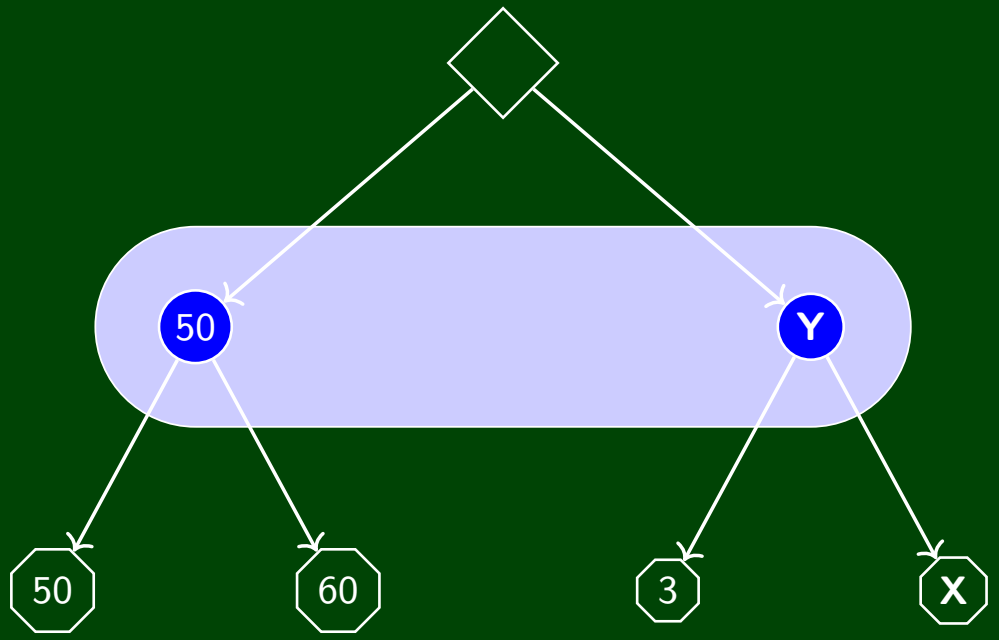
Introduction to Programming Methods

Alphabeta Pruning and Transposition Tables

Max's Turn

Min's Turn

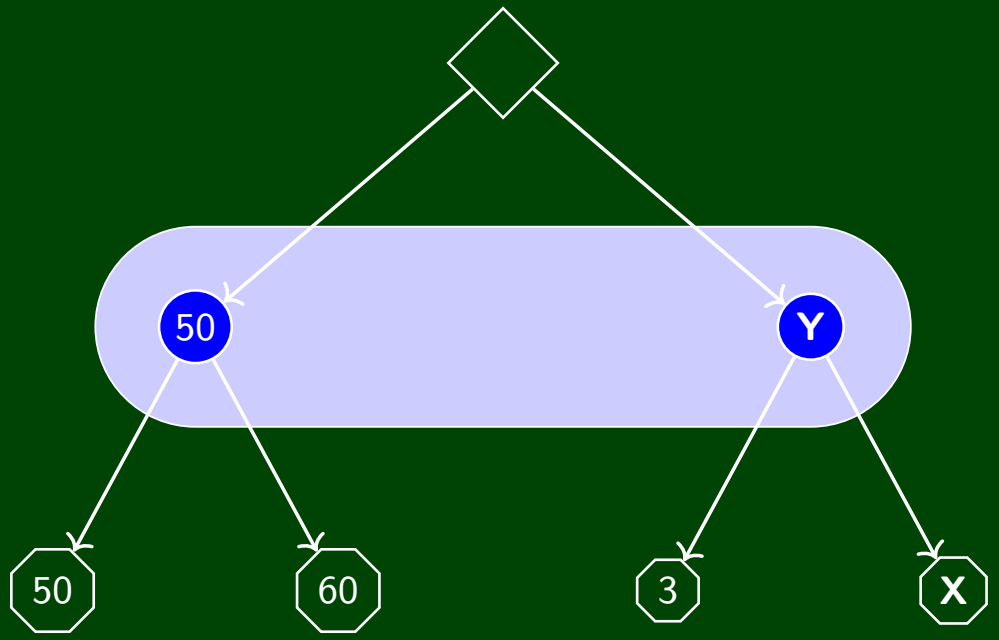
Max's Turn



Max's Turn

Min's Turn

Max's Turn

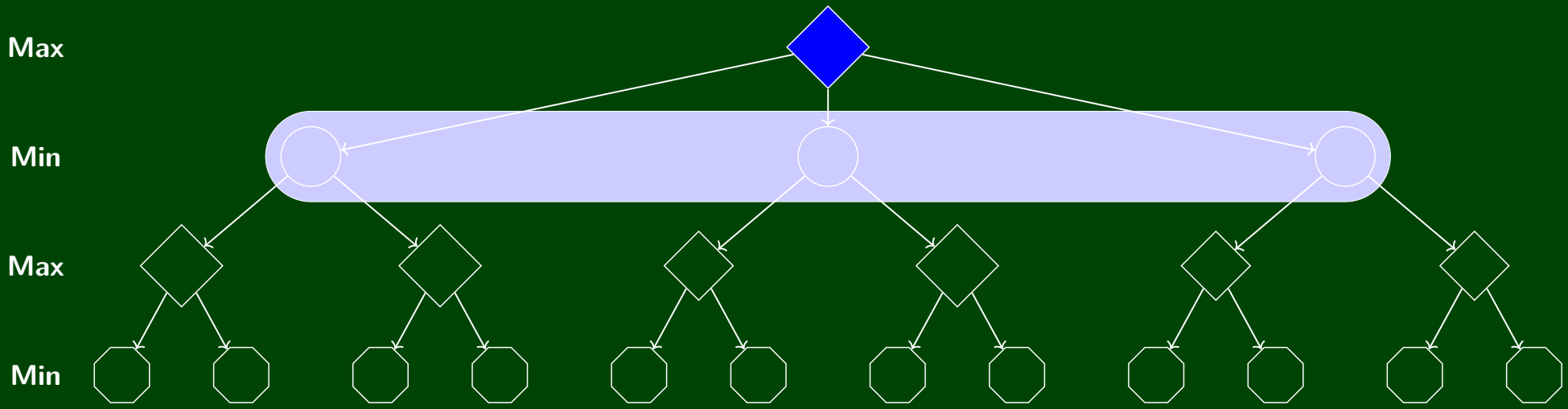


To fill in Y, **MIN** will take $\min(3, X)$. So, there are two cases:

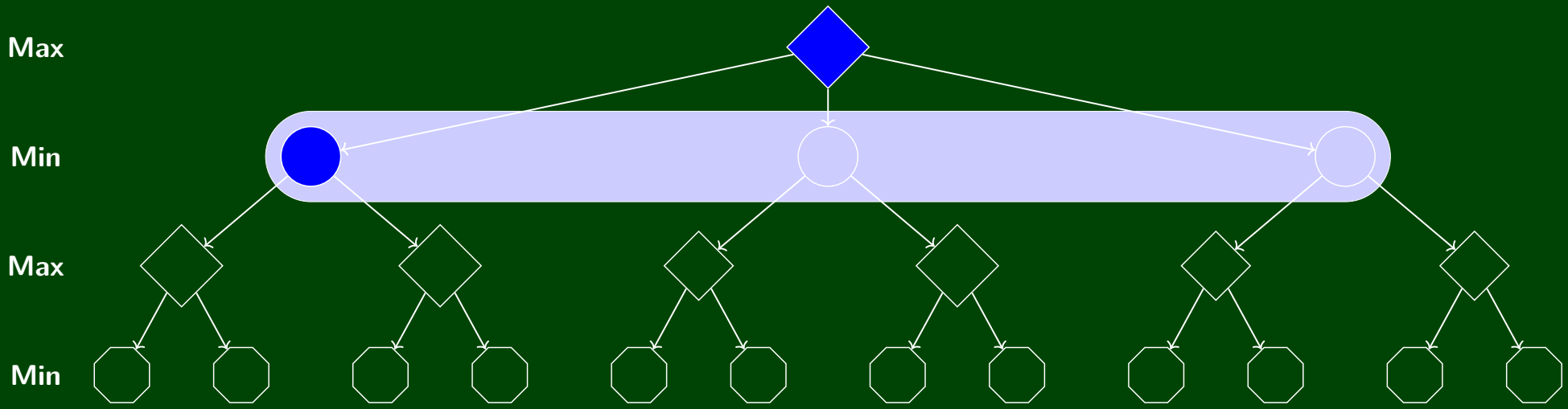
- $4 = X > 3$. Then, $Y = \min(3,4) = 3$. So, the box is 50.
- $2 = X < 3$. Then, $Y = \min(3,2) = 2$. So, the box is 50.

The values of X and Y don't matter! Don't calculate them!

