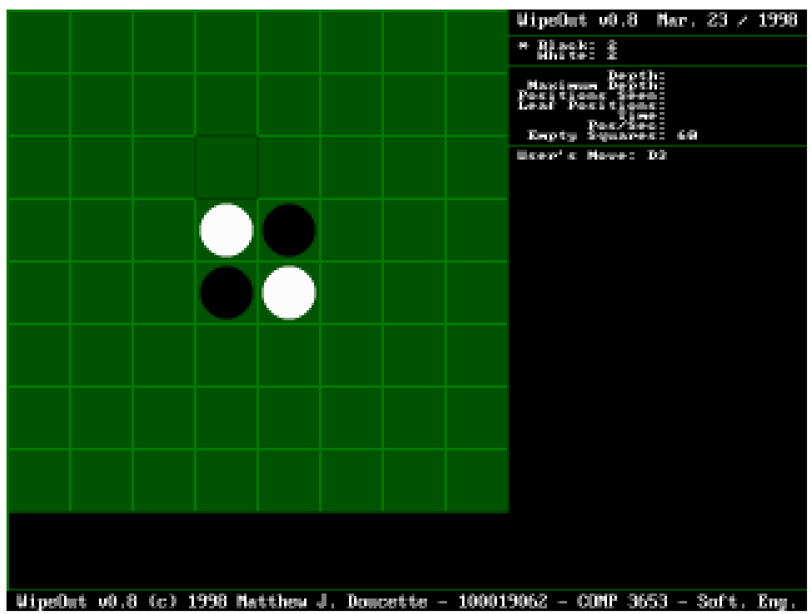
Game Playing

Chapter 5 - supplement

Various deterministic board games

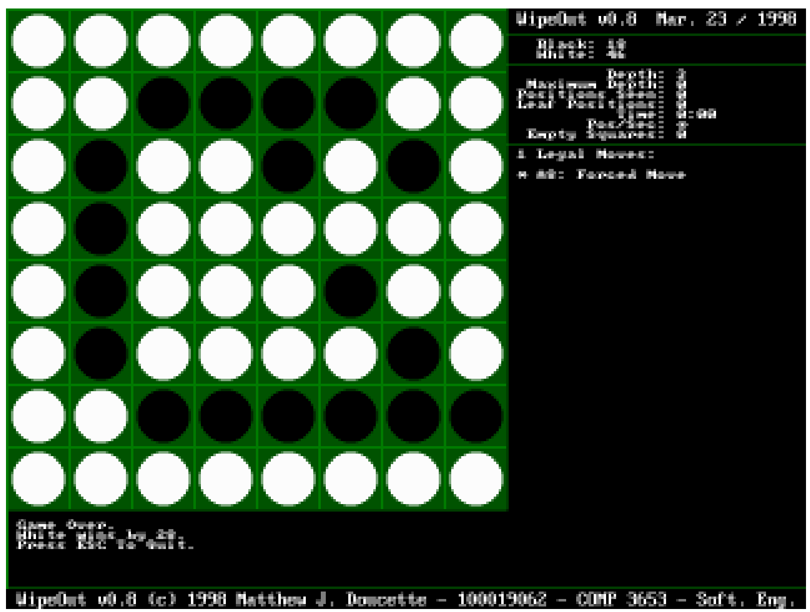
Othello (reversi, lagno)

- 8x8 board of cells
- The tokens have two sides: one black, one white
- One player is putting the white side and the other player is putting the black side
- The game starts like this:



Othello

- The game proceeds by each side putting a piece of his own color
- The winner is the one who gets more pieces of his color at the end of the game
- Below, white wins by 28

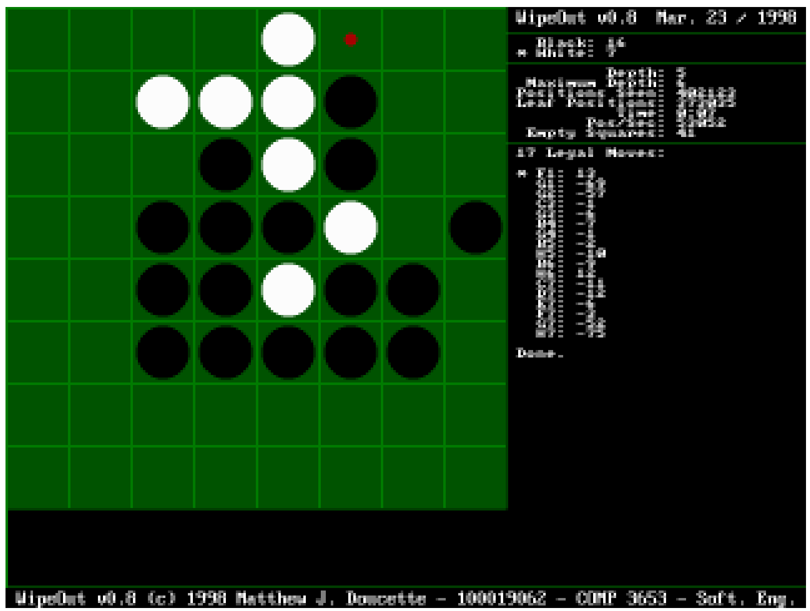


Othello

- When a black token is put onto the board, and on the same horizontal, vertical, or diagonal line there is another black piece such that every piece between the two black tokens is white, then all the white pieces are flipped to black.
- A move can only be made if it causes flipping of pieces. A player can pass a move iff there is no move that causes flipping. The game ends when neither player can make a move.

