

Develop your own Database

Week 8

Review Sprint 3

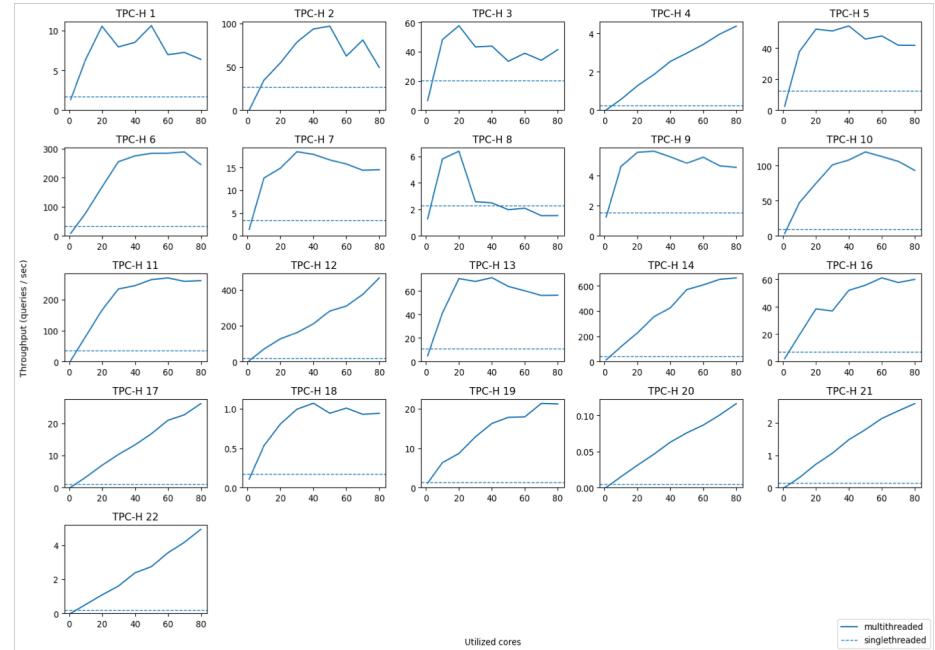
- Master's project
- Review Sprint 3
- Performance Challenge
- Group Meetings

#1: Multi-Threading and NUMA

- Mostly, we have looked at single-threaded performance

- Some queries can be run in parallel quite well, others perform worse the more cores we use

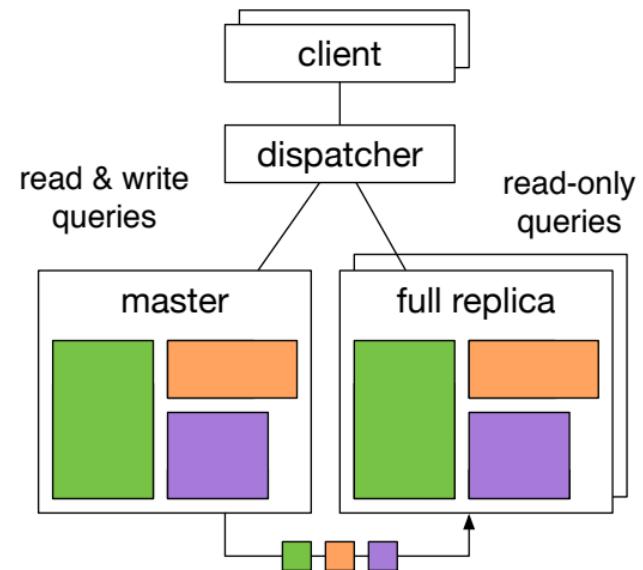
- We want to improve the scheduler and remove dependencies between tasks



- Wherever it is a bottleneck, we also want to improve the NUMA placement
- The measurement infrastructure is there - let's run Hyrise on 480 cores

