

Reo exercises

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Tic-tac-toe. The standard version of the Tic-Tac-Toe consists of 9 cells and two players. Players, using their own and unique symbol ('X' or a 'O'), alternatively decide to place their symbol on an empty cell of the board. The game stops whenever a player aligns 3 of its symbol, or when all cells on the board are filled. We propose to represent, as a Reo circuit, variants of the standard game of the Tic-Tac-Toe. We first express the arena of the game as a Reo connector, then introduce the rules of the game as a protocol among the board, and finally define winning plays as additional components synchronizing with the game.

1. *Arena.* Represent a $\text{cell}(a,b)$ of the board as a Reo component, that can input a symbol once on a , save the input symbol internally, and output on b the recorded input symbol, or none if no symbol was input, as many times as required. Represent the $\text{board}(a[1..9],b[1..9])$ as a connector consisting of 9 cell components, where $\text{cell}(a[i],b[i])$ is the i -cell of the board.
2. *External components.* Players are represented with two additional components: $\text{cross}(a)$ and $\text{circ}(b)$. The components $\text{cross}(a)$, respectively $\text{circ}(b)$, output the symbol 'X', respectively 'O', on its output port. The state component has 9 input ports, each connected to the output port of a cell, and one output port. A component $\text{Display}(a)$ takes a string of the kind '.....' as input. The string represents the current state of the board, where 'X:O:.....' is the state with one 'X' symbol on the top left cell, and one 'O' symbol on the top middle cell.
3. *Rules.* The first rule is that players circ and cross output a symbol to a single one cell at each time. The second rule imposes that the two players alternate. Implement the two rules as a Reo circuit among the board and the input components.
4. *Winning play.* Relate the input ports of the state component to the output port of the cell components. Detect, after every input of a player, whether the board contains three aligned cells with the same symbol. For this question, use an arbitrary assignment of position for each cell, e.g, $\text{cell}(a[1],b[1])$ represent the top left most cell, $\text{cell}(a[2],b[2])$ represent the top middle cell, etc.

5. *Strategies.* Define some strategy components, for each three cells involved in an alignment, to enforce optimal moves from **circ** and **cross** whenever possible.
6. *Variants.* Consider a variant of the game. Instead of two, we now have only one symbol 'X', and still two players. A player loses if three cells on an alignments are filled with the same symbol after its move. The winning condition is not to lose. Build a protocol that implements the variant of Tic-Tac-Toe.