ECS 165B: Database System Implementation
Lecture 21

UC Davis

May 14, 2010

Class Agenda

- Last time:
  - Views and Relational Encodings of XML (2)
  - DavisDB Part 4 Sneak Preview
- Today:
  - DavisDB Part 4 Overview and Architectural Cookbook Session
- Reading:
  - Ch 15 of Ramakrishnan and Gehrke

Announcements

- Grades for Part 2 have been sent out
- Reminder: Part 3 due Sunday @ 11:59pm
- Don't forget to turn off any printf debugging statements before submitting (they interfere with shell output)
  - At this point, you should be using a debugger, not printfs, anyway!
- Project Part 4: out tonight

DavisDB, Part 4: Query Evaluation Engine

DavisDB, Part 4: Query Engine

- Culmination of the project: you'll implement a query engine for a fragment of SQL consisting of four commands:
  - Queries: `select-from-where`
  - Updates: `insert into`, `delete from`, `update`
- As in Part 3, `SystemParser` handles the front-end, you implement the back-end: a class called `QueryEngine`
- Relatively low bar for getting full credit
  - Optimization not required
  - Starter code and architectural template provided
- Opportunities for extra credit
  - e.g., Query optimizer

The Select Command: Syntax

```
  select <attrName>, ... , <attrName>
  from <relName>, ..., <relName>
[ where <attrName> <cmpOp> <attrOrValue> and ... and
       <attrName> <cmpOp> <attrOrValue> ] ;
```

- Each attribute name `<attrName>` must be *fully-qualified*
  - e.g., `select R.A, S.B` rather than `select A,B`
- No self-joins (no duplicates in `<relName>` list)
- `where` clause is optional
  - `<cmpOp>` one of `<, >, =, <>, <=, >=`
  - `<attrOrValue>` either a fully-qualified attribute name, or a constant:
    - quoted string like "abc", "xyz", ...
    - integer like 2, -1
    - float like 2.0, -1.7 (floats **must** contain a decimal point)

The Select Command: Semantics

- Execute the query, according to standard SQL semantics
- Parser calls `QueryEngine::select` to execute:

```
ReturnCode select(
        int nAttributes, const RelationAttribute attributes[],
        int nRelations, const char* relations[],
        int nConditions, const Condition conditions[]
);
```

- Must check that query typechecks wrt the database schema
- Print results to console output using SystemPrinter, as in `print` command from Part 3
- How to implement? We'll discuss in a moment...

The Select Command: Example

```
select Sailors.sid, Sailors.sname
from Sailors
where Sailors.rating > 5 and Sailors.age < 30.0;
Sailors.sid int, Sailors.sname char(32)
--------------------------------------------------
32,Andy
71,Zorba
2 records total.
 => RC_OK
```

The Insert Command: Syntax and Semantics

```
insert into <relName> values (<value>, ..., <value>) ;
```

- Values specified as in other commands:
  - quoted string like "abc", "xyz", ...
  - integer like 2, -1
  - float like 2.0, -1.7 (floats **must** contain a decimal point)
- Semantics: calls `QueryEngine::insert` to perform the insertion

```
ReturnCode insert(const char* relName, int nValues,
                  const TypedValue values[]);
```

- Must verify that it typechecks wrt the database schema; don't forget to update indices too!

The Delete Command: Syntax

```
  delete from <relName>
[ where <attrName> <cmpOp> <attrOrValue> and ... and
        <attrName> <cmpOp> <attrOrValue>] ;
```

- Each attribute name `<attrName>` must be *fully-qualified*
- `where` clause is optional
  - `<cmpOp>` one of `<, >, =, <>, <=, >=`
  - `<attrOrValue>` either a fully-qualified attribute name, or a constant:
    - quoted string like "abc", "xyz", ...
    - integer like 2, -1
    - float like 2.0, -1.7 (floats **must** contain a decimal point)

The Delete Command: Semantics

- Invokes `QueryEngine::remove` to delete all tuples matching the specified conditions (or all tuples, if none specified)

```
ReturnCode remove(const char* relName,
                  int nConditions,
                  const Condition conditions[]);
```

- Must verify that query typechecks wrt schema; don't forget to update indices!
- Looks a bit like a selection query, with a deletion operation on top? Bear this in mind when designing execution engine...

