

Tic-Tac-Toe: A Simple, But Ultimately Trivial And Futile, Game of Strategy

For avid board gamers who like to know the fine points of every game—and how to win!

by Jerry Kindall <kindall@gmail.com>

Tic-Tac-Toe¹ is a simple two-player game played on a two-dimensional grid of nine squares arranged in three rows and three columns. Players take turns marking squares in the grid (traditionally using Xs and Os) until one player has marked three squares in a row, thereby winning, or until all squares have been marked (which is a draw).

The game is “solved”—an optimal strategy is known that always results in, at worst, a draw when it is employed perfectly. For this reason, adults rarely play Tic-Tac-Toe seriously; the game is played mainly by children, who often learn about strategy and sportsmanship while discovering the best way to win.

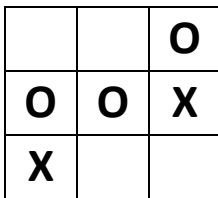
It is reasonably straightforward to program a computer to play a perfect game of Tic-Tac-Toe. In fact, this is a common assignment for Freshman computer science students.

The Game Board

The Tic-Tac-Toe board, a 3x3 grid of nine squares, is usually drawn on a sheet of paper or some other markable surface (for example, a chalkboard or a whiteboard) using an appropriate marking tool. The board does not need to be large; dozens of games can easily fit on a single page of letter-sized paper.

While the spaces on a Tic-Tac-Toe board are called “squares,” they need not be quite that precise. It is quite common to draw the board roughly, using pairs of intersecting horizontal and vertical lines and omitting the outer border of the grid, as in the third example below.

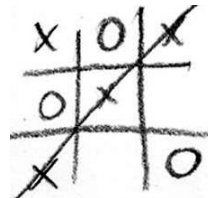
A Few Kinds of Tic-Tac-Toe Boards



The Platonic ideal



Board with pieces



Hand-drawn board



Board with rotating “squares”

Other types or styles of boards may be used, with some offering removable markers (as in the second example), or fixed pieces that can be rotated to “mark” a square (as in the fourth).

Making Marks

Traditionally, one player marks their squares on the board with the letter X, while the other player marks squares with the letter O, using the same (or similar) implement that was used to draw the board.

Other marks or markers may also be used as long as they are easily identifiable as belonging to one player or the other. For example, Tic-Tac-Toe can be played with red and black checkers on a 3x3 section of a checkerboard, if that’s what’s at hand. If such physical markers are used, each player will need five.

¹ This game is usually called “Noughts and Crosses” in British Commonwealth countries. Other common names include “Xs and Os,” “Three in a Row,” and variations on “Tic-Tac-Toe” such as “Tit-Tat-Toe.”

Gameplay and Goal

Players take turns marking squares (for example, writing an X or an O on the board). Players may only mark squares that have not yet been marked. Players may not remove or change marks during a game.

Either player may go first. When playing a series of games, players usually alternate taking the first turn.

The goal of Tic-Tac-Toe is for a player to mark any three squares in a row in any direction—horizontally, vertically, or on one of the board’s two diagonals that include the center—while preventing her or his opponent from doing the same.

Ways to Get Three in a Row

X	X	X

Any Row

	O	
	O	
	O	

Any Column

		X
	X	
X		

Diagonal 1

O		
	O	
		O

Diagonal 2

When a player has marked three squares in a row, that player wins, and the game ends. Traditionally, the winning player then draws a line through the winning squares, perhaps to mark it for posterity.

If all nine squares have been marked, but neither player has succeeded in marking three squares in a row, the game ends in a **draw**, or a tie.²

After a game ends, a new grid may be drawn on the same surface if there is room, or on a new one if not—or the board otherwise reset, however that’s done for the board in use—and a new game begun.

Games are short, typically lasting only seconds. Even very inexperienced players can finish a game in under a minute. Repeated play is the usual way to pass longer spans of time. It is common for each player to keep track of his or her wins in such a session using tally marks (||||) or a similar method.

Fork to Win

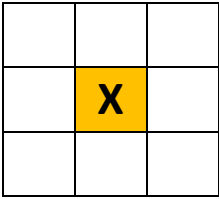
The goal of the game being to mark *three* squares in a row, a player who hopes to win must first mark *two* squares in a row. This is not difficult early in the game, when open squares are abundant. But once a player achieves two in a row (adjacent to an empty square that provides the potential for a win on their next turn), the win is easily **blocked** by the other player on their intervening turn. Curses, foiled again!

So, assuming neither player makes an obvious error such as failing to block, winning a game of Tic-Tac-Toe requires that one player take a position where they can win in *two different ways*, a tactic referred to as **forking**. The other player can only block one of these potential wins on their next turn, allowing the first player to win the game on the turn after that. Once a player has forked, then, that player inevitably wins. The only way to beat a fork is to prevent it from forming in the first place.

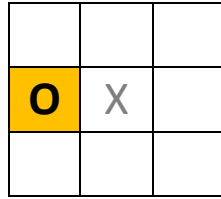
A game in which forking is employed by X to beat O is shown on the next page.

² Also known as a “cat’s game.”

