Hex 2017: MoHex wins the 11x11 and 13x13 tournaments

Ryan B. HAYWARD and Noah WENINGER [1]
Department of Computing Science, University of Alberta, Canada

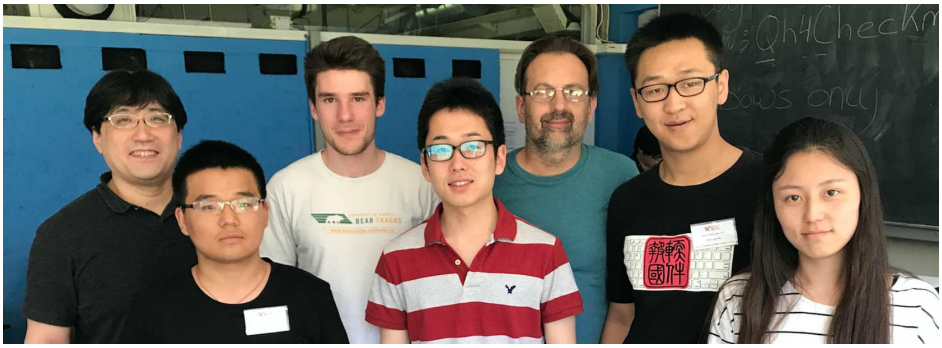

Figure 1. Participants at the Hex competitions. From left, Masahito Yamamoto, You RunZe, Noah Weninger, Kei Takada, Ryan Hayward, Ma Shengjie, Wu Tong.

1. The Tournaments

The 2017 Olympiad in Leiden hosted two Hex tournaments, board sizes 11×11 and 13×13.[2] Three programs competed in each tournament. These are at present the only annual computer Hex tournaments. 11×11 is the original board size introduced by Piet Hein in 1942. Recently, all 1-move openings on 9×9 Hex have been solved by computers, as have two 10×10 openings [9]. So, in recent years the 13×13 competition, a preferred size in the Little Golem online Hex community [8], was introduced.

The 11×11 contestants were HEXCITED by Ma Shengjie from China; EZO-CNN by Kei Takada, supervised by Masahito Yamamoto, from Japan; and MOHEX by Broderick Arneson, Ryan Hayward, Philip Henderson, Aja Huang, Jakub Pawlewicz, Noah Weninger, and Kenny Young from Canada. The 13×13 contestants were HEXCELLENT by Wu Tong, operatored by You RunZe and (another, no relation) Wu Tong from China; EZO-CNN; and MOHEX-CNN by Chao Gao and the MOHEX authors from Canada.

MOHEX [5], the winner of the previous seven Olympiad Hex competitions [3], is an MCTS program that uses the Benzene Hex framework built on the code base of FUEGO

[1] Corresponding author: Ryan B. Hayward, UAlberta, Edmonton, Canada, hayward@ualberta.ca.

[2] [4] gives .sgf game records and other source files for this report. [1] gives an .sgf viewer. Smart Game Format (sgf) was develop by [6].

id	11x11	MoHex	Ezo-CNN	Hexcited	Total	Result
M	MoHex		7-5	4-0	11-5	Gold
M	Ezo-CNN	5-7		3-0	8-7	Silver
M	Hexcited	0-4	0-3		0-7	Bronze

