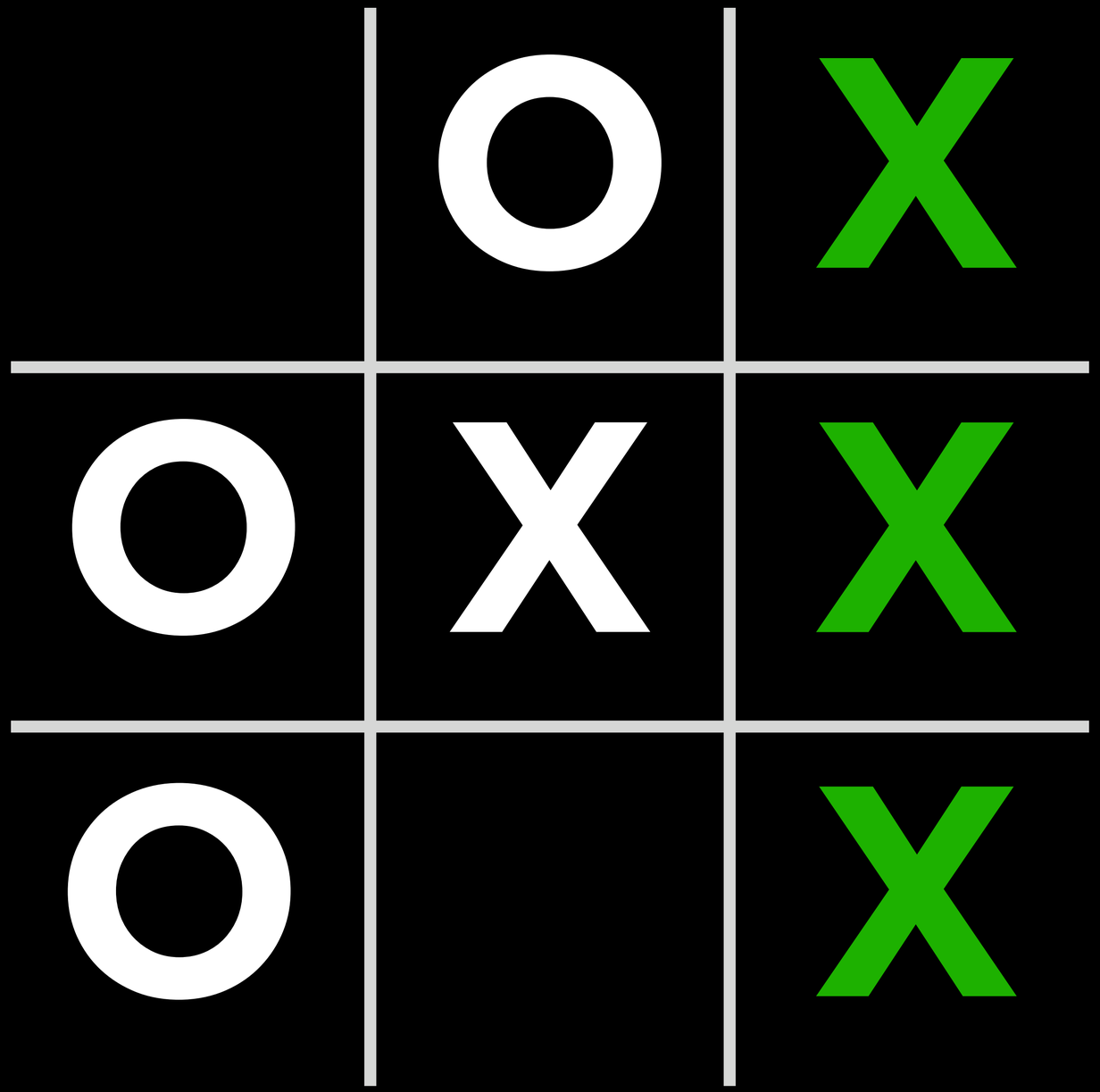
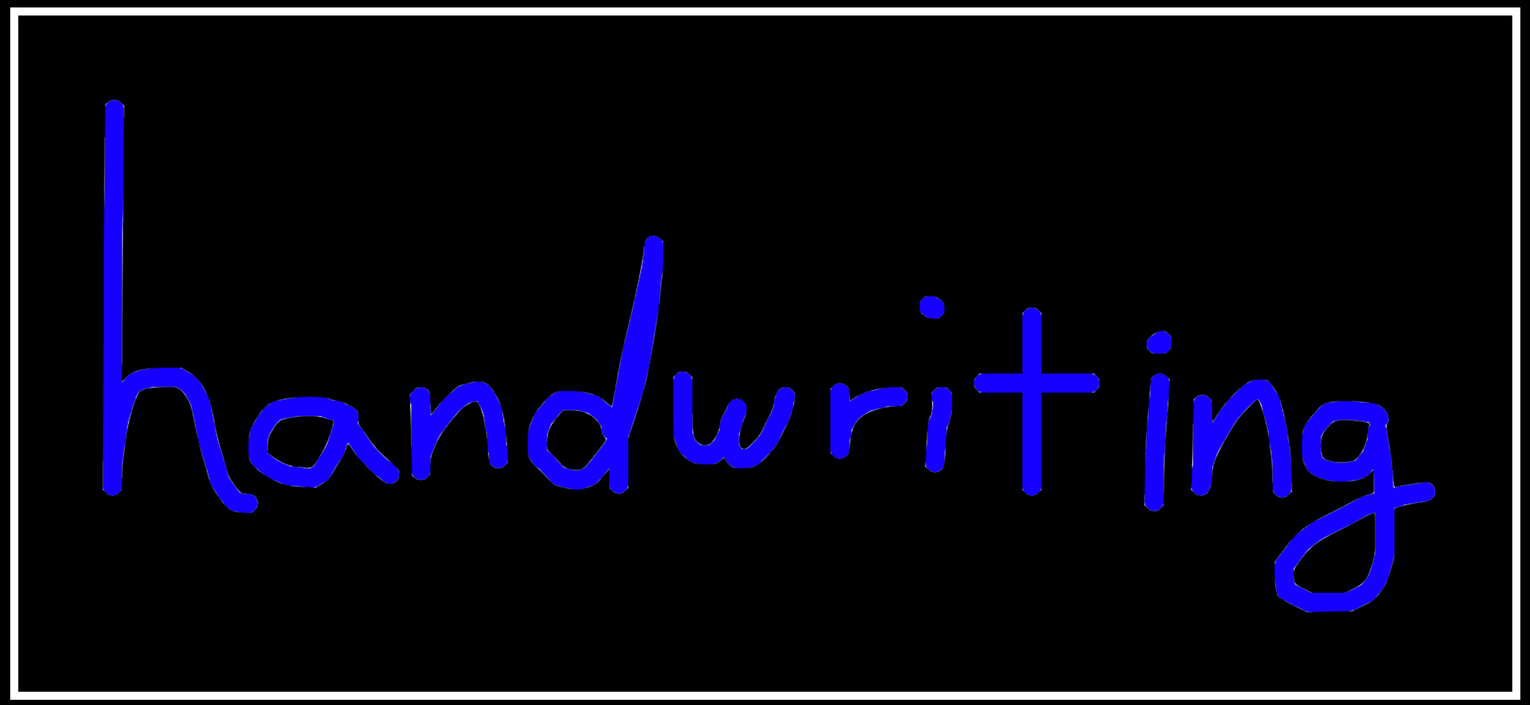
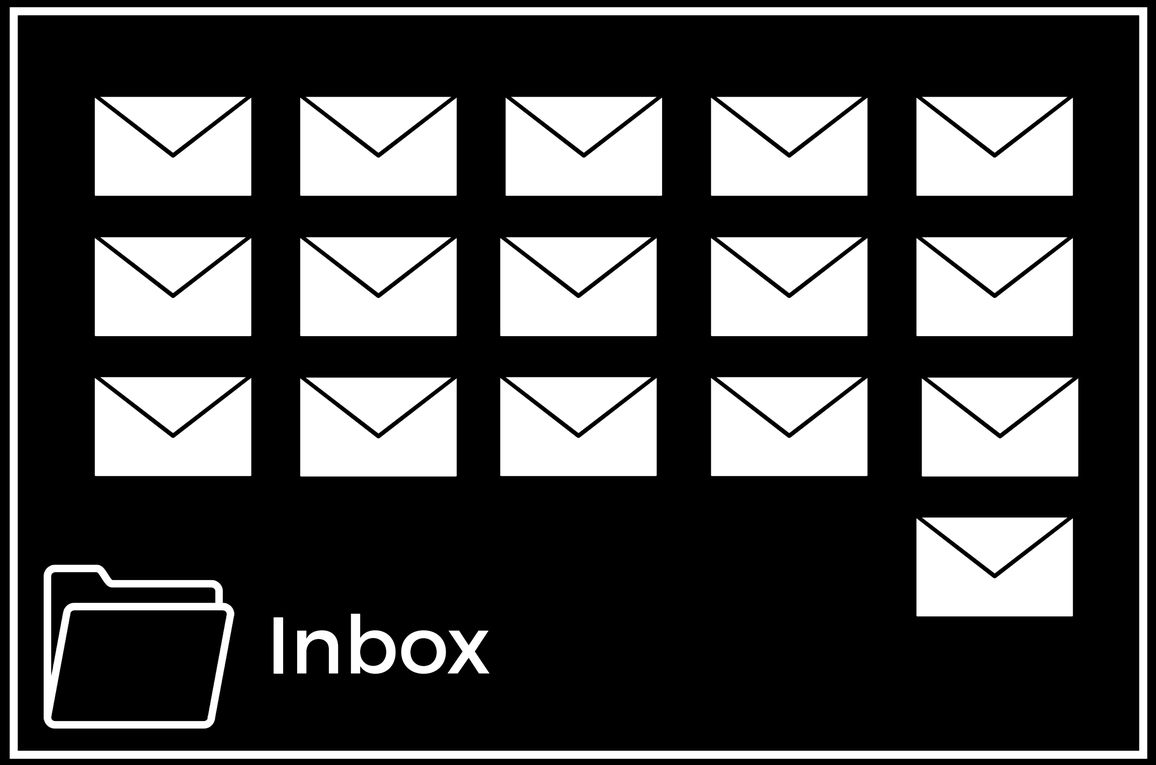
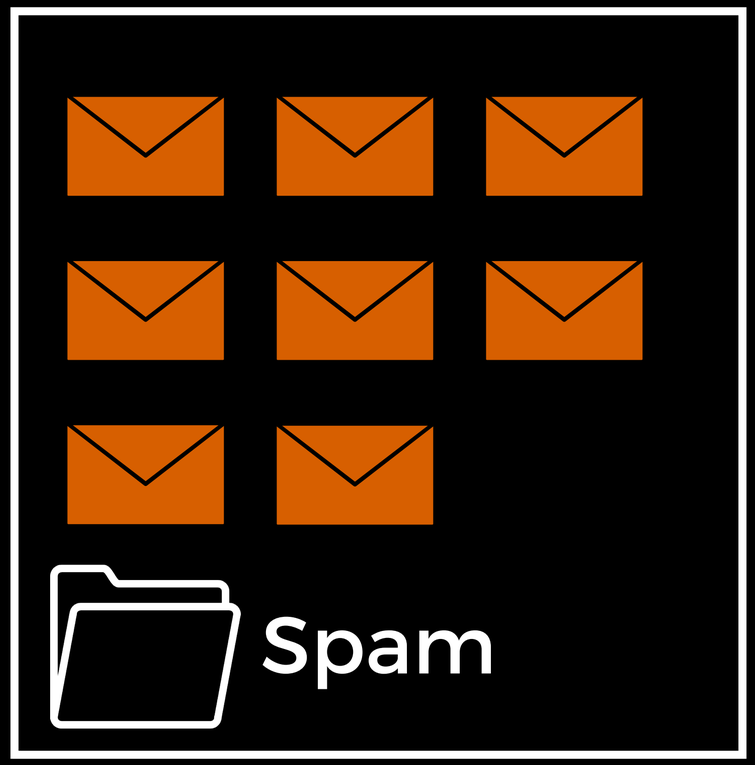
Artificial Intelligence


