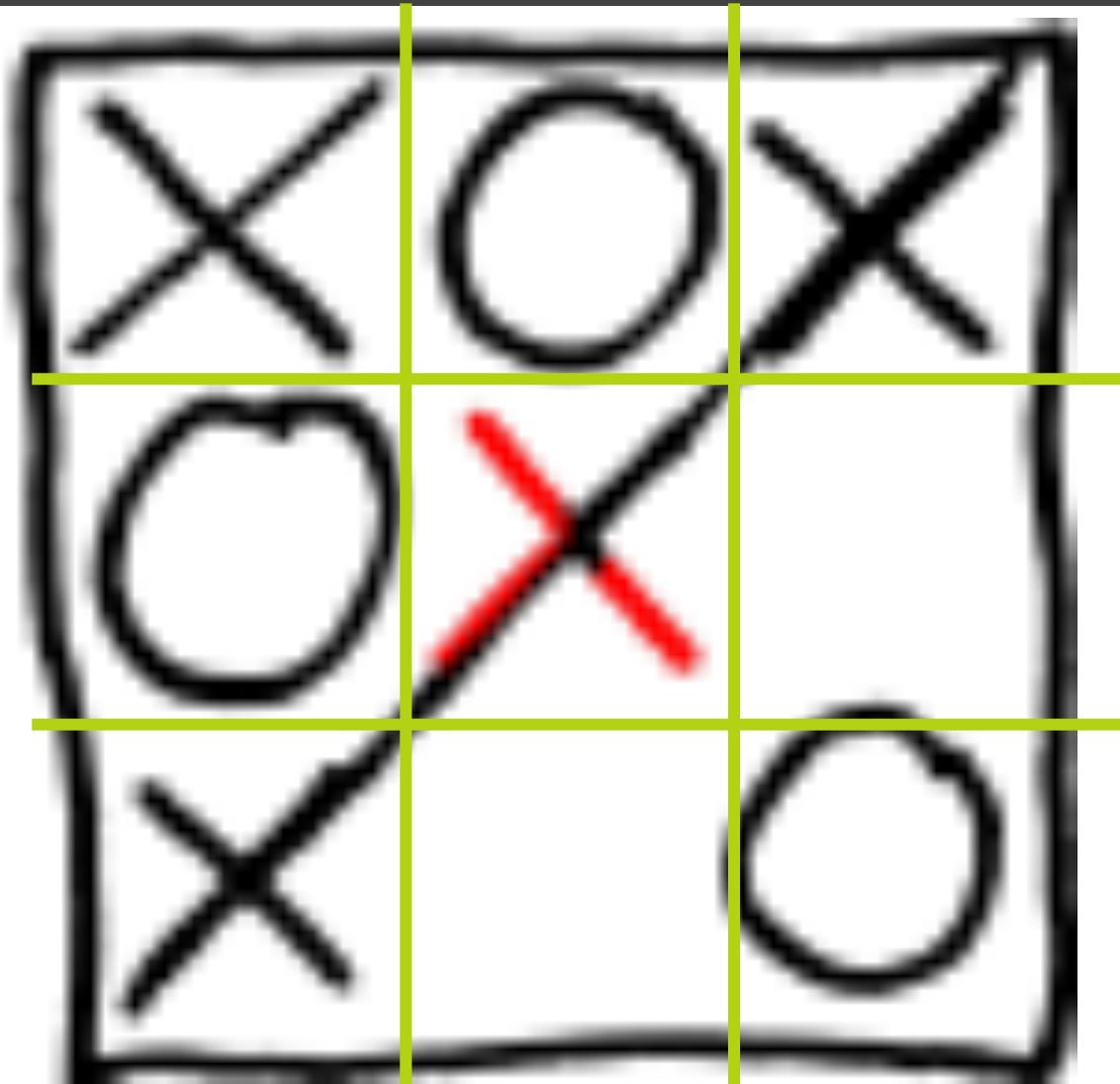
X Move 3



X Move 3



X Move 4 To Win



How Big is the Tic-Tac-Toe Tree?

- Assuming that all nine positions must be filled before the game ends, how big does this tree get?

How Big is the Tic-Tac-Toe Tree?

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At most $9*8*7*6*5*4*3*2*1 = 9! = 362,880$

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 - What is the first level of the tree where this can occur?

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Ending on the 5th move. 3Xs, 2 Os
 - How big is this tree up to this level?
 $9*8*7*6*5 = 15,120$

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

Chess - Infeasibility

- Human beings play chess, some very well!
- A complete analysis of a chess game is *computationally infeasible*
- *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 are approximately 20 possible moves at each turn, looking ahead 15 moves requires examining about 3.3×10^{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

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: $\sim 35^{100}$ (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

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**.