Table 1. 11×11 tournament results

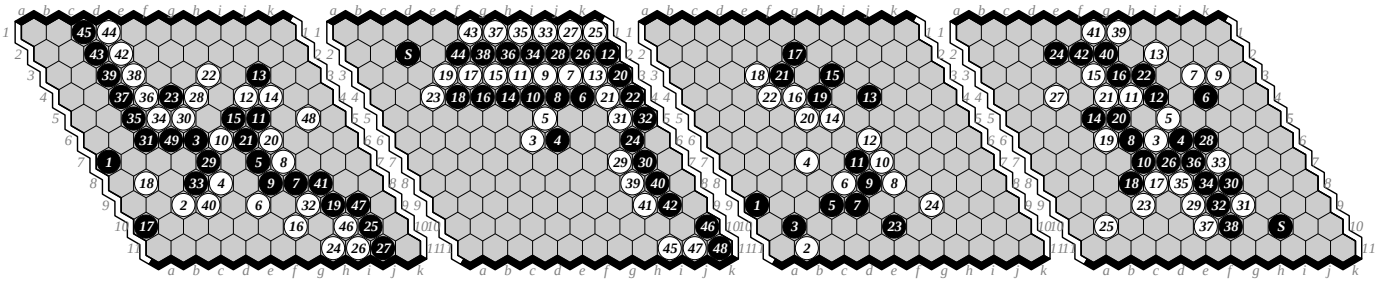

Figure 2. Hexcited-MoHex Games 1-4. M-H 1-0, H-M 0-1, M-H 1-0, H-M 0-1.

[2]. MoHex performs knowledge computation in UCT tree nodes visited at least 256 times. MoHex ran on Firecreek, a 24 core shared-memory machine, with four cores reserved for the DFPNS solver [9], which produces perfect play if it solves the position within the time allotted. MoHex uses a book built by Broderick Arneson with Thomas Lincke's method [7]. Noah Weninger expanded the book and added a feature allowing the use of rotational symmetry for openings whose rotation is in the book. For each board size, the book covers at least eight openings.

MoHex-CNN is a convolutional neural net (CNN) version of MoHex. At each new node of the Monte Carlo search tree, a policy CNN biases child selection by initializing child visit and win counts with artificial values. MoHex-CNN ran remotely on a machine with two CPUs and one GPU.

Ezo-CNN is a CNN version of Ezo, which competed in the 2016 and previous Olympiads. Ezo, based on the Benzene framework, uses iterative deepening alpha-beta search with an evaluation function using a linear combination of two network connectivity measures [10]. Ezo-CNN uses a convolutional neural policy network for move ordering. Ezo-CNN ran remotely on a machine with two CPUs and one GPU, with one CPU-thread for search and one CPU-thread for Benzene's Depth-First Proof Number Search endgame solver.

Hexcited and Hexcellent are new MCTS programs written respectively by Ma Shengjie and Wu Tong of the Beijing Institute of Technology. Each ran locally on a laptop.

Each tournament was scheduled for 8 games between each two of the three competitors, with 30'/game per player. The tournaments started on July 1 and finished on July 5. See Tables 1 and 2 and Figures 2-7. In many games, the losing operator resigned once Benzene solved the game. Figures 4 and 7 show typical continuations after resignation.

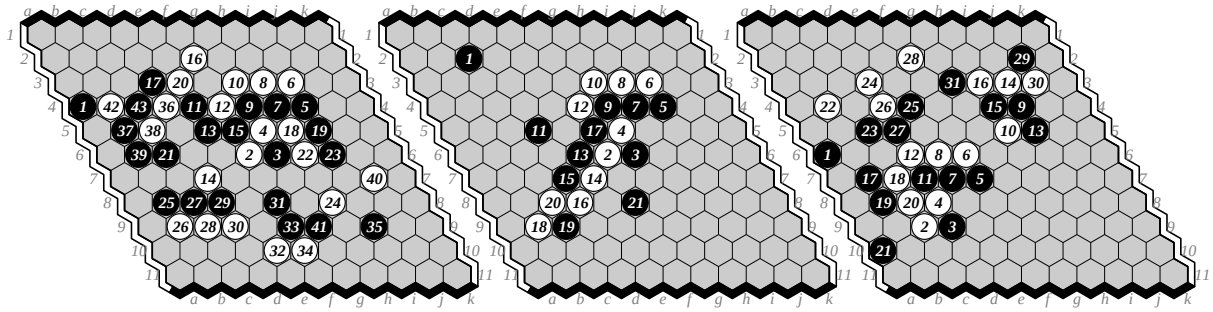

Figure 3. HEXCITED-EZO-CNN Games 1-3. E-H 1-0, H-E 0-1, E-H 1-0. In Game 1, Black finishes with one of **{e8,h7}**.