O X
O X X
O X



handwriting


Inbox


Spam

Watch History

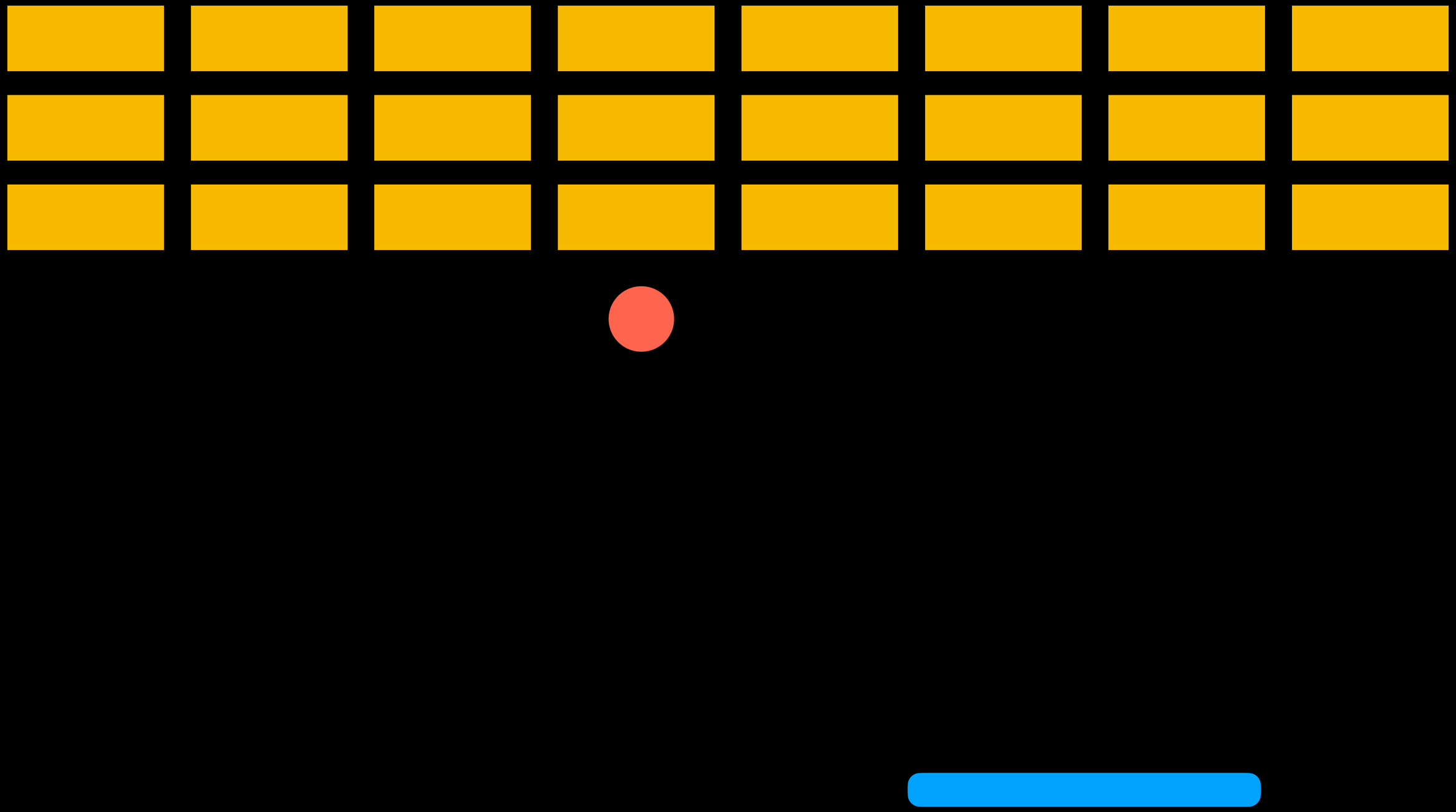
Recommended

Image 1

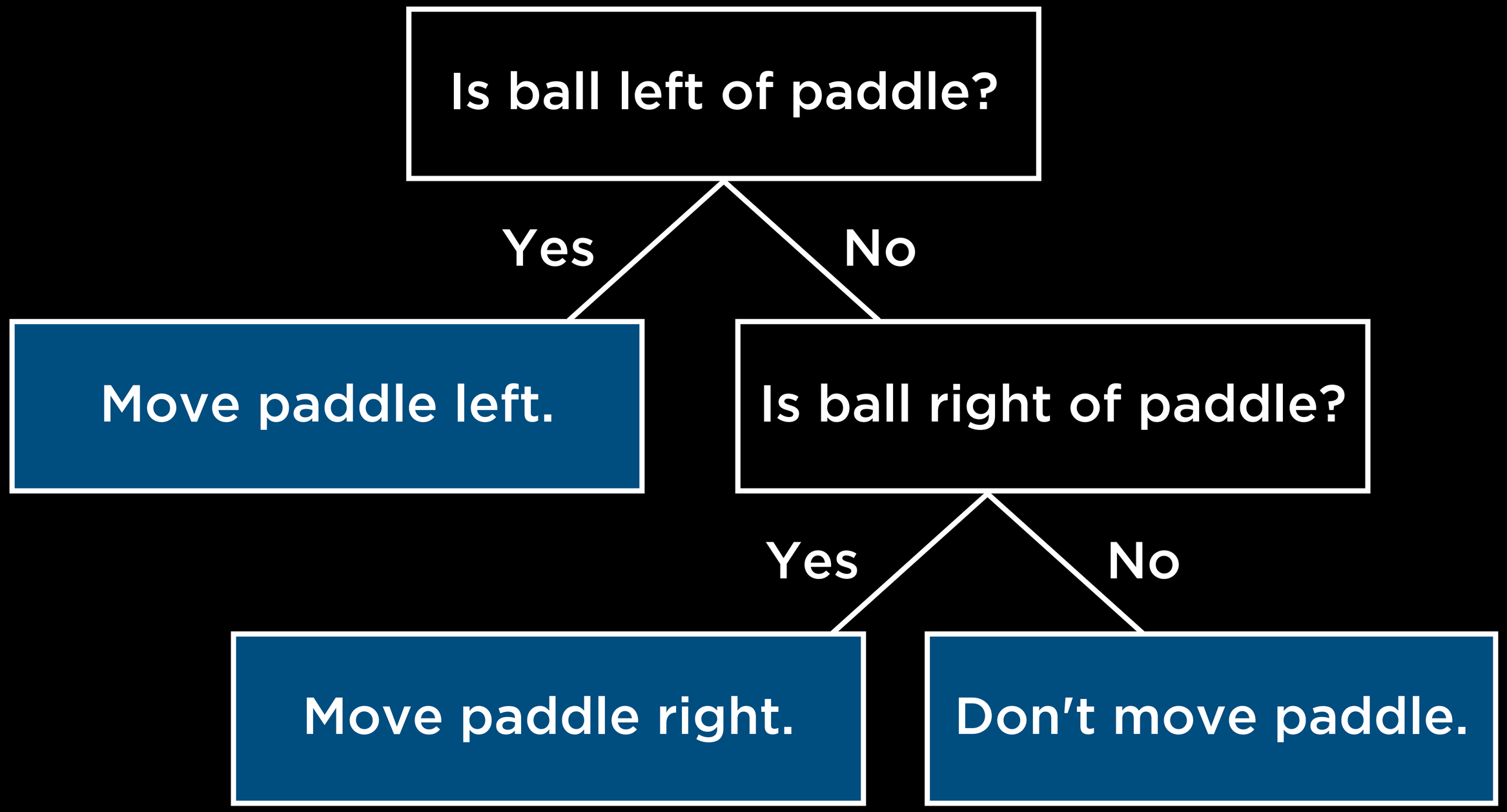
Image 2

Artificial Intelligence

Decision-Making

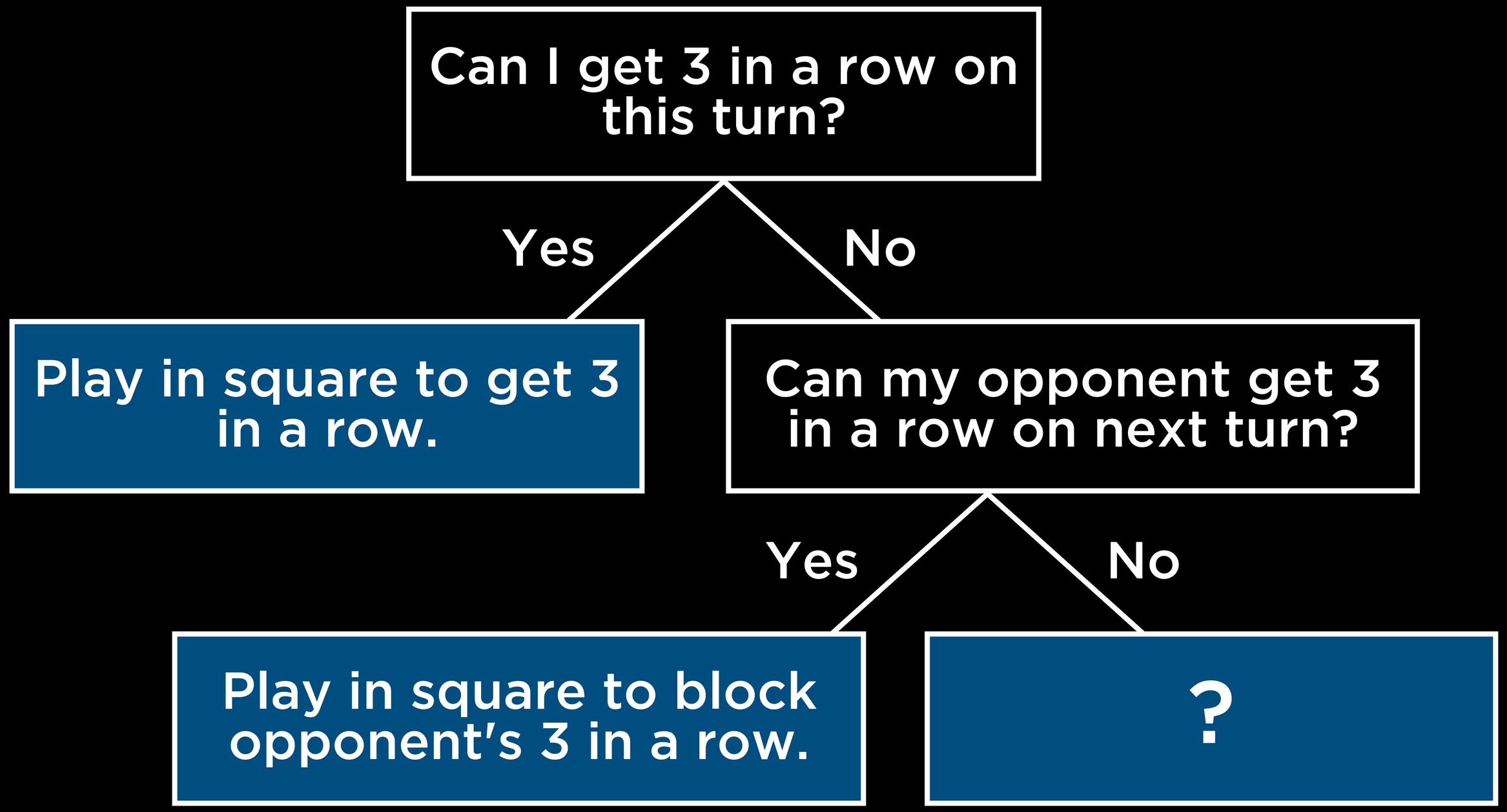


Decision Trees


Is ball left of paddle?
Yes
No
Move paddle left.
Is ball right of paddle?
Yes
No
Move paddle right.
Don't move paddle.

```
while game is ongoing:
    if ball left of paddle:
        move paddle left
    else if ball right of paddle:
        move paddle right
    else:
        don't move paddle
```

		O
	X	
X		O


Can I get 3 in a row on this turn?
Yes
No
Play in square to get 3 in a row.
Can my opponent get 3 in a row on next turn?
Yes
No
Play in square to block opponent's 3 in a row.
?

Minimax

- MAX (X) aims to maximize score.
- MIN (O) aims to minimize score.

O	X	X
O	O	
O	X	X

-1

X	O	X
O	O	X
X	X	O

0

O		X
	X	O
X	O	X

1

O	X	O
O	X	X
X	X	O

Value: 1

Turn = O

Value: 0

	X	O
O	X	X
X		O

Value: 1

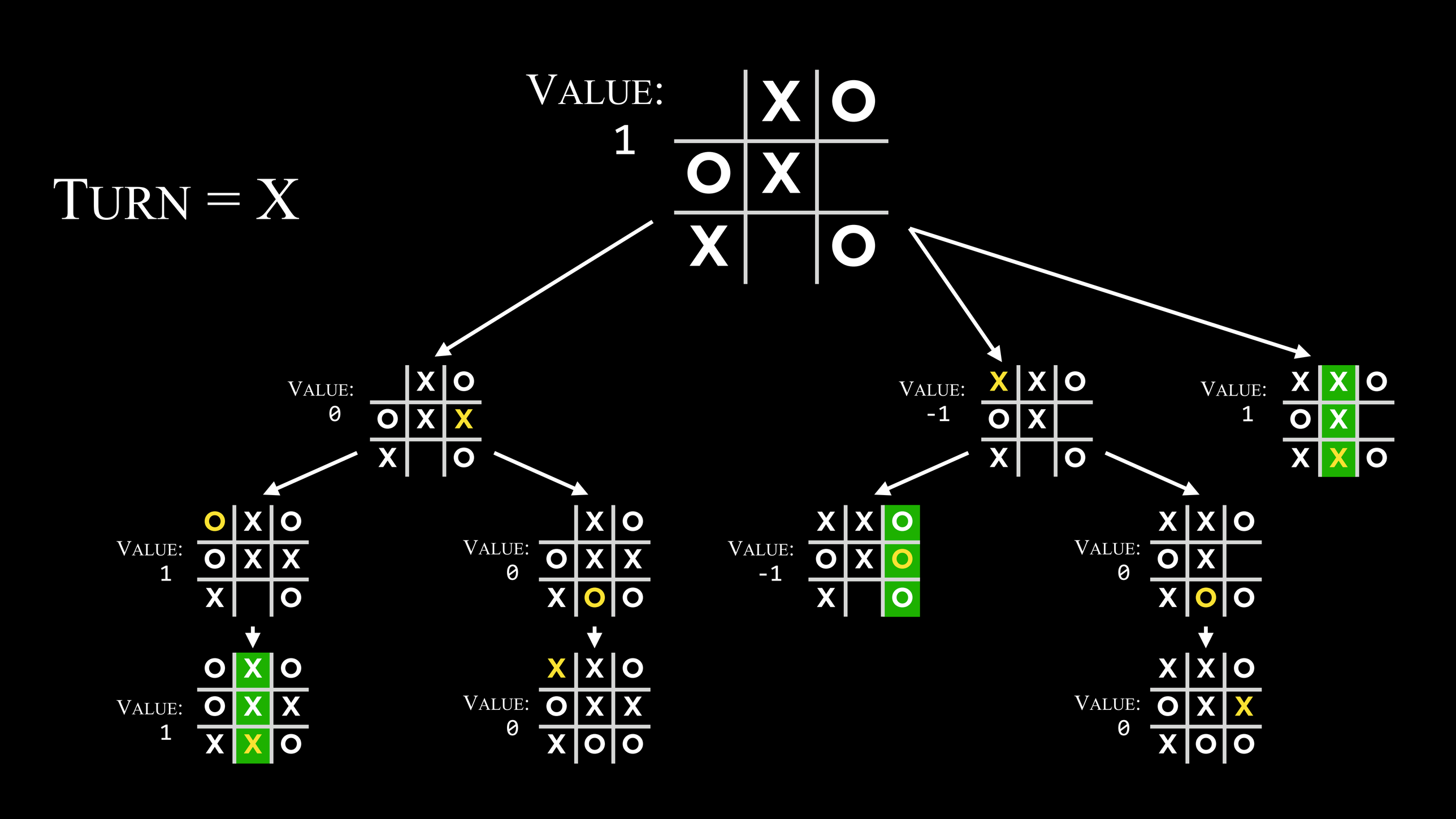
O	X	O
O	X	X
X		O

O	X	O
O	X	X
X	X	O

Value: 0

	X	O
O	X	X
X	O	O

X	X	O
O	X	X
X	O	O


Turn = X
Value: 1
Value: 0
Value: -1
Value: 1
Value: 1
Value: 0
Value: 0
Value: -1
Value: 0
Value: 0

Minimax

```
if player is X:
    for all possible moves:
        calculate score for board
    choose move with highest score

else:
    for all possible moves:
        calculate score for board
    choose move with lowest score
```

255,168

total possible Tic-Tac-Toe games

288,000,000,000,000

total possible chess games
for the first four moves

$$10^{29241}$$

total possible chess games
(lower bound)

