Query Execution from Interpretation to Compilation on RDBMS

Driven by Hardware Revolution

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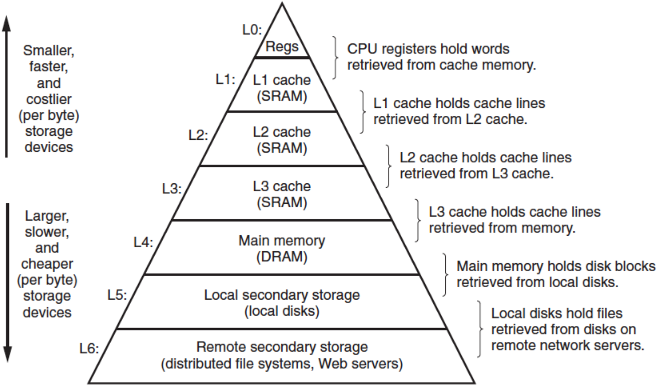
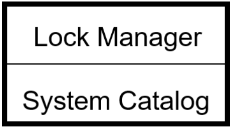
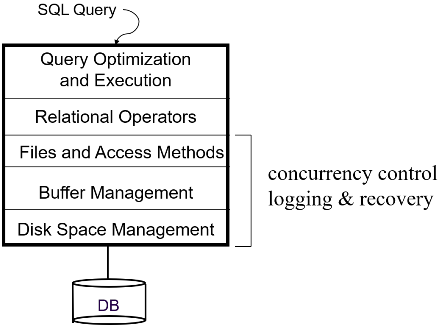
Storage hierarchy



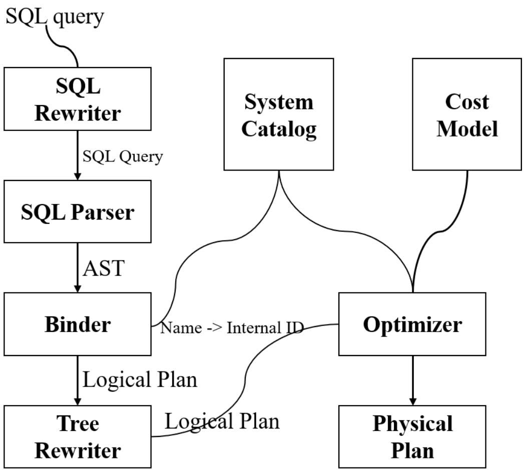
Architecture of Relational Database Management Systems

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





Architecture of Query Planning



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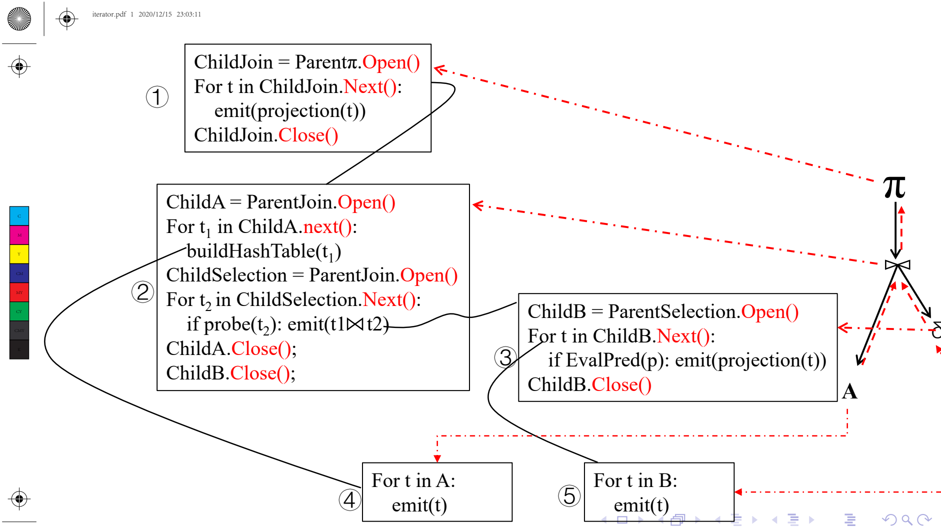
SQL Query Example

