CS525: Advanced Database Organization

Notes 6: Query Processing
Part I : Overview

Yousef M. Elmehdwi

Department of Computer Science

Illinois Institute of Technology

yelmehdwi@iit.edu

November 1ˢᵗ 2023

Slides: adapted from courses taught by Hector Garcia-Molina, Stanford, & Shun Yan Cheung, Emory University

Where we are

- How a DBMS processes queries and the methods it uses to optimize their performance.

- Goals: *Understand the basic concepts underlying the steps in query processing and optimization and estimating query processing cost; apply query optimization techniques*

Query Processing

- So far, we have looked
  - hardware features such as disks and memory
  - data structures allowing fast lookup
- Remember that SQL is a declarative language
  - User tells the DBMS what answer they want, not how to get the answer.
  - DBMS needs to translate a SQL statement into an executable query plan
  - This allows for optimization decisions, and for many queries there is a wide range of possible execution strategies, which can differ greatly in their resulting performance
    - i.e., there can be a big difference in performance based on plan is used
- A query processor must find a plan how to execute the query
  - query compilation
  - query execution

Query Processing

- There might be several ways to implement a query - the query compiler should find an appropriate plan
  - parsing: translating the query into a parsing tree
  - query rewrite: the parse tree is transformed into an expression tree of relational algebra (logical query plan[1])
  - physical plan generation: translate the logical plan into a physical plan[2]
    - select algorithms to implement each operator
    - choose order of operations
- *Logical Query Plan the optimal sequence of relational algebra operations to perform the query.*
- *Physical Query Plan the optimal sequence of relational algebra algorithms to perform the query.*

---

[1] *The logical plan is roughly equivalent to the relational algebra expressions in the query.*

[2] *Physical operators define a specific execution strategy using an access path for the different operators in the query plan.*

Query Plan

- The DBMS converts a SQL statement into a query plan.
- Operators in the query plan are arranged in a tree.
- Data flows from the leaves of this tree towards the root.
- The output of the root node in the tree is the result of the query.
- Typically operators are binary (1-2 children).
- The same query plan can be executed in multiple ways.
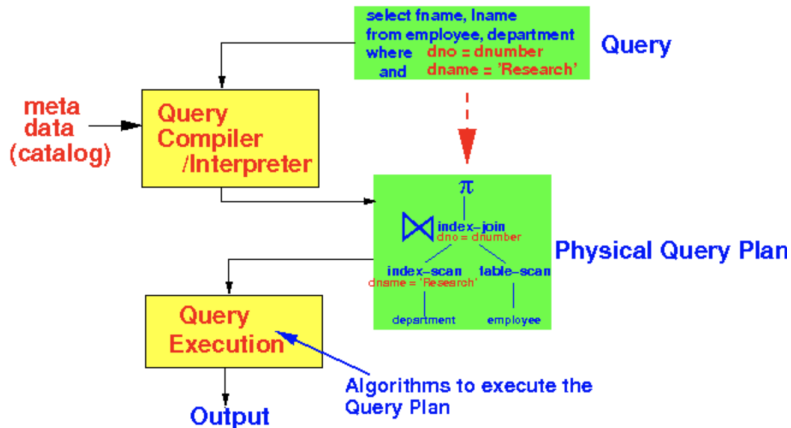- Most DBMSs will want to use an index scan as much as possible

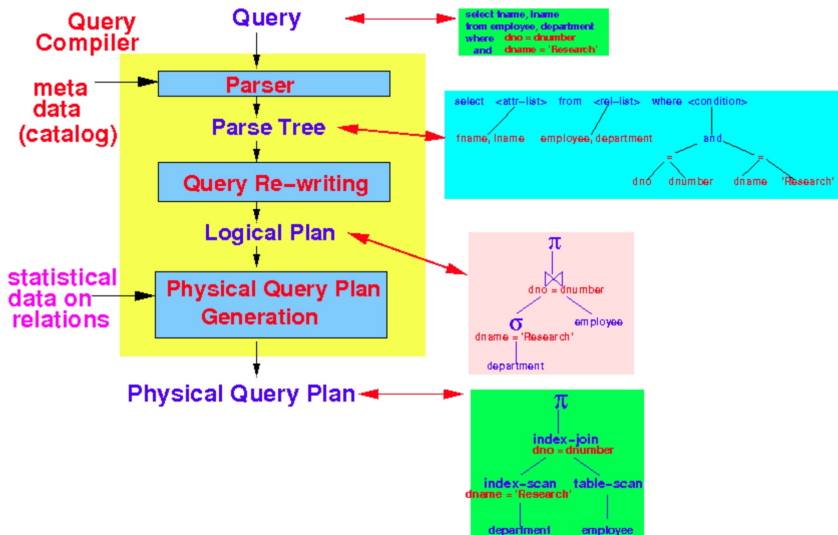- Making logical and physical query plans are often called query optimizing

query

generate plans

pruning

estimate cost

select best
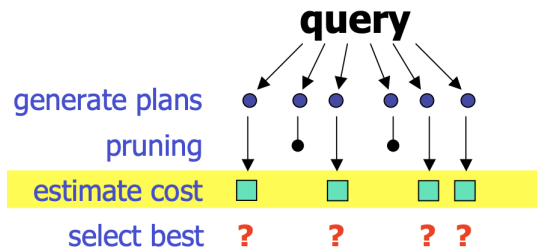
- Steps needed to process a query (SQL command)

- The **Query Compiler** consists of 3 major steps

Query Processing: Example

```
SELECT B,D
FROM R,S
WHERE R.A='c' and S.E=2 and R.c=S.c
```

R	A	B	C
	a	1	10
	b	1	20
	c	2	10
	d	2	35
	e	3	45

S	C	D	E
	10	x	2
	20	y	2
	30	z	2
	40	x	1
	50	y	3

R	A	B	C		S	C	D	E
	a	1	10			10	x	2
	b	1	20			20	y	2
	c	2	10			30	z	2
	d	2	35			40	x	1
	e	3	45			50	y	3

Answer

B	D
2	x

How do we execute query?

- One idea
    - Scan relations
    - Do Cartesian product
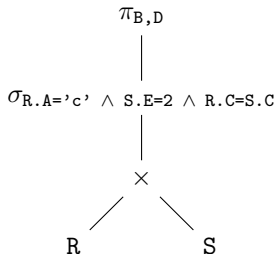   - Select tuples
    - Do projection

$R \times S$

R.A	R.B	R.C	S.C	S.D	S.E
a	1	10	10	x	2
a	1	10	20	y	2
.					
.					
C	2	10	10	x	2
.					
.					

RXS

R.A	R.B	R.C	S.C	S.D	S.E
a	1	10	10	x	2
a	1	10	20	y	2
.					
.					
C	2	10	10	x	2
.					
.					

Bingo! →

Got one...

Relational Algebra

- Can be used to describe plans
- Example: Plan I: Initial query plan constructed directly from the query.

$$\pi_{\text{B,D}}$$

$$\sigma_{\text{R.A='c'} \wedge \text{S.E=2} \wedge \text{R.C=S.C}}$$

$$\times$$

R   S

- FROM expressed by a `product`, WHERE by a `selection` above it, Select by a `projection`

Relational Algebra

- Can be used to describe plans
- Example: Plan I: Initial query plan constructed directly from the query.

$$\pi_{B,D}^{FLY}$$

$$\sigma_{R.A='c' \land S.E=2 \land R.C=S.C}^{FLY}$$

$$\times$$
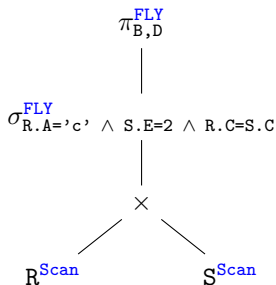
$$R^{Scan} \qquad S^{Scan}$$

1. Scan R
2. For each tuple r of R scan S
3. For each tuple r,s, where s in S, select and project on the fly
- OR: $\pi_{B,D}^{FLY}\left[\sigma_{R.A='c' \land S.E=2 \land R.C=S.C}^{FLY}(R^{Scan} \times S^{Scan})\right]$

- Example: Plan I: Initial query plan constructed directly from the query.

$$\pi_{\texttt{B,D}}$$

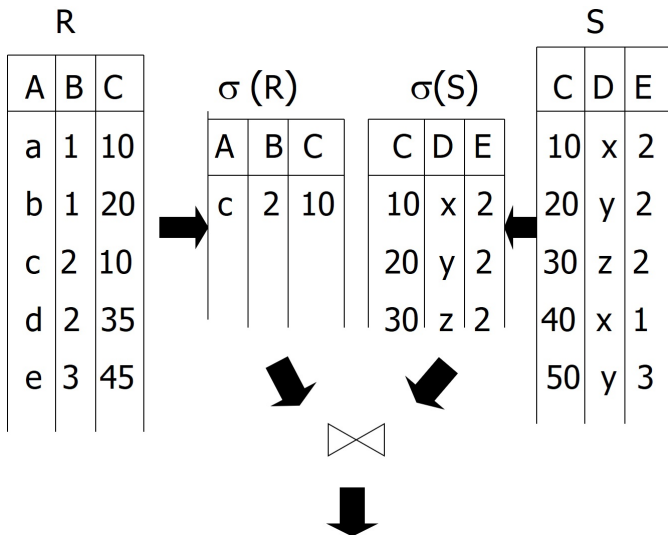$$\sigma_{\texttt{R.A='c'} \,\wedge\, \texttt{S.E=2} \,\wedge\, \texttt{R.C=S.C}}$$

$$\times$$

R   S
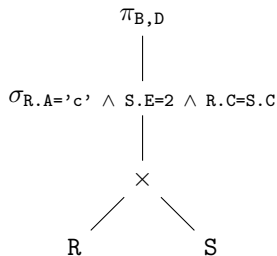
- OR: $\pi_{\texttt{B,D}}\big[\sigma_{\texttt{R.A='c'} \,\wedge\, \texttt{S.E=2} \,\wedge\, \texttt{R.C=S.C}}(\texttt{R} \times \texttt{S})\big]$

Another idea

- Example: Plan II: Scan `R` and `S`, perform on the fly selections, do natural join, project

$$\pi_{B,D}$$

$$\bowtie$$

$$\sigma_{R.A='c'} \qquad \sigma_{S.E=2}$$

$$R \qquad\qquad S$$

R

A	B	C
a	1	10
b	1	20
c	2	10
d	2	35
e	3	45

σ (R)

A	B	C
c	2	10

σ(S)

C	D	E
10	x	2
20	y	2
30	z	2

S

C	D	E
10	x	2
20	y	2
30	z	2
40	x	1
50	y	3

⋈
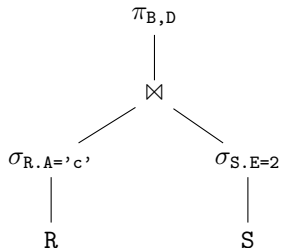
1. Use `R.A index` to select R tuples with `R.A = 'c'`
2. For each `R.C` value found, use `S.C index` to find matching tuples
3. Eliminate S tuples `S.E` $\neq$ 2
4. Join matching `R,S` tuples, project `B,D` attributes and place in result

1. Use `R.A index` to select R tuples with `R.A = 'c'`

R

A	B	C
a	1	10
b	1	20
c	2	10
d	2	35
e	3	45

A = "c"

I_1

C

I_2

<c,2,10>

<10,x,2>

S

C	D	E
10	x	2
20	y	2
30	z	2
40	x	1
50	y	3
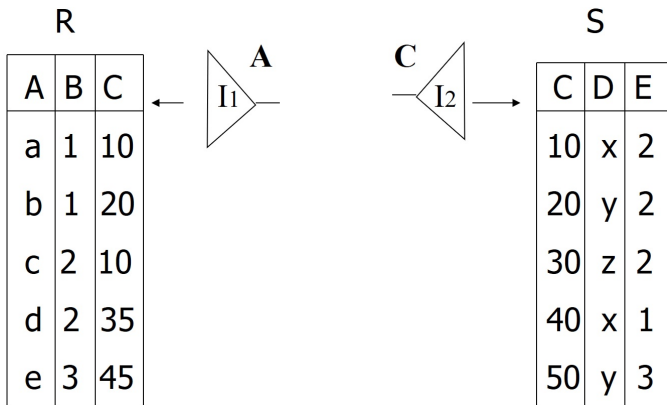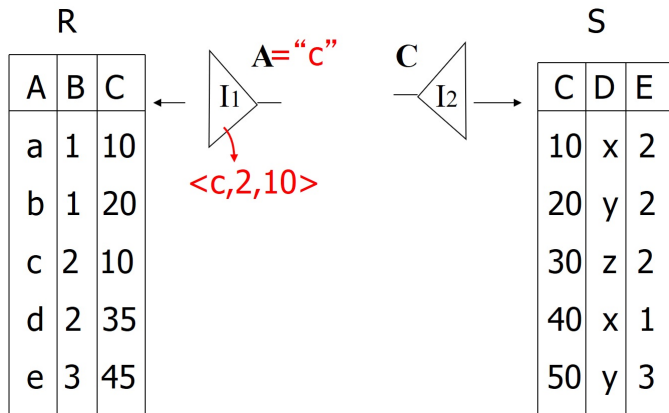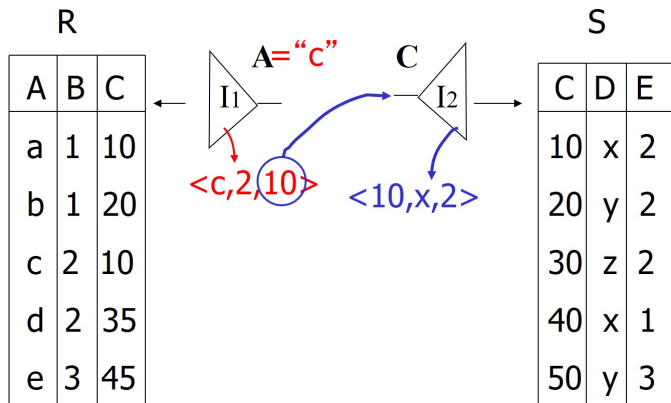
2. For each R.C value found, use S.C index to find matching tuples
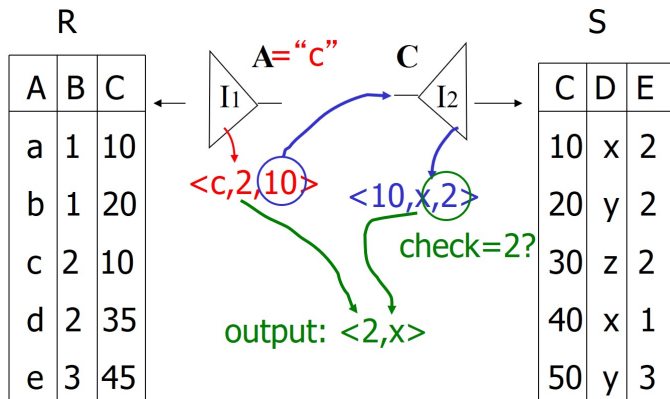
3. Eliminate S tuples `S.E` $\neq$ 2
4. Join matching `R,S` tuples, project `B,D` attributes and place in result