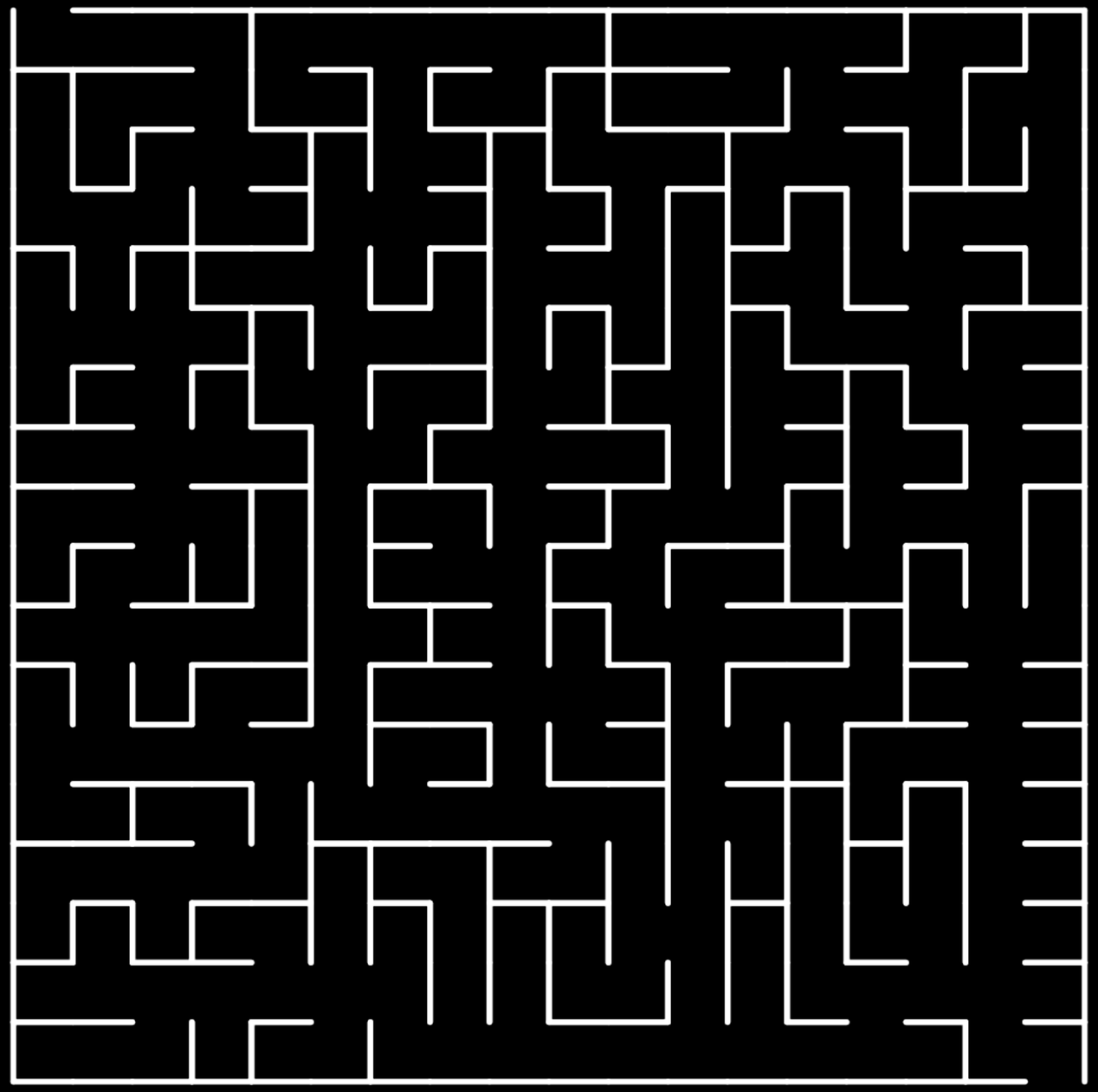
Depth-Limited Minimax

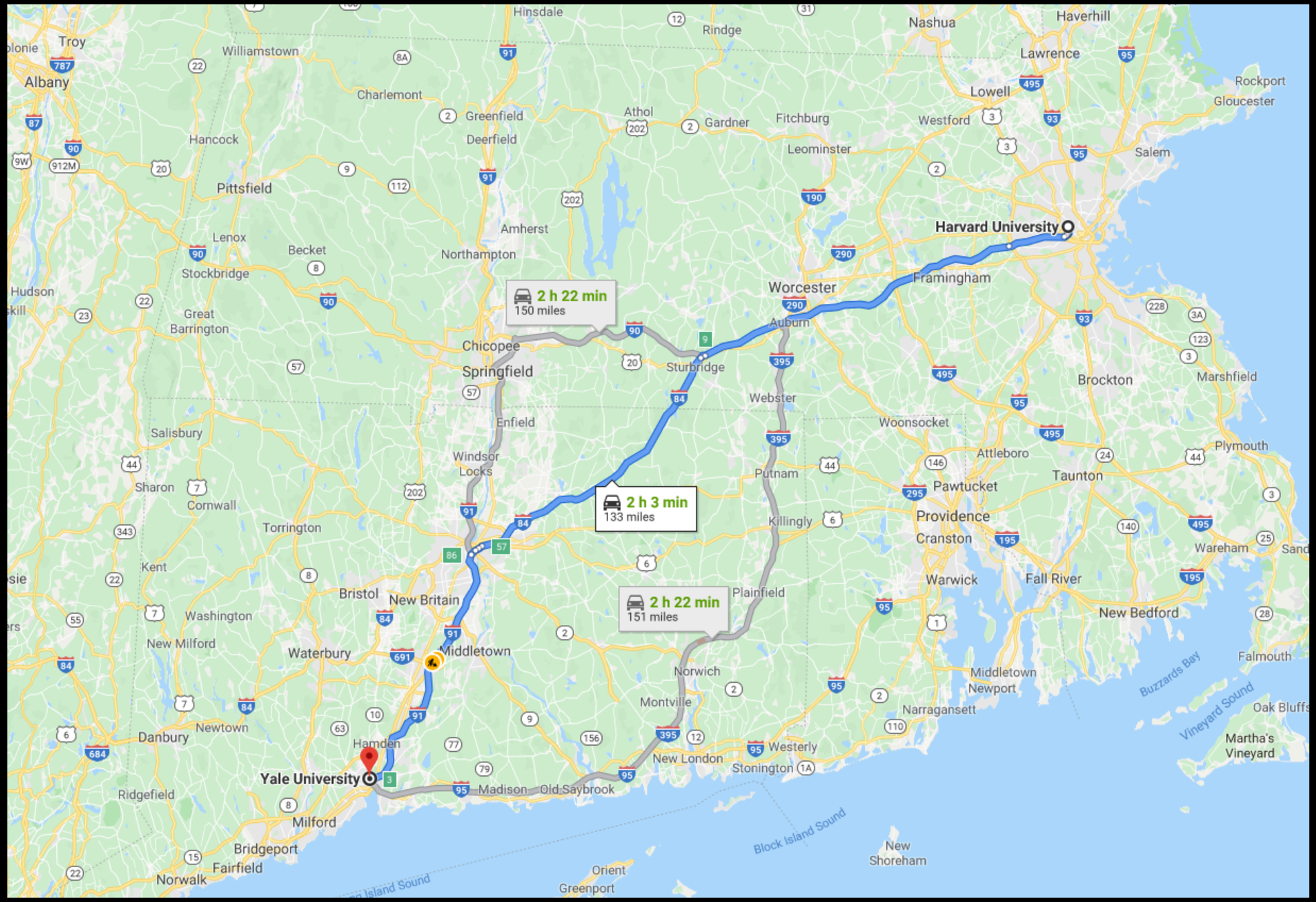
evaluation function

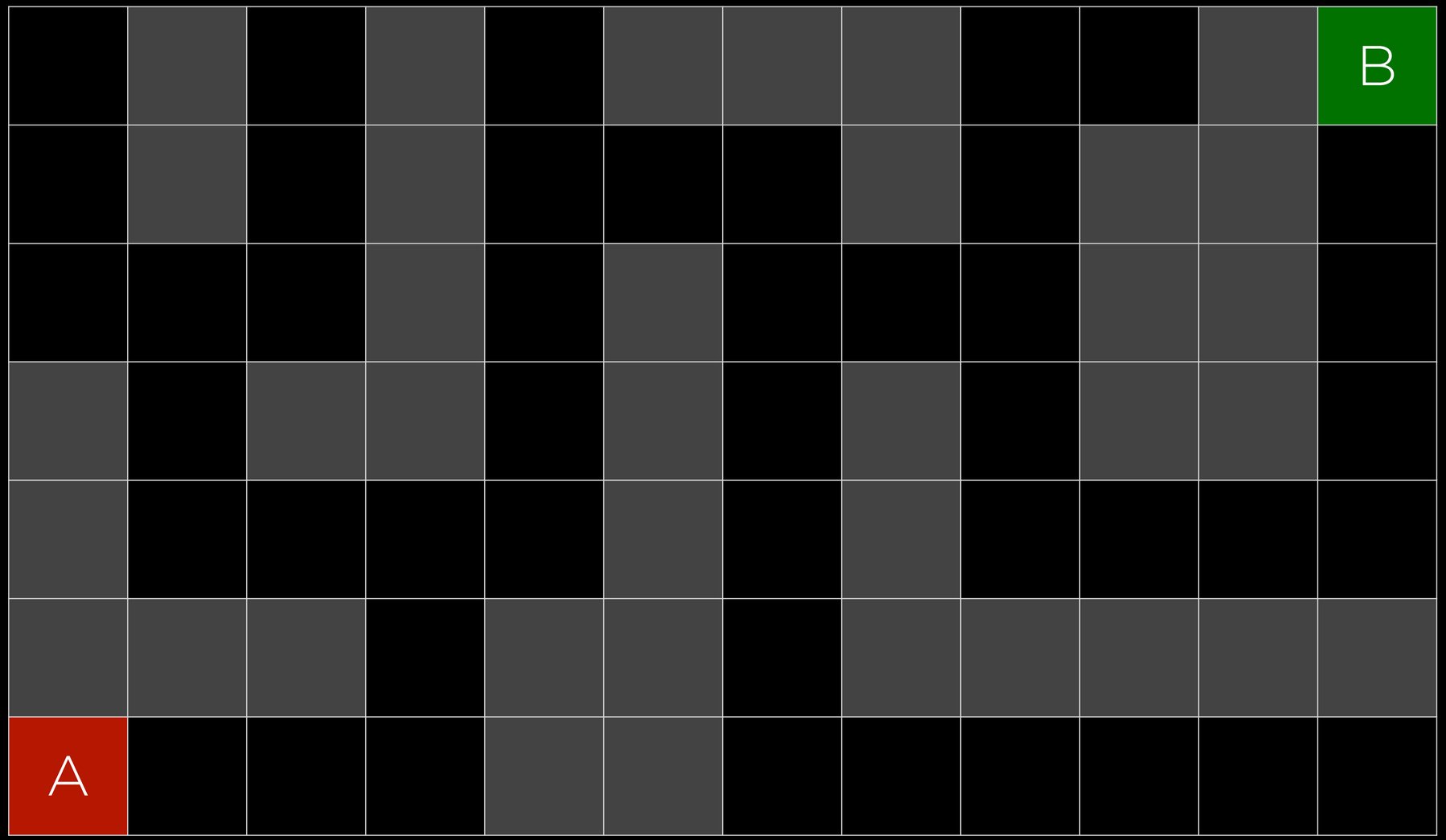
function that estimates the expected utility of the game from a given state

Search

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	

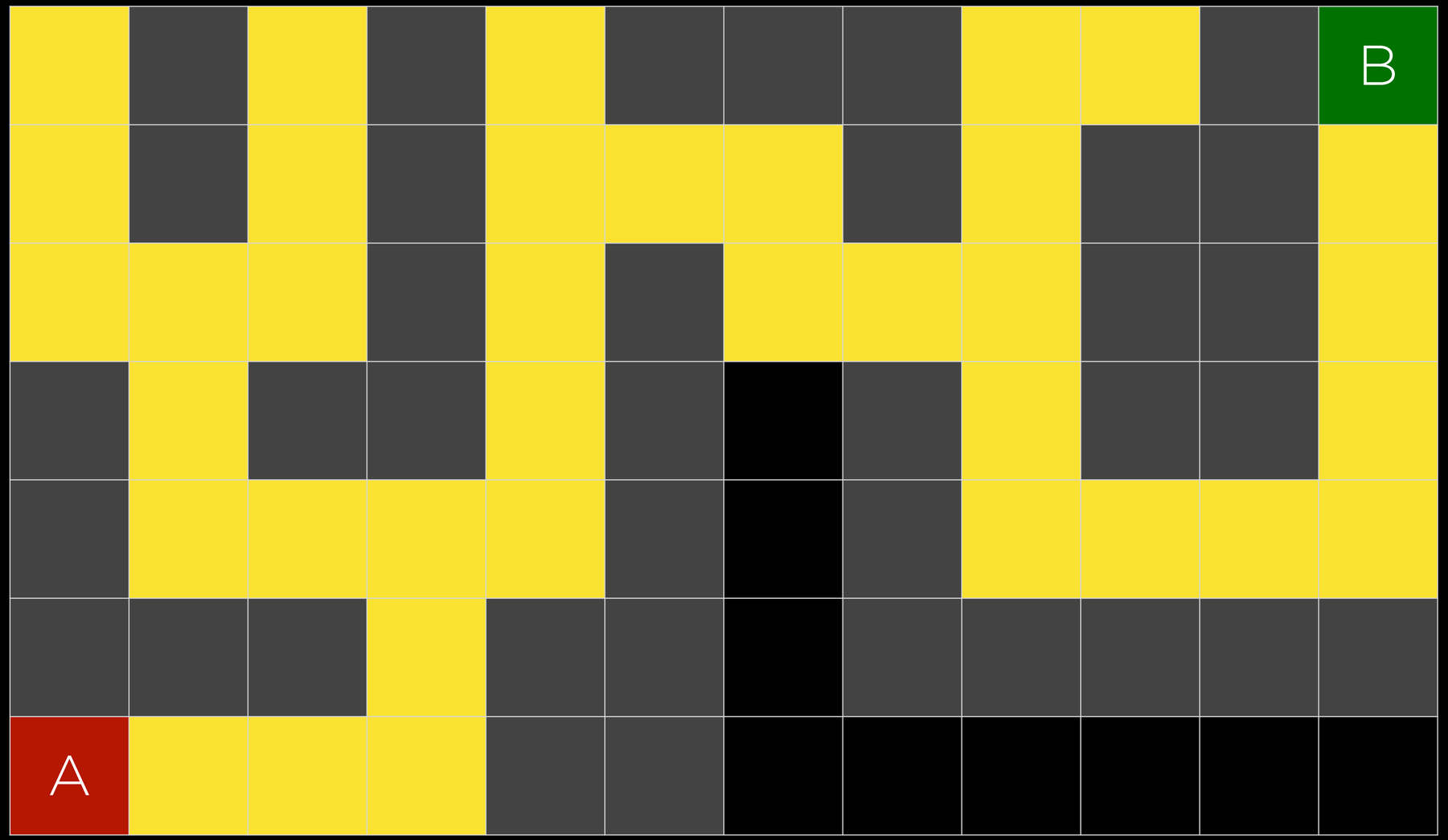



Harvard University
Yale University
2 h 22 min
150 miles
2 h 3 min
133 miles
2 h 22 min
151 miles
Hinsdale
Rindge
Nashua
Haverhill
Lawrence
Lowell
Rockport
Gloucester
Salem
Troy
Albany
Williamstown
Charlemont
Greenfield
Deerfield
Athol
Gardner
Fitchburg
Westford
Leominster
Hancock
Pittsfield
Lenox
Becket
Stockbridge
Amherst
Northampton
Hudson
Great Barrington
Worcester
Framingham
Auburn
Chicopee
Springfield
Sturbridge
Webster
Brockton
Marshfield
Enfield
Windsor Locks
Salisbury
Sharon
Cornwall
Torrington
Putnam
Woonsocket
Attleboro
Pawtucket
Taunton
Plymouth
Providence
Cranston
Killingly
Kent
Bristol
New Britain
Washington
New Milford
Waterbury
Middletown
Plainfield
Warwick
Fall River
New Bedford
Wareham
Falmouth
Buzzards Bay
Vineyard Sound
Oak Bluffs
Martha's Vineyard
Middletown
Newport
Narragansett
Norwich
Montville
Newtown
Danbury
Hamden
New London
Westerly
Stonington
Ridgefield
Madison
Old Saybrook
Milford
Bridgeport
Fairfield
Norwalk
Orient
Greenport
Block Island Sound
New Shoreham

