FPT’11 Design Competition

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

Nexus-6 mkII

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Connect6 Solver Algorithm

Search in a game tree
✓ mini-Max search
✓ α-β pruning
✓ Evaluation function

At each node, execute recursively
1. Candidate generation
2. Board score comp.
3. Partial sort for top $m$ scores
   \Rightarrow promising moves

Game tree of Connect6
Candidate Generation & Board Scoring

Candidates gen. w/ proximity stencil

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

Board score w/ connectability

- Connectable $N : C_N$
  - Count of necessary stones for opponent’s defense
- Horizontal, vertical, diagonals
- $N = 6,5,4,3,2$

Architecture and Design

Candidates generation module

- Two 19 x 19 systolic arrays

Partial sorter for top N scores

- Linear array of comparison unit

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: $7.5 \times 10^4$ candidates/s (1000 cycles each)
  - A streaming core: $5 \times 10^4$ boards /s (1500 cycles each)
  - Accelerator w/ 12 cores: $1.4 \times 10^4$ 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**
  - Test players: Yasuhiro Sasao, Yuichi Miyake, Tomohiro Ueno, Kenji Okazaki, Yoshiaki Kono (Yamamoto/Sano Lab.)
  - Development boards: ALTERA co ltd.