id	13x13	MOHEX-CNN	EZO-CNN	HEXCELLENT	Total	Result
M	MOHEX-CNN		6-2	2-0	8-2	gold
E	EZO-CNN	2-6		4-0	6-6	silver
H	HEXCELLENT	0-2	0-4		0-6	bronze

Table 2. 13×13 tournament results

2. 11×11 Tournament

In a game, if the second move is 'swap', then players exchange colors and the first player plays the next move: in the corresponding diagram, black 'S' marks the first two moves and white '3' the next move. In the figures, 'A-B 1-0' indicates that A plays first, starting as black, and A wins (as white if B swapped, as black if not).

The new program HEXCITED opened strongly in several games. In its first game against MOHEX, HEXCITED is in a strong position after 15 moves, but misses the promising 16.W[g3]. Even with this move, HEXCITED would be hard pressed to beat MOHEX: its Benzene framework includes a virtual connection engine that often finds a win before a typical tree search detects that the game is decided. EZO-CNN also uses the Benzene framework, and HEXCITED was unable to win against either opponent. For this reason, once the final ranking was decided, HEXCITED's operator resigned its remaining games without play. Due to the late arrival of HEXCITED, MOHEX and EZO-CNN played their games first. The contest for gold required a four-game playoff between MOHEX and EZO-CNN, which was not decided until the final game.

3. 13×13 Tournament.

For this tournament no playoff was required. Again, the final ranking was determined before all scheduled games had been played, so the operator of HEXCELLENT resigned its final games without play.