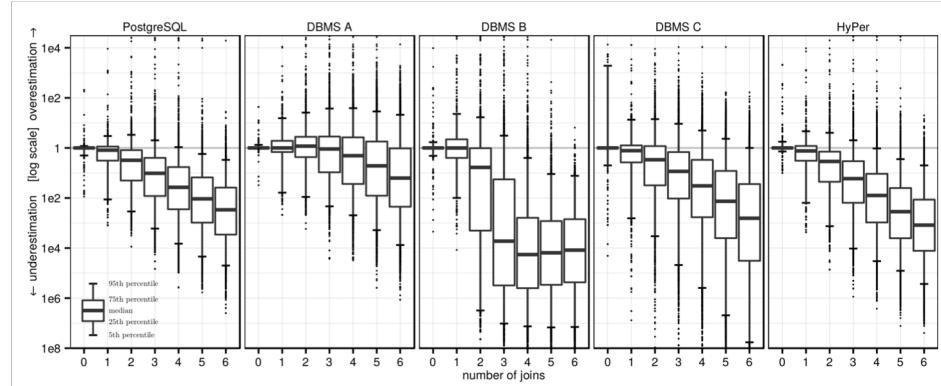
#2: Replication and Logging

- Analytical workloads can saturate single machine database servers
- Replica nodes can process read-only queries on snapshots of the master node without violating transactional consistency
- To update the replica nodes, logging information can be used



#3: Cardinality and Statistics

- Cardinality estimations are crucial for finding good query plans
- Currently, we have only histograms in Hyrise
- There are further statistics with different tradeoffs, i.e., Cost vs Estimation quality
- How do we select the appropriate one?



#4: TPC-DS

- So far, we have worked with the TPC-H benchmark
- The TPC-DS (Decision Support) benchmark uses more complex SQL queries (sometimes 100s of lines)
- By improving the optimizer and the operators, we hope to (again) improve the performance of Hyrise by orders of magnitude
- Also, we will get to implement still missing SQL features

Benchmark	prev. iter/s	new iter/s	change
TPC-H 1	0.827	6.21	+651%
TPC-H 2	0.028	133.346	+471876%
TPC-H 3	12.287	62.216	+406%
TPC-H 4	0.007	23.581	+353477%
TPC-H 5	5.903	50.192	+750%
TPC-H 6	34.571	192.292	+456%
TPC-H 7	0.883	21.315	+2313%
TPC-H 8	0.007	86.341	+1249787%
TPC-H 9	2.07	26.306	+1171%
TPC-H 10	10.964	33.873	+209%
TPC-H 11	27.335	220.087	+705%
TPC-H 12	5.229	63.781	+1120%
TPC-H 13	13.372	28.587	+114%
TPC-H 14	19.918	190.899	+858%
TPC-H 15	0.082	90.281	+110051%
TPC-H 16	3.1	69.887	+2155%
TPC-H 17	0.002	7.15	+386292%
TPC-H 18	0.012	19.353	+160190%
TPC-H 19	0.646	59.471	+9111%
TPC-H 20	0.007	4.112	+58781%
TPC-H 21	0.033	2.082	+6201%
TPC-H 22	0.465	124.38	+26636%
average			+129241%

