

MOHEX WINS HEX 11x11 AND HEX 13x13 TOURNAMENTS

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1. THE TOURNAMENTS

This year, in addition to the 11×11 Hex tournament, there was a 13×13 Hex tournament. Three programs competed in each tournament: EZO by Kei Takada, supervised by Masahito Yamamoto, from Japan; MOHEX 2.0 (Huang *et al.*, 2013), by Broderick Arneson, Ryan Hayward, Philip Henderson, Aja Huang, and Jakub Pawlewicz, from Canada; and DEEPHEX by Jakub Pawlewicz, from Poland.

After the tournaments there was an informal man-machine exhibition: Tony van der Valk (TV), the 5th-ranked Hex player on Little Golem, played two games — 11×11, 15m/player — each against DEEPHEX and MOHEX.

EZO is a stronger version of the program that competed in the 2013 Olympiad. EZO uses alpha-beta search with an evaluation function based on a weighted combination of two different network connectivity measures. EZO ran on an i7 laptop.

DEEPHEX is a new program based on Sibling Conspiracy Number Search. DEEPHEX, like MOHEX, is based on the Benzene framework, developed by Broderick Arneson, Philip Henderson, Ryan Hayward, Aja Huang, and Jakub Pawlewicz. DEEPHEX ran on a 16 core shared-memory machine. As an opening book, DEEPHEX cached its evaluation scores in a database, running for 24 hours on each possible opening.

MOHEX, the winner of the previous four Olympiad Hex competitions, is an MCTS program that uses the Benzene Hex framework built on the code base of FUEGO, the Go program developed by Martin Müller, Markus Enzenberger and others at the University of Alberta. Benzene allows virtual connection and inferior cell computations. MOHEX performs these computations in UCT tree nodes visited at least 256 times. MOHEX ran on a 24 core shared-memory machine, with 4 cores reserved for the Depth-First Proof Number Search solver, which produces perfect play if it solves the position within the time allotted for a move. MOHEX prepared an opening book for two 11×11 openings and one 13×13 opening.

Here are the tournament scores (playoff scores inside parentheses).

11x11	MOHEX	DEEPHEX	EZO	total	result
MOHEX		3-1	4-0	7-1	gold
DEEPHEX	1-3		4-0	5-3	silver
EZO	0-4	0-4		0-8	bronze

13x13	MOHEX	DEEPHEX	EZO	total	result
MOHEX		2-2 (2-0)	4-0	6-2 (2-0)	gold
DEEPHEX	2-2 (0-2)		4-0	6-2 (0-2)	silver
EZO	0-4	0-4		0-8	bronze

2. THE GAMES

Each tournament was a three-player double round robin, so 12 games, i.e. 8 games for each player. Post-game win-detection is by our solver. Tony van der Walk contributed to this commentary.

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11×11 Tournament D: DEEPHEX E: EZO M: MOHEX

Game 1. E-M 0-1. 1.B[a7] 2.W[swap] 3.W[c9] ... MOHEX sees the win by move 30.B[e4].

Game 2. D-E 1-0. 1.B[a3] 2.W[c9] ... EZO opens well, but blunders: 28.W[h2] wins.

Game 3. M-D 1-0. 1.B[a2] 2.W[swap] 3.W[a6] ... MOHEX scores increases steadily. Move 19 wins.

Game 4. M-E 1-0. 1.B[a2] 2.W[j2] 3.B[g6] ... MOHEX is happy with EZO's row 2 ladder. Move 17 wins.

Game 5. E-D 0-1. 1.B[k5] 2.W[swap] 3.W[i3] ...

EZO plays 27.W[i4] instead of j8 or other options that look safer. DEEPHEX sees that 28.B[k2] wins.

Game 6. D-M 1-0. 1.B[g2] 2.W[swap] 3.W[e4] ... MOHEX is never comfortable. 23.W[c9] wins.

Game 7. E-M 0-1. 1.B[f10] 2.W[swap] 3.W[f6] ... Move 16 wins.

Game 8. D-E 1-0. 1.B[f2] 2.W[d6] 3.W[e6] ... Move 13 wins.

Game 9. M-D 1-0. 1.B[a6] 2.W[swap] 3.W[g5] ...

