(Not yet Adaptive) Compression of In-Memory Databases

Database Implementation Lab Course

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Project Introduction

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- Open Source SQL OLAP RDBMS in-process developed in Amsterdam research centre CWI (SQLite for OLAP) https://github.com/duckdb/duckdb
- Columnar Storage format
- Vectorized execution engine
- Has already lots of different compression possibilities for persistent data on disk

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How do we compress the transient data while having efficient lookups without decompressing everything?

Background: Succinct Data Structures

- Data structures which uses space close to the theoretic lower bound but allows efficient query operations (in-place without needing to decompress)
- Exists for e.g. (bit) vectors, trees, planar graphs, ...

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Succinct Integer Vector

Space requirement for integer x is $\ell = \lfloor \log_2(x) \rfloor + 1$ bits

0
1
1
0
0
0
1
0
1
0
0
0
1
0

= 7
= 0
= 5
= 4
= 6

Succinct Integer Vector

Space requirement for integer x is $\ell = \lfloor \log_2(x) \rfloor + 1$ bits



Encode integers with the minimal length of the max integer $3 = |\log_2(7)| + 1$



We already reduce memory by 25%

SDSL: Succinct Data Structure Library

- ► C++11 library and abstraction for succinct data structures
- ▶ Open Source https://github.com/simongog/sdsl-lite
- Contains varierty of different data structures. For now we only used the Integer Vectors.

SDSL: Integer Vectors

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```
sdsl::int_vector <32> v(10000);
for (size_t i = 0; i < 10000; i++) v[i] = i;
cout << "Width: " << v.width() << ", size: "
     << sdsl::size_in_bytes(v) << endl;
sdsl::util::bit_compress(v);
cout << "Width: " << v.width() << ", size: "
     << sdsl::size_in_bytes(v) << endl;
Width: 32, size: 40008
Width: 14, size: 17513
```

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         Reduces memory by 56.2% (\approx 22.5 KB)
```

Delta compression of sdsl::int_vector

```
sdsl::int_vector <32> v(10000);
for (size_t i = 0; i < 10000; i++)</pre>
    v[i] = i + 10.000.000;
cout << "Width: " << v.width() << ", size: "</pre>
     << sdsl::size_in_bytes(v) << endl;
sdsl::util::bit_compress(v);
cout << "Width: " << v.width() << ", size: "</pre>
     << sdsl::size_in_bytes(v) << endl;
Width: 32, size: 40008
Width: 24, size: 30008
```

Delta compression of sdsl::int_vector

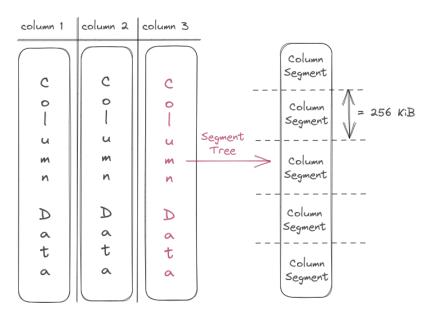
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cout << "Width: " << v.width() << ", size: "</pre>
     << sdsl::size_in_bytes(v) << endl;
extractMinFromVector(v);
sdsl::util::bit_compress(v);
cout << "Width: " << v.width() << ", size: "
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Delta compression of sdsl::int_vector

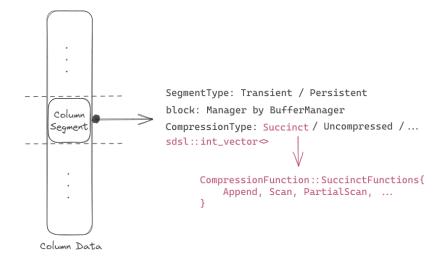
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In DuckDB we know the minimum of the vector directly without searching (column statistics)

DuckDB Storage Architecture 100 meter view



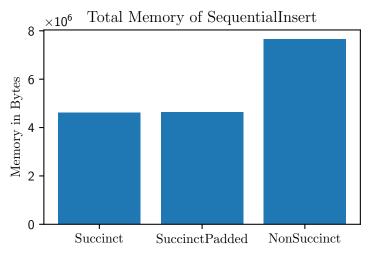
DuckDB Storage Architecture 10 meter view



Benchmarks: Sequential Insert and total Scan

Scanning 10⁶ rows.

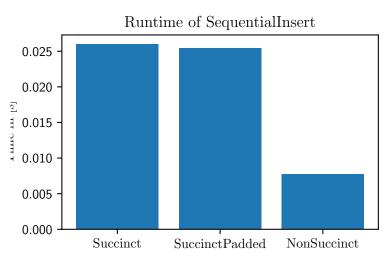
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SELECT * FROM t1;
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Benchmarks: Sequential Insert and total Scan

Scanning 10⁶ rows.

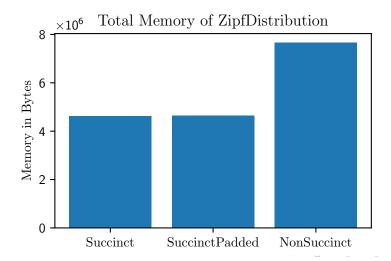
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SELECT * FROM t1;
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Benchmarks: Zipf Selection

10.000 selections with Zipf Distribution of 10⁶ total rows.

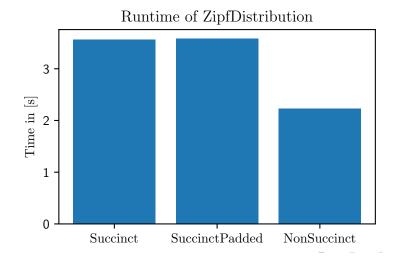
```
SELECT i FROM t1
WHERE i == {ZIPF_DISTRIBUTED_NUMBER};
```



Benchmarks: Zipf Selection

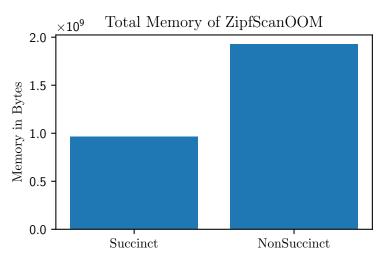
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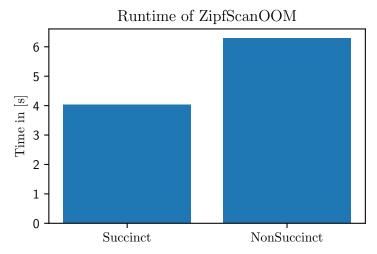
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Conclusion and Future Work

- ► For OLAPish queries it is not (yet?) worth it, large overhead.
- ▶ For OLTP transactions it might be worth it. Reduces memory by $\approx 40\%$ but increases runtime by $\approx 35\%$.
- Huge benefit if succinct representation fits in memory vs spilling to disk.

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Future Work:

- Need to investigate in access statistics to only compress rarely used column segments.
- Currently copying a lot of data as execution engine expects an uncompressed flat vector. Adapt execution engine to allow succinct vectors as well since they allow random access.