Review Sprint 3

- Good Things First ☺
 - Most implementations work out of the box
 - 6 / 7 compile on macOS / Linux without changes
 - The number of tests range from 46 to 71 (Group 5)
 - One group's tests were failing
 - One test case took more than 80 seconds to complete
 - Some shortcut opportunities for dictionaries are missed
 - Sometimes code could be made more understandable by adding a comment
 - Not all groups did format / lint their code before handing it in

```

1 /**
2 * This file contains the actual filter logic.
3 * Every filter has its own struct.
4 * The structs implement three major methods:
5 *   check_value
6 *   This method is used to compare plain values (i.e. in
7 *   check_value_id)
8 *   This method is used to compare value ids (i.e. in Di
9 *   Note that the comparison operator in use might be di
10 *   This will be explained in detail later.
11 * begin_dictionary_column
12 * Since tables may have multiple chunks, and dictionary
13 * on a per-chunk basis, the value id of the filter val
14 * This method is used to look up the respective value
15 *
16 *
17 * Optimizations
18 *
19 * Sorted, dictionary-compressed columns offer a great way
20 * First, we use binary searches to look up the respective
21 * Second, depending on the operator, we either use a lowe
22 * The idea is to make use of the respective characteristic
23 * lower_bound
24 * Returns the first value in a vector that is greater
25 * Returns vector.end() if last value is strictly less
26 * upper_bound
27 * Returns the first value in a vector that is strictly g
28 * Returns vector.end() if last value is less than or eq
29 *
30 * In conclusion, this offers the following possibilities:
31 * Operator | Applied Logic
32 * -----|-----
33 * >= | lb / >=
34 * > | ub / >=
35 * < | lb / <
36 * <= | ub / <
37 *
38 * As an example, let's look at the '>' operator.
39 * We use upper_bound to search for the value in the dict.
40 * We now have two options:
41 * 1. The searched value is in the dict.
42 *    upper_bound will return the value in the vector tha
43 *    We can therefore include this value when we filter
44 *    However, we do not include the searched value as th
45 * 2. The searched value is not in the dict.
46 *    upper_bound will return the value in the vector tha
47 *    that is smaller than the searched value.
48 *    This value must be greater than the searched value
49 * Consequently, using the '>=' operator on the found value
50 *
51 * The main advantage we get out of this is that if the val
52 * we do not have to spend time to decide that we actually
53 * rather than the requested '>' operator.
54 * The other operators mentioned above behave similarly.
55 * The 'BETWEEN' operator is a combination of '>=' and '<='
56 * '=' and '!=' use lower_bound and check if the returned v
57 *
58 * Additionally, the operators implement logic to recognize
59 * For example, if there is an equal scan requested on a di
60 * present in the dictionary, we can completely disregard t
61 */
62
63 #pragma once
64
65 #include <limits>
66 #include <vector>
67
68 #include "types.hpp"
69
70 namespace opossum {
71
72 enum class ScanScope { ALL, SCAN, NONE };
73
74 template <typename T>
75 struct EqFilter {
76     explicit EqFilter(const T &value) : value(value) {}
77
78     const T &value;
79
80     void operator()(const T &v) const {
81         if (v == value) {
82             result = true;
83         }
84     }
85
86     bool result;
87
88     friend std::ostream &operator<<(std::ostream &os, const EqFilter &filter) {
89         os << "EqFilter(" << filter.value << ")";
90         return os;
91     }
92
93     friend std::string to_string() const {
94         return "EqFilter(" + to_string(value) + ")";
95     }
96
97     friend EqFilter operator=(const T &value) {
98         EqFilter result{value};
99         return result;
100    }
101
102    friend EqFilter operator|(EqFilter left, EqFilter right) {
103        EqFilter result{left.value};
104        result |= right.value;
105        return result;
106    }
107
108    friend EqFilter operator|(EqFilter left, const T &value) {
109        EqFilter result{left.value};
110        result |= value;
111        return result;
112    }
113
114    friend EqFilter operator|(const T &value, EqFilter right) {
115        EqFilter result{value};
116        result |= right.value;
117        return result;
118    }
119
120    friend EqFilter operator|(const T &value, const T &right) {
121        EqFilter result{value};
122        result |= right;
123        return result;
124    }
125
126    friend EqFilter operator|(EqFilter left, const EqFilter &right) {
127        EqFilter result{left.value};
128        result |= right.value;
129        return result;
130    }
131
132    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third) {