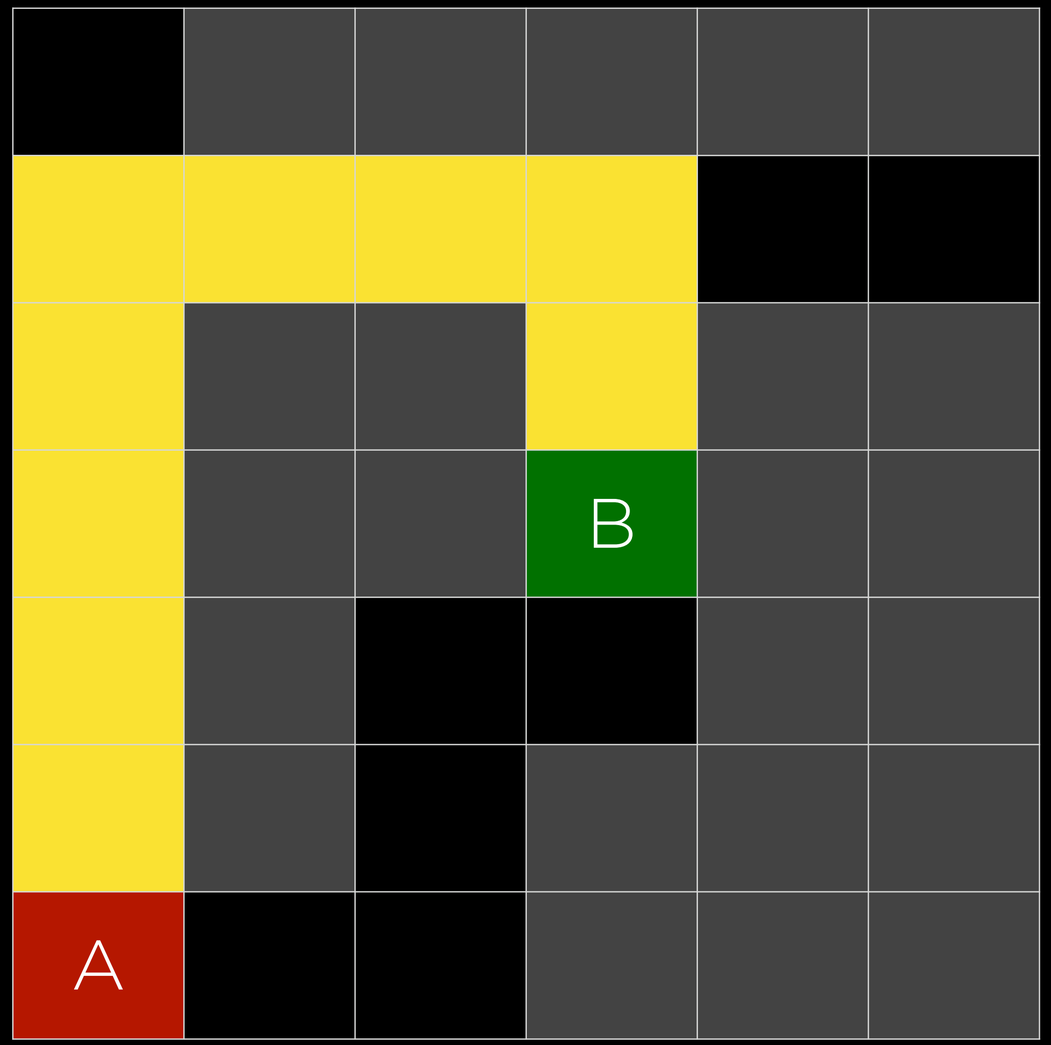

B
A

Depth-First Search

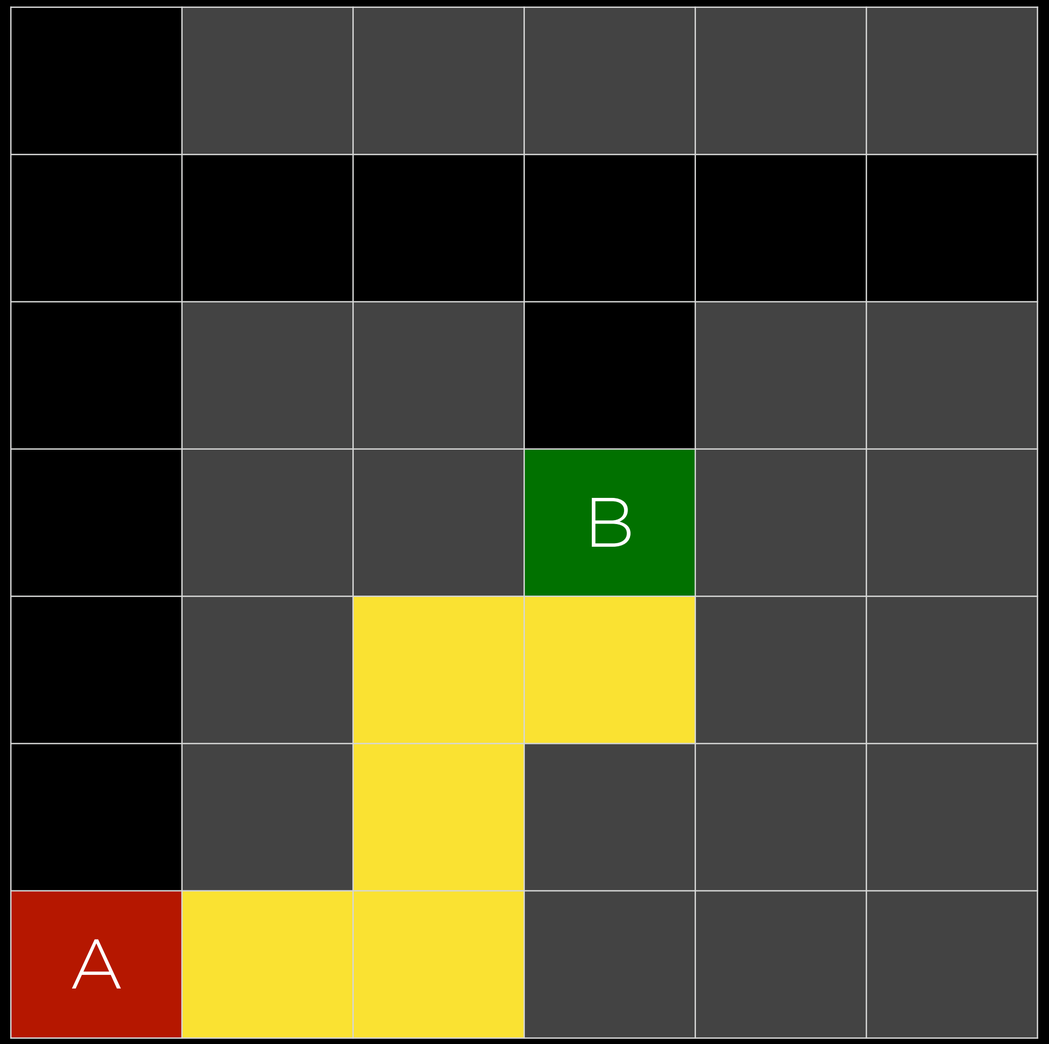
Depth-First Search



Depth-First Search

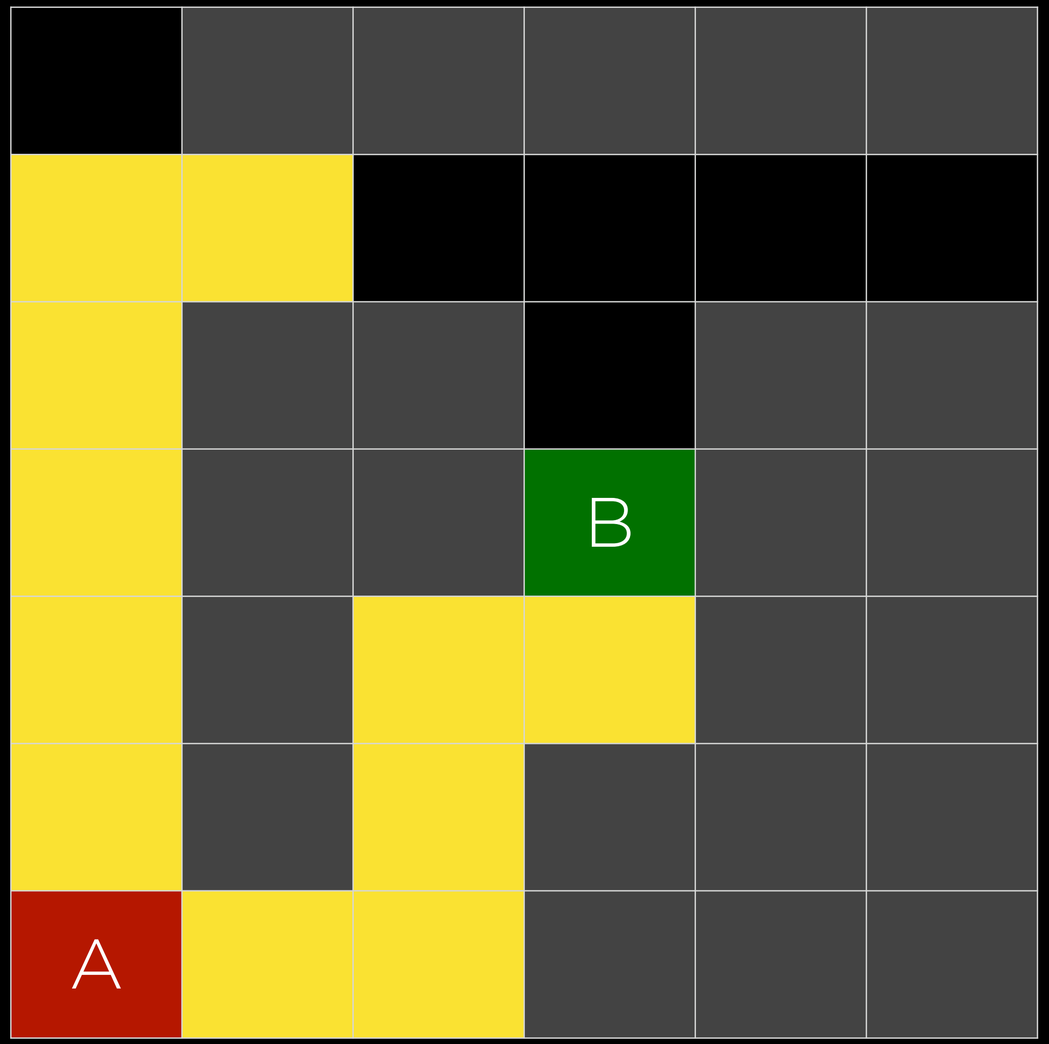


Depth-First Search

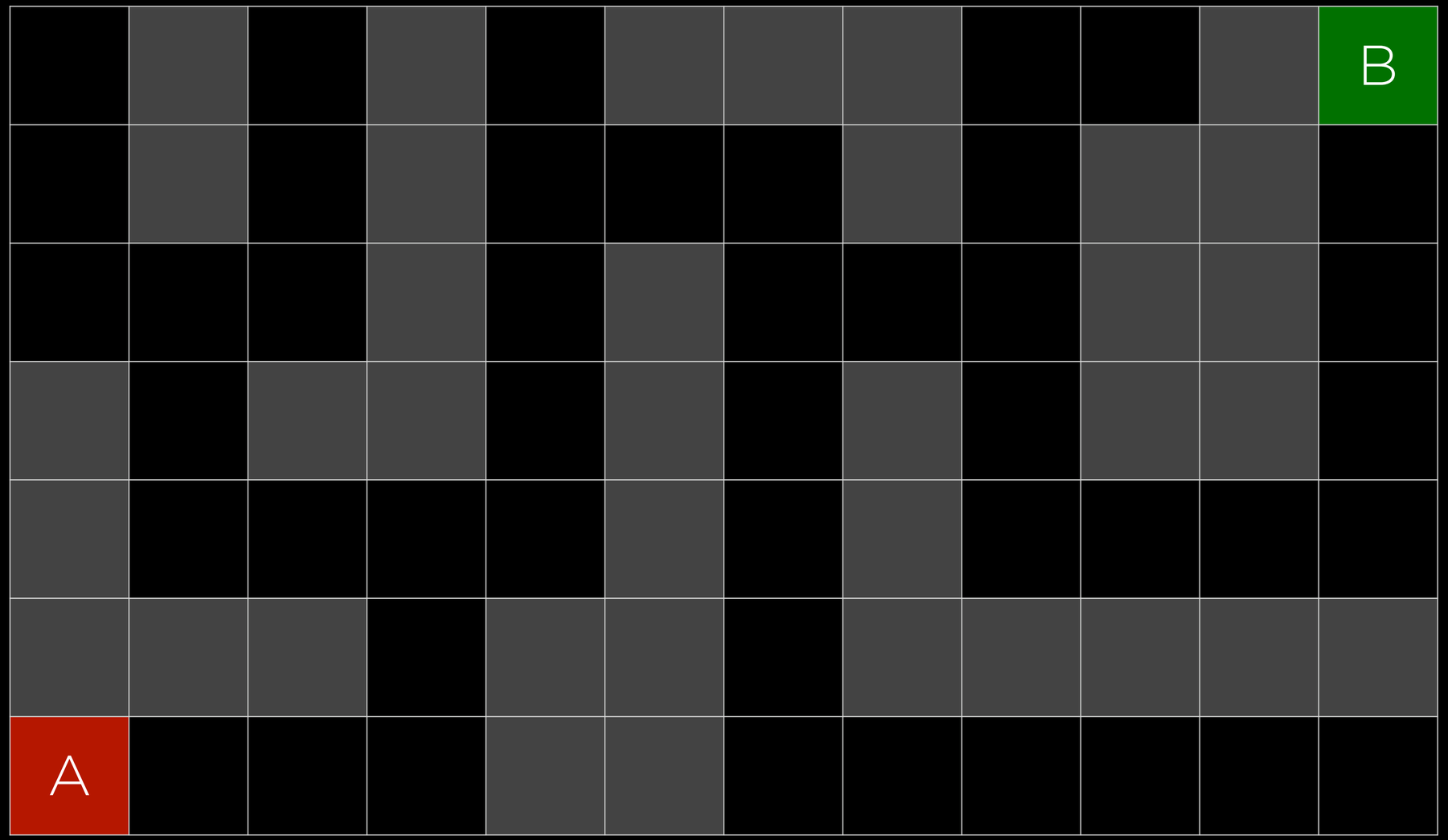


Breadth-First Search

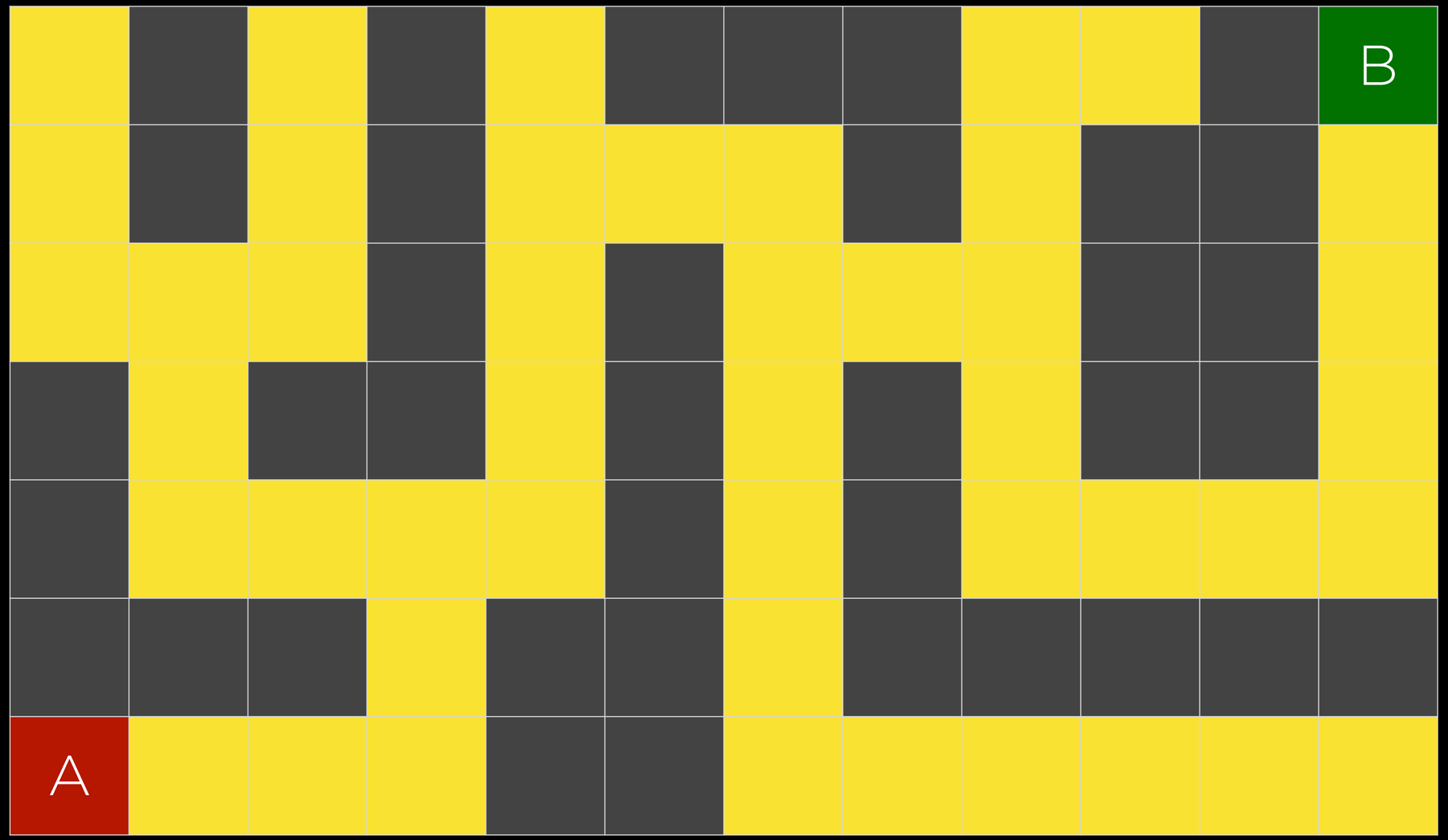
Breadth-First Search



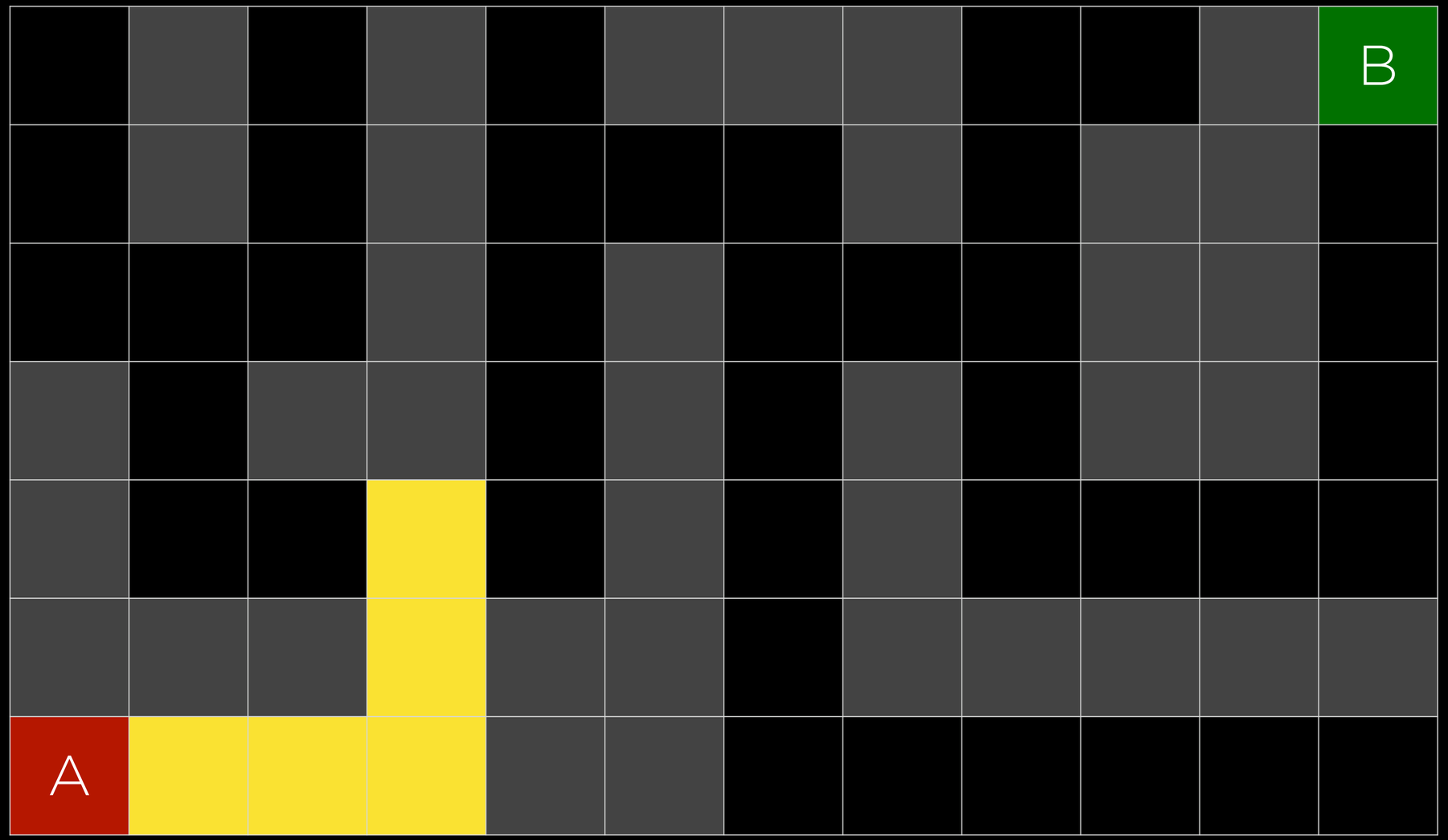
Breadth-First Search



Breadth-First Search



Breadth-First Search



uninformed search

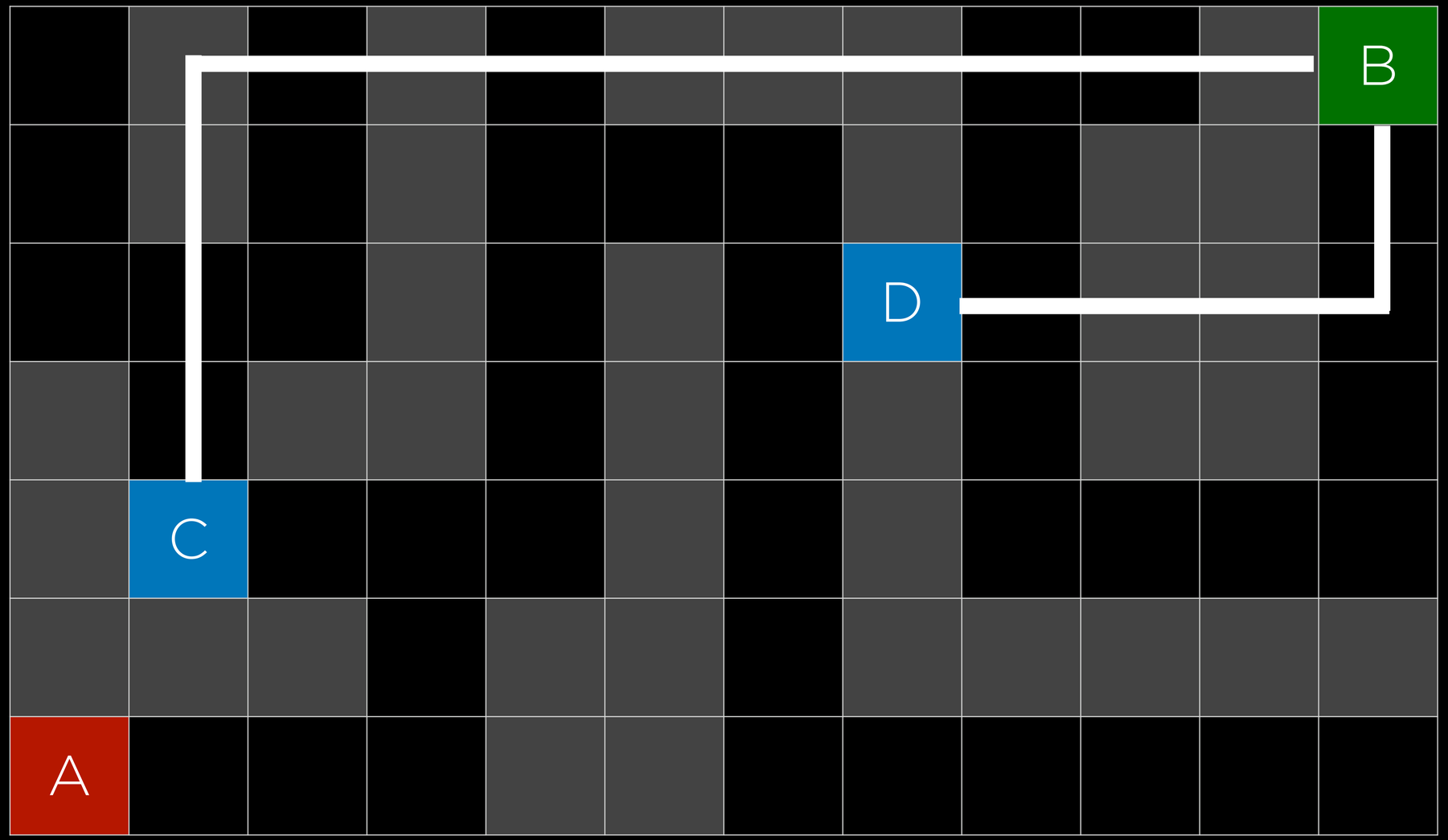
informed search

search strategy that uses problem-specific knowledge to find solutions more efficiently

greedy best-first search

search algorithm that chooses what to explore based on a heuristic

Heuristic function? Manhattan distance.



Greedy Best-First Search

11		9		7				3	2		B
12		10		8	7	6		4			1
13	12	11		9		7	6	5			2
	13			10		8		6			3
