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Query Evaluation

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❖ DBMS Architecture

COMP3311 is not a course on DBMS Architecture (that's COMP9315)

But knowing just a little about how DBMSs work can help

- to avoid/fix inefficiencies in database applications

DBMSs attempt to handle this issue in modules for ...

- query processing (QP) .. methods for evaluating queries

As a programmer, you cede a lot of control to the DBMS, but can

- use QP knowledge to make DB applications efficient

i.e. if we understand how the DBMS works under the hood (specifically what i can/can't do fast) then we can write our queries such that the DBMS can do them fast

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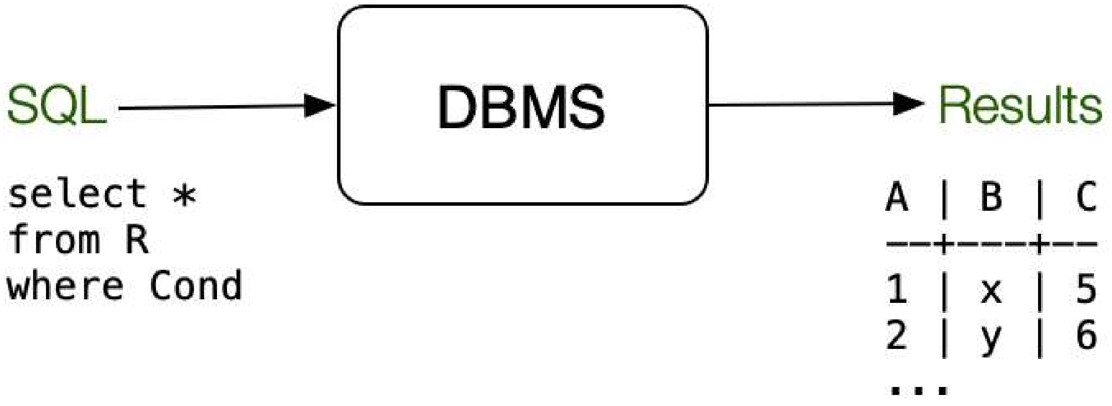
❖ DBMS Architecture (cont)

Our view of the DBMS so far ...



A machine to process SQL queries.

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❖ DBMS Architecture (cont)

One view of DB engine: "relational algebra virtual machine"

Machine code for such a machine:

selection (σ)	projection (π)	join (⋈, ×)
union (∪)	intersection (∩)	difference (-)
sort	insert	delete

For each of these operations:

- various data structures and algorithms are available
- DBMSs may provide only one, or may provide a choice

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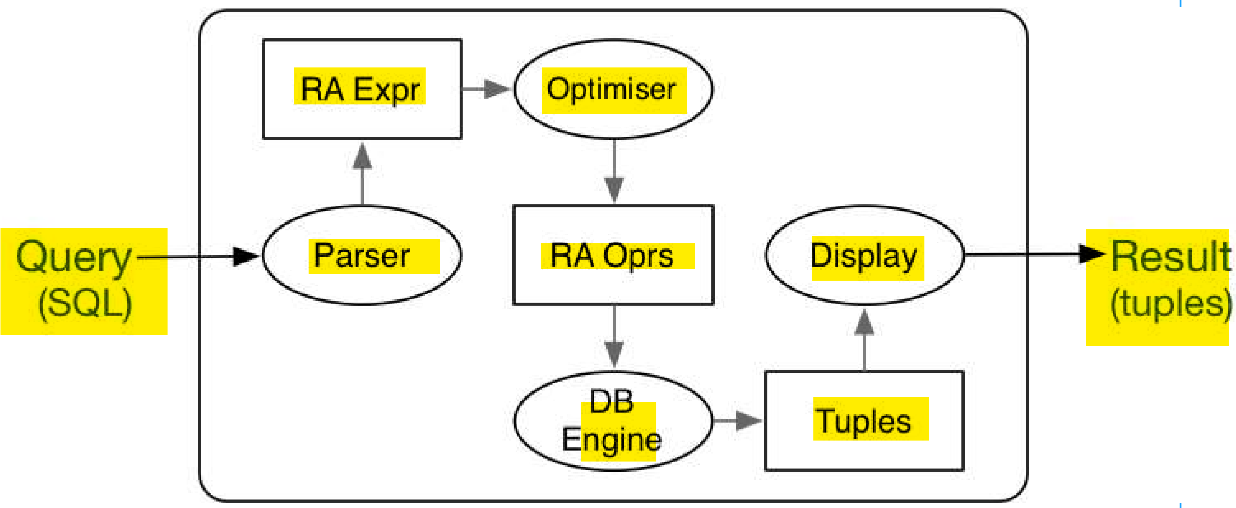
❖ Query Evaluation

