Hardware-Sensitive Scan Operator Variants for Compiled Selection Pipelines

OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG
INF FAKULTÄT FÜR INFORMATIK

Databases and Software Engineering

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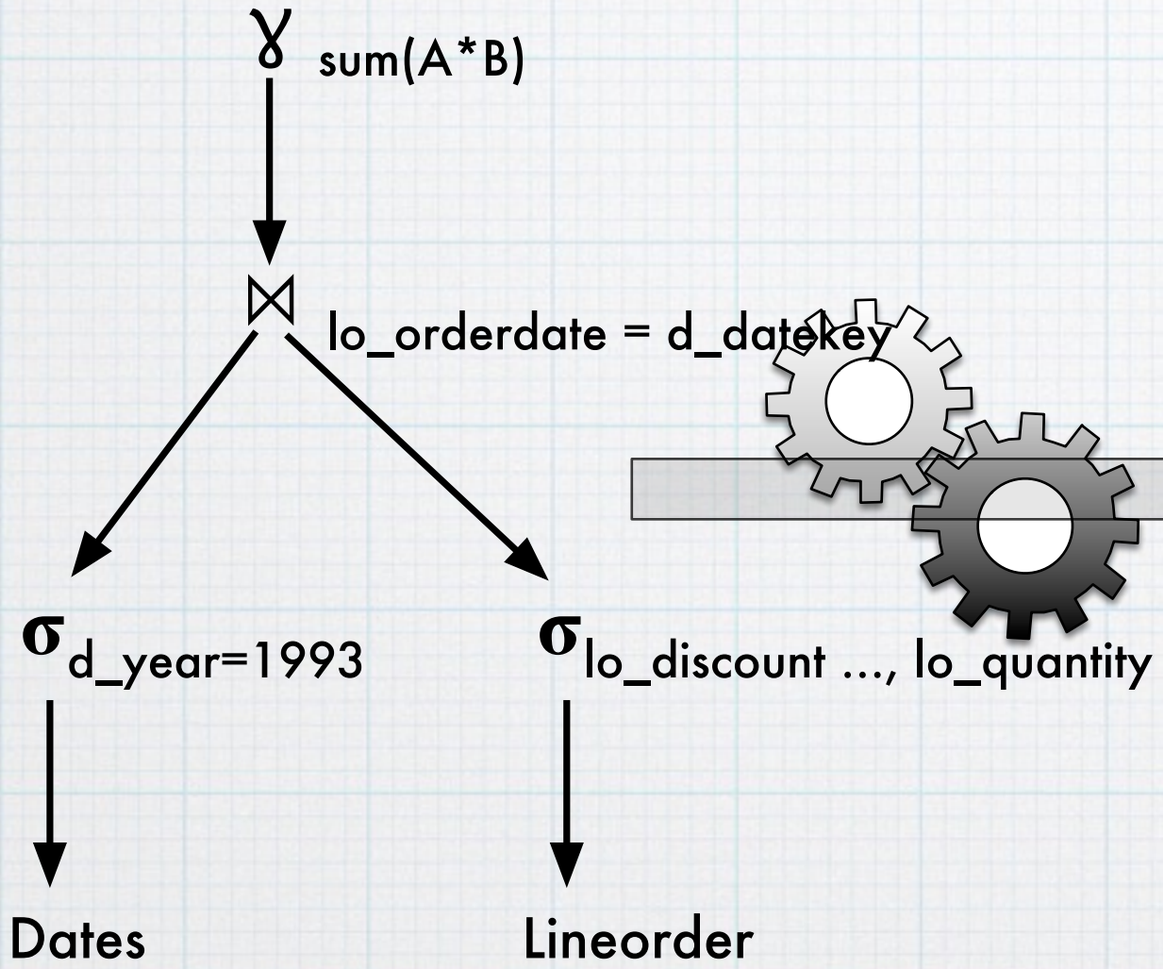
Introduction Query Compilation




```
int32_t* array_LINEORDER1_LINEORDER_LO_QUANTITY1 = getArrayFromColumn_int32_t(col_LINEORDER1_LINEORDER_LO_QUANTITY1);

TID tuple_id_DATES1=0;
HashTablePtr generic_hashtable_DATES_D_DATEKEY1=getHashTable(table_DATES1, "DATES.D_DATEKEY.1");
hashtable_t* hashtable_DATES_D_DATEKEY1= (hashtable_t*) getHashTableFromSystemHashTable(generic_hashtable_DATES_D_DATEKEY1);
double computed_var = double(0);
SUM_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM = 0;


size_t current_result_size=0;
size_t allocated_result_elements=10000;
double* result_array_REVENUE = (double*) realloc(NULL, allocated_result_elements * sizeof(double));

size_t num_elements_LINEORDER_1 = getNumberOfRows(table_LINEORDER1);
for(size_t tuple_id_LINEORDER1=0; tuple_id_LINEORDER1<num_elements_LINEORDER_1; ++tuple_id_LINEORDER1) {
    if((( array_LO_DISCOUNT1[tuple_id_LINEORDER1] >= 1.0f))) {
        if((( array_LO_DISCOUNT1[tuple_id_LINEORDER1] <= 3.0f))) {
            if(((array_LINEORDER1_LINEORDER_LO_QUANTITY1[tuple_id_LINEORDER1] < 25))) {
                unsigned long hash_DATES_D_DATEKEY1 = HASH(array_LO_ORDERDATE1[tuple_id_LINEORDER1]) & hashtable_DATES_D_DATEKEY1->mask;
                hash_bucket_t *b_Datek = &hashtable_DATES_D_DATEKEY1->buckets[hash_DATES_D_DATEKEY1];
                while (b_Datek) {
                    for (size_t b_tid_Datek = 0; b_tid_Datek < b_Datek->count; b_tid_Datek++) {
                        if (b_Datek->tuples[b_tid_Datek].key == array_LO_ORDERDATE1[tuple_id_LINEORDER1]) {
                            tuple_id_DATES1=b_Datek->tuples[b_tid_Datek].value;

                            computed_var = array_LO_EXTENDEDPRICE1[tuple_id_LINEORDER1] *  array_LO_DISCOUNT1[tuple_id_LINEORDER1];
                            SUM += computed_var;
                        }
                    }
                    b_Datek = b_Datek->next;
                }

            }
        }
    }
}
result_array_REVENUE[current_result_size] = SUMarray_LO_ORDERDATE1_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM;
current_result_size++;
std::vector<ColumnPtr> result_columns;
result_columns.push_back(createResultArray_double("REVENUE", result_array_REVENUE, current_result_size));
TablePtr result_table=createTableFromColumns("LINEORDER", &result_columns[0], result_columns.size());
/* Add build hash tables to result table. */

/* Clean up resources. */

return result_table;
```

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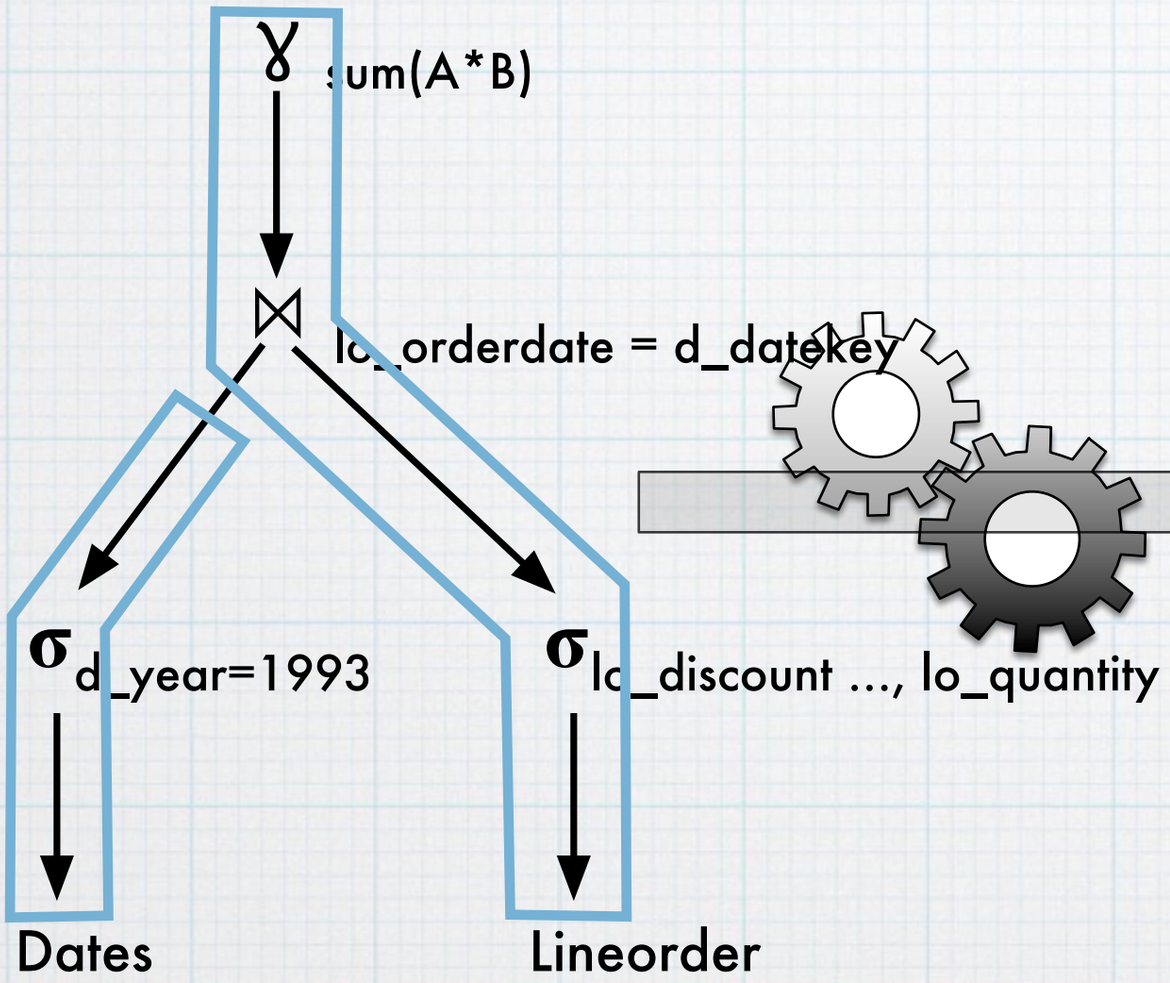
Introduction Query Compilation

