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

Sprawozdanie, laboratorium numer 3 WSI

Rafał Kuśmierz 305858

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'
```
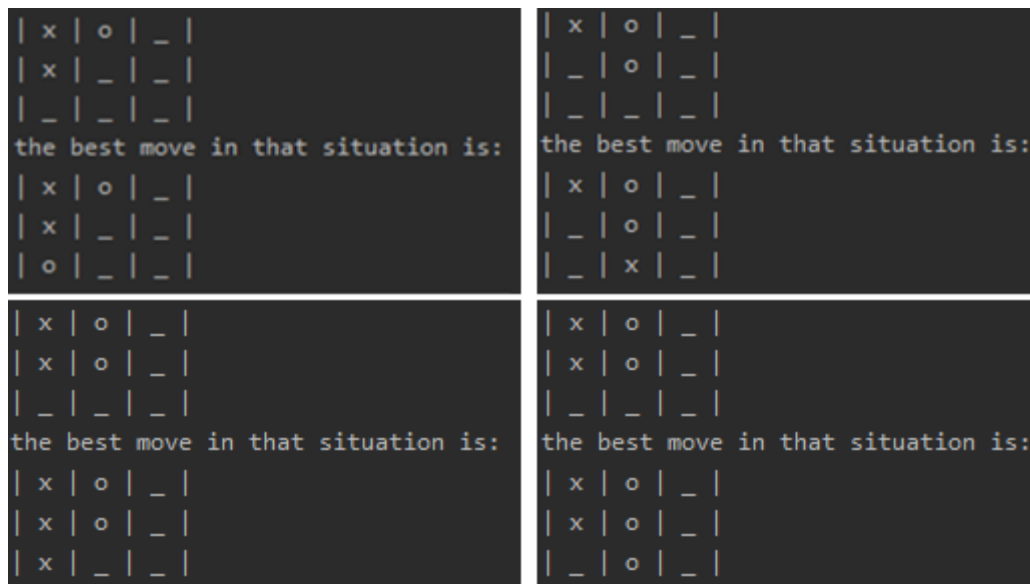
tak, aby zmaksymalizować jego szansę na pokonanie przeciwnika. Działanie sprawdzałem przyjmując jako gracza **x**, a jako przeciwnika **o**. Program podpowiada więc **x**'owi. Jeżeli podpowiedzi oczekuje kółko, wystarczy zamienić kolejność znaków (zakomentować pierwszą i odkomentować drugą przedstawioną 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.
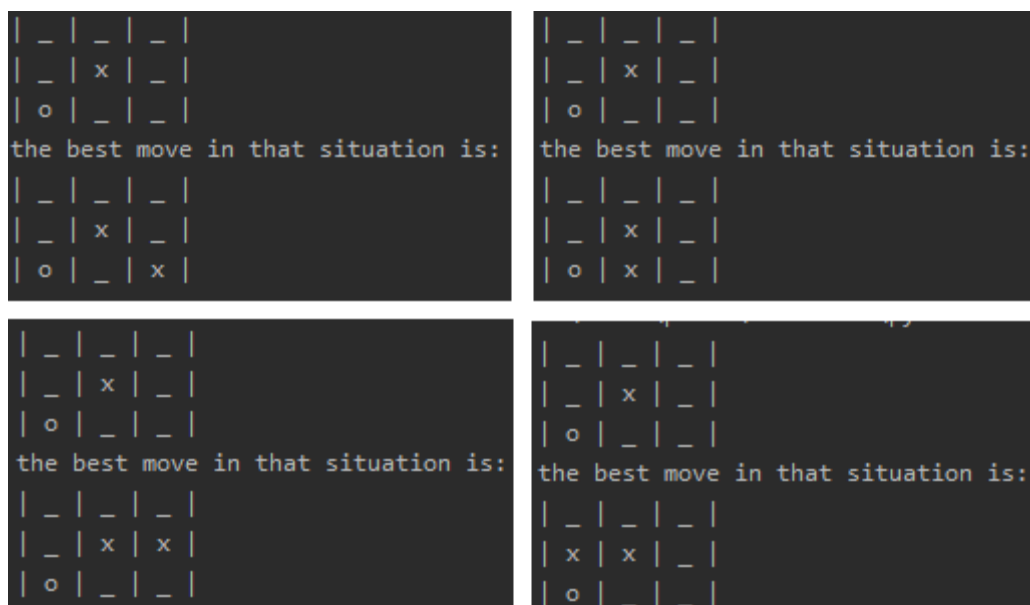
```
| o | x | o |        | o | x | _ |        | o | x | o |
| x | x | o |        | o | x | _ |        | x | x | o |
| _ | x | _ |        | o | _ | _ |        | o | o | x |
x has already won!  o has already won!  it is draw already!
```

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**.

