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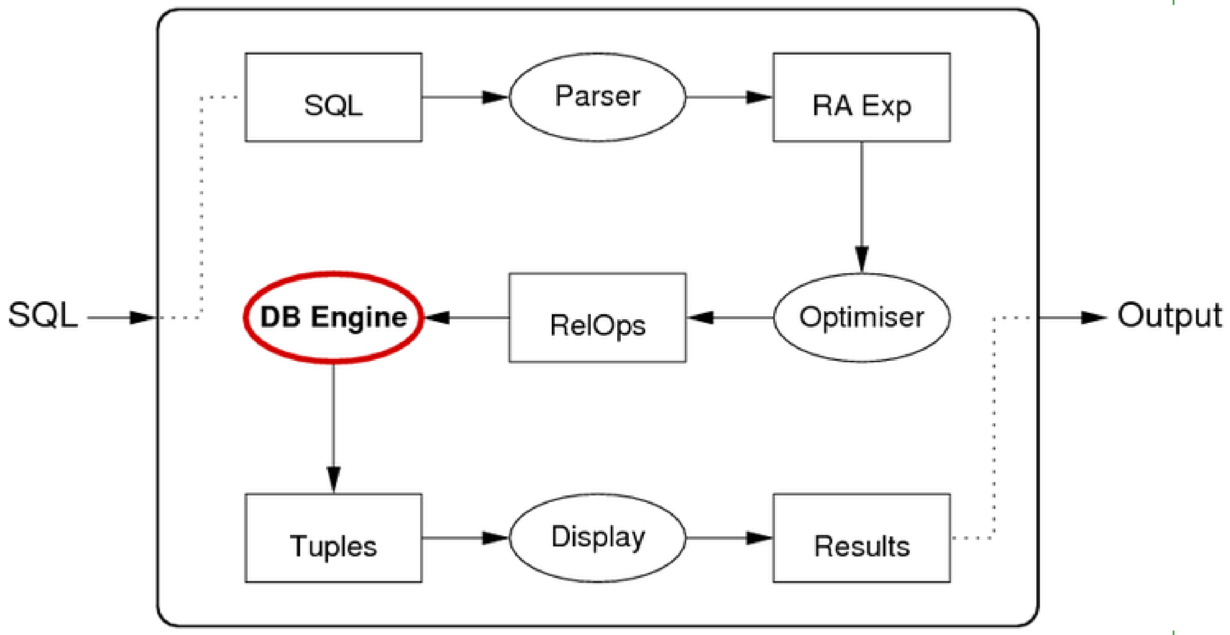
Query Execution

❖ Query Execution

Query execution: applies evaluation plan → result tuples



❖ Query Execution (cont)

Example of query translation:

```
select s.name, s.id, e.course, e.mark
from   Student s, Enrolment e
where  e.student = s.id and e.semester = '05s2';
```

maps to

$\pi_{name,id,course,mark}(Stu \Join_{e.student=s.id} (\sigma_{semester=05s2}Enr))$

maps to

```
Temp1  = BtreeSelect[semester=05s2](Enr)
Temp2  = HashJoin[e.student=s.id](Stu,Temp1)
Result = Project[name,id,course,mark](Temp2)
```

❖ Query Execution (cont)

A query execution plan:

- consists of a collection of RelOps
- executing together to produce a set of result tuples

Results may be passed from one operator to the next:

- materialization ... writing results to disk and reading them back
- pipelining ... generating and passing via memory buffers

❖ Materialization

Steps in materialization between two operators

- first operator reads input(s) and writes results to disk
- next operator treats tuples on disk as its input
- in essence, the **`Temp`** tables are produced as real tables

Advantage:

- intermediate results can be placed in a file structure
  (which can be chosen to speed up execution of subsequent operators)

Disadvantage:

- requires disk space/writes for intermediate results
- requires disk access to read intermediate results

❖ Pipelining

How pipelining is organised between two operators:

- operators execute "concurrently" as producer/consumer pairs
- structured as interacting iterators (open; while(next); close)

Advantage:

- no requirement for disk access (results passed via memory buffers)

Disadvantage:

- higher-level operators access inputs via linear scan, or
- requires sufficient memory buffers to hold all outputs

❖ Iterators (reminder)

Iterators provide a "stream" of results:

- **`iter = startScan(`*params*`)`**
  - set up data structures for iterator (create state, open files, ...)
  - *params* are specific to operator (e.g. reln, condition, #buffers, ...)
- **`tuple = nextTuple(iter)`**
  - get the next tuple in the iteration; return null if no more
- **`endScan(iter)`**
  - clean up data structures for iterator

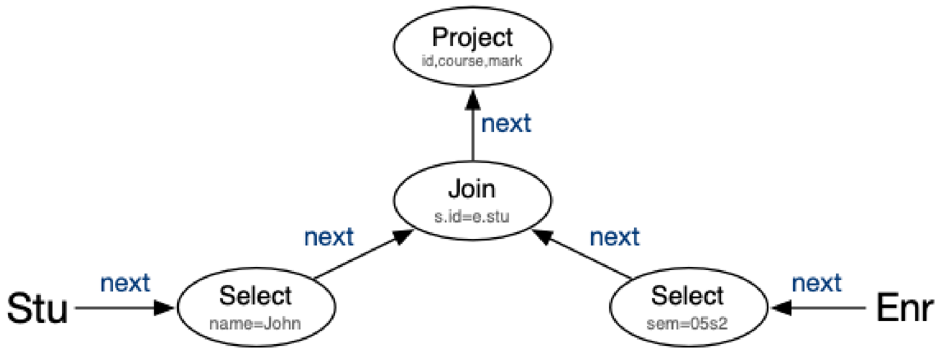
Other possible operations: reset to specific point, restart, ...

❖ Pipelining Example

Consider the query:

```
select s.id, e.course, e.mark
from   Student s, Enrolment e
where  e.student = s.id and
       e.semester = '05s2' and s.name = 'John';
```

Evaluated via communication between RA tree nodes:



Note: likely that projection is combined with join in PostgreSQL

❖ Disk Accesses

Pipelining cannot avoid all disk accesses.

Some operations use multiple passes (e.g. merge-sort, hash-join).

- data is written by one pass, read by subsequent passes

Thus ...

- within an operation, disk reads/writes are possible
- between operations, no disk reads/writes are needed

❖ PostgreSQL Query Execution

Defs: `src/include/executor` and `src/include/nodes`

Code: `src/backend/executor`

PostgreSQL uses pipelining (as much as possible) ...

- query plan is a tree of `Plan` nodes
- each type of node implements one kind of RA operation
  (node implements specific access method via iterator interface)
- node types e.g. `Scan`, `Group`, `Indexscan`, `Sort`, `HashJoin`
- execution is managed via a tree of `PlanState` nodes
  (mirrors the structure of the tree of Plan nodes; holds execution state)

❖ PostgreSQL Executor

Modules in `src/backend/executor` fall into two groups:

`execXXX` (e.g. execMain, execProcnode, execScan)

- implement generic control of plan evaluation (execution)
- provide overall plan execution and dispatch to node iterators

`nodeXXX` (e.g. nodeSeqscan, nodeNestloop, nodeGroup)

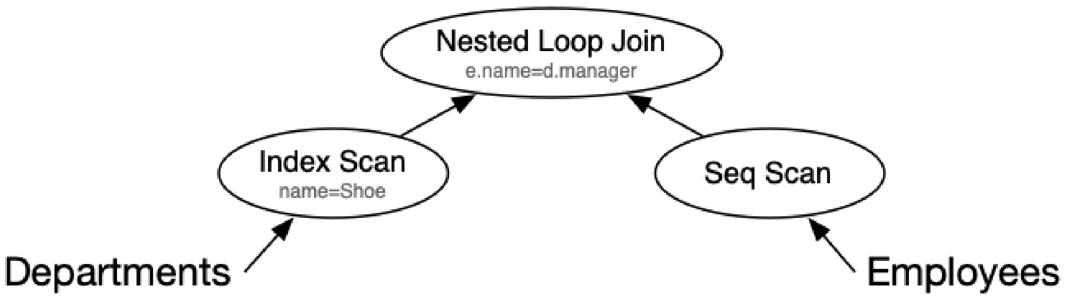
- implement iterators for specific types of RA operators
- typically contains `ExecInitXXX`, `ExecXXX`, `ExecEndXXX`

