SEGClobber - A Linear Clobber Solver

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University of Alberta

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- Breaks into subgames frequently: ■□■□_■■□ = ■□■□ + ■■□

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- Chen et al. recently proposed a proof of (■□)^n conjecture

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  - Complexity score
  - Simplest (nondominated) move
  - Link to SEG (Simplest Equal Game)
  - The board itself

Normal Form

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- ■ □ ■ _ ■ ■ □ ■ _ □ ■ ■ _ _ □ _ _ _ ■ □ _

Normal Form

- ■ □ ■ _ ■ ■ □ ■ _ □ ■ ■ _ _ □ _ _ _ ■ □ _
- Shape: (3, 4, 3, 1, 2)

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2. Omit redundant empty squares

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   - (4, 3, 3, 2)

Normal Form

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- Shape: (3, 4, 3, 1, 2)

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2. Omit redundant empty squares
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   - (4, 3, 3, 2)
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- Shape: (3, 4, 3, 1, 2)

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Complexity Score

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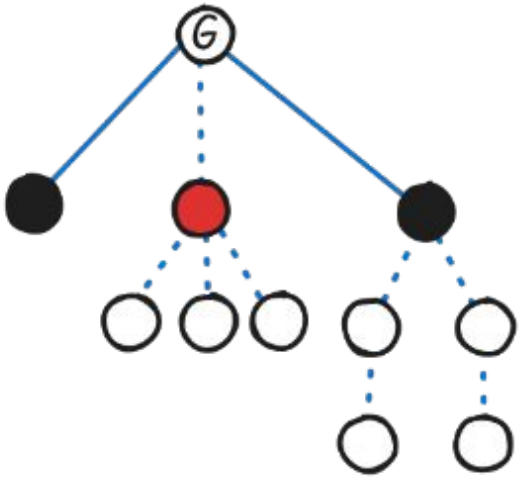
Non-strictly-dominated move

Strictly-dominated move



CS3(G) = 2

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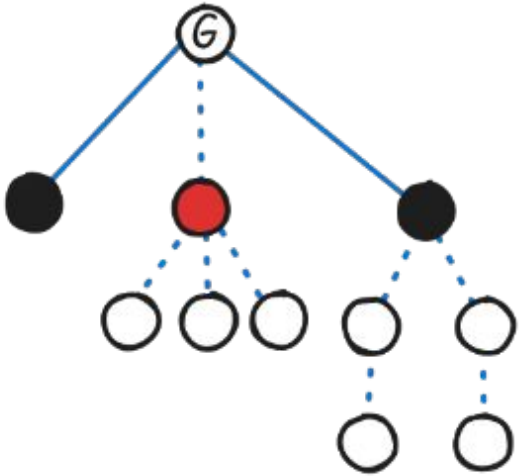

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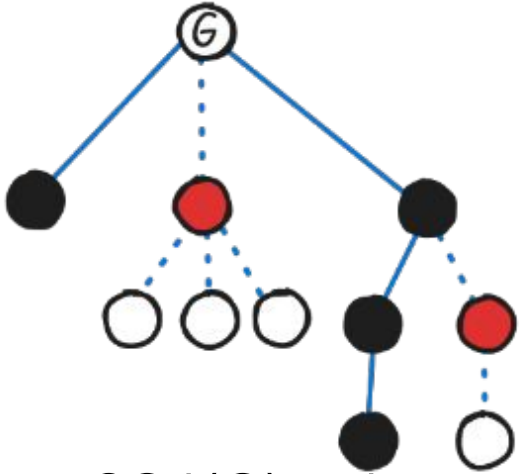

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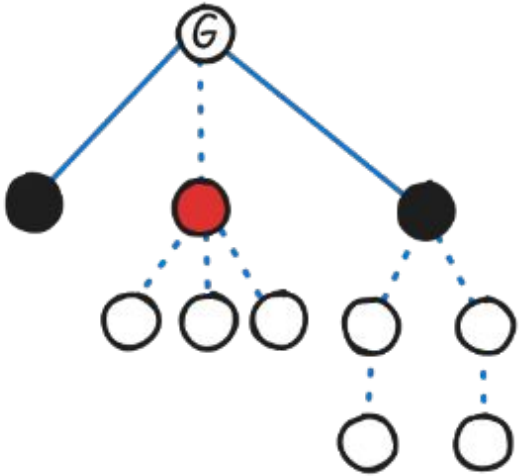

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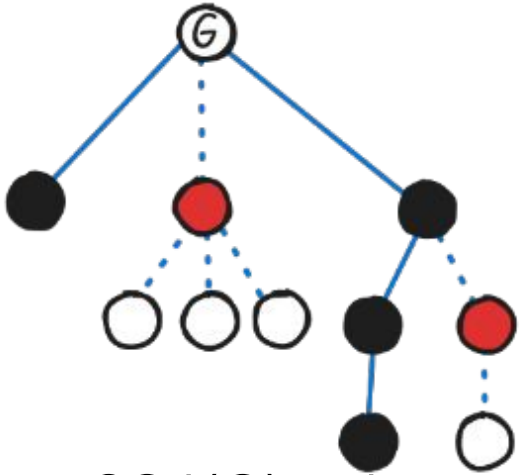

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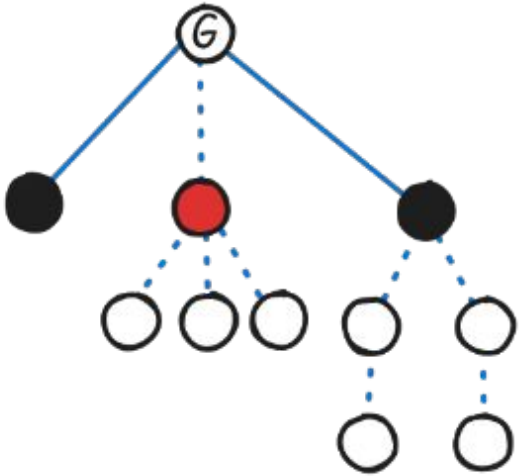

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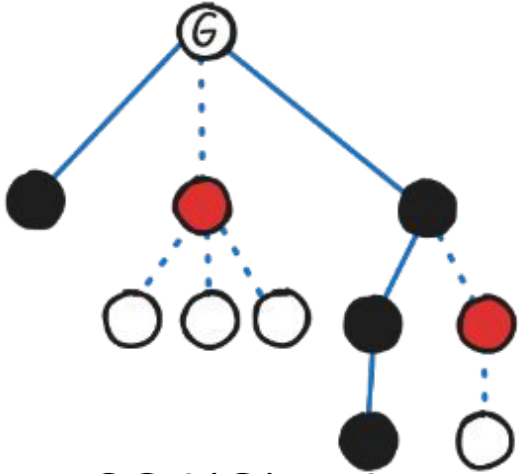

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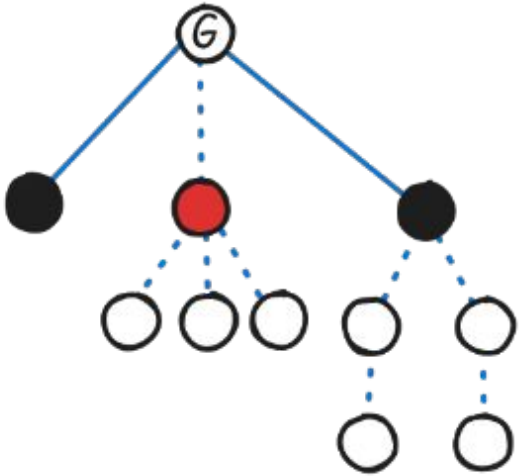

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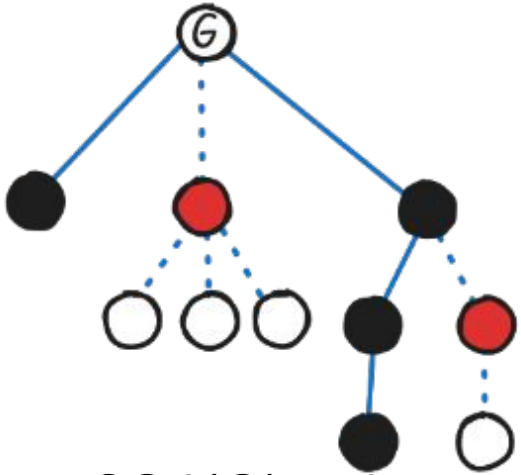

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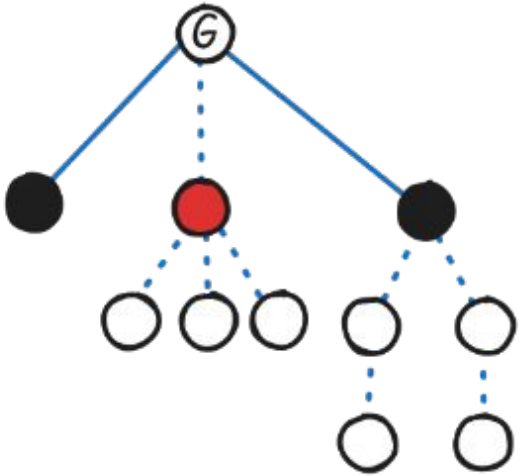

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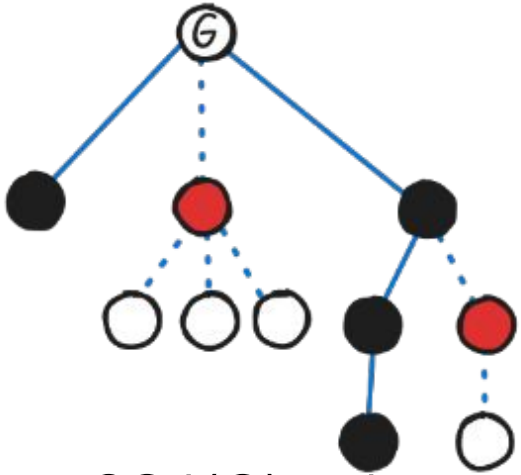

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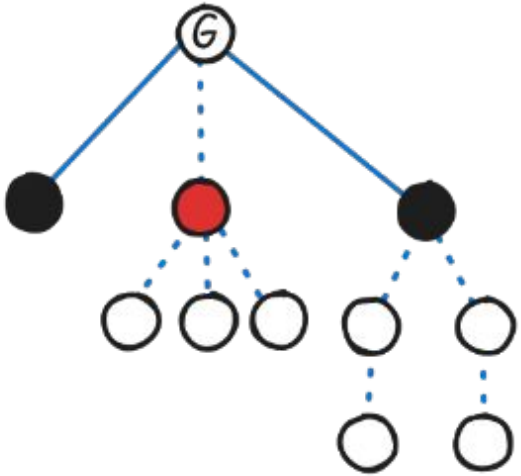

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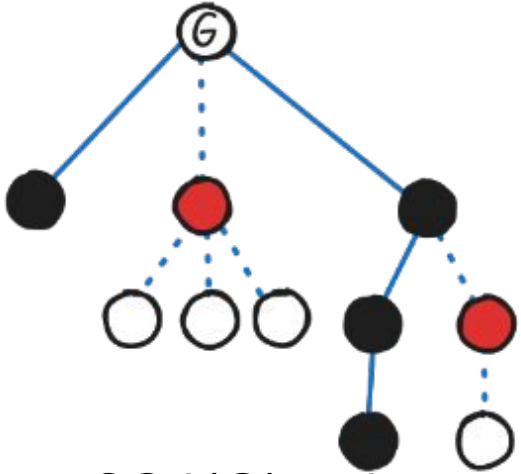

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  - A database entry contains the **simplest** such game, if it exists

