

And-Not-Or Set Matrix

by Sven Nilsen, 2020

In this paper I derive the complexity of Boolean Algebra of n objects, using an and-not-or set matrix.

Since $\text{and}(a, b) = \text{and}(b, a)$ and $\text{or}(a, b) = \text{or}(b, a)$, one can put both inside a set matrix:

	00	01	10	11
00	11	01	10	11
01	00	10	11	11
10	00	00	01	11
11	00	01	10	00

and	not	or
-----	-----	----

The diagonal is filled with the inverse, since $\text{and}(a, a) = a$ and $\text{or}(a, a) = a$.

This $m \times m$ set matrix is a complete representation of a Boolean Algebra of sets with size m .

Since $\text{and}[\text{not}] \Leftrightarrow \text{or}$, the whole matrix can be generated from a triangle using the diagonal:

$$m \cdot (m - 1) / 2 + m \quad \text{Size of a strictly triangular matrix plus the diagonal}$$

For example:

$$\text{or}(01, 10) = \text{not}(\text{and}(\text{not}(01), \text{not}(10))) = \text{not}(\text{and}(10, 01)) = \text{not}(00) = 11$$

One can use nand alone since $\text{nand}(a, a) = \text{not}(a)$ and $\text{not}(\text{nand}(a, b)) = \text{and}(a, b)$.

However, this has the same complexity since $\text{nand}(a, a)$ fills the diagonal.

For n objects, the number of sets are 2^n , so this gives the complexity of the Boolean Algebra:

$$2^n \cdot (2^n - 1) / 2 + 2^n$$

n	complexity									
0	1	2	3	4	5	6	7	8	9	
1	3	10	36	136	528	2080	8256	32896	131328	

The $n = 0$ algebra contains only the empty set, characterized by $\text{not}(a) = a$.

The $n = 1$ algebra is isomorphic to the Boolean Algebra on bits.

When n goes to infinity, the ratio of $\text{complexity}(n+1) / \text{complexity}(n)$ converges to 4.