The Update Command: Syntax

```
   update <relName>
   set <attrName> = <attrOrValue>
 [ where <attrName> <cmpOp> <attrOrValue> and ... and
         <attrName> <cmpOp> <attrOrValue> ] ;
```

- Each attribute name `<attrName>` must be *fully-qualified*
- `where` clause is optional
  - <cmpOp> one of `<, >, =, <>, <=, >=`
  - `<attrOrValue>` either a fully-qualified attribute name, or a constant:
    - quoted string like "abc", "xyz", ...
    - integer like 2, -1
    - float like 2.0, -1.7   (floats **must** contain a decimal point)

The Update Command: Semantics

- `QueryEngine::update` invoked to perform the specified update for any records matching the selection conditions

```
ReturnCode update(const char* relName,
                  const RelationAttribute* left,
                  const AttributeOrValue* right,
                  int nConditions, const Condition conditions[]);
```

- Again, must verify that it typechecks wrt schema, and update indices too
- Like delete, looks a lot like a selection query, but with an update operation on top...

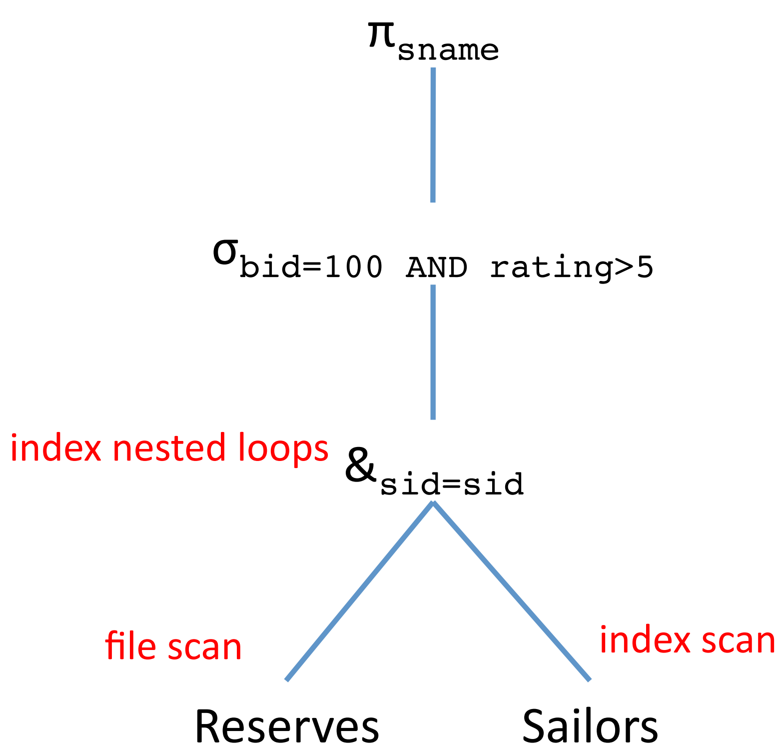
Query Engine API

- (cf. the Doxygen docs...)

How to Implement an Execution Engine?

- You are free to do this any way you like!
  - Modulo a few requirements we'll mention in a bit...
- We'll give sample code and interfaces to give you a starting point
  - You are free to use these, or ignore them in favor of your own design
- Provided:
  - IQueryOperator, a generic interface for operators in the tree
  - Implementations of two operators: FileScanOperator and ProjectionOperator
  - Some skeleton code in QueryEngine showing how to construct a plan

How to Implement an Execution Engine?