The path of a query through its evaluation:



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❖ Mapping SQL to RA

Mapping SQL to relational algebra, e.g.

```
-- schema: R(a,b) S(c,d)
select a as x
from   R join S on (b=c)
where  d = 100
-- could be mapped to
Tmp1(a,b,c,d) = R Join[b=c] S
Tmp2(a,b,c,d) = Sel[d=100](Tmp1)
Tmp3(a)       = Proj[a](Tmp2)
Res(x)        = Rename[Res(x)](Tmp3)
```

In general:

- `SELECT` clause becomes *projection*
- `WHERE` condition becomes *selection* or *join*
- `FROM` clause becomes *join*

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❖ Mapping Example

Consider the database schema:

```
Person(pid, name, address, ...)
Subject(sid, code, title, uoc, ...)
Terms(tid, code, start, end, ...)
Courses(cid, sid, tid, ...)
Enrolments(cid, pid, mark, ..)
```

and the query: *Courses with more than 100 students in them?*

which can be expressed in SQL as

```
select s.sid, s.code
from   Course c join Subject s on (c.sid=s.sid)
       join Enrolment e on (c.cid=e.cid)
group  by s.sid, s.code
having count(*) > 100;
```

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❖ Mapping Example (cont)

The SQL might be compiled to

```
Tmp1(cid,sid,pid)    = Course Join[c.cid = e.cid] Enrolment
Tmp2(cid,code,pid)   = Tmp1 Join[t1.sid = s.sid] Subject
Tmp3(cid,code,nstu) = GroupCount[cid,code](Tmp2)
Res(cid,code)        = Sel[nstu > 100](Tmp3)
```

or, equivalently

```
Tmp1(cid,code)       = Course Join[c.sid = s.sid] Subject
Tmp2(cid,code,pid)   = Tmp1 Join[t1.cid = e.cid] Enrolment
Tmp3(cid,code,nstu) = GroupCount[cid,code](Tmp2)
Res(cid,code)        = Sel[nstu > 100](Tmp3)
```

Which is better?

❖ Query Cost Estimation

The cost of evaluating a query is determined by

- the operations specified in the query execution plan
- size of relations (database relations and temporary relations)
- access mechanisms (indexing, hashing, sorting, join algorithms)
- size/number of main memory buffers (and replacement strategy)

Analysis of costs involves *estimating*:

- the size of intermediate results
- then, based on this, cost of secondary storage accesses

Accessing data from disk is the dominant cost in query evaluation

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❖ Query Cost Estimation (cont)

An execution plan is a sequence of relational operations.

Consider execution plans for: $\sigma_c\,(R \bowtie_d S \bowtie_e T)$

```
tmp1   :=  hash_join[d](R,S)
tmp2   :=  sort_merge_join[e](tmp1,T)
result :=  binary_search[c](tmp2)
```

or

```
tmp1   :=  sort_merge_join[e](S,T)
tmp2   :=  hash_join[d](R,tmp1)
result :=  linear_search[c](tmp2)
```

or

```
tmp1   :=  btree_search[c](R)
tmp2   :=  hash_join[d](tmp1,S)
result :=  sort_merge_join[e](tmp2)
```

All produce same result, but have different costs.

❖ Implementations of RA Ops

Sorting (quicksort, etc. are not applicable)

- external merge sort (cost $O(N\log_B N)$ with B memory buffers)

Selection (different techniques developed for different query types)

- sequential scan (worst case, cost $O(N)$)
- index-based (e.g. B-trees, cost $O(\log N)$, tree nodes are pages)
- hash-based ($O(1)$ best case, only works for equality tests)

Join (fast joins are critical to success of relational DBMSs)

- nested-loop join (cost $O(N.M)$, buffering can reduce to $O(N+M)$)
- sort-merge join (cost $O(N\log N+M\log M)$)
- hash-join (best case cost $O(N+M.N/B)$, with B memory buffers)

❖ Query Optimisation

What is the "best" method for evaluating a query?

Generally, *best* = lowest cost = fastest evaluation time

Cost is measured in terms of pages read/written

- data is stored in fixed-size blocks (e.g. 4KB)
- data transferred disk↔>memory in whole blocks
- cost of disk↔memory transfer is highest cost in system
- processing in memory is very fast compared to I/O

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❖ Query Optimisation (cont)

A DBMS query optimiser works as follows:

```
Input: relational algebra expression
Output: execution plan (sequence of RA ops)

bestCost = INF; bestPlan = none
while (more possible plans) {
   plan = produce a new evaluation plan
   cost = estimated_cost(plan)
   if (cost < bestCost) {
      bestCost = cost; bestPlan = plan
   }
}
return bestPlan
```

Typically, there are very many possible plans

- smarter optimisers generate likely subset of possible plans

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