

Query Execution from Interpretation to Compilation on RDBMS

Driven by Hardware Revolution

JunpengZhu(朱君鹏)

Department of Computer Science and Technology
Nanjing University

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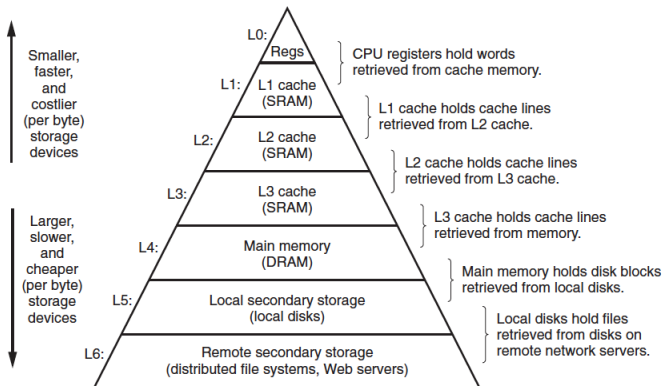


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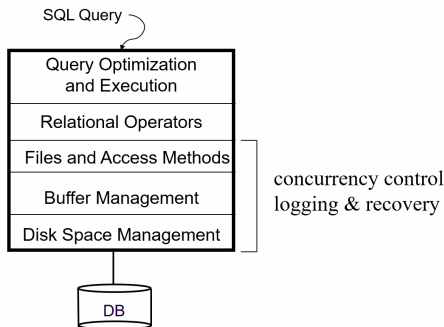
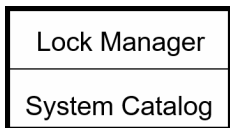
Storage hierarchy



Architecture of Relational Database Management Systems



- Disk space management
- Buffer pool management
- Files and access methods
- Relational operators
- Query optimization and execution





Architecture of Query Planning

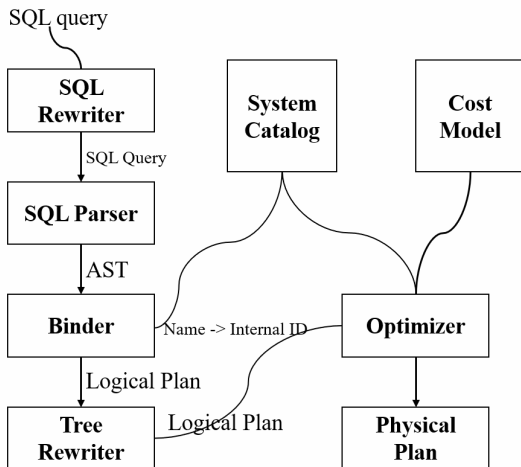




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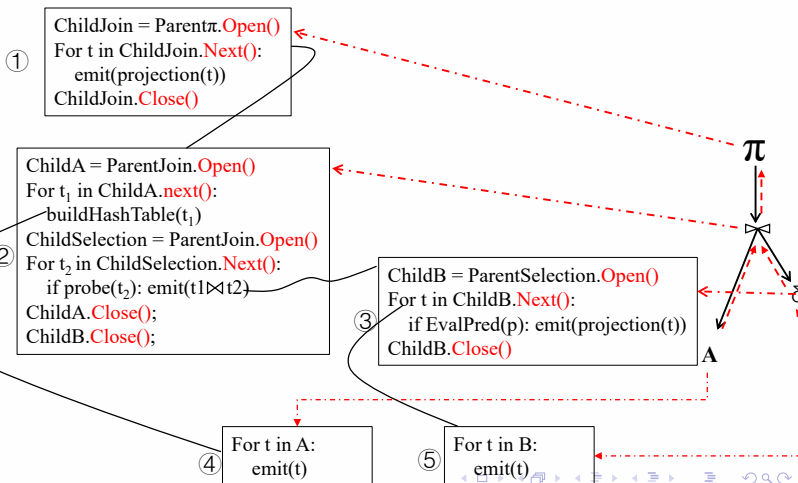


SQL Query Example

```
SELECT A.id , B.value  
FROM A, B  
WHERE A.id = B.id AND B.value >= 100 * 3
```



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Characteristics of Iterator/Volcano Processing Model

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- **Generous Purpose** - It is suitable for OLAP/OLTP on disk-oriented RDBMS.



Materialization Processing Model



00:00:00 00:00:00



①
`out = {}`
 For `t` in `ChildJoin.Output()`:
 `out.add(projection(t))`

②
`out = {}`
 For `t1` in `ChildA.Output()`:
 `buildHashTable(t1)`
 For `t2` in `ChildSelection.Output()`:
 if `probe(t2)`: `out.add(t1 ⋈ t2)`

③
`out = {}`
 For `t` in `ChildB.Output()`:
 if `EvalPred(p)`: `out.add(projection(t))`

④
`out = {}`
 For `t` in `A`:
 `out.add(t)`

⑤
`out = {}`
 For `t` in `B`:
 `out.add(t)`

π

\bowtie

δ

A



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- **OLTP** - It is suitable for OLTP on disk-oriented RDBMS.



Vectorization Processing Model



monitor g000 0000000000 00:00:00



①

```
out = {}
ChildJoin = Parent $\pi$ .Open()
For t in ChildJoin.Next():
    emit(projection(t))
ChildJoin.Close()
```

②

```
out = {}
ChildA = ParentJoin.Open()
For t1 in ChildA.next():
    buildHashTable(t1)
ChildSelection = ParentJoin.Open()
For t2 in ChildSelection.Next():
    if probe(t2): out.add(t1 ⋈ t2)
ChildA.Close();
ChildB.Close();
```

③

```
out = {}
ChildB = ParentSelection.Open()
For t in ChildB.Next():
    if EvalPred(p): emit(projection(t))
ChildB.Close()
```

④

```
For t in A:
    emit(t)
```

⑤

```
For t in B:
    emit(t)
```

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What's the problem?

