Othello AI Tournament!

CS2: Intro. to Programming Methods
Weeks 9-10
Wednesday, March 9, 2016

Administrative notes

- Next assignment is due Tuesday, March 15 at 17:00
- Tournament cutoff is Monday, March 14, at 23:59
  - TAs need some time to set things up
  - We may accept tournament submissions after that, but there's no guarantee

Administrative notes

- The tournament itself will be held in Annenberg 104 (the lab)
- Tournament starts Tuesday March 17 in the afternoon
- The games themselves will be displayed on the lab computers as they are played
- Come by and watch!

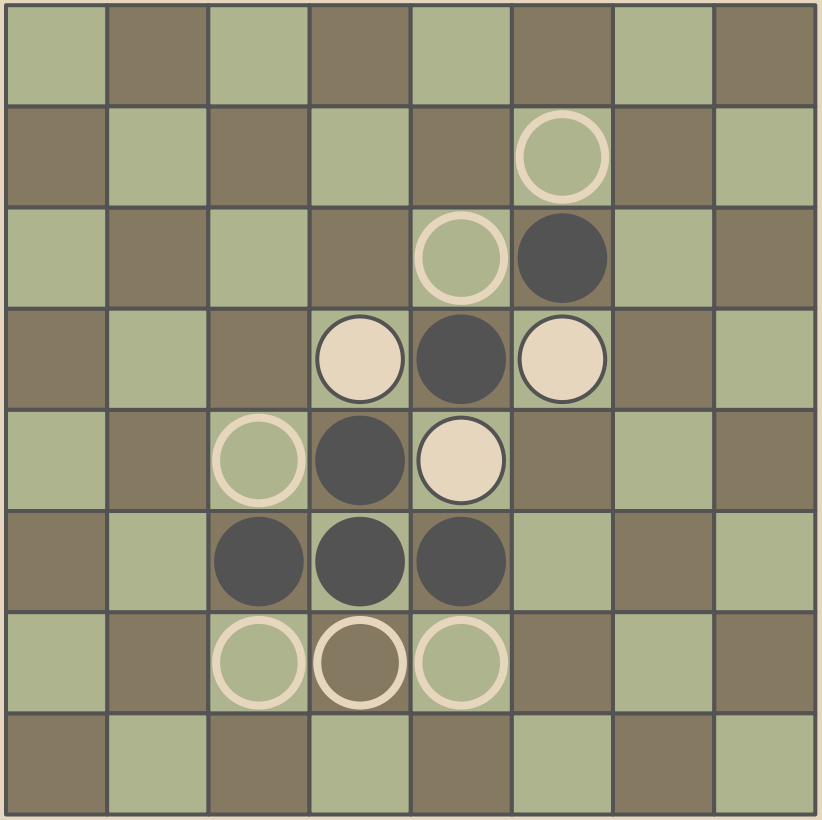
Othello++: additional considerations

- Board
  - Bitboards
  - You’re on your own for this one...
- Evaluation
- Search

Othello++: additional considerations

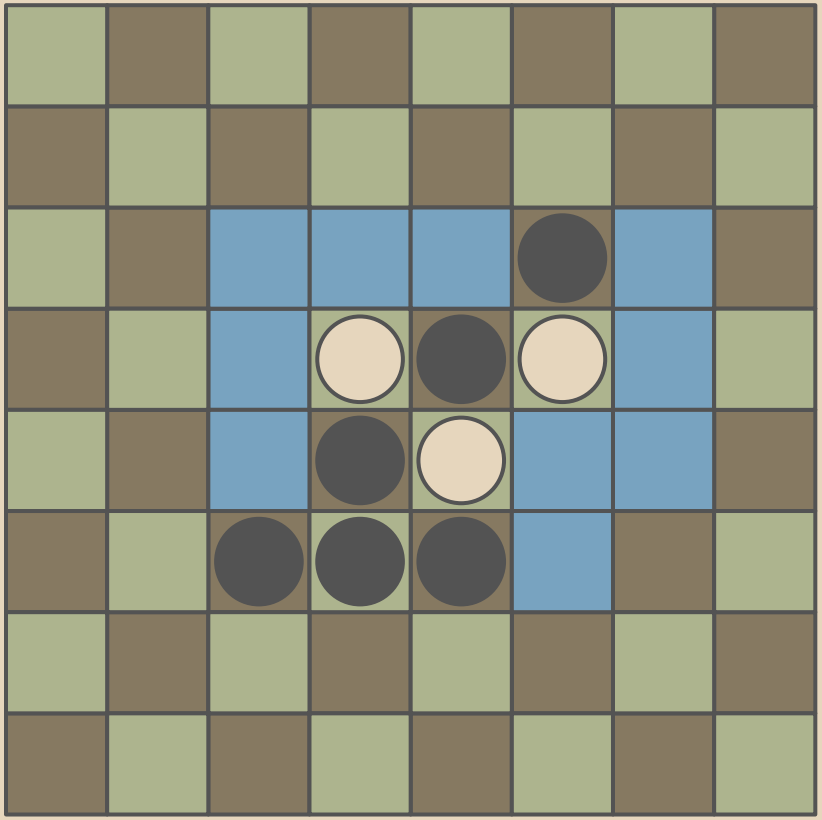
- Mobility
- Frontier squares
- Alpha-beta pruning
  - Move ordering
- Transposition tables
- Iterative deepening
- Opening books
- Endgame solver

Mobility



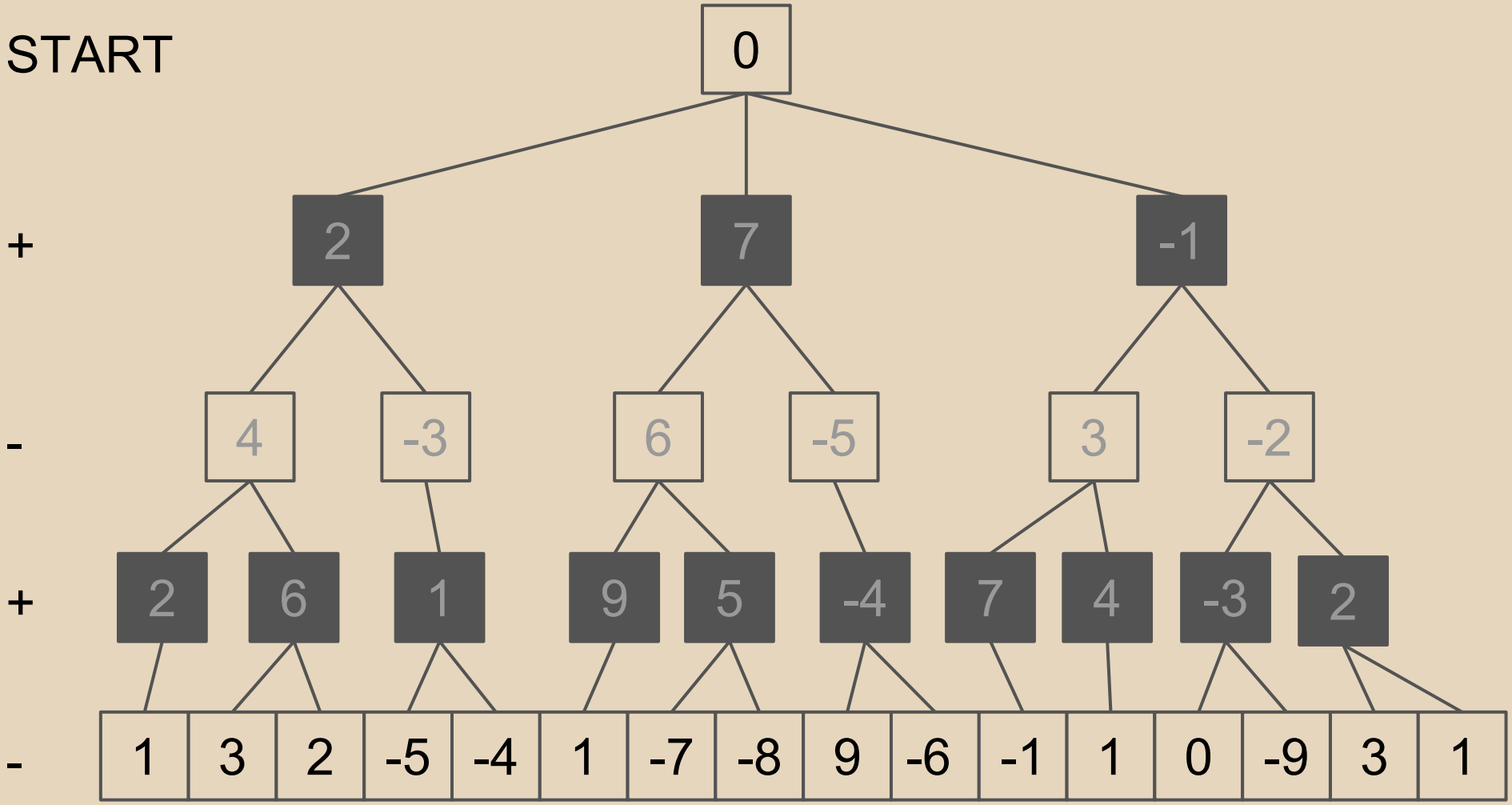
- The number of moves available
- Generally a good thing
  - more choices = better chance of a good choice
  - maximize for self
  - minimize for the other player
- Slow to calculate, but very important!

Frontier squares



- The number of open squares adjacent to our own pieces
- Generally bad for us
  - more frontier squares = more potential points for attack
  - minimize for self
  - maximize for opponent

Minimax again!