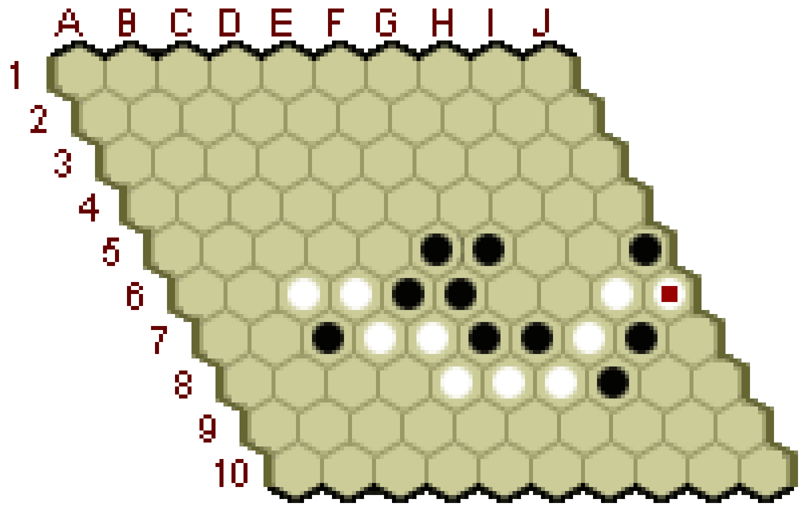
Othello

Below there are 17 possible moves for white



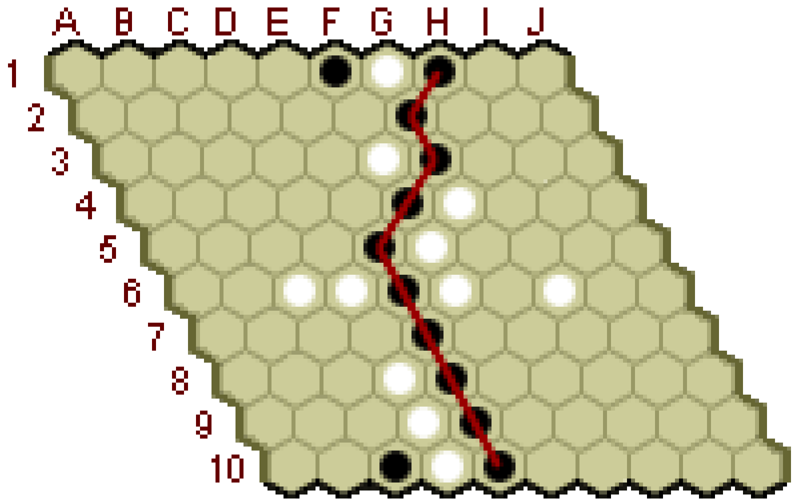
Hex

- Hexagonal cells are arranged as below . Common sizes are 10x10, 11x11, 14x14, 19x19.
- The game has two players: Black and White
- Black always starts (there is also a swapping rule)
- Players take turns placing their pieces on the board



Hex

- The object of the game is to make an uninterrupted connection of your pieces from one end of your board to the other



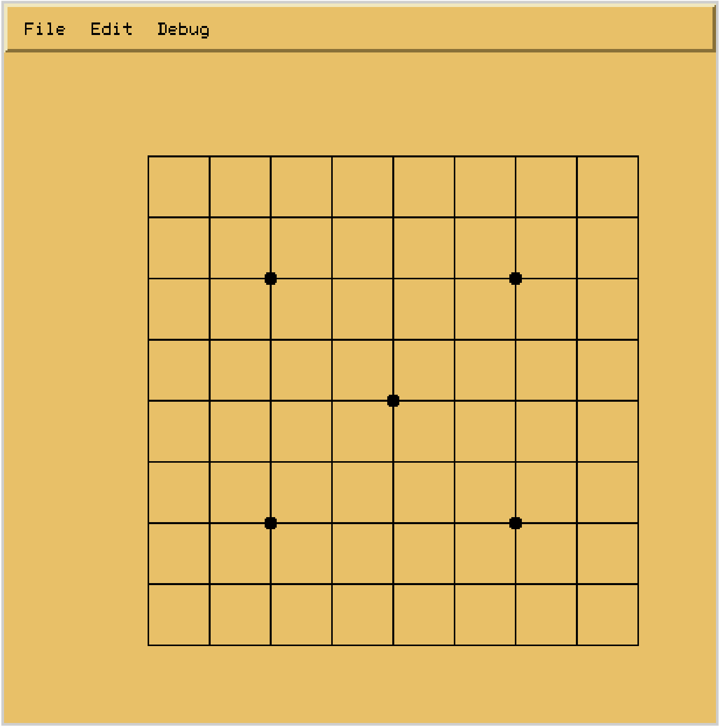
- Other properties
  - First player always wins
  - No ties

Hex

- **Invented independently by Piet Hein in 1942 and John Nash in 1948.**
- **Every empty cell is a legal move, thus the game tree is wide b = ~80 (chess b = ~35, go b = ~250)**
- **Determining the winner (assuming perfect play) in an arbitrary Hex position is PSPACE-complete [Rei81].**
- **How to get knowledge about the “potential” of a given position without massive game-tree search?**
- **There are good programs that play with heuristics to evaluate game configurations.**

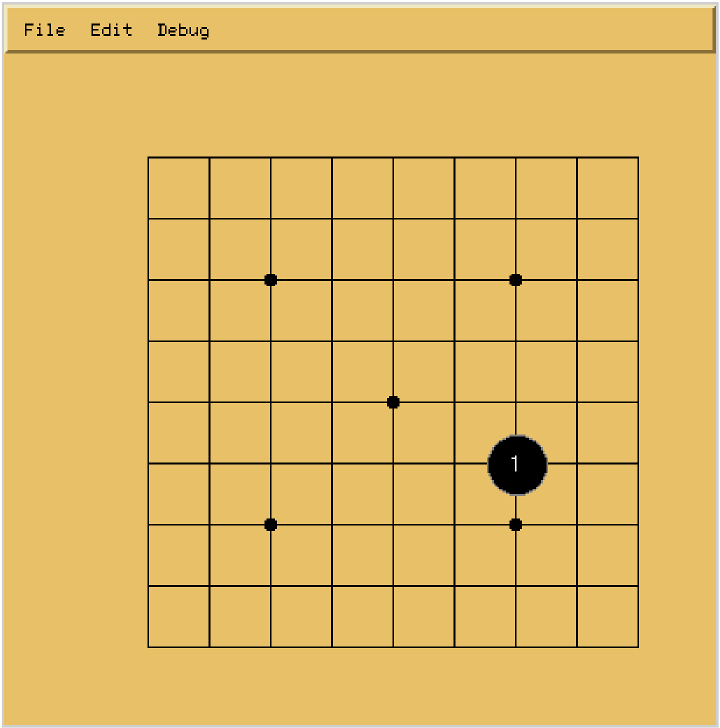
The Game of Go

Go is a two-player game played using black and white stones on a board with 19x19, 13x13, or 9x9 intersections.