	14	13	12	11		9		7	6	5	4
			13			10					
A	16	15	14			11	10	9	8	7	6

Greedy Best-First Search

11		9		7				3	2		B
12		10		8	7	6		4			1
13	12	11		9		7	6	5			2
	13			10		8		6			3
	14	13	12	11		9		7	6	5	4
			13			10					
A	16	15	14			11	10	9	8	7	6

Greedy Best-First Search

	10	9	8	7	6	5	4	3	2	1	B
	11										1
	12		10	9	8	7	6	5	4		2
	13		11						5		3
	14	13	12		10	9	8	7	6		4
			13		11						5
A	16	15	14		12	11	10	9	8	7	6

Greedy Best-First Search

	10	9	8	7	6	5	4	3	2	1	B
	11										1
	12		10	9	8	7	6	5	4		2
	13		11						5		3
	14	13	12		10	9	8	7	6		4
			13		11						5
A	16	15	14		12	11	10	9	8	7	6

Greedy Best-First Search

	10	9	8	7	6	5	4	3	2	1	B
	11										1
	12		10	9	8	7	6	5	4		2
	13		11						5		3
	14	13	12		10	9	8	7	6		4
			13		11						5
A	16	15	14		12	11	10	9	8	7	6

A* search

search algorithm that chooses what to explore based both on cost so far and a heuristic