Alpha-beta pruning

- We can do better than exhaustive search.
- Store two numbers (alpha and beta) for each node as we're doing our depth-first search
  - Alpha: the maximum score we are assured of so far
  - Beta: the minimum score our opponent is assured of so far
- Note: minimax is alpha-beta with no beta

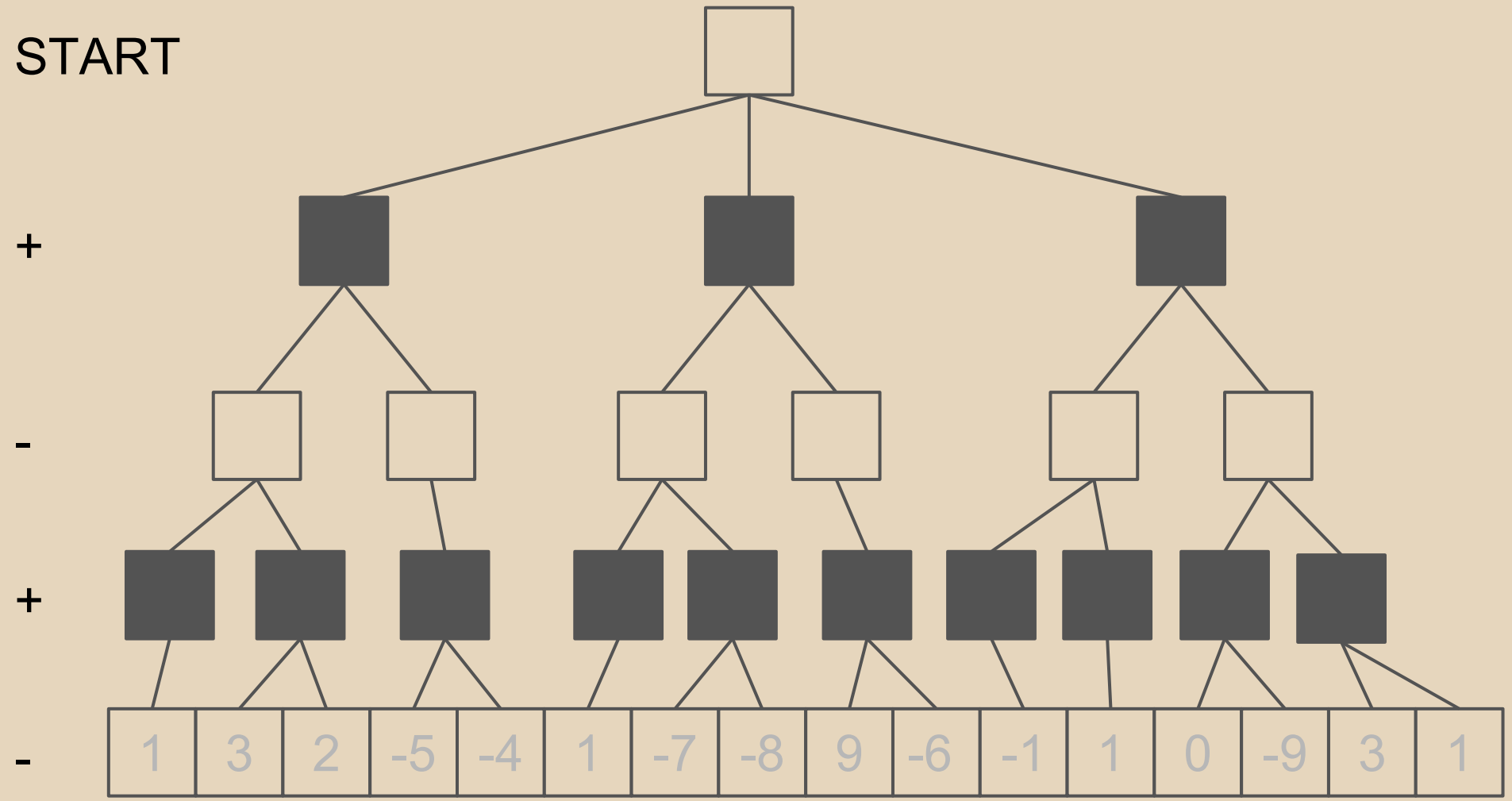
Alpha-beta pruning

- What if we can make a move such that alpha > beta?
  - Then the opponent should never have let us get here in the first place
- What if opponent can make a move such that beta < alpha?
  - Then we should never have let the opponent get there in the first place
- In either case, we can stop evaluating the current subtree

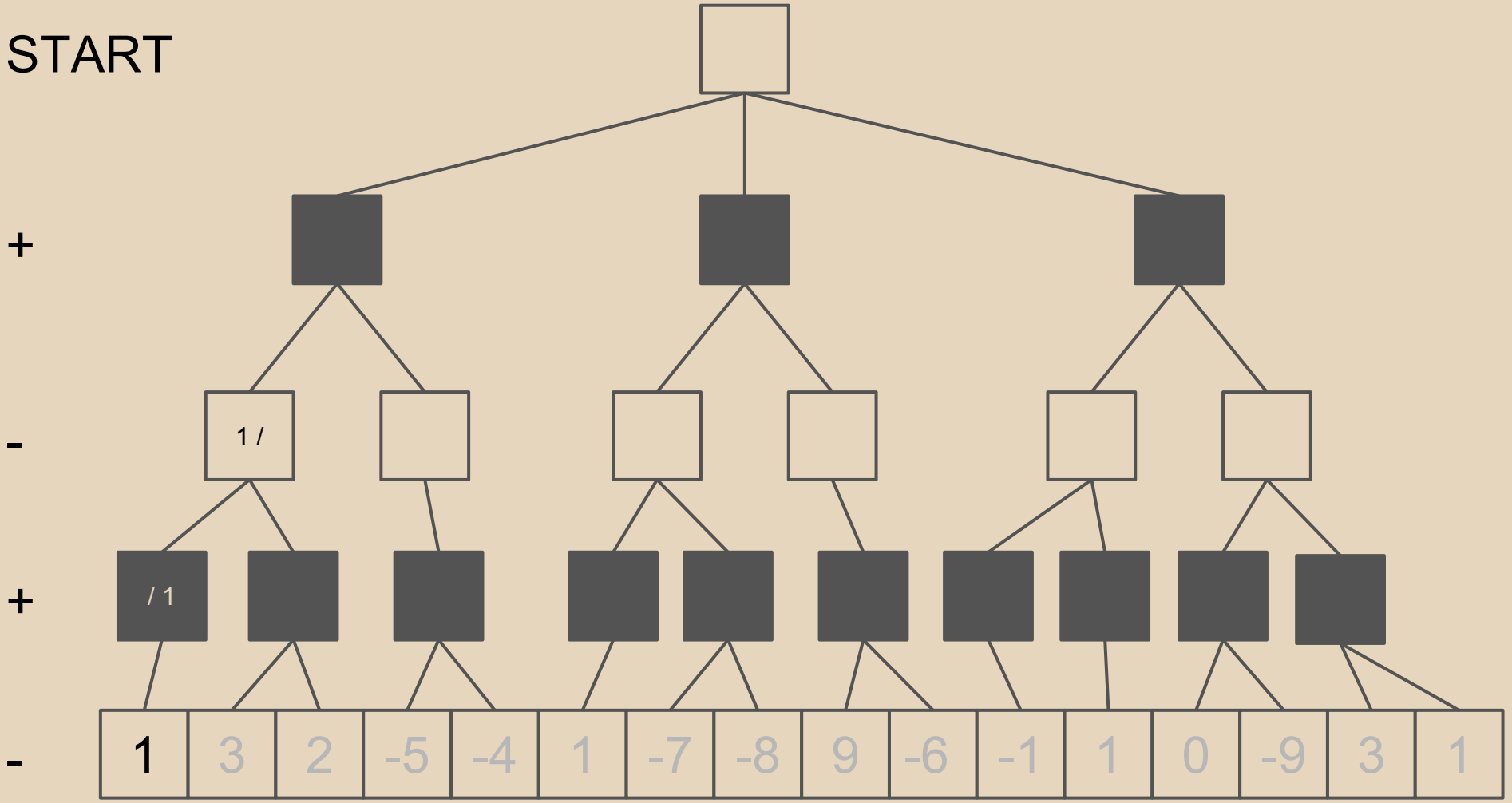
Computing alpha-beta in practice

- My turn?
  - I'm trying to maximize
  - Return alpha = max(alpha, beta $\forall$ children)
- Opponent's turn?
  - Opponent wants to minimize
  - Return beta = min(beta, alpha $\forall$ children)
- Recursive algorithm
  - If it's my turn for a given node, it's the opponent's turn for all the children
  - Inherit alpha/beta values from parent
  - Base case: bottom of tree (where value is given)
  - Initial call: alpha, beta = INFINITY

Alpha-beta example



Now start searching...