At move 22, DEEPHEX hesitates between j5, which loses, and i8, which leads to complicated positions where MOHEX cannot find correct moves. But DEEPHEX plays 22.B[j5]. Move 30 wins.

Game 10. M-E 1-0. 1.B[a6] 2.W[c9] 3.W[g7] ... Move 26 wins.

Game 11. E-D 0-1. 1.B[e10] 2.W[g8] 3.W[f8] ... Move 25 wins.

Game 12. D-M 0-1. 1.B[e2] 2.W[f6] 3.B[c8] ... DEEPHEX is never comfortable. Move 13 wins.

13×13 Tournament D: DEEPHEX E: EZO M: MOHEX

Game 1. E-M 0-1. 1.B[a8] 2.W[swap] 3.W[b12] ... Move 30 wins.

Game 2. D-E 1-0. 1.B[a10] 2.W[l2] 3.B[j3] ... Move 31 wins.

Game 3. M-D 1-0. 1.B[a7] 2.W[swap] 3.W[i5] ... For many moves, both programs see this game as even. MOHEX turns the corner with move 29, not seeing how to use i5 to connect to the right side. 45.W[g4] is unexpected, but wins. This game shows the importance of virtual connections and an endgame solver.

Game 4. M-E 1-0. 1.B[a7] 2.W[c11] 3.B[i8] ... MOHEX finds a win by 35.B[h3].

Game 5. E-D 0-1. 1.B[m3] 2.W[swap] 3.W[l2] ... 28.W[f2] looks reasonable, but is out of the mustplay region computed by Benzene's virtual connection engine, so DEEPHEX finds a win with the next move.

Game 6. D-M 1-0. 1.B[j2] 2.W[g8] 3.W[d10] ...

Another close game. MOHEX blunders with 54.W[f9]; 54.W[l11] wins. DEEPHEX sees the win soon after.

Game 7. E-M 0-1. 1.B[m8] 2.W[f8] 3.B[b12] ... MOHEX sees the win by move 38.

Game 8. D-E 1-0. 1.B[a11] 2.W[b12] 3.B[c11] ... EZO looks behind early, DEEPHEX sees a win by move 23.

Game 9. M-D 1-0. 1.B[a7] 2.W[swap] 3.W[i5] ...

The same opening as Game 3. Non-deterministic MOHEX plays differently from move 5. Move 33 wins.

Game 10. M-E 1-0. 1.B[a7] 2.W[c11] 3.W[i8] ...

MOHEX score jumps after 10.W[g12] (expected k3) and after 24.W[j3]. MOHEX sees the win by move 27.

Game 11. E-D 0-1. 1.B[a4] 2.W[swap] 3.W[k3] ... A close game. From move 20, DEEPHEX behaves unexpectedly, perhaps because its move selection does not consider inferior cells: move 28 considers neither a3 nor f2 (which captures a3). Here MOHEX likes f2, but DEEPHEX plays k4. EZO then takes a3, and gets into a winning position: 47.W[k11] wins, although this takes the solver a long time to check. But EZO plays 47.W[j10] and DEEPHEX grinds out a win.

Game 12. D-M 0-1. 1.B[d2] 2.W[e9] 3.B[g8] ... MOHEX never looks comfortable. Move 35 wins.

Playoff Game 1. M-D 1-0. 1.B[a7] 2.W[h12] 3.B[c11] ... Earlier DEEPHEX swapped and lost, so here not-swaps. MOHEX scores increase gradually. Move 46 wins.

Playoff Game 2. D-M 0-1. 1.B[j2] 2.W[swap] 3.W[d3] ... Earlier MOHEX not-swapped and lost, so here swaps. No stones touch until move 14. MOHEX sees a win by move 24.

11×11 Man-Machine Exhibition D: DEEPHEX M: MOHEX T: TONY VAN DER WALK Each player had 15 minutes for all moves. The bots won all games.

Game 1. M-T 1-0. 1.B[a2] 2.W[swap] 3.W[f6] ... Move 23 wins.

Game 2. T-M 0-1. 1.B[f2] 2.W[e7] 3.B[c8] ... Move 16 wins.

Game 3. D-T 1-0. 1.B[g2] 2.W[f4] 3.B[h5] ... Move 15 wins.

Game 4. T-D 0-1. 1.B[f2] 2.W[h9] 3.B[f9] ... Move 24 wins.

