

FPT'11 Design Competition

SW and HW Co-design of Connect6 Accelerator with Scalable Streaming Cores

Nexus-6 mkII

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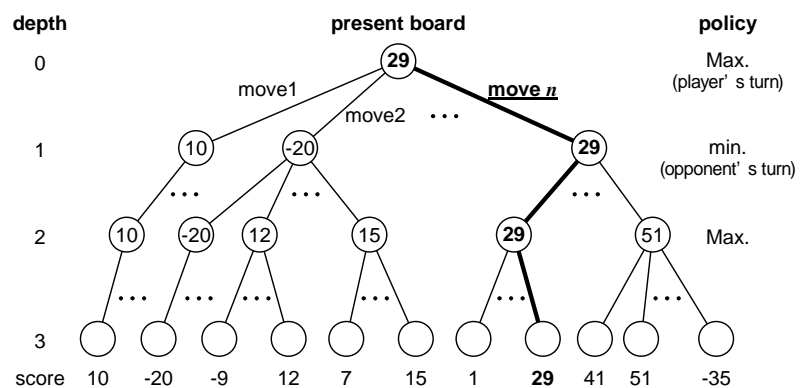
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Connect6 Solver Algorithm

Search in a game tree

- ✓ mini-Max search
- ✓ α - β pruning
- ✓ Evaluation function



Game tree of Connect6

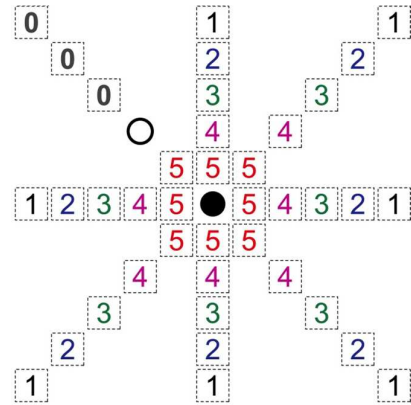
At each node, execute recursively

1. Candidate generation
2. Board score comp.
3. Partial sort for top m scores
⇒ promising moves

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Candidates gen. w/ proximity stencil

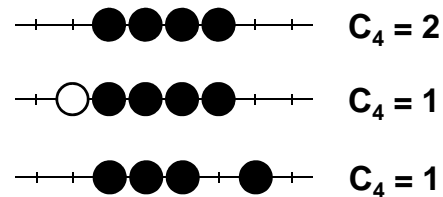
- ✓ Higher score for closer place
- ✓ Blocked by an opponent's stone
- ✓ Threshold for score sum of stencils



Proximity stencil

Board score w/ *connectability*

- ✓ **Connectable N** : C_N
my N stones in non-blocked places
- ✓ Count of necessary stones for opponent's defense
- ✓ Horizontal, vertical, diagonals
- ✓ $N = 6,5,4,3,2$

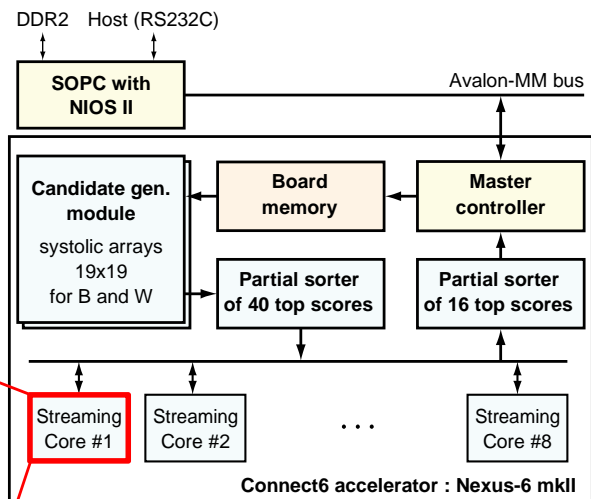
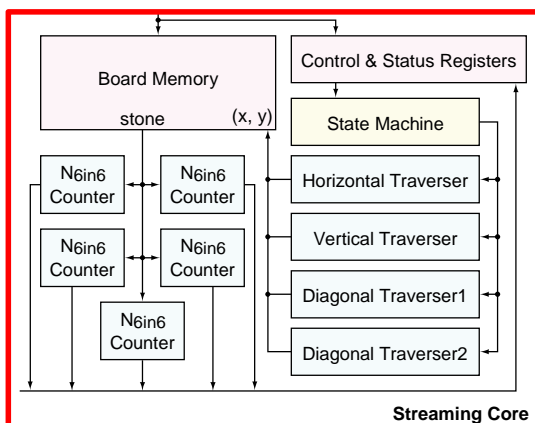


Candidates generation module

- ✓ Two 19 x 19 systolic arrays

Partial sorter for top N scores

- ✓ Linear array of comparison unit



System overview

Board-score comp. module

- ✓ 12 streaming cores
- ✓ Parallel counters for C_N ($N=2,3,4,5,6$) of B & W



Implementation Results

- **ALTERA Cyclone IV (DE2-115 board) -- 114,480 LCells**
- **Resource Utilization**
 - ✓ Entire system 112,010 LCells (98%)
 - ✓ Connect6 accelerator 106,137 LCells (93%)
 - ✓ SOPC with NIOS II 5,713 LCells (5.0%)
- **Performance**
 - ✓ Fmax 75MHz
 - ✓ Two systolic arrays 7.5×10^4 candidates/s (1000 cycles each)
 - ✓ A streaming core 5×10^4 boards /s (1500 cycles each)
 - ✓ Accelerator w/ 12 cores 1.4×10^4 nodes /s (5500 cycles each node)
 - ✓ A game tree with a depth of 10



Summary

- **Algorithm of connect6 solver**
 - ✓ mini-Max tree-search algorithm w/ alpha-beta pruning
 - ✓ Candidate generation, board score comp. and partial sort
- **Connect6 accelerator**
 - ✓ Candidate generation module
 - ✓ Board scoring modules (streaming cores)
 - ✓ Partial sorters
- **Acknowledgement**

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Development boards ALTERA co ltd.