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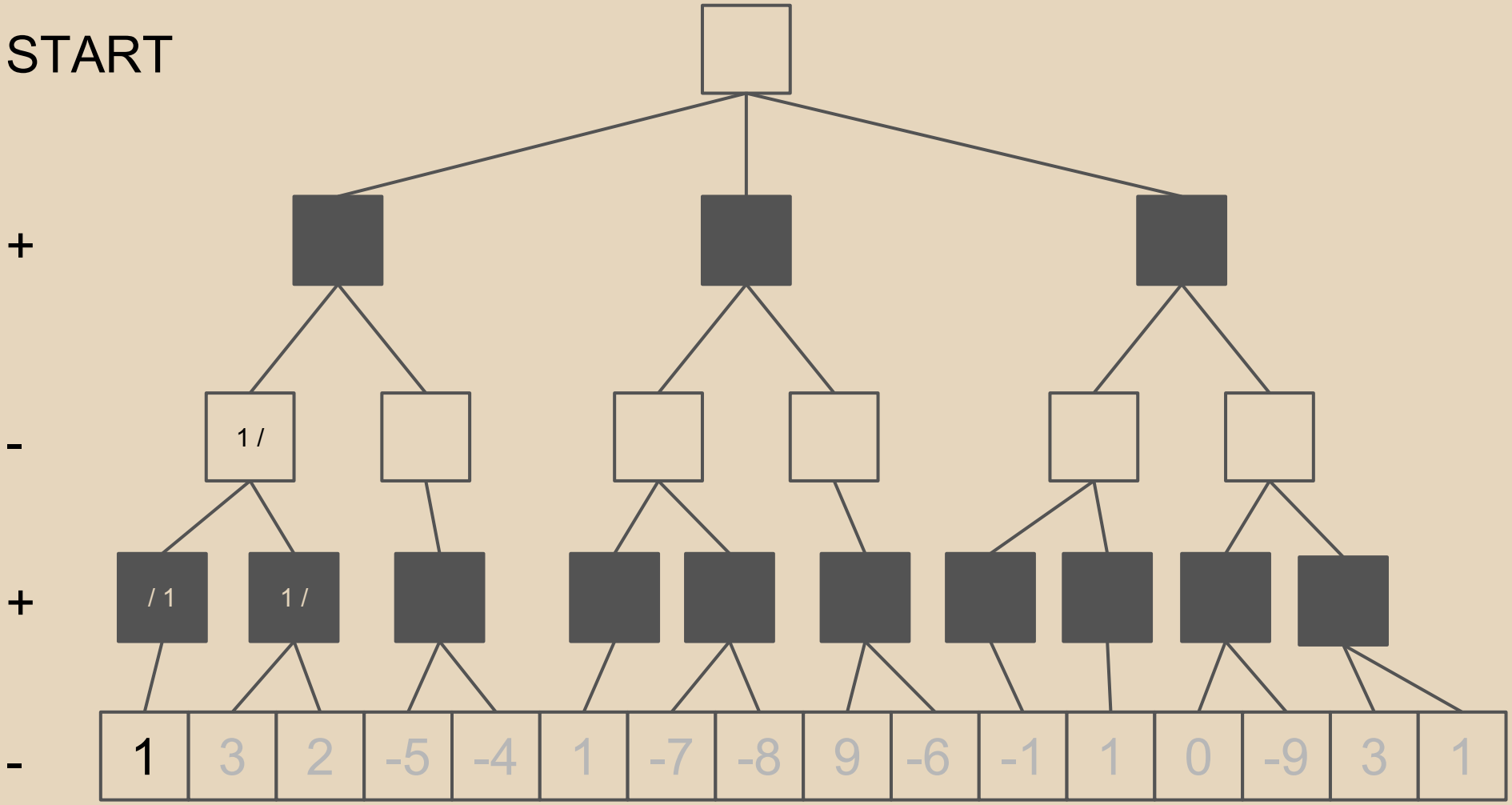

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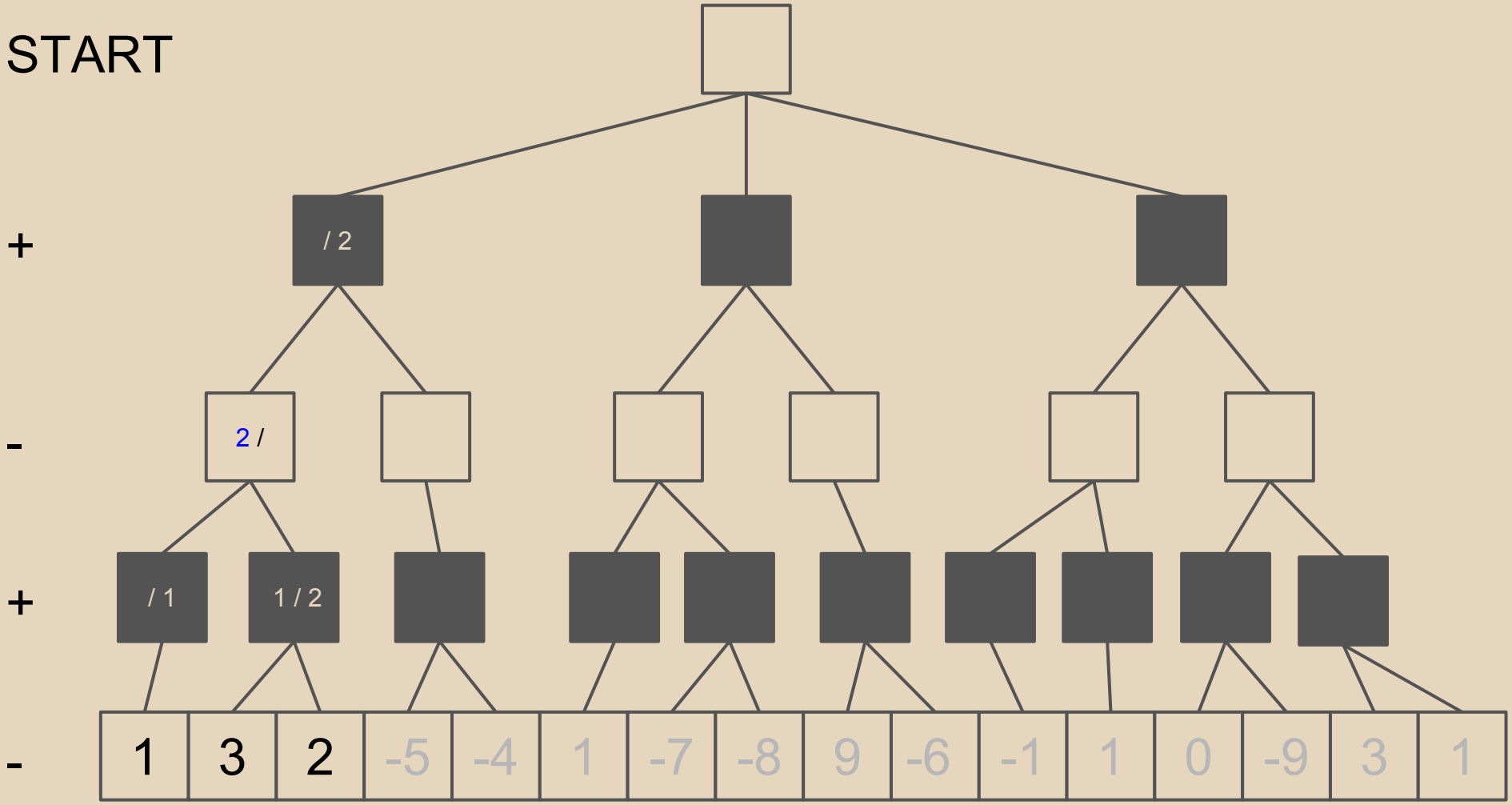

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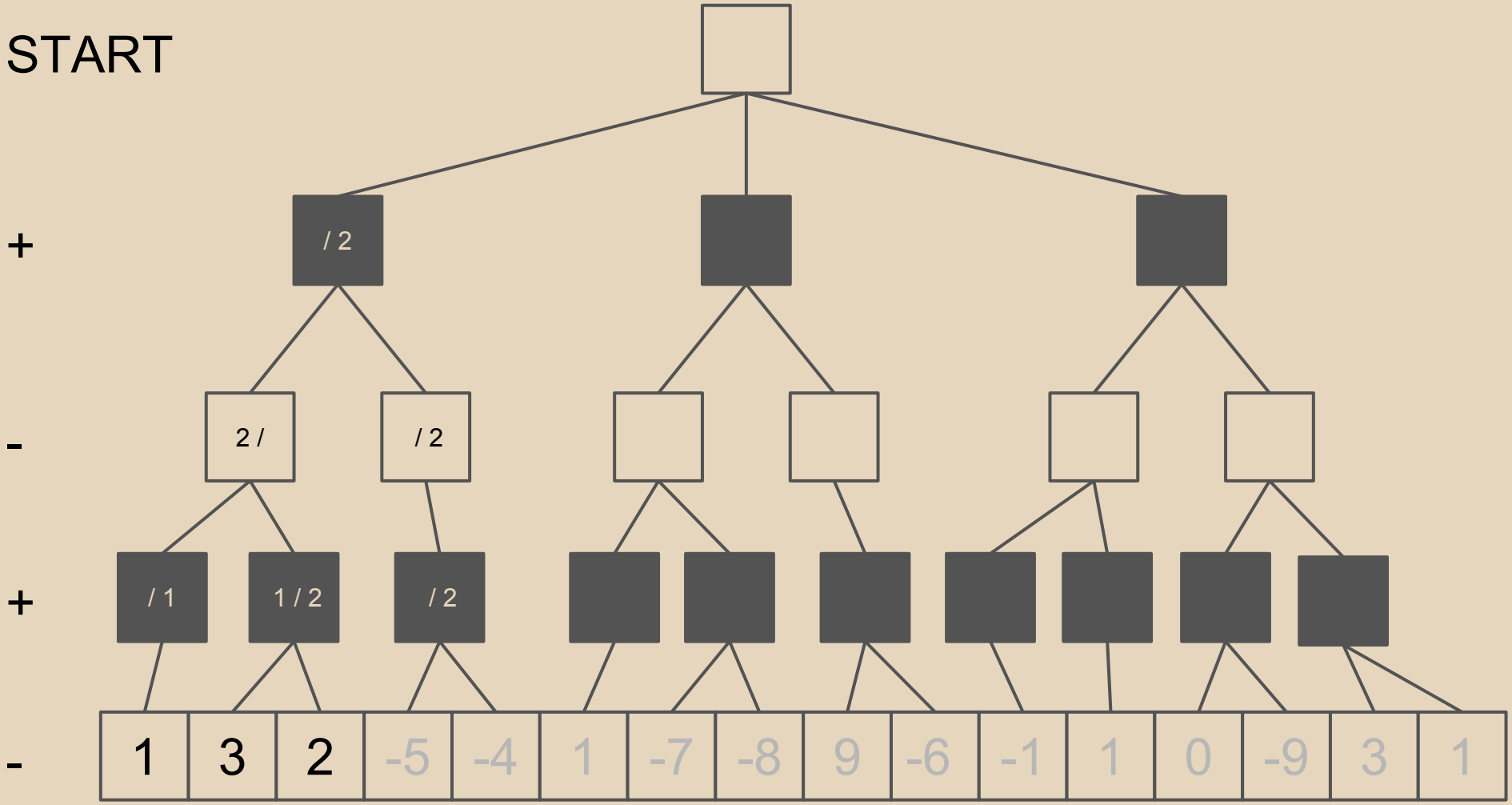