3. CONCLUSIONS

EZO's performance was stronger than its record indicates. It played some strong openings and had winning moves deep into games against DEEPHEX. It was unlucky not to win a game.

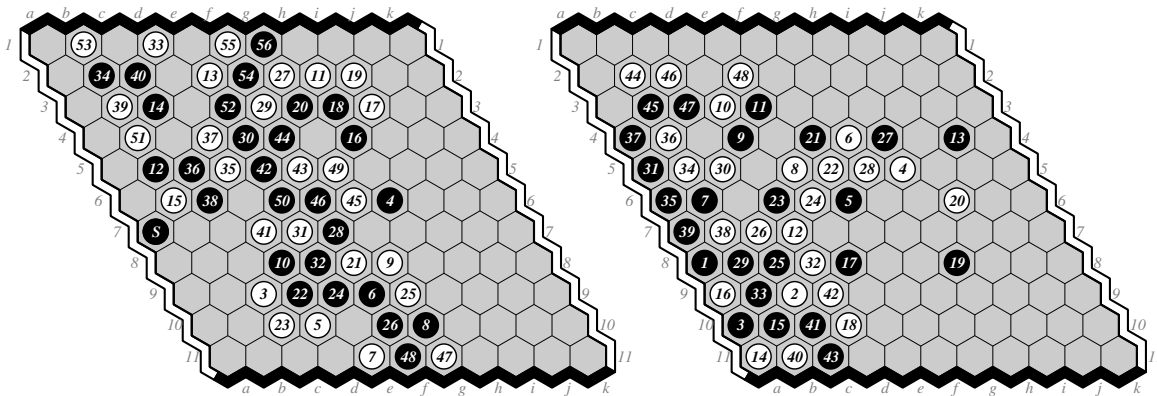
DEEPHEX and MOHEX were evenly matched, but play different styles. MOHEX seems stronger in opening and early middle play, but its Monte Carlo simulations cannot handle tactical positions. DEEPHEX thrives on tactical positions, and is especially strong in the late middle game in complicated positions.