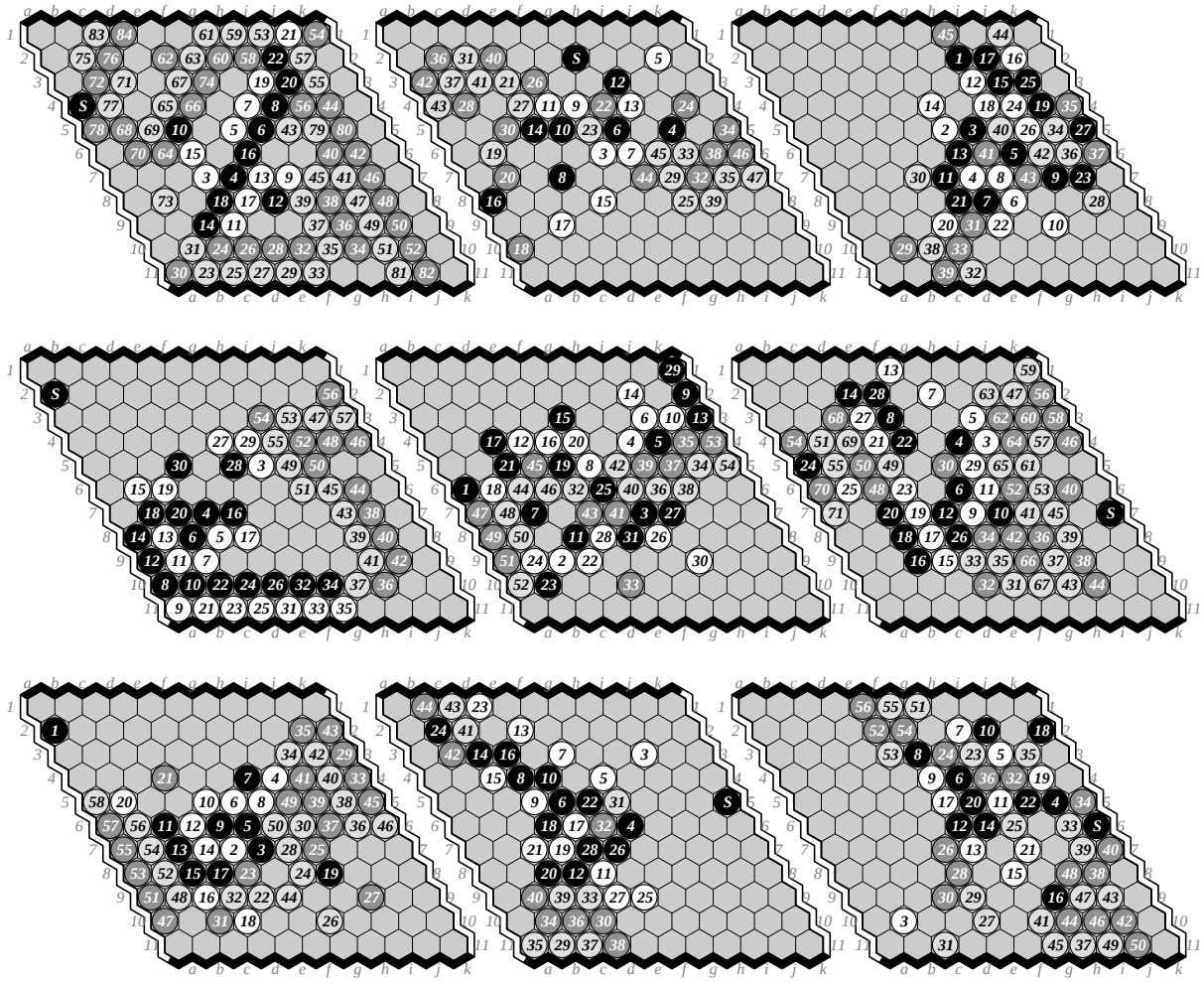

Figure 4. EZO-CNN-MOHEX Games. a) 1-3. E-M 0-1, M-E 1-0, E-M 1-0. b) 4-6. M-E 1-0, M-E 0-1, E-M 1-0. c) 7-9. M-E 0-1, E-M 0-1, E-M 0-1.

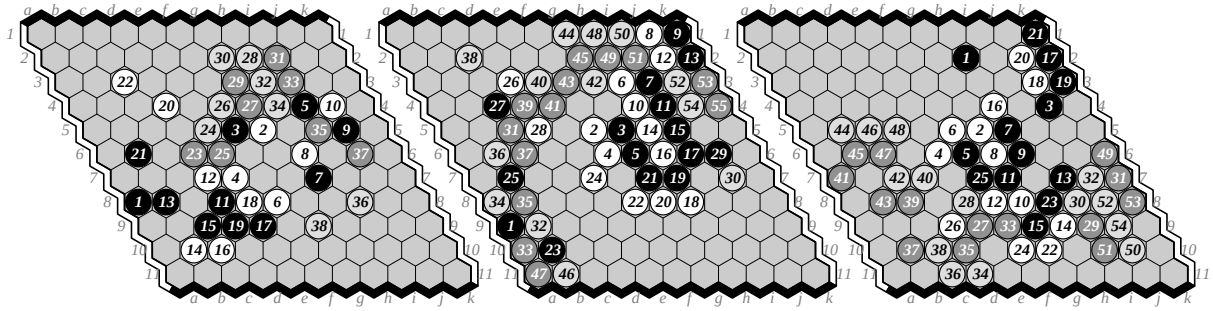

Figure 5. EZO-CNN-MOHEX Games 10-12. M-E 0-1, M-E 1-0, E-M 0-1.

