Query Processing: A Systems View

Introduction to Databases

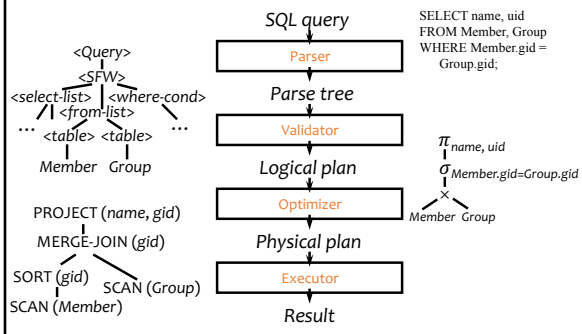
CompSci 316 Spring 2019

DUKE COMPUTER SCIENCE

Announcements (Thu., Apr. 4)

- Monday 04/08: Hw4-problem 2 due
- Friday 04/12: HW4-problem 1 + this week's problem due
- Remember to submit project update on piazza tomorrow (Friday)

A query's trip through the DBMS

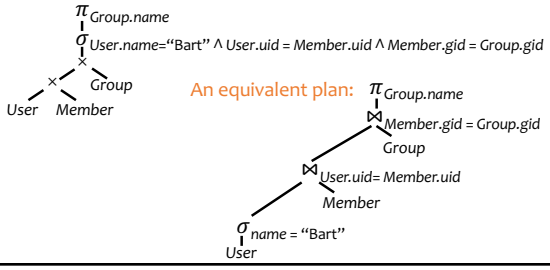


Parsing and validation

- Parser: SQL → parse tree
  - Detect and reject syntax errors
- Validator: parse tree → logical plan
  - Detect and reject semantic errors
    - Nonexistent tables/views/columns?
    - Insufficient access privileges?
    - Type mismatches?
      - Examples: AVG(name), name + pop, User UNION Member
  - Also
    - Expand *
    - Expand view definitions
  - Information required for semantic checking is found in system catalog (which contains all schema information)

Logical plan

- Nodes are logical operators (often relational algebra operators)
- There are many equivalent logical plans

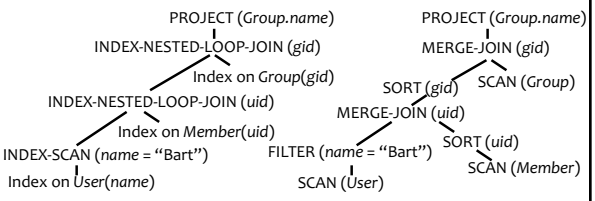


Physical (execution) plan

- A complex query may involve multiple tables and various query processing algorithms
  - E.g., table scan, index nested-loop join, sort-merge join, hash-based duplicate elimination…
- A physical plan for a query tells the DBMS query processor how to execute the query
  - A tree of physical plan operators
  - Each operator implements a query processing algorithm
  - Each operator accepts a number of input tables/streams and produces a single output table/stream

Examples of physical plans

```
SELECT Group.name
FROM User, Member, Group
WHERE User.name = 'Bart'
AND User.uid = Member.uid AND Member.gid = Group.gid;
```



- Many physical plans for a single query
  - Equivalent results, but different costs and assumptions!

  ☞DBMS query optimizer picks the "best" possible physical plan

Physical plan execution

- How are intermediate results passed from child operators to parent operators?
  - Temporary files
    - Compute the tree bottom-up
    - Children write intermediate results to temporary files
    - Parents read temporary files
  - Iterators
    - Do not materialize intermediate results
    - Children pipeline their results to parents

http://www.dreamstime.com/royalty-free-stock-image-basement-pipelines-grey-image25917236

Iterator interface

- Every physical operator maintains its own execution state and implements the following methods:
  - open(): Initialize state and get ready for processing
  - getNext(): Return the next tuple in the result (or a null pointer if there are no more tuples); adjust state to allow subsequent tuples to be obtained
  - close(): Clean up