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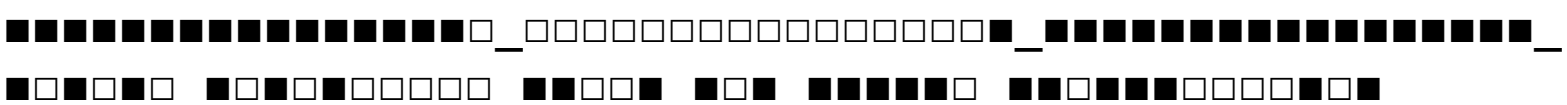

Sum Simplification

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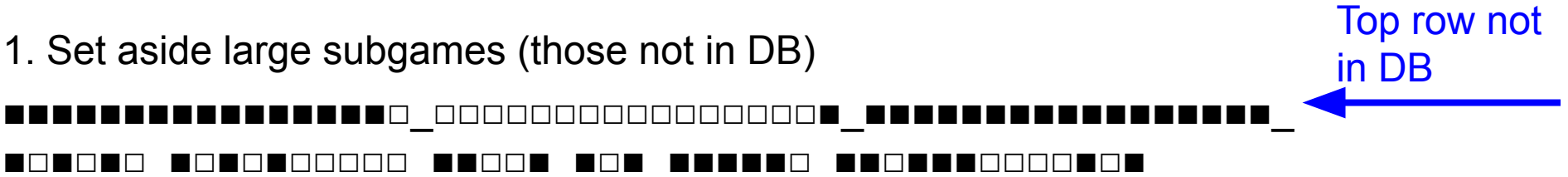

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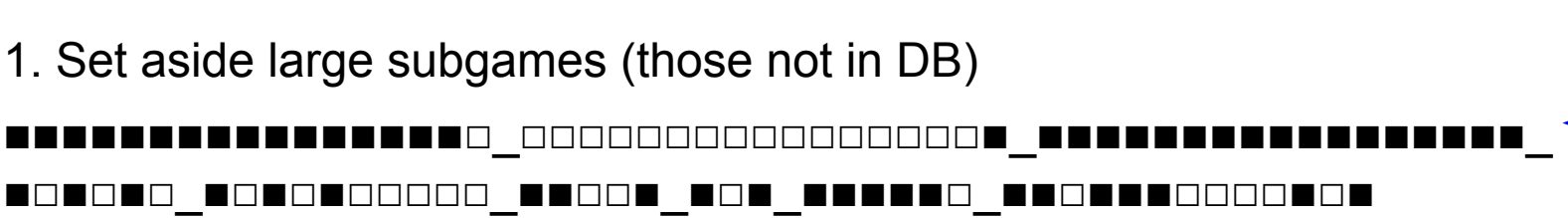

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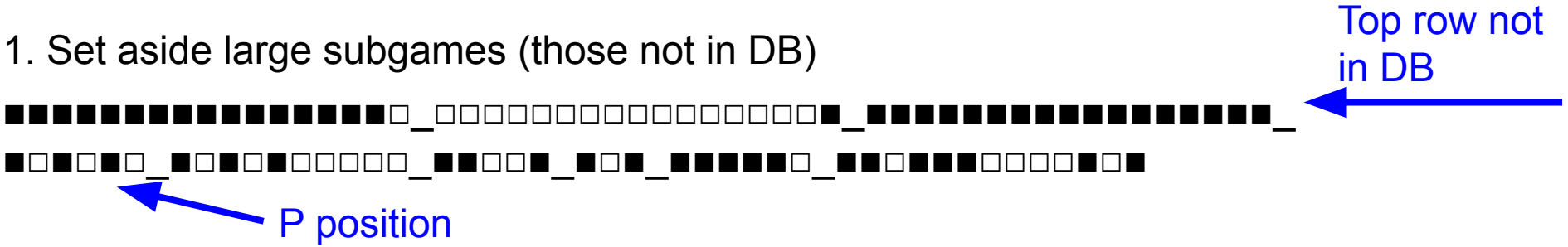

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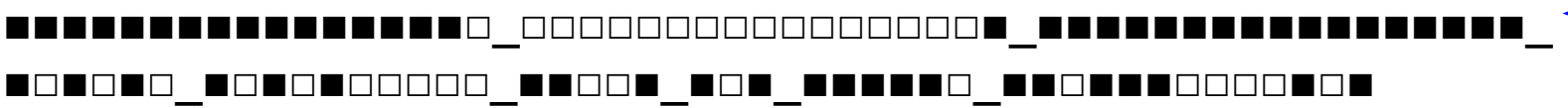

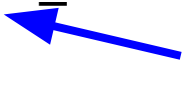

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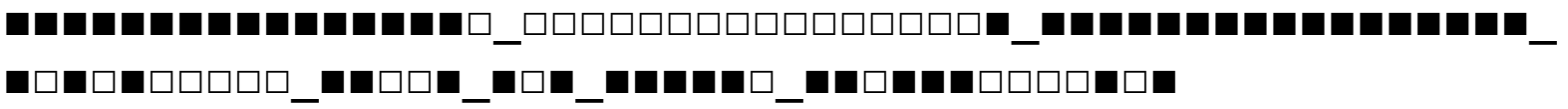
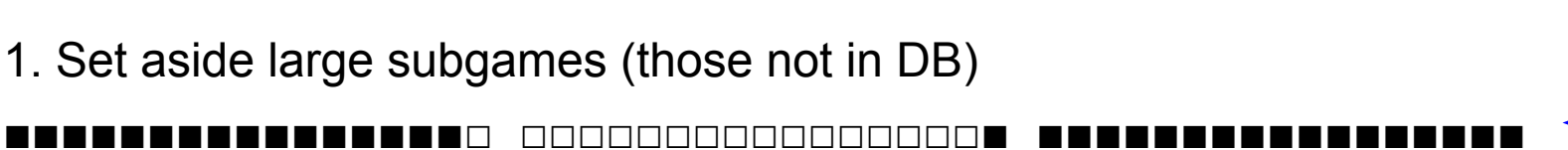
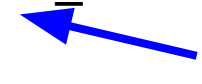


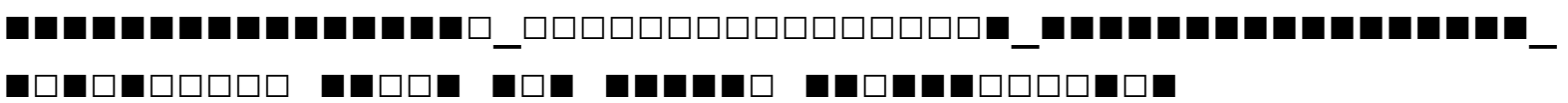
Sum Simplification

1. Set aside large subgames (those not in DB)





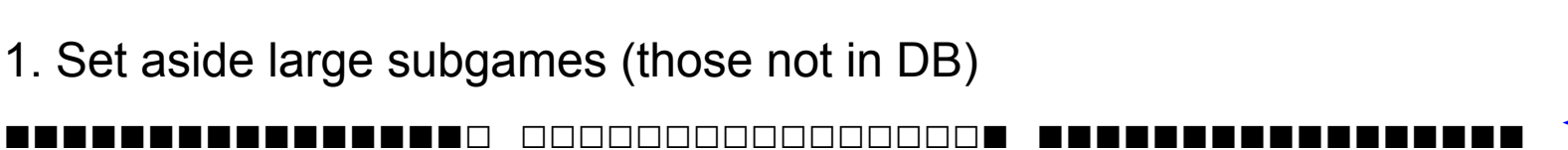
2. Using DB, delete single P positions (= 0)

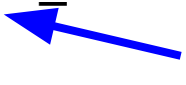


3. Sort remaining subgames in order of decreasing length

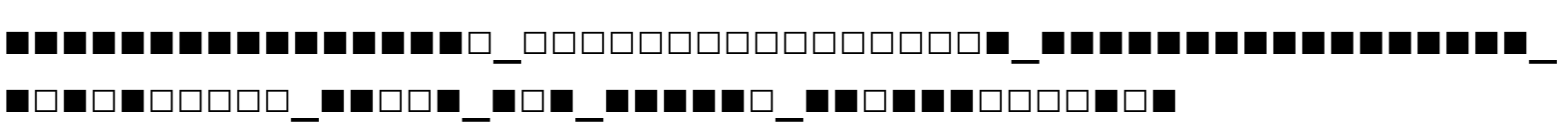
Sum Simplification

1. Set aside large subgames (those not in DB)

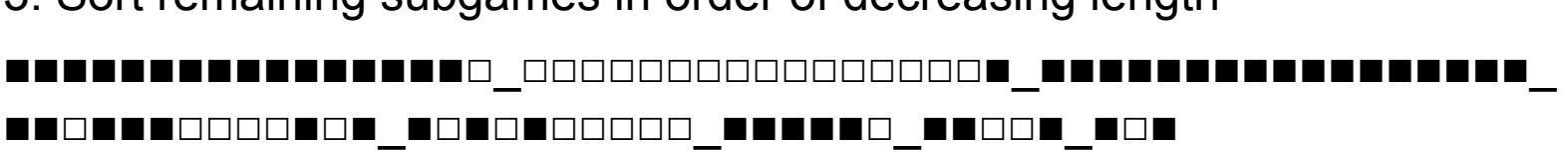




2. Using DB, delete single P positions (= 0)

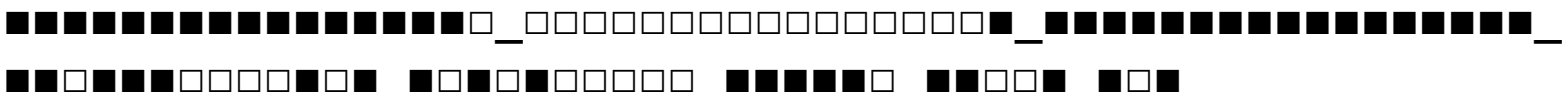


3. Sort remaining subgames in order of decreasing length



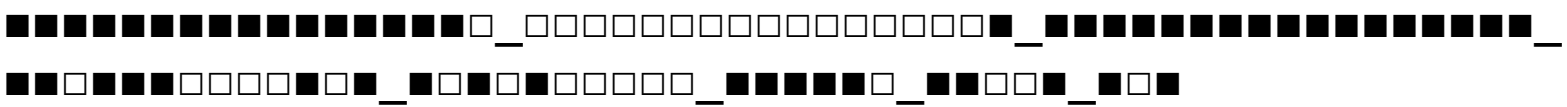
Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



4. Replace sums of 3+ (using sliding window of length 16)

Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length

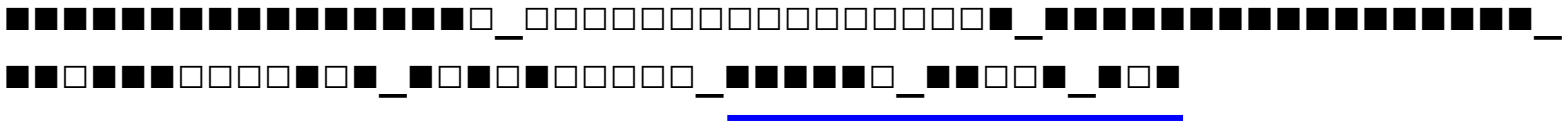
■■■■■■■■■■■■■■■□_□□□□□□□□□□□□□□□■_■■■■■■■■■■■■■■■_
■■□■■■□□□□■□■_■□■□■□□□□□_■■■■■□_■■□□■_■□■

■■■■■□_■■□□■_■□■ = □■■■■

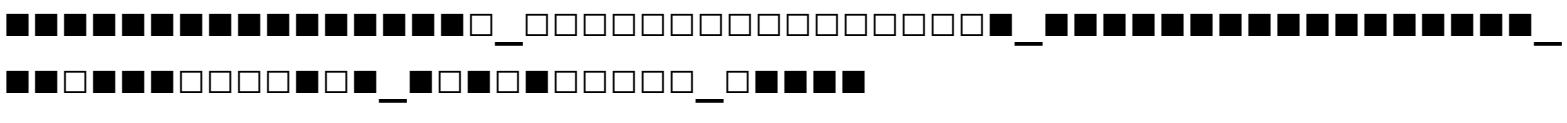
4. Replace sums of 3+ (using sliding window of length 16)

Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length

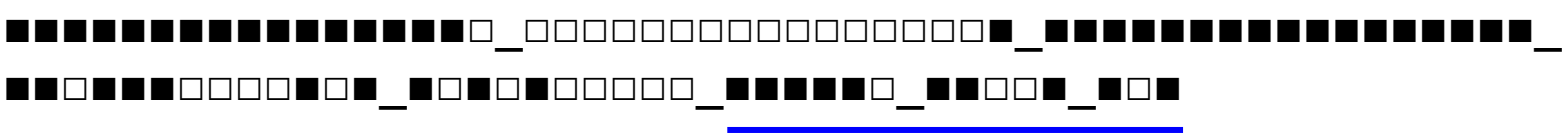


4. Replace sums of 3+ (using sliding window of length 16)

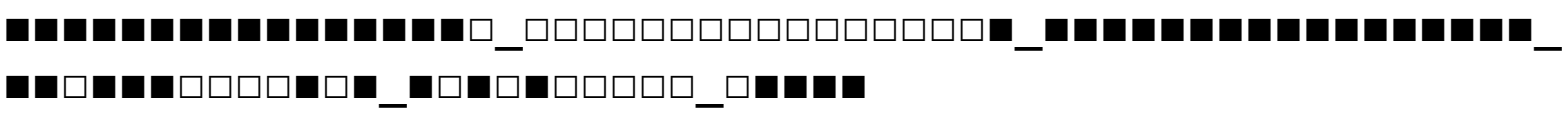


Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



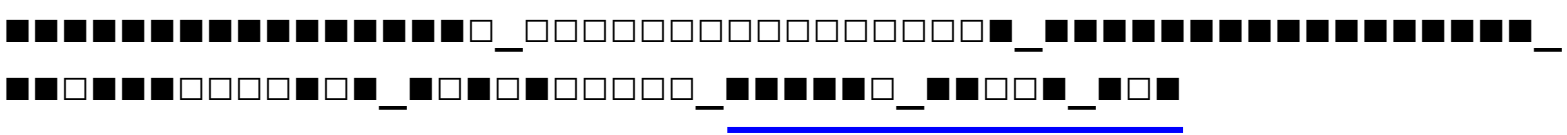
4. Replace sums of 3+ (using sliding window of length 16)



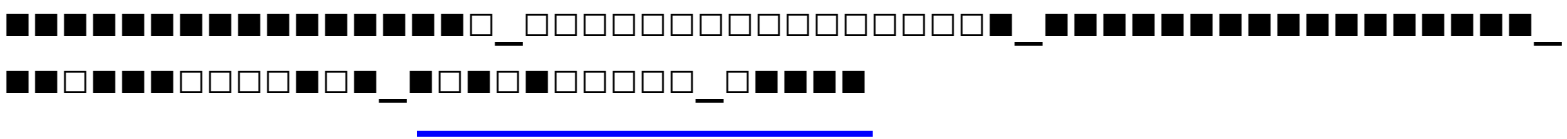
5. Replace pairs

Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



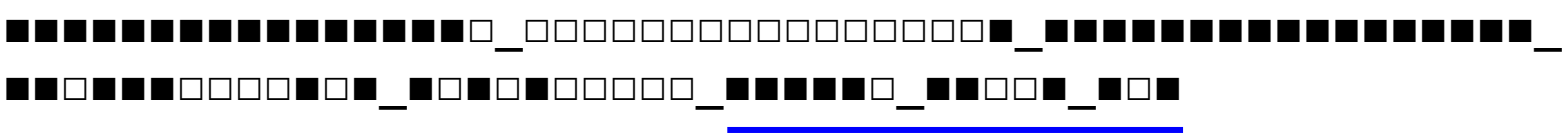
4. Replace sums of 3+ (using sliding window of length 16)



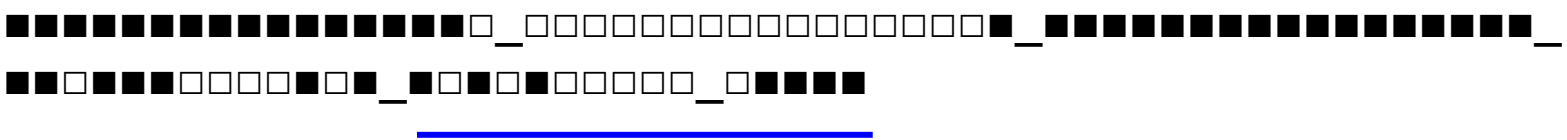
5. Replace pairs

Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



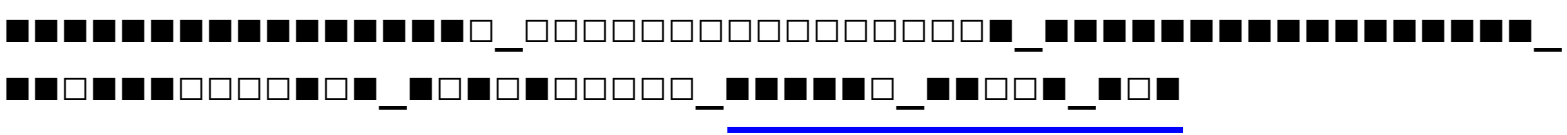
4. Replace sums of 3+ (using sliding window of length 16)



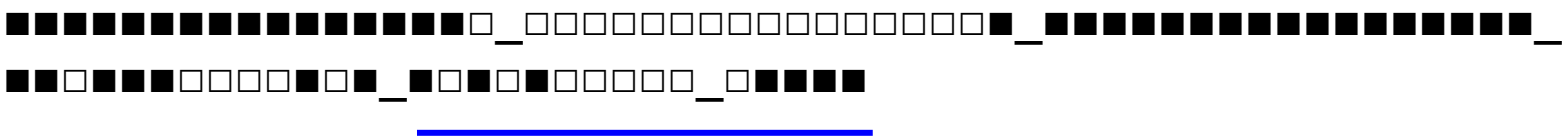
5. Replace pairs

Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



4. Replace sums of 3+ (using sliding window of length 16)

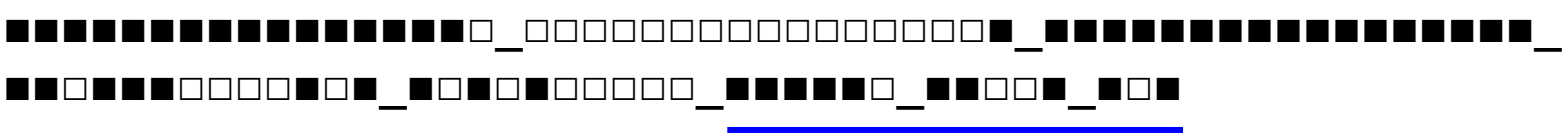


5. Replace pairs

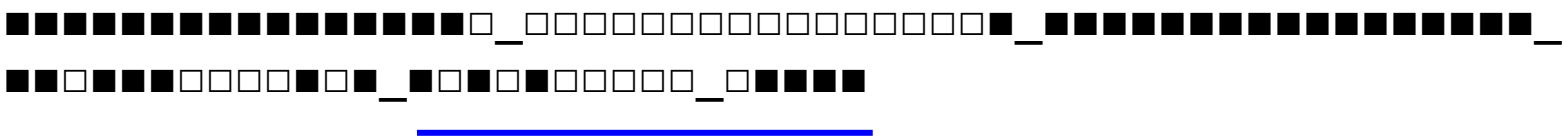
6. Replace singles

Sum Simplification (Continued)

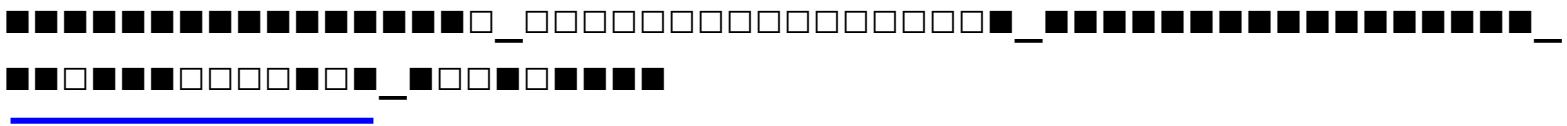
3. Sort remaining subgames in order of decreasing length



4. Replace sums of 3+ (using sliding window of length 16)



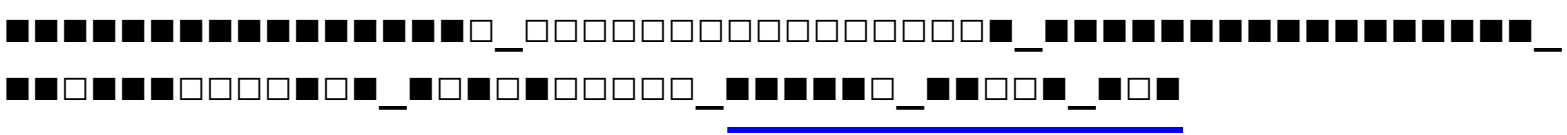
5. Replace pairs



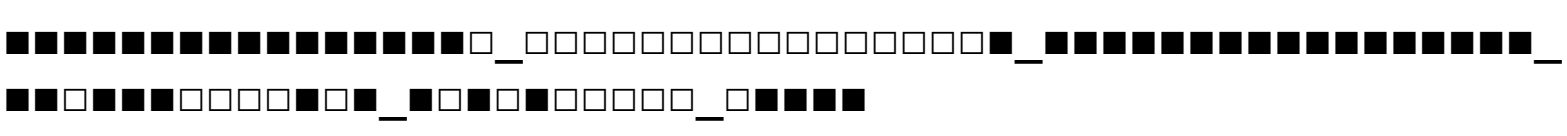
6. Replace singles

Sum Simplification (Continued)

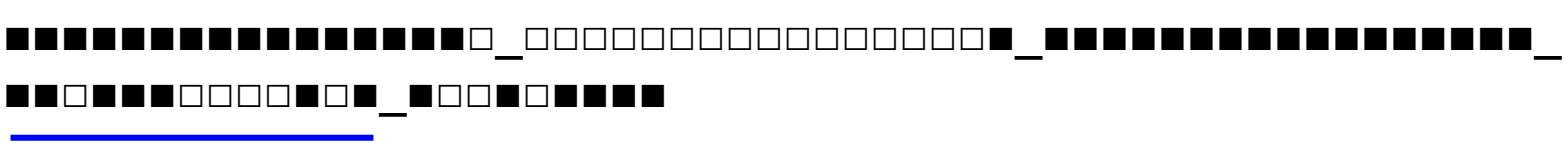
3. Sort remaining subgames in order of decreasing length



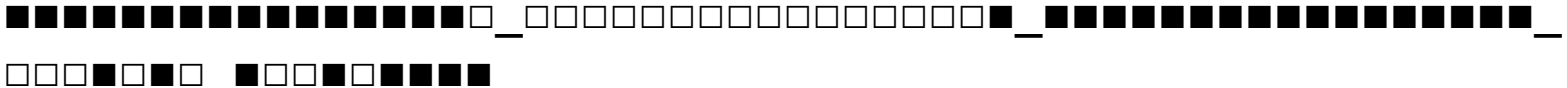
4. Replace sums of 3+ (using sliding window of length 16)



