

Project Task 14:

Minimax Integration- against Human Player and Machine Players

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This is the fourteenth and final task in my semester-long project to create Mancala-playing machines. In this task, I updated the human vs machine game playing interface and machine vs machine testing to integrate the minimax player. The code updates are relatively trivial, but the results confirm that the minimax player is performing as expected.

Observations:

- Even though the human player always has first player advantage, the Minimax Machine player is very difficult to beat. A knowledge of strong opening moves is essential.
- The first player advantage continues to show itself in the machine vs machine tests. The Minimax Machine is undefeated in games where it is the first player.
- The strongest opponent against the Minimax Machine is the Move Again Heuristic Machine. This may be because they share strategic elements in common- both rely on long chains of moves.
- While the previous iteration of the machine vs machine tests ran in negligible time, the updated version with Minimax tests took over 12 minutes.

Code- Note: this code consists of updates of previously-written functions

```
(defun machine-game-turns (player verbose machine1 machine2)
  (cond
    (verbose
      (format t "Player ~A's turn ~%" player)
    )
  )
  (cond
    ((eql player 'a)
      (setf machine machine1)
    )
    (t
      (setf machine machine2)
    )
  )
  (cond
    ((= machine 1)
      (random-move player verbose)
    )
    ((= machine 2)
      (heuristic-again-move player verbose)
    )
  )
)
```

```

    (= machine 3)
    (heuristic-max-score-move player verbose)
  )
  (t
    (minimax-move player verbose)
  )
)
(cond
  ((or (empty-side 'a) (empty-side 'b))
    t
  )
  ((eql player 'a)
    (machine-game-turns 'b verbose machine1 machine2)
  )
  (t
    (machine-game-turns 'a verbose machine1 machine2)
  )
)
)

(defun alternate-moves(machine)
  (format t "~%Human player's turn!~%~%")
  (human-move)
  (cond
    ((not (or (empty-side 'a) (empty-side 'b)))
      (format t "~%Machine player's turn!~%~%")
      (cond
        ((= machine 1)
          (random-move 'b t)
        )
        (( = machine 2)
          (heuristic-again-move 'b t)
        )
        ((= machine 3)
          (heuristic-max-score-move 'b t)
        )
        (t
          (minimax-move 'b t)
        )
      )
    )
    (cond
      ((not (or (empty-side 'a) (empty-side 'b)))
        (alternate-moves machine)
      )
    )
  )
)
)

```

)

```
(defun machine-vs-machine-game-test ()
  (format t "Testing machine players against one another~%")
  (format t "Test 1: 2 Random Players for 100 games: ~%")
  (setf lst (machine-vs-machine-stats 1 1 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 2: 2 Move Again Heuristic Players for 100
games: ~%")
  (setf lst (machine-vs-machine-stats 2 2 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 3: 2 Max Score Heuristic Players for 100
games: ~%")
  (setf lst (machine-vs-machine-stats 3 3 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 4: Minimax Players for 100 games: ~%")
  (setf lst (machine-vs-machine-stats 4 4 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 5: Player 1 Random, Player 2 Move Again
Heuristic for 100 games: ~%")
  (setf lst (machine-vs-machine-stats 1 2 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 6: Player 1 Move Again Heuristic, Player 2
Random for 100 games: ~%")
  (setf lst (machine-vs-machine-stats 2 1 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 7: Player 1 Random, Player 2 Max Score
Heuristic for 100 games: ~%")
  (setf lst (machine-vs-machine-stats 1 3 0 0 0 1))
  (format t "Player 1 wins: ~A ~%" (nth 0 lst))
  (format t "Player 2 wins: ~A ~%" (nth 1 lst))
  (format t "Ties: ~A ~%" (nth 2 lst))
  (format t "Test 8: Player 1 Max Score Heuristic, Player 2
Random for 100 games: ~%"))
```

```

(setf lst (machine-vs-machine-stats 3 1 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 9: Player 1 Minimax, Player 2 Random for 100
games: ~%")
(setf lst (machine-vs-machine-stats 4 1 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 10: Player 1 Random, Player 2 Minimax for 100
games: ~%")
(setf lst (machine-vs-machine-stats 1 4 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 11: Player 1 Move Again Heuristic, Player 2
Max Score Heuristic for 100 games: ~%")
(setf lst (machine-vs-machine-stats 2 3 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 12: Player 1 Max Score Heuristic, Player 2
Move Again Heuristic for 100 games: ~%")
(setf lst (machine-vs-machine-stats 3 2 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 13: Player 1 Minimax, Player 2 Move Again
Heuristic for 100 games: ~%")
(setf lst (machine-vs-machine-stats 4 2 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 14: Player 1 Move Again Heuristic, Player 2
Minimax for 100 games: ~%")
(setf lst (machine-vs-machine-stats 2 4 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
(format t "Test 15: Player 1 Minimax, Player 2 Max Score
Heuristic for 100 games: ~%")
(setf lst (machine-vs-machine-stats 4 3 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))

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(format t "Test 16: Player 1 Max Score Heuristic, Player 2
Minimax for 100 games: ~%")
(setf lst (machine-vs-machine-stats 3 4 0 0 0 1))
(format t "Player 1 wins: ~A ~%" (nth 0 lst))
(format t "Player 2 wins: ~A ~%" (nth 1 lst))
(format t "Ties: ~A ~%" (nth 2 lst))
)