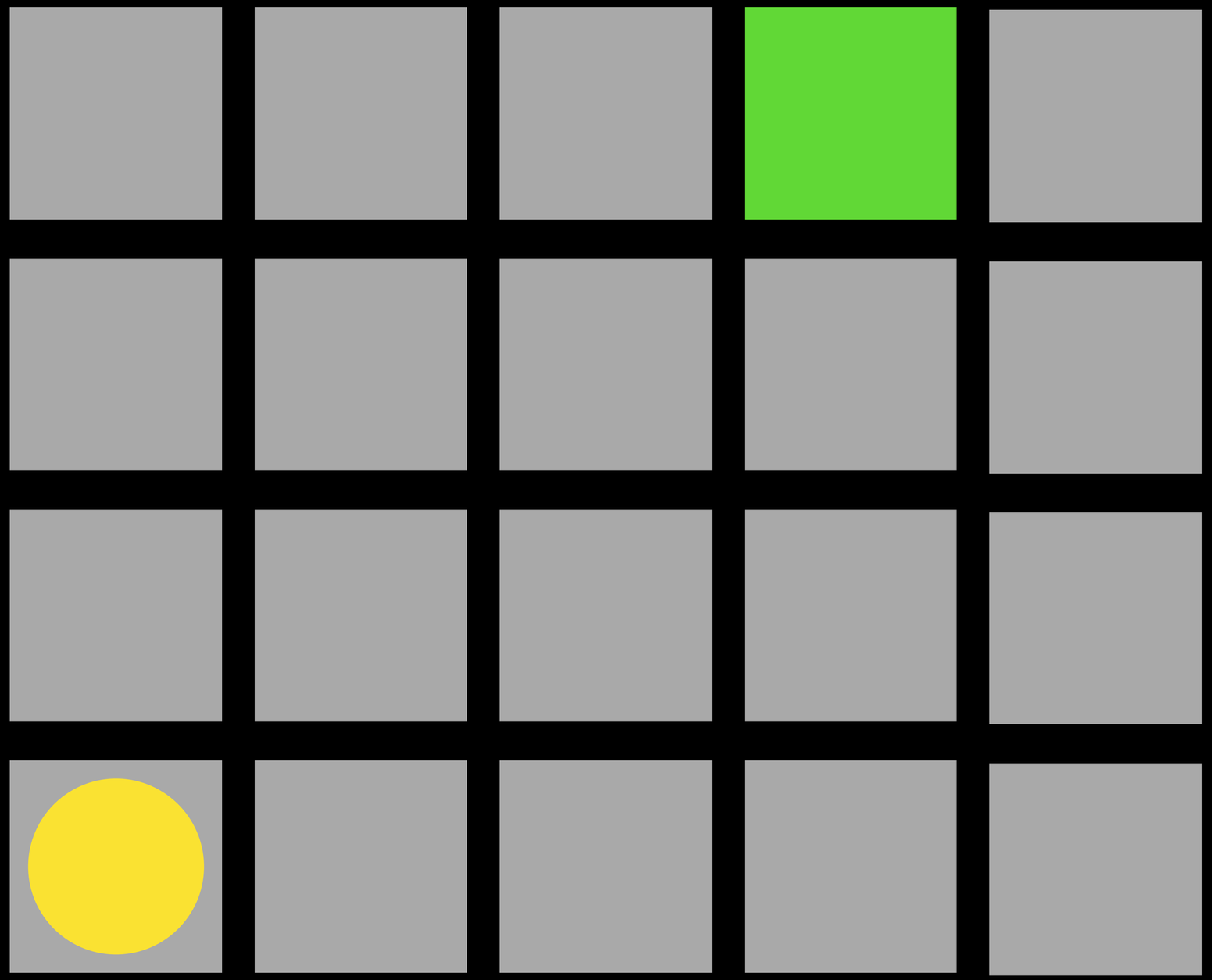
A* Search

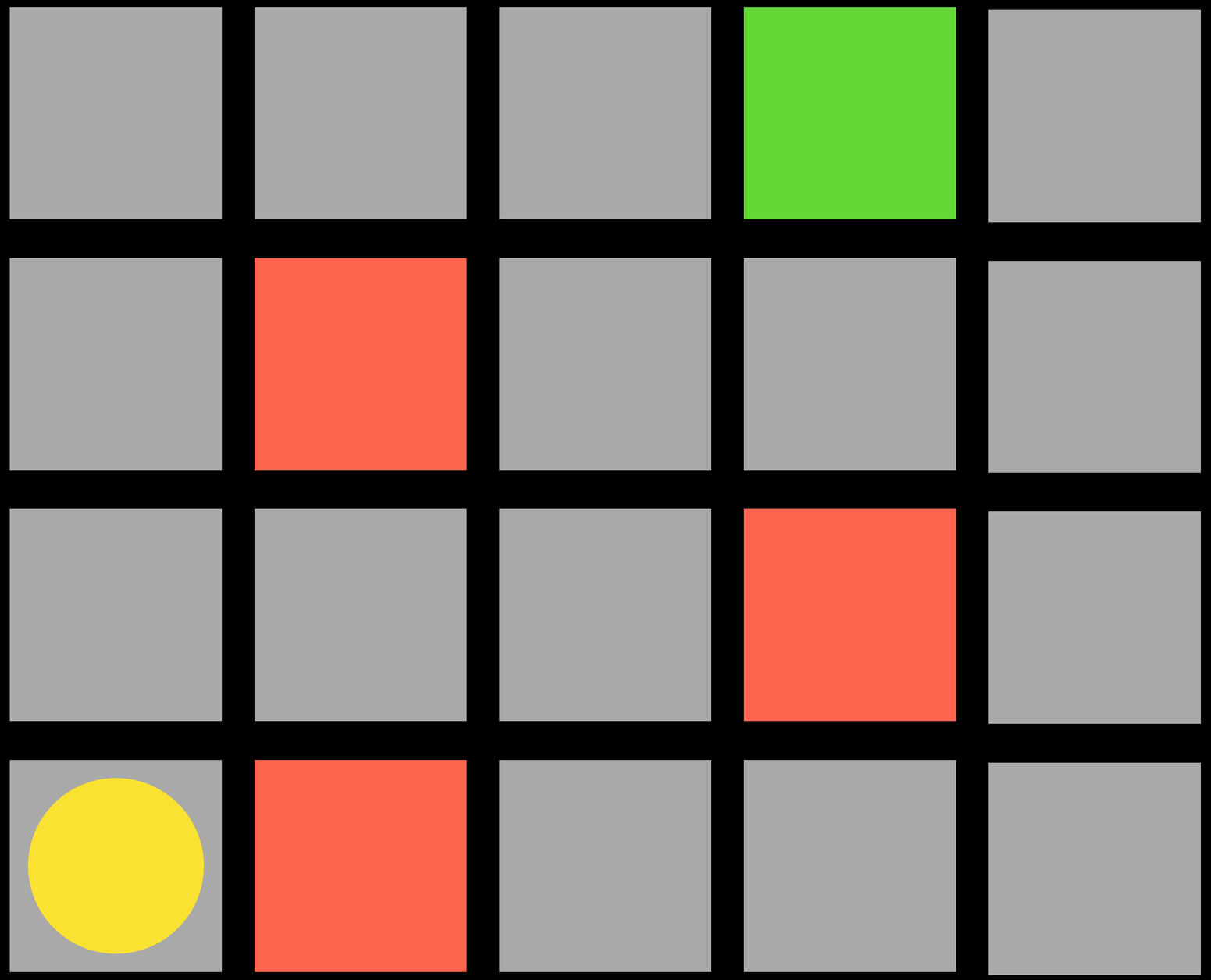
	10	9	8	7	6	5	4	3	2	1	B
	11										1
	12		10	9	8	7	6	5	4		2
	13		11						5		3
	14	13	12		10	9	8	7	6		4
			13		11						5
A	16	15	14		12	11	10	9	8	7	6

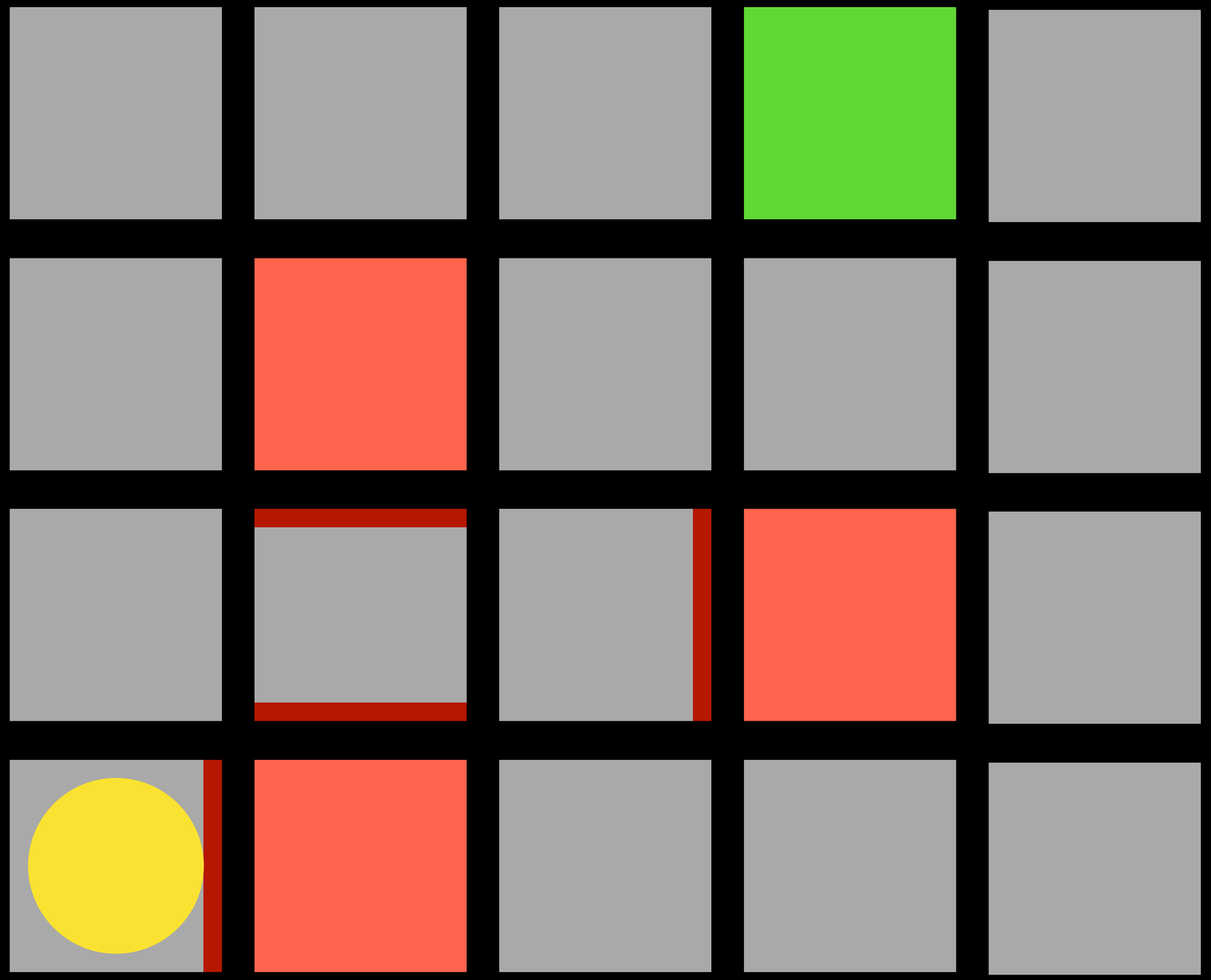
A* Search

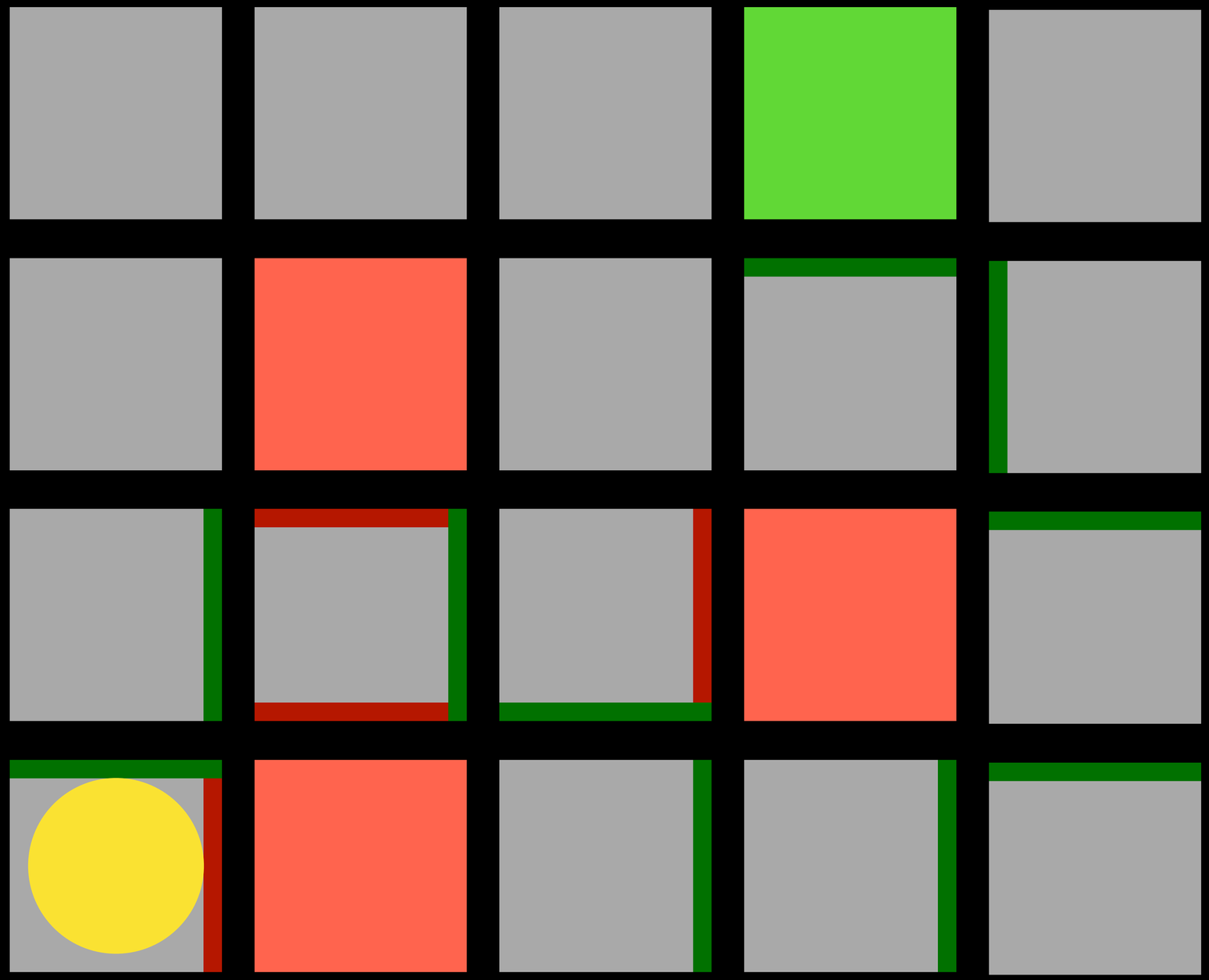
	11+10	12+9	13+8	14+7	15+6	16+5	17+4	18+3	19+2	20+1	B
	10+11										1
	9+12		7+10	8+9	9+8	10+7	11+6	12+5	13+4		2
	8+13		6+11						14+5		3
	7+14	6+13	5+12		10	9	8	7	15+6		4
			4+13		11						5
A	1+16	2+15	3+14		12	11	10	9	8	7	6

Reinforcement Learning









Explore vs. Exploit

Explore vs. Exploit Strategy

```
epsilon = 0.10

if random() < epsilon:
    make a random move
else:
    make the move with the highest value
```

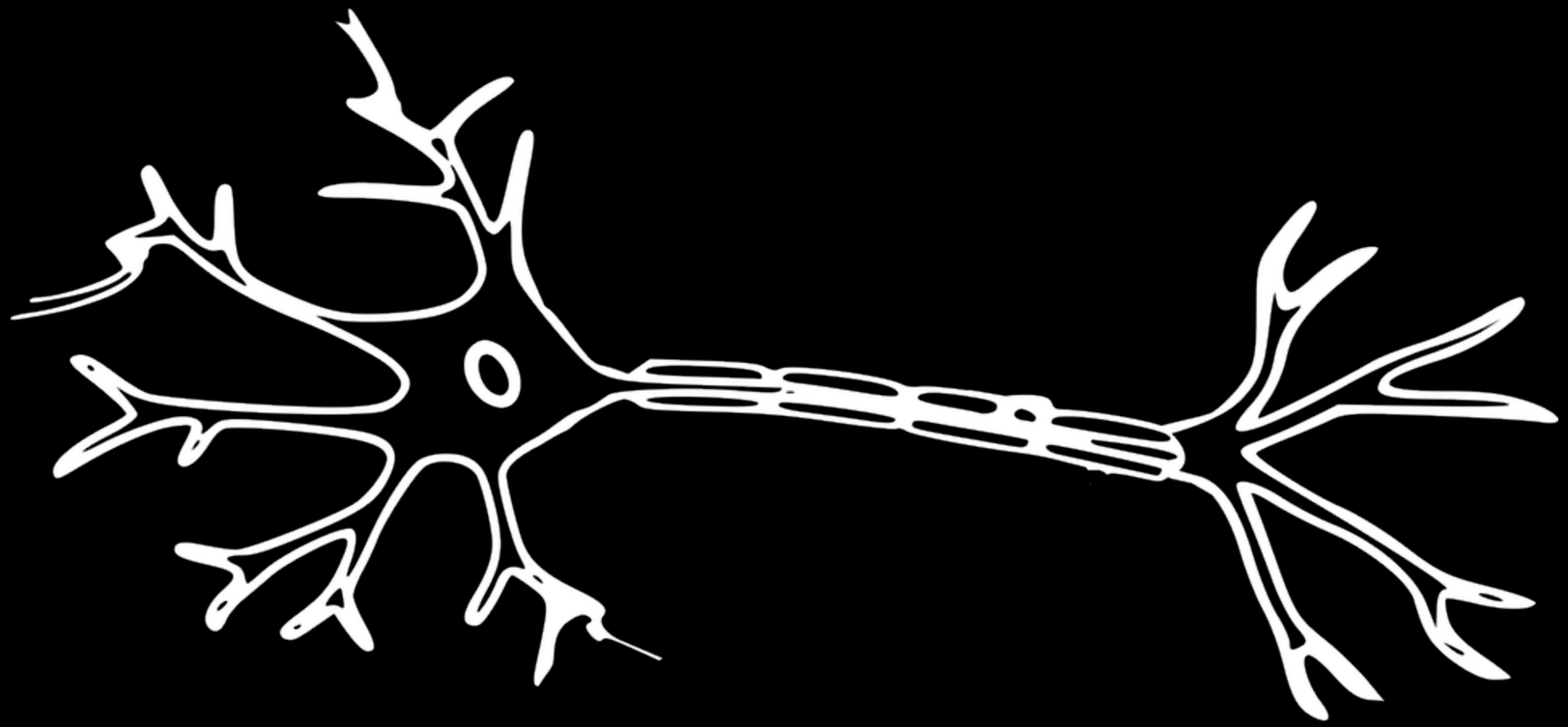
Robot Motor Skill Coordination with EM-based Reinforcement Learning