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hashtable_t* hashtable_DATES_D_DATEKEY1= (hashtable_t*) getHashTableFromSystemHashTable(generic_hashtable_DATES_D_DATEKEY1);
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SUM_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM = 0;


size_t current_result_size=0;
size_t allocated_result_elements=10000;
double* result_array_REVENUE = (double*) realloc(NULL, allocated_result_elements * sizeof(double));

size_t num_elements_LINEORDER_1 = getNumberOfRows(table_LINEORDER1);
for(size_t tuple_id_LINEORDER1=0; tuple_id_LINEORDER1<num_elements_LINEORDER_1; ++tuple_id_LINEORDER1) {
    if((( array_LO_DISCOUNT1[tuple_id_LINEORDER1] >= 1.0f))) {
        if(((  array_LO_DISCOUNT1[tuple_id_LINEORDER1] <= 3.0f))) {
            if(((array_LINEORDER1_LINEORDER_LO_QUANTITY1[tuple_id_LINEORDER1] < 25))) {
                unsigned long hash_DATES_D_DATEKEY1 = HASH(array_LO_ORDERDATE1[tuple_id_LINEORDER1]) & hashtable_DATES_D_DATEKEY1->mask;
                hash_bucket_t *b_Datek = &hashtable_DATES_D_DATEKEY1->buckets[hash_DATES_D_DATEKEY1];
                while (b_Datek) {
                    for (size_t b_tid_Datek = 0; b_tid_Datek < b_Datek->count; b_tid_Datek++) {
                        if (b_Datek->tuples[b_tid_Datek].key == array_LO_ORDERDATE1[tuple_id_LINEORDER1]) {
                            tuple_id_DATES1=b_Datek->tuples[b_tid_Datek].value;

                            computed_var = array_LO_EXTENDEDPRICE1[tuple_id_LINEORDER1] *  array_LO_DISCOUNT1[tuple_id_LINEORDER1];
                            SUM += computed_var;
                        }
                    }
                    b_Datek = b_Datek->next;
                }

            }
        }
    }
}
result_array_REVENUE[current_result_size] = SUMarray_LO_ORDERDATE1_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM;
current_result_size++;
std::vector<ColumnPtr> result_columns;
result_columns.push_back(createResultArray_double("REVENUE", result_array_REVENUE, current_result_size));
TablePtr result_table=createTableFromColumns("LINEORDER", &result_columns[0], result_columns.size());
/* Add build hash tables to result table. */

/* Clean up resources. */

return result_table;
```

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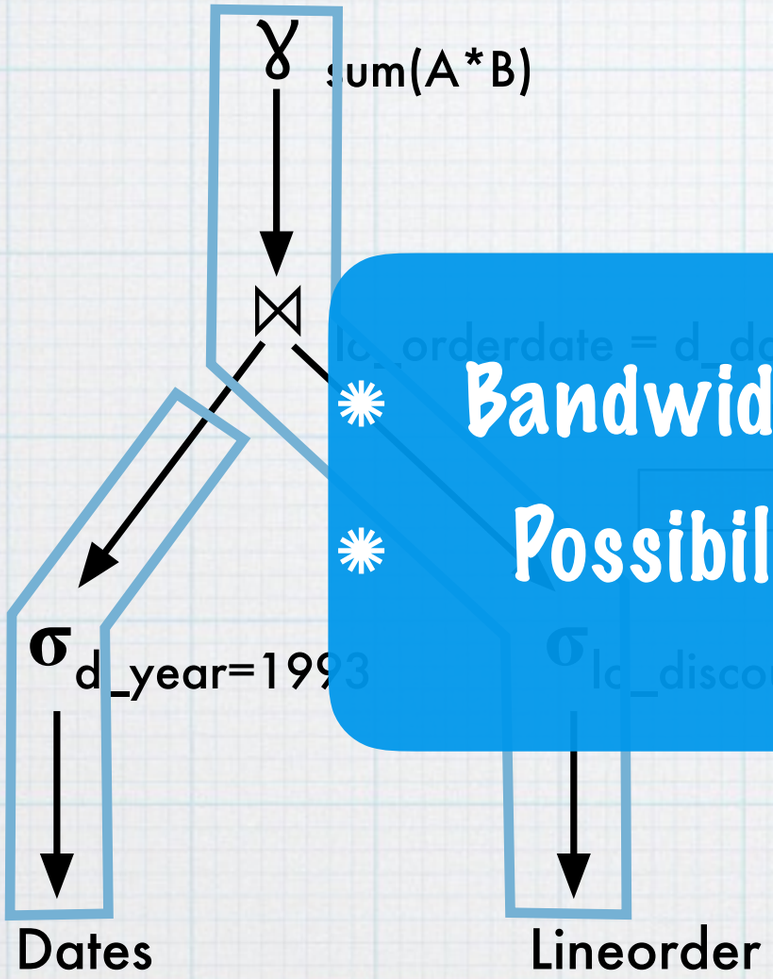

- Bandwidth-bound -> compute-bound
- Possibility for code optimizations

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hashtable_t* hashtable_DATES_D_DATEKEY1= (hashtable_t*) getHashTableFromSystemHashTable(generic_hashtable_DATES_D_DATEKEY1);
double computed_var = double(0);
SUM_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM = 0;
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```
result_array_REVENUE[current_result_size] = SUMarray_LO_ORDERDATE1_OF_LINEORDER_LO_EXTENDEDPRICE1_MUL_LINEORDER_LO_DISCOUNT1_SUM;
current_result_size++;
std::vector<ColumnPtr> result_columns;
result_columns.push_back(createFixedSizeDoubleColumn("REVENUE", result_array_REVENUE, current_result_size));
TablePtr result_table=createTableFromColumns("LINEORDER", &result_columns[0], result_columns.size());
/* Add build hash tables to result table. */

/* Clean up resources. */

return result_table;
```

Motivating Examples

Motivating Examples

Branching

```
1  for(int i = 0; i < input_size; ++i){
2    if(col[i] < pred)
3        agg+=agg_col[i];
4  }
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Predicated

```
1  for(int i = 0; i < input_size; ++i){
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```

SIMD [ZR02]

```
1  for(int i = 0; i < simd_size; ++i){
2    mask= SIMD_COMP(simd_col[i],pred);
3    if(mask){
4      for (int j=0;j < SIMD_LENGTH;++j){
5        if((mask >> j) & 1)
6          agg+=agg_col[i];
7      }
8    }
9  }
```

