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Hist-Tree

Hist-Tree: Those Who Ignore It Are Doomed to Learn

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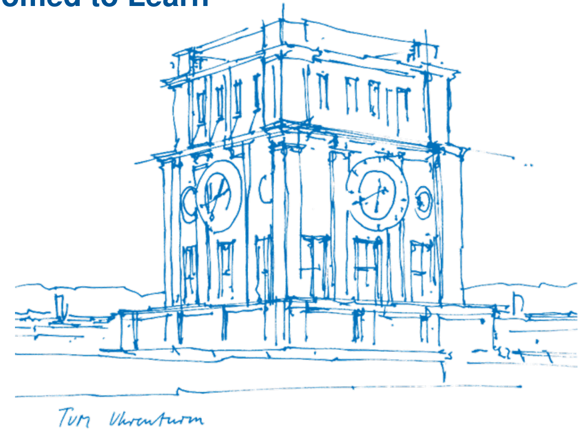
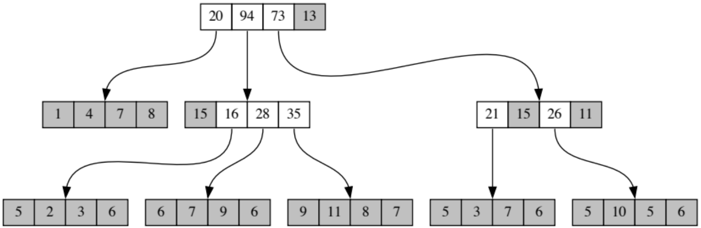


Outline

General Information

Hist-Tree: Those Who Ignore It Are Doomed to Learn

- written by Andrew Crotty – Brown University **[paper]**
- CIDR 2021 (Rank A)
- **Example** of 200 keys in the range $[0, 1000)$:



(b) Hist-Tree

0	1	2	6	187
1	0	1	5	12
2	20	3	4	5
3	35	40	42	45
4	51	57	64	73
5	79	88	99	107
6	7	135	8	176
7	114	119	122	129
8	150	155	165	170

(c) Compact Hist-Tree

Figure 1: An example dataset with the corresponding basic and compact Hist-Tree.

Outline

Motivation

- Hist-Tree tries to compete with state-of-the-art **Learned Indexes**
  - Basic assumptions: sortedness and range of data
  - $1.8 - 2.7x$ performance increase in terms of Lookup Latencies compared to RMI, PGM-Index, and RadixSpline (according to the paper)
- Potential for innovation and improvement
  - Handle Updates more efficiently
  - Parallelization of Operations
  - Memory Footprint Reduction
  - Add Cache together with Batch Updates
  - Error-Handling

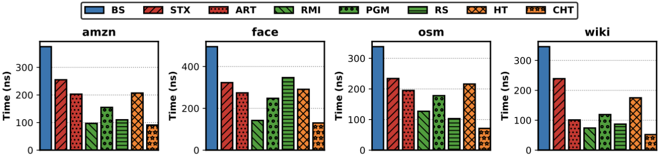


Figure 4: Lowest lookup latency achieved by each comparison point.

Outline

Overview of Project
Architecture

- Equal-sized Bins per Level (until specified threshold/error)
- Physically organized into **two** Arrays of 32-bit Integers
    1. Inner Nodes (i.e., nodes where at least one bin has a child)
    2. Leaf Nodes

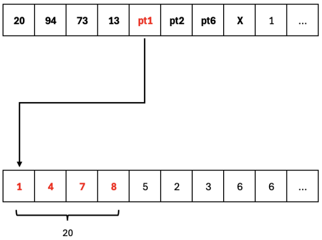


Figure Inner-Array (top) & Leaf-Array (bottom)