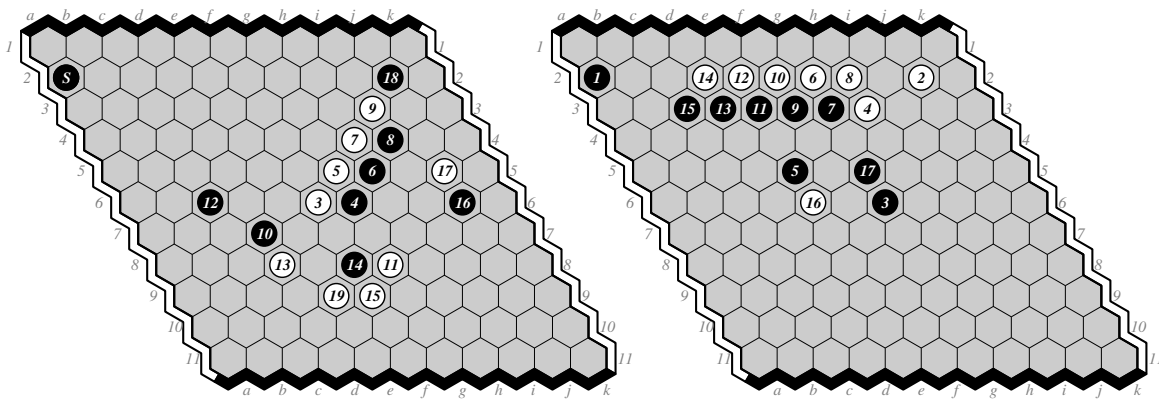
REFERENCES TO BE ADDED

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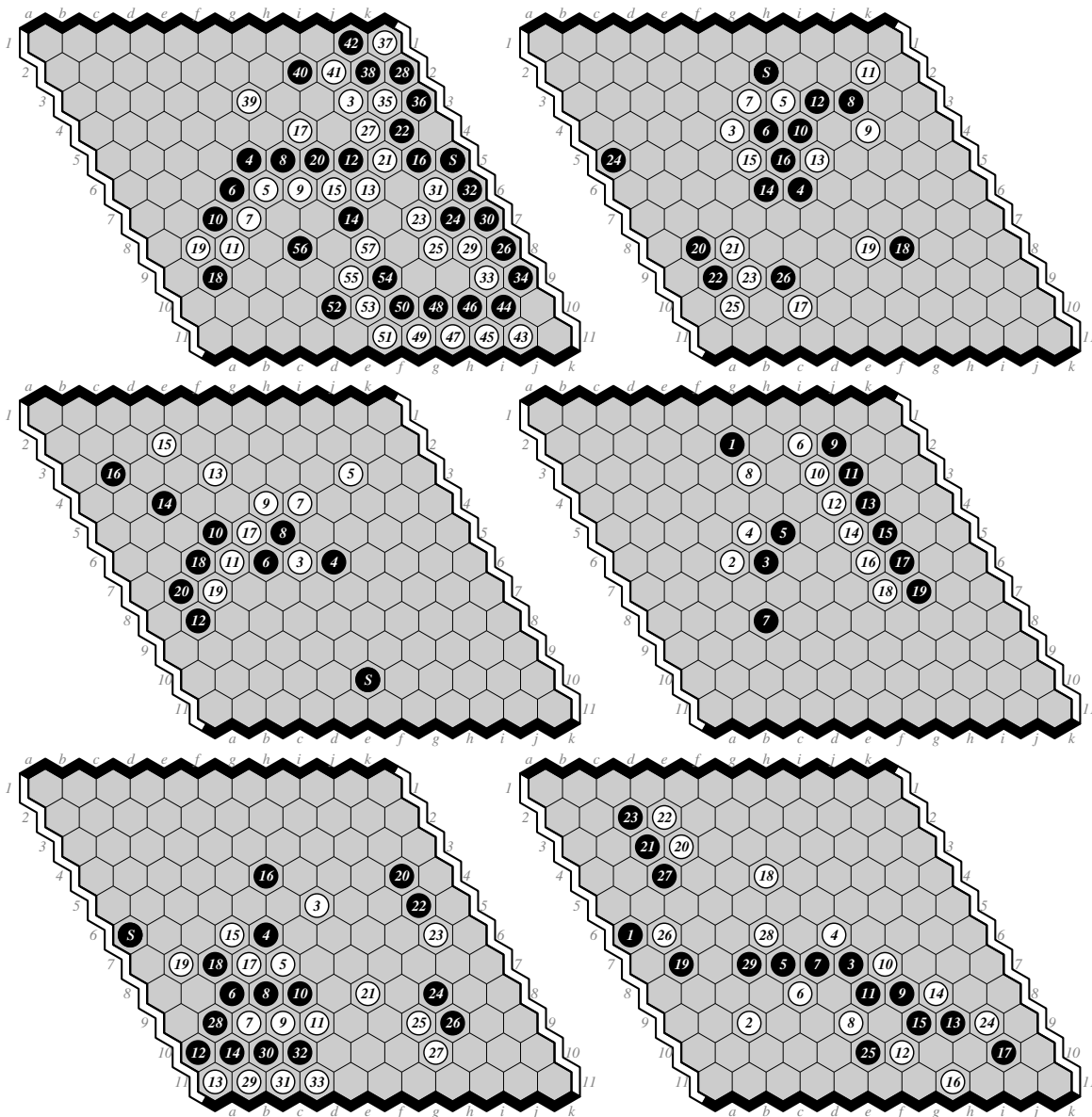
4. REFERENCES