Motivating Examples

Branching

```
1  for(int i = 0; i < input_size; ++i){
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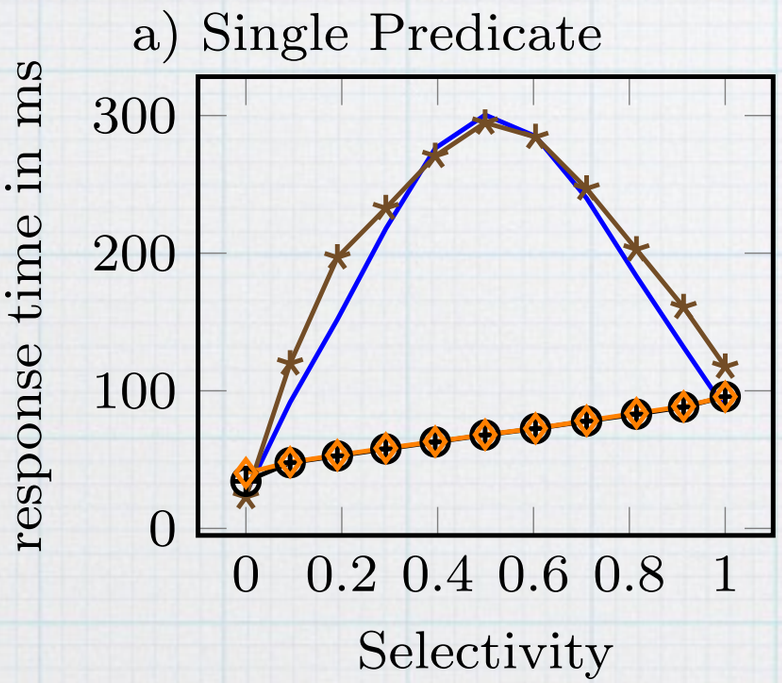
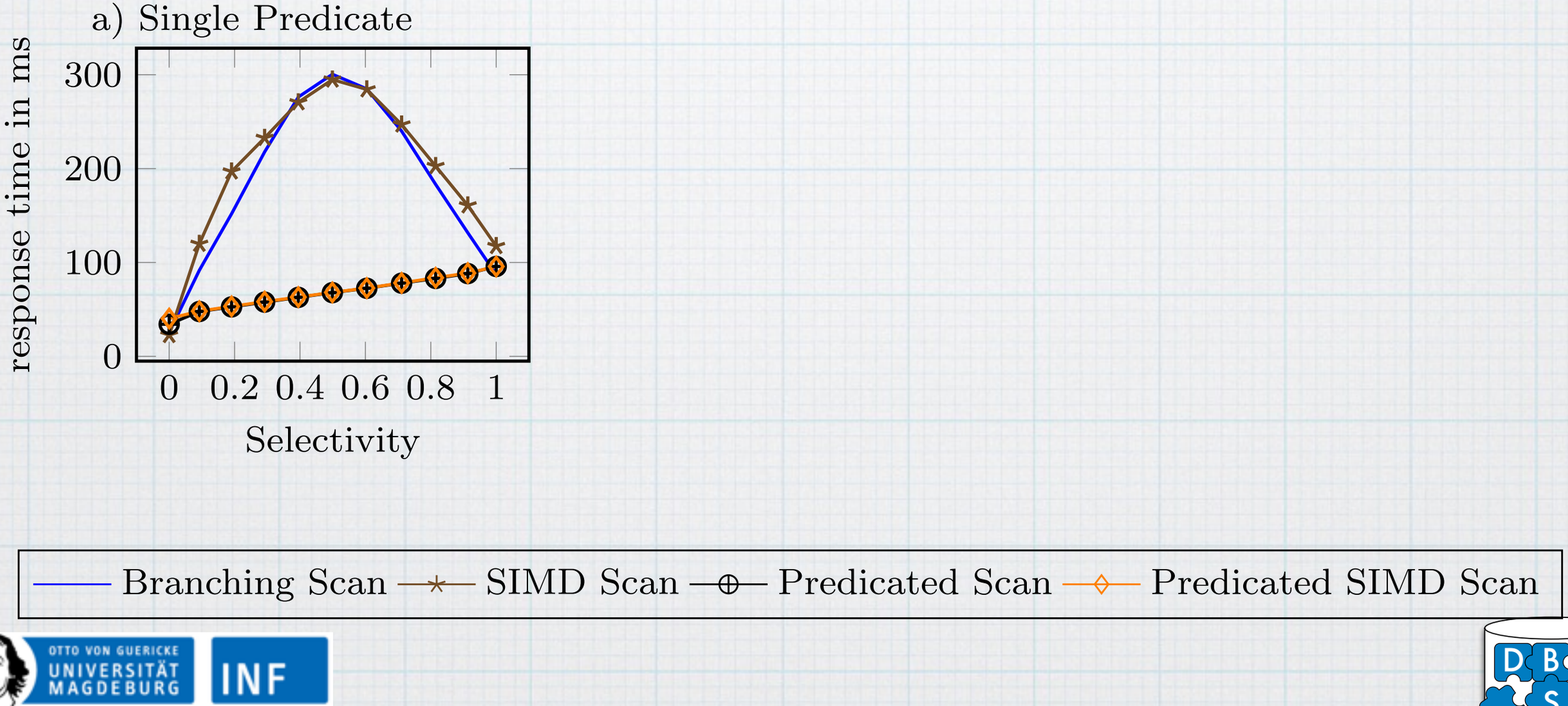
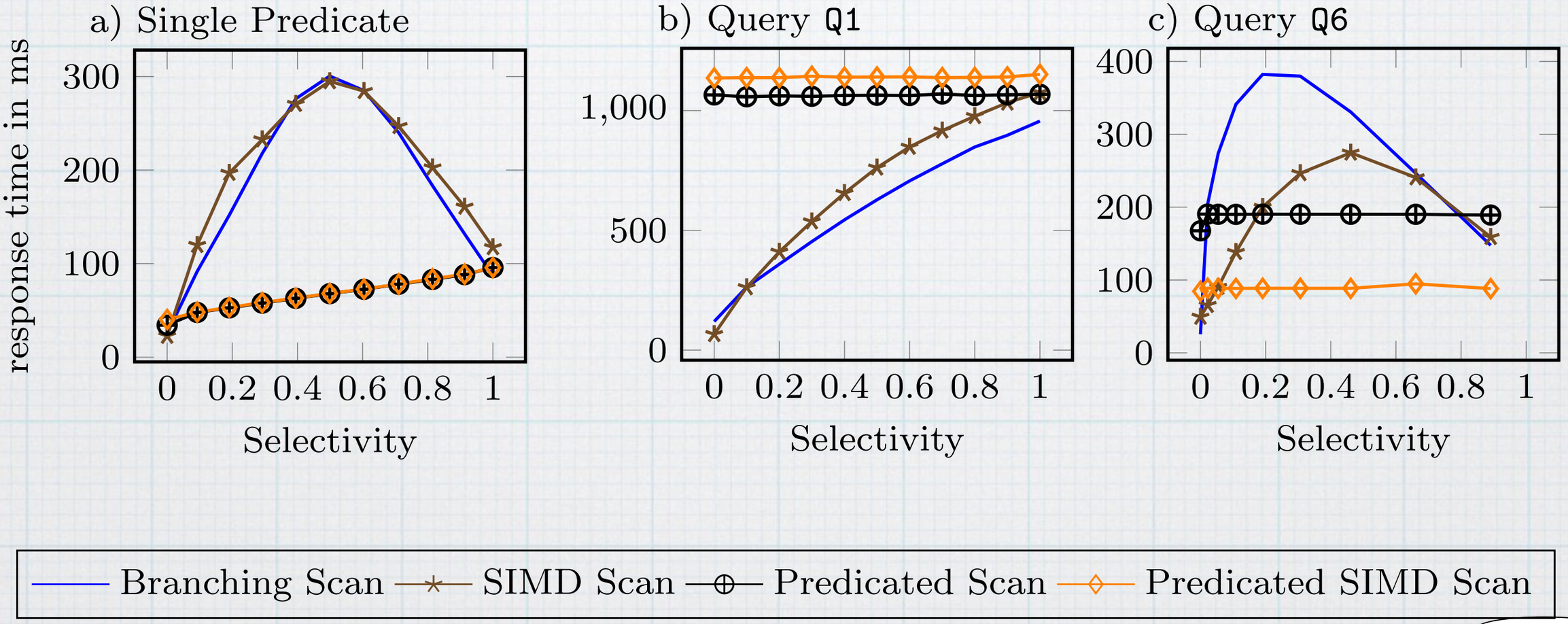


Motivating Examples

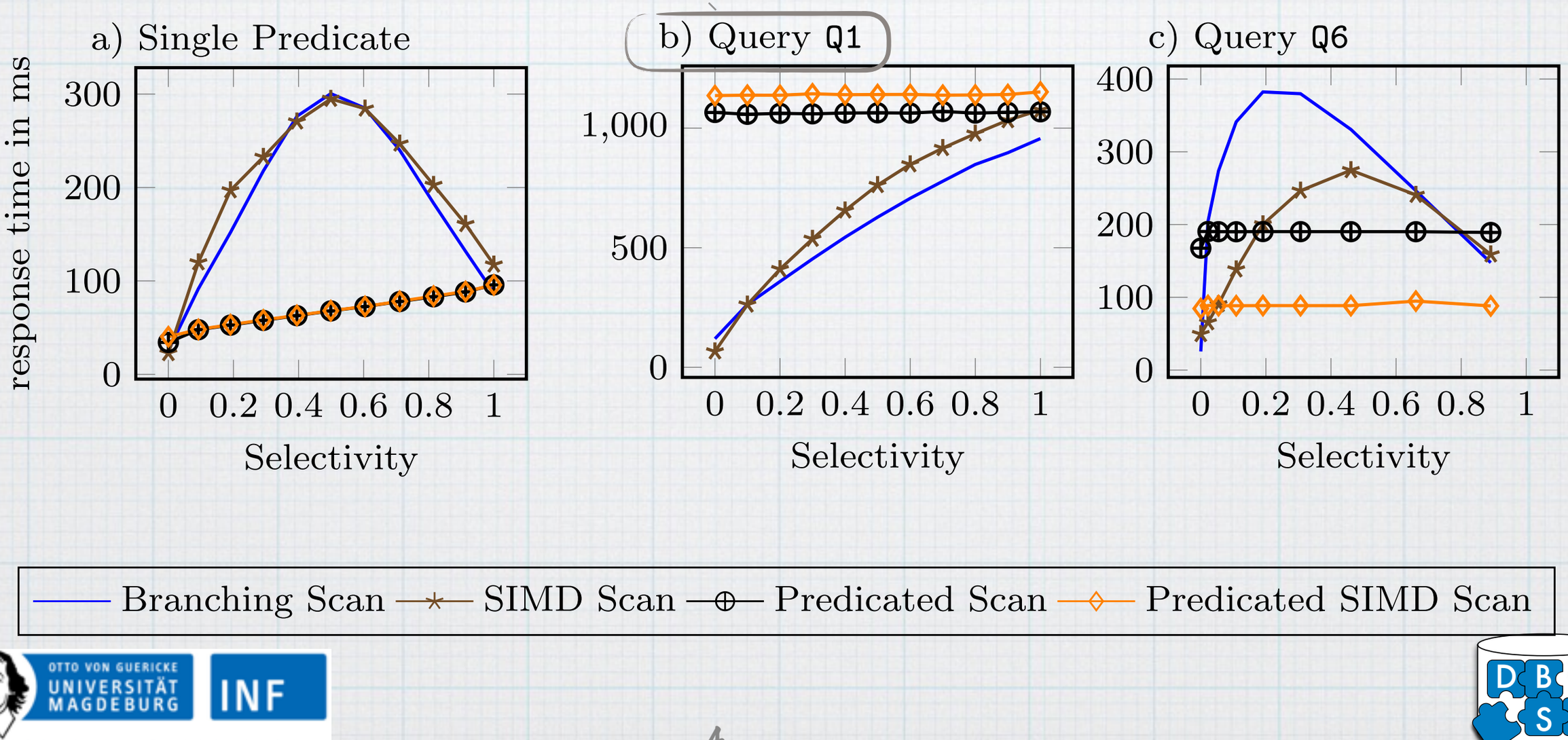


Motivating Examples



Motivating Examples

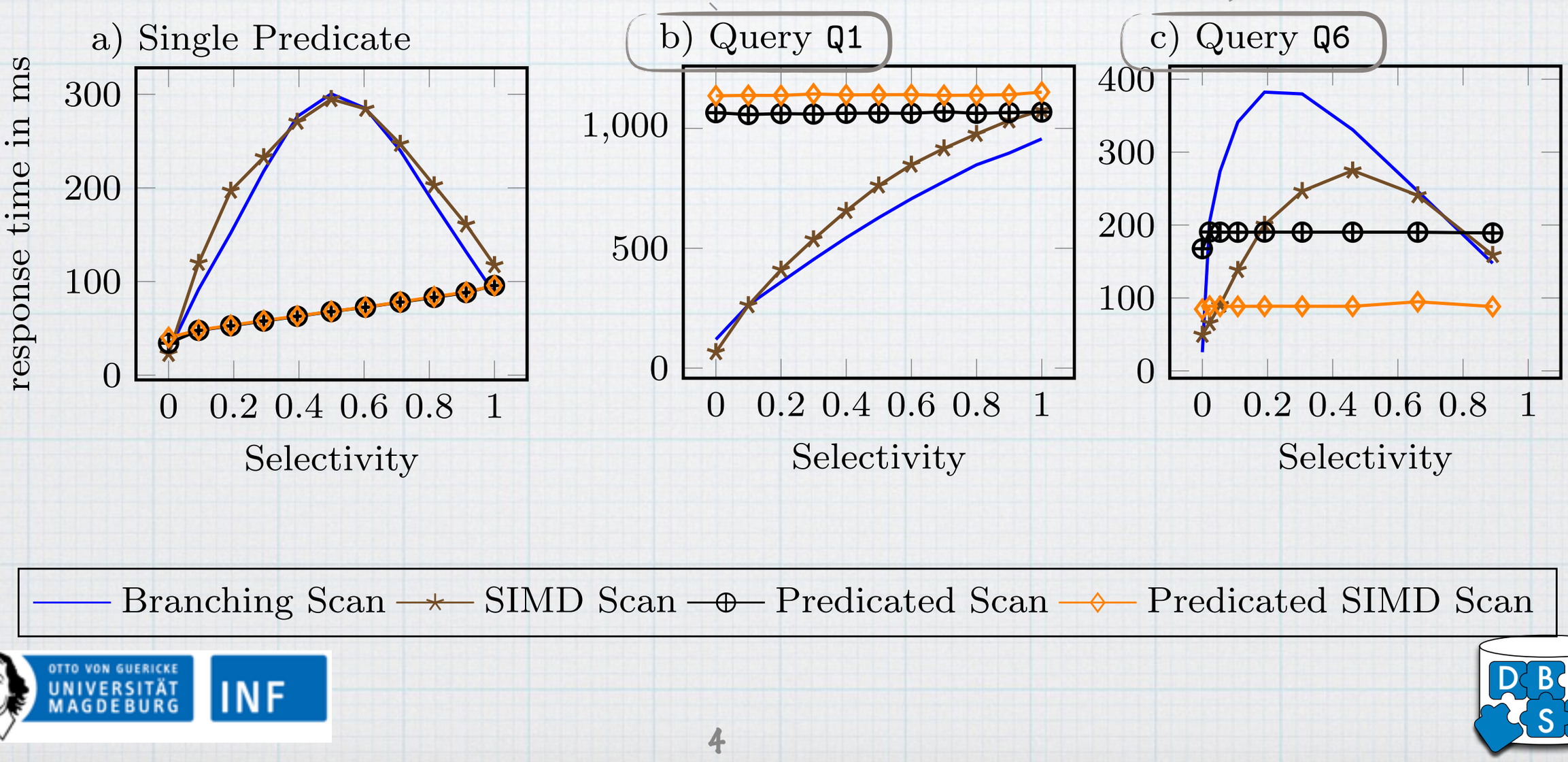
8 Aggregates
1 Filter Predicate



Motivating Examples

8 Aggregates
1 Filter Predicate

1 Aggregate
3 Filter Predicates



Motivating Examples

8 Aggregates
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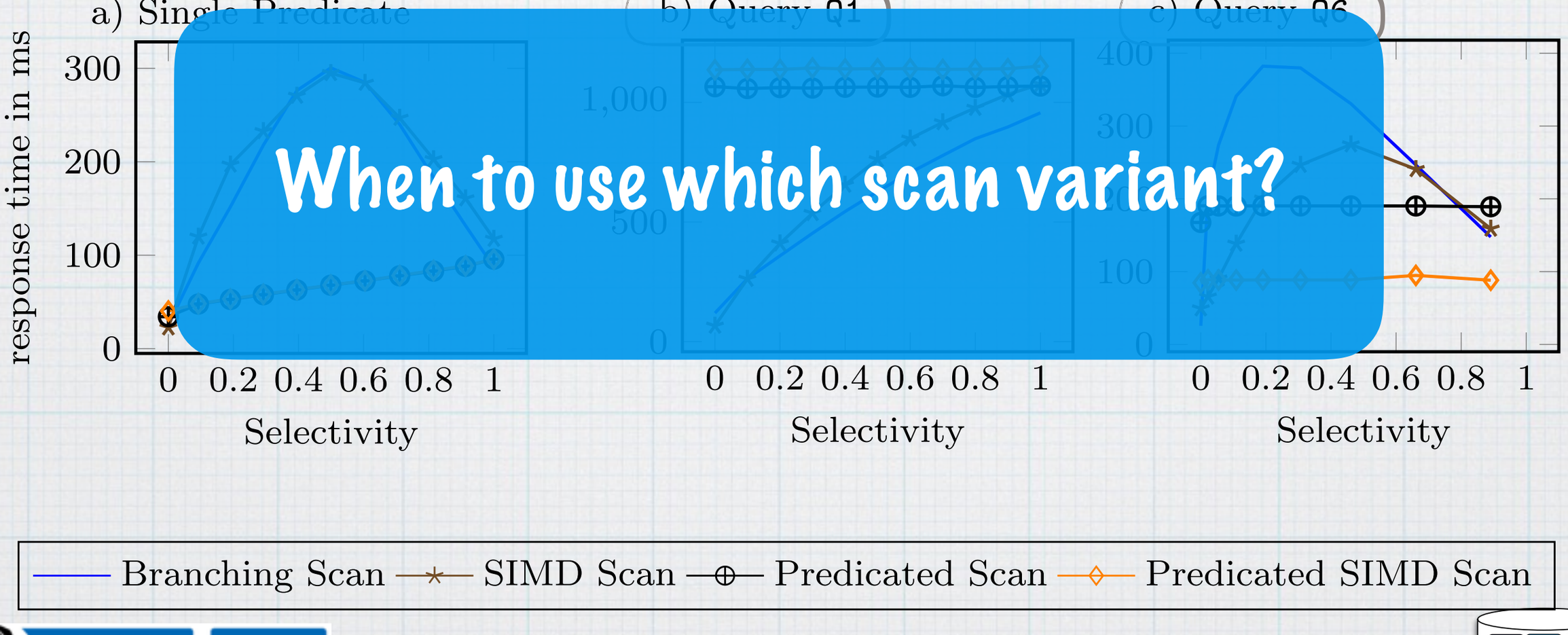


When to use which scan variant?

Evaluation Setup