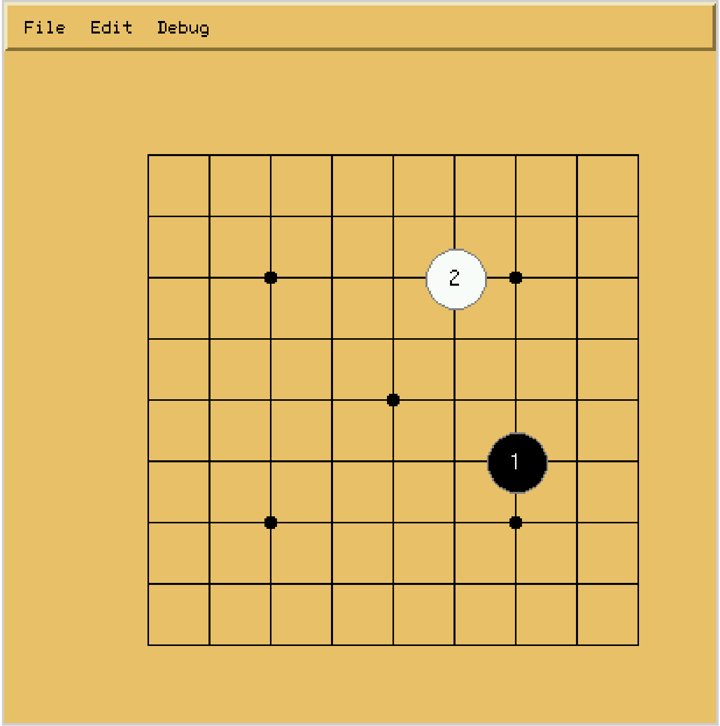
The Game of Go

Players take turns placing stones onto the intersections.
Goal: surround the most territory (empty intersections).

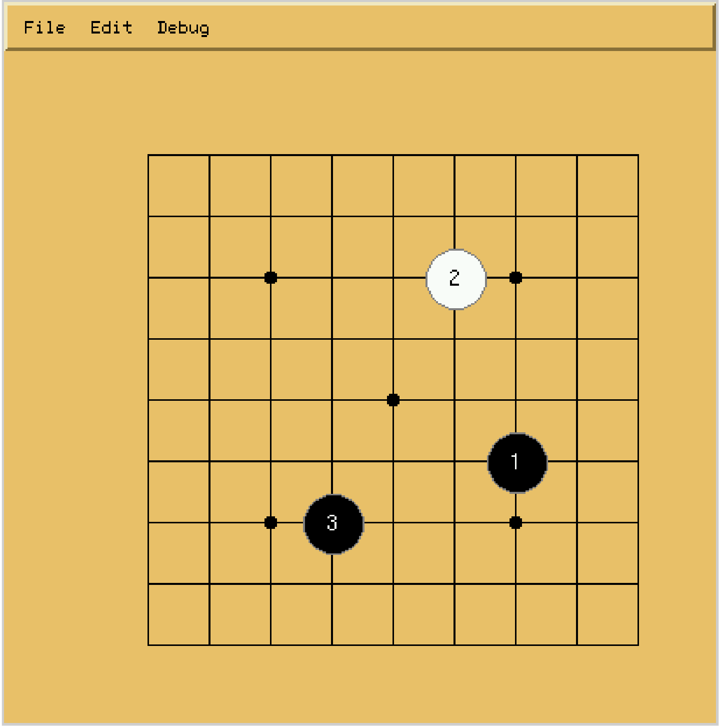


The Game of Go

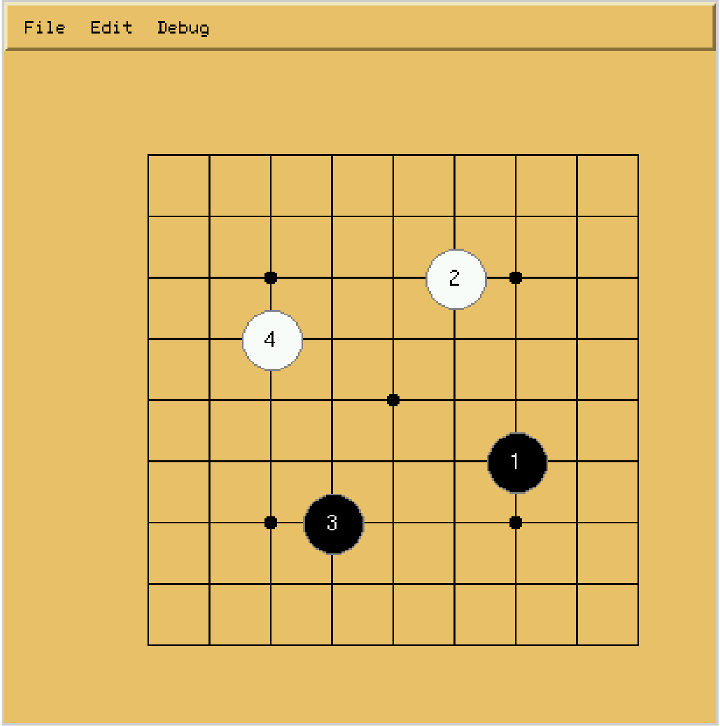
Once placed onto the board, stones are not moved.