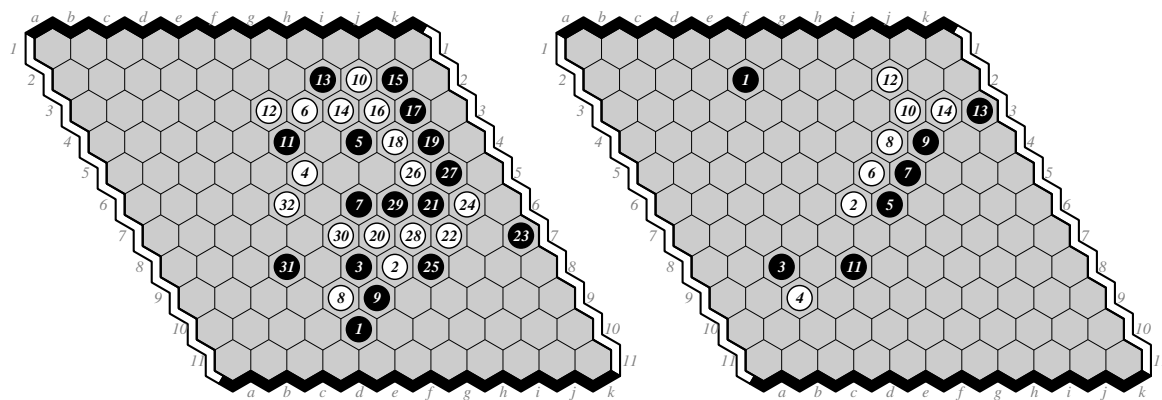
Huang, S., Arneson, B., Hayward, R. B., Müller, M., and Pawlewicz, J. (2013). MoHex 2.0: A Pattern-Based MCTS Hex Player. *Computers and Games - 8th International Conference, CG 2013, Yokohama, Japan, August 13-15, 2013, Revised Selected Papers* (eds. H. J. van den Herik, H. Iida, and A. Plaat), Vol. 8427 of *Lecture Notes in Computer Science*, pp. 60–71, Springer.



