Program podpowiadający najlepszy ruch w grze kółko i krzyżyk w oparciu o algorytm minimax

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Działanie zaimplementowanego programu badałem na podstawie gry w kółko i krzyżyk. Funkcja findBestMove(state) przyjmuje jako argument obecny stan gry. W naszym przypadku jest to plansza o wymiarach 3x3 w trakcie rozgrywki. Funkcja podpowiada **graczowi**:

```
player, opponent = 'x', 'o'
# player, opponent = 'o', 'x'
```

tak, aby zmaksymalizować jego szansę na pokonanie przeciwnika. Działanie sprawdzałem przyjmując jako gracza **x**, a jako przeciwnika **o**. Program podpowiada więc **x**'owi. Jeżeli podpowiedzi oczekuje kółko, wystarczy zamienić kolejność znaków (zakomentować pierwszą i odkomentować drugą przedstawioną powyżej linijkę).

Na początku program sprawdza, czy w podanym stanie nie zaszły już wydarzenia terminalne – czy gra nie jest już zakończona. Jeżeli jest, to odpowiednio o tym informuje.

```
      | o | x | o |
      | o | x | _ |
      | o | x | o |

      | x | x | o |
      | o | x | _ |
      | x | x | o |

      | _ | x | _ |
      | o | o | x |
      |

      x has already won! o has already won! it is draw already!
```

W innym przypadku przy użyciu algorytmu minimax znajduje najlepsze możliwe rozwiązanie i sugeruje je graczowi.

Jeżeli przeciwnik ma możliwość wygrania w kolejnym ruchu – algorytm podpowiada, żeby go zablokować. Jeżeli jest możliwość – sugeruje zakończyć rozgrywkę. Jeżeli ustalimy, że to **o** jest graczem, program podpowiada dla **o**.

Jeżeli rozgrywka nie jest blisko zakończenia i istnieją równie dobre ruchy – program zgodnie z zadaniem laboratoryjnym wybiera jeden z nich losowo. Poniżej dla zadanego stanu udało mi się uzyskać kilka różnych podpowiedzi.

Przeprowadziłem jeszcze kilka testów działania programu oraz algorytmu minimax.

Gra w kółko i krzyżyk nie jest skomplikowana. Postanowiłem wygenerować kilkadziesiąt przykładowych tablic i przekierować wyniki do pliku txt. Po przejrzeniu wyników zauważyć można, że w przypadku kiedy mamy do czynienia z początkowym stanem gry, **x** najchętniej przyjmuje środkowe położenie, które uczestniczy aż w 4 możliwych zwycięskich rezultatach.

1_1_1_1
1_1_1_1
0 _ _
the best move in that situation is:
1_1_1_1
_ x _
0 _ _
_ _ 0
1_1_1_1
1_1_1_1
the best move in that situation is:
_ _ 0
_ x _
1_1_1_1
=======================================

Poniżej znajduje się kilkadziesiąt przykładowych działań programu. Po ich przeanalizowaniu można dojść do wniosków, że program działa tak, jak powinien.

_ _	o _ _	o x o
_ 0 _	1_1_1_1	x o _
x o _	_ x _	_ _ x
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ x _	• _ _	o x o
_ 0 _	_ _	x o _
x o _	x x _	x _ x
=======================================	=======================================	=======================================
_ _	1_1_1	_ _
1-1-1-1	o x _	1 - 1 - 1
1	_ _ _	1_1_1
the best mayo in that		_ _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ _	_ _ _	
_ _	o x _	_ _ x
x _ _	_ _ x	_ _
	=======================================	
o _ _	_	1_1_1_1
_ x _	o _ _	_ o _
_ _ 0	1_1_1_1	1_1_1_1
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o _ _	_ o x	_ _
_ x _		_ 0 _
_ x o	_ _ x	_ _ x
	1_1_1^1	_ _ ^
_ _	_ 0 _	1_1_1_1
_ _ 0	1 1 1 1	- - -
	_ _ x	o x o
the best move in that	the best move in that	the best move in that
situation is:		
	situation is:	situation is:
!-!-!-!	_ o x	_ _
_ x o	_ _ _	_ x _
_ _	_ _ x	o x o
=======================================	=======================================	=======================================
_ _	_ _ 0	0 _ _
_ _	_ _ x	x _ _
_ 0 _	o _ _	_ o _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1_1	_ _ 0	o _ _
1_1_1_1	_ x x	x x _
_ o x		_ 0 _
=======================================	=======================================	=======================================