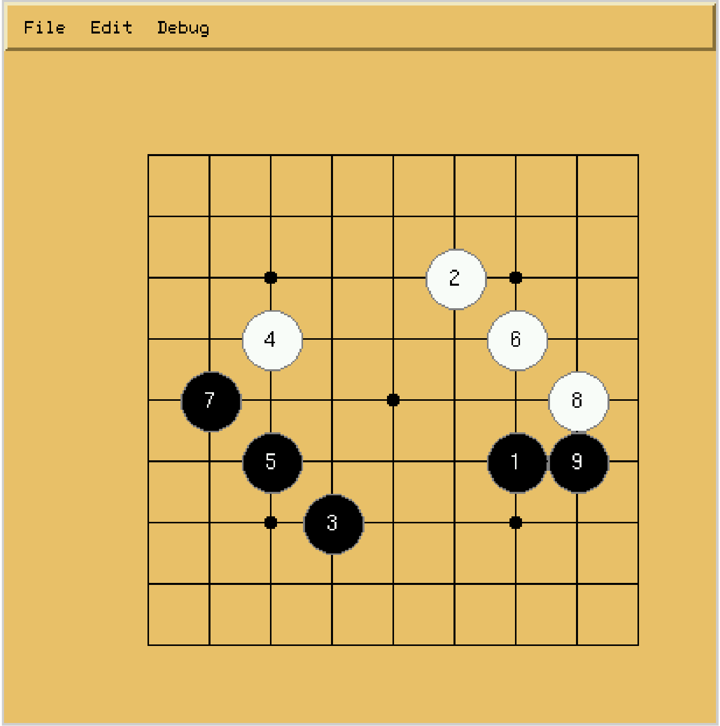
The Game of Go



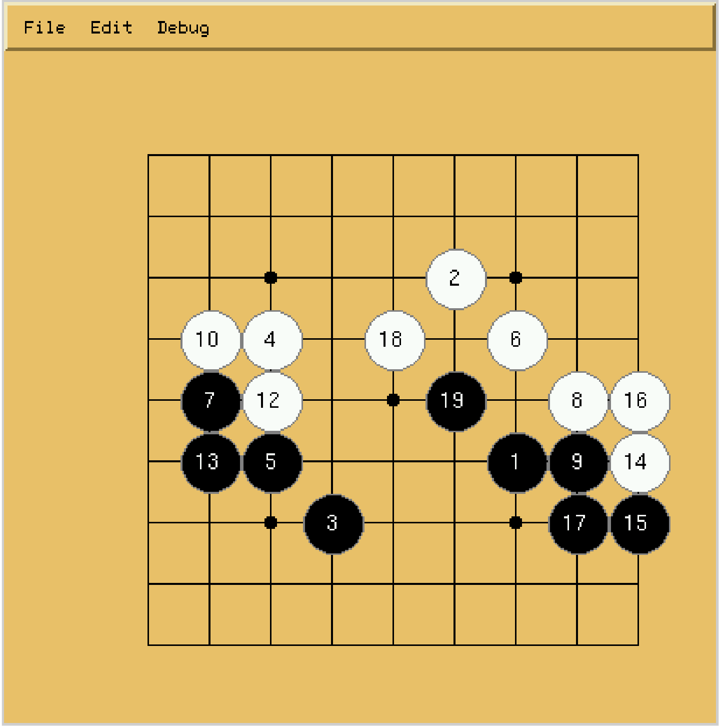
The Game of Go



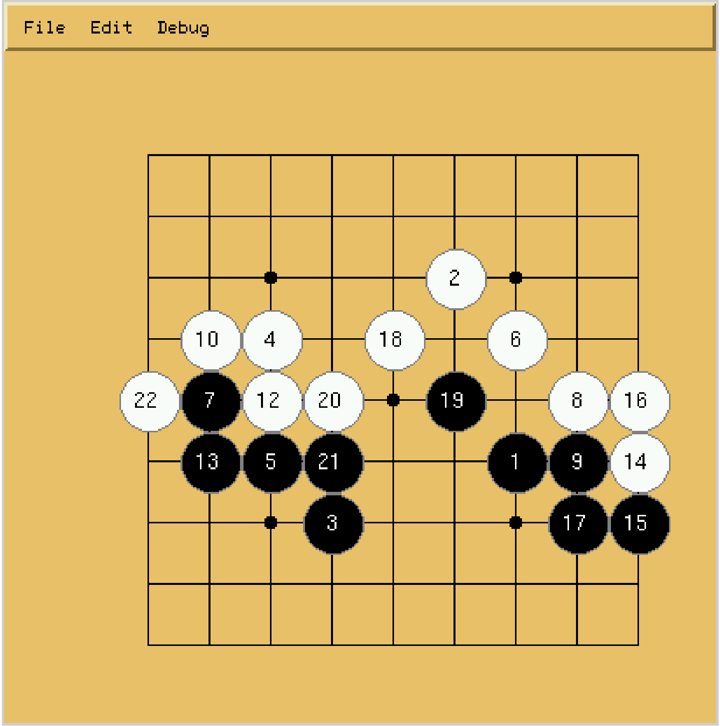
The Game of Go



The Game of Go

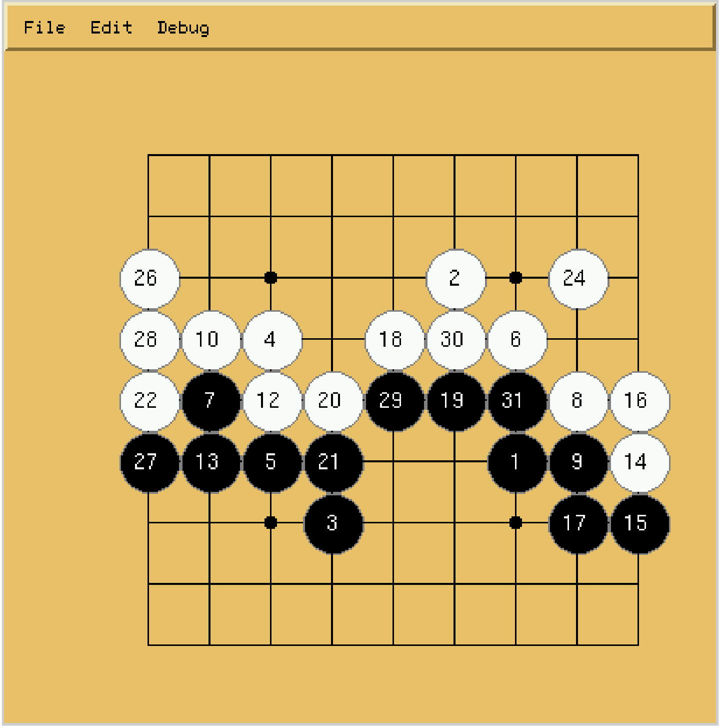


The Game of Go



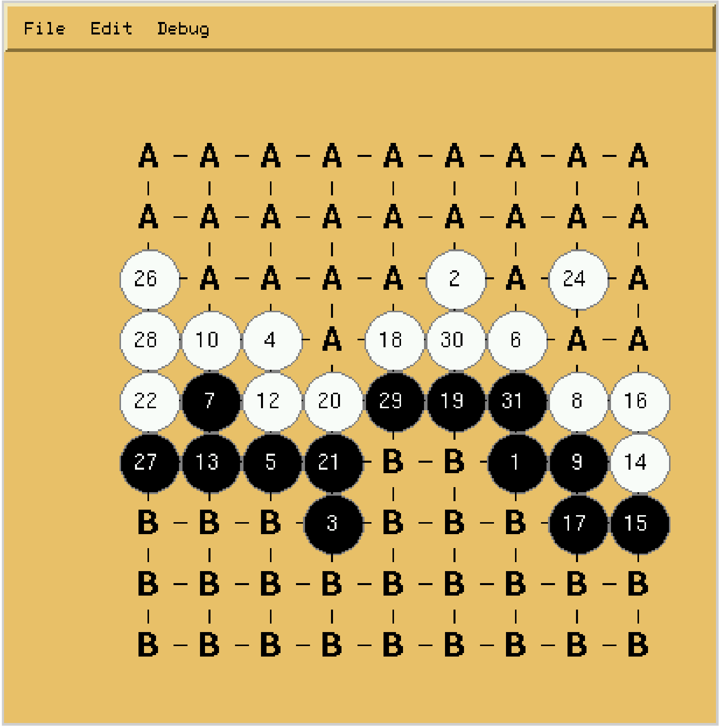