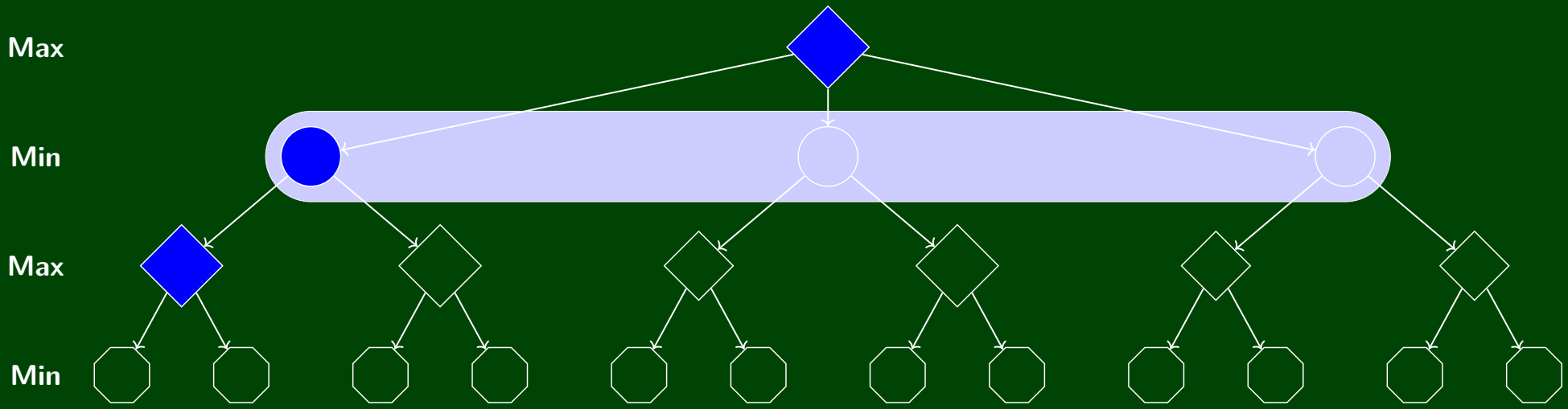
Pruning



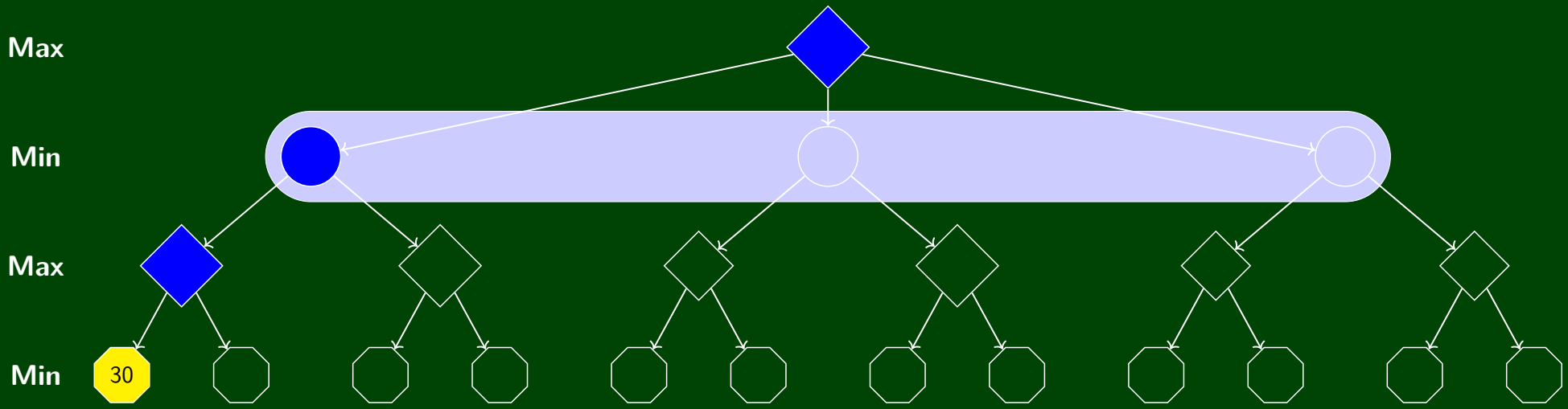
Pruning



Pruning



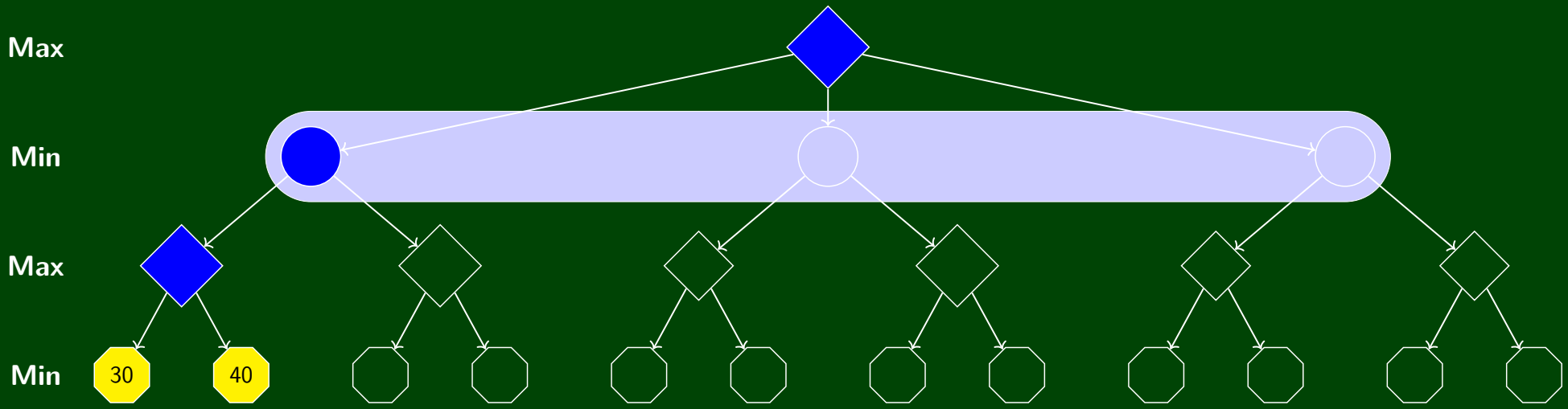
Pruning



Do we check the next node?

We currently have no information. So, yes!

Pruning



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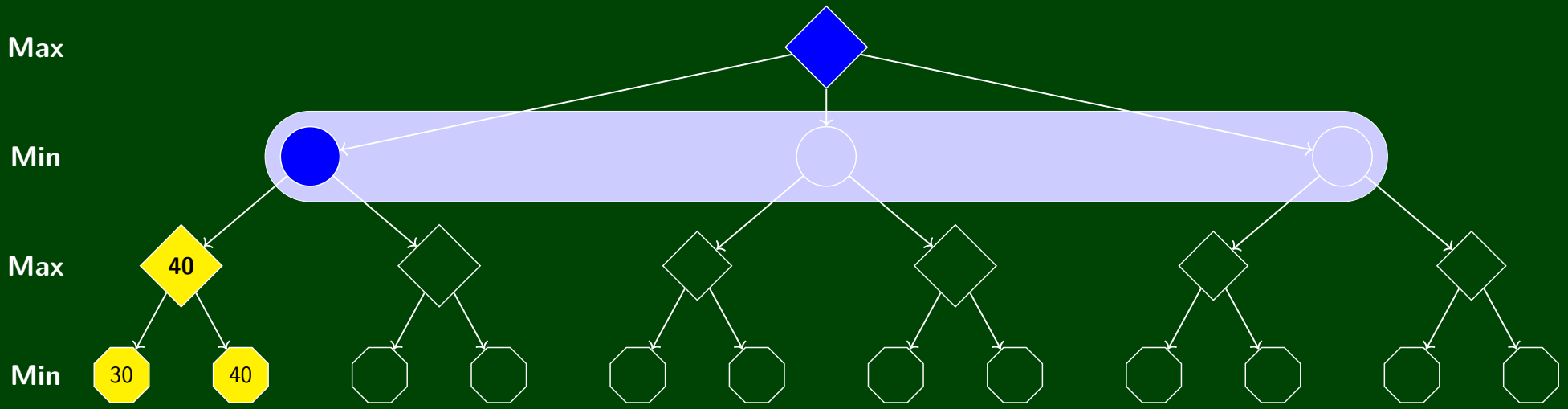