5. Replace pairs

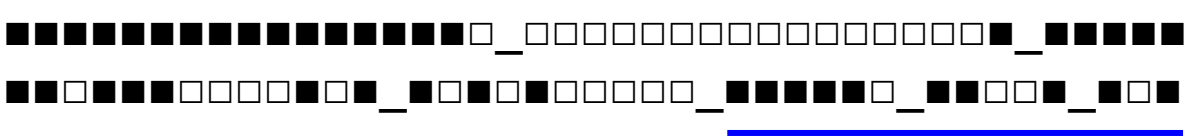


6. Replace singles



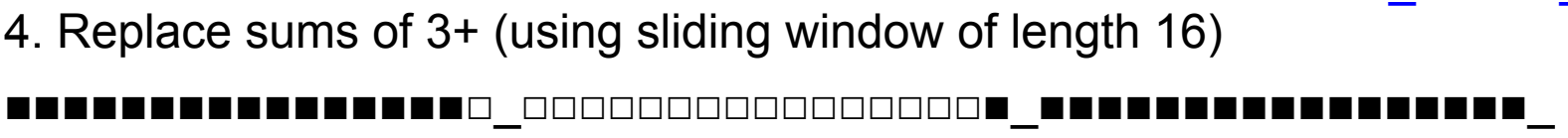
Sum Simplification (Continued)

3. Sort remaining subgames in order of decreasing length



CS4: 5409 -> 8

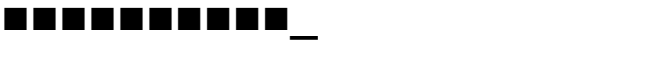
4. Replace sums of 3+ (using sliding window of length 16)



CS4: 52434 -> 80

5. Replace pairs

CS4: 32747 -> 16



6. Replace singles

Sum Simplification (Continued)

6. Replace singles

■■■■■■■■■■■■■■■■□_□□□□□□□□□□□□□□□□■_■■■■■■■■■■■■■■■■_
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Sum Simplification (Continued)

6. Replace singles

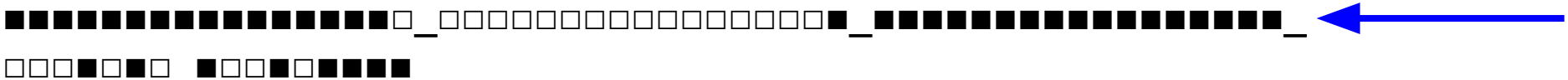
■■■■■■■■■■■■■■■□_□□□□□□□□□□□□□□□■_■■■■■■■■■■■■■■■_
□□□■□■□_■□□■□■■■■

7. Now also consider previously set aside games.

Sum Simplification (Continued)

Resume considering top row

6. Replace singles

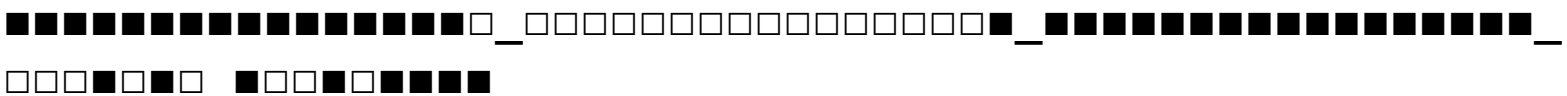


7. Now also consider previously set aside games.

Sum Simplification (Continued)

Resume considering top row

6. Replace singles

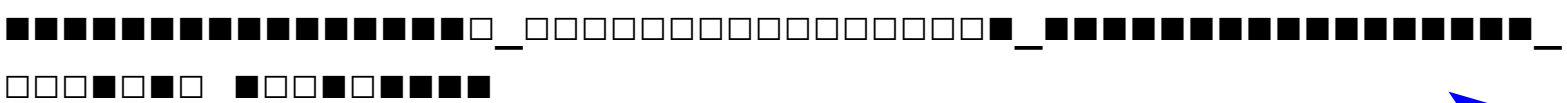


7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

Sum Simplification (Continued)

6. Replace singles



Resume considering top row

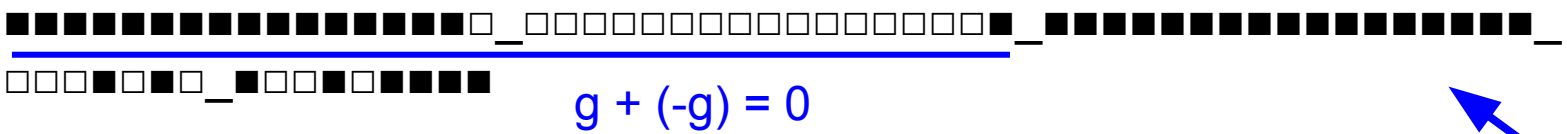
No moves

7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

Sum Simplification (Continued)

6. Replace singles

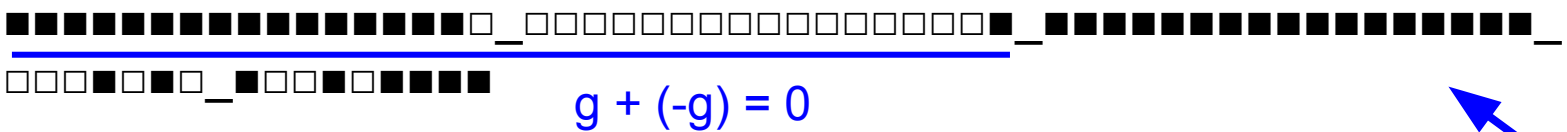


7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

Sum Simplification (Continued)

6. Replace singles

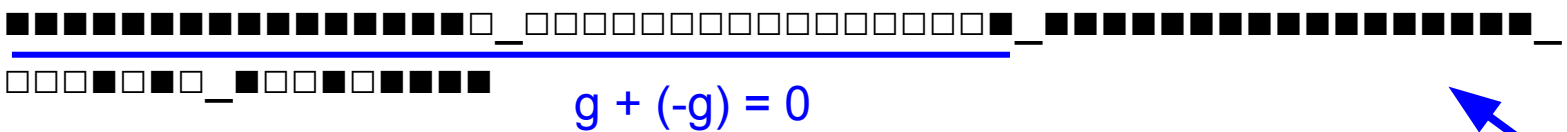


7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

Sum Simplification (Continued)

6. Replace singles



7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

9. Convert to normal form

Sum Simplification (Continued)

6. Replace singles

■■■■■■■■■■■■■■■□_□□□□□□□□□□□□□□□■_■■■■■■■■■■■■■■■_

□□□■□■□_■□□■□■■■■

Resume considering top row

g + (-g) = 0

No moves

7. Now also consider previously set aside games.

8. Delete subgames with no moves, and pairs of visually identifiable inverses

□□□■□■□_■□□■□■■■■

9. Convert to normal form

■□□■□■■■■_□□□■□■□

Search Algorithm

Search Algorithm

1. Simplify board

Search Algorithm

1. Simplify board
2. Check database, then transposition table

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves
    - Move ordering informed by:

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves
    - Move ordering informed by:
        - Outcome classes

Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves
    - Move ordering informed by:
        - Outcome classes
        - DB “simplest moves”

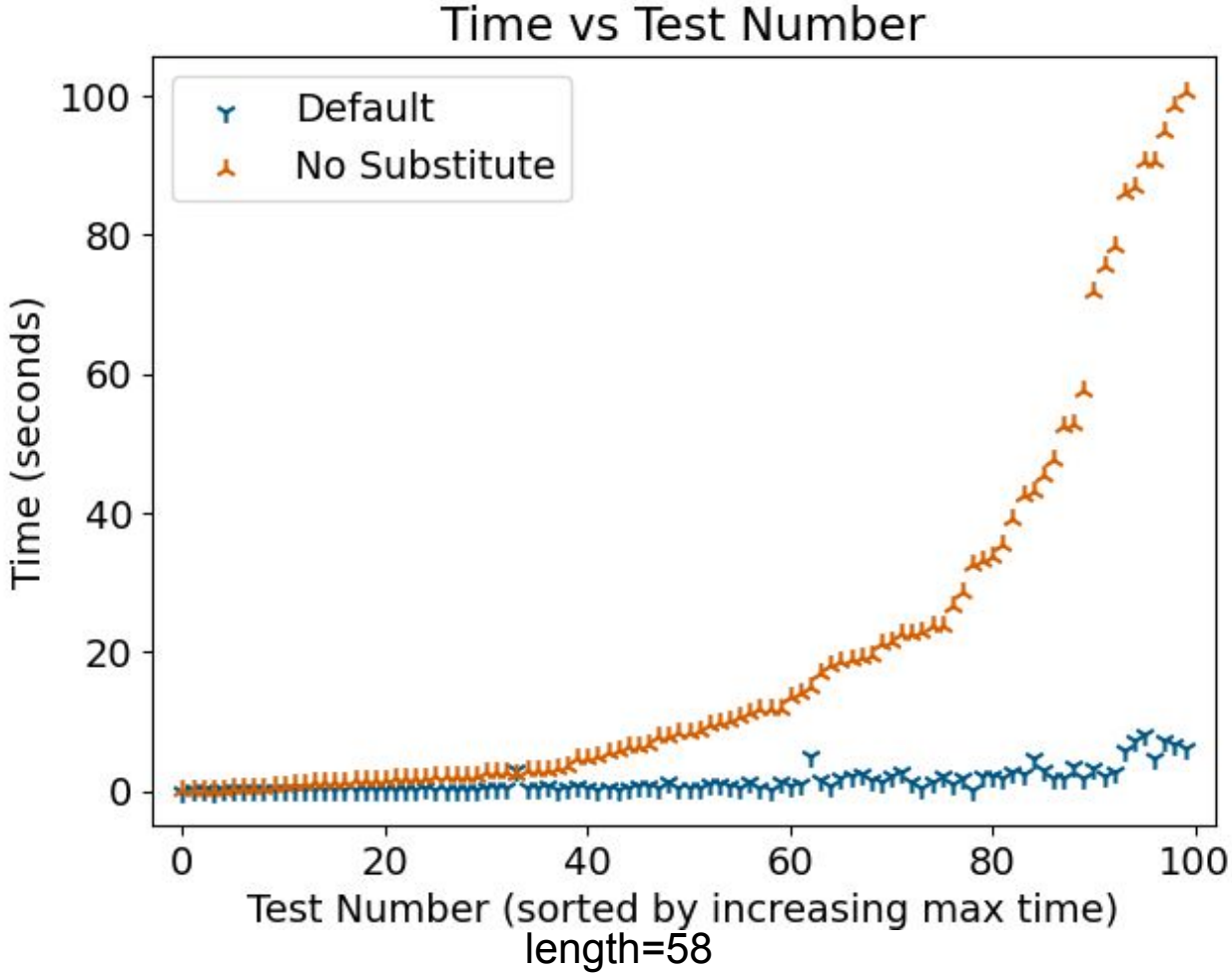
Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves
    - Move ordering informed by:
        - Outcome classes
        - DB “simplest moves”
        - Heuristic “best moves”