133        EqFilter result{left.value};
134        result |= right.value;
135        result |= third.value;
136        return result;
137    }
138
139    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth) {
140        EqFilter result{left.value};
141        result |= right.value;
142        result |= third.value;
143        result |= fourth.value;
144        return result;
145    }
146
147    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth) {
148        EqFilter result{left.value};
149        result |= right.value;
150        result |= third.value;
151        result |= fourth.value;
152        result |= fifth.value;
153        return result;
154    }
155
156    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth) {
157        EqFilter result{left.value};
158        result |= right.value;
159        result |= third.value;
160        result |= fourth.value;
161        result |= fifth.value;
162        result |= sixth.value;
163        return result;
164    }
165
166    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh) {
167        EqFilter result{left.value};
168        result |= right.value;
169        result |= third.value;
170        result |= fourth.value;
171        result |= fifth.value;
172        result |= sixth.value;
173        result |= seventh.value;
174        return result;
175    }
176
177    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth) {
178        EqFilter result{left.value};
179        result |= right.value;
180        result |= third.value;
181        result |= fourth.value;
182        result |= fifth.value;
183        result |= sixth.value;
184        result |= seventh.value;
185        result |= eighth.value;
186        return result;
187    }
188
189    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth, const EqFilter &ninth) {
190        EqFilter result{left.value};
191        result |= right.value;
192        result |= third.value;
193        result |= fourth.value;
194        result |= fifth.value;
195        result |= sixth.value;
196        result |= seventh.value;
197        result |= eighth.value;
198        result |= ninth.value;
199        return result;
200    }
201
202    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth, const EqFilter &ninth, const EqFilter &tenth) {
203        EqFilter result{left.value};
204        result |= right.value;
205        result |= third.value;
206        result |= fourth.value;
207        result |= fifth.value;
208        result |= sixth.value;
209        result |= seventh.value;
210        result |= eighth.value;
211        result |= ninth.value;
212        result |= tenth.value;
213        return result;
214    }
215
216    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth, const EqFilter &ninth, const EqFilter &tenth, const EqFilter &eleventh) {
217        EqFilter result{left.value};
218        result |= right.value;
219        result |= third.value;
220        result |= fourth.value;
221        result |= fifth.value;
222        result |= sixth.value;
223        result |= seventh.value;
224        result |= eighth.value;
225        result |= ninth.value;
226        result |= tenth.value;
227        result |= eleventh.value;
228        return result;
229    }
230
231    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth, const EqFilter &ninth, const EqFilter &tenth, const EqFilter &eleventh, const EqFilter &twelfth) {
232        EqFilter result{left.value};
233        result |= right.value;
234        result |= third.value;
235        result |= fourth.value;
236        result |= fifth.value;
237        result |= sixth.value;
238        result |= seventh.value;
239        result |= eighth.value;
240        result |= ninth.value;
241        result |= tenth.value;
242        result |= eleventh.value;
243        result |= twelfth.value;
244        return result;
245    }
246
247    friend EqFilter operator|(EqFilter left, const EqFilter &right, const EqFilter &third, const EqFilter &fourth, const EqFilter &fifth, const EqFilter &sixth, const EqFilter &seventh, const EqFilter &eighth, const EqFilter &ninth, const EqFilter &tenth, const EqFilter &eleventh, const EqFilter &twelfth, const EqFilter &thirteenth) {
248        EqFilter result{left.value};
249        result |= right.value;
250        result |= third.value;
251        result |= fourth.value;
252        result |= fifth.value;
253        result |= sixth.value;
254        result |= seventh.value;
255        result |= eighth.value;
256        result |= ninth.value;
257        result |= tenth.value;
258        result |= eleventh.value;
259        result |= twelfth.value;
260        result |= thirteenth.value;
261        return result;
262    }
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```

Review Sprint 3