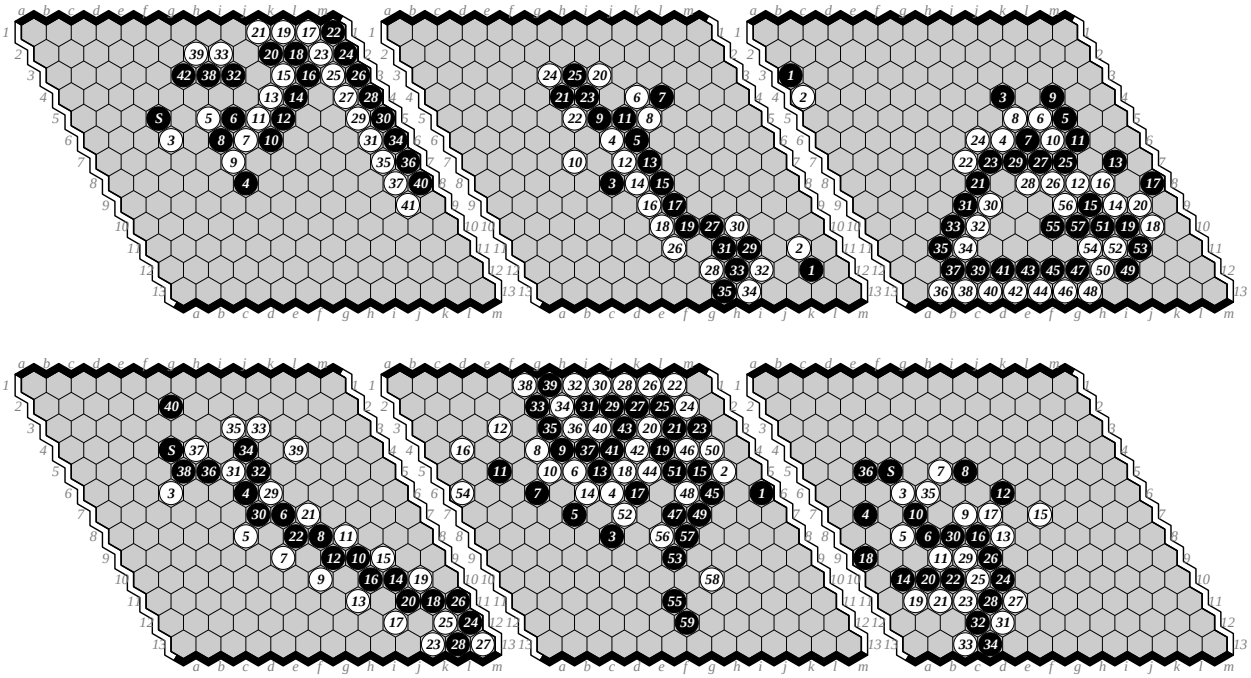

Figure 6. Hexcellent Games. a) 1-3. H-M 0-1, M-H 1-0, E-H 1-0. b) 4-6. H-E 0-1, E-H 1-0, H-E 0-1.

4. Conclusions

On 11×11 MoHex and Ezo-CNN seem evenly matched. MoHex's search seems too narrow, especially near the opening. In positions with plural good-looking moves, initial playouts can bias final move selection, and MoHex sometimes makes a bad move early in the game. The purpose of MoHex's book is to avoid early bad moves. This played a role in the final playoff game, where Ezo-CNN opened with 1.B[H2].

In an earlier game, Ezo-CNN played the same opening and won easily after MoHex replied 2.W[f5], which is not on the main diagonal and does little to block Black. But in the playoff game, MoHex replied 2.W[g5] and won. Post-tournament testing shows that MoHex likes both moves more than all others, but that the superiority of **g5** to **f5** is not clear. If initial rollouts are unlucky, MoHex will not see that **g5** is better.

On 13×13 MoHex-CNN seems stronger than Ezo-CNN. MoHex-CNN suffered from a lack of testing prior to the tournament. Consequently, it played the first three games with its rapid access value estimation (RAVE) feature turned off. This search was too narrow, so RAVE was turned on for the remaining five games, which improved performance.