The Game of Go

The game ends when neither player wishes to add more stones to the board.



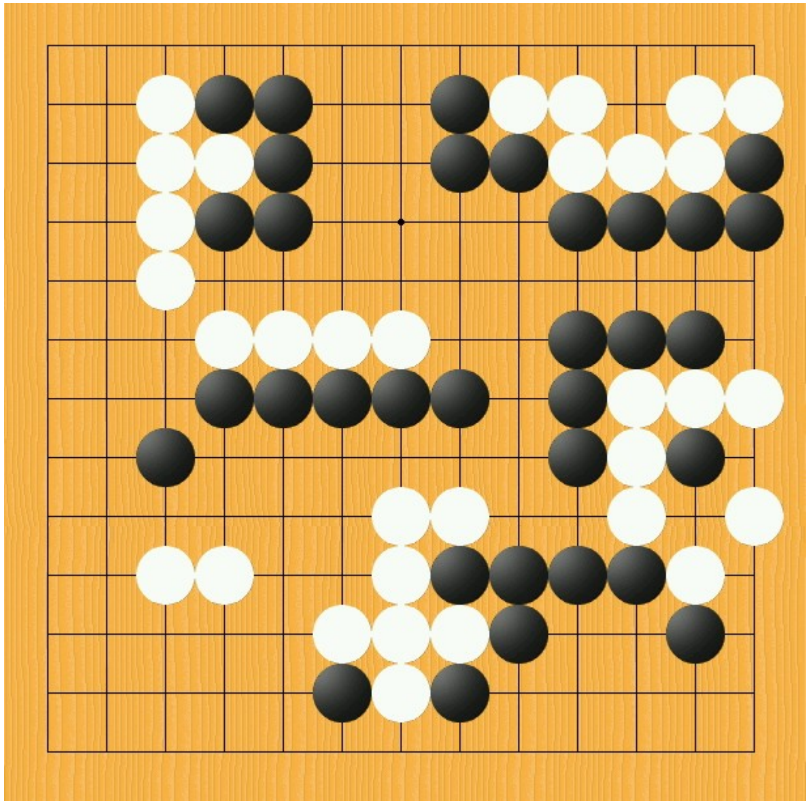
The Game of Go

The player with the most enclosed territory wins the game. (With *komi*, White wins this game by 7.5 pts.)