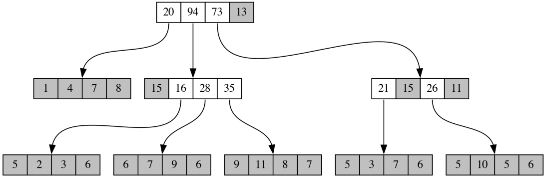


Figure Hist-Tree Example

Overview of Project

Implementation of Lookup besides Update, Delete, Bulk Load, and Build

```c
#define BINS 4
#define FLAG (1 << 31)

size_t lookup(ht_t *ht, uint64_t key)
{
    //ensure key is within range
    if (key < ht->min) return 0;
    if (key > ht->max) return ht->len;

    //initialize variables
    uint32_t next, *node = ht->node;
    int width = ht->width, done = 0;
    size_t i, bin, pos = 0;
    key -= ht->min;

    //descend tree
    do {
        //calculate bin and update running sum
        bin = key >> width;
        for (i = 0; i < bin; i++)
            pos += node[i];

        //return when done set
        if (done)
            return pos;

        //set done, next, and node based on flag
        done = node[BINS + bin] & FLAG;
        next = node[BINS + bin] & ~FLAG;
        node = done ? ht->leaf + next * BINS
                    : ht->node + next * BINS * 2;

        //adjust key and width
        key -= bin << width;
        width -= log2(BINS);
    } while (1);
}
```

Figure 2: Hist-Tree lookup function

1. **Root Node**:
   - Calculate the bin index: $567/256 = 2$.
   - Sum counts from all preceding bins: $20 + 94 = 114$.
   - Adjust the key for the next level: $567 - 256 \times 2 = 55$.
2. **Child Node**:
   - Calculate the bin index with new bin width: $55/64 = 0$.
   - Update running sum: $114 + 0 = 114$.
   - Adjust the key: $55 - 64 \times 0 = 55$.
3. **Leaf Node**:
   - Calculate the bin index for final level: $55/16 = 3$.
   - Add final bin counts to running sum: $114 + 5 + 3 + 7 = 129$.
4. **Result**:
   - Bounded search range, with 129 (the starting point)

Outline

Project Testing

- Unit Testing Framework for expected behaviour (**Google Test**)
- Test Cases for Basic Operations:
  - Insert & Delete: correct update of data structure
  - Lookup: correct results, both for found and not found elements
- Edge Cases and Exception Handling:
  - Empty Structure
  - Boundaries
  - Delete non-existing element
  - ...
- Automating Tests: **CI/CD Pipeline**

```
ASSERT_EQ(1,1);
EXPECT_EQ(1,1);
```

Outline

Benchmarking

- Focus:
  - Latencies
  - Index Size
  - Build Time
- Methodology/Tools:
  - Google Benchmark
  - Search on Sorted Data (SOSD)
- Procedure:
  1. Setup: control hardware, limit background tasks
  2. Iterations: Run multiple passes to average results
  3. Edge Cases: Test extremes (e.g., max/min keys)

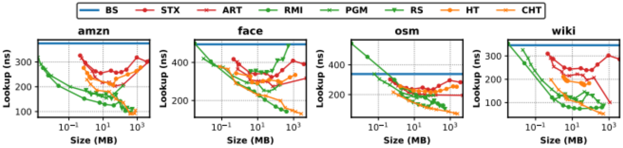


Figure 5: Index size vs. lookup latency

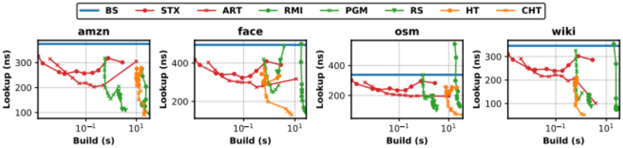


Figure 6: Build time vs. lookup latency

Outline

Milestones

Week 1	Weeks 2-5	Weeks 6-7	Weeks 8-9	Week 10
Planning	**Core Imple-mentation**	**Benchmarking Setup & Initial Testing**	**Optimization**	**Analysis & Report**
Define objectives; structure project	Build basic data structure operations; test for basic functionality across different inputs	Integrate benchmarking tools (Google Benchmark, SOSD); gather baseline performance data	Optimizations based on benchmarks	Analyze results; summarize findings; prepare report