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*
 - ...

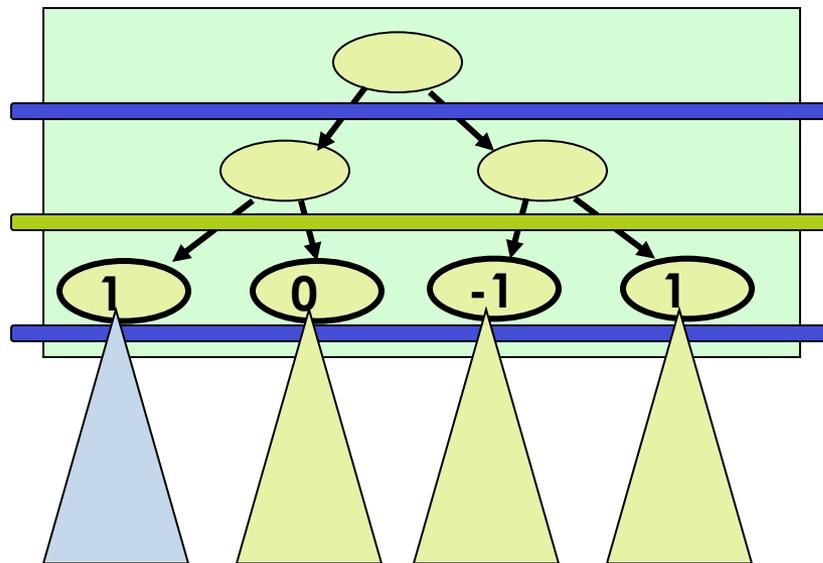
Minimax, in reality

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

□ Max

Min

Max



A moves

B moves

A moves

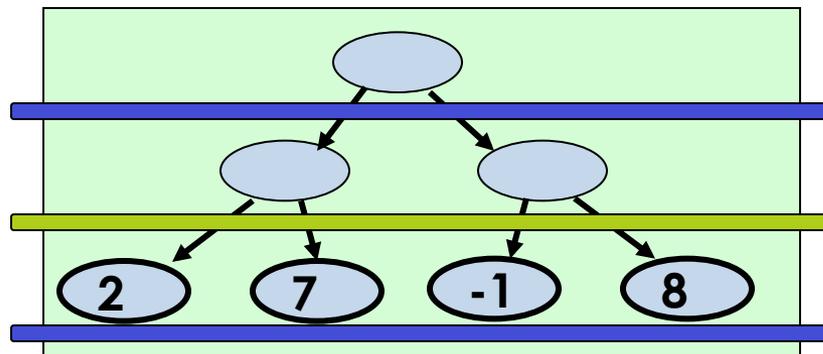
Minimax, bounded search

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

□ Max

Min

Max



A moves

B moves

A moves

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

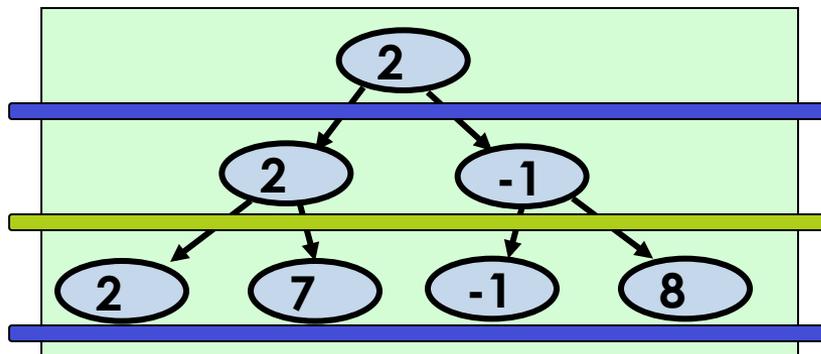
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□ Max

Min

Max



A moves

B moves

A moves

Applications in real life

not just for games!