Evaluation Criteria

* Number of predicates
* Number of aggregates inside loop

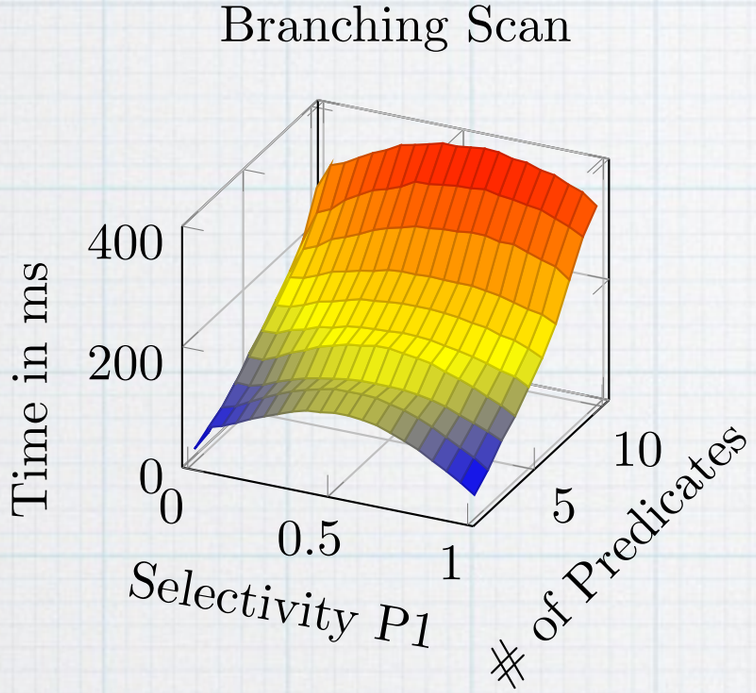
Workload & Machine

* TPC-H Lineltem table SF 10
* Intel Xeon E5-2630 v3 with SSE4.2

Variants:

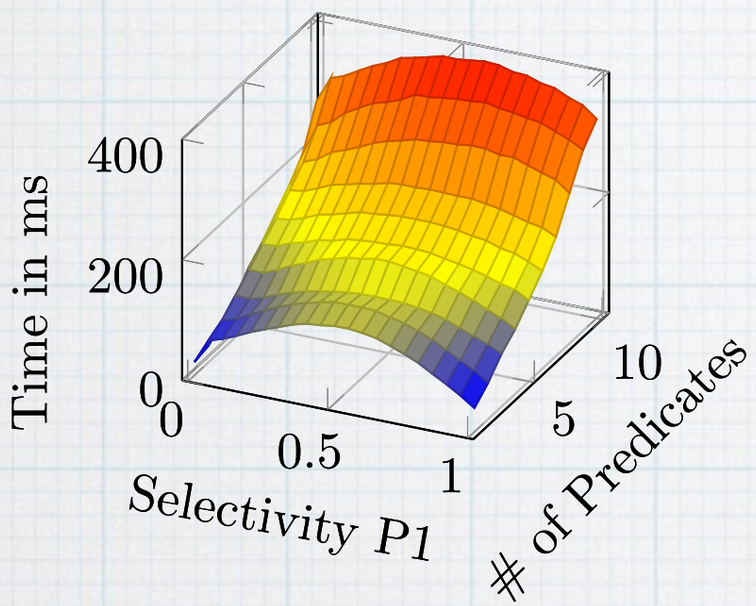
* Branching vs. Predication
* Scalar vs. SIMD

Number of Predicates

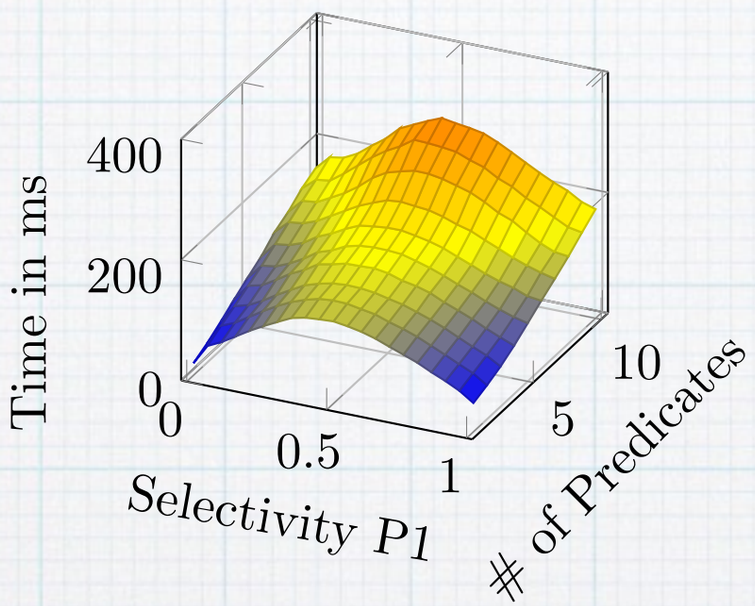


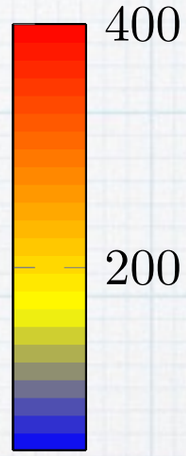
Number of Predicates

Branching Scan

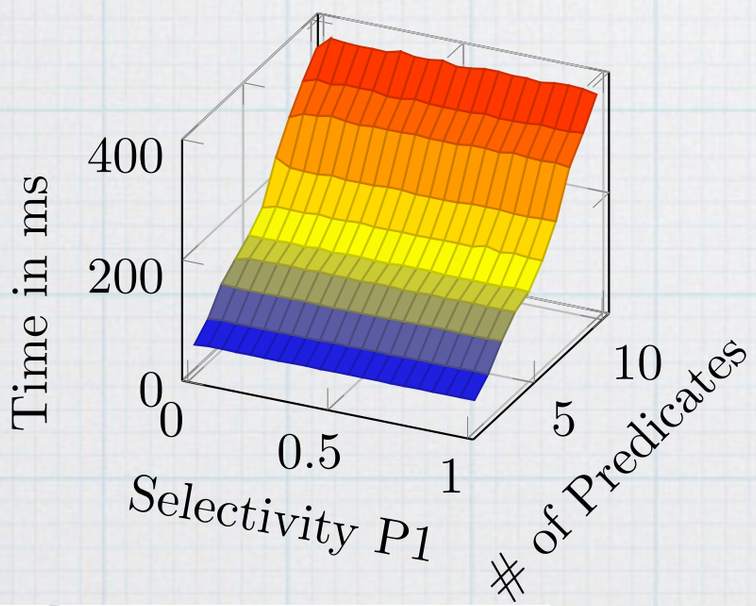


SIMD Scan

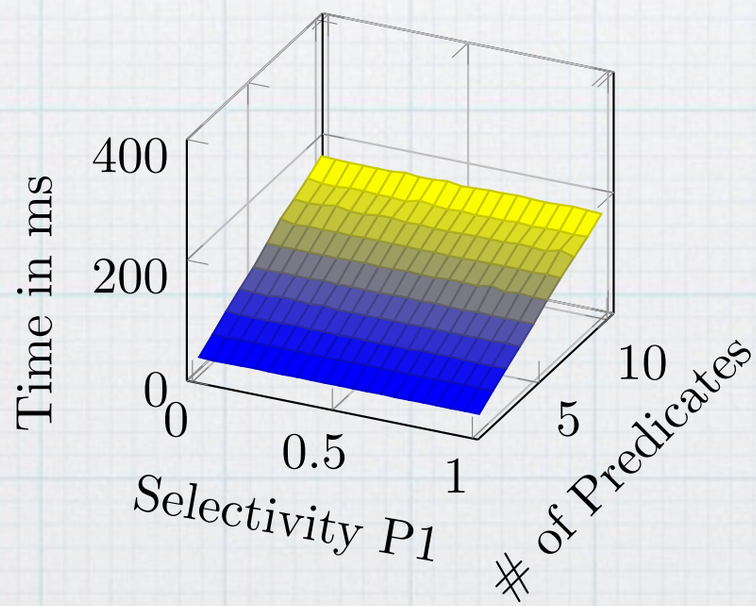




Predicated Scan



SIMD Predicated Scan



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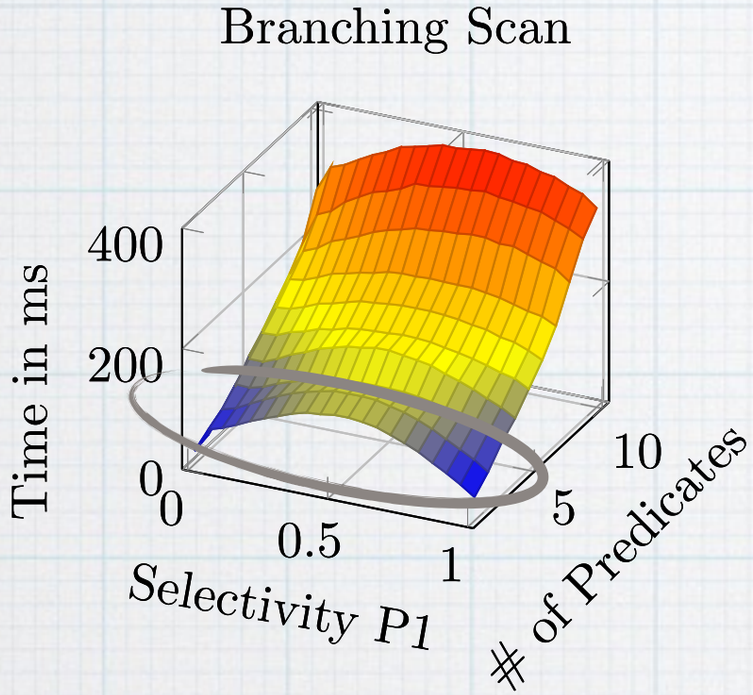