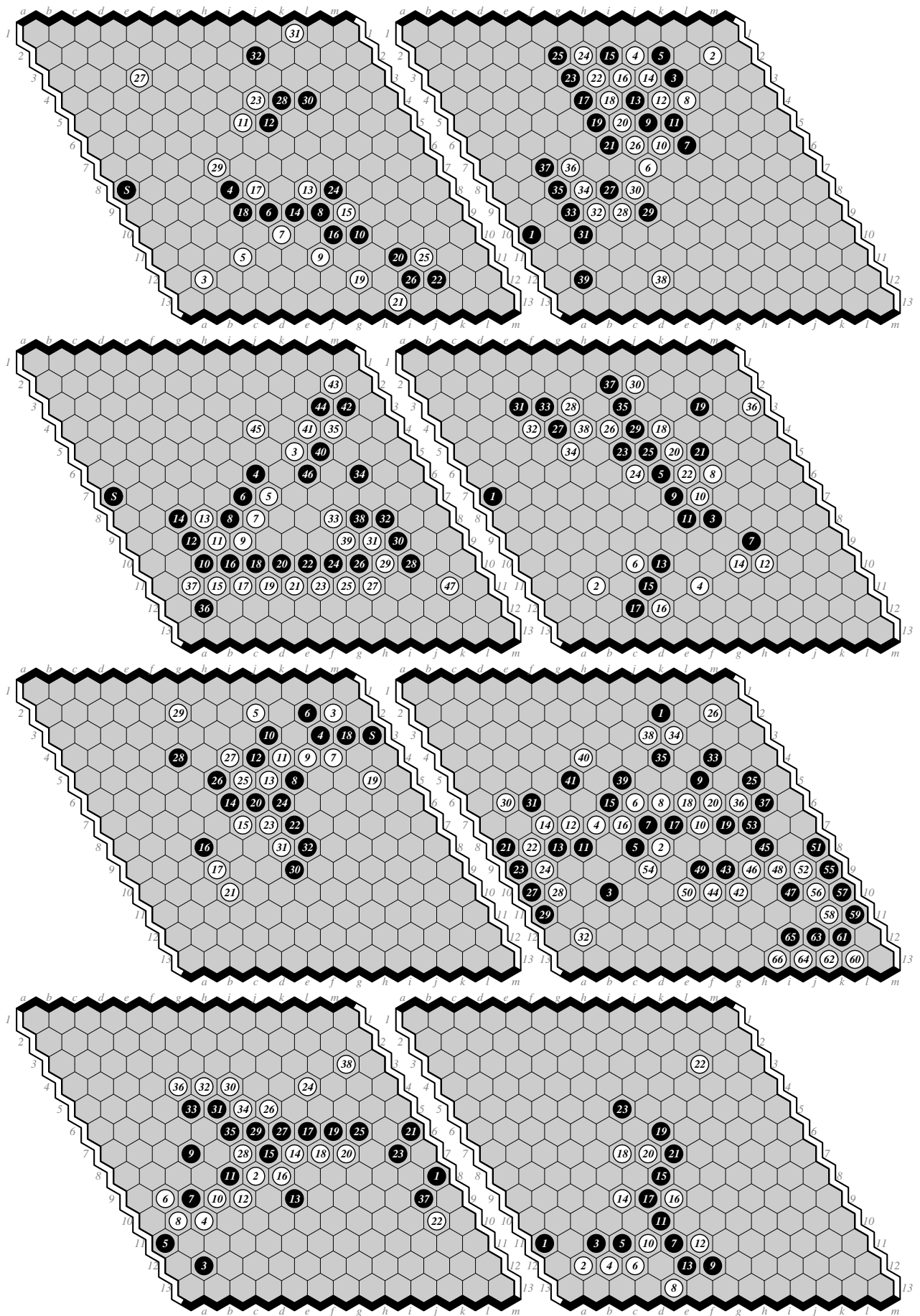


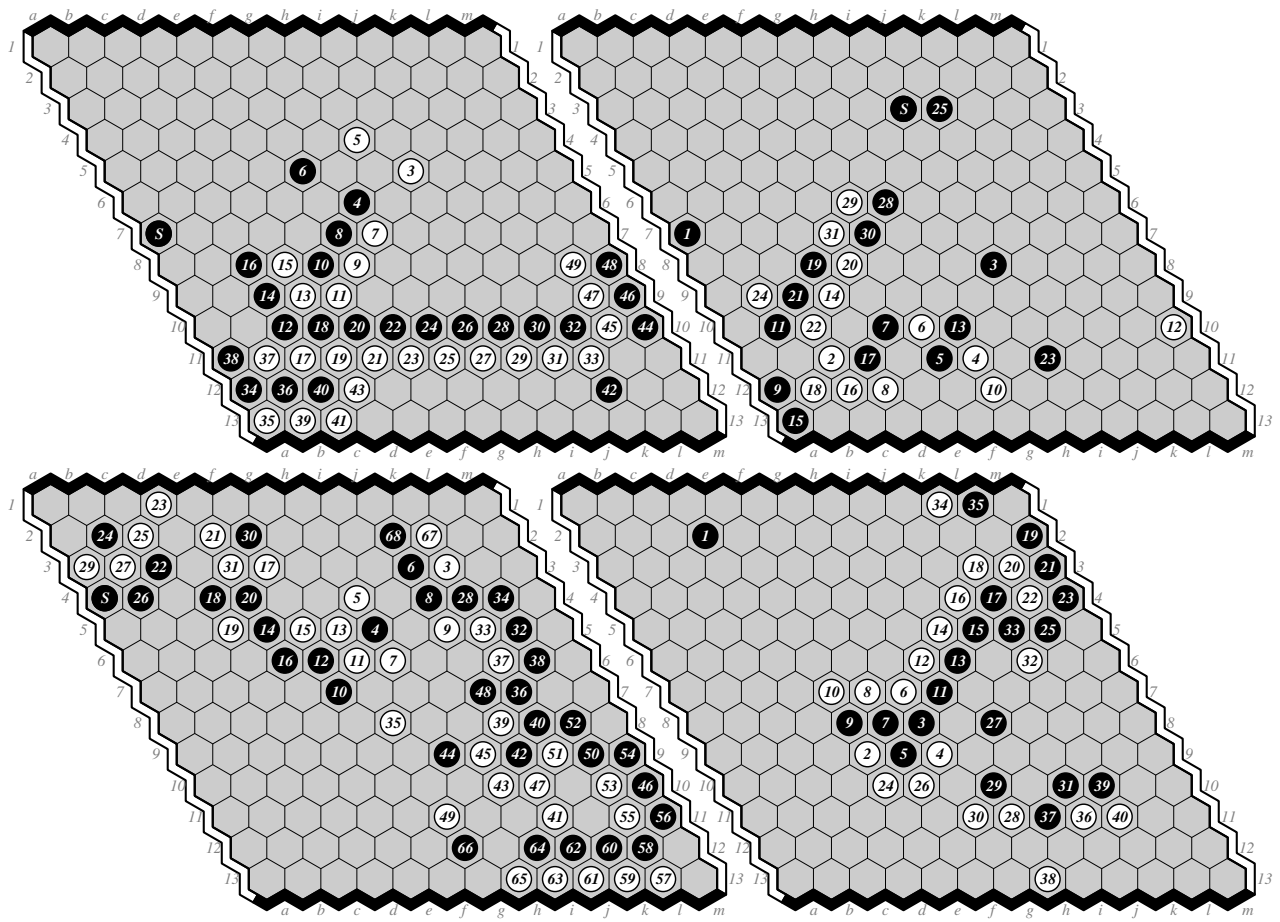
11×11: Games 1-4 (top left/right, bottom left/right). EZO-MoHEX 0-1, DEEPHEX-EZO 1-0, MoHEX-DEEPHEX 0-1, MoHEX-EZO 1-0.