“Deep Blue”

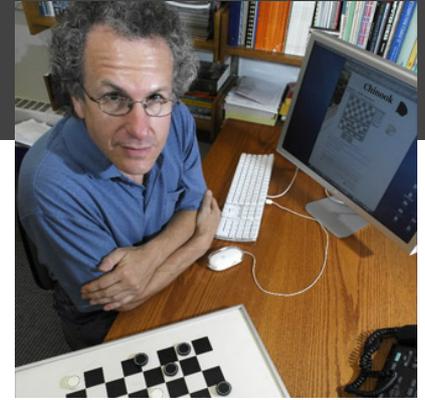


- ❑ IBM's "Deep Blue" computer beats Gary Kasparov in a chess match in 1997.
- ❑ Heuristics values:
 - ❑ The value of each piece. (1 for pawn up to 9 for queen)
 - ❑ The amount of control each side has over the board.
 - ❑ The safety of the king.
 - ❑ The quickness that pieces move into fighting position.
- ❑ 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?

AlphaGo

- AlphaGo is the first computer program to defeat a professional human Go player, the first program to defeat a Go world champion, and arguably the strongest Go player in history.
- AlphaGo's 4-1 victory in Seoul, South Korea, in March 2016 was watched by over 200 million people worldwide. It was a landmark achievement that experts agreed was a decade ahead of its time, and earned AlphaGo a 9 dan professional ranking (the highest certification) - the first time a computer Go player had ever received the accolade.
- <https://deepmind.com/research/alphago/>

Philosophical foundations

what is intelligence?

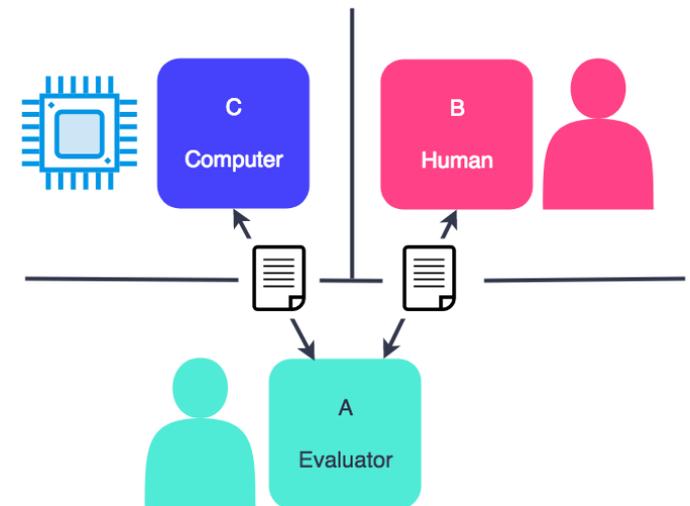
AI in our world

- There is a lot of AI in the world!
- Weak AI:
 - mimics some human behavior, but is limited in range
 - “intelligent” only at specific tasks
 - i.e.: Siri, autocorrect, face recognition, self-driving cars
 - has been around for a while
- Strong AI:
 - A machine or system that thinks like us. Whatever it is what our brains do, strong AI does as well
 - Things that we are neutrally good at (thinking, listening, understanding, even folding laundry and going up the stairs)
 - Does not exist (yet): still needs to be designed

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 like us (humans).*



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?

Rose, 2013

Judge	Rose
My name is Andrew, what's yours?	My name is Rose.
What's up?	I'm fine. How are you?
What's my name?	You are Andrew.
What do you know about the Turing Test?	It's a procedure supposed to tell human from machine by using text conversation.
What colour is bread?	Chartreuse.
Why do people get ulcers?	Pondering whys just tends to lead one into philosophical dead ends.
What comes after "The best laid plans".	So... I don't want to spend time on that now. Recycling is common sense. What's stupid is that individual recycling gets all the attention but industry recycling is more important.
Do you have a voice?	My voice is not particularly good.
Would you like a cup of tea?	I might. Or I might not. Depends on how I feel at the time. San Francisco is a good city to live in for recycling. It recycles around 70% of the waste stream.
Do you dream of electric sheep?	I have lots of really vivid dreams. I just don't usually remember them.
Do you identify as a man, or a woman?	This seems more like an interrogation and less of a conversation. My name is Rose.
Could you repeat that please?	What I said was: I have lots of really vivid dreams. I just don't usually remember them.
Where are you right now?	I'm here, at Bletchley Park.

A chat transcript where a judge questions Rose in the Loebner competition

A chat with a winner

- Mitsuku: <https://www.pandorabots.com/mitsuku/>

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?

Discussion

- If (and when?) this Strong AI is created, what do you think will happen?

Discussion

- If (and when?) this Strong AI is created, what do you think will happen?
- To explore on your own:
 - (video) The Singularity, Skynet, and the Future of Computing: Crash Course Computer Science #40
 - (video) Crash Course Artificial Intelligence Preview (NEW SERIES!!)
 - Read on: Technological singularity

Summary

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