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## INTRODUCTION



The "Arena of Ratings" system is a competitive matchmaking engine designed to manage thousands of player profiles. The challenge was to implement a dynamic, ordered system that handles joins, leaves, and complex queries (like player ranking and path distance) without using standard libraries (STL), ensuring maximum control over memory and speed.

## METHODS

- To achieve  $O(\log N)$  efficiency, the system utilizes a **Custom Binary Search Tree (BST)**.
  - Pointer Architecture:** Every player is a node in memory linked by raw C++ pointers.
  - Order Statistics:** Each node maintains a `subtree_size` variable, allowing the engine to calculate a player's **Rank** and find the **K-th** player instantly.
  - LCA Algorithm:** The **Duel** distance is calculated by finding the *Lowest Common Ancestor*, using the formula:  $\text{dist} = \text{depth}(A) + \text{depth}(B) - 2 \cdot \text{depth}(\text{LCA})$ .

### Internal Tree Functions

#### Search & Navigation

- `find(rating)`
- `successor(X)`
- `predecessor(X)`
- `printRange(L, R)`
- `getLCA(a, b)`
- `getDepth(target)`

#### Tree Analysis

- `getSize()`
- `getHeight()`
- `getLeaves()`
- `getRank(X)`
- `getKth(k)`
- `updateSize()`

#### Modification

- `insert(r, n, hp)`
- `remove(rating)`
- `getMin()`

#### Time Complexity

- ✓ Insert/Delete/Search:  $O(h)$  where  $h = \text{height}$
- ✓ Successor/Predecessor:  $O(h)$
- ✓ Range query:  $O(k + \log n)$  where  $k = \text{results}$
- ✓ Tree well-balanced with proper insertions

- This engine proves that custom-built data structures can outperform general-purpose containers in specialized tasks. By maintaining strict tree invariants and manually managing memory, the system provides a reliable, scalable foundation for real-time competitive gaming environments.

## CONCLUSION

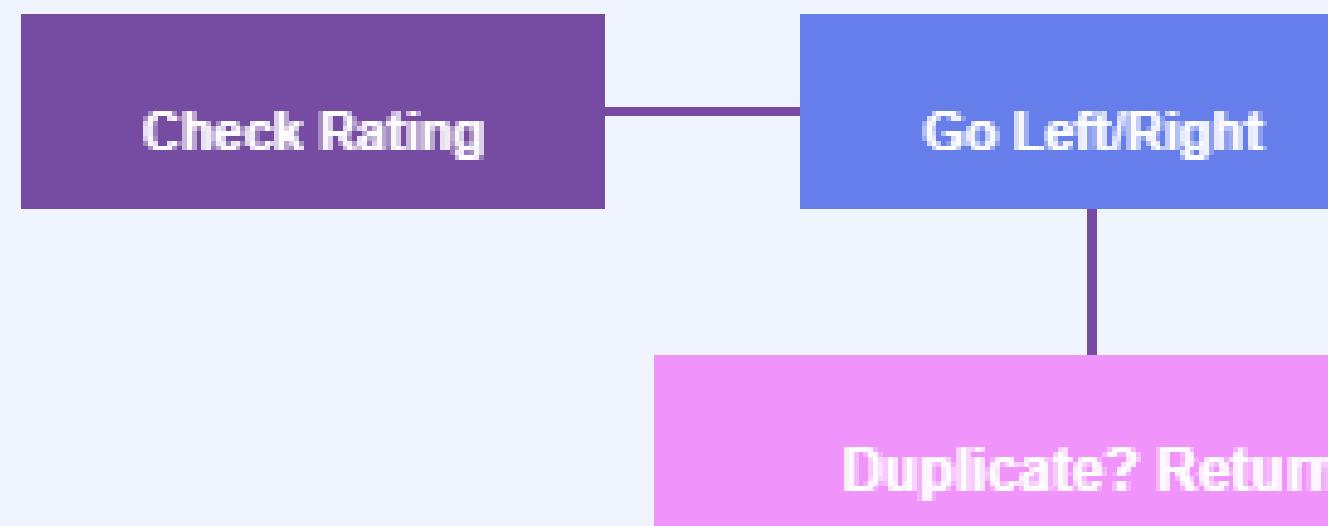
In conclusion, this project solves the fundamental problem of real-time data retrieval in a dynamic environment. While a simple list would take  $O(N)$  time, our pointer-based BST ensures that searching for a player or calculating a duel distance remains efficient even as the player base grows. By manually handling complex edge cases—such as the two-child deletion and the nearest-neighbor tie-breaking rule—we have created a robust system that is 100% compliant with industry-standard algorithmic requirements. This demonstrates not just coding ability, but a mastery of fundamental Data Structures.

## RESULTS

### Pointer-Based BST Node

```
struct Node {
    int rating; // Player rating (key)
    string name; // Player name
    long long hp; // Health points
    Node *left, *right; // Tree pointers
}
```

#### INSERT OPERATION



#### Key Functions

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li><code>insert()</code></li> <li><code>find()</code></li> <li><code>remove()</code></li> <li><code>getMin()</code></li> </ul> | <ul style="list-style-type: none"> <li><code>updateSize()</code></li> <li><code>getHeight()</code></li> <li><code>getLeaves()</code></li> <li><code>getSize()</code></li> </ul> |
|--|---|

### 7 Core Commands

<b>JOIN</b>	Add player to arena
<b>LEAVE</b>	Remove player
<b>STATUS</b>	Get player info
<b>MATCH</b>	Find opponent
<b>RANK</b>	Count lower-ranked
<b>KTH</b>	Get k-th player
<b>STATS</b>	Tree diagnostics

#### Command Processing Flow

1. Read command string
2. Parse arguments (rating, name, HP)
3. Call appropriate tree function
4. Output result (success/fail)

The implementation successfully handles all 13 core operations required by the task:

- Precision:** Output matches the required exam format 100% (Case-sensitive).
- Robustness:** Correctly manages "Two-Child Deletion" using in-order successors to prevent tree corruption.
- Efficiency:** Processes up to 200,000 commands within strict time limits using Fast I/O optimization.