❖ Example PostgreSQL Execution

Consider the query:

```
-- get manager's age and # employees in Shoe department
select e.age, d.nemps
from   Departments d, Employees e
where  e.name = d.manager and d.name ='Shoe'
```

and its execution plan tree



❖ Example PostgreSQL Execution (cont)

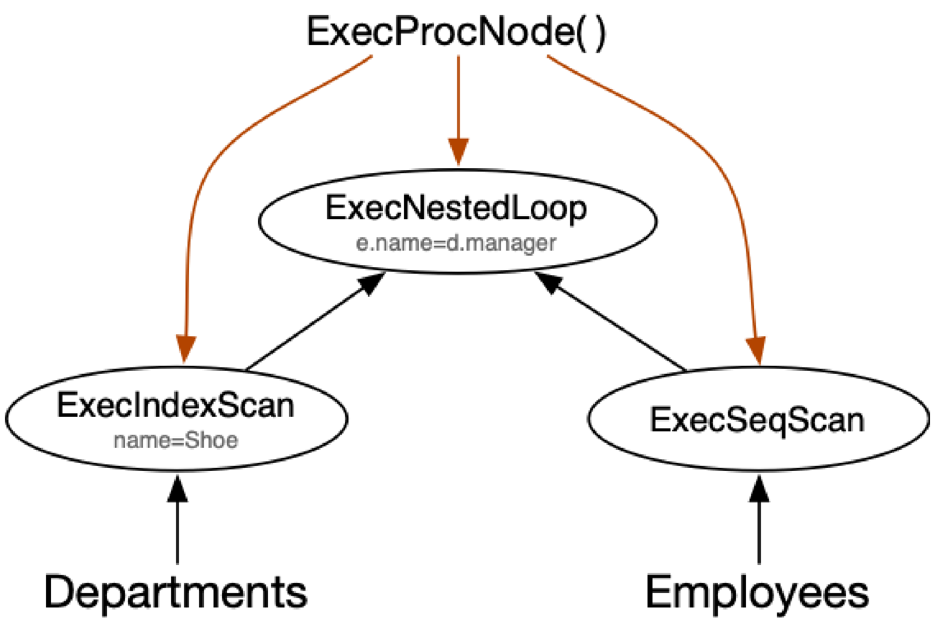
Initially **`InitPlan()`** invokes **`ExecInitNode()`** on plan tree root.

`ExecInitNode()` sees a **`NestedLoop`** node ...
  so dispatches to **`ExecInitNestLoop()`** to set up iterator
  then invokes **`ExecInitNode()`** on left and right sub-plans
    in left subPlan, **`ExecInitNode()`** sees an **`IndexScan`** node
     so dispatches to **`ExecInitIndexScan()`** to set up iterator
    in right sub-plan, **`ExecInitNode()`** sees a **`SeqScan`** node
     so dispatches to **`ExecInitSeqScan()`** to set up iterator

Result: a plan *state* tree with same structure as plan tree.

❖ Example PostgreSQL Execution (cont)

Plan state tree (collection of iterators):



❖ Example PostgreSQL Execution (cont)

Then **`ExecutePlan()`** repeatedly invokes **`ExecProcNode()`**.

```
ExecProcNode() sees a NestedLoop node ...
  so dispatches to ExecNestedLoop() to get next tuple
  which invokes ExecProcNode() on its sub-plans
     in left sub-plan, ExecProcNode() sees an IndexScan node
        so dispatches to ExecIndexScan() to get next tuple
        if no more tuples, return END
        for this tuple, invoke ExecProcNode() on right sub-plan
           ExecProcNode() sees a SeqScan node
              so dispatches to ExecSeqScan() to get next tuple
              check for match and return joined tuples if found
              continue scan until end
           reset right sub-plan iterator
```

Result: stream of result tuples returned via **`ExecutePlan()`**

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