```
_attribute_vector =
    std::dynamic_pointer_cast<BaseAttributeVector>(
        std::make_shared<FittedAttributeVector<uint8_t>>(
            column.size()));
```

```
const std::shared_ptr<ValueSegment<T>>& p_segment =
    std::dynamic_pointer_cast<ValueSegment<T>>(base_segment);
```

```
const auto value_column =
    dynamic_cast<ValueSegment<T>*>(base_segment.get());
```

Review Sprint 3

```
...
else if (scan_type == ScanType::OpNotEquals &&
          search_value_lower_bound == search_value_upper_bound) {
    for (ChunkOffset chunk_offset{0}; chunk_offset < values.size();
         chunk_offset++) {
        pos_list->push_back(RowID{chunk_id, chunk_offset});
    }
    return;
}
```

Review Sprint 3

```
switch (attribute_vector->width()) {
    case sizeof(uint8_t): {
        const auto fitted_attribute_vector = std::static_pointer_cast<
            const FittedAttributeVector<
                uint8_t>>(attribute_vector);
        DebugAssert(fitted_attribute_vector != nullptr, "cast failed");
```

```
auto row_id = RowID();
row_id.chunk_offset = i;
row_id.chunk_id = current_chunk_id;
pos_list->emplace_back(std::move(row_id));
```



mrzzzrm 5 hours ago

Although the compiler *might* speed this up, constructing the RowID and only writing its values afterwards is possibly slow. Also, `std::move(row_id)` will have no effect, RowID doesn't have data for which moving is more efficient than copying.

This is both shorter and likely faster: `pos_list->emplace_back(chunk_id, chunk_offset);`



Reply...

Review Sprint 3

```
// Scanning reference columns
for (const auto& pos : *ref_pos_list) {
    const auto& value_seg = std::dynamic_pointer_cast<ValueSegment<T>>(
        ref_seg);
    const auto& dict_seg = std::dynamic_pointer_cast<DictionarySegment<T>>(
        ref_seg);

    if (value_seg != nullptr) {
        const auto& value = value_seg->values()[chunk_offset];
        match = _matches_search_value(value);
    } else if (dict_seg != nullptr) {
        const auto& value = dict_seg->get(chunk_offset);
        match = _matches_search_value(value);
    }
    ...
}
```

Review Sprint 3

```
147 +         // Add entry to pos list using the compare function.  
148 +         for (ChunkOffset chunk_offset = 0; chunk_offset < attribute_vector->size(); ++chunk_offset) {  
149 +             if (is_greater_than_whole_chunk || is_unEqual_whole_chunk ||
```



mflueggen a day ago

If you pull `is_greater_than_whole_chunk` and `is_unEqual_whole_chunk` out of the loop and just add all the `chunk_offsets` to `pos_list` you might gain a performance benefit.



mrzzzrm 4 hours ago

If you already know (from `is_greater_than_whole_chunk || is_unEqual_whole_chunk`) that the entire Chunk matches, why check this again for each line?



Reply...

```
150 +             compare_function(attribute_vector->get(chunk_offset), value_id)) {  
151 +                 pos_list->emplace_back(RowID({ChunkID{chunk_index}, ChunkOffset{chunk_offset}}));  
152 +             }  
153 +         }
```

Review Sprint 3

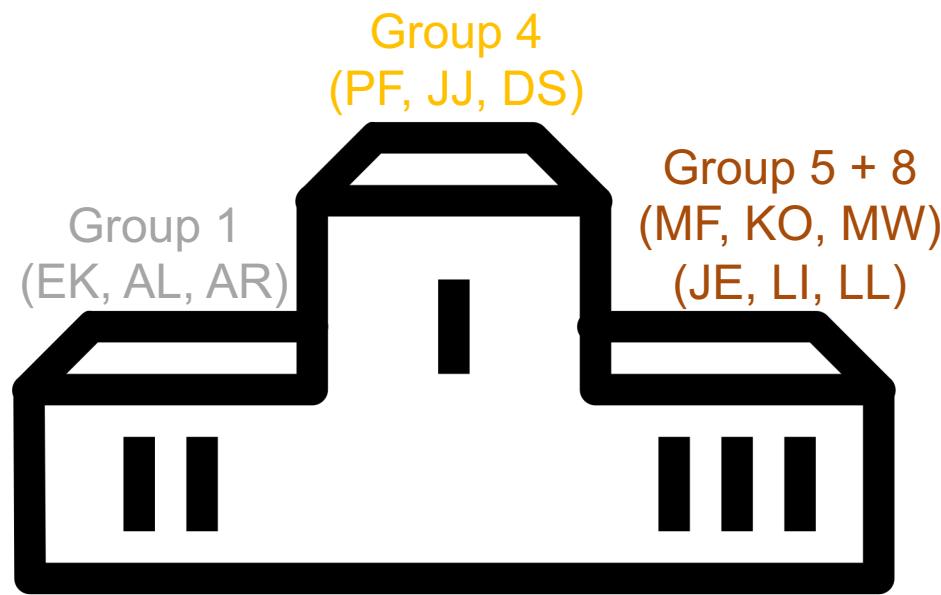
```
template <typename S>
std::function<bool(S, S)> get_comparator(ScanType scanType) {
    std::function<bool(S, S)> result;
    switch (scanType) {
        case ScanType::OpEquals: {
            result = [](S left, S right) { return left == right; };
            break;
        }
        ...
    }
}
```