Petar Kormushev, Sylvain Calinon, and Darwin G. Caldwell

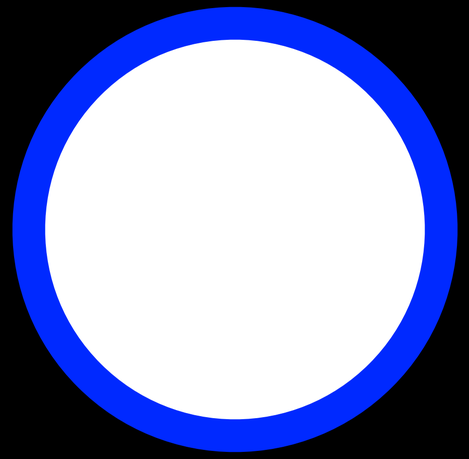
Italian Institute of Technology

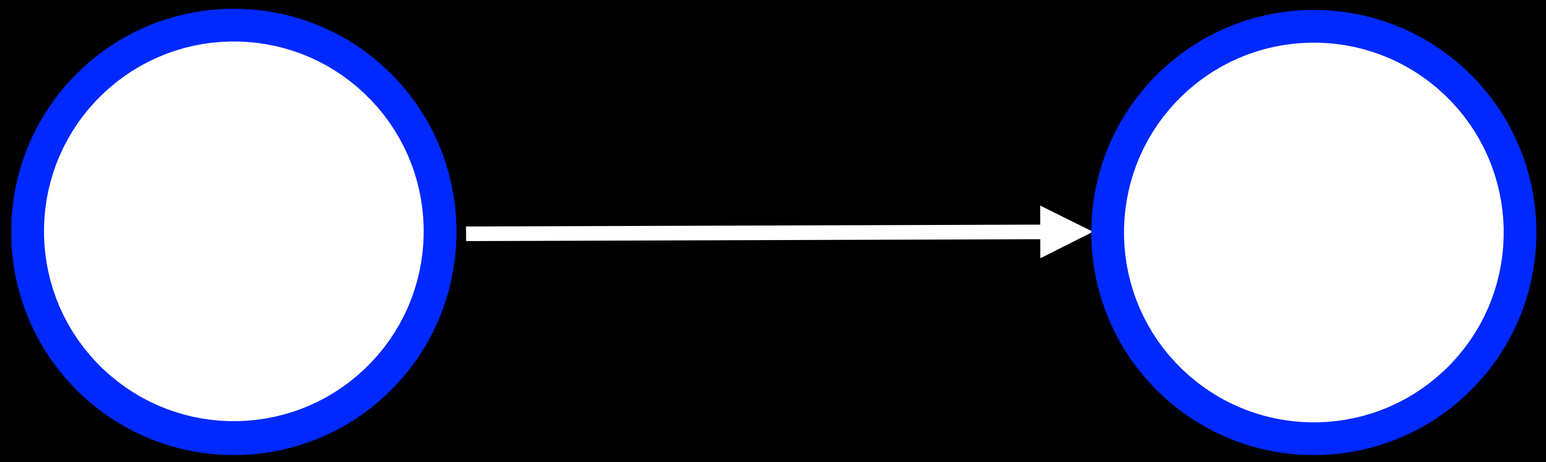
Watch History

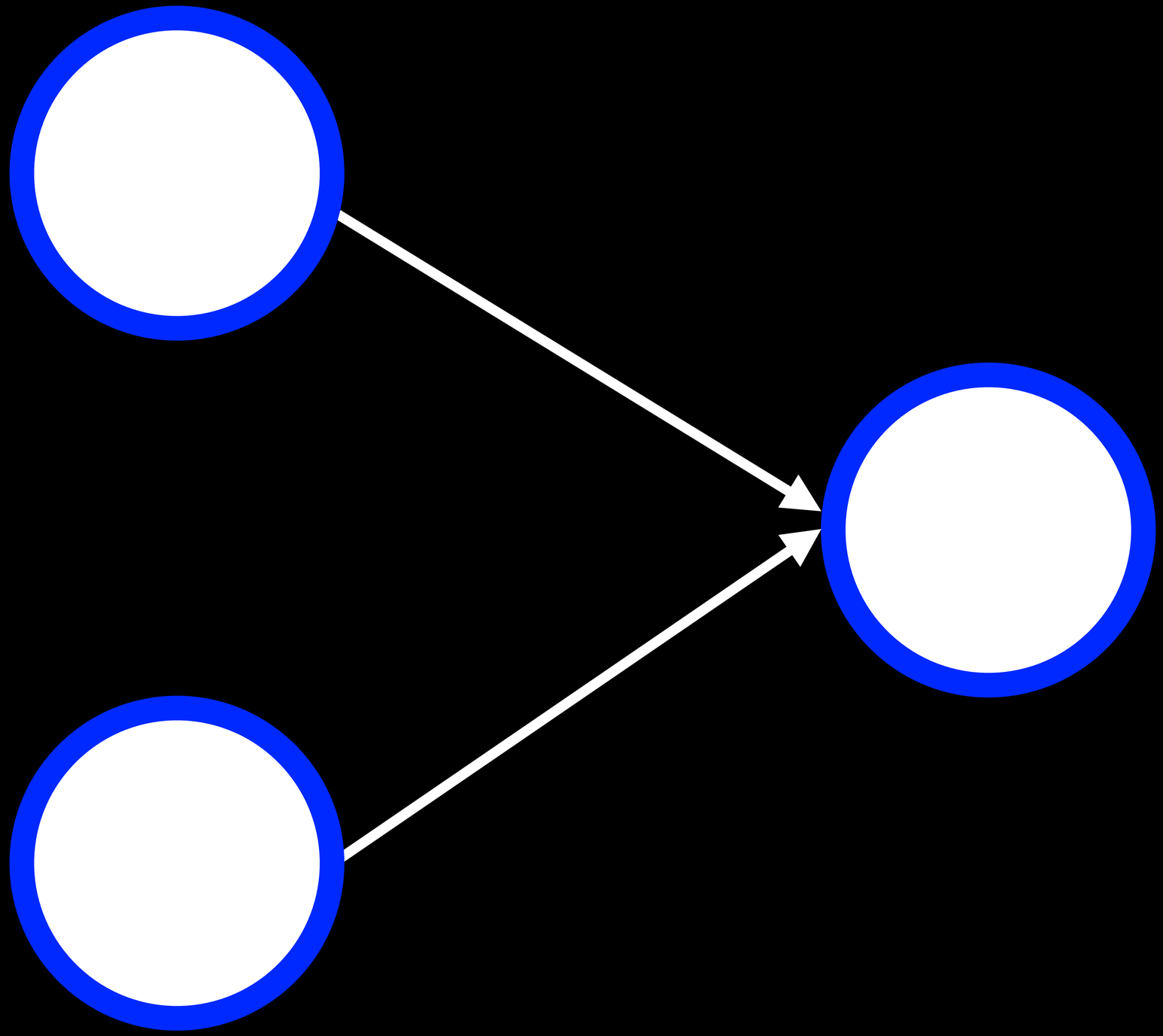
Recommended

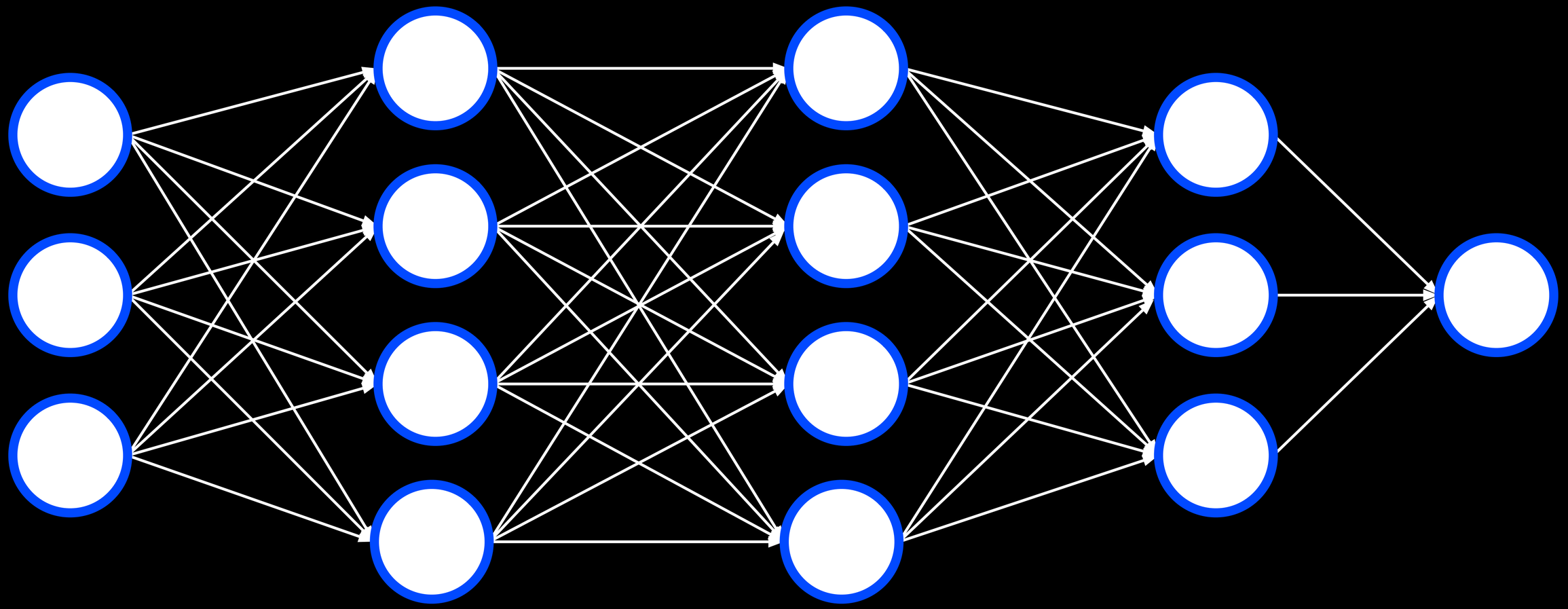


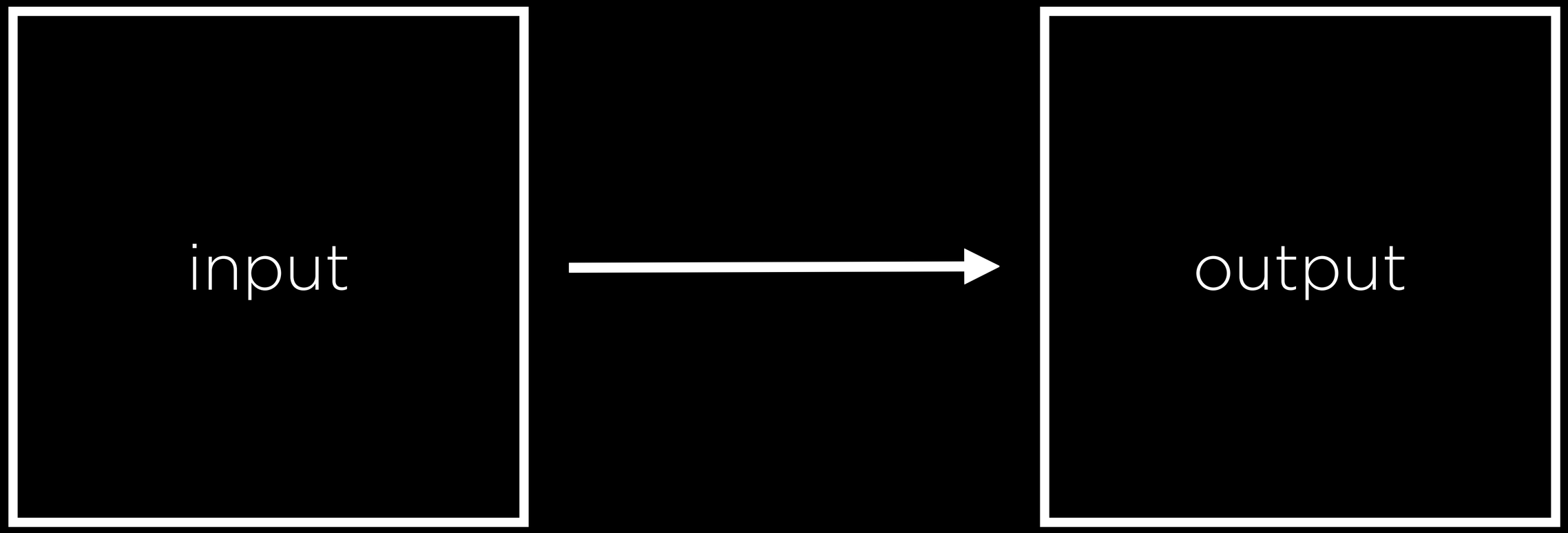
Neural Networks

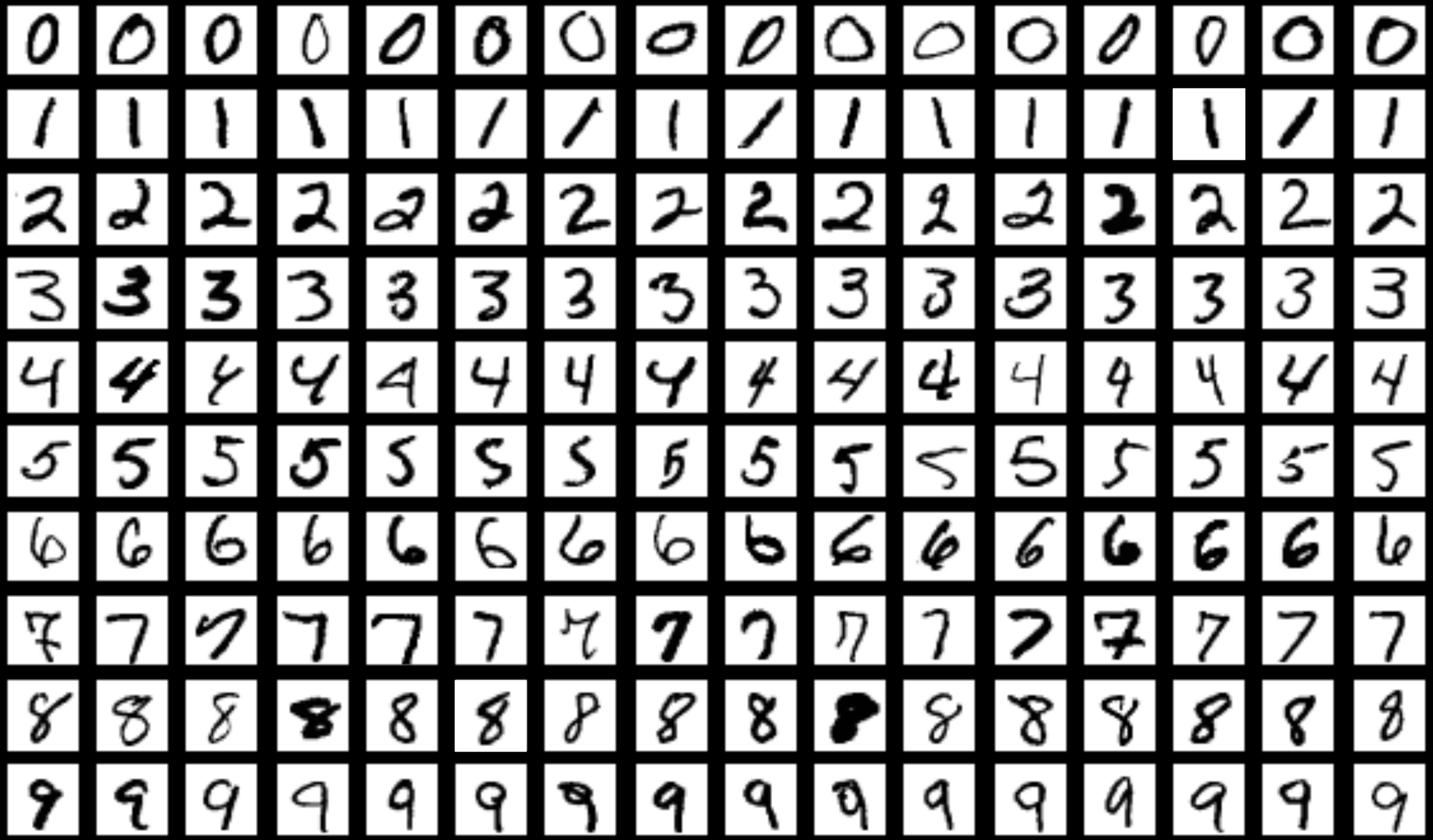