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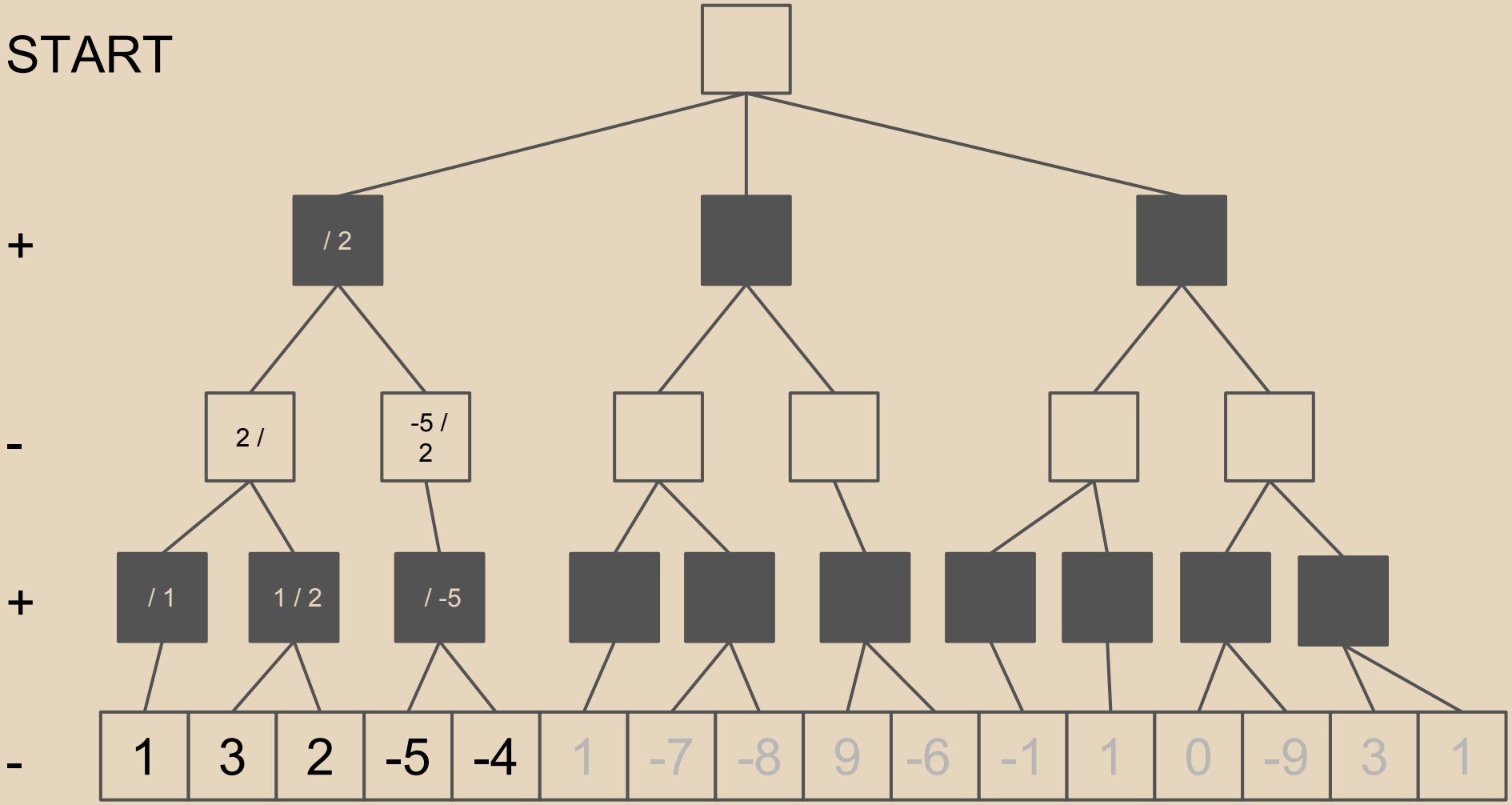

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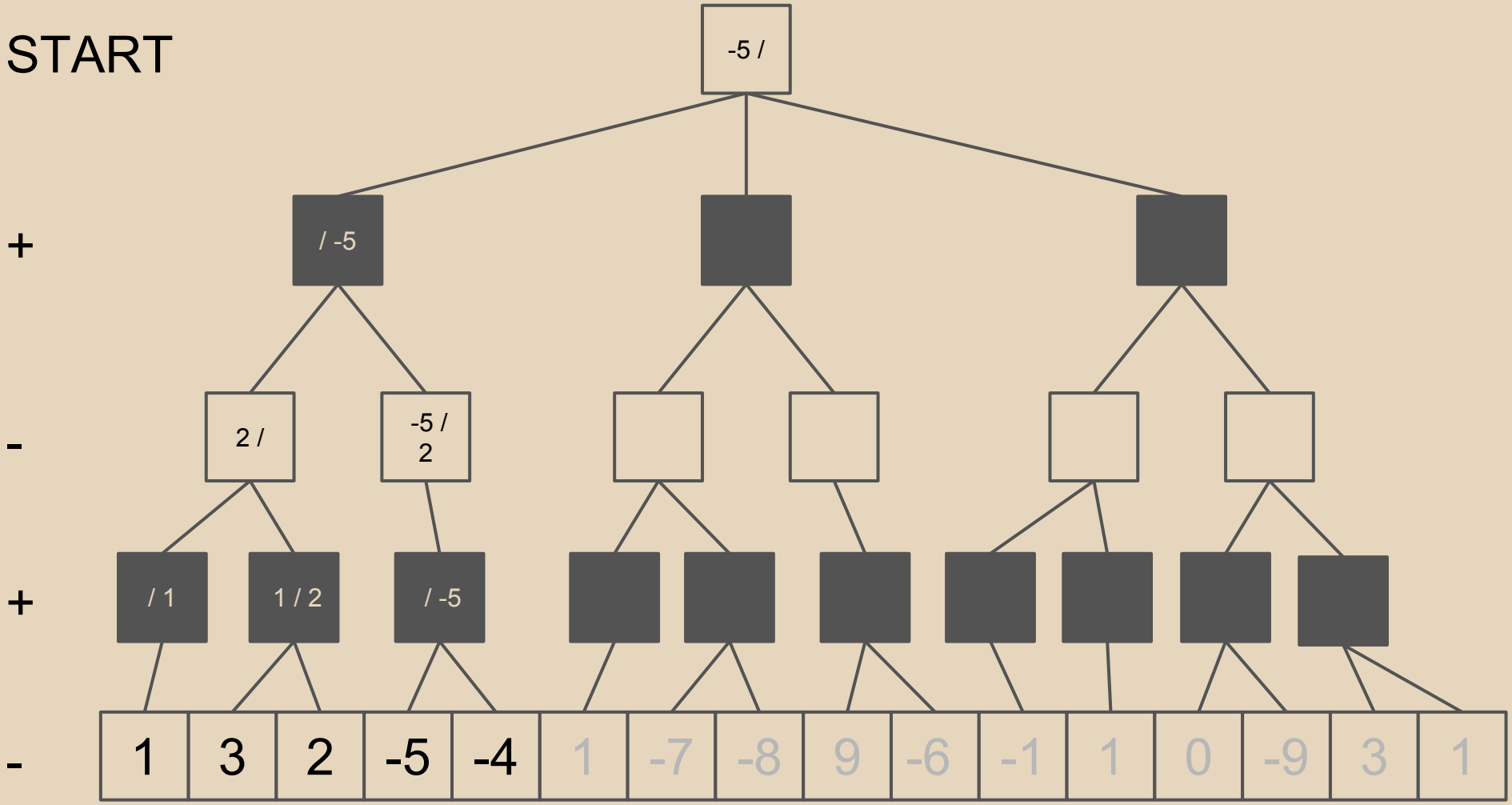