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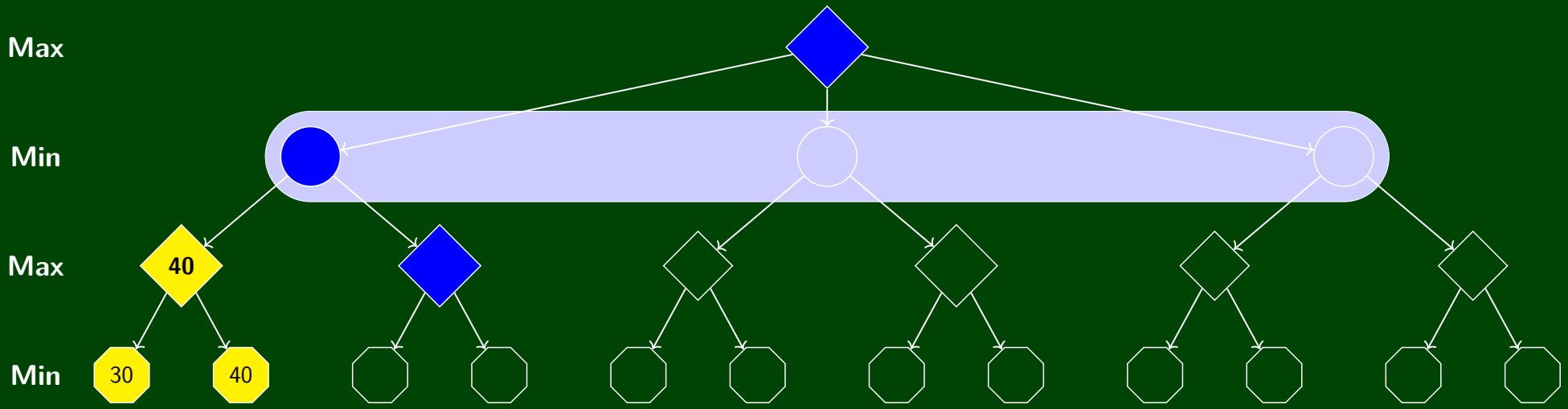
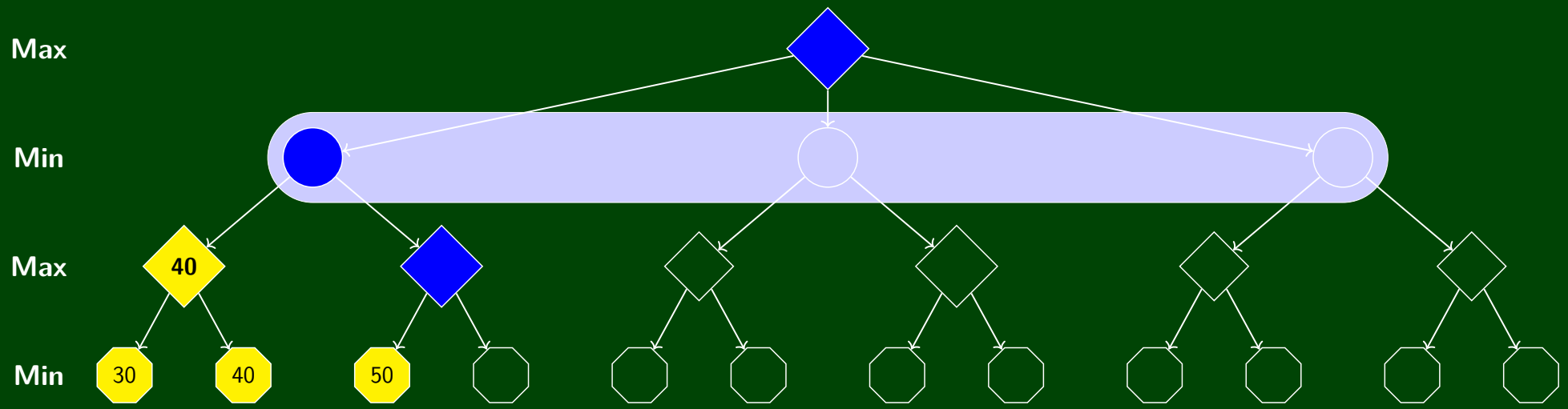


Do we check the next node?

The current bounds are $[-\infty, 40]$. So, we **might** do better!

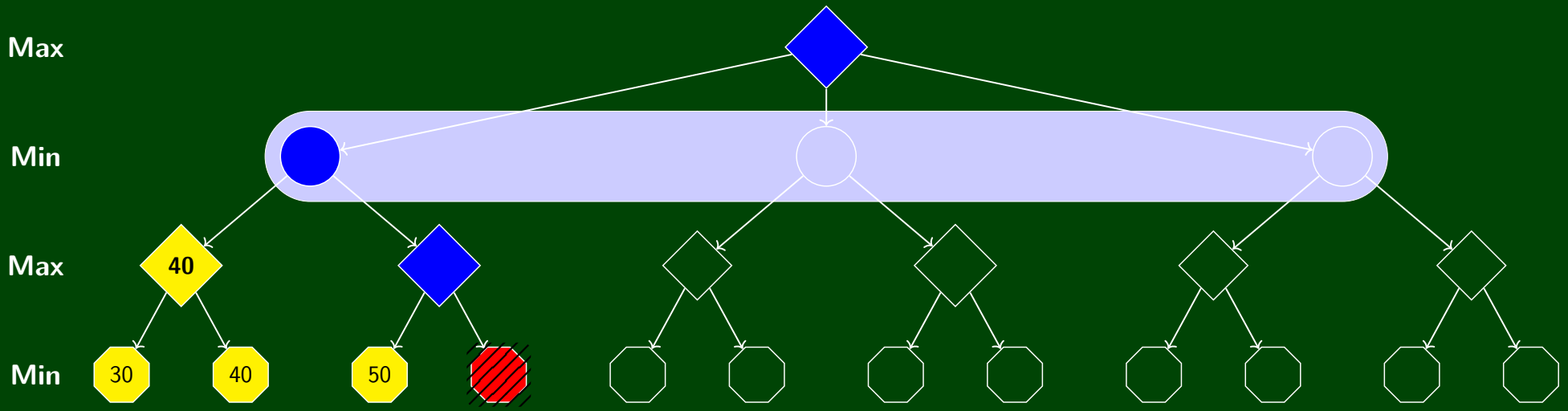


Do we check the next node?

Max will choose $x \geq 50$ which is already worse than the 40.

The current bounds are $[50, 40]$. Don't bother.

Pruning



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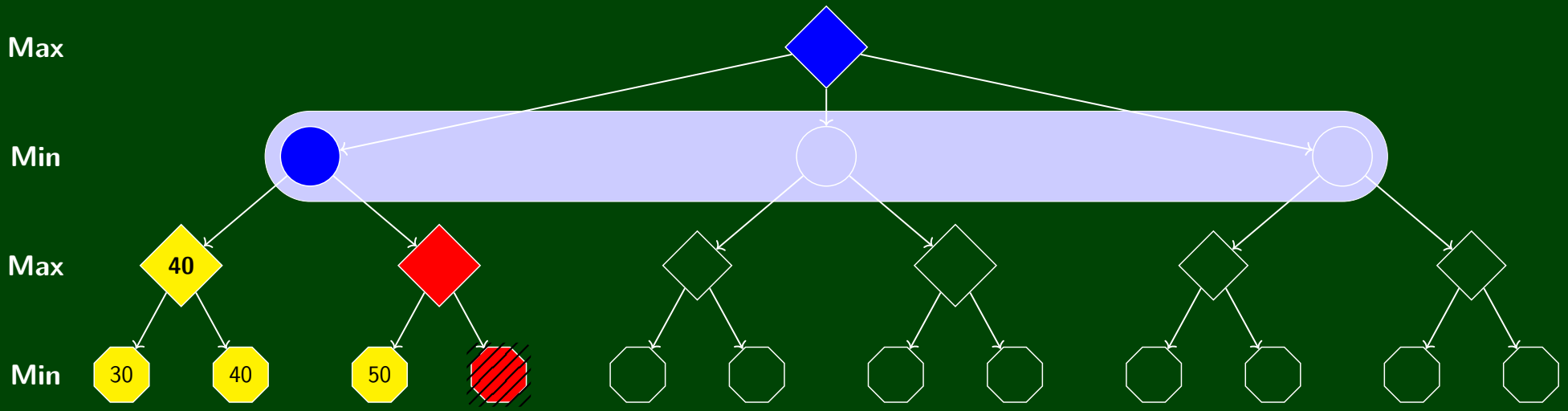

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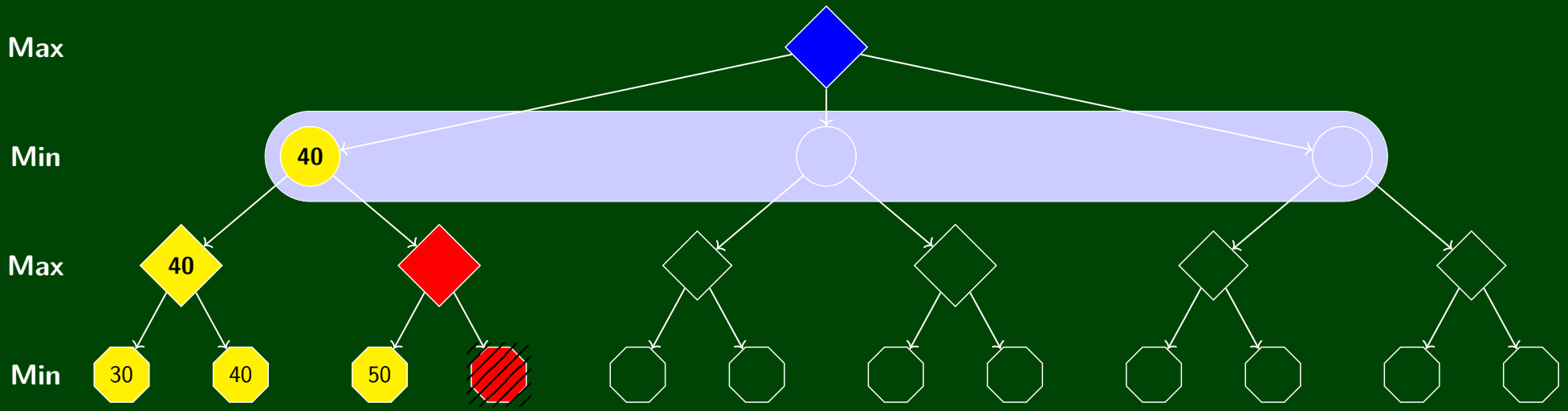

