Game Rules GBG

2048

1-player game.

The game starts with game score 0 and two tiles with value '2' or '4' placed randomly on the otherwise empty 4x4 game board. Whenever the player makes an action, the environment adds a random tile '2' (90%) or '4' (10%) in one of the cells being empty after the player's action.

The player has at most these four actions: LEFT, UP, RIGHT, DOWN. An action is only **legal** if it moves at least one tile. If the player chooses LEFT, all tiles are moved to the left until they are adjacent to another tile. If now in a row two adjacent tiles have the same number 'X', the leftmost pair of those is merged to a new tile '2X'. In Figure 1, if a LEFT action is triggered, the 1st row gets the two leftmost '8's merged into one '16'. In the 2nd row the two '2's are merged into one '4'.

Whenever two tiles are merged, the merged value is added to the **game score**.

Figure 1: Intermediate position in the game 2048. The possible legal actions are LEFT, RIGHT and DOWN. The action UP is not legal since it would not move a single tile

The game **ends** if no legal move is possible (all cells filled and no merge possible).

The first goal of the game is to reach the '2048' tile. But beyond this, the broader goal is to reach even higher tiles and the highest possible game score.

Connect Four

2-player game.

Each player in turn places a piece of his/her color on the (6 rows x 7 columns)-board. The pieces fall in each column down to the lowest empty cell.
Yellow (X) starts.

The player who gets four-in-a-row (horizontal, vertical or diagonal) wins. If no player reaches this and no moves are left, it is a tie.
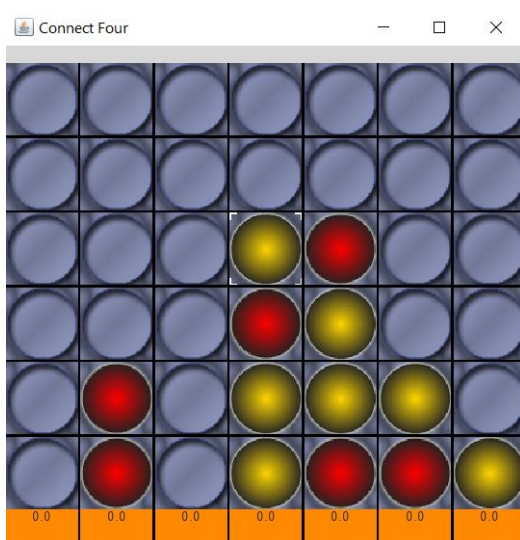

Figure 2: Yellow (X) wins in Connect Four.

Hex

2-player game.

Scalable game with scalable parameter N = side length of board.

The game board is a diamond with side length N of hexagonal cells. Two adjacent rims of the diamond are colored black, the other two white. Each player in turn places a piece of his/her color on a free cell.
Black (X) starts.

The player who forms a connected line of his/her color between the adjacent rims of his/her color **wins** the game. Hex **cannot** end in a tie.
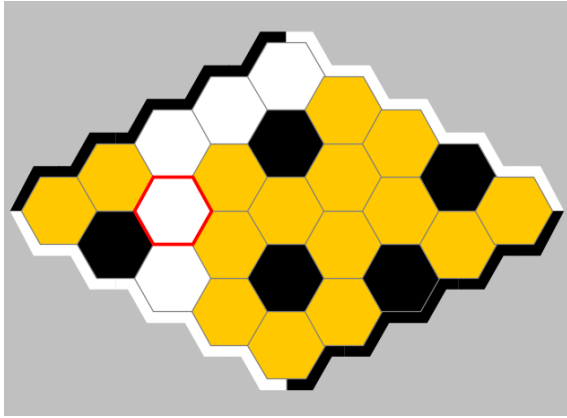
Figure 3: White wins in 5x5 Hex

Nim

2-player game.

Scalable game with three scalable parameters: (a) number of heaps N, (b) size of each heap S (number of items), (c) maximum number of items to take in one move ("Max Minus") M.

The game starts with N heaps of size S. Each player in turn takes away 1,2,…,M items from **one** heap. Black (X) starts.

The player who takes away the last item **wins** the game.
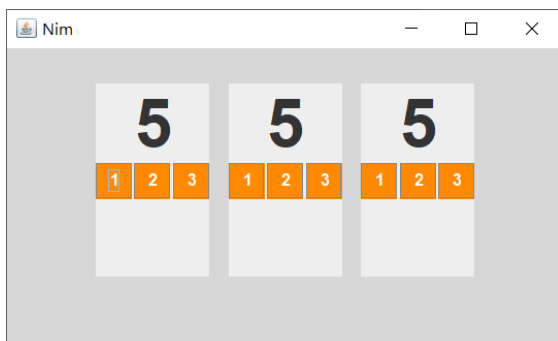
Nim **cannot** end in a tie.

Figure 4 Starting position for Nim: N=3 heaps of size S=5, Max Minus = 3.

Nim3P

3-player game.