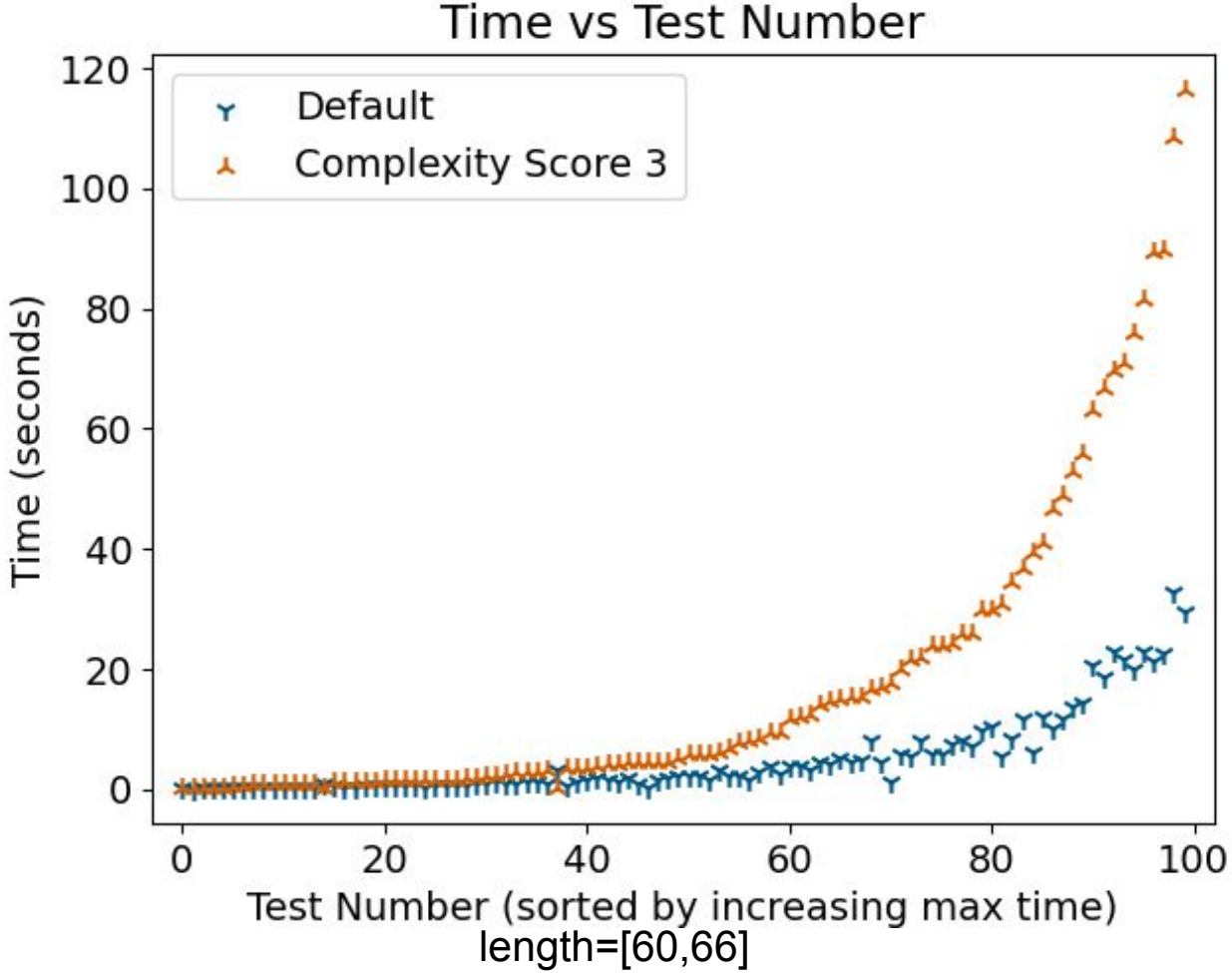
Search Algorithm

1. Simplify board
2. Check database, then transposition table
3. Try outcome class and bounds to solve
4. Speculative subgame removal
    - For subgame Gi with certain known outcome classes, try to solve G - Gi instead
5. Generate and play moves
    - Move ordering informed by:
        - Outcome classes
        - DB “simplest moves”
        - Heuristic “best moves”
        - Middle of subgames

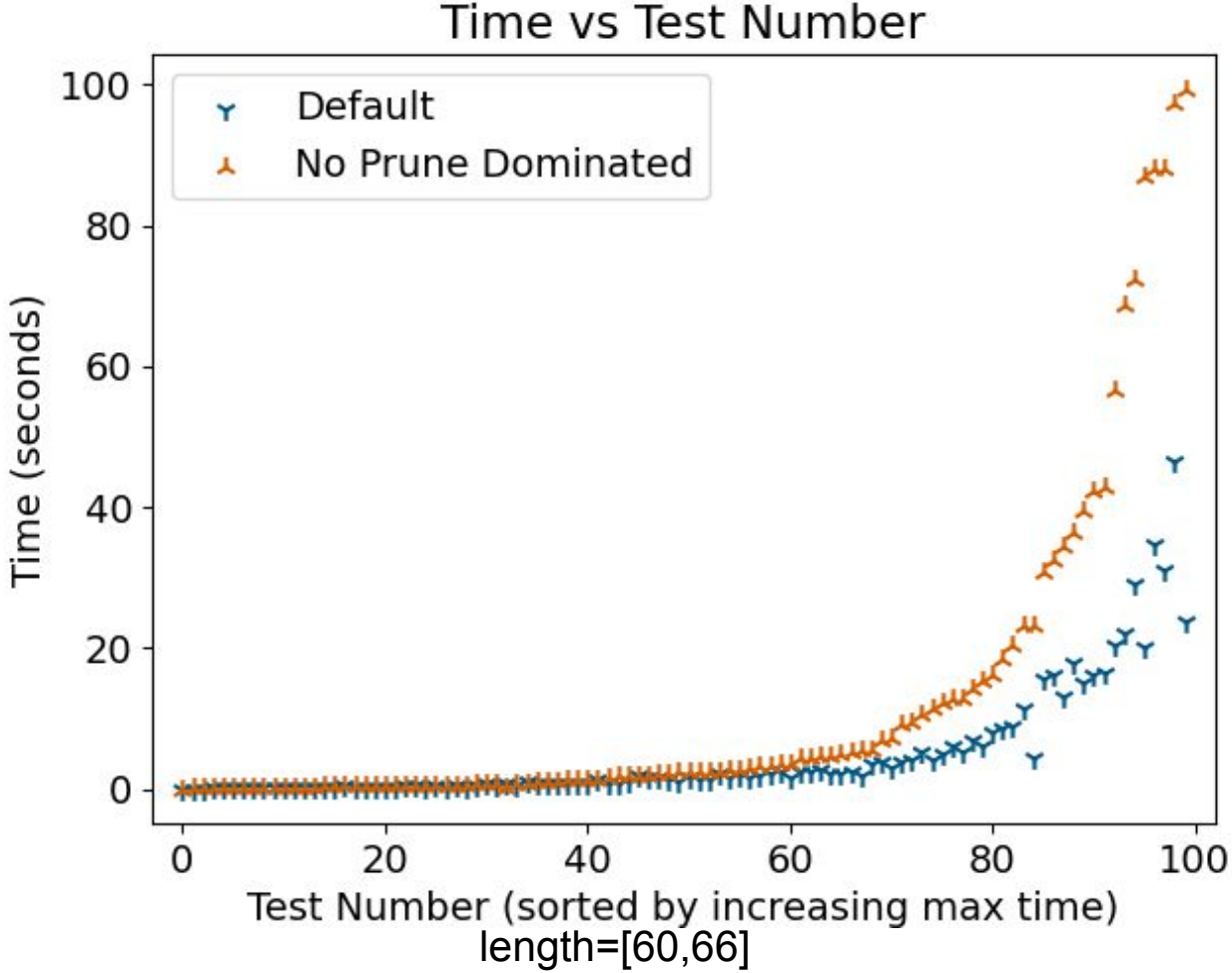
Ablation: Substitution



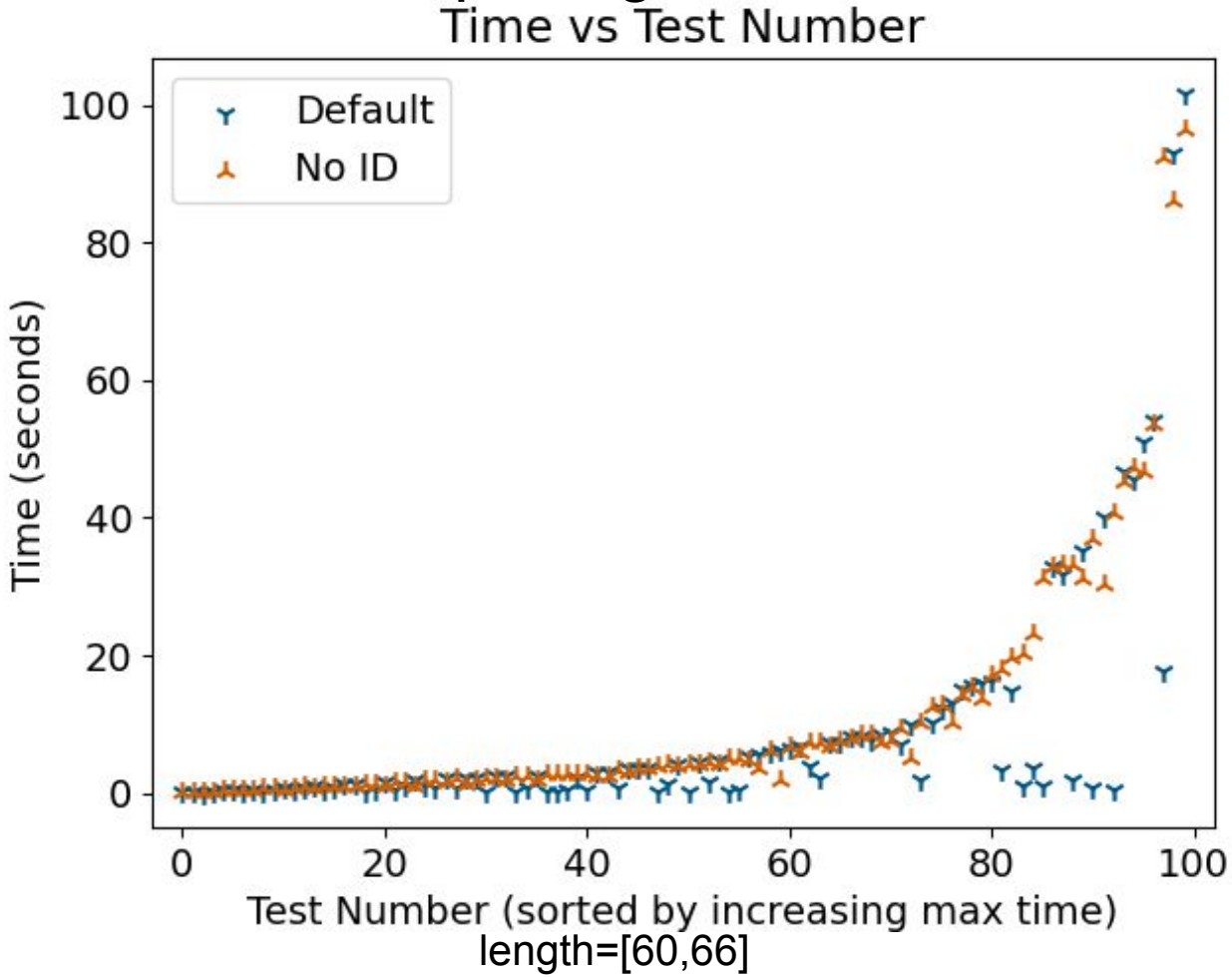
Ablation: Complexity Score (CS4 vs CS3)



Ablation: Prune Dominated Moves



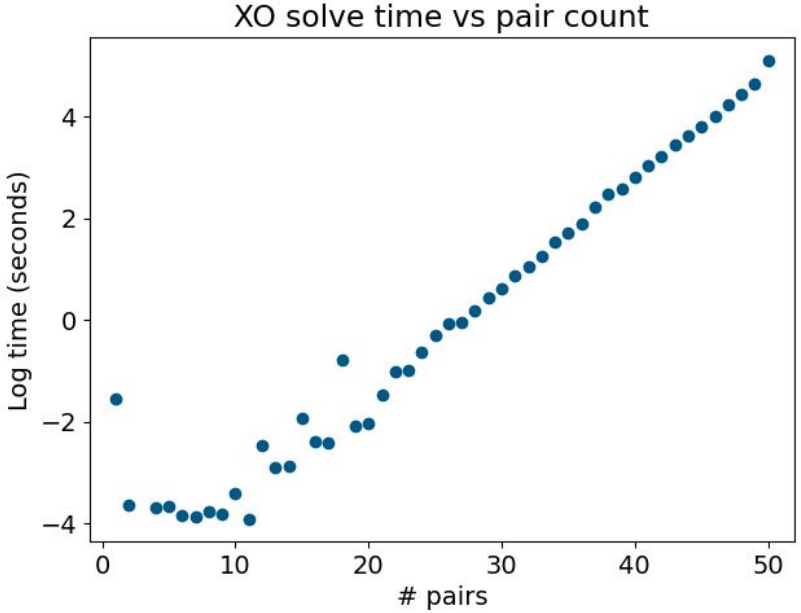
Ablation: Iterative Deepening



length=[60,66]