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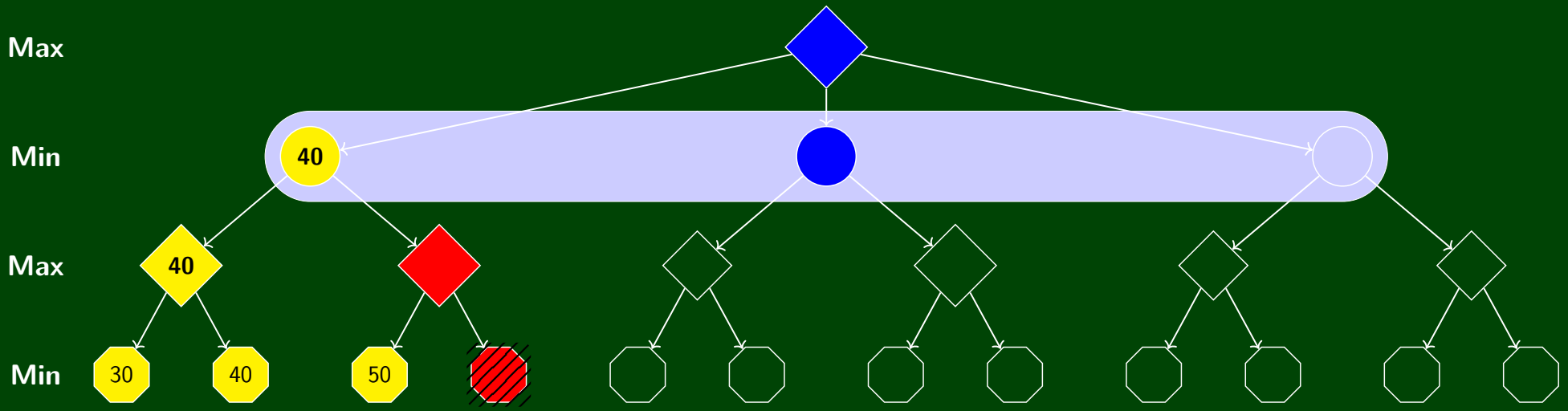

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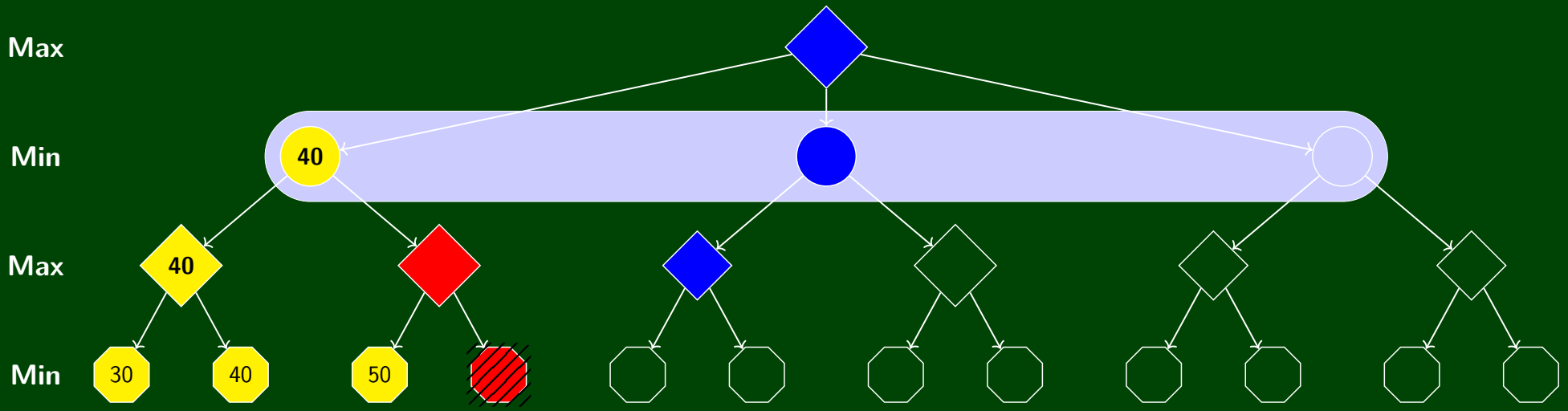

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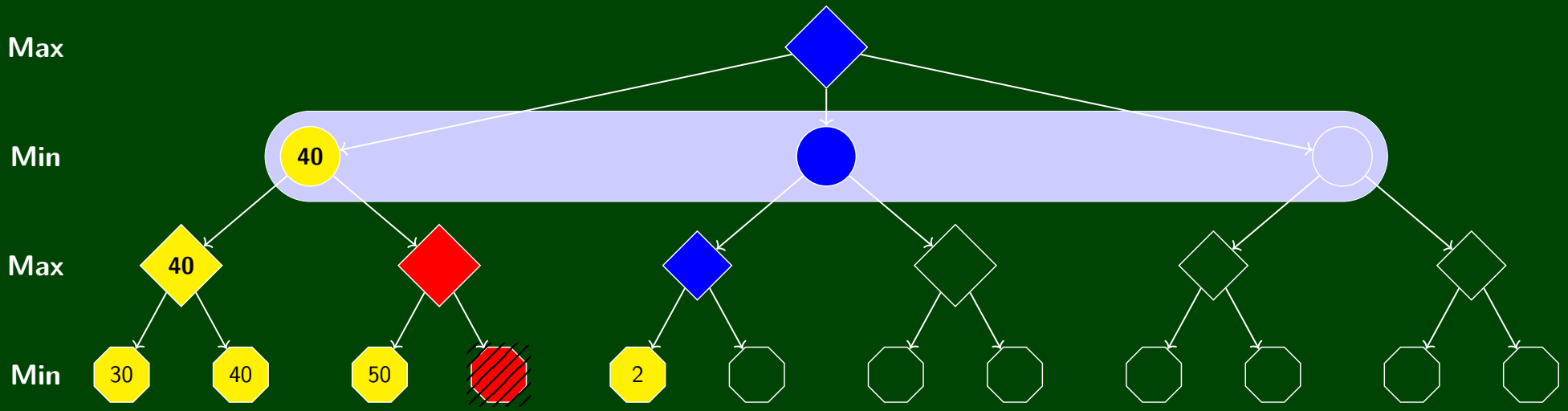

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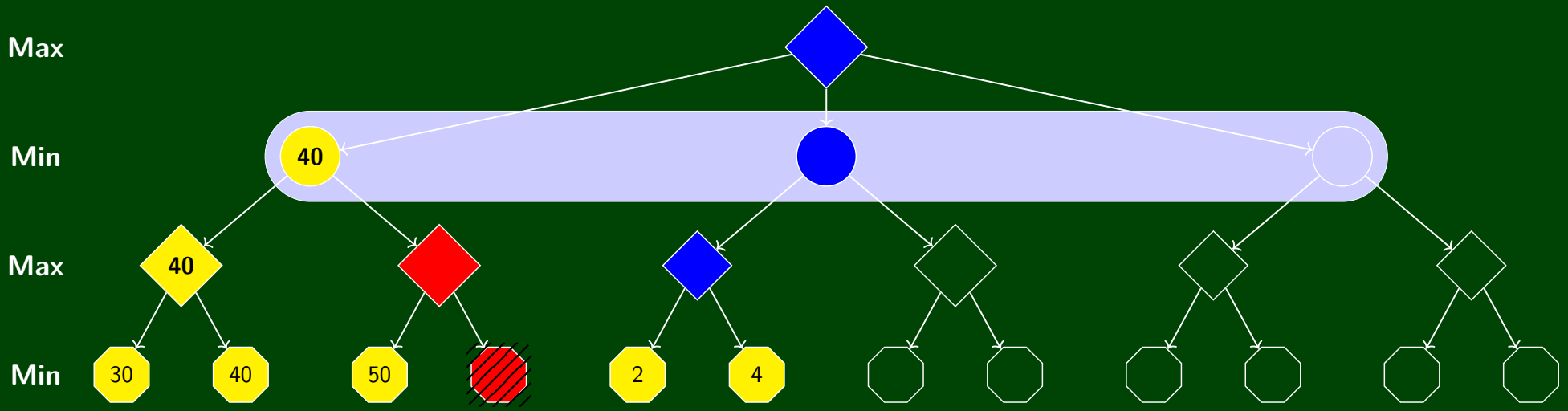