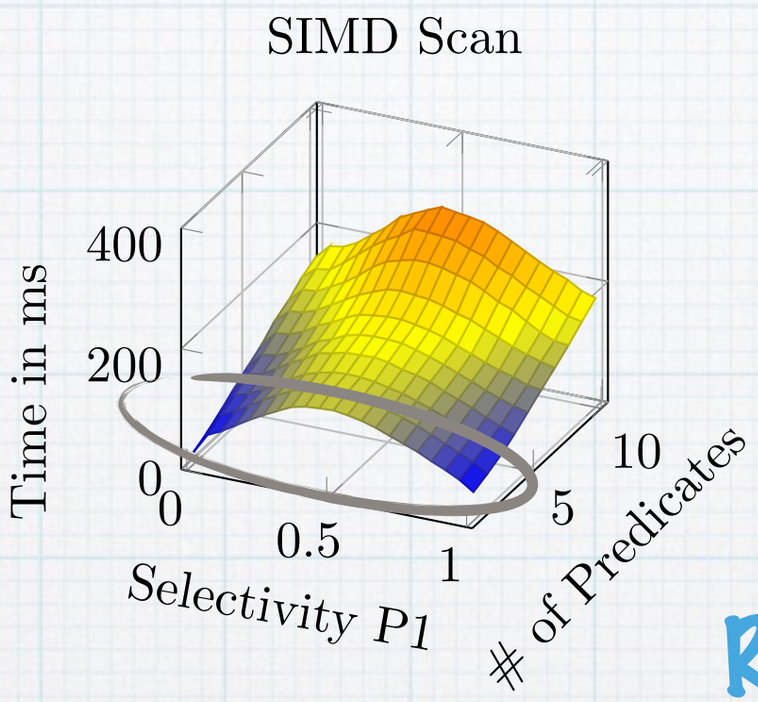
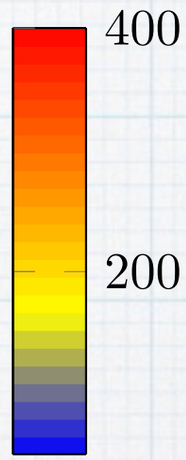
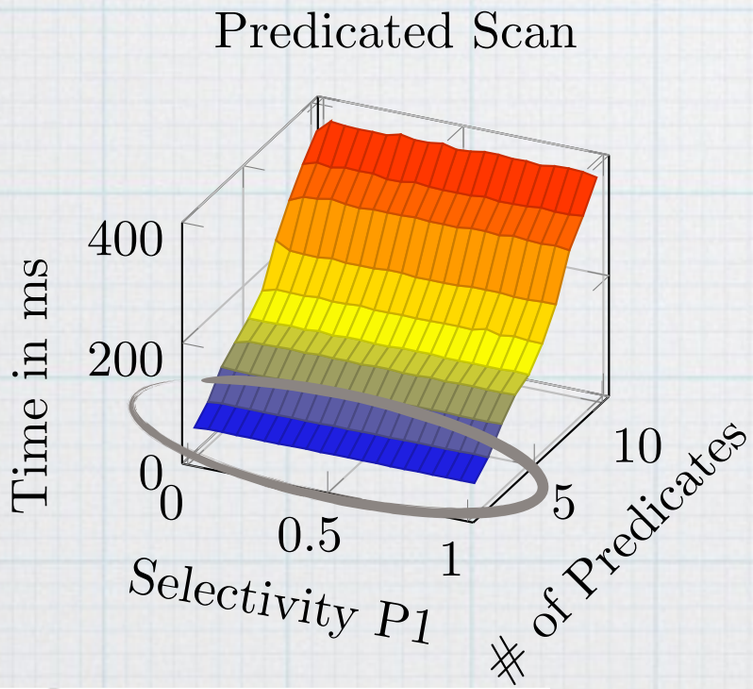
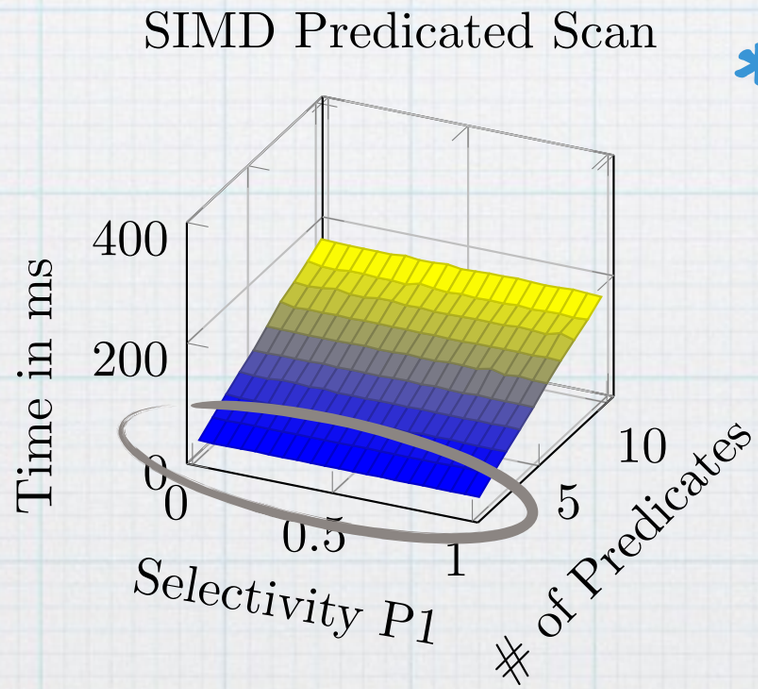
Number of Predicates







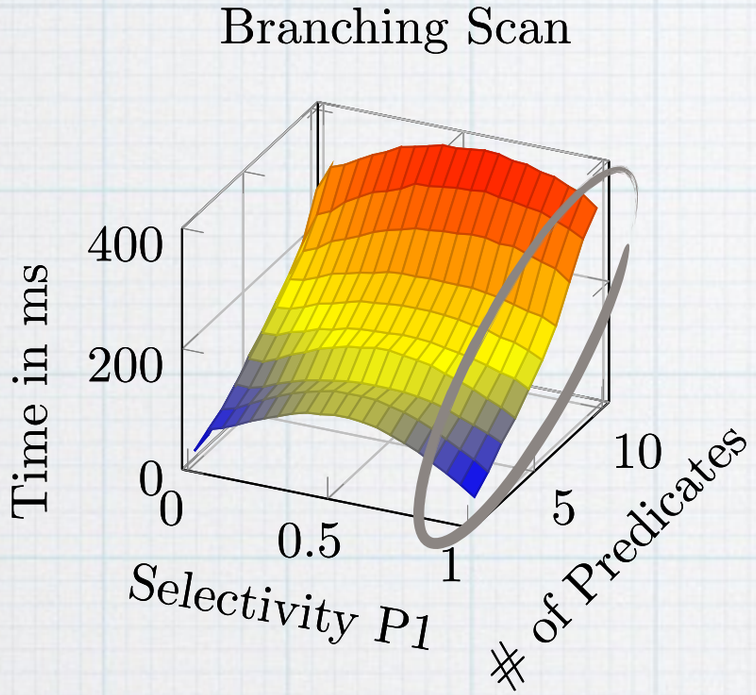


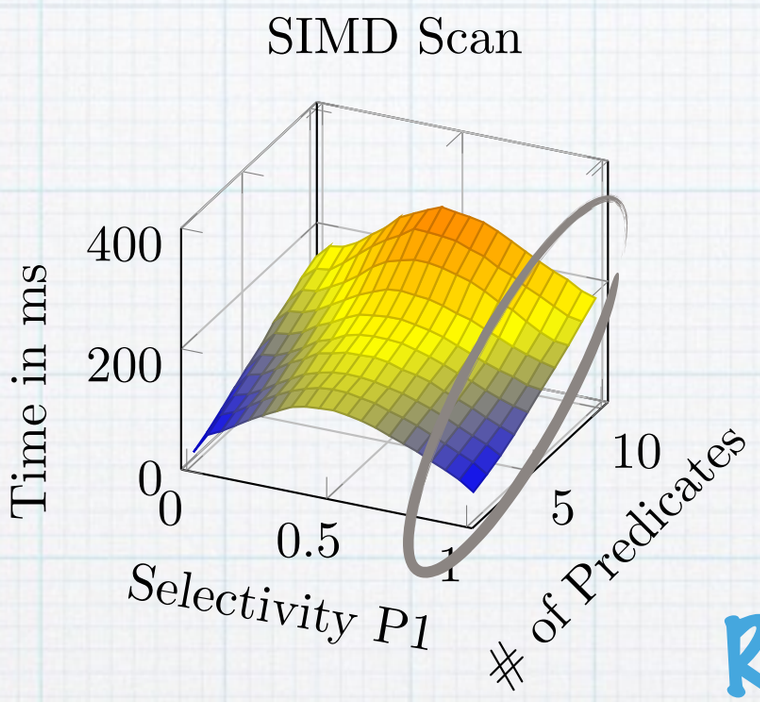


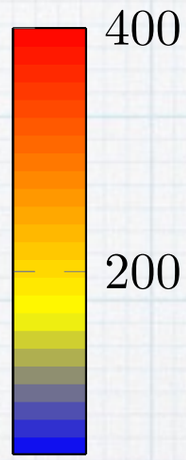
Results:

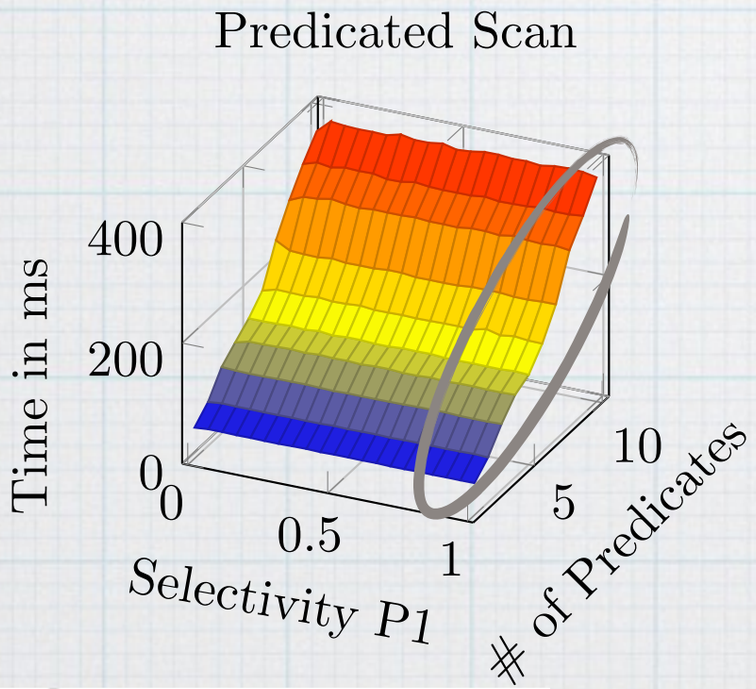
* For one predicate SIMD does not pay out

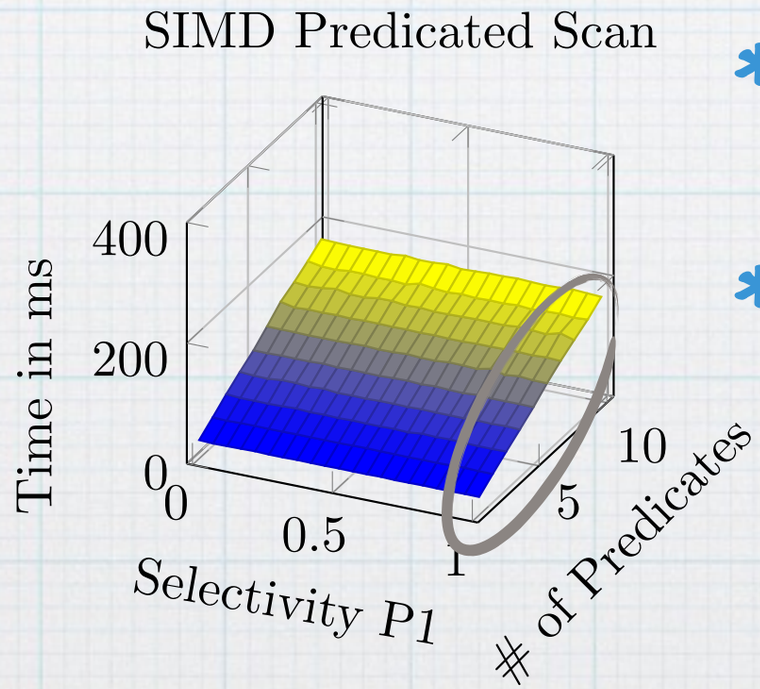
Number of Predicates











Results:

- For one predicate SIMD does not pay out
- The more predicates, the better SIMD

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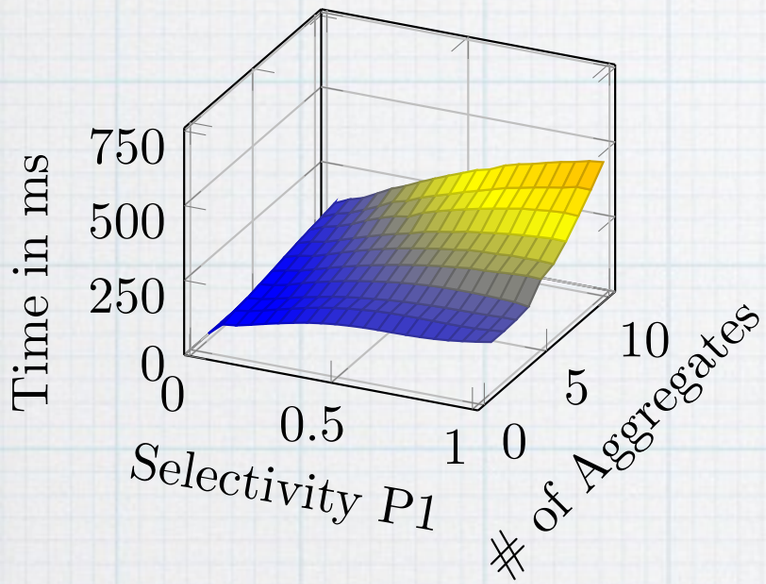
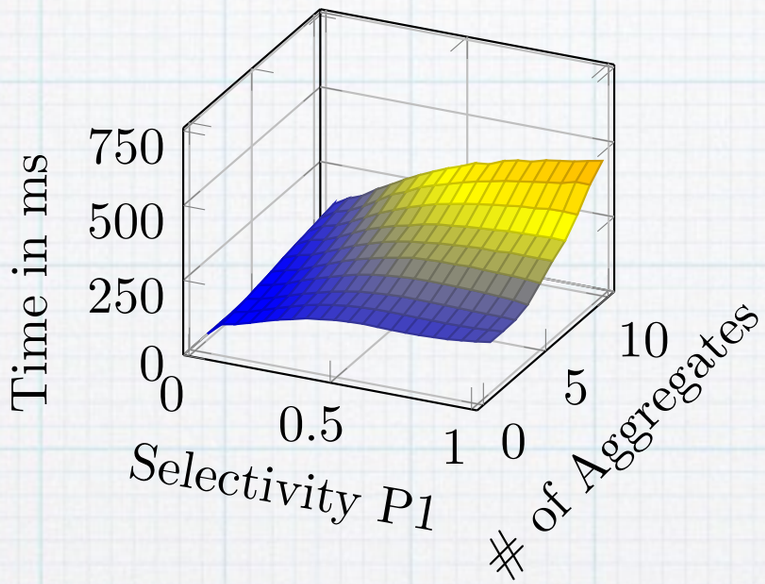