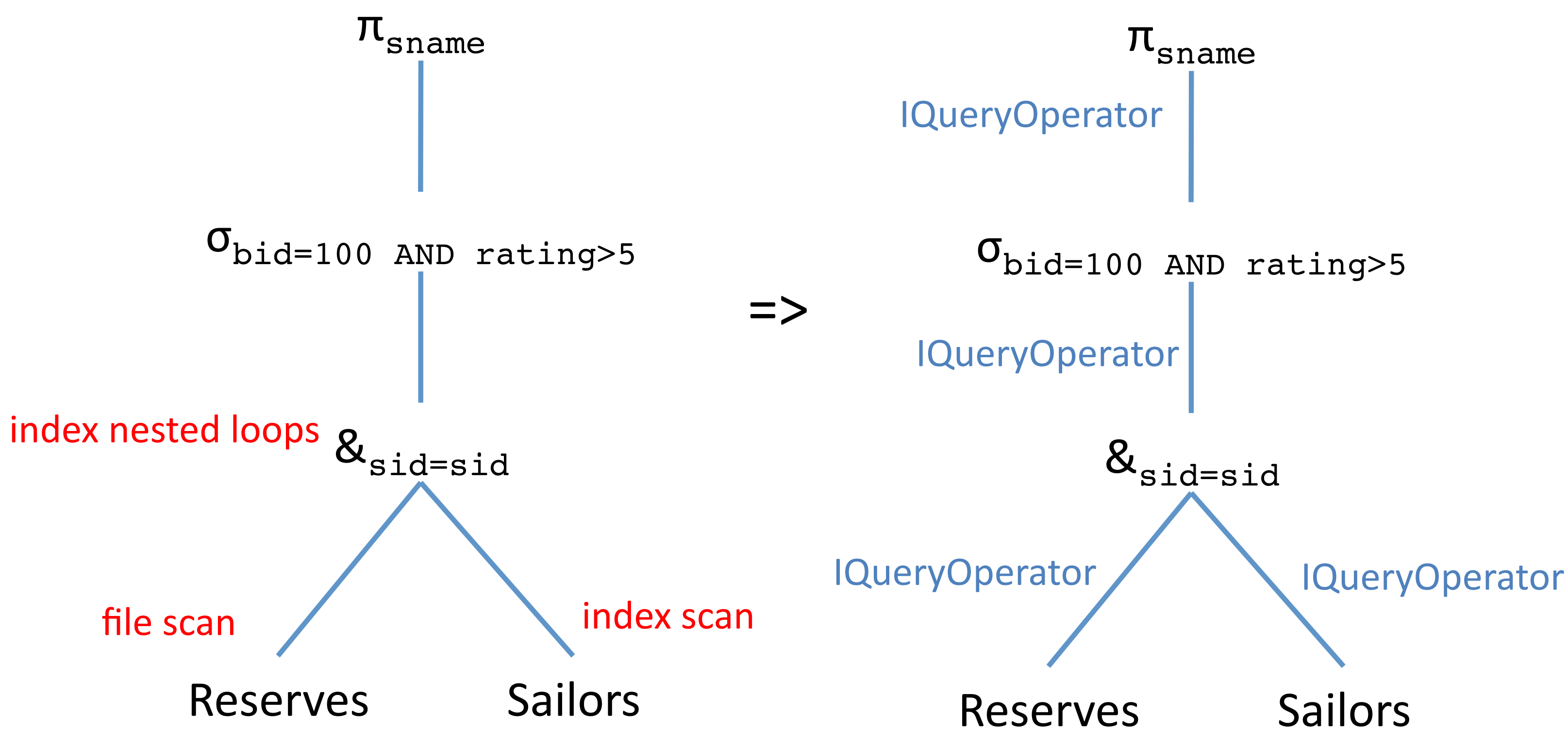


=> ???

Physical query plan

C++ implementation

How to Implement an Execution Engine?



Physical query plan

C++ implementation

IQueryOperator: an Abstract Interface

- What is an "abstract interface" in C++?
- A base class with only **pure virtual** methods

```
virtual ReturnCode getNextRecord(char* data) = 0;
```

- Other classes inherit from this base class ("implement" the interface) and fill in the method implementations
- One technical exception: virtual destructor must have implementation, but can be empty

```
virtual ~IQueryOperator() {};
```

What's a Virtual Method?

- C++ versus Java: in Java, **all** methods are virtual!

```
class A {
        void foo() { printf("A foo"); }
        virtual void bar() { printf("A bar"); }
}
```

```
class B : A {
        void foo() { printf("B foo"); }
        virtual void bar() { printf("B bar"); }
}
```

```
void biz(A* a, B* b) {
        A* a, B* b;  A* c = (A*)b;
        a->foo();
        a->bar();
        b->foo();
        b->bar();
        c->foo();
        c->bar();
}
```