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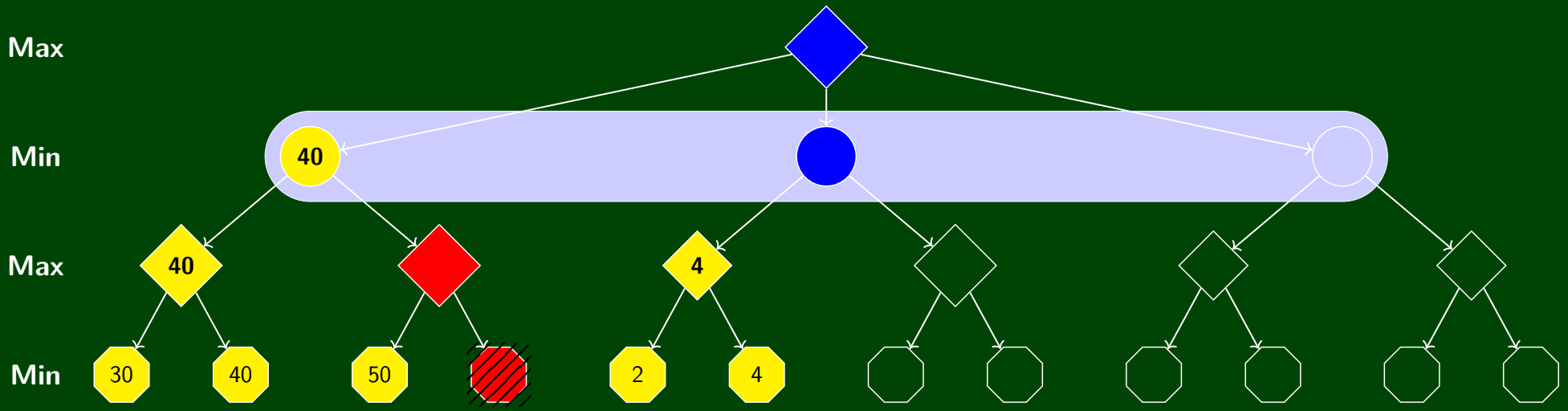

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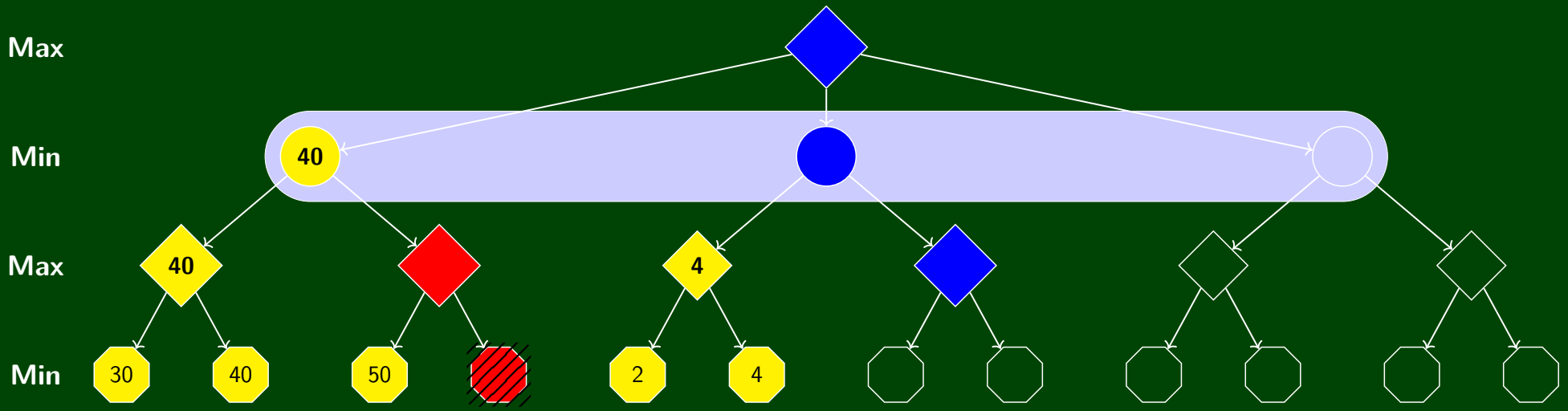
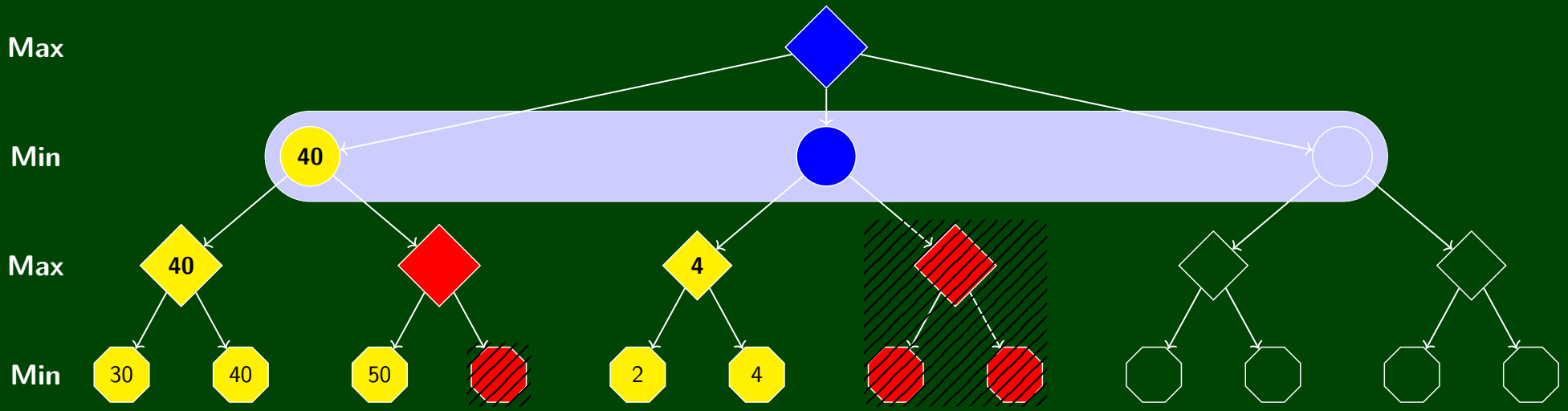


Do we check the next node?

Min will choose $x \leq 4$ which is already worse than the 40.

The current bounds are $[40, 4]$. Don't bother.

Pruning



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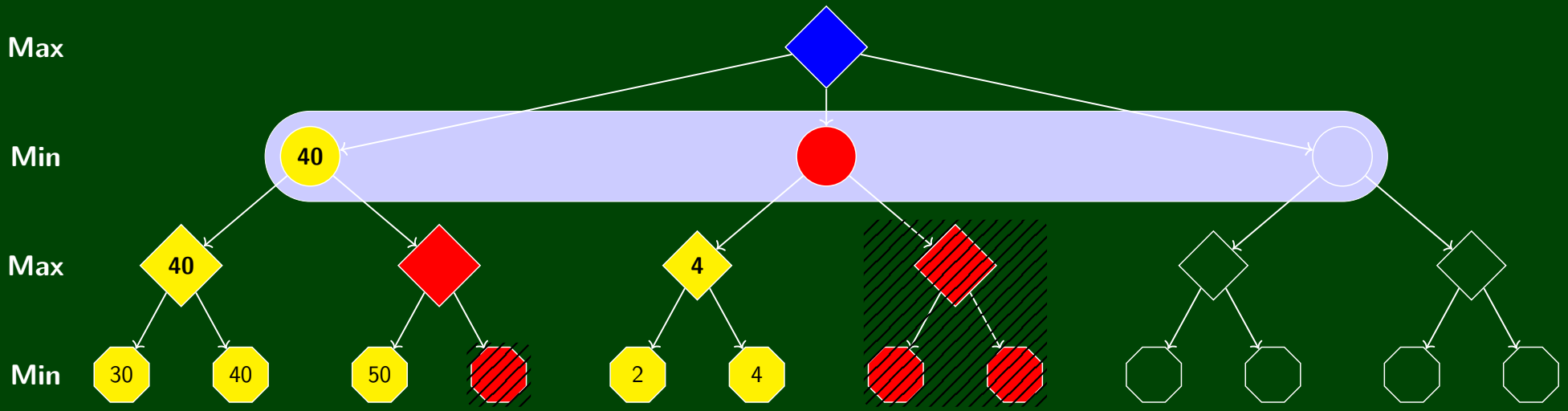