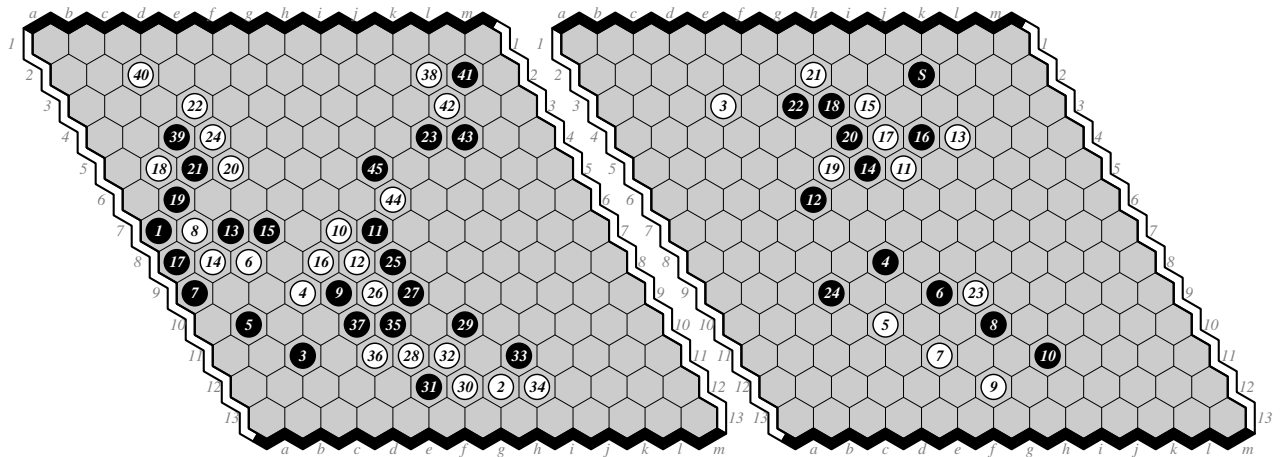


11×11: Games 5-12.