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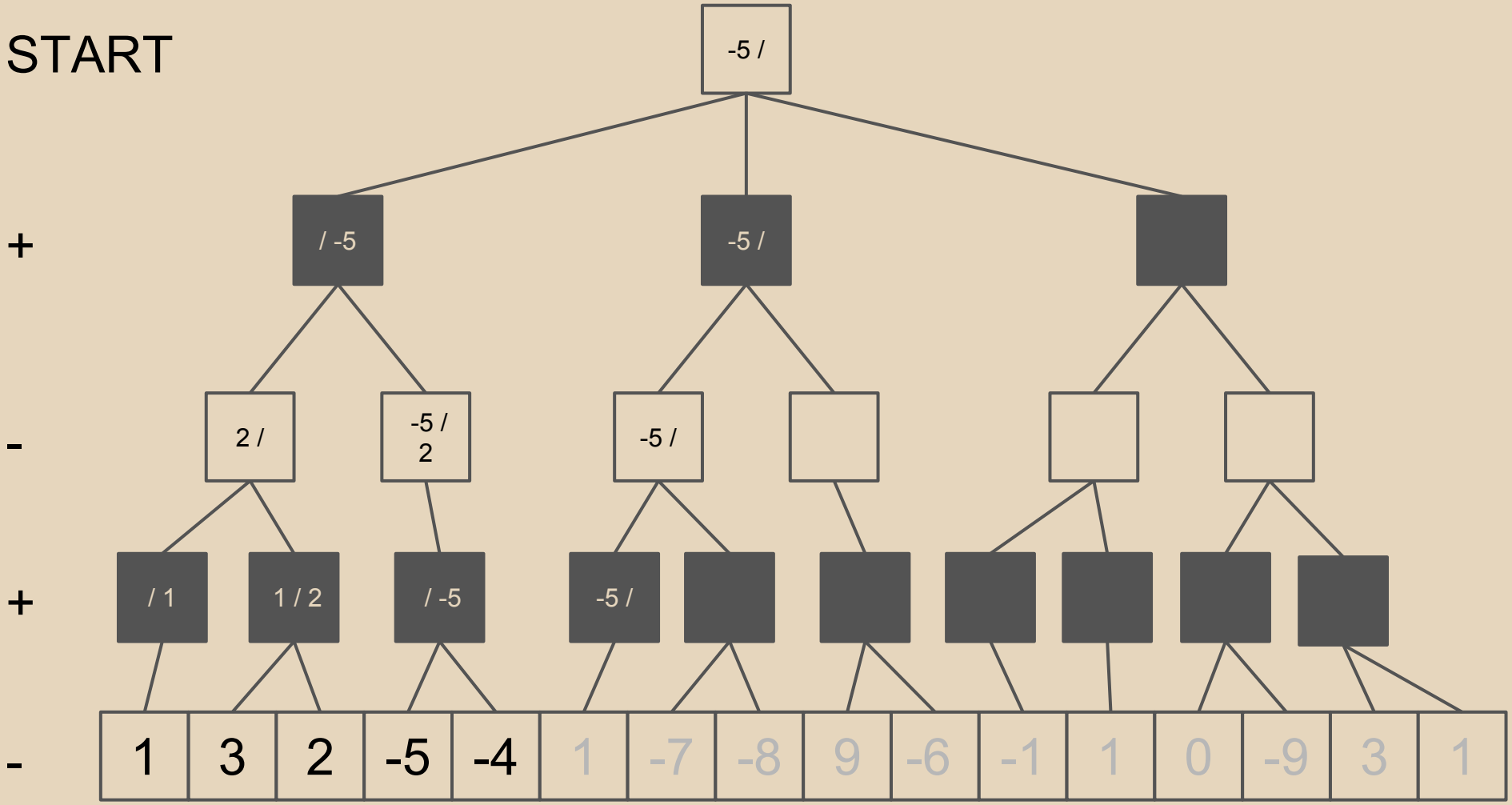

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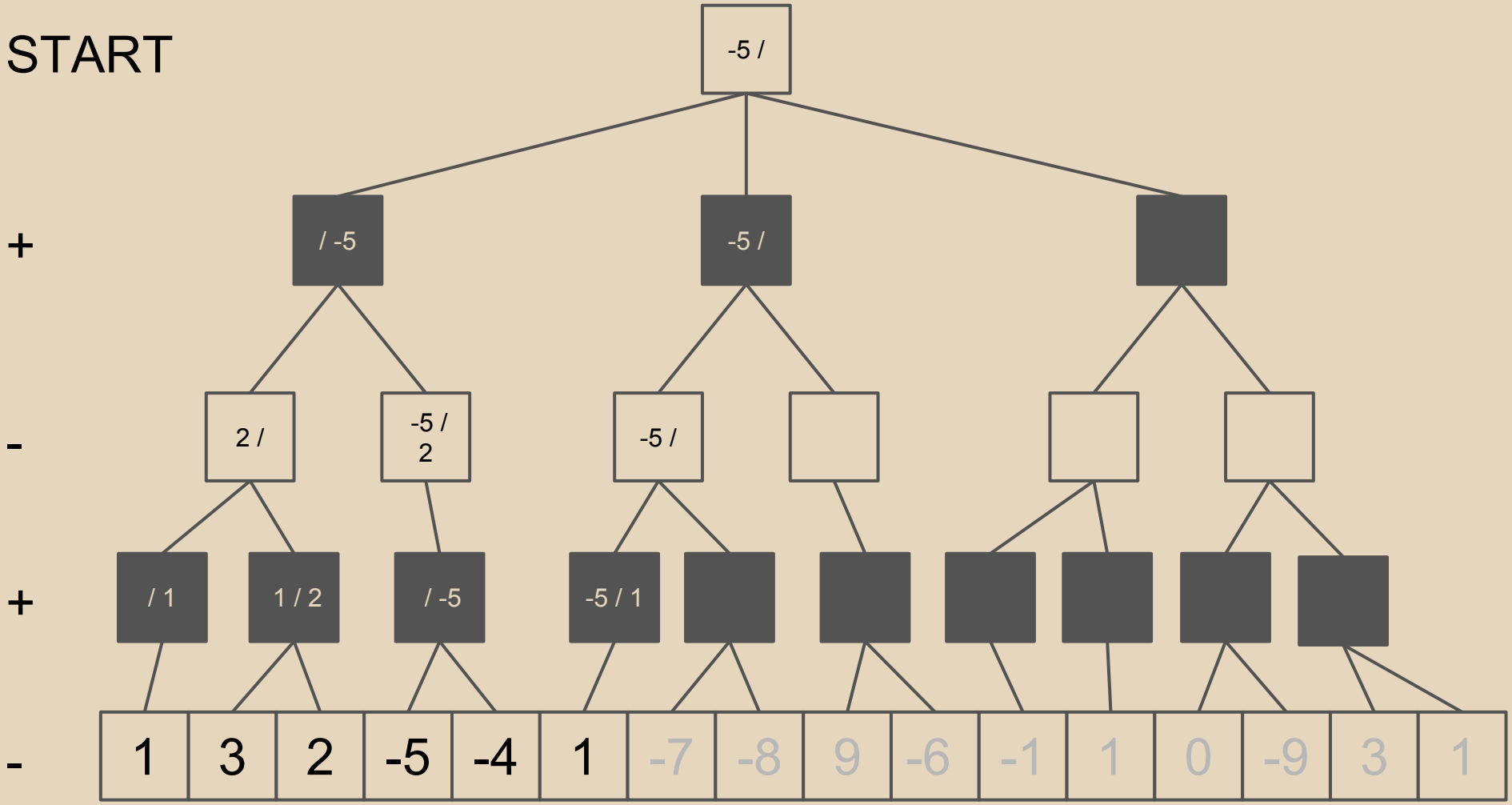