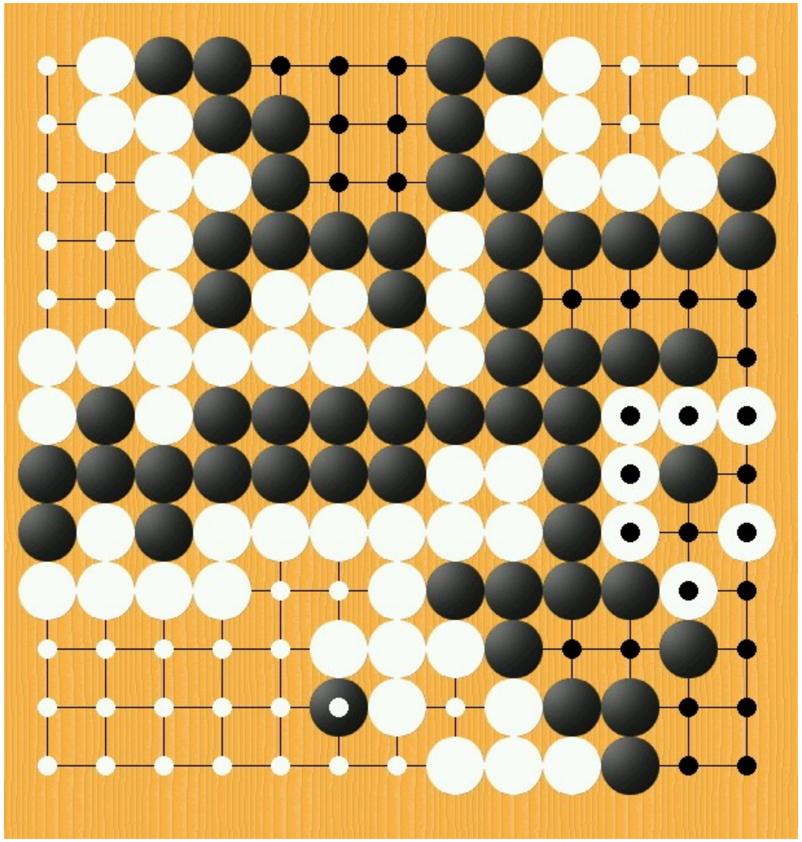
Example on 13x13 Board

What territory belongs to White? To Black?



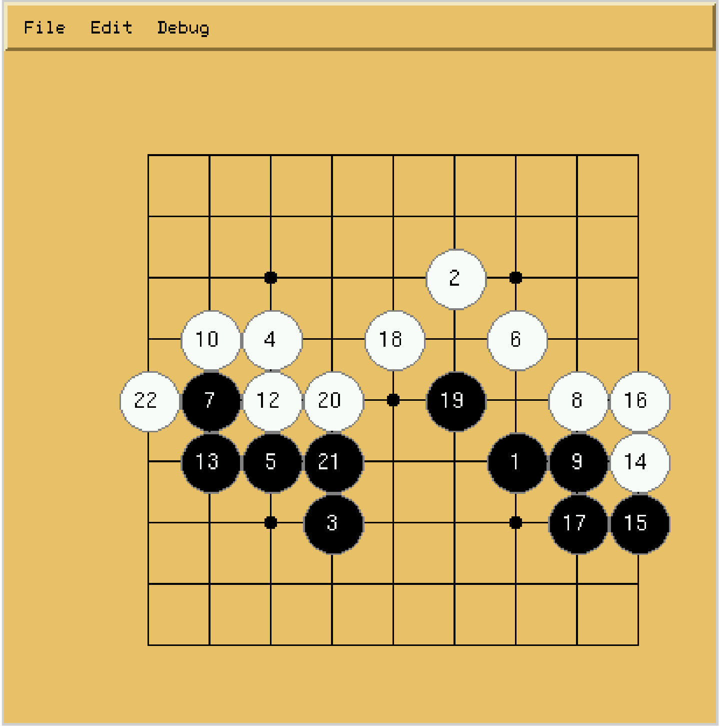
Example on 13x13 Board

Black ahead by 1 point. With *komi*, White wins by 4.5 pts.



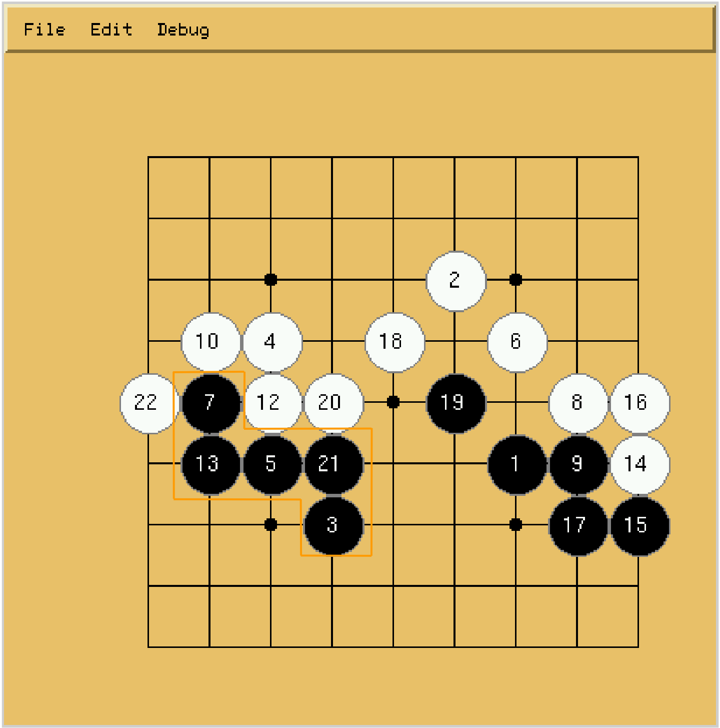
The Game of Go

A **block** is a set of adjacent stones (up, down, left, right) of the same color.



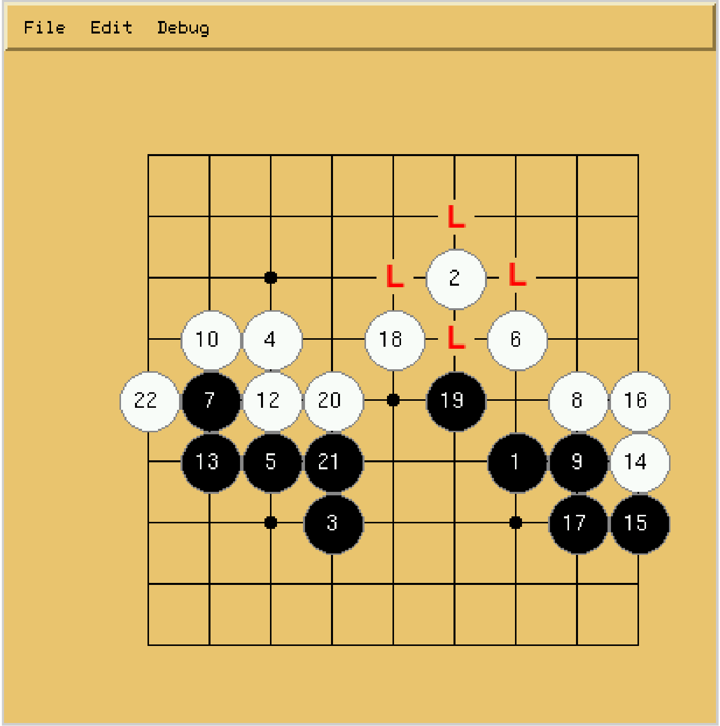
The Game of Go

A **block** is a set of adjacent stones (up, down, left, right) of the same color.