```
template<typename S, typename Comparator>
void scan(...) {
    for (const auto& value : segment) {
        if (Comparator{}(value, search_value)) {
            // ... the value matches
        }
    }
}
scan<T, std::equal_to<T>>()
```

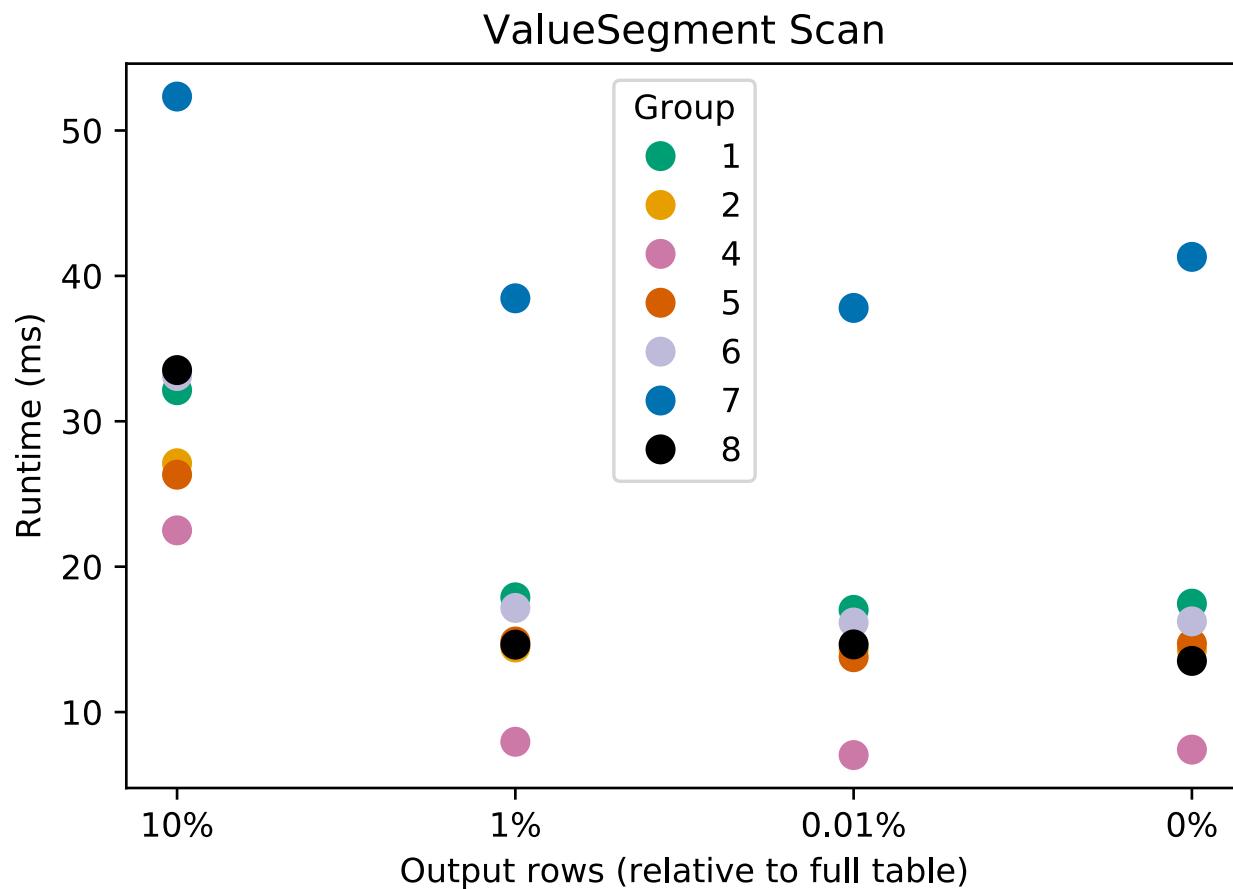
Performance Challenge

- One table of 10.000.000 records
 - Chunk sizes: 100K, 1M, 9.9M