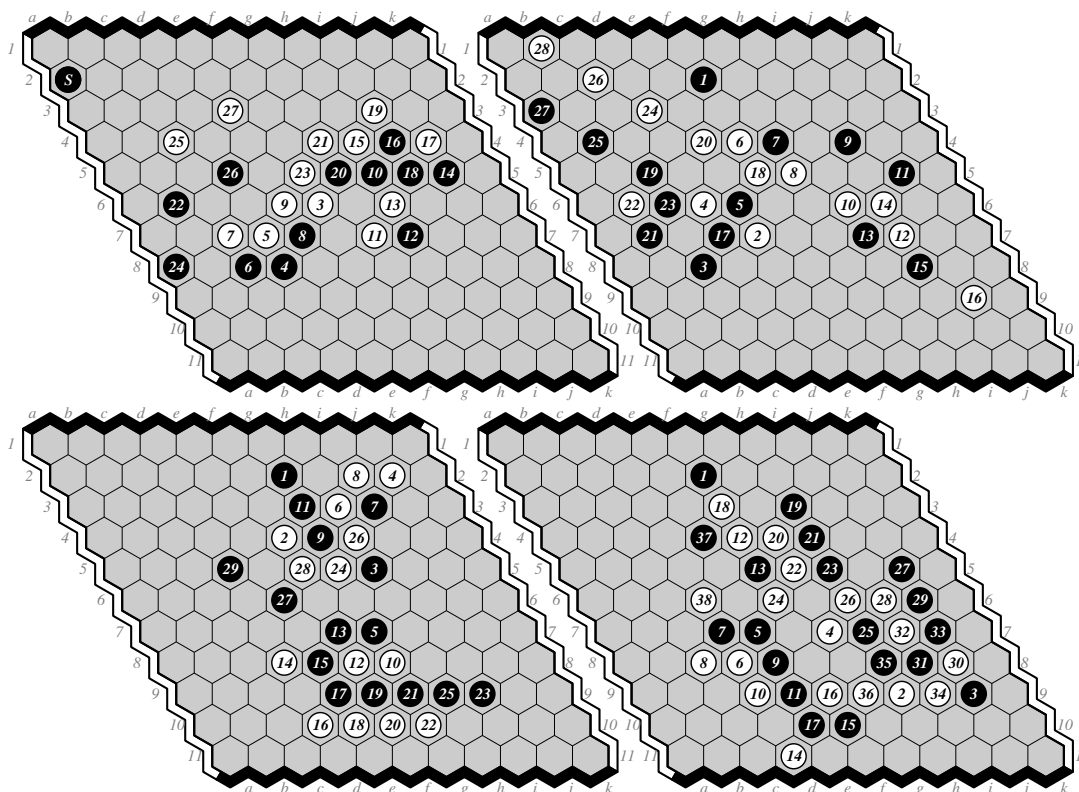




13×13: Games 1-12.



13×13: Playoff games. MOHEX-DEEPHEX 1-0, DEEPHEX-MOHEX 0-1.



Human-computer games. Top: MOHex-TV 1-0, TV-MoHex 0-1. Bottom: DEEPHex-TV 1-0, TV-DEEPHex 0-1. Each player had 15 minutes to make all moves.

Tony comments I just pick a few games to comment upon. Hard to know if my comments are better on a par with the outcome of the programs reasoning. For instance, look at 11x11 game 9m-d. In your comment you state 22 J5 is losing. But in my analysis 22 J5, 23 J6, 24 F9 could well be winning. Do you agree? Does Mohex agree?

Ryan: no, 25.W[e10] wins.

Next look at 13x13 game 6d-m. "Game 6. DEEPHEX-MOHEX 1-0. 1.B[j2] 2.W[g8] 3.W[d10] . . . Another close game. MOHEX blunders with 54.W[f9]; 54.W[i11] wins. DEEPHEX sees the win soon after." Move 3 should be B[d10] I presume. Perhaps I do not understand the comments here: at move 66 I13 white seems to be winning after all? So what is wrong with 54 W[f9]?

ome further notes...

First I see now why Game 13.06d-m was lost. Incredible that the program could find such elaborate moves as W[f9] or W[i11]. But when I go back a little further in the game I wonder about 30 W[b6] which is clearly too early. Human players would always play 30Wb11; 31Ba12; 32Wb12; 33Ba13 first and only then 34Wb6. Next the same sequence may happen at the right side of the board, resulting in the position of the attached game. I think this is a white win.

Ryan: no, solver finds black wins from this state: PV j12 j11 i12 i11 h12 h11 g12 g11 f12 f10 j3 i4 i3 h4 h2 h3 i2 g3 g2 e3 f1 d2 e12 d12 e11 d11 f3 e5 g10 f11 d3 e2

In game 13.11e-d Deephex plays remarkably indeed, discarding the obvious connection at a3. However, after 27Ba3 black would face difficulties connecting the black chain on the left to the bottom. I can see no easy win for white after 27Bk4 as played in the game. In your comment you mention that 47Wk11 would be a win for EZO. However black seems to have opportunities to defend against Wk11, of which my analysis in the attached game presents one example. Other progressions are possible too, but I did not yet find a better answer for white. All in all this game shows to me how very deep Deephex is looking into the game!

In the first playoff game we see white answering very far to the bottom, playing 2Wh12 instead of a usual (human) move like 2Wi10. Next 6Wc8 seems a weak move. As long as white has at least two options to connect it should postpone connecting and strengthen instead, but if white has only one remaining option it seems better to connect

right away. This could result in a better position like in the commented game: 6Wb9; 7Bc9; 8Wd7; until 15Wb5. But of course black may answer differently. "Playoff Game 1. MOHEX-DEEPHEX 1-0. 1.B[a7] 2.W[h12] 3.W[c11] . . . DEEPHEX lost earlier when swapping this opening, so here it does not swap. MOHEX scores gradually increased, and finds a win by move 46." I guess move three has to be 3.B[c11]? I can see that in the game 47Bj6 is a winning move.