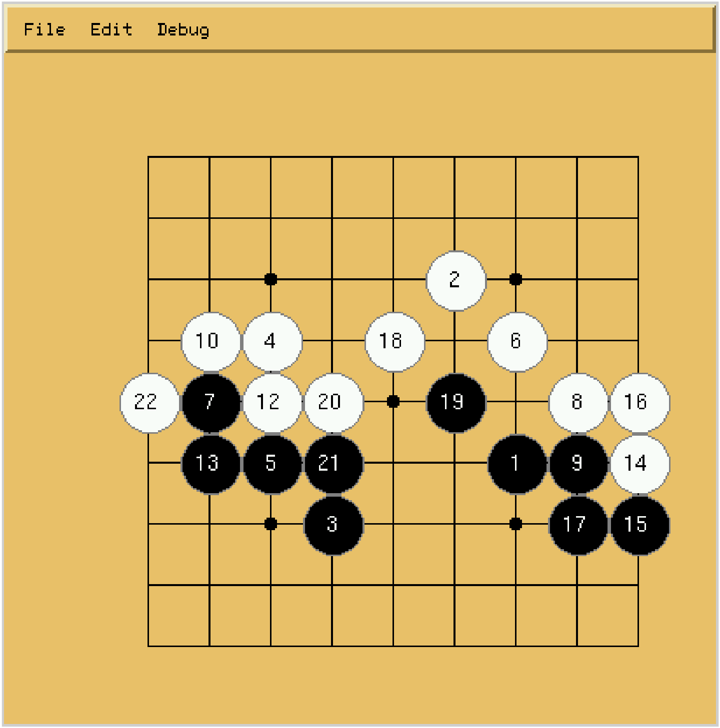


The Game of Go

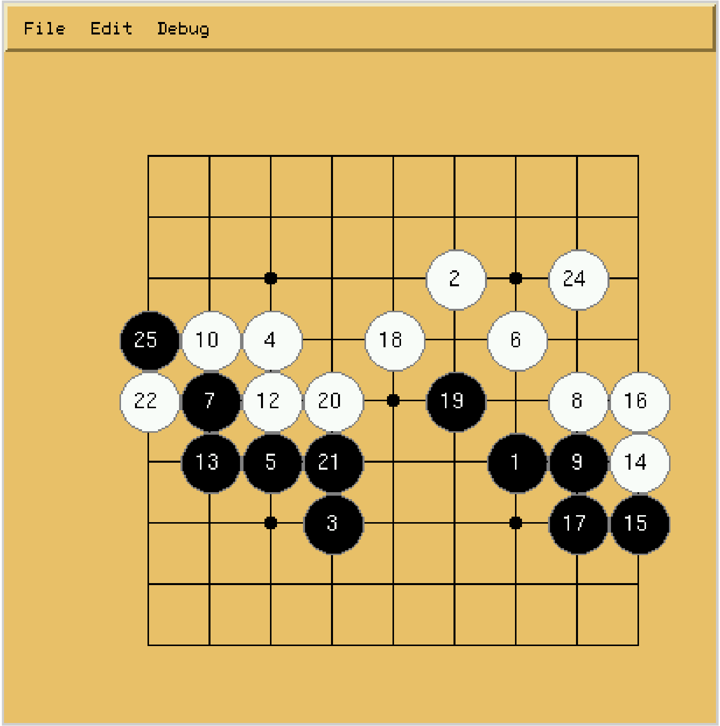
A **liberty** of a block is an empty intersection adjacent to one of its stones.