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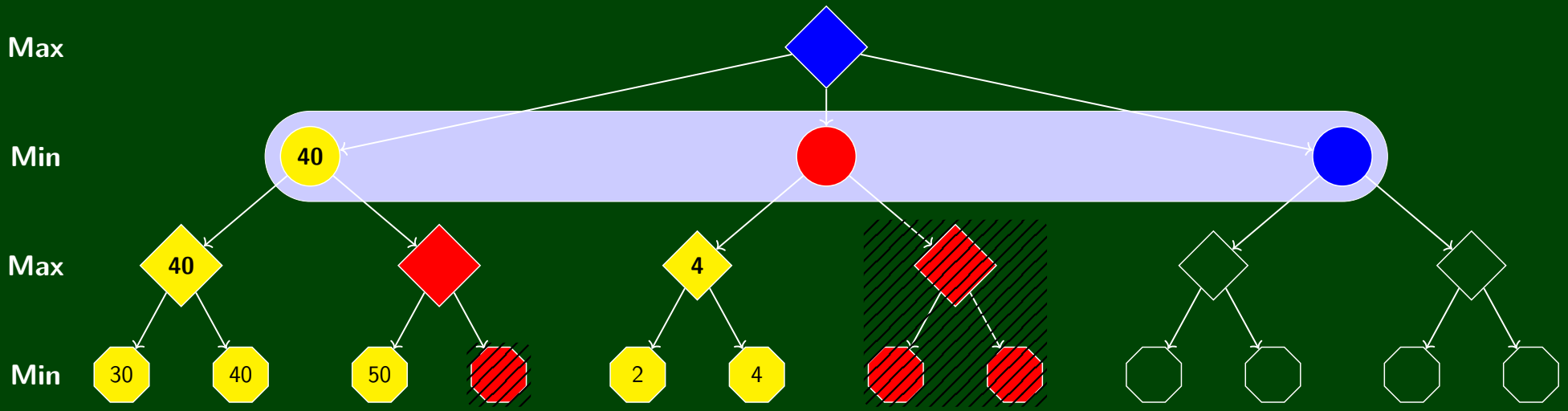

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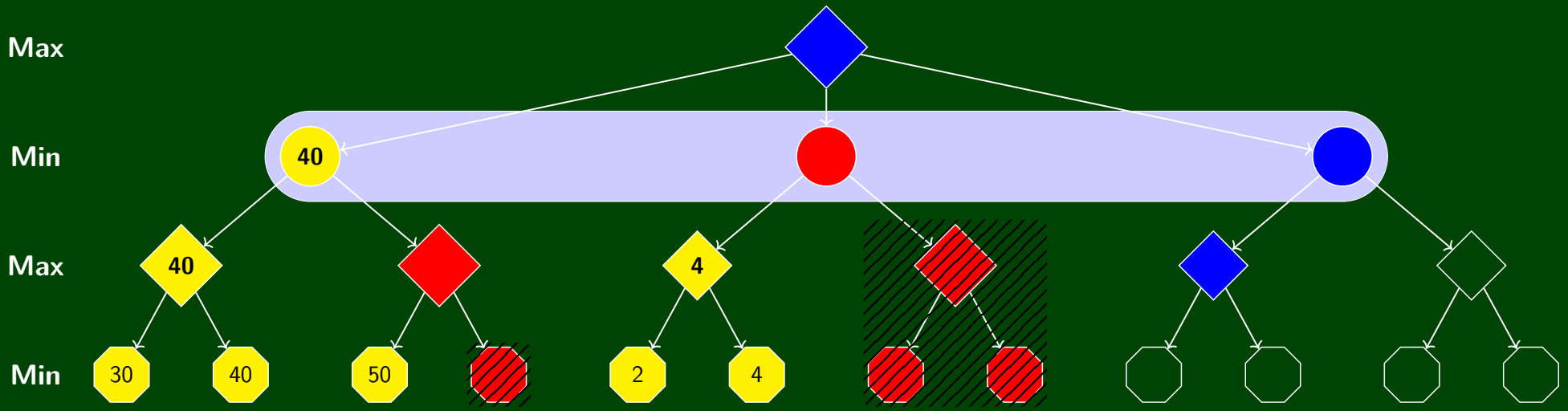

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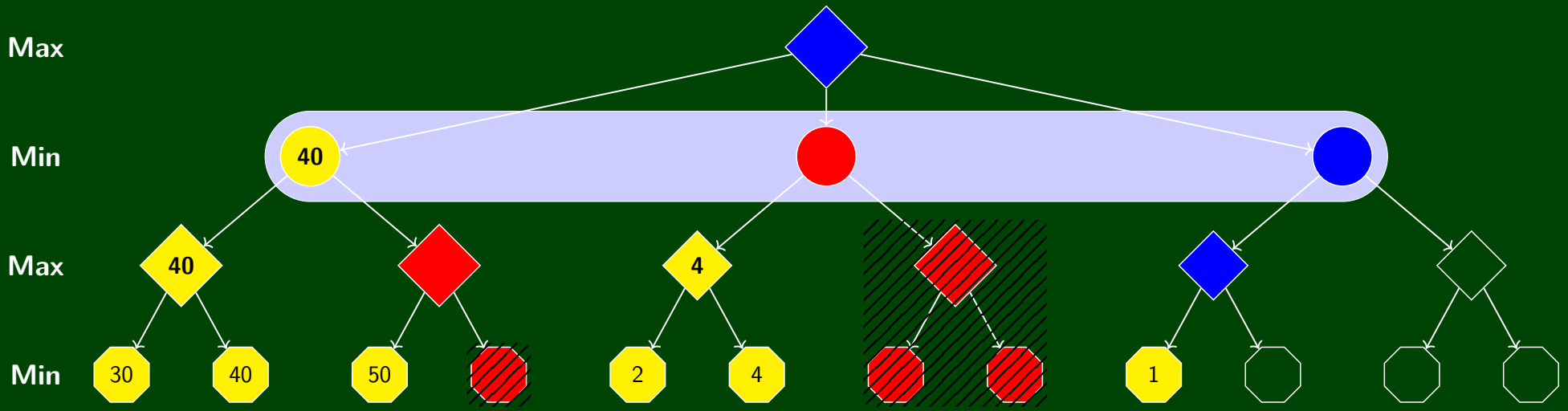

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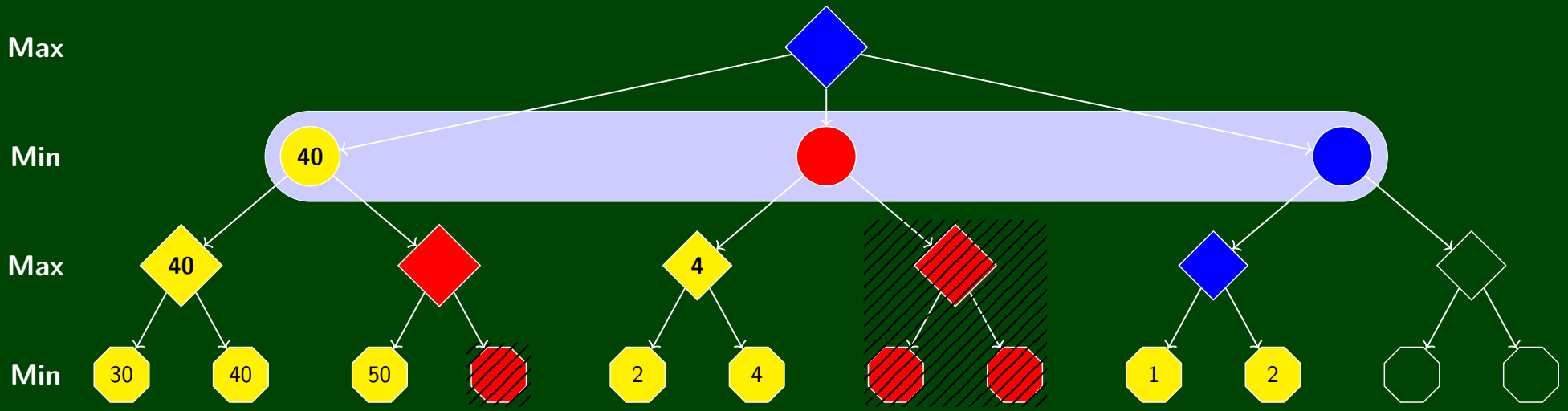

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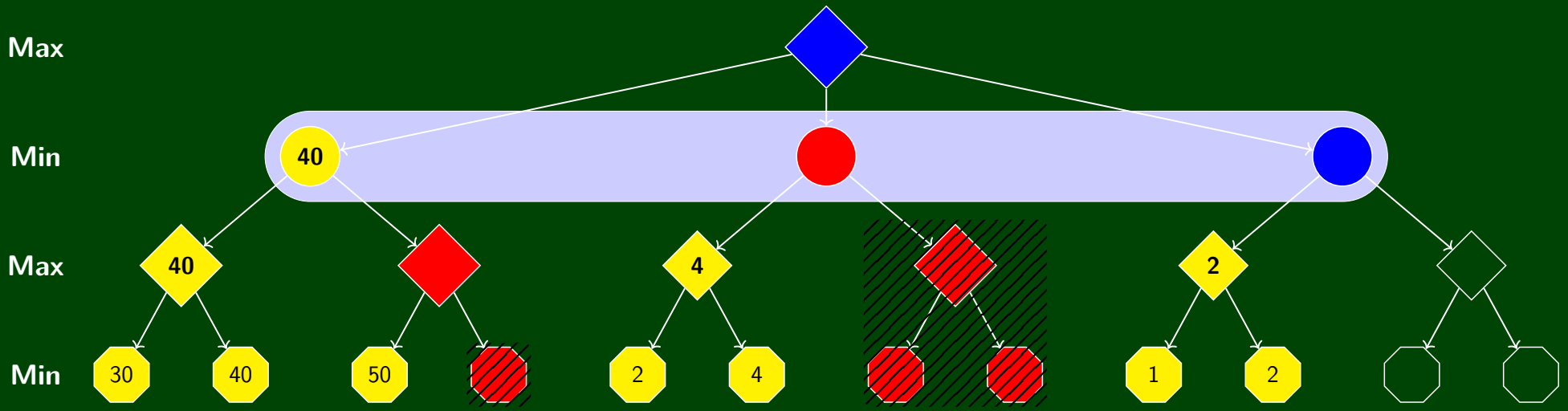