Same game layout (see Figure 4) and same move rule as for Nim. Scalable parameters: (a) number of heaps N, (b) size of each heap S (number of items), (c) whether the extra rule is active or not. The maximum number of items to take from each heap ("Max Minus") is in Nim3P always M=S.

Now three players P0, P1, P2 move in turn and take items away.
P0 starts.

Win rule: The player **who follows** the player taking the last item is the player who wins. He/she gets a reward 1, both others get reward 0.

Extra rule (optional): If scalable parameter "Extra Rule" is set to true, then the player who follows the winning player gets an extra reward of 0.2. This helps to break ties for otherwise 'undecided' states.

Nim3P **cannot** end in a tie.

Othello (Reversi)

2-player game.

This game is played on a 8x8 board. The start position has two white pieces and two black pieces in the center. Each player in turn places a piece of his/her color on the 8x8 board. Placement can be only made in those empty cells that enclose – with a help of another piece of the player – one or more opponent pieces (see Figure 4: the green rectangles mark the legal moves). All enclosed opponent pieces have their color reversed to the player's color. Black (X) starts.
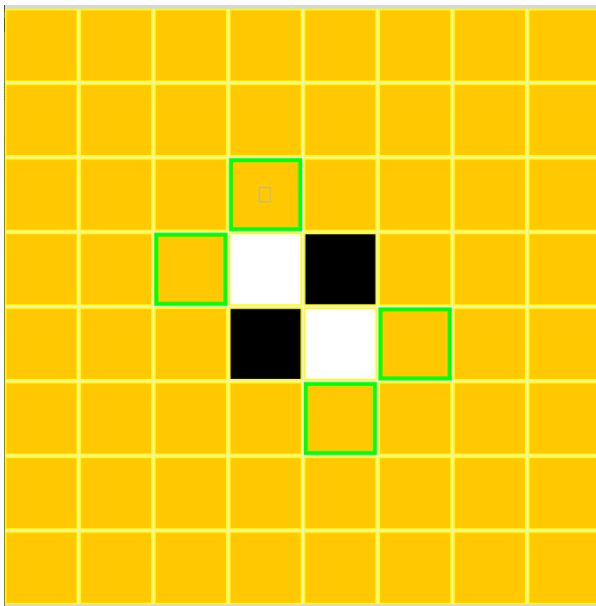

Figure 5 Starting position for Othello. Black starts and the green rectangles mark his/her legal moves.

If a player cannot make a legal move, he has to pass and the opponent moves again. If both players cannot move, the game is over. The player with the most pieces on the board **wins**. If both players have an equal number of pieces, it is a tie.

Rubik's Cube

1-player game.

(in preparation)

Sim

2- or 3-player game.

Scalable game with these scalable parameters: (a) K = number of nodes and (b) P = number of players (2 or 3).

The game board is a complete graph with K nodes. Each player in turn colors a free edge of the graph with his/her color.
Black (X) starts.

The player who completes a monochromatic triangle of his/her color **loses**. In the 2-player variant, the opponent is the winner, in the 3-player variant the two opponents continue to play until one of them also loses. If two or more players do not complete a triangle when the graph is completely colored, it is a **tie**. In the 3-player variant there are two kinds of a tie: (a) a tie between all players or (b) one player loses and it is only a tie between the remaining two opponents.

It is known from Ramsey theory that for $K \geq K_0$ with $K_0 = 6$ (2 player) and $K_0 = 17$ (3 player) the game **cannot** end in an all-player tie. But for smaller $K < K_0$ the game is likely to end in a tie.
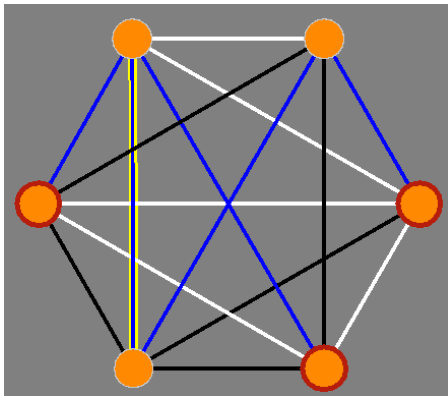

Figure 6: White loses in 3-player Sim with K=6 nodes. The last move (marked by yellow bar) of Blue does not close a monochromatic triangle, so it is a tie between Black and Blue.

Within the 3-player variant we allow additionally two *Coalition* variants:
- *Coalition = None*:   all 3 players play for their own, or
- *Coalition = 1-2*:   players 1 and 2 form a coalition against the third player 0 who plays alone.

Tic Tac Toe

2-player game.

Each player in turn places a piece of his/her color on the 3x3 board.
Black (X) starts.

The player who gets three-in-a-row (horizontal, vertical or diagonal) **wins**. If no player reaches this, it is a tie.
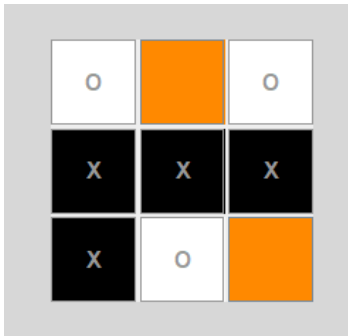
Figure 7: Black (X) wins in Tic Tac Toe.