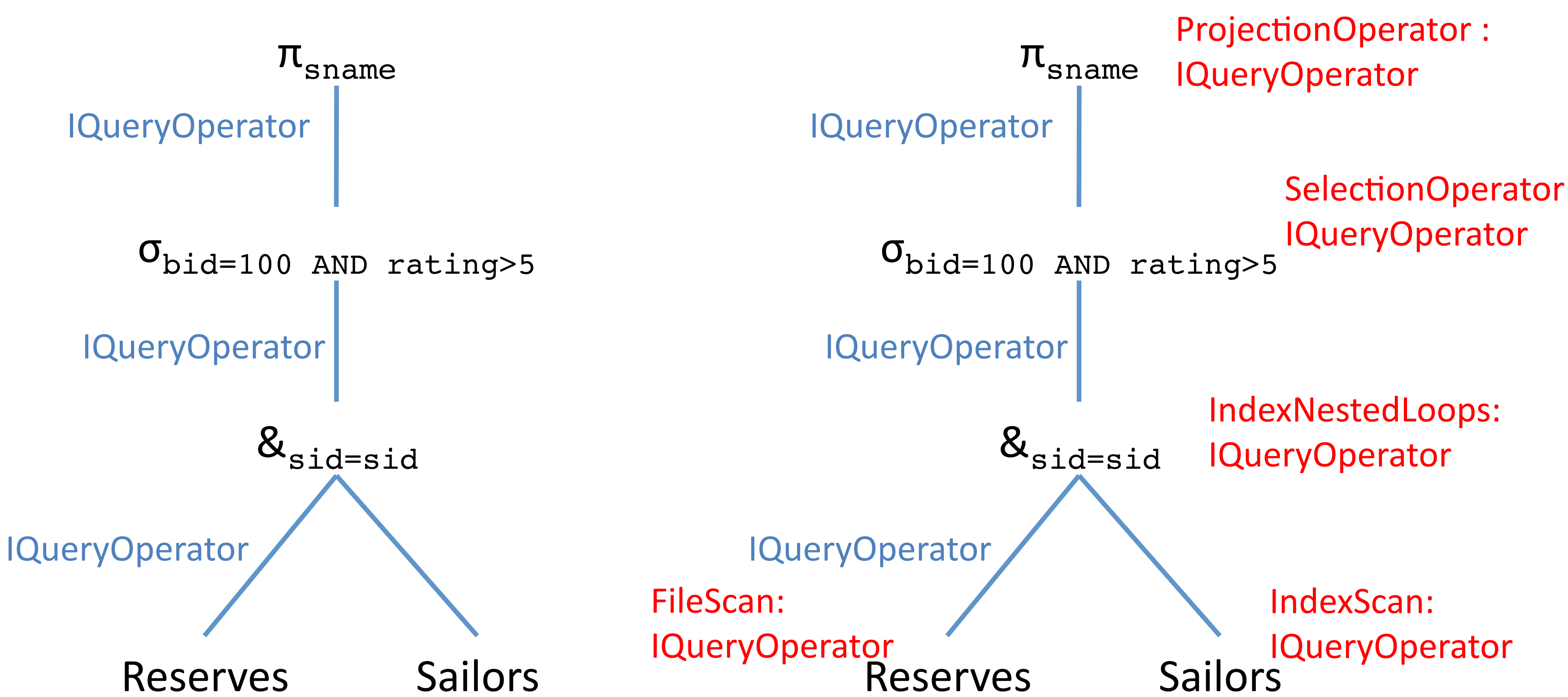
OUTPUT of call to biz(a,b):

A foo
A bar
B foo
B bar
A foo
B bar

QUESTION: why declare destructors virrtual?

Why Use Interfaces in the Execution Engine?

- An operator shouldn't have to know about all the different physical operators that might be below it in the tree!



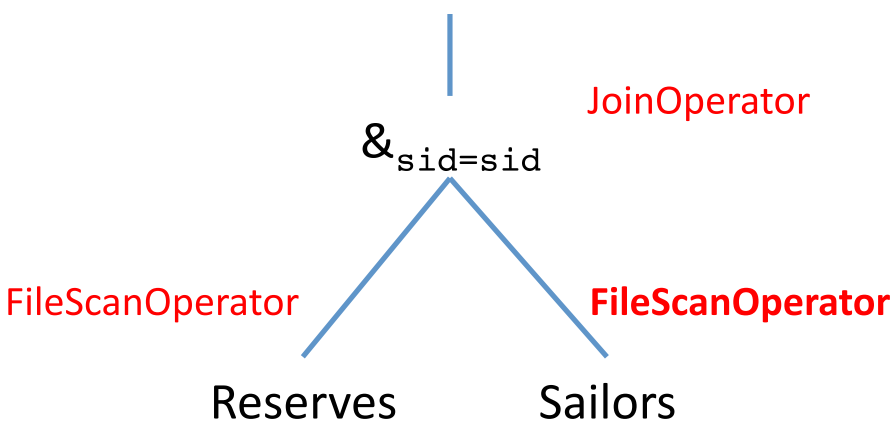
IQueryOperator

- (cf. the Doxygen docs...)