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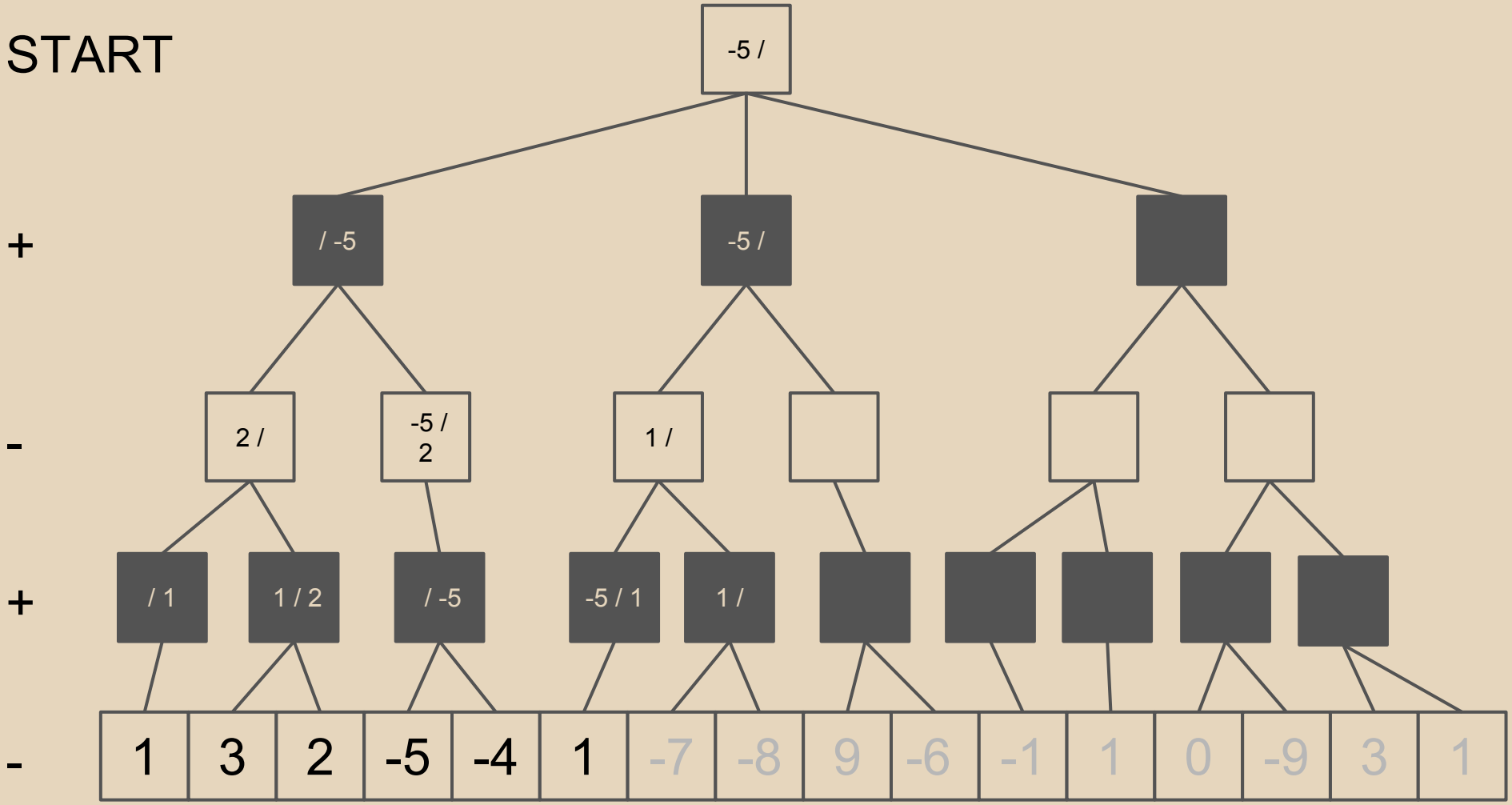
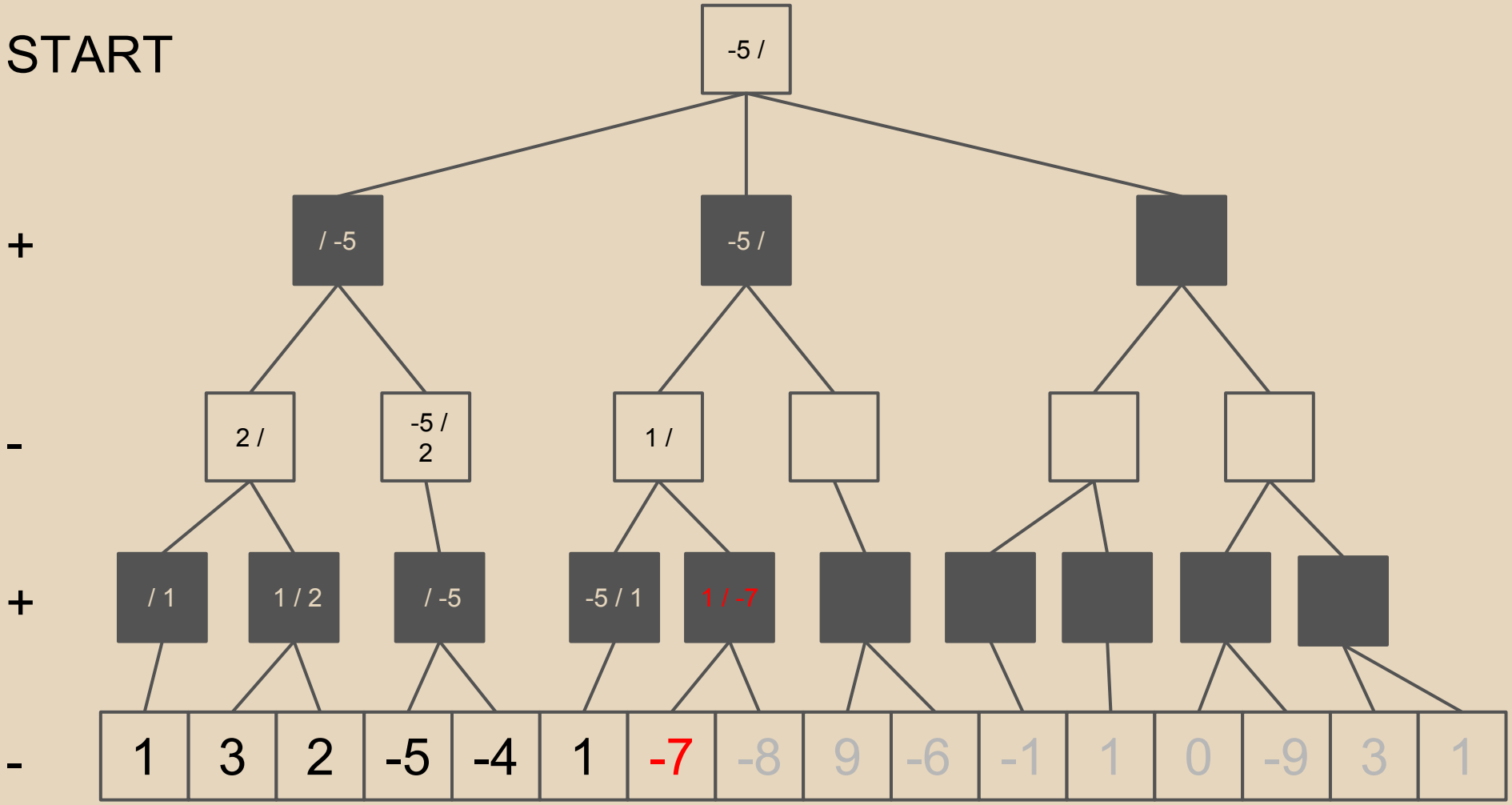
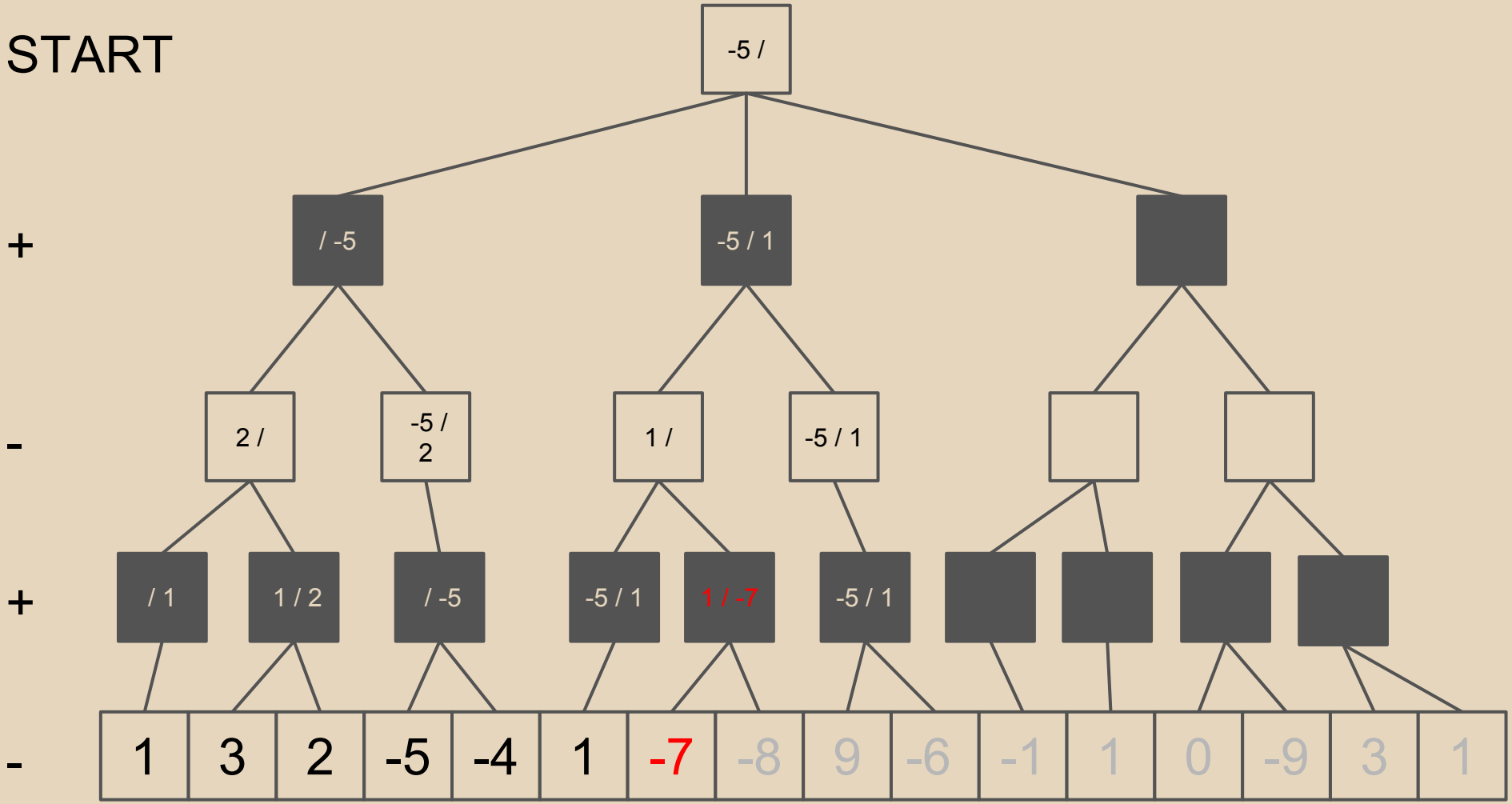


Cutoff!