 - 3 integer columns
 - Varying uniqueness -> different selectivities
- Several experiments on
 - ValueSegments
 - DictionarySegments
 - Dictionary + ReferenceSegments
- 100 executions per experiment including cache flushing
- All working solutions produced the same results

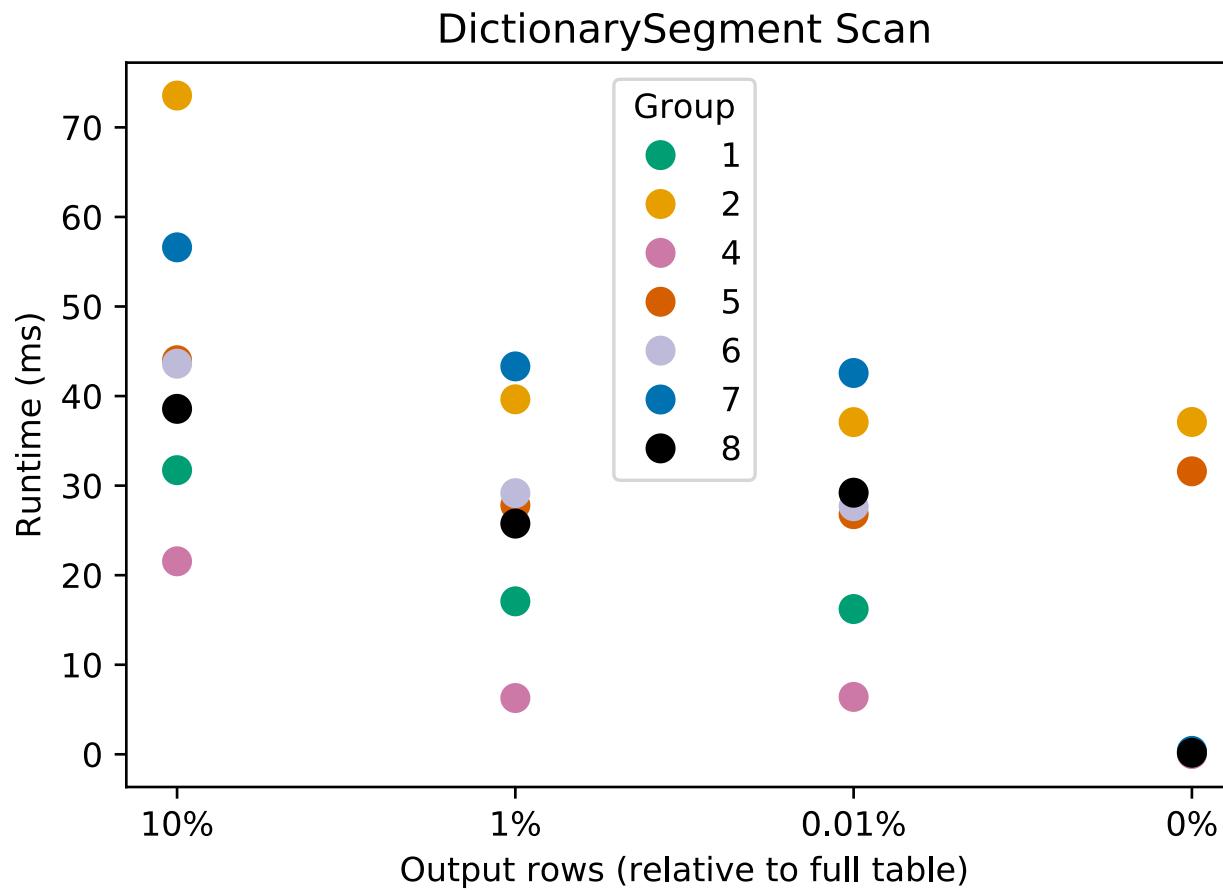
Ranking



ValueSegment



DictionarySegment



ReferenceSegment