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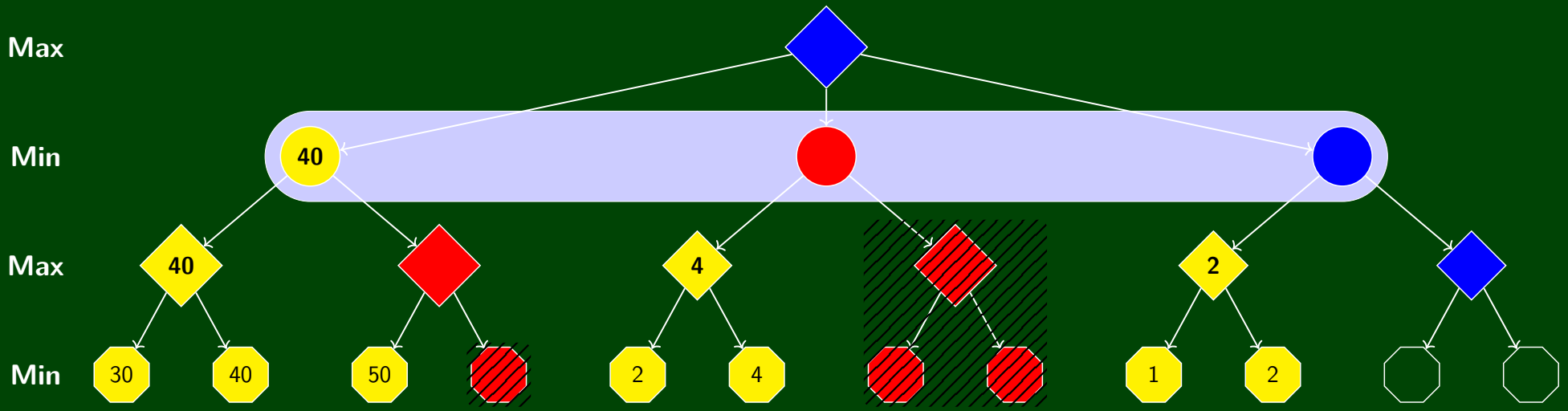

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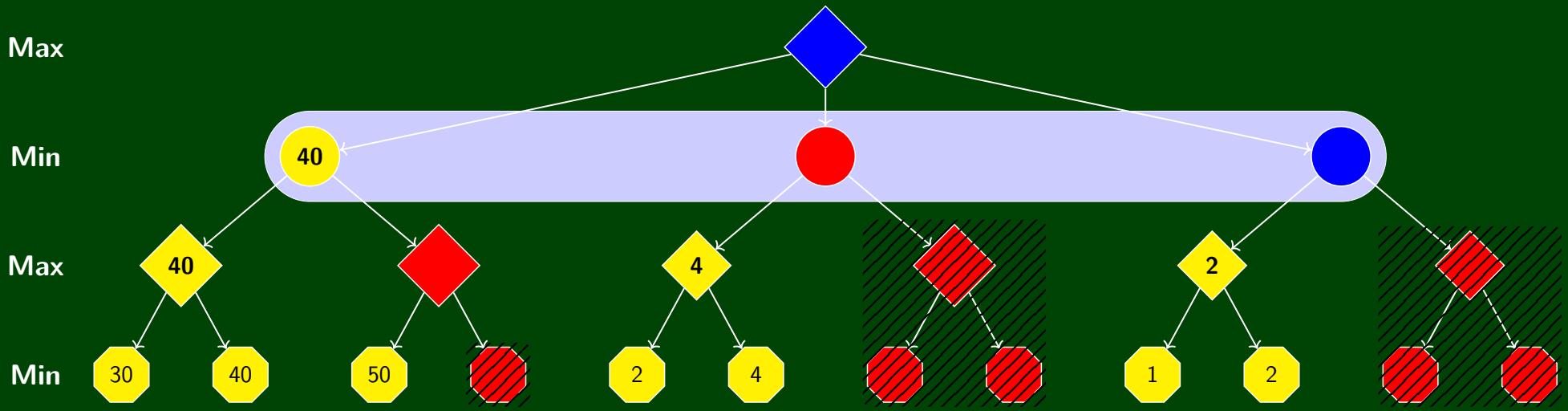

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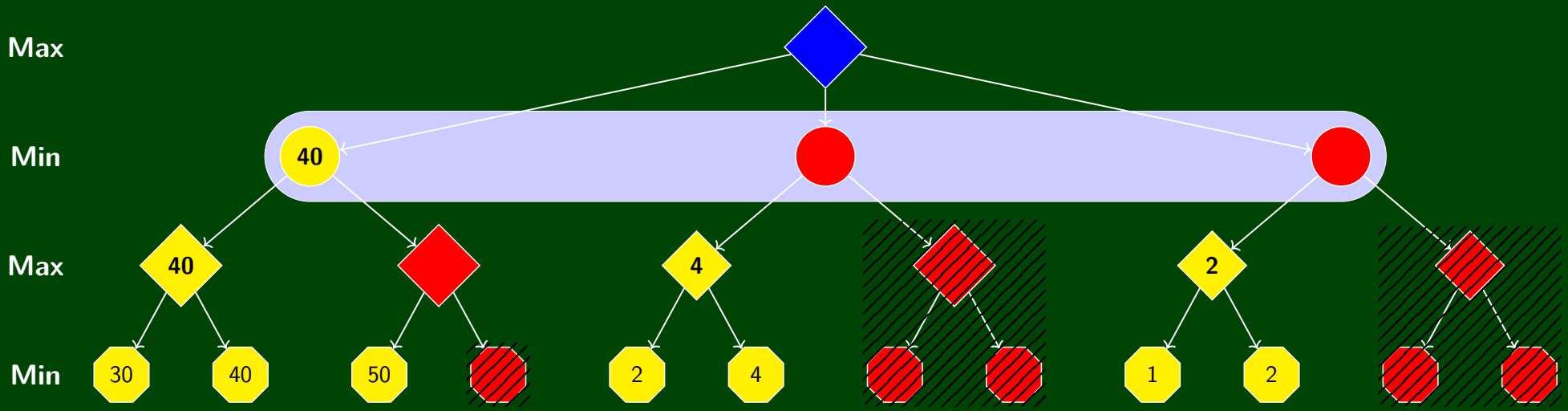

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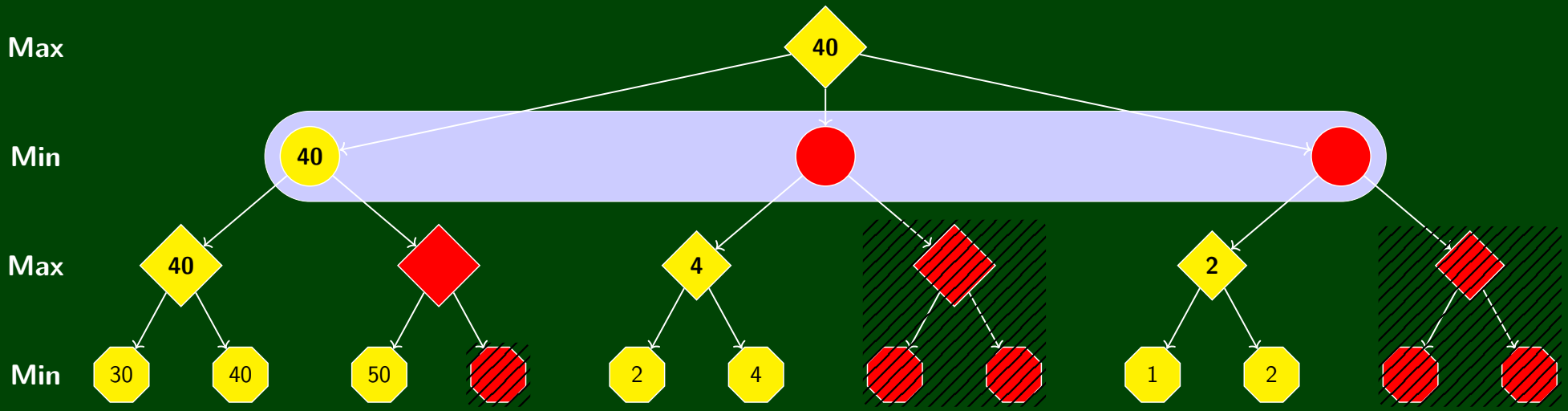
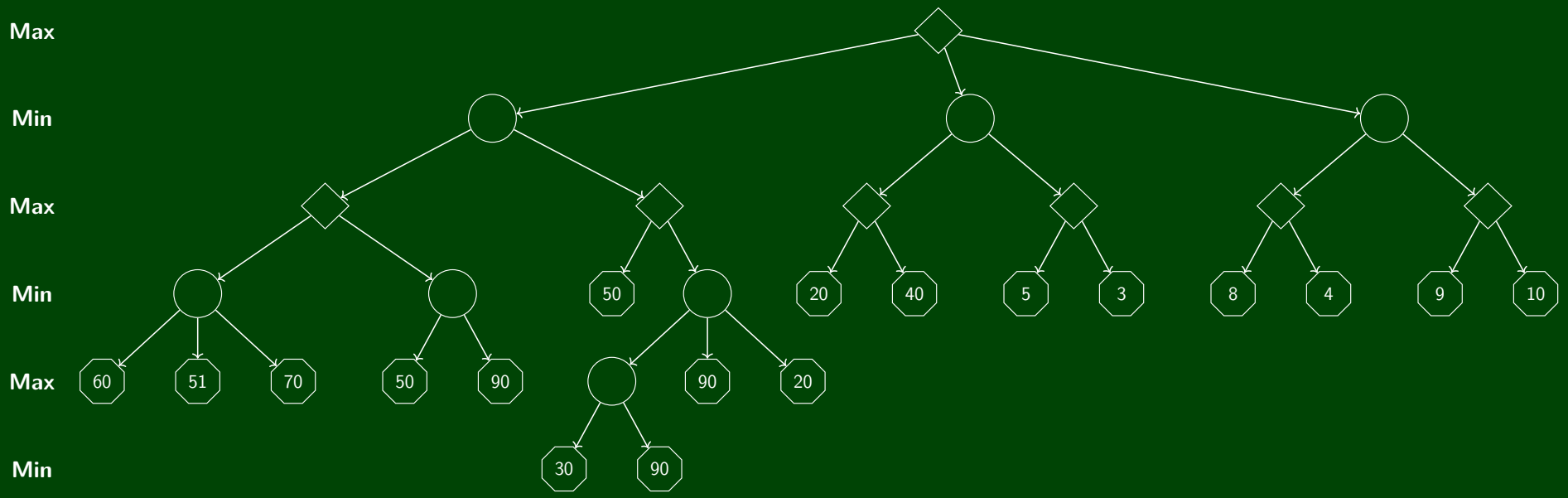