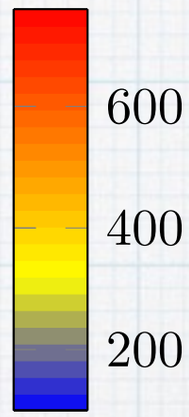
Work Inside the Loop

Branching Scan

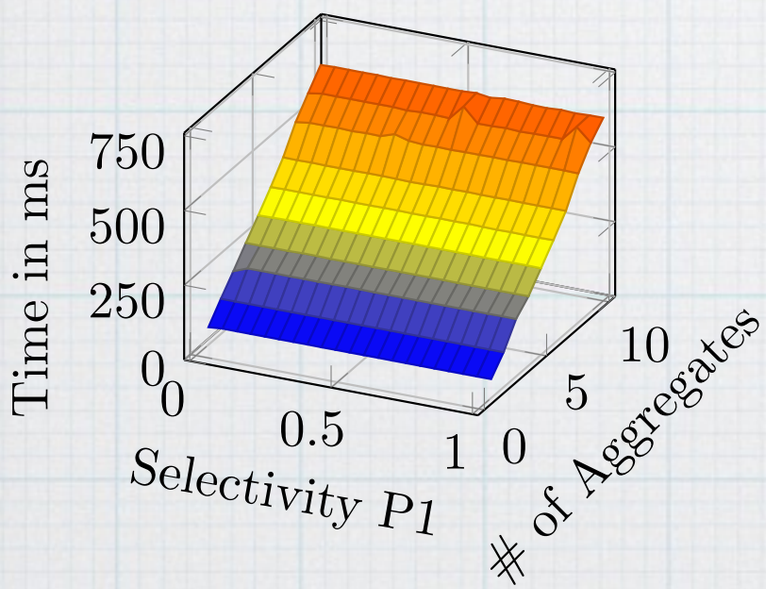


SIMD Scan

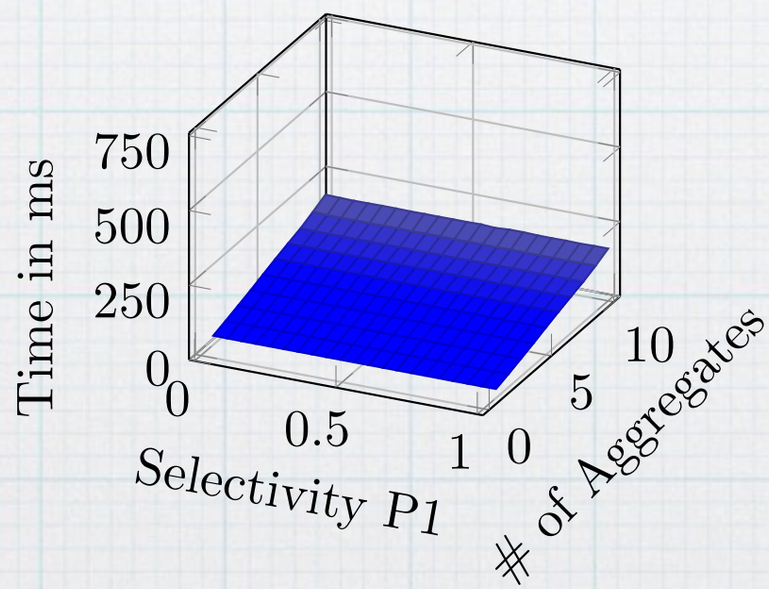




Predicated Scan



SIMD Predicated Scan



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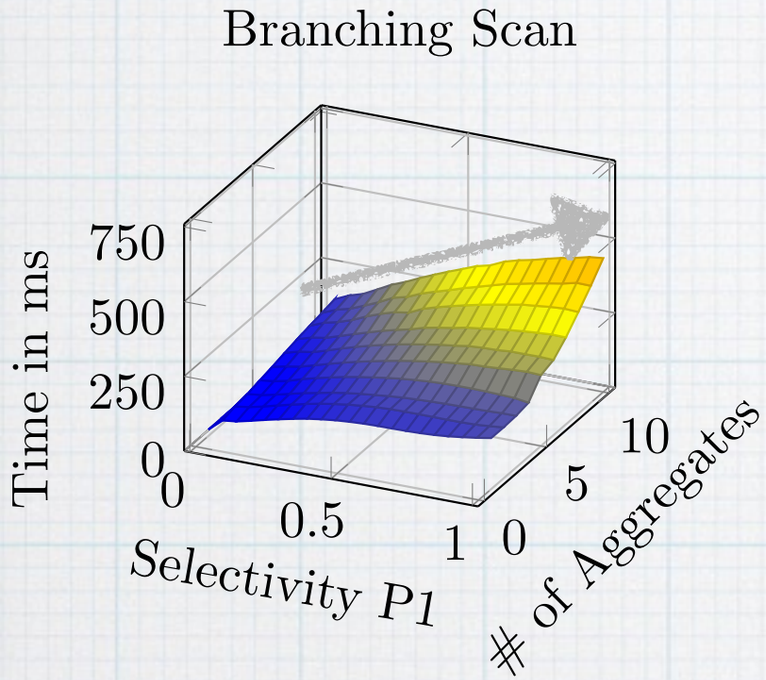
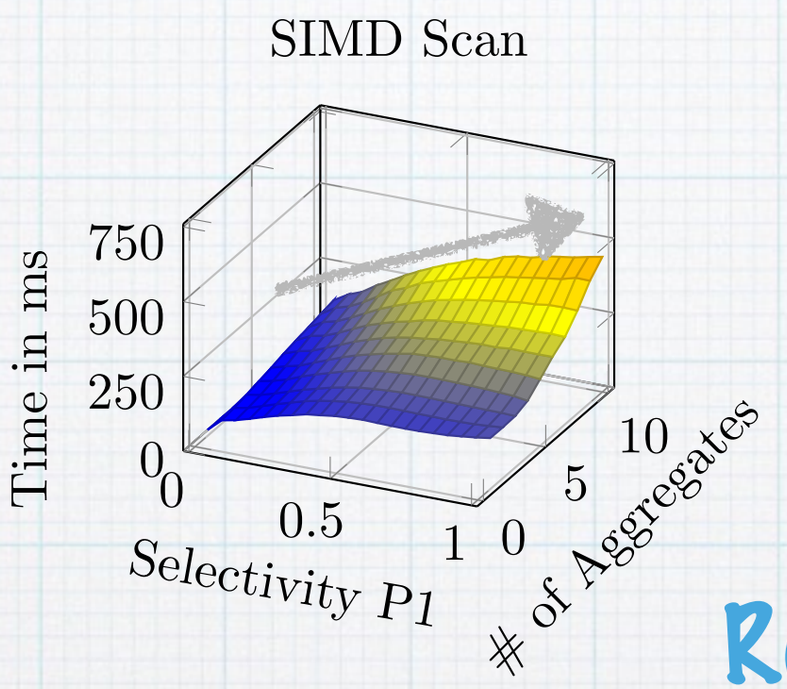
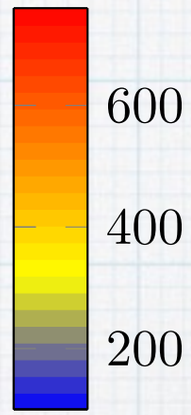
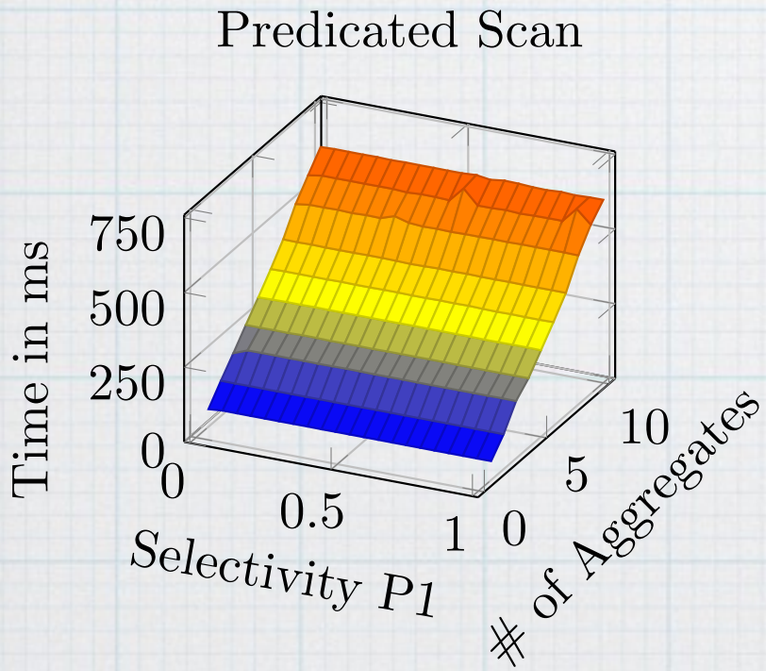
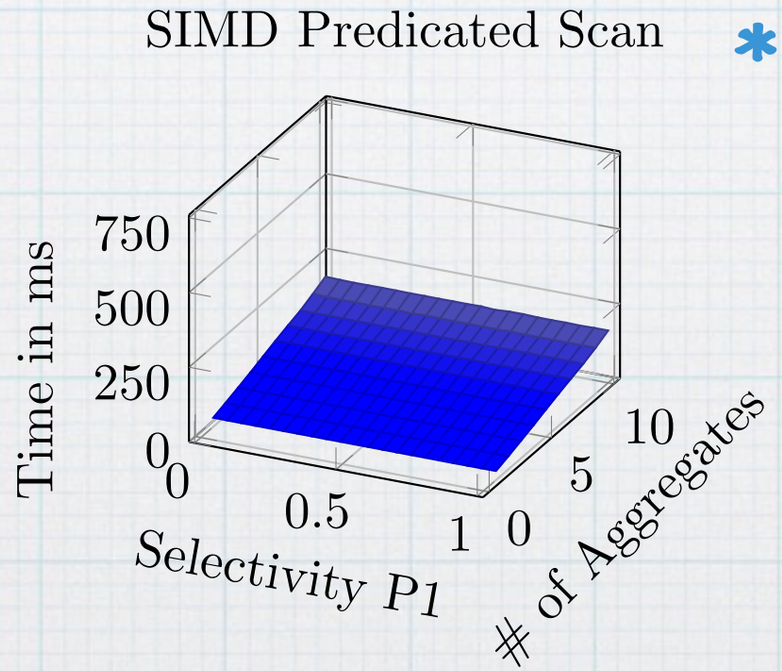
Work Inside the Loop







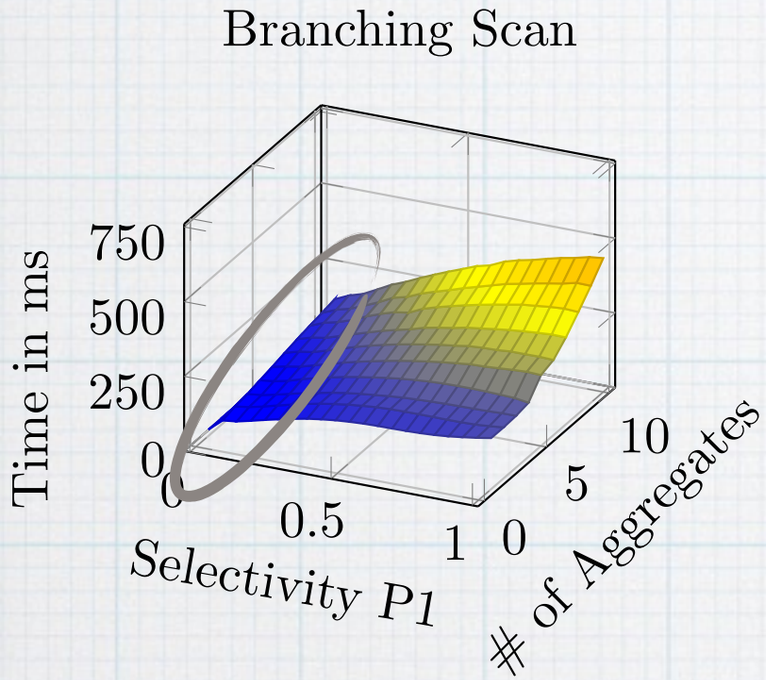


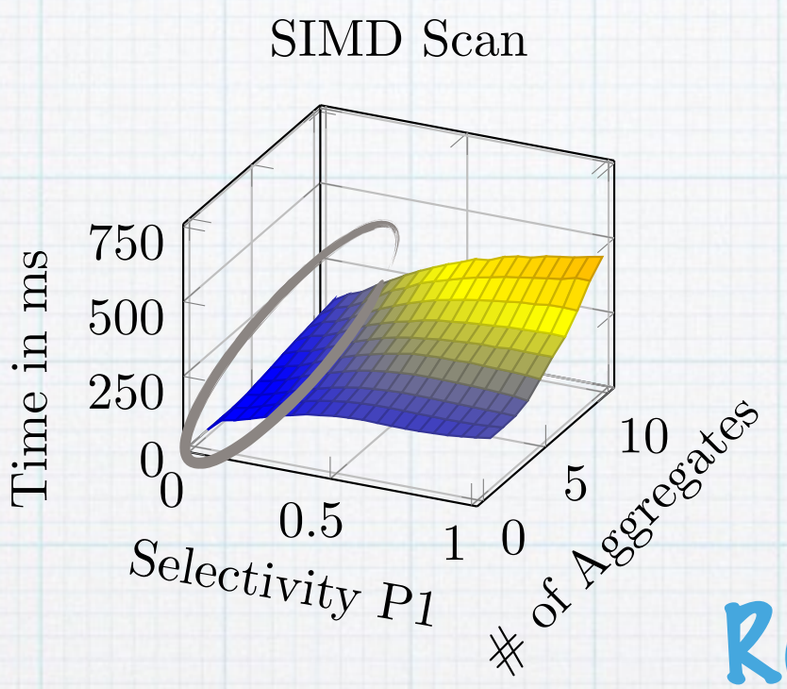


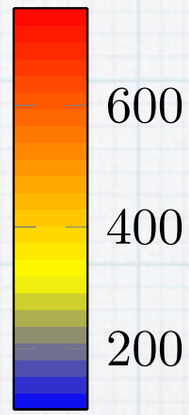
Results:

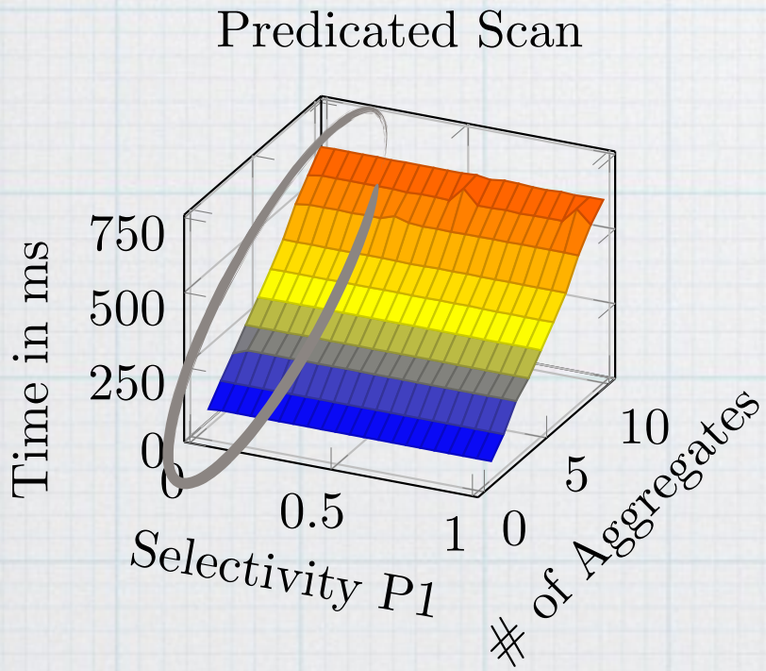
* More aggregates, less impact of branch misprediction