```

Demo:

```
[> (human-vs-machine-game 4)
```

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	4	4	4	4	4	4	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	0
	4	4	4	4	4	4	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a2

Human player picks up stones in A2

HB	B6	B5	B4	B3	B2	B1	
—	4	4	4	4	4	4	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	0
	4	0	5	5	5	5	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	4	4	5	5	5	5	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	1
	4	0	5	5	5	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B4

HB	B6	B5	B4	B3	B2	B1	
—	5	5	0	5	5	5	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	1
	5	1	6	5	5	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A3

HB	B6	B5	B4	B3	B2	B1	
—	5	5	0	5	6	6	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	2
	5	1	0	6	6	1	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B2

HB	B6	B5	B4	B3	B2	B1	
—	6	6	1	6	0	6	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	2
	6	2	0	6	6	1	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A2

HB	B6	B5	B4	B3	B2	B1	
—	6	6	1	6	0	6	—
0	—	—	—	—	—	—	
	—	—	—	—	—	—	2
	6	0	1	7	6	1	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	6	6	2	7	1	7	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	3
—	6	0	1	0	7	2	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B4

HB	B6	B5	B4	B3	B2	B1	
—	7	7	0	7	1	7	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	3
—	6	0	1	0	7	2	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B6

HB	B6	B5	B4	B3	B2	B1	
—	0	7	0	7	1	7	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	4
—	7	1	2	1	8	3	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala
Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	0	7	0	7	1	7	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	4
—	7	1	2	1	8	3	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

|_____|
 Select your move: a1
 Human player picks up stones in A1

HB	B6	B5	B4	B3	B2	B1	
—	0	7	0	7	1	8	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	5
—	0	2	3	2	9	4	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B1

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	5
—	1	3	4	2	9	4	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A3

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	6
—	1	3	0	3	10	5	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala
 Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	6
—	1	3	0	3	10	5	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

|_____|
 Select your move: a4
 Human player picks up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	7
—	1	3	0	0	11	6	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala
 Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	7
—	1	3	0	0	11	6	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a2
 Human player picks up stones in A2

HB	B6	B5	B4	B3	B2	B1	
—	1	8	1	8	2	0	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	7
—	1	0	1	1	12	6	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A5

HB	B6	B5	B4	B3	B2	B1	
—	2	9	2	9	3	1	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	8
—	2	1	2	2	0	7	—
—	—	—	—	—	—	—	—

	A1	A2	A3	A4	A5	A6	HA
--	----	----	----	----	----	----	----

Picking up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	2	9	2	9	3	1	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	8
—	2	1	2	0	1	8	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	3	10	3	10	4	2	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	9
—	3	1	2	0	1	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A1

HB	B6	B5	B4	B3	B2	B1	
—	3	10	3	10	4	2	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	9
—	0	2	3	1	1	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	3	10	3	0	4	2	—
0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	0	2	3	1	1	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

| _____ |

Machine player's turn!