Continue searching



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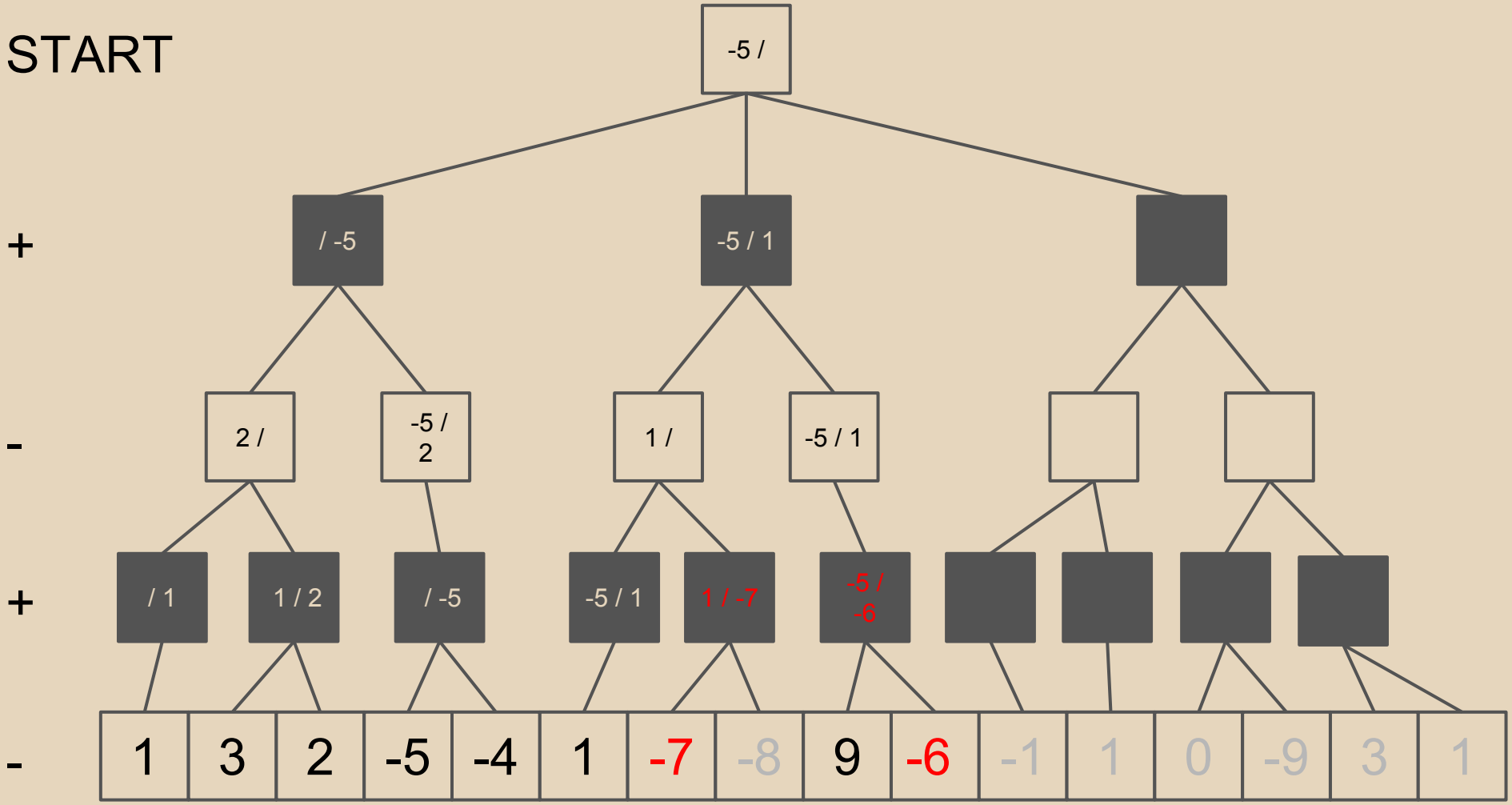

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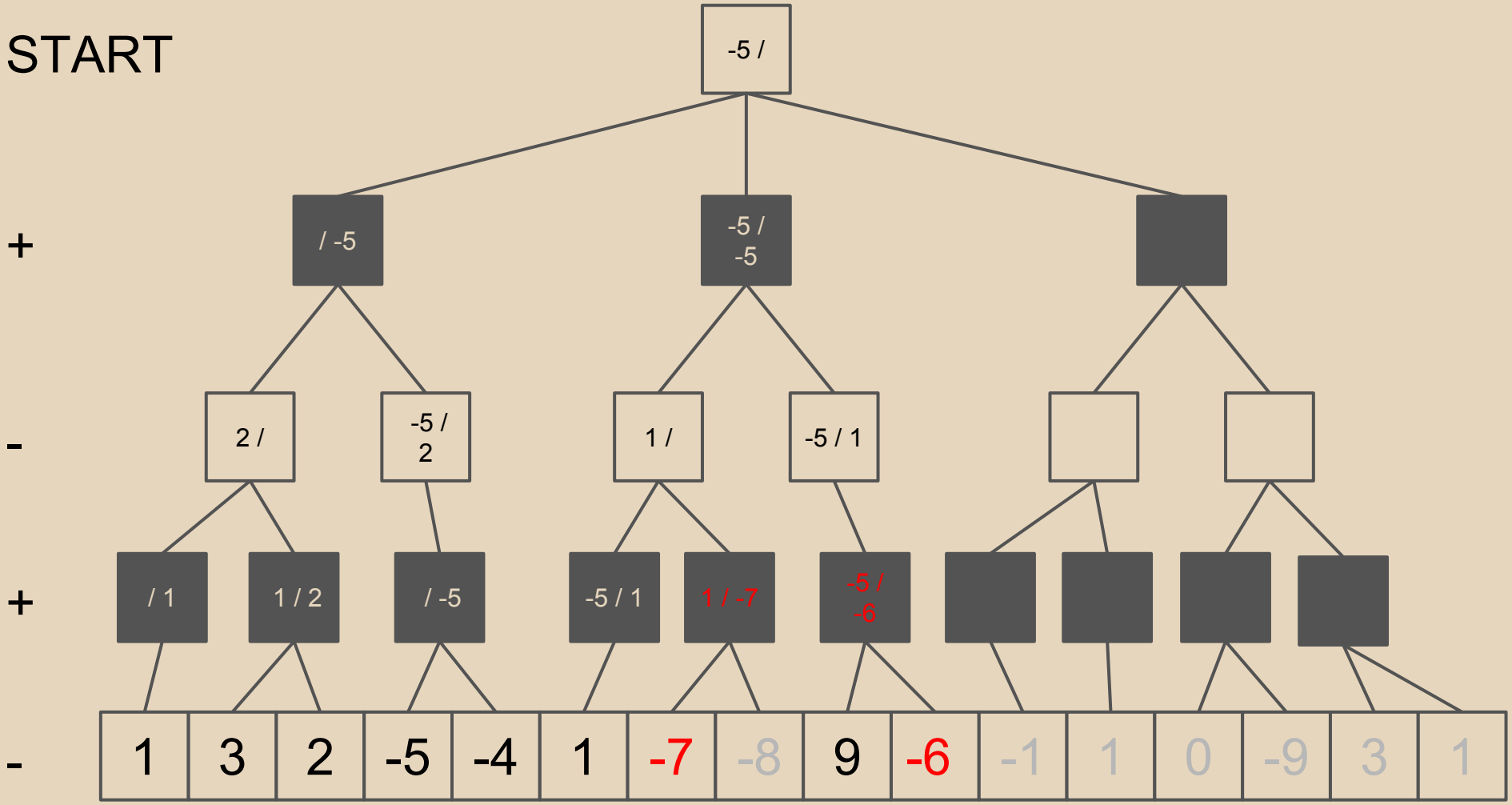
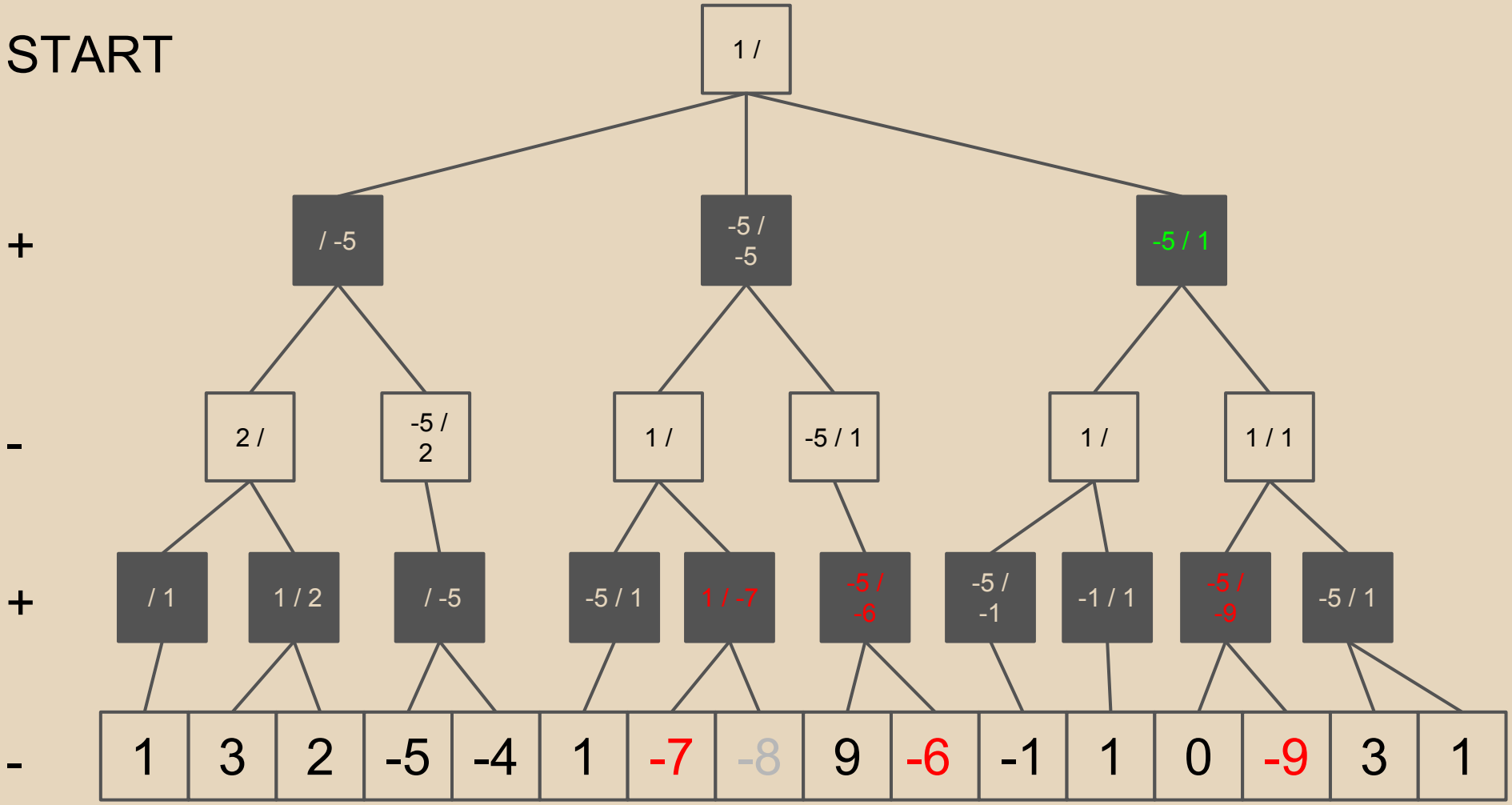