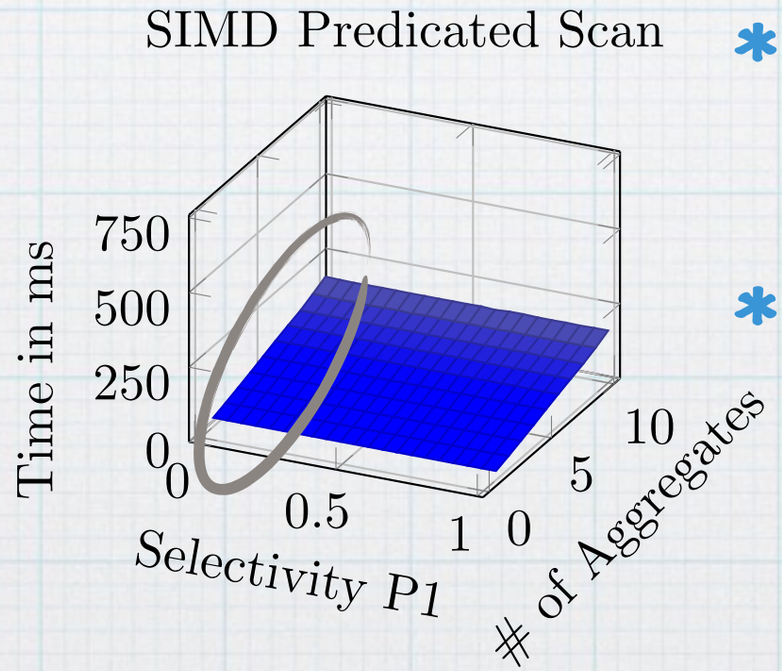
Work Inside the Loop









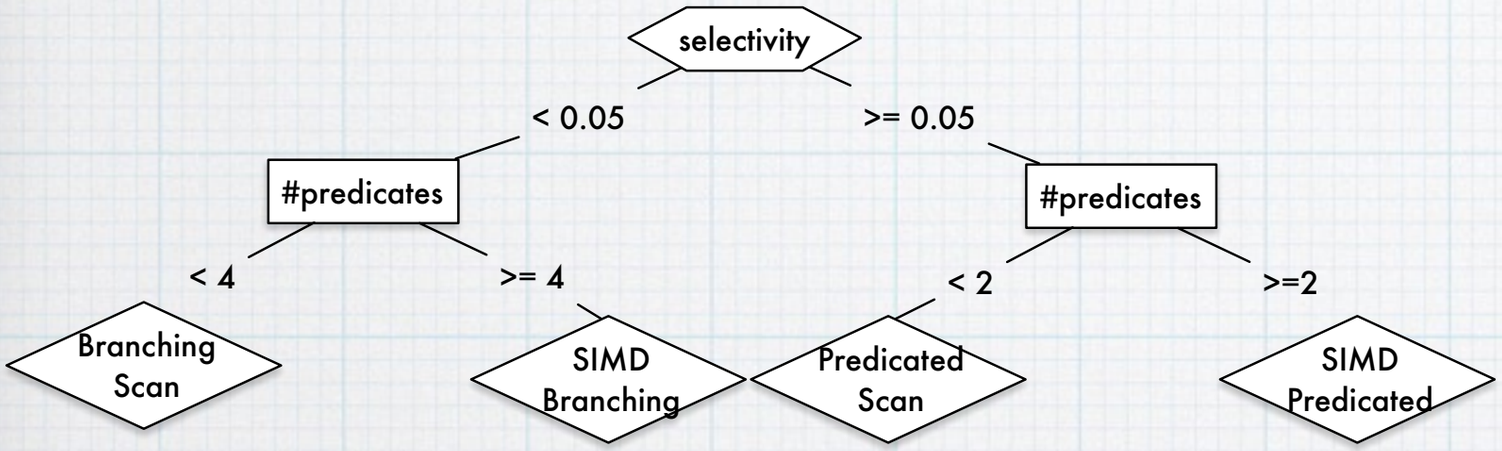


Results:

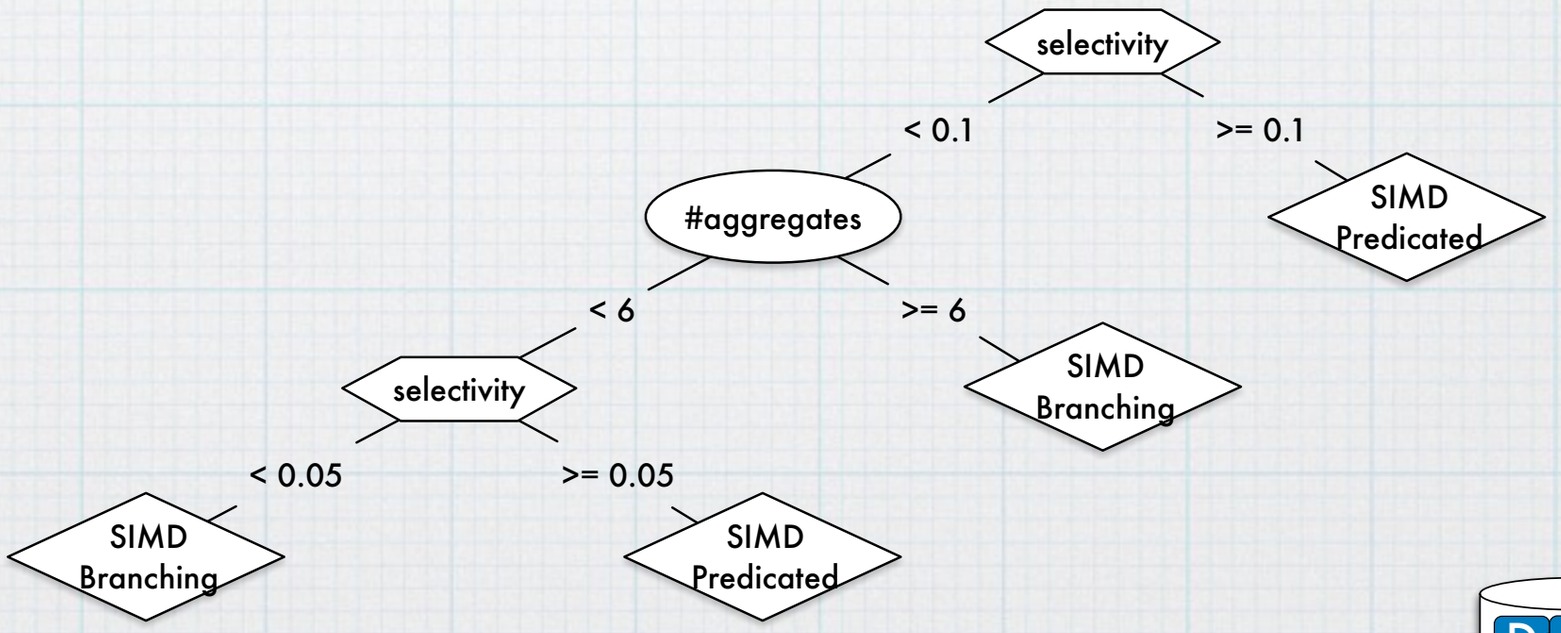
* More aggregates, less impact of branch misprediction
* The more aggregates, the better branching scans for low selectivity

Decision Trees

Number of Predicates



Number of Aggregates



Conclusion

* Increasing number of aggregates slows down predicated variants
* SIMD outperforms scalar variants for several predicates
* Pipeline code for filter-&-aggregate pipelines[1]
* Decision trees as a result of our evaluation in the paper

Future Work

* Hash table put / probe (joins, groupings)
* Automatic calibration for query compilation