		=======================================
	_ _ 0	
i i i i	i i i i	o x _
	1	
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
!_!_!_!	_ _ 0	_ _
_ x _	_ x _	o x _
0 _ _	1_1_1_1	_ _ x
=======================================	=======================================	=======================================
_ _ 0	1_1_1_1	1_1_1_1
x _ o	1_1_1_1	1_1_1_1
_ _ x	_ _ 0	o _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ 0	1 1 1 1	
	1_1_1_1	1_1_1_1
x _ o	_ x _	_ x _
x _ x	_ _ 0	0 _ _
=======================================	=======================================	=======================================
_ _ 0	0 _ _	_ 0 _
_ x _	_ _	x _ _
_ _ 0	_ _	_ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ 0	0 _ _	_ o _
_ x x	_ x _	x x _
0		
1_1_101	_ _ _ ==========================	_ _ _
	1 1 1	
1_1_1_1	1_1_1_1	_ _
!-!-!-!	!-!-!-!	_ 0 _
0 _ _	0 _ _	x _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1_1	_ _	_ _
_ x _	_ x _	_ 0 _
o _ _	o _ _	x x
=======================================	=======================================	=======================================
	1 1 1 1	_ _ o
_ 0 _	1	1
_ x o	o x o	
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x _ _	_ _	_ _ 0
_ 0 _	_ x _	_ x _
_ x o	o x o	1_1_1_1
=======================================	=======================================	=======================================

_ _ _ _	
x _ o _ _ _ x _ o _ _ _ _ _ _ _ _ _ the best move in that the best move in that the best move in that situation is: situation is: _ o x x _ o _ _ _ x _ o x _ o _ x _ _ _ _ _ _ x _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	
_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ <td></td>	
the best move in that situation is: situation is: _ _ _ _	
situation is: situation is: _ _ 0 _ _ x _ 0 _ _ _ _ x _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	
_ _ o	
x _ 0 _ _ _ _ x _ 0 _ x _ 0 _ x _ x _ _ x _ 0 _ x _ 0 _ x _ 0	
_ _ x _	
_ _ _	
_ o _ _ _ _	====
_ o _ _ _ _	
_ _	
the past move in that the hast move in that the hast move in that	
the best move in that the best move in that the best move in that	
situation is: situation is: situation is:	
_ _ _ o _ x	
_ o _	
_ _ x	
=======================================	=====
_ _	
the best move in that the best move in that the best move in that	
situation is: situation is: situation is:	
x _ _	
o _ x	
o _ _	
=======================================	=====
_ _ 0	
the best move in that the best move in that the best move in that	
situation is: situation is: situation is:	
_ _ o	
_ _ _	
_ x x	
=======================================	
_ _ _	
x o x	
the best move in that the best move in that the best move in that	
situation is: situation is: situation is:	
_ x _	
	=====

=======================================		=======================================
o x _	o _ _	_ _ 0
_ 0 _	_ x o	x _ _
1_1_1_1	1_1_1_1	_ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o x _	o _ _	x _ o
_ 0 _	_ x o	x _ _
_ _ x	_ x _	1_1_1_1
=======================================	=======================================	=======================================
o _ _	_ 0 _	o x _
1_1_1_1	_ _ x	1_1_1_1
_ _ x	1_1_1_1	o _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o _ x	_ 0 _	o x _
1_1_1_1	_ x x	x _ _
_ _ x	1_1_1_1	0 _ _
=======================================	=======================================	=======================================
o _ _	_ o _	1_1_1_1
1_1_1_1	x _ _	1_1_1_1
1_1_1_1	_ _ 0	1_1_1_1
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o _ _	_ 0 _	1_1_1_1
_ x _	x x _	1_1_1_1
1_1_1_1	_ _ 0	_ _ x
=======================================	=======================================	=======================================
1_1_1_1	_ 0 _	_ o _
1_1_1_1		_ x _
o _ x	_ _ x	
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ x	_ o x	_ o _
1_1_1_1	i_i_i_i_i	_ x _
o _ x	_ _ x	_ _ x
=======================================	=======================================	=======================================
_ o x	1_1_1_1	_ _ 0
_ 0 _		_ x _
	_ _ 0	0 _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ o x	1_1_1	_ _ 0
_ 0 _	_ x _	_ x _
_ x _	0	o x _