An iterator for table scan

- State: a block of memory for buffering input R; a pointer to a tuple within the block
- open(): allocate a block of memory
- getNext()
  - If no block of R has been read yet, read the first block from the disk and return the first tuple in the block
    - Or null if R is empty
  - If there is no more tuple left in the current block, read the next block of R from the disk and return the first tuple in the block
    - Or null if there are no more blocks in R
  - Otherwise, return the next tuple in the memory block
- close(): deallocate the block of memory

An iterator for nested-loop join

R: An iterator for the left subtree
S: An iterator for the right subtree

- open()

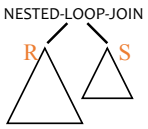
```
R.open()
S.open()
r = R.getNext()
```

- getNext()

```
while True:
  s = S.getNext()
  if s is null: # no more tuple from S
    S.close() # reopen S
    S.open()
    s = S.getNext()
    if s is null: # S is empty!
      return null
    r = R.getNext() # move on to next r
    if r is null: # no more tuple from R
      return null
  if joins(r, s):
    return concat(r, s)
```

- close()

```
R.close()
S.close()
```



Is this tuple-based or block-based nested-loop join?

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An iterator for 2-pass merge sort

- open()
  - Allocate a number of memory blocks for sorting
  - Call open() on child iterator
- getNext()
  - If called for the first time
    - Call getNext() on child to fill all blocks, sort the tuples, and output a run
    - Repeat until getNext() on child returns null
    - Read one block from each run into memory, and initialize pointers to point to the beginning tuple of each block
  - Return the smallest tuple and advance the corresponding pointer; if a block is exhausted bring in the next block in the same run
- close()
  - Call close() on child
  - Deallocate sorting memory and delete temporary runs

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Blocking vs. non-blocking iterators

- A blocking iterator must call getNext() exhaustively (or nearly exhaustively) on its children before returning its first output tuple
  - Examples: sort, aggregation
- A non-blocking iterator expects to make only a few getNext() calls on its children before returning its first (or next) output tuple
  - Examples: dup-preserving projection, filter, merge join with sorted inputs

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Execution of an iterator tree

- Call root.open()
- Call root.getNext() repeatedly until it returns null
- Call root.close()

☞Requests go down the tree

☞Intermediate result tuples go up the tree

☞No intermediate files are needed

- But maybe useful if an iterator is opened many times
  - Example: complex inner iterator tree in a nested-loop join; "cache" its result in an intermediate file

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Iterators are showing their age…

While iterators are an elegant way of pipelining execution, their implementation tends to be inefficient on modern architectures

- Too many (virtual) function calls
- Poor data locality—in memory instead of CPU registers
- Fail to take advantage of
  - Compiler loop unrolling
  - CPU pipelining
  - SIMD (single instruction, multiple data)

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Which one do you think runs faster?

```
class NLJ
    open()
        R.open()
        S.open()
        r = R.getNext()
    getNext()
        while True:
          s = S.getNext()
          if s is null: # no more tuple from S
            S.close() # reopen S
            S.open()
            s = S.getNext()
            if s is null: # S is empty!
              return null
            r = R.getNext() # move on to next r
            if r is null: # no more tuple from R
              return null
          if join(r, s)
            return concat(r, s)
    close()
        R.close()
        S.close()
```

versus

```
count = 0
for r in R:
    for s in S:
        if r.A = s.A:
            count += 1
return count
```

```
class Aggr
    open()
        R.open()
        state = init()
    getNext()
        while True:
          r = R.getNext()
          if r is null: # no more tuple from R
            return finalize(state)
          state = accumulate(state, r)
    close()
        R.close()
```

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Whole-stage "codegen"

- Given a physical plan, fuse operators together to generate query-specific code, with loops instead of iterator function calls
- Instead of "interpreting" the physical plan, give generated code to an optimizing compiler

☞Functionality of a general-purpose execution engine; performance as if system is hand-built to run your specific query

- This approach has been adopted by newer systems, such as Spark