You get the idea...



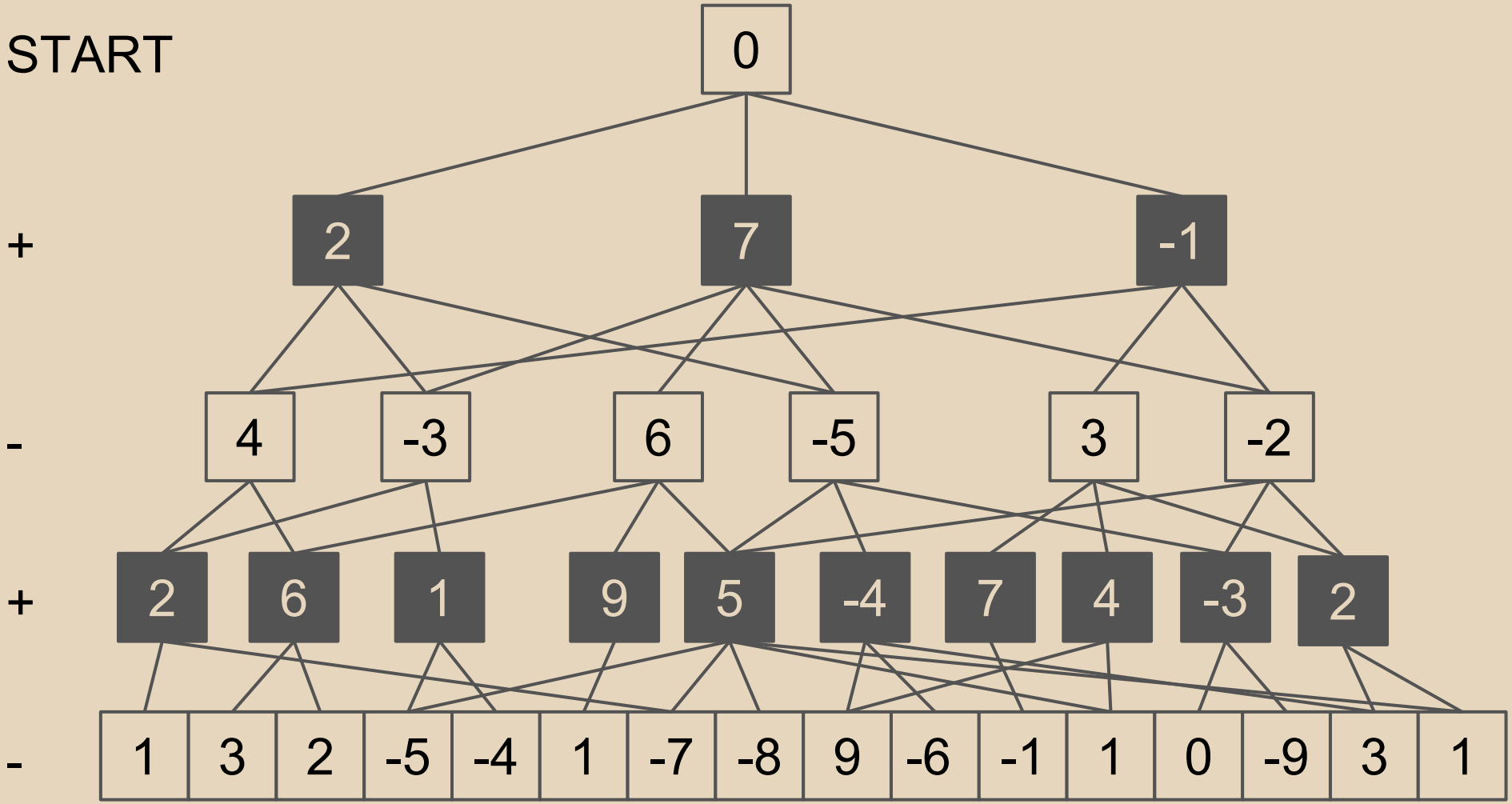
Negamax

- Don’t worry if that was confusing…
- Othello is a zero-sum game
  - Flip the scores and always maximize

Negamax alpha-beta

```
ab (depth, alpha, beta)
    if (depth == 0)
        evaluate()
    for each move:
        score = -ab(depth-1, -beta, -alpha)
        if (score > alpha)
            alpha = score
        if (score >= beta)
            cutoff!
return alpha
```

Game trees can contain duplicate positions...



Transposition tables

- Basically add memoization to our search
  - Remember dynamic programming?
  - If the same position comes up (with the same parameters) and we've already analyzed it, we don't want to reanalyze it
  - Better to look up the solution we already have
- Best way to do this is by hash table
  - Convert board position to a 'hash'
  - (almost) Constant-time lookup then

Transposition tables

- Caution: There are lots of possible positions
  - >> 10^20 legal positions
  - *Cannot* store all of them!
  - Store only the positions that are the most 'popular'
  - Could simply overwrite filled buckets, or keep some sort of popularity metric (for multi-slot buckets)
- Caution #2: Very difficult to implement correctly!
  - Things typically stored: best move (if available), bound and bound type, depth
  - Zobrist hashing

Iterative deepening

- Your time is limited!
  - Up to 16 minutes
  - Want to use our time as efficiently as possible
  - Follow paths that result in fast cutoffs
- Want to be able to do decently even if we run out of time or are interrupted

Iterative deepening

- Start search at a shallow depth
- Store some information about the results
  - Which moves might force alpha-beta cutoffs early?
  - Evaluate the best moves first.
- Repeat search at a deeper depth
- Continue in this vein for as long as needed
  - until we can't afford to spend any more time
- If interrupted, can use the result from an earlier depth rather than from an incomplete search

Move Ordering

- Essential to getting the most out of alpha-beta
- Use:
  - transposition table
  - iterative deepening results
  - shallow searches
  - other heuristics… (PV vs. non-PV nodes, piece-square tables, fastest-first, etc.)
  - You need a good understanding of alpha-beta conceptually to do this effectively

Opening books

- Precalculated responses to early moves
  - Records the best series of responses to particular moves in the early game (down to some small depth)
  - Reduces amount of calculation necessary in the early game
  - Again, dynamic programming / memoization is your friend!
- Often pre-generated
  - The best programs update their opening books after each game
  - We don't expect you to do that

Endgame solvers

- Counting the number of stones is bad in the midgame… (good players often try to minimize this in the early midgame)
- But once the game ends, stone count is the only thing that matters!
- Detect the end of the game and use a different evaluation function
- Can be optimized

For the adventurous…

- Negascout/PVS
  - Fail-soft alpha beta, aspiration windows
- Pattern-based evaluations / machine learning
- Multi-prob cut

Useful git commands: Stash

Suppose we want to save our current changes *without* committing (say, to pull from the remote repository)

- `git stash`: Stashes local changes without committing, reverts back to HEAD state
- `git stash apply`: Replays last stash change (does not commit)

Example: You've been working for hours and find out you need to fix a bug *NOW*. Don't want to lose your work -- so stash it!

Useful git commands: Branch

Sometimes we aren't quite sure what direction our code should take; or we want to try something out without destroying the main branch.

- `git branch`: Start a new branch
- `git checkout`: Switch to another branch
- `git merge`: Synchronize two branches
  - Can have "merge conflicts" to resolve before the merge is complete

Example: You fixed the bug in a branch, now sync with the main repo for your users.

:)

Have fun!