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

Iterator/Volcano Processing Model



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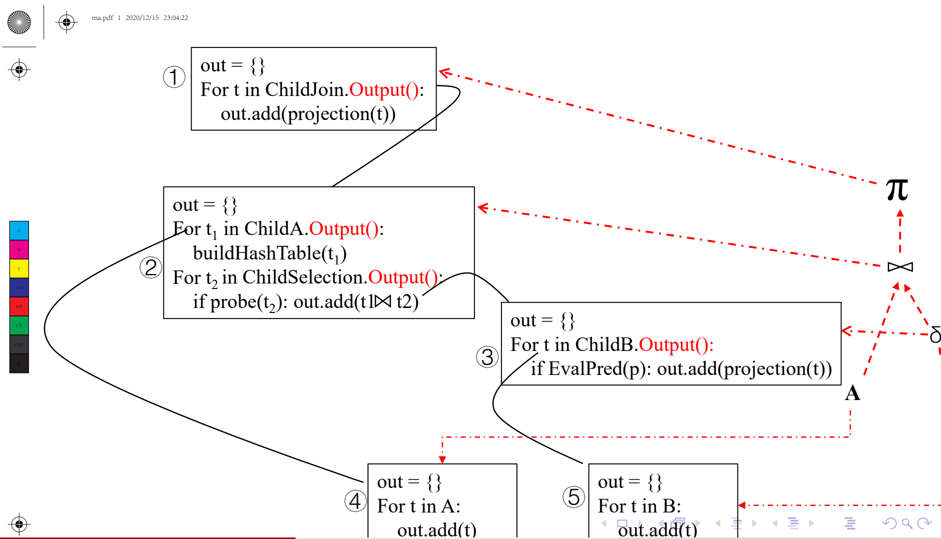
Materialization Processing Model



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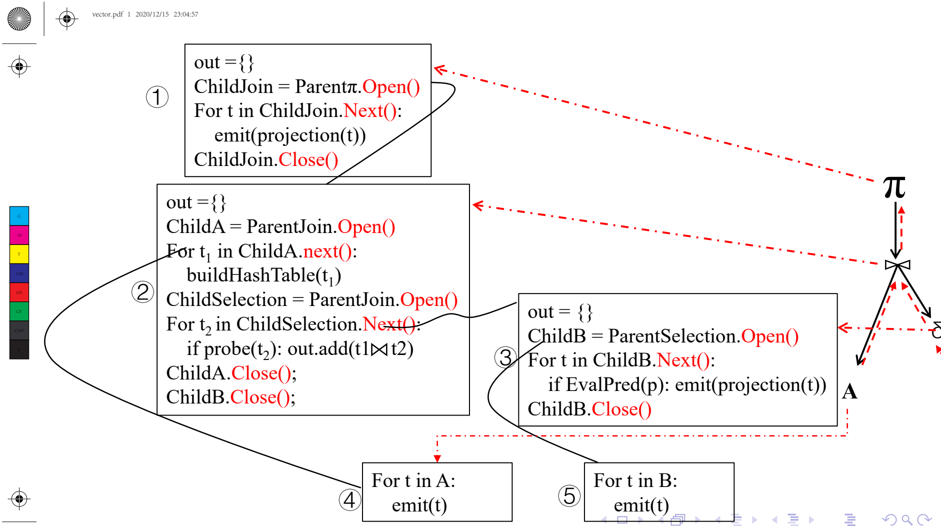
Vectorization Processing Model



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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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- 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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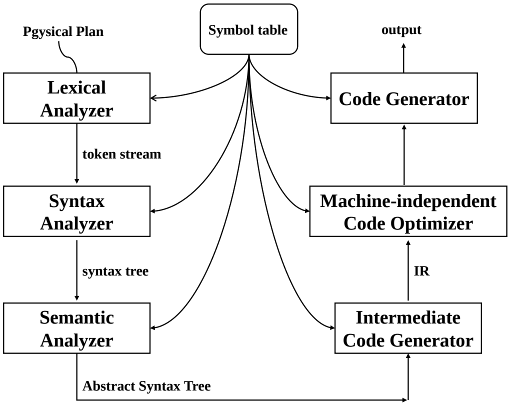
- How to compile?
- What is the result of compiling?

Compiler Overview



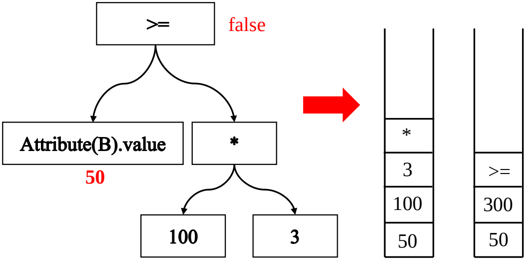
Examples of Expression Interpretation

Execution Context

SELECT * from B
WHERE B.value >= 100 * 3

current tuple
(123,50)

schema
(id, value)



Disadvantages of Expression Interpretation

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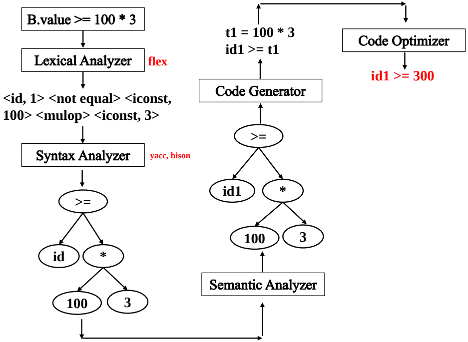
How to solve these issues?

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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- 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

- Tahboub, R.Y. and Rompf, T., 2020, June. Architecting a Query Compiler for Spatial Workloads. In Proceedings of the 2020 ACM SIGMOD International Conference on Management of Data (pp. 2103-2118).
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Thank you!
Welcome for any questions!

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