- **Iterator Overhead** - Iterator is generally implemented using a virtual function, which requires multiple function calls per line of data read, incurring some overhead.



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- **Iterator Overhead** - Iterator is generally implemented using a virtual function, which requires multiple function calls per line of data read, incurring some overhead.
- **Cache Inefficiency** - Use a pull and push model, after the data is loaded into memory and cannot stay in the cache and the register, need more memory access.
- **CPU Inefficiency** - Iterator model of a large number of branch statements, memory access is not friendly to the CPU.



Attempt

Based on these issues, industry began to explore the path of query compilation, but it was not until recent years that it began to get more practical application.

Industrial products such as Impala, SparkSQL, PostgreSQL also began to adopt the scheme of compilation execution.

However, there is still a lot of imagination space for query compilation. And there is still a gap between the product landing in the industry and the academic research.



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Questions



- What can be compiled in a query?



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- How to compile?

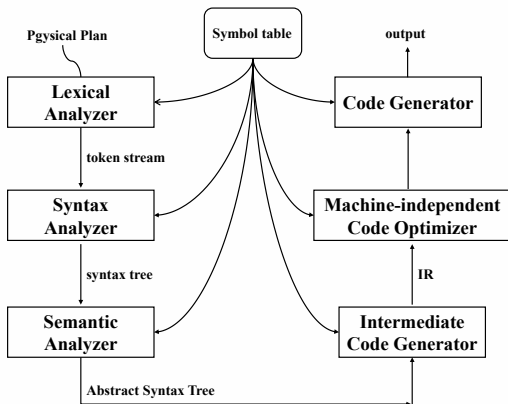


Questions

- What can be compiled in a query?
- How to compile?
- What is the result of compiling?

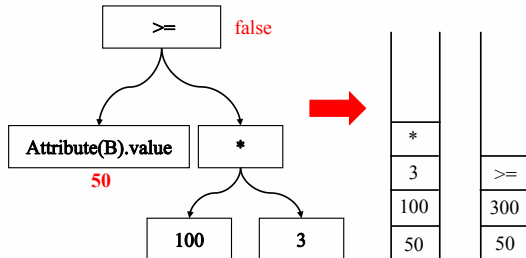
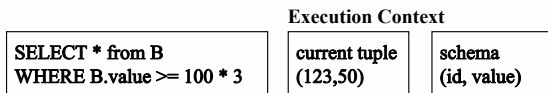


Compiler Overview





Examples of Expression Interpretation





Disadvantages of Expression Interpretation

- The implementation of interpreting execution often recursively interprets each Operator, each Operand, resulting in multiple function calls.



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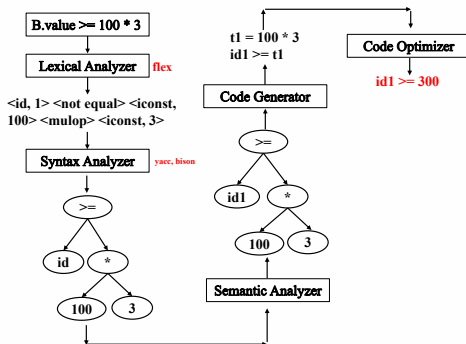
Disadvantages of Expression Interpretation

- The implementation of interpreting execution often recursively interprets each operator, each operand, resulting in multiple function calls.
- Query interpreter needs to interpret once for each tuple, which is inefficient.

How to solve these issues?



Examples of Expression Compilation





Example of Attributes of Tuples Compilation

```
void MaterializeTuple(char* tuple) {  
    for (int i = 0; i < num_slots_; ++i)  
    {  
        char* slot = tuple + offsets_[i];  
        switch(types_[i]) {  
            case BOOLEAN:  
                *slot = ParseBoolean();  
                break;  
            case INT:  
                *slot = ParseInt();  
                break;  
            case FLOAT: ...  
            case STRING: ...  
            // etc.  
        }  
    }  
}
```

interpreted

```
void MaterializeTuple(char* tuple) {  
    *(tuple + 0) = ParseInt();    // i = 0  
    *(tuple + 4) = ParseBoolean();// i = 1  
    *(tuple + 5) = ParseInt();    // i = 2  
}
```

codegen'd



Example of Operators Compilation

Interpretation

```
for t in range(table.num_tuples):  
    tuple = get_tuple(table, t)  
    if eval(predicate, tuple, parameters):  
        emit(tuple)
```

Compilation

```
tuple_size = xxx  
predicate.offset = xxx  
parameters_value = xxx  
for t in range(table.num_tuples):  
    tuple = table.data + t * table.size  
    val = (tuple + predicate.offset) + 1  
    if (val == parameter_value):  
        emit(tuple)
```

- Get schema in the system catalog for table.
- Calculate the offset based on the tuple size.
- Return the pointer to the tuple.



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Conclusions

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- Compilers generate machine code, whereas interpreters interpret intermediate code.
- Interpreters are easier to write and can provide better error messages (symbol table is still available).
- Interpreters are at least 5 times slower than machine code generated by compilers.
- Interpreters also require much more memory than machine code generated by compilers.



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References I



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Welcome for any questions!



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