Minimax Player's selected move: (B5 B6 B4)

HB	B6	B5	B4	B3	B2	B1	
—	4	0	3	0	5	3	—
1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	1	3	4	2	2	1	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B2

HB	B6	B5	B4	B3	B2	B1	
—	5	1	4	1	0	3	—
2	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	1	3	4	2	2	1	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	1	4	1	0	3	—
3	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	2	4	5	3	2	1	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	0	1	4	1	0	4	—
3	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	2	4	5	0	3	2	—
—	—	—	—	—	—	—	—
—	A1	A2	A3	A4	A5	A6	HA

|_____|
Picking up stones in B1

HB	B6	B5	B4	B3	B2	B1	
—	0	2	5	2	1	0	—
3	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	2	4	5	0	3	2	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B5

HB	B6	B5	B4	B3	B2	B1	
—	1	0	5	2	1	0	—
4	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	2	4	5	0	3	2	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	0	—
5	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	3	5	5	0	3	2	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A2

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	1	—
5	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	3	0	6	1	4	3	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	1	—
8	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	3	0	6	1	4	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	1	—
8	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	3	0	6	1	4	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a1

Human player picks up stones in A1

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	1	—
8	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	0	1	7	2	4	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	2	1	0	2	1	1	—
8	—	—	—	—	—	—	—
—	—	—	—	—	—	—	19
—	0	1	7	0	5	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

[illegible]

Player picks up stones in opposite space and places them in the player's mancala

	HB	B6	B5	B4	B3	B2	B1	
	—	2	1	0	2	1	0	—
8	—	—	—	—	—	—	—	
	—	—	—	—	—	—	—	20
	0	1	7	0	5	1		
—	—	—	—	—	—	—	—	
		A1	A2	A3	A4	A5	A6	HA

Machine player's turn!

```
Minimax Player's selected move: (B3 B4)
```

HB	B6	B5	B4	B3	B2	B1	
—	2	2	1	0	1	0	—
8	—	—	—	—	—	—	
—	—	—	—	—	—	—	20
—	0	1	7	0	5	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B5

HB	B6	B5	B4	B3	B2	B1	
—	3	0	1	0	1	0	—
9	—	—	—	—	—	—	
	0	1	7	0	5	1	20
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	0	1	0	—
9	—	—	—	—	—	—	—
—	—	—	—	—	—	—	20
—	0	1	7	0	5	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	0	1	0	—
10	—	—	—	—	—	—	—
—	—	—	—	—	—	—	20
—	0	0	7	0	5	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	0	1	0	—
10	—	—	—	—	—	—	—
—	—	—	—	—	—	—	20
—	0	0	7	0	5	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a6

Human player picks up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	0	1	0	—
10	—	—	—	—	—	—	—
—	—	—	—	—	—	—	21
—	0	0	7	0	5	0	—
—	—	—	—	—	—	—	—

	A1	A2	A3	A4	A5	A6	HA	

Last stone placed in player's mancala
 Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	0	1	0	—
10	—	—	—	—	—	—	
	0	0	7	0	5	0	21
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a3

Human player picks up stones in A3

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	1	2	1	—
10	—	—	—	—	—	—	
	—	—	—	—	—	—	22
	0	0	0	1	6	1	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Machine player's turn!

Minimax Player's selected move: (B1 B6)

HB	B6	B5	B4	B3	B2	B1	
—	3	1	0	1	3	0	—
10	—	—	—	—	—	—	
	0	0	0	1	6	1	22
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B2

HB	B6	B5	B4	B3	B2	B1	
—	3	2	1	2	0	0	—
10	—	—	—	—	—	—	—
—	—	—	—	—	—	—	22
—	0	0	0	1	6	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B5

HB	B6	B5	B4	B3	B2	B1	
—	4	0	1	2	0	0	—
11	—	—	—	—	—	—	—
—	—	—	—	—	—	—	22
—	0	0	0	1	6	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	—
—	—	—	—	—	—	—	22
—	1	1	1	1	6	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	—
—	—	—	—	—	—	—	22
—	1	1	1	1	6	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

|_____|
 Select your move: a6
 Human player picks up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	—	—	—	—	—	—	23
	1	1	1	1	6	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala
 Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	—	—	—	—	—	—	23
	1	1	1	1	6	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a1
 Human player picks up stones in A1

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	—	—	—	—	—	—	23
	0	2	1	1	6	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in A2

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	—	—	—	—	—	—	23
	0	0	2	2	6	0	
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

|_____|
Picking up stones in A4

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	1	23
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	0	1	2	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	1	23
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Machine player's turn!

Minimax Player's selected move: (B3)

HB	B6	B5	B4	B3	B2	B1	
—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	1	23
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	1	23
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	1	23
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a6

Human player picks up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	0	24
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	
	0	0	2	0	7	0	24
—	—	—	—	—	—	—	—

	A1	A2	A3	A4	A5	A6	HA	

Select your move: a3

Human player picks up stones in A3

	HB	B6	B5	B4	B3	B2	B1	
	—	0	1	2	0	0	0	—
12	—	—	—	—	—	—	—	
		0	0	0	1	8	0	24
	—	—	—	—	—	—	—	—
		A1	A2	A3	A4	A5	A6	HA

Picking up stones in A5

HB	B6	B5	B4	B3	B2	B1	
12	1	2	3	1	1	1	
							25
	0	0	0	1	0	1	
	A1	A2	A3	A4	A5	A6	HA

Machine player's turn!