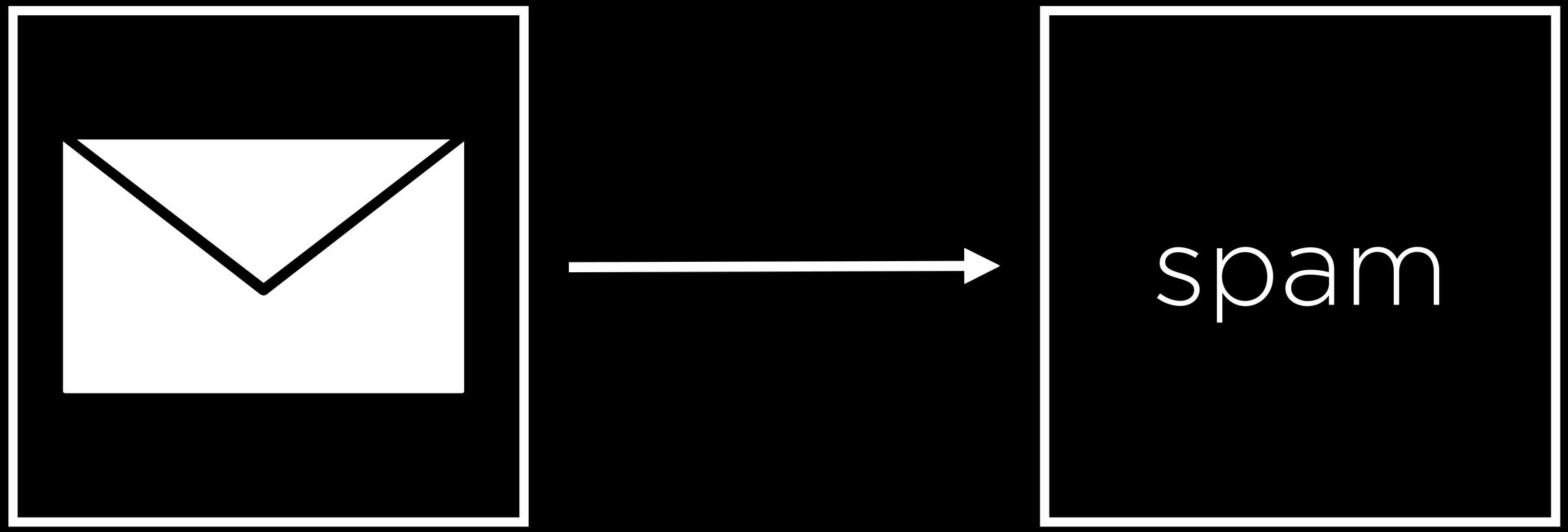


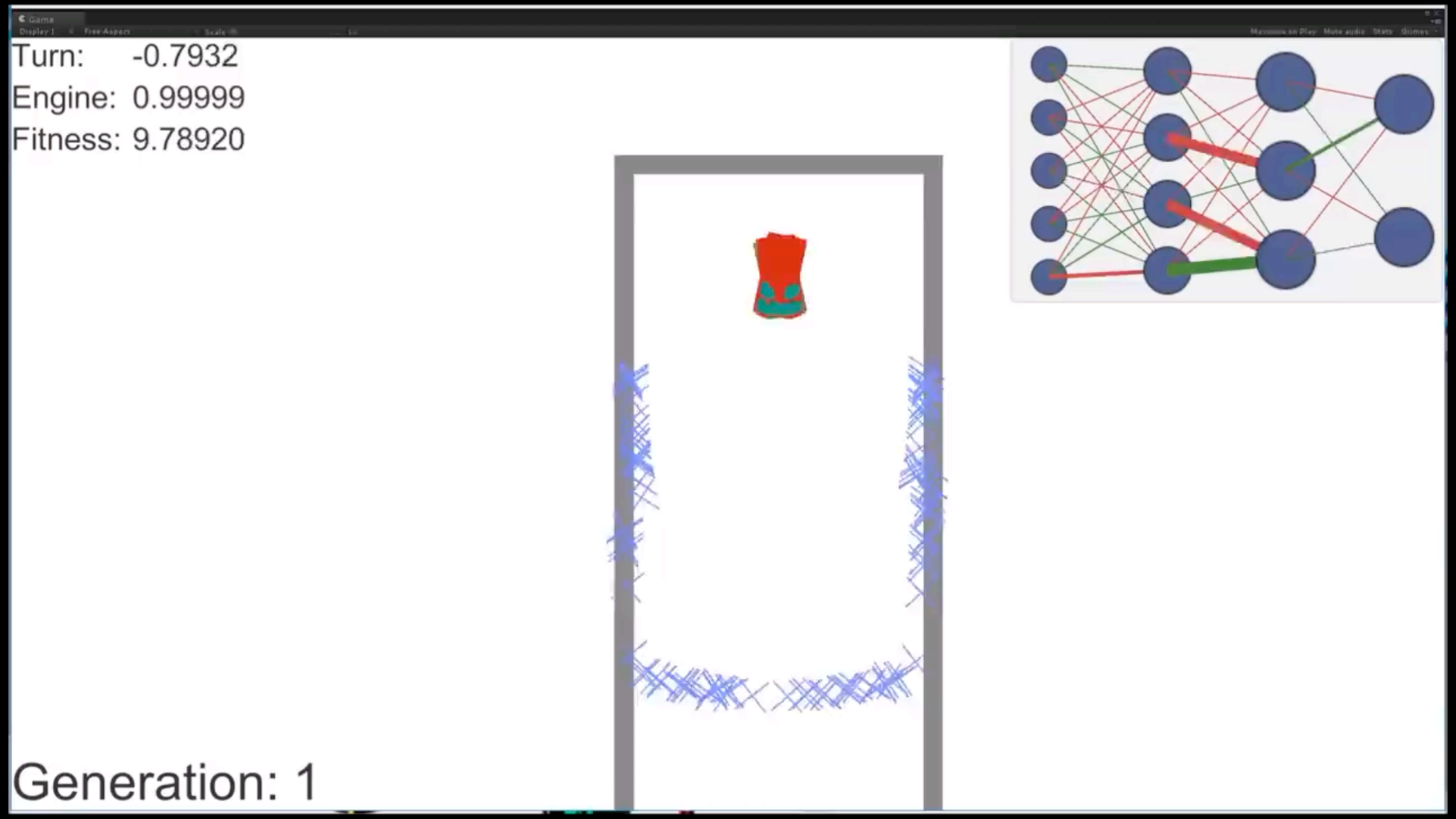


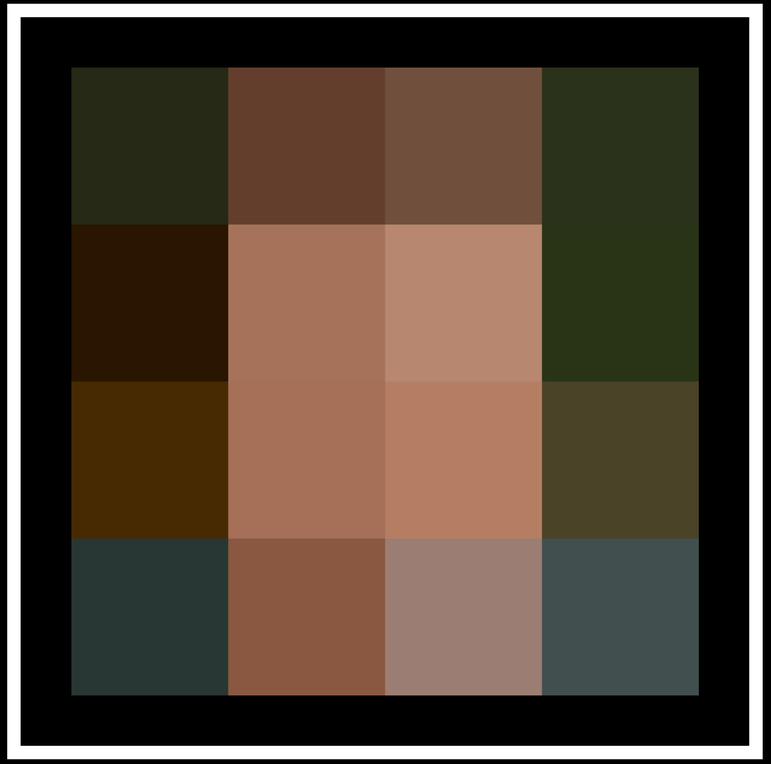

input
output

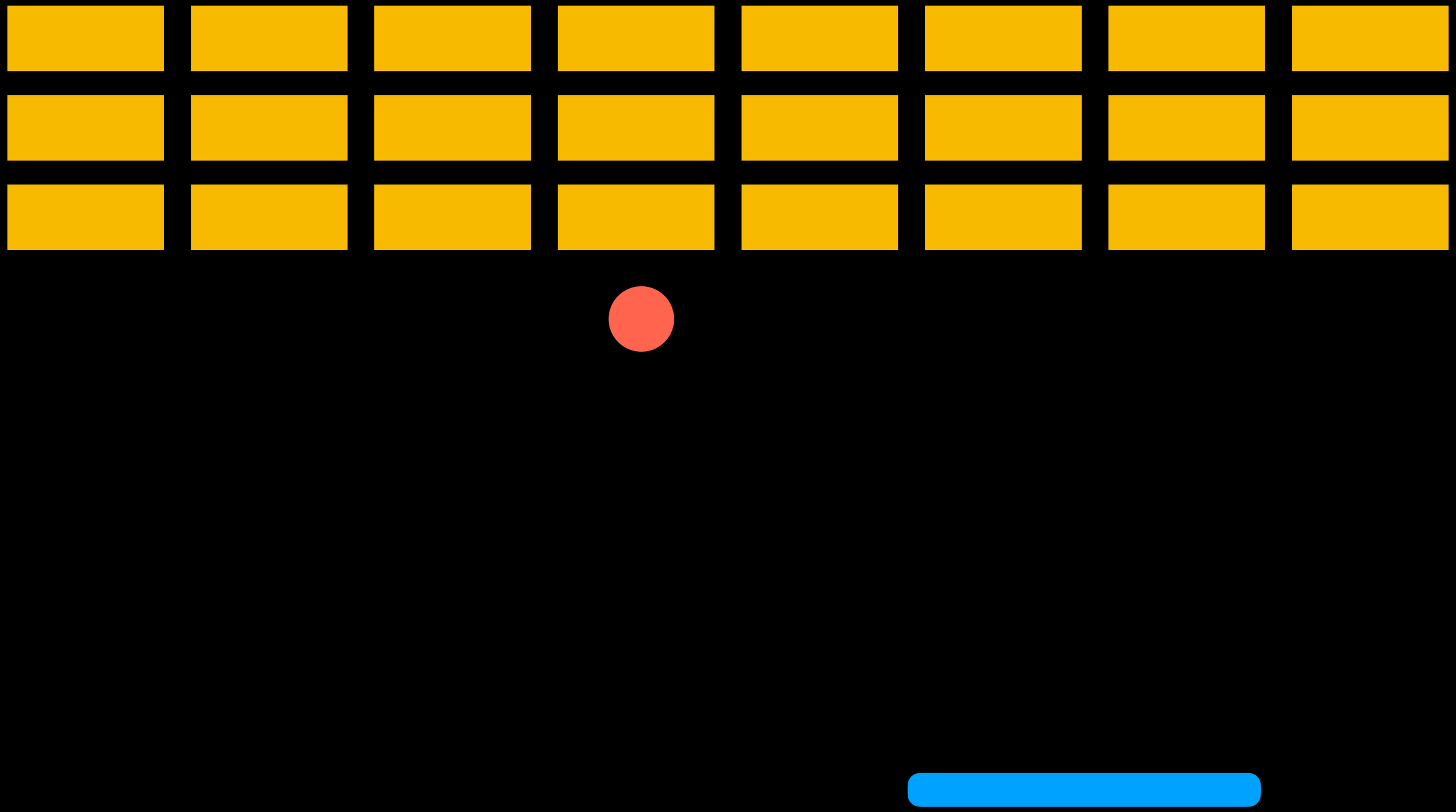


8


spam


Turn: -0.7932
Engine: 0.99999
Fitness: 9.78920
Generation: 1





Google DeepMind

Training Time: 10 minutes

Google DeepMind

Training Time: 2 hours

Google DeepMind

Training Time: 4 hours

Artificial Intelligence