The algorithm we just ran is called **AlphaBeta**.

α is the lower bound; β is the upper bound

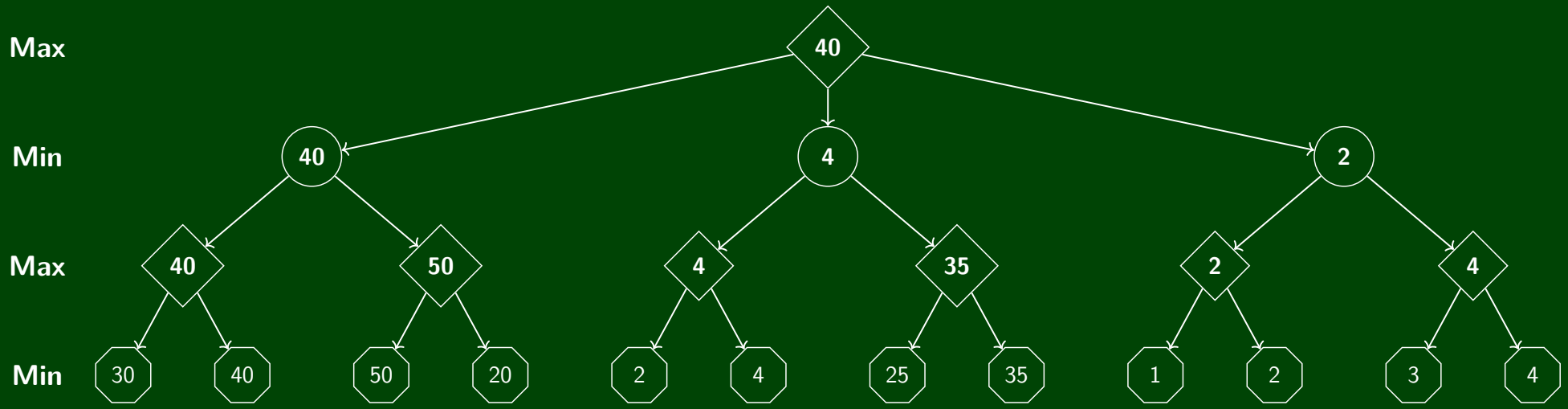
Another AlphaBeta Example

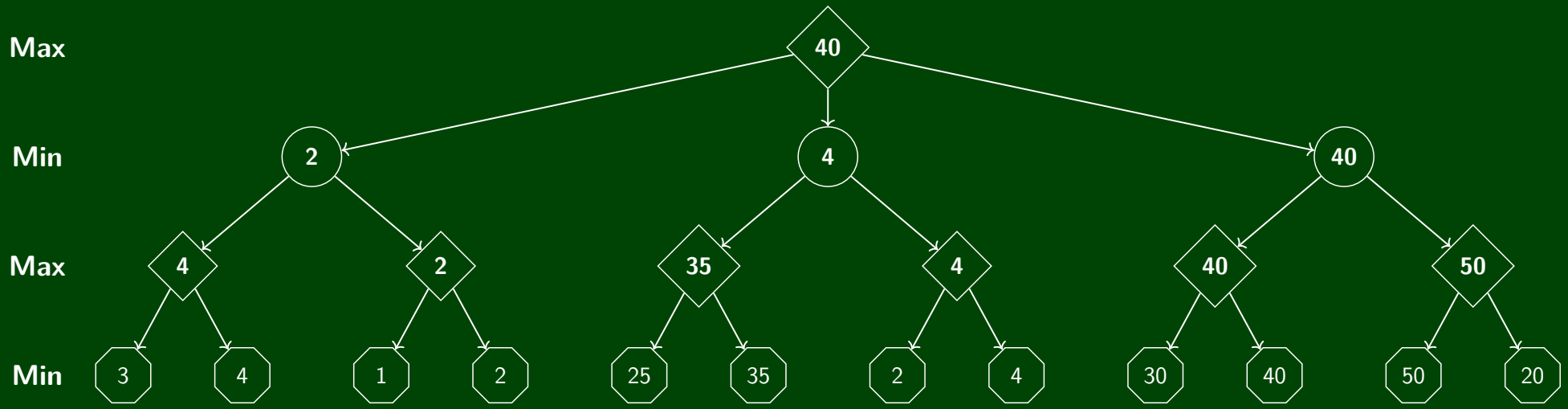


AlphaBeta Psuedocode


```
 1 int alphabeta(Position p, int alpha, int beta) {
 2    if (p.gameOver()) {
 3       return p.evaluate();
 4    }
 5
 6    for (Move m : p.getMoves()) {
 7       int value = -alphabeta(m, -beta, -alpha);
 8
 9       // If value is between alpha and beta, we've
10       // found a new lower bound
11       if (value > alpha) {
12          alpha = value;
13       }
14
15       // If the value is bigger than beta, we won't
16       // actually be able to get this move
17       if (alpha >= beta) {
18          return alpha;
19       }
20    }
21
22    // Return the best achievable value
23    return alpha;
24 }
```

Move Ordering





A **branching factor** is how many times a node splits at each level. In Othello, for a random position, the average branching factor is:

10

The average Othello game lasts about

58 Moves

If we wanted to evaluate the whole game, we would be evaluating 10^{58} **leaves**. If we were able to evaluate **1 trillion** leaves a second, we would need 10^{46} seconds.

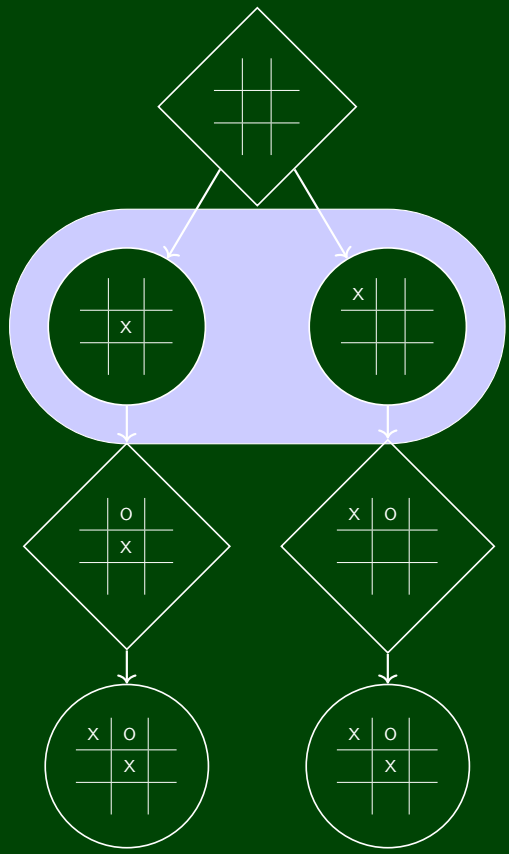
Depth-Limited Search

X's Turn

O's Turn

X's Turn

O's Turn



Zobrist Hashing