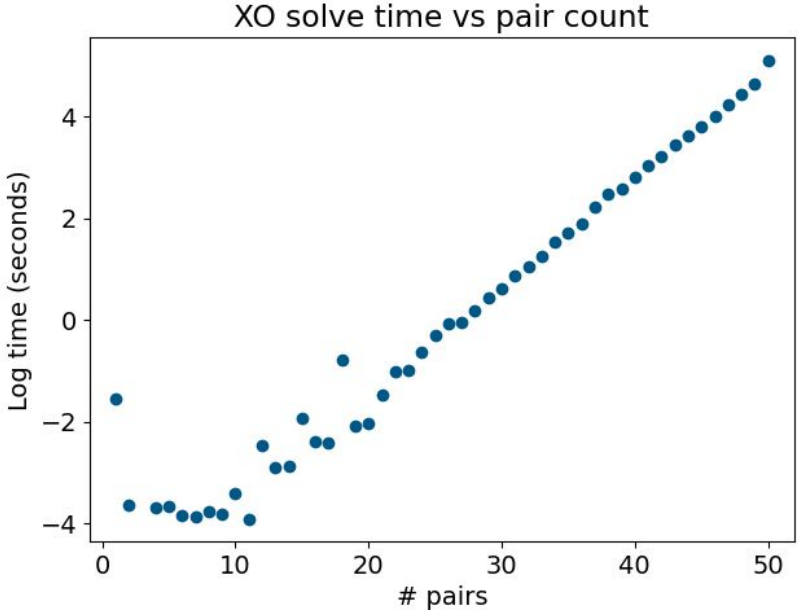
Verifying (■□)^n Conjecture

Verifying (■□)^n Conjecture



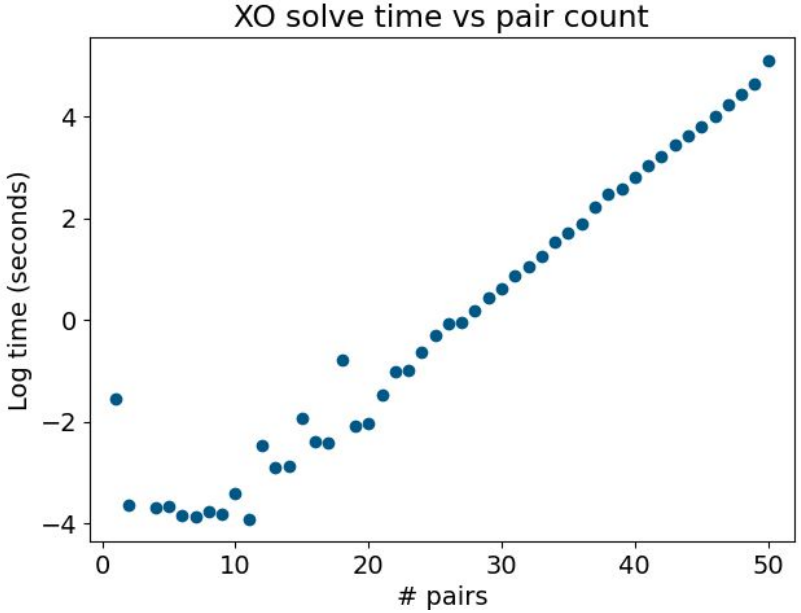
Verifying (■□)^n Conjecture

- Transposition table not cleared between runs



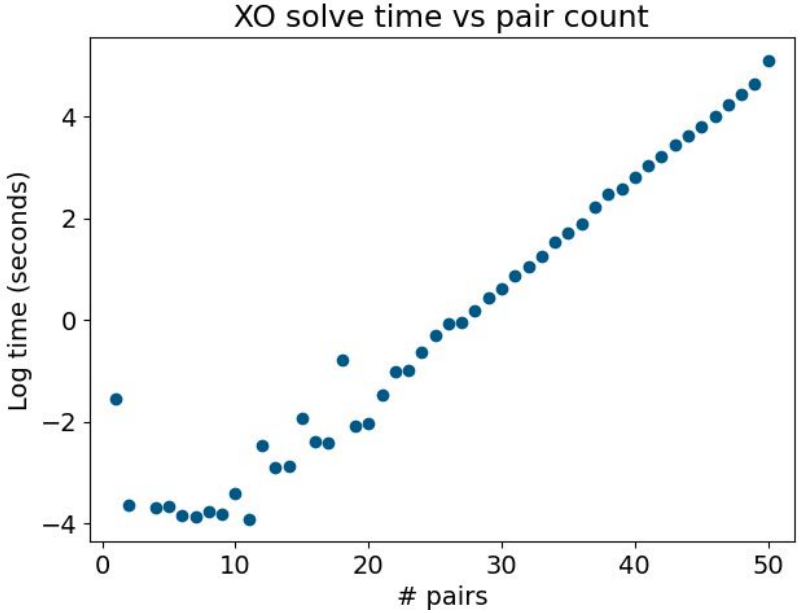
Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries



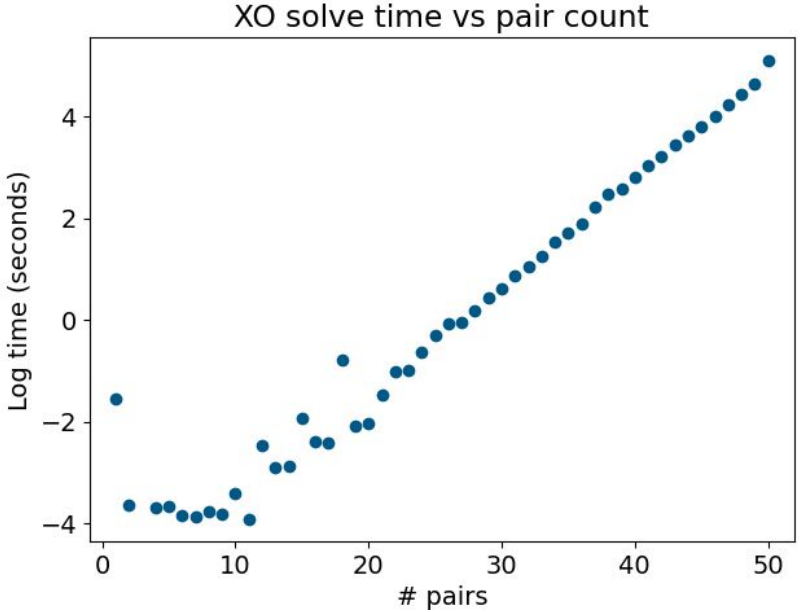
Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right



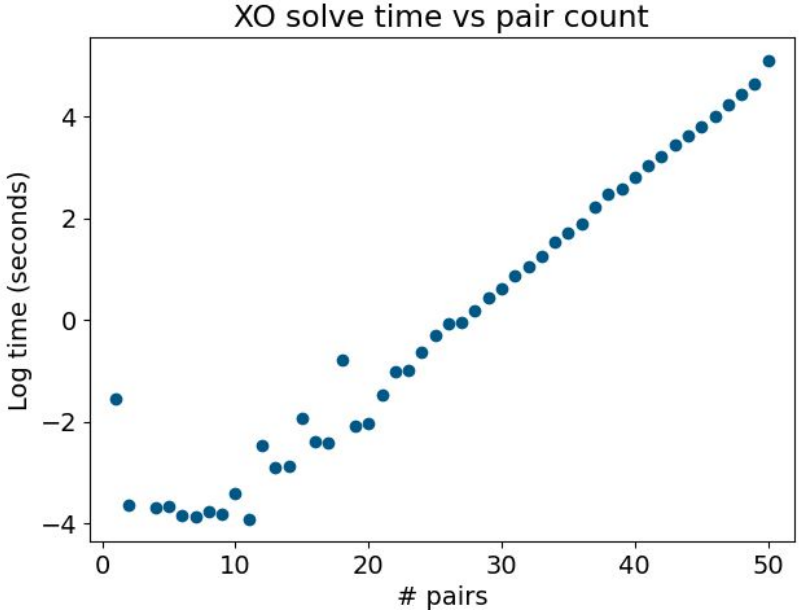
Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time



Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black



Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
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- Root node plays hardcoded move: 13 -> right
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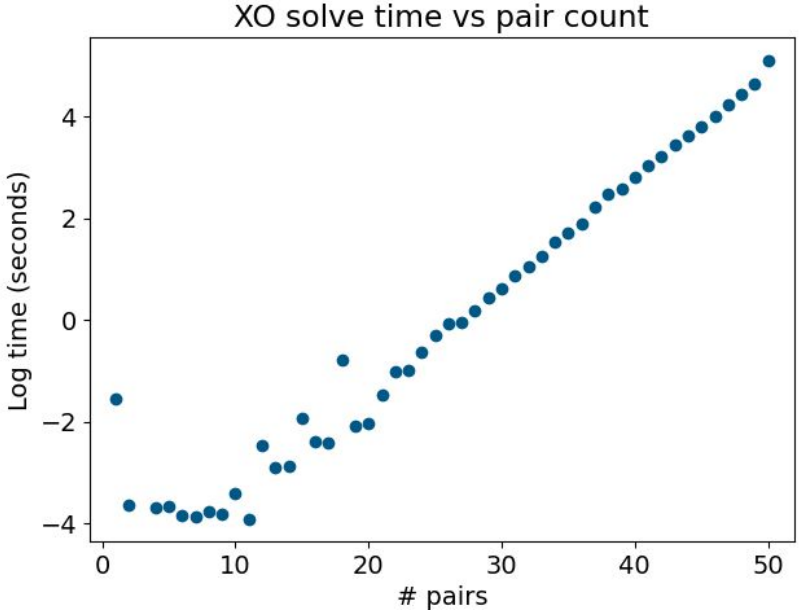
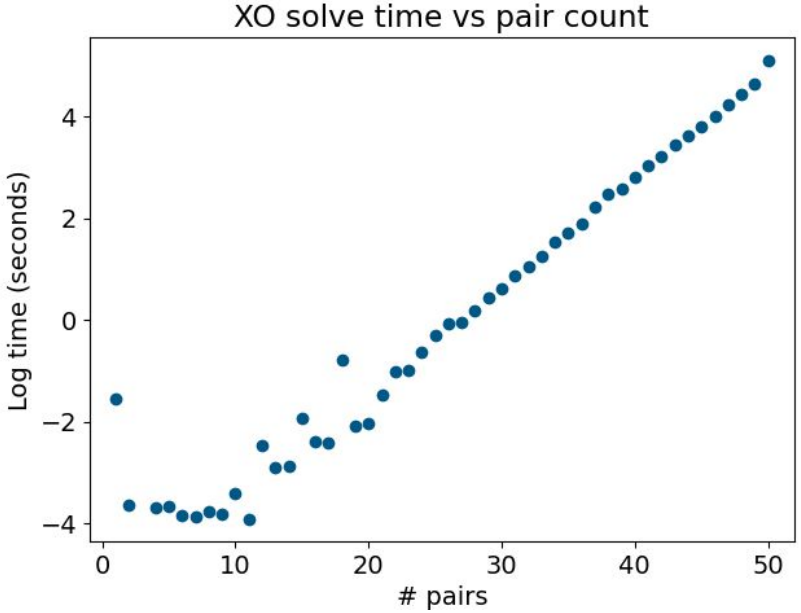