		=======================================
1_1_1_1	_ o x	_ o _
o x _	o _ _	x _ _
_ o x	_ x _	o _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x _ _	_	_ •
o x _	o _ _	x x _
_ o x	x x _	o _ _
=======================================	=======================================	=======================================
1_1_1_1	o x _	_ _ 0
1_1_1_1	_ _ 0	1_1_1_1
o _ _	1_1_1_1	_ _ x
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1_1	o x _	x _ o
_ x _	_ x o	1_1_1_1
o _ _	1_1_1_1	_ _ x
=======================================	=======================================	=======================================
o _ _	1_1_1_1	_ _ 0
_ x _	o _ _	1_1_1_1
_ 0 _	_ x o	1_1_1_1
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o _ _	1_1_1_1	_ _ 0
_ x _	o x _	_ x _
x o _	_ x o	1_1_1_1
=======================================	=======================================	=======================================
o _ _	_	1_1_1_1
1_1_1_1	o _ _	1_1_1_1
_ _ x	1_1_1_1	0 _ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
o _ _	_	1_1_1_1
1_1_1_1	o _ _	_ x _
x _ x	_ _ x	0 _ _
=======================================	=======================================	=======================================
_ _ 0	1_1_1_1	1_1_1_1
_ _ x	_ _ 0	1_1_1_1
o _ x	_ x _	_ _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ 0	1_1_1_1	_ _
_ x x	_ x o	
o _ x	_ x _	_ x _
=======================================		

_ • _	1_1_1_1	_ _ 0
_ _	o _ _	x _ _
x _ _		
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x o _	1_1_1_1	x _ o
1_1_1_1	o _ x	x _ _
x _ _	1_1_1_1	_ _
=======================================	=======================================	=======================================
1_1_1_1	_ _ 0	o _ x
_ _ 0	1_1_1_1	_ _ 0
_ _ x	_ x _	1_1_1_1
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1	_ _ 0	o _ x
_ _ 0	1_1_1_1	x _ o
_ x x	_ x x =========	_ _ _
_ _	0 _ _	_ 0 _
1_1_1		
- - -	_ _ ×	x _ _
1_1_1_1	_ 0 _	1_1_1_1
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _	o _ _	_ 0 _
	_ x x	x x _
x	_ 	i i i i
=======================================	=======================================	=======================================
1_1_1_1	_ _	_ _ 0
_ _ 0	_ _ 0	
	1 1 1	_ x _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1	_ _ x	_ _ 0
_ _ 0	_ _ 0	_ _
_ _ x		
_ _ X ================================	_ _	_ x x
_ _ 0	o x _	_ 0 _
_ _	_ _ 0	_ _
_ x _	_ x _	_ _ x
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ _ 0	o x _	_ 0 _
1_1_1_1	_ x o	_ x _
_ x x	_ x _	_ _ x
=======================================	=======================================	=======================================