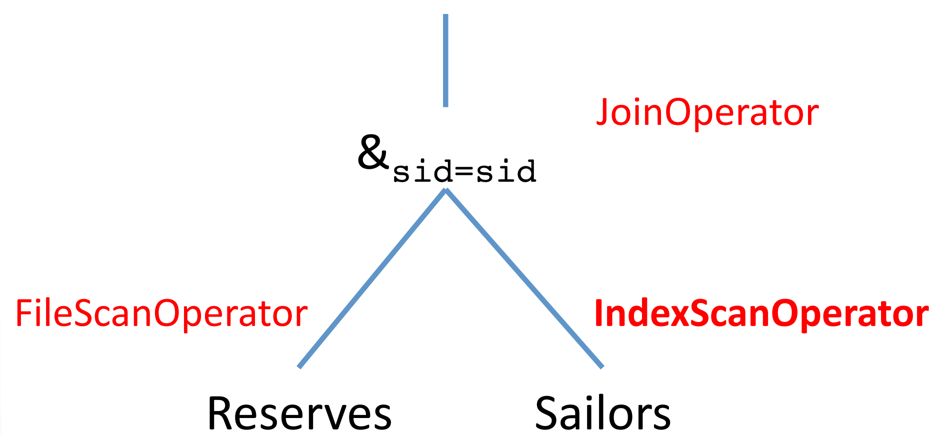
Join Operator Implementation

- You will be required to implement at least two join algorithms, **nested loops join** and **index nested loops join**

- **TIP**: these can be implemented using just **one** join operator (that doesn't even know which join it's implementing)!



Nested Loops Join



Index Nested Loops Join

WARNING: IQueryOperator is Not Complete!

- You will probably need to tweak `IQueryOperator` to suit your needs, or introduce new interfaces extending `IQueryOperator` will special capabilities
  - e.g., index nested loops join needs to communicate KEYS to right child, via something more than `getNextTuple()` alone... something like:

```
openScan(condition); getNextTuple()*; closeScan()
```

- Could, e.g., introduce an `IScanOperator` extending (inheriting from) `IQueryOperator` to add such methods
  - to be implemented by BOTH `FileScanOperator`, AND `IndexScanOperator` --- so that `JoinOperator` does not need to care about whether an index is present or not!

TIP: Make Operators for Delete and Update, Too!

- Will again require a tweak to `IQueryOperator`, as `RecordID`s need to be returning along with records: e.g., change

```
  virtual ReturnCode getNextRecord(char* data) = 0;
```

  to

```
  virtual ReturnCode getNextRecord(Record* record) = 0;
```

- What should `DeleteOperator` or `UpdateOperator` return for `getNextRecord()`? What should their schemas be?
  - Doesn't really matter... the results won't be printed
- What is the `RecordID` of the result of a join?
  - Doesn't really matter... there won't be any operators above the join that care about the `RecordID` (update operations don't use joins)

TIP: a Selection Operator Simplification

- Using several operators instead of one doesn't necessarily cost much in terms of efficiency
- Don't worry about implementing a selection operator that can take conjunctions of conditions

e.g, instead of

$\sigma_{bid=100\ AND\ rating>5}$

just do

$\sigma_{bid=100}$

$\sigma_{rating>5}$

"Canonical" Execution Plans

- **Requirement**: however you build your execution engine, will need to produce plans that work (a) with indices, using Index Nested Loops Join, and (b) without indices (Nested Loops Join)

- Given a `select-from-where` query, will only be required to build a "canonical" execution plan of your own design

  – A plan fully determined by the order of relations in the "from" clause and availability of indices

  – Writeup should describe what kinds of plans you produce

Extra Credit Opportunities

- Small amount of extra credit: figure out some **heuristics** and use them to produce more efficient plans for queries/updates
  - Must document what you've done in the writeup
- Small amount of extra credit: exceptionally clean architecture and code
- Large amount of extra credit: implement a full-blown System R style query optimizer
  - Variable amount of credit, will depend on how much you do
  - Should consider different join orders and do some sort of cost estimation to compare plans
  - Will require maintaining and using **cardinality statistics**, at a minimum