```
| x | o | _ |                  | x | o | _ |
| x | _ | _ |                  | _ | o | _ |
| _ | _ | _ |                  | _ | _ | _ |
the best move in that situation is:   the best move in that situation is:
| x | o | _ |                  | x | o | _ |
| x | _ | _ |                  | _ | o | _ |
| o | _ | _ |                  | _ | x | _ |
```

```
| x | o | _ |                  | x | o | _ |
| x | o | _ |                  | x | o | _ |
| _ | _ | _ |                  | _ | _ | _ |
the best move in that situation is:   the best move in that situation is:
| x | o | _ |                  | x | o | _ |
| x | o | _ |                  | x | o | _ |
| x | _ | _ |                  | _ | 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.

```
| _ | _ | _ |                  | _ | _ | _ |
| _ | x | _ |                  | _ | x | _ |
| o | _ | _ |                  | o | _ | _ |
the best move in that situation is:   the best move in that situation is:
| _ | _ | _ |                  | _ | _ | _ |
| _ | x | _ |                  | _ | x | _ |
| o | _ | x |                  | o | x | _ |
```

```
| _ | _ | _ |                  | _ | _ | _ |
| _ | x | _ |                  | _ | x | _ |
| o | _ | _ |                  | o | _ | _ |
the best move in that situation is:   the best move in that situation is:
| _ | _ | _ |                  | _ | _ | _ |
| _ | x | x |                  | x | x | _ |
| o | _ | _ |                  | o | _ | _ |
```

```
| _ | _ | _ |
| _ | x | _ |
| o | _ | _ |
the best move in that situation is:
| _ | x | _ |
| _ | x | _ |
| o | _ | _ |
```

```
| _ | _ | _ |
| _ | x | _ |
| o | _ | _ |
the best move in that situation is:
| x | _ | _ |
| _ | x | _ |
| o | _ | _ |
```

Przeprowadziłem jeszcze kilka testów działania programu oraz algorytmu minimax.

```
| _ | x | o |
| o | x | _ |
| o | _ | _ |
the best move in that situation is:
| _ | x | o |
| o | x | _ |
| o | x | _ |
```

```
| _ | x | _ |
| o | _ | _ |
| o | _ | _ |
the best move in that situation is:
| x | x | _ |
| o | _ | _ |
| o | _ | _ |
```

```
| x | x | _ |
| o | o | _ |
| o | _ | _ |
the best move in that situation is:
| x | x | x |
| o | o | _ |
| o | _ | _ |
```

```
| x | x | o |
| o | _ | _ |
| o | _ | _ |
the best move in that situation is:
| x | x | o |
| o | x | _ |
| o | _ | _ |
```

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.

```
================================
| _ | _ | _ |
| _ | _ | _ |
| o | _ | _ |
the best move in that situation is:
| _ | _ | _ |
| _ | x | _ |
| o | _ | _ |
================================
================================
| _ | _ | o |
| _ | _ | _ |
| _ | _ | _ |
the best move in that situation is:
| _ | _ | o |
| _ | x | _ |
| _ | _ | _ |
================================
```

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

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

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

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

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_	_	o
_	_	_
_	_	_
the best move in that
situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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_	x	_
o	_	_
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o	x	o
the best move in that
situation is:
_	_	_
_	x	_
o	x	o
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_	_	_
o	x	_
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the best move in that
situation is:
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o	x	_
_	_	x
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situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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x	x	_
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the best move in that
situation is:
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| x | _ | o |
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the best move in that
situation is:
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| _ | _ | x |
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the best move in that
situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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the best move in that
situation is:
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o	x	_
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the best move in that
situation is:
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the best move in that
situation is:
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situation is:
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situation is:
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the best move in that situation is:
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the best move in that situation is:
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the best move in that situation is:
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the best move in that situation is:
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the best move in that situation is:
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| _ | o | _ |
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| x | _ | _ |
the best move in that
situation is:
| x | o | _ |
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| _ | _ | _ |
| o | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| _ | _ | _ |
| o | _ | x |
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| _ | _ | o |
| x | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| x | _ | o |
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| _ | _ | _ |
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the best move in that
situation is:
| _ | _ | _ |
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| _ | _ | o |
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the best move in that
situation is:
| _ | _ | o |
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| o | _ | x |
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the best move in that
situation is:
| o | _ | x |
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the best move in that
situation is:
| _ | _ | _ |
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```
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| o | _ | _ |
| _ | _ | x |
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the best move in that
situation is:
| o | _ | _ |
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```
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| _ | o | _ |
| x | _ | _ |
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the best move in that
situation is:
| _ | o | _ |
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| _ | _ | _ |
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the best move in that
situation is:
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| _ | _ | _ |
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the best move in that
situation is:
| _ | _ | x |
| _ | _ | o |
| _ | _ | _ |
======================
```

```
======================
| _ | _ | o |
| _ | _ | _ |
| _ | x | _ |
the best move in that
situation is:
| _ | _ | 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 | _ |
| _ | x | o |
| _ | x | _ |
======================
```

```
======================
| _ | o | _ |
| _ | _ | _ |
| _ | _ | x |
the best move in that
situation is:
| _ | o | _ |
| _ | x | _ |
| _ | _ | x |
======================
```

