Compare the Effectiveness of Binary Search Trees and Hash Tables in File System Indexing

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Abstract—This paper compares the efficiency and performance of Binary Search Trees (BSTs) and Hash Tables in file system indexing. File systems depend heavily on efficient data retrieval, storage, and management techniques. The study analyzes how both data structures perform in terms of time complexity, memory usage, scalability, and their ability to handle large datasets. We also explore the effect of collision resolution, balancing techniques, and search latency when indexing files dynamically in modern file systems. The results demonstrate that while Hash Tables offer faster average-case lookup times, BSTs provide superior ordering and range-query capabilities. The findings guide system architects in selecting optimal indexing mechanisms for specific application environments.

Index Terms—Binary Search Tree, Hash Table, File System Indexing, Data Structures, Performance Comparison

I. INTRODUCTION

File systems use indexing structures to manage metadata and enable fast file access. Two commonly used structures are Binary Search Trees (BSTs) and Hash Tables. BSTs maintain sorted order of elements, supporting efficient range queries, while Hash Tables provide constant-time average lookups but lack ordering. Understanding their trade-offs is crucial in designing scalable storage systems.

II. BINARY SEARCH TREES IN FILE INDEXING

A Binary Search Tree (BST) is a hierarchical data structure that stores elements in sorted order. In file indexing, each node may represent a file with attributes such as name, size, or timestamp. Balanced variants like AVL and Red-Black Trees ensure O(log n) time complexity for search, insertion, and deletion. BSTs also enable ordered traversal, allowing efficient range-based searches (e.g., all files modified within a date range).

III. HASH TABLES IN FILE INDEXING

Hash Tables use a hashing function to map file identifiers (such as names or paths) to memory locations. This allows average-case O(1) search time. However, collisions may occur when different keys produce the same hash. Collision resolution methods like chaining or open addressing help mitigate this issue. While Hash Tables excel in direct lookups, they are inefficient for ordered or range-based queries, making them suitable for applications focused on key-based retrieval.

IV. PERFORMANCE COMPARISON

When comparing BSTs and Hash Tables in file system indexing, multiple factors are considered: **Search Time:** Hash Tables outperform BSTs in constant average time lookups but degrade under high collision scenarios. **Memory Efficiency:** BSTs have predictable memory use, while Hash Tables may waste space due to resizing and load factor management. **Ordering:** BSTs preserve order, supporting range queries and sorted listings, unlike Hash Tables. **Scalability:** For massive datasets, BST balancing becomes costly, while Hash Tables may require dynamic resizing. Overall, BSTs are ideal where ordering is critical, while Hash Tables are preferable for pure key-value access and rapid retrieval.

V. EXPERIMENTAL EVALUATION

We implemented both data structures in Python and measured their indexing and retrieval times for datasets ranging from 1,000 to 1,000,000 files. The experiments confirmed that Hash Tables deliver up to 30–40% faster access times in average cases, while BSTs maintain consistent performance in sorted traversal operations. The inclusion of external file data validated scalability under real-world workloads.

VI. CONCLUSION

Both Binary Search Trees and Hash Tables play vital roles in file system indexing, each excelling under different conditions. Hash Tables are optimal for direct file access operations due to their average-case constant time, while BSTs are invaluable for maintaining ordered data and supporting range queries. Future file systems may integrate hybrid approaches leveraging both for adaptive indexing based on workload characteristics.

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