FANORONA IS A DRAW

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1. INTRODUCTION TO FANORONA

Fanorona is the national and indigenous board game originally played in Madagascar. There are three commonly known variants of the game which differ in board size: (1) Fanoron-Tsivy commonly referred to as Fanorona and played on a 5×9 board; (2) Fanoron-Dimyand played on a 5×5 board and (3) Fanoron-Telo played on a 3×3 board. The initial position of a Fanorona game is depicted in Figure 1. The board is a 5×9 grid, pieces are placed on the intersections of lines. The players alternately move a stone, starting with White. One is only allowed to move over a line and only to an adjacent point. Capturing is done by *approaching* or *withdrawing* opponent stones. It is possible to capture a complete line of opponent stones at once if these stones are positioned on the same line directly behind the approached or withdrawn stone. During a capturing sequence, (1) it is not allowed to arrive at the same position and (2) to move the stone in the same direction as moved directly before in the capturing sequence. Capturing is *obliged* if possible, moreover, it is *allowed* to continue capturing with the same stone if possible, but discontinuing the capture is also allowed. The objective of the game is to capture all opponent stones. If both players cannot find a way to win the game by capturing its opponents stones, the game is a draw. For a complete description of the rules and some examples we refer to Schadd (2006) and Chauvicourt and Chauvicourt (1980).

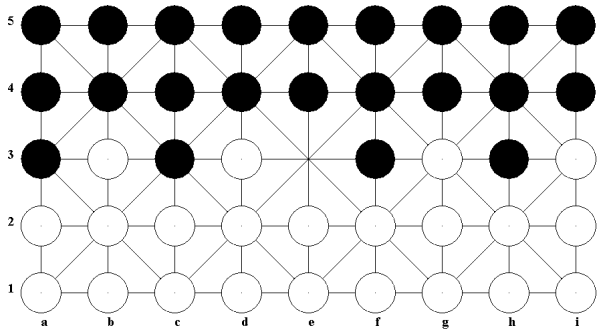

Figure 1: The initial position of Fanorona.

Analysis of the game has shown that the game-tree complexity is 10^{40} and the state-space complexity is 10^{21}. Furthermore, a superficial investigation reveals that the majority of moves is played with only a few stones on the board. Since solving games has always been a great challenge for AI research (Van den Herik, Uiterwijk, and Van Rijswijk, 2002) and since the analysis indicated that Fanorona might be weakly solvable (Allis, 1994), we decided to undertake this challenge. Next to the standard board, we decided to solve other board sizes too.

2. SOLVING FANORONA

Solving the game has been done in two steps. The first step was constructing an endgame database using retrograde analysis (Ströhlein, 1970). During this research a 7-stone endgame database consisting of 6,261,651,660 positions was constructed. The amount of draws found in the endgame databases is remarkable. For instance, in 45.4% of the possible 2vs4 positions, a draw can still be achieved.

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The second step was to implement the PN^2 variant of Proof-Number Search (Breuker, Uiterwijk, and Van den Herik, 2001). We used our greedy-numbers approach for initializing proof numbers and disproof numbers. The size of the solution tree was significantly decreased when using this technique on the smaller variants of the board (Schadd, 2006).

The combination of the endgame database and the enhanced Proof-Number (PN) search form the core of our program KING RALOMBO. This program was able to solve the initial position of Fanorona in almost 79 hours on an AMD Quad Opteron with 32 GB memory. The size of the solution tree for Fanorona consisted of 130,820,097,938 nodes. It turns out that Fanorona is a draw.

During this project smaller variants have been solved as well. In Table 1 the game-theoretic values for different board sizes are given. The column labelled *Nodes* indicates the total number of nodes needed to solve the game. As shown in Table 1 all variants with one side equal to size 3 are a win for White. Thus, White as starting player can exploit a narrow board and force a win. We conjecture that for boards where both sides have at least size 5 White does not have this advantage for the majority of cases.

Board Size	*Winner*	*DB size (stones)*	*Nodes*
3×3	White	0	122
3×5	White	0	2,490
5×3	White	0	1,491
3×7	White	0	87,210
7×3	White	0	172,101
5×5	Draw	9	108,593
3×9	White	5	209,409
9×3	White	5	262,217,017
5×7	Black	7	72,826,963
7×5	White	7	1,053,126
9×5	Draw	7	130,820,097,938

Table 1: Overview of the game-theoretic values for different board sizes.

3. FURTHER RESEARCH

At the time of writing this note, the 5×9 variant has not yet been solved weakly. Preliminary results suggest that this variant is much harder to solve than the 9×5 variant. The next task is *strongly* solving the 5×5 variant of the game. Although Fanorona has been solved, there does not exist a program that can play the game perfectly under tournament conditions at present. So, this is also a future task.

4. REFERENCES

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