Minimax Player's selected move: (B6 B5 B6 B4 B6 B2 B4)

	HB	B6	B5	B4	B3	B2	B1	
	—	0	2	3	1	1	1	—
13	—	—	—	—	—	—	—	
		0	0	0	1	0	1	25
	—	—	—	—	—	—	—	
		A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	1	0	3	1	1	1	—
14	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	0	3	1	1	1	—
15	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	1	1	1	—
16	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	1	0	1	1	1	—
17	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	0	1	0	2	0	1	—
17	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B3

HB	B6	B5	B4	B3	B2	B1	
—	0	2	1	0	0	1	—
17	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Picking up stones in B5

HB	B6	B5	B4	B3	B2	B1	
—	1	0	1	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Player picks up and stones in opposite space and places them in the player's mancala

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Human player's turn!

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	25
—	0	0	0	1	0	1	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Select your move: a6

Human player picks up stones in A6

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	26
—	0	0	0	1	0	0	—
—	—	—	—	—	—	—	—
	A1	A2	A3	A4	A5	A6	HA

Last stone placed in player's mancala

Human player moves again!

HB	B6	B5	B4	B3	B2	B1	
—	1	1	0	0	0	1	—
18	—	—	—	—	—	—	—
—	—	—	—	—	—	—	26

HB	B6	B5	B4	B3	B2	B1	
19	1	1	0	0	1	0	
							26
	0	0	0	0	0	0	
	A1	A2	A3	A4	A5	A6	HA

Final Score:

Human Player: 26

Machine Player: 22

Human Player wins!

[]> (machine-vs-machine-game-test)

Testing machine players against one another

Test 1: 2 Random Players for 100 games:

Player 1 wins: 49

Player 2 wins: 40

Ties: 11

Test 2: 2 Move Again Heuristic Players for 100 games:

Player 1 wins: 82

Player 2 wins: 12

Ties: 6

Test 3: 2 Max Score Heuristic Players for 100 games:

Player 1 wins: 100

Player 2 wins: 0

Ties: 0

Test 4: Minimax Players for 100 games:

Player 1 wins: 100

Player 2 wins: 0

Ties: 0

Test 5: Player 1 Random, Player 2 Move Again Heuristic for 100 games:

Player 1 wins: 17

Player 2 wins: 79

Ties: 4

Test 6: Player 1 Move Again Heuristic, Player 2 Random for 100 games:

Player 1 wins: 96

Player 2 wins: 2

Ties: 2

Test 7: Player 1 Random, Player 2 Max Score Heuristic for 100 games:
Player 1 wins: 19
Player 2 wins: 76
Ties: 5

Test 8: Player 1 Max Score Heuristic, Player 2 Random for 100 games:
Player 1 wins: 85
Player 2 wins: 11
Ties: 4

Test 9: Player 1 Minimax, Player 2 Random for 100 games:
Player 1 wins: 100
Player 2 wins: 0
Ties: 0

Test 10: Player 1 Random, Player 2 Minimax for 100 games:
Player 1 wins: 1
Player 2 wins: 97
Ties: 2

Test 11: Player 1 Move Again Heuristic, Player 2 Max Score Heuristic for 100 games:
Player 1 wins: 86
Player 2 wins: 11
Ties: 3

Test 12: Player 1 Max Score Heuristic, Player 2 Move Again Heuristic for 100 games:
Player 1 wins: 28
Player 2 wins: 69
Ties: 3

Test 13: Player 1 Minimax, Player 2 Move Again Heuristic for 100 games:
Player 1 wins: 100
Player 2 wins: 0
Ties: 0

Test 14: Player 1 Move Again Heuristic, Player 2 Minimax for 100 games:
Player 1 wins: 48
Player 2 wins: 46
Ties: 6

Test 15: Player 1 Minimax, Player 2 Max Score Heuristic for 100 games:
Player 1 wins: 100
Player 2 wins: 0
Ties: 0

Test 16: Player 1 Max Score Heuristic, Player 2 Minimax for 100 games:
Player 1 wins: 1
Player 2 wins: 98

Ties: 1