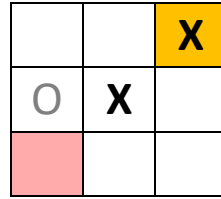
How X Can Use Forking to Beat O



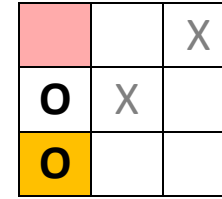
1. X takes the center



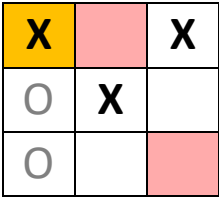
2. O takes an edge



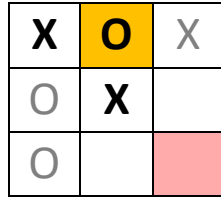
3. X takes a corner getting 2 in a row and setting up win



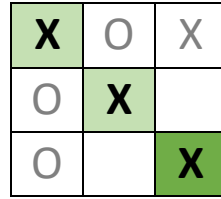
4. O blocks X and gets 2 in a row, threatening to win



5. X blocks O and forks, producing two ways to win



6. O blocks one of X's potential wins but can't block both



7. X completes the other potential path for the win!

Legend Most recent move Threat (possible win) Winning move Additional squares in win

Novice players quickly understand that you should *never* mark an edge square as your first move, as O did here. Indeed, if the first player takes the center or a corner square, and the second player then takes an edge square, the first player can *always* fork, and will therefore win. This was a serious error by O.

Optimal Strategy

Tic-Tac-Toe is even simpler than it first appears—**trivial**, even—because the symmetry of the board makes many positions strategically equivalent. There are only 138 distinct games of Tic-Tac-Toe that can be played. 91 are wins for the first player, 44 are wins for the second player, and *only three* are draws.

While there is a clear “first mover” advantage in the number of winning positions, a strategy exists that prevents a player who employs it from ever losing. If the strategy is executed perfectly by both players, the only possible outcome is a draw. For this reason, the game of Tic-Tac-Toe is called **futile**.

This optimal strategy is as follows. On each turn, simply use the first rule below that applies. (If a rule would let you take more than one square, it doesn't matter which of them you choose.)

1. If you can win, do so. *Game over, man!*
2. If the other player can win on their next turn, block them.
3. If you can fork, do so.
4. If your opponent can fork on their next turn, block them by taking a square they would need in order to fork. Another approach is to create a position where you can win on your next turn, forcing your opponent to block now and fork later, when it may no longer be possible.
5. If the center square is available, take it.
6. If a corner square diagonally opposite a corner square held by your opponent is open, take it.
7. If any corner is empty, take it.
8. Take any available square.
9. If no squares are available, the game is a draw.

Computer Play

A computer can be programmed to play a perfect game of Tic-Tac-Toe, allowing it to always win or draw against a human player. One approach is to explicitly follow the strategy described above, analyzing the board at each turn to determine which rule applies and making an appropriate move.

A solution requiring no built-in knowledge of Tic-Tac-Toe strategy can be developed using minimax.³ Minimax is a recursive algorithm that analyzes every possible move the computer might make, every possible human response to each of these, the computer's possible responses to *those*, and so on, using a scoring function to identify moves that might lead to a win and eliminate those that cannot. Tic-Tac-Toe is sufficiently simple that all this searching still seems instantaneous to a human, even early in the game when the search space is at its largest.

A hybrid approach, where the initial moves are generated by strategy (that is, always play the center or a corner) and the rest calculated using minimax, may be useful where computing power is at a premium.

If made to play against itself, a particularly smart computer may determine that the game is pointless and decline to play further, noting that, as with nuclear war, “the only winning move is not to play.”⁴

History

The game of Tic-Tac-Toe is very old; some sources claim to trace it as far back as ancient Egypt. A very similar game was played in the Roman Empire as early as the first century BC; recognizable Tic-Tac-Toe boards have been found scratched all over Rome.

Similar Games and Variants

A number of games are played by players placing marks or markers on a grid. In some, players can move their markers during the game, or are required to do so. Some are old, but modern games (some marketed commercially) have also gained a measure of popularity. They include:

- The Morris family (e.g. Three Men's Morris)
- Connect Four
- Gobblet
- Order and Chaos
- Quarto
- Mojo
- Toss Across

Games very much like Tic-Tac-Toe but with different board sizes (e.g. 4x4) and different win conditions (e.g. 4 in a row) are also common. A three-dimensional variant also exists, in which the game is played in a 3x3x3 cube, with vertical sequences also constituting a win.

Another variant is for each square on a Tic-Tac-Toe board to itself be a Tic-Tac-Toe game, which the player must win before being able to mark the containing square. Due to the optimal strategy, of course, this game is just as futile as regular Tic-Tac-Toe—arguably even more so, since if both players play perfectly, no larger square will ever be marked and the “outer” game cannot even begin!

³ Jason Robert Fox has an in-depth article on solving Tic-Tac-Toe using minimax, including an interesting wrinkle where the computer makes dumb moves when it realizes it can't win. <http://neverstopbuilding.com/minimax>

⁴ See the movie *WarGames*, if it happens that you're not old enough or geeky enough to know it by heart.