	_ o _	o _ x
1_1_1		
_ _	_ x _	_ 0 _
o _ _	_ _	x o x
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
1_1_1_1	_ 0 _	o _ x
	_ x _	—
_ x _		_ o x
0 _ _	_ _ x	x o x
=======================================	=======================================	=======================================
_ o _	_ o x	_ 0 _
	_ _ 0	_ x _
1_1_1_1	x _ _	_ _ 0
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x o _	_ o x	_ 0 _
i_i_i_i	_ x o	_ x x
1_1_1_1		
1_1_1_1	x _ _	_ _
=======================================	=======================================	=======================================
_ 0 _	_ 0 _	1_1_1_1
x _ _	x o _	0 _ _
o _ x	x o _	_ x _
the best move in that	o has already won!	the best move in that
situation is:		situation is:
_ 0 _		1_1_1_1
x x _		o x _
o _ x		_ x _
=======================================	=======================================	=======================================
o x o	o _ _	_ _ o
1 1 1 1		· — · — ·
	x o x	
_ _ _ - _	x o x	- -
	o x _	_ _ _ _ _ _
the best move in that	o x _ the best move in that	$\begin{vmatrix} - & - & - & \\ - & - & - & \end{vmatrix}$ the best move in that
	o x _	_ _ _ _ _ _
the best move in that situation is:	o x _ the best move in that situation is:	$\begin{vmatrix} - & - & - & \\ - & - & - & \end{vmatrix}$ the best move in that
the best move in that situation is:	o x _ the best move in that situation is: o _ x	_ _ _ _ _ _ the best move in that situation is: _ _ o
the best move in that situation is: o x o _ _ _	o x _ the best move in that situation is: o _ x x o x	_ _ _ _ _ _ the best move in that situation is:
the best move in that situation is:	o x _ the best move in that situation is: o _ x	_ _ _ _ _ _ the best move in that situation is: _ _ o
the best move in that situation is: o x o _ _ _	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ _
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ _
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ _ ===================
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ _ ===================
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ _ _ _ _ _ _
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ the best move in that situation is: _ _ o _ x _ _ _ _ _ _ o _ x the best move in that
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ the best move in that situation is: _ _ o _ x _ _ _ ===================
the best move in that situation is: o x o	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ the best move in that situation is: _ _ o _ x _ _ _ _ _ _ o _ x the best move in that
the best move in that situation is: o x o _ _ _ x x _ =================================	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ the best move in that situation is: _ _ o _ x _ _ _
the best move in that situation is: o x o _ _ _ x x _ ================================	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ _ _ _ the best move in that situation is: _ _ o _ x _ _ _ ===================
the best move in that situation is: o x o _ _ _ x x _ =================================	o x _ the best move in that situation is: o _ x x o x o x _ =================================	_ _ _ the best move in that situation is: _ _ o _ x _ _ _

=======================================	=======================================	=======================================
o x o	_ _ 0	1_1_1_1
i_i_i_i	x _ o	_ 0 _
1 1 1	x _ o	x _ o
the best move in that	o has already won!	the best move in that
situation is:	That arready Worr	situation is:
o x o		x _ _
_ x _		_ 0 _
1_1_1_1		x _ o
0 _ _	_ _ 0	o _ x
_ _ x	_ _	_ o x
o _ _	1_1_1_1	_ _ 0
the best move in that	the best move in that	o has already won!
situation is:	situation is:	
o _ _	_ _ 0	
x _ x	_ x _	
	i i i i	
=======================================		
1 1 1	_	_ _ 0
	: - : : :	
_ 0 _	_ _ _	x _ _
_ x o	o x _	o x _
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x _ _	_	_ _ 0
_ 0 _	1_1_1_1	x x _
_ x o	o x x	o x _
=======================================	=======================================	=======================================
_ o x	_ _ 0	1_1_1_1
o _ _	_ x o	_ _ 0
x o _	_ x o	x o _
the best move in that	o has already won!	the best move in that
situation is:		situation is:
_ o x		x _ _
		_ _ 0
o x _		
x o _		x o _
_ 0 _	1_1_1_1	_ o _
x o x	_ _ 0	x _ _
o _ x	x _ _	o x o
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
_ o x	1_1_1_1	_ 0 _
x o x	_ _ 0	x x _
o _ x	x _ x	o x o
=======================================	=======================================	=======================================

=======================================	=======================================	=======================================
_ 0 _	_ 0 _	o _ _
1_1_1_1	x o _	_ _
x _ o	_ _ x	_
the best move in that	the best move in that	the best move in that
situation is:	situation is:	situation is:
x o _	_ 0 _	o _ _
1_1_1_1	x o _	_ x _
x _ o	_ x x	_
=======================================	=======================================	=======================================