(■□)^19 = previous record

Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black

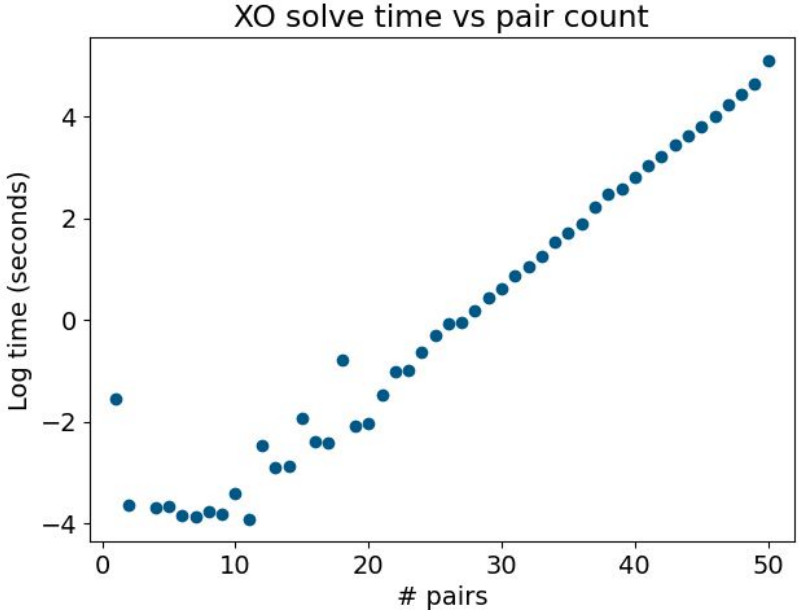


(■□)^19 = previous record

■□

Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black



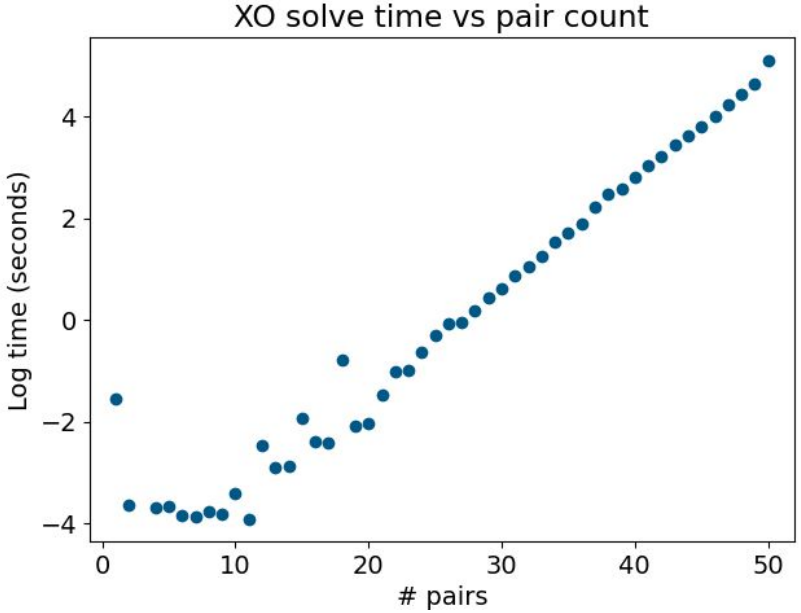
(■□)^19 = previous record

■□

0.084 seconds on clean start!

Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black

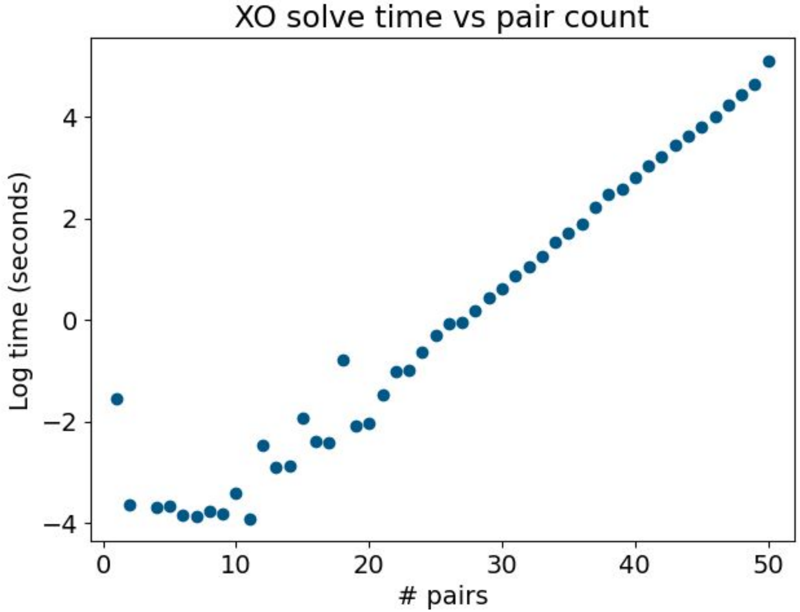


(■□)^19 = previous record
■□■
0.084 seconds on clean start!

(■□)^50 = new record

Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black

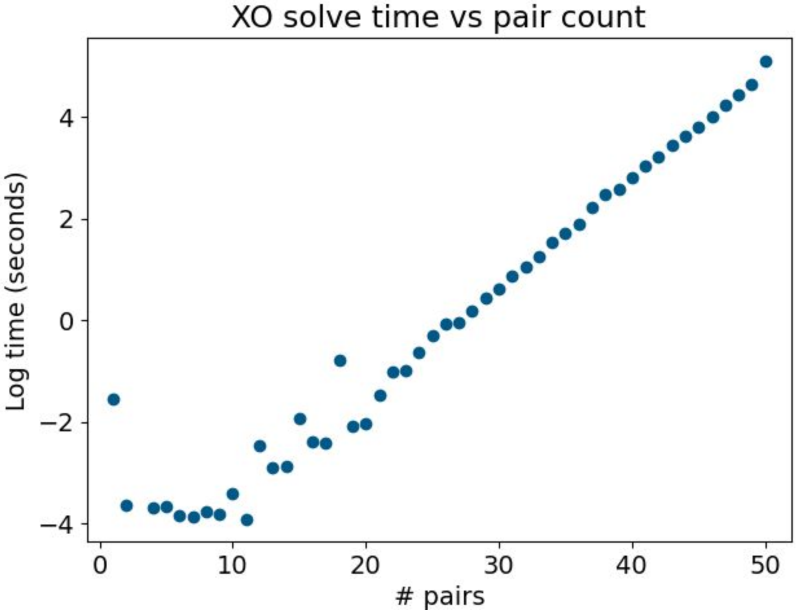


(■□)^19 = previous record
■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□
0.084 seconds on clean start!

(■□)^50 = new record
■□■
□

Verifying (■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- Root node plays hardcoded move: 13 -> right
- From n to n+1 -> ~1.6x time
- Solve only for Black



(■□)^19 = previous record

■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□■□

0.084 seconds on clean start!

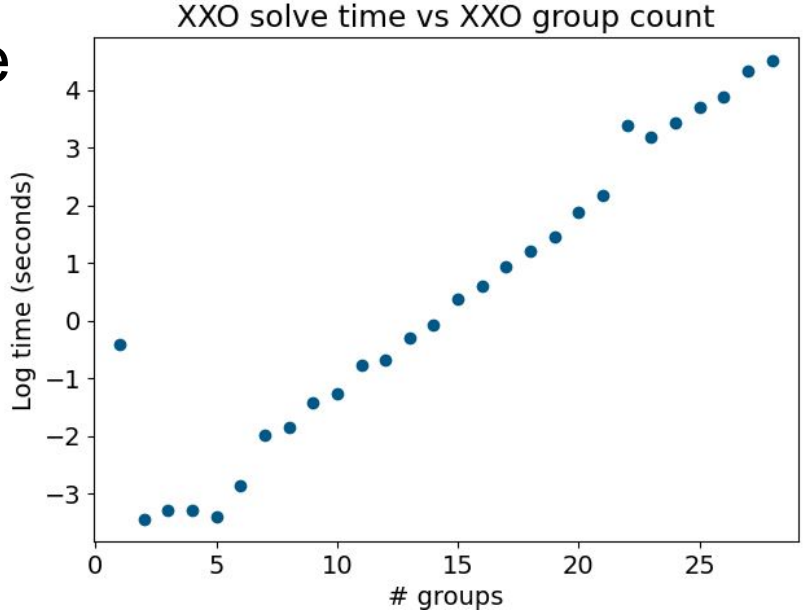
(■□)^50 = new record

■□■
□

~35 hours

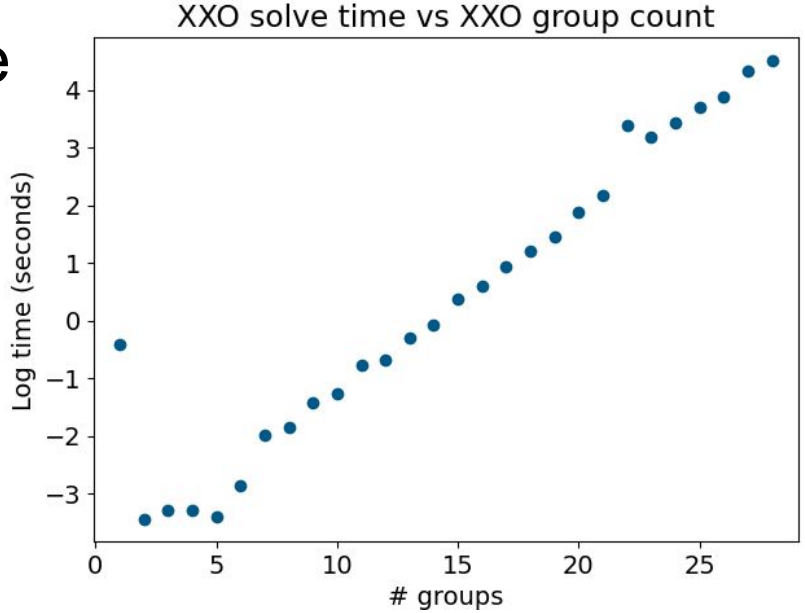
Verifying (■■□)^n Conjecture

Verifying (■■□)^n Conjecture



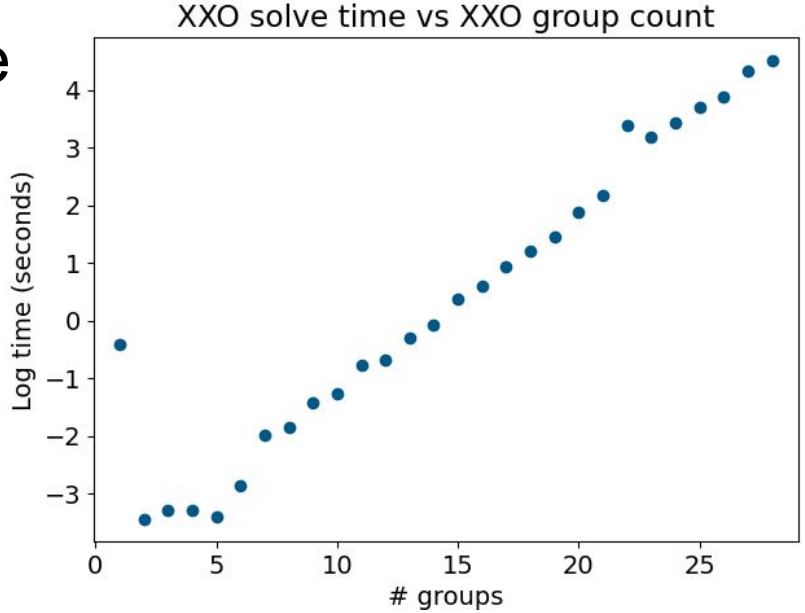
Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries



