Home * Board Representation * **Bitboards**

Samuel Bak - Boards Meeting [4]

Bitboards,
also called bitsets or bitmaps, are among other things used to represent the board inside a chess program in a **piece centric** manner. Bitboards, are in essence, finite sets of up to 64 elements - all the squares of a chessboard, one bit per square. Other board games with greater board sizes may be use set-wise representations as well [1], but classical chess has the advantage that one 64-bit word or register covers the whole board. Even more bitboard friendly is Checkers with 32-bit bitboards and less piece-types than chess [2] [3] .

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The Board of Sets

To represent the board we typically need one bitboard for each piece-type and color - likely encapsulated inside a class or structure, or as an array of bitboards as part of a position object. A one-bit inside a bitboard implies the existence of a piece of this piece-type on a certain square - one to one associated by the bit-position.

- Square Mapping Considerations
- Standard Board-Definition

Bitboard Basics

Of course bitboards are not only about the existence of pieces - it is a general purpose, **set-wise** data-structure fitting in one 64-bit register. For example, a bitboard can represent things like attack- and defend

sets, move-target sets and so on.

General Bitboard Techniques

The fundamental bitboard basics.

- General Setwise Operations
- Population Count
- BitScan
- Flipping Mirroring and Rotating
- Fill Algorithms

Pattern and Attacks

This is basically about chess, how to calculate attack-sets and various pattern for evaluation and move generation purposes.

- Pawn Pattern and Properties
- Knight Pattern
- King Pattern
- Sliding Piece Attacks including rotated and magic bitboards
- Square Attacked By
- X-ray Attacks
- Checks and Pinned Pieces
- Design Principles

Move Generation Issues

Bitboard aspects on move generation and static exchange evaluation (SEE).

- Bitboard Serialization
- Pieces versus Directions
- DirGolem
- SEE - The Swap Algorithm
- Attack and Defend Maps

Miscellaneous

- Backtracking - Eight Queens puzzle with Bitboards
- De Bruijn Sequence Generator

- Quad-Bitboards
- Traversing Subsets of a Set

Defining Bitboards

To be aware of their scalar 64-bit origin, we use so far a type defined unsigned integer U64 in our C *or* C++ *source snippets, the scalar 64-bit long in* Java*. Feel free to define a distinct type or wrap U64 into classes for better abstraction and type-safety during compile time. The macro C64 will append a suffix to 64-bit constants as required by some compilers*:

```
typedef unsigned __int64 U64;    // for the old microsoft compilers
typedef unsigned long long  U64; // supported by MSC 13.00+ and C99
#define C64(constantU64) constantU64##ULL
```

Bitboard-History

The general approach of bitsets was proposed by Mikhail R. Shura-Bura in 1952 [5] [6]. The bitboard method for holding a board game appears to have been invented also in 1952 by Christopher Strachey using White, Black and King bitboards in his checkers program for the Ferranti Mark 1 [7], and in the mid 1950's by Arthur Samuel in his checkers program as well. In computer chess, bitboards were first described by Georgy Adelson-Velsky et al. in 1967 [8] , reprinted 1970 [9] . Bitboards were used in Kaissa and in Chess. The invention and publication of Rotated Bitboards by Robert Hyatt [10] and Peter Gillgasch with Ernst A. Heinz in the 90s was another milestone in the history of bitboards. Steffan Westcott's innovations, too expensive on 32-bit x86 processors, should be revisited with x86-64 and SIMD instructions in mind. With the advent of fast 64-bit multiplication along with faster memory, Magic Bitboards as proposed by Lasse Hansen [11] and refined by Pradu Kannan [12] have surpassed Rotated.

Analysis

The use of bitboards has spawned numerous discussions about their costs and benefits. The major points to consider are:

- Bitboards can have a high information density.
- Single populated or even empty Bitboards have a low information density.
- Bitboards are weak in answering questions like what piece if any resides on square x. One reason to keep a redundant mailbox board representation with some additional update costs during make/ unmake.

- Bitboards can operate on all squares in parallel using bitwise instructions. This is one of the main arguments used by proponents of bitboards, because it allows for a flexibility in evaluation.
- Bitboards are rather handicapped on 32 bit processors, as each bitwise computation must be split into two or more instructions [13] . As most modern processors are now 64 bit, this point is somewhat diminished [14] .
- Bitboards often rely on bit-twiddling and various optimization tricks and special instructions for certain hardware architectures, such as bitscan and population count. Optimal code requires machine dependent header-files in C/C++. Portable code is likely not optimal for all processors.
- Some operations on bitboards are less general, f.i. shifts. This requires additional code overhead.

Publications

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Forum Posts

1994

- bitboard move generation by Robert Hyatt, rgc, October 25, 1994
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1995 ...

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- Bit Board Bonkers?? by Dave, rec.games.chess.computer, July 28, 1997
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- To bitboard or not to bitboard? by Tord Romstad, CCC, August 30, 2003
- How important are Bitboards? by Martin Schreiber, CCC, February 29, 2004
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- Speedup with bitboards on 64-bit CPUs by Tord Romstad, CCC, April 27, 2007
- Speedup by bitboards by Onno Garms, Winboard Forum, July 13, 2007
- BitBoard representations of the board by Uri Blass, CCC, October 14, 2007
- Bitboards / move generation on larger boards by Gregory Strong, CCC, January 09, 2009
- Bitboard techniques in Xiangqi by Harm Geert Muller, CCC, February 12, 2009 » Chinese Chess
- Bitboards using 2 DOUBLE's ? by Carey, CCC, June 02, 2009 » Double

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- 64 bits for 64 squares ? by Thomas Petzke, mACE Chess, April 28, 2013 » Population Count
- Bitboard Tricks for Large Chess Variants by Ed Trice, CCC, November 01, 2014

2015 ...

- Bitboard database code samples by Steven Edwards, CCC, May 25, 2015 » Symbolic
- M42 - A C++ library for Bitboard attack mask generation by Syed Fahad, CCC, April 30, 2016 [17]
- Checkers Bitboard representation by Pranav Deshpande, CCC, July 02, 2017 » Checkers
- Bitboards and Java by Fred Hamilton, CCC, November 14, 2017 » Java

Viewer & Calculator

- Bibob
- Bitboard Calculator by Giuseppe Cannella
- Free Chess Bitboard Viewer - Computer Chess Programming by Steve Maughan
- New free tool : Bitboards Helper by Julien Marcel

External Links

- Bitboards from Wikipedia
- Bit-Array from Wikipedia
- Bitboard-History from Wikipedia
- Chess board representations by Robert Hyatt

- Bitboards (aka bitmaps) by Tom Likens
- An Introduction to BITBOARDS by Franck Zibi
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