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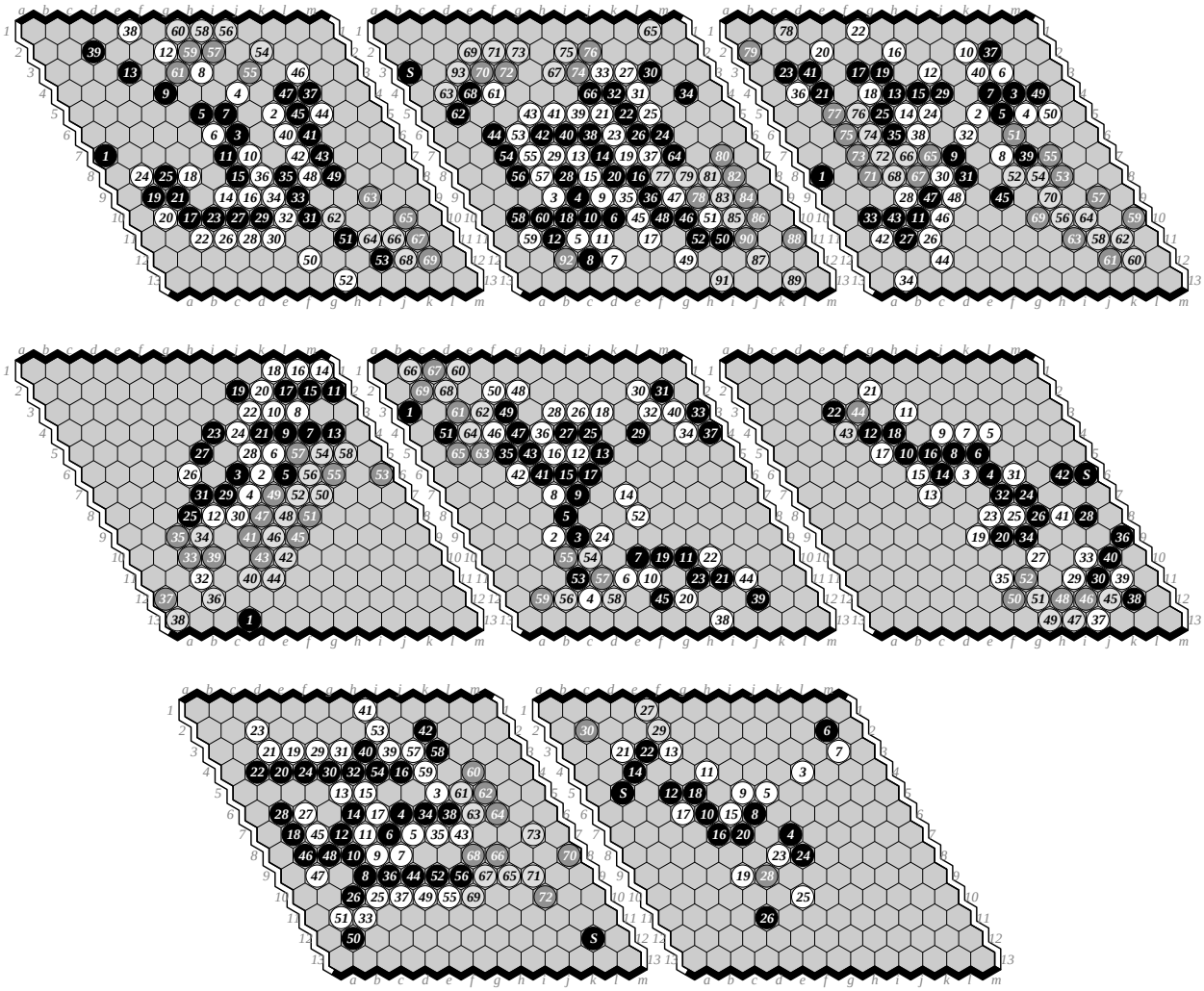

Figure 7. EZO-CNN-MOHEX-CNN Games. a) 1-3. M-E 1-0, E-M 1-0, M-E 0-1. b) 4-6. E-M 0-1, M-E 1-0, E-M 0-1. c) 7-8. M-E 1-0, E-M 0-1.

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