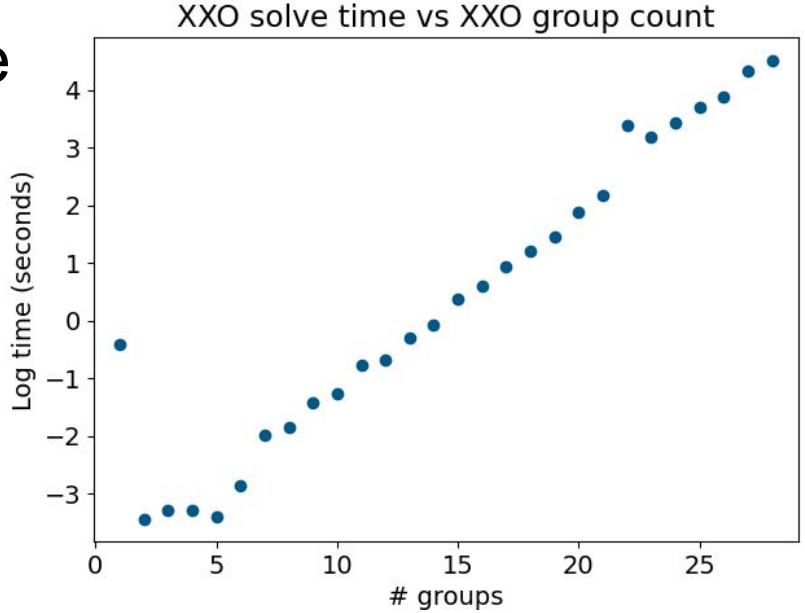
Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time



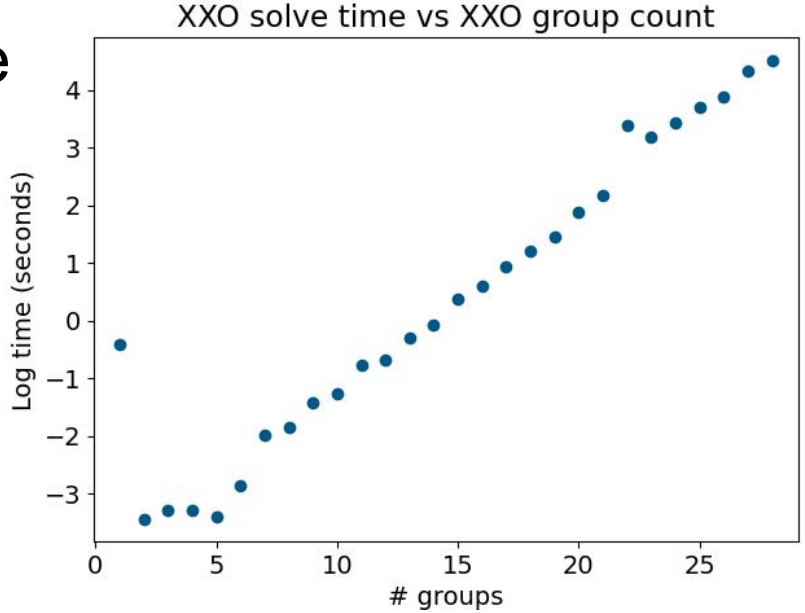
Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



Verifying (■■□)^n Conjecture

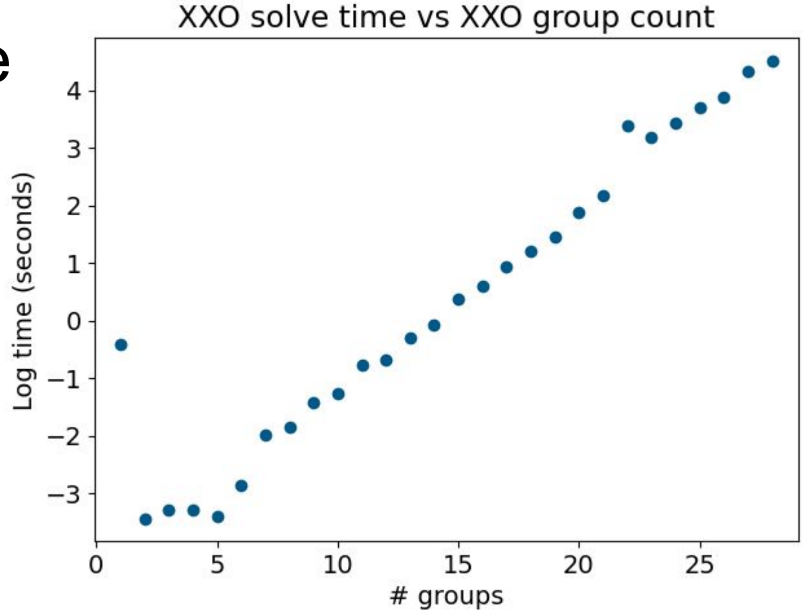
- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



(■■□)^17 + 9(□□■) = previous record

Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White

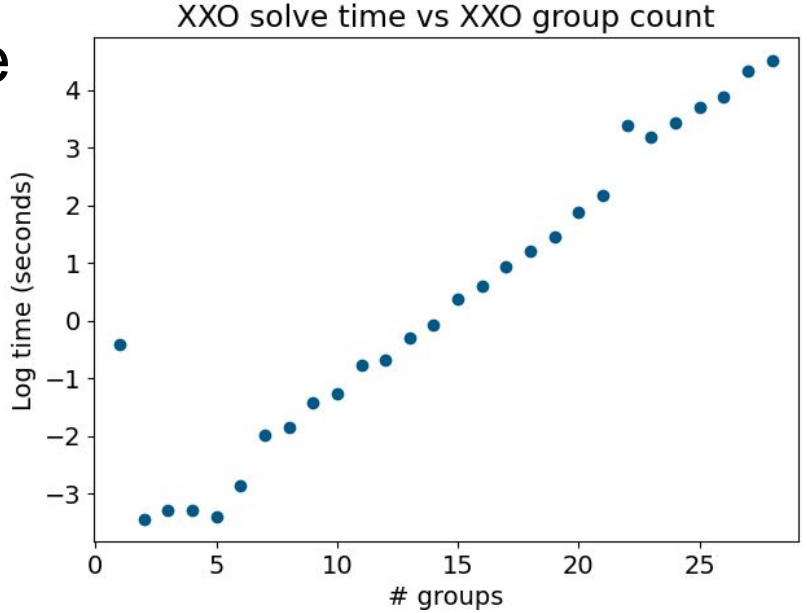


(■■□)^17 + 9(□□■) = previous record

■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■

Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



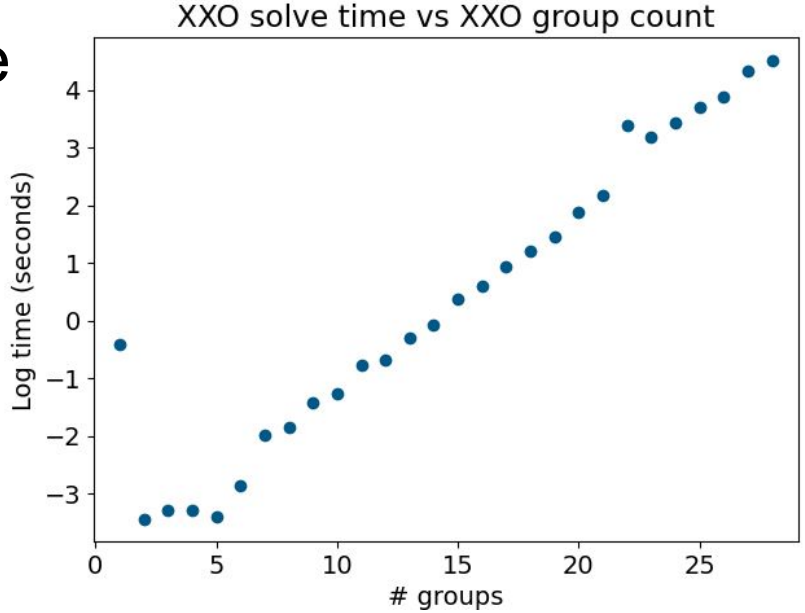
(■■□)^17 + 9(□□■) = previous record

■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■

12.72 seconds on clean start!

Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



(■■□)^17 + 9(□□■) = previous record

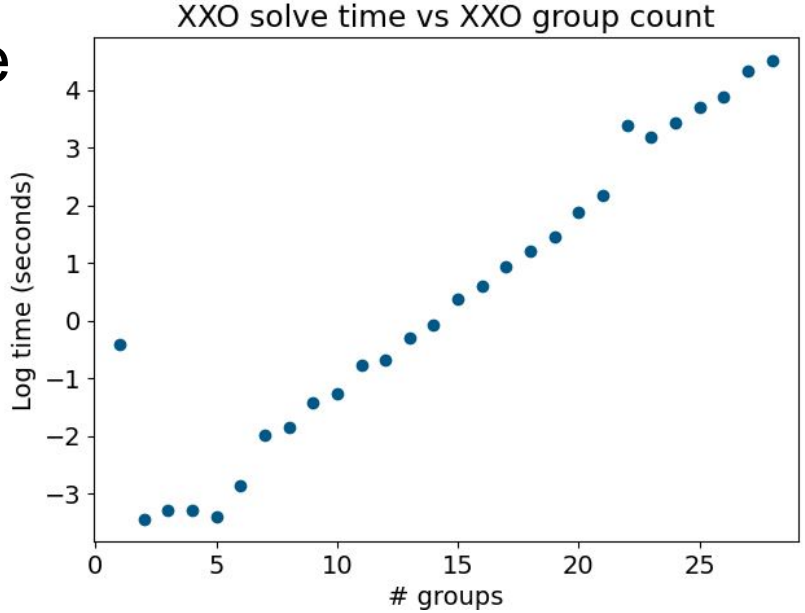
■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■

12.72 seconds on clean start!

(■■□)^28 + 14(□□■) = new record

Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



(■■□)^17 + 9(□□■) = previous record

■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■

12.72 seconds on clean start!

(■■□)^28 + 14(□□■) = new record

■■□_□□■_□□■_□□■_□□

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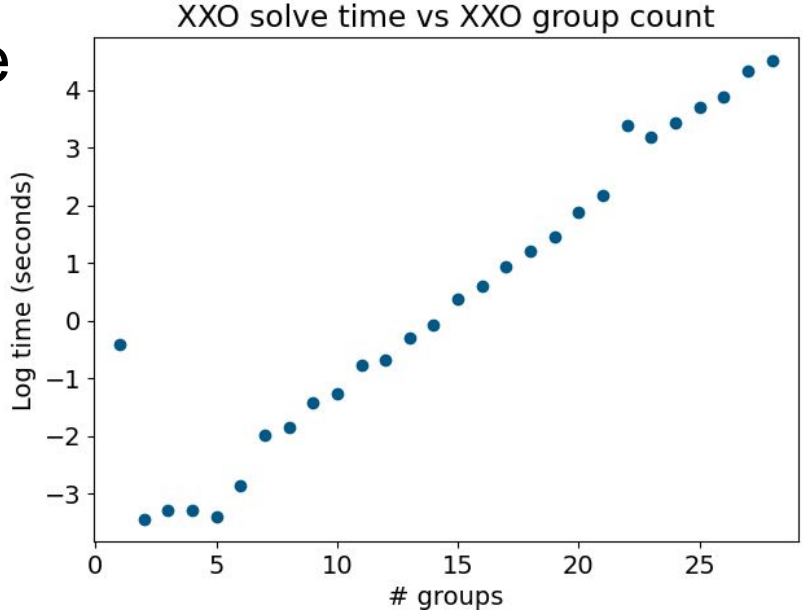
Verifying (■■□)^n Conjecture

- Transposition table not cleared between runs
- 4*2^29 table entries
- From n to n+1 -> ~2.12x time
- Solve for both Black and White



(■■□)^17 + 9(□□■) = previous record

■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□■■□_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■_□□■

12.72 seconds on clean start!

(■■□)^28 + 14(□□■) = new record

■■□_□□■_□□■_□□■_□□

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~9 hours

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- Thanks for listening!