```
=====================
| _ | _ | _ |
| _ | _ | _ |
| o | _ | _ |
the best move in that
situation is:
| _ | _ | _ |
| _ | x | _ |
| o | _ | _ |
=====================
| _ | o | _ |
| _ | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| x | o | _ |
| _ | _ | _ |
| _ | _ | _ |
=====================
| _ | o | _ |
| x | _ | _ |
| o | _ | x |
the best move in that
situation is:
| _ | o | _ |
| x | x | _ |
| o | _ | x |
=====================
| o | x | o |
| _ | _ | _ |
| x | _ | _ |
the best move in that
situation is:
| o | x | o |
| _ | _ | _ |
| x | x | _ |
=====================
| _ | _ | o |
| _ | x | o |
| _ | x | _ |
the best move in that
situation is:
| _ | x | o |
| _ | x | o |
| _ | 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 |
| _ | x | o |
| x | _ | _ |
=====================
| _ | o | _ |
| x | o | _ |
| x | o | _ |
o has already won!
=====================
| o | _ | _ |
| x | o | x |
| o | x | _ |
the best move in that
situation is:
| o | _ | x |
| x | o | x |
| o | x | _ |
=====================
| o | _ | _ |
| _ | _ | _ |
| _ | x | _ |
the best move in that
situation is:
| o | _ | _ |
| _ | _ | _ |
| x | x | _ |
```

```
=====================
| o | _ | x |
| _ | o | _ |
| x | o | x |
the best move in that
situation is:
| o | _ | x |
| _ | o | x |
| x | o | x |
=====================
| _ | o | _ |
| _ | x | _ |
| _ | _ | o |
the best move in that
situation is:
| _ | o | _ |
| _ | x | x |
| _ | _ | o |
=====================
| _ | _ | _ |
| o | _ | _ |
| _ | x | _ |
the best move in that
situation is:
| _ | _ | _ |
| o | x | _ |
| _ | x | _ |
=====================
| _ | _ | o |
| _ | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| _ | _ | o |
| _ | x | _ |
| _ | _ | _ |
=====================
| o | _ | _ |
| x | _ | _ |
| o | _ | x |
the best move in that
situation is:
| o | _ | _ |
| x | _ | x |
| o | _ | x |
=====================
```

```
=====================
| o | x | o |
| _ | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| o | x | o |
| _ | x | _ |
| _ | _ | _ |
=====================
| o | _ | _ |
| _ | _ | x |
| o | _ | _ |
the best move in that
situation is:
| o | _ | _ |
| x | _ | x |
| o | _ | _ |
=====================
| _ | _ | _ |
| _ | o | _ |
| _ | x | o |
the best move in that
situation is:
| x | _ | _ |
| _ | o | _ |
| _ | x | o |
=====================
| _ | o | x |
| o | _ | _ |
| x | o | _ |
the best move in that
situation is:
| _ | o | x |
| o | x | _ |
| x | o | _ |
=====================
| _ | o | _ |
| x | o | x |
| o | _ | x |
the best move in that
situation is:
| _ | o | x |
| x | o | x |
| o | _ | x |
=====================
```

```
=====================
| _ | _ | o |
| x | _ | o |
| x | _ | o |
o has already won!
=====================
| _ | _ | o |
| _ | _ | _ |
| _ | _ | _ |
the best move in that
situation is:
| _ | _ | o |
| _ | x | _ |
| _ | _ | _ |
=====================
| _ | o | x |
| _ | _ | _ |
| o | x | _ |
the best move in that
situation is:
| _ | o | x |
| _ | _ | _ |
| o | x | x |
=====================
| _ | _ | o |
| _ | x | o |
| _ | x | o |
o has already won!
=====================
| _ | _ | _ |
| _ | _ | o |
| x | _ | _ |
the best move in that
situation is:
| _ | _ | _ |
| _ | _ | o |
| x | _ | x |
=====================
```

```
=====================
| _ | _ | _ |
| _ | o | _ |
| x | _ | o |
the best move in that
situation is:
| x | _ | _ |
| _ | o | _ |
| x | _ | o |
=====================
| o | _ | x |
| _ | o | x |
| _ | _ | o |
o has already won!
=====================
| _ | _ | o |
| x | _ | _ |
| o | x | _ |
the best move in that
situation is:
| _ | _ | o |
| x | x | _ |
| o | x | _ |
=====================
| _ | _ | _ |
| _ | _ | o |
| x | o | _ |
the best move in that
situation is:
| x | _ | _ |
| _ | _ | o |
| x | o | _ |
=====================
| _ | o | _ |
| x | _ | _ |
| o | x | o |
the best move in that
situation is:
| _ | o | _ |
| x | x | _ |
| o | x | o |
=====================
```

```
=======================
| _ | o | _ |
| _ | _ | _ |
| x | _ | o |
the best move in that
situation is:
| x | o | _ |
| _ | _ | _ |
| x | _ | o |
=======================
```

```
=======================
| _ | o | _ |
| x | o | _ |
| _ | _ | x |
the best move in that
situation is:
| _ | o | _ |
| x | o | _ |
| _ | x | x |
=======================
```

```
=======================
| o | _ | _ |
| _ | _ | _ |
| _ | x | o |
the best move in that
situation is:
| o | _ | _ |
| _ | x | _ |
| _ | x | o |
=======================
```