Poker

Poker is a game with a high number of different variants (e.g. five-card draw, community card poker, …) and different house rules specifying the detailed parameters of the game. Because of this, the following paragraphs won't cover all possible options but will focus on the implemented game mechanics.

How many players are part of the game?

Poker is a multiplayer for 2-10 players depending on the chosen variant.

How to win the game?

Anyone who has lost all of their chips is knocked out of the game. The last remaining person is the winner.

How is the game played?

The game is played with a deck of 52 cards. Every player gets the same amount of chips. The dealer is the first player of the group. After the initial setups there are as many rounds played until there is only one remaining player.

How is a game round structured?

A game round can be structured into six different phases:

- **Setup:** The first player next to the dealer is placing the *small blind* and the player after that placing the *big blind*. These are forced bets and the players do not have the option to pass or fold at this step. The *big blind* is equal to the minimum bet and the *small blind* is half of the big blind.[1] After the blinds are placed every player gets two cards which are referred to as *hole-cards.* The hole cards are only visible and accessible to the respective player.
- **Pre-Flop:** After the hole cards are dealt there is a first betting round.
- **Flop:** Three community cards referred to as the *flop* and available to each player are revealed. After this new information there is a second betting round.
- **Turn:** Another community card referred to as the *turn* and available to each player is revealed. After this new information there is a third betting round.
- **River:** Another community card referred to as the *river* and available to each player is revealed. After this new information there is a fourth betting round.

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[1] In many tournament settings the *small* and *big blind* are increasing over time to create more action in the game. In this implementation, small and big blind stay constant over time.

- **Showdown:** During the showdown the winning hand is determined and the pots are awarded to the respective winner(s).

After the showdown a new game round starts and each player with remaining chips can participate again.

Betting round: Each player chooses an *Action* until every player has either matched the placed bets or folded.

Actions
- **Check:** If there are no bets placed in the current round, the active player has the option to *check*. With this he declines to makes a bet but still remains in the game. If all players are *checking* the betting round may end without a bet and the game will move to the next stage.
- **Bet:** If there are no bets placed in the current round the active player has the option to make a bet. In the implemented version the size of the bet is predefined as the minimum bet. If the active player has not a sufficient amount of chips to place a bet he will be forced to go *all in* if he chooses to bet. With this the size of the bet is equal to the amount of chips the player has available.
- **Fold:** A player has always the option to *fold*. With this the active player drops out of the current game round and cannot make any further actions.
- **Call:** If a bet has been placed, the active player has the option to *call* the existing bet. With this he places the same amount of chips as the size of the bet.
- **Raise:** If a bet has been placed, the active player has the option to *raise* the existing bet. With this he increases the betted amount by the minimum bet.
- **All In:** If a player goes *all in*, all remaining chips of the active players are bet. If a player is *all in*, he cannot make another action during this game round. This might result into a *split pot* because the active player might not be eligible for the complete Pot. For example: Player A and Player B are betting 100 chips each, resulting in a pot of 200. Player C has only 50 chips left and goes all in. Resulting in Pot_1: 150 chips where Player A, B and C are eligible and Pot_2: 100 chips where only Player A and B are eligible because C didn't have sufficient chips.

Determine the winning hand
During the showdown the best five cards, out of the given seven (two hole-cards and the five community cards) are chosen. If there are two players with the same hand there are options to break the tie. If there are no options left to break the tie, the pot will be shared.

Hand	Definition	Tie break
Royal flush	A *straight flush* with an Ace as the highest card	-
Straight flush	Both a *straight* and a *flush*	The highest card in the straight flush breaks the tie.
Four of a kind	Four cards of the same rank	The highest rank of the four of a kind breaks the tie. If it is still a tie, the highest fifth card breaks the tie.

Full House	A three of a kind and a pair	The rank of the three of a kind breaks the tie. If it is still a tie, the highest pair breaks the tie.
Flush	All five cards with the same suit	The highest rank in the flush breaks the tie. If it is still a tie, the second highest rank breaks the tie.
Straight	All five cards in a continuous sequence. As a special case the ace can take the place of the lowest rank in a straight from ace to 5 as well as the highest rank in a straight from 10 to ace. A straight "around the corner" e.g., Q-K-A-2-3 is not possible.	The highest rank in the straight breaks the tie.
Three of a kind	Three cards of the same rank	The rank of the three of a kind breaks the tie. If it is still a tie, the highest card breaks the tie. If it is still a tie the second highest card breaks the tie.
Two pair	Two pairs	The highest rank of the pairs breaks the tie. If it is still a tie, the second pair breaks the tie. If it is still a tie the highest card breaks the tie.
One pair	Two cards of the same rank	The rank of the pair breaks the tie. If it is still a tie, the highest card breaks the tie. If it is still a tie, the second highest card breaks the tie …
High card	The highest card	The rank of the highest card breaks the tie. If it is still a tie, the second highest card breaks the tie …