The Game of Go

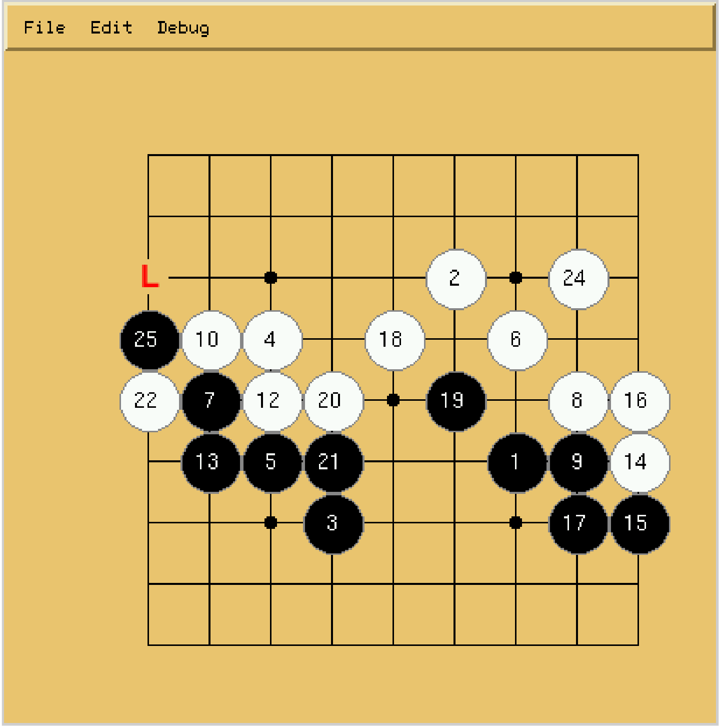


The Game of Go



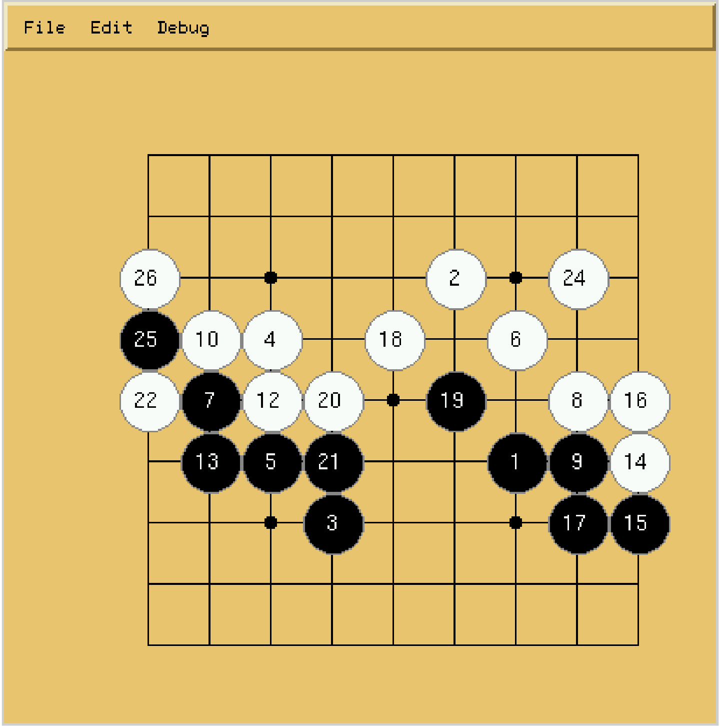
The Game of Go

If a block runs out of liberties, it is captured. Captured blocks are removed from the board.



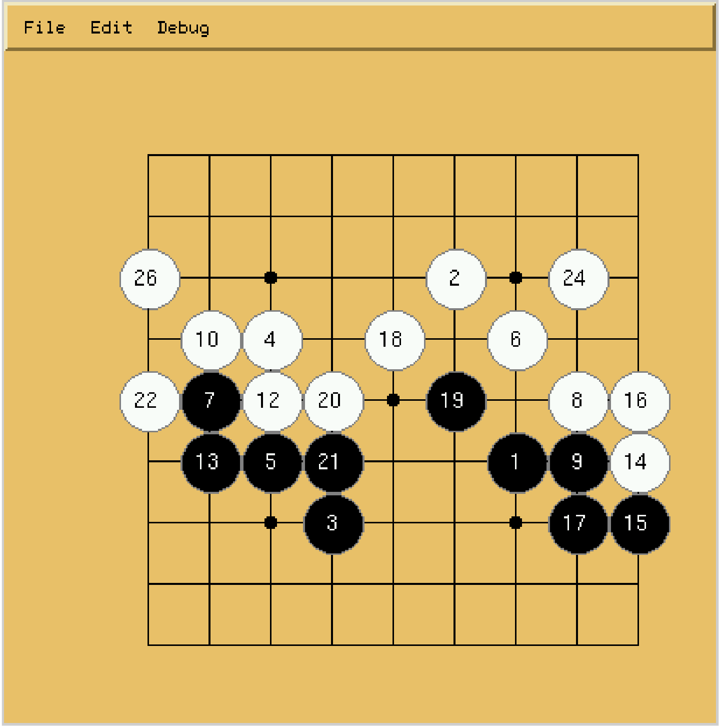
The Game of Go

If a block runs out of liberties, it is captured. Captured blocks are removed from the board.



The Game of Go

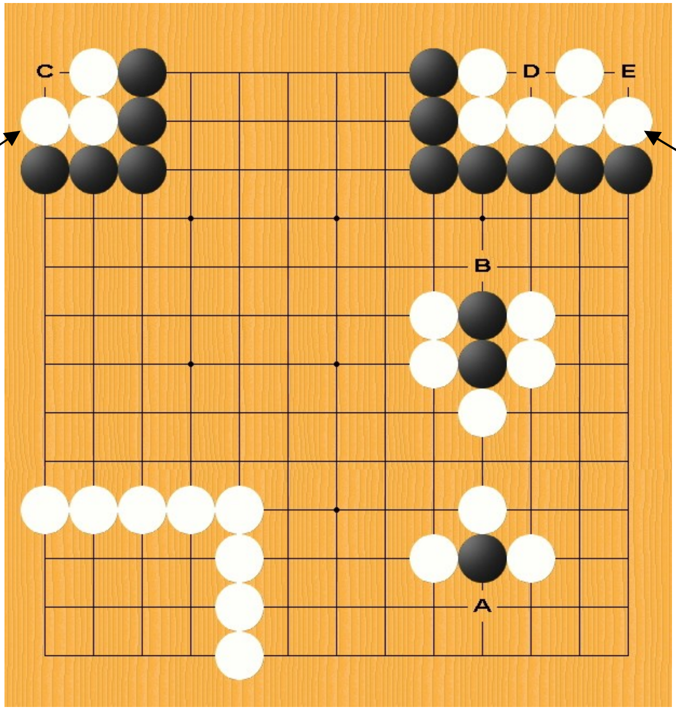
If a block runs out of liberties, it is captured. Captured blocks are removed from the board.



Alive and Dead Blocks

White can capture by playing at A or B. Black can capture by playing at C. Black can't play at D and E simultaneously.

With only one eye, these stones are dead. No need for Black to play at C.



With two eyes at D and E, these White stones are alive.

Challenges for computer Go

Much higher search requirements

- Minimax game tree has $O(b^d)$ positions
- In chess, b = ~35 and d = ~100 half-moves
- In Go, b = ~250 and d = ~200 half-moves
- However, 9x9 Go seems almost as hard as 19x19

Accurate evaluation functions are difficult to build and computationally expensive

- In chess, material difference alone works fairly well
- In Go, only 1 piece type with no easily extracted features

Determining the winner from an arbitrary position is PSPACE-hard (Lichtenstein and Sipser, 1980)