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[1] http://git.iti.cs.ovgu.de/dbronesk/BTW-Pipeline-Variants

DBSE

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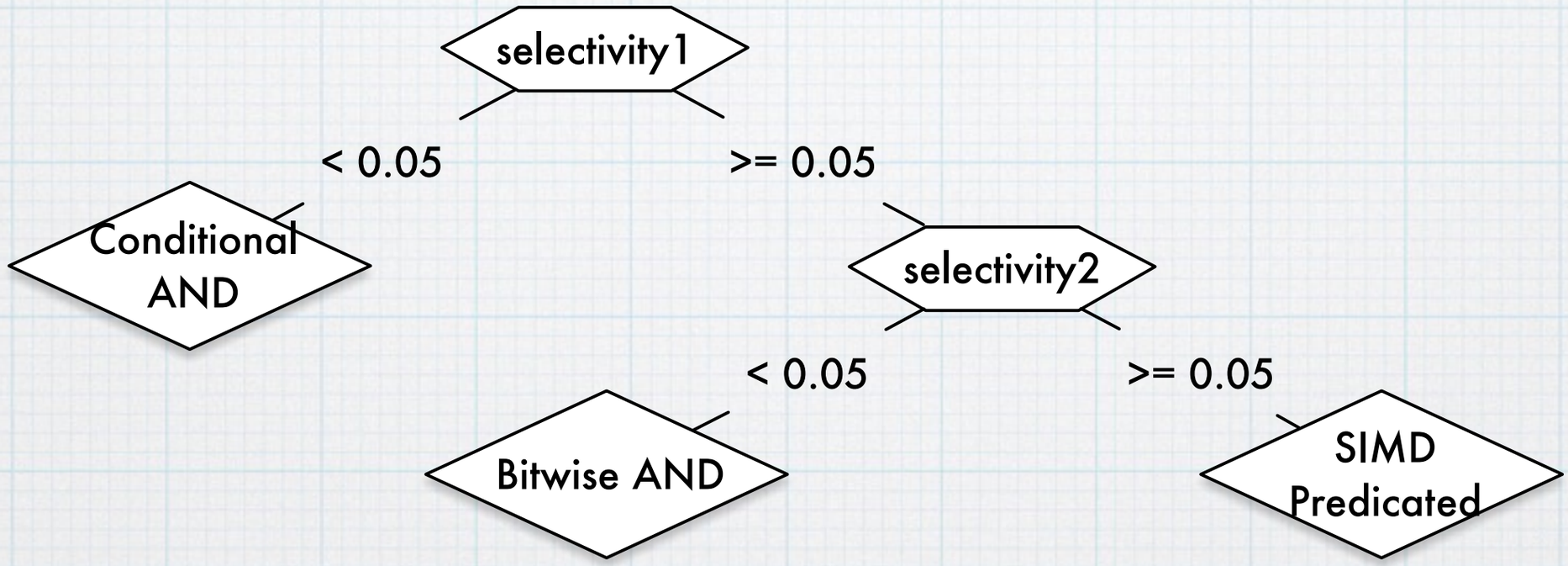
[BBS14] David Broneske, Sebastian Breß, and Gunter Saake. Database Scan Variants on Modern CPUs: A Performance Study. In Proceedings of the 2nd International Workshop on In-Memory Data Management and Analytics (IMDM), Lecture Notes in Computer Science, pages 97-111. Springer, 2014

[ZR02] Jingren Zhou, Kenneth A. Ross: Implementing database operations using SIMD instructions. In: SIGMOD. Pp. 145-156, 2002.

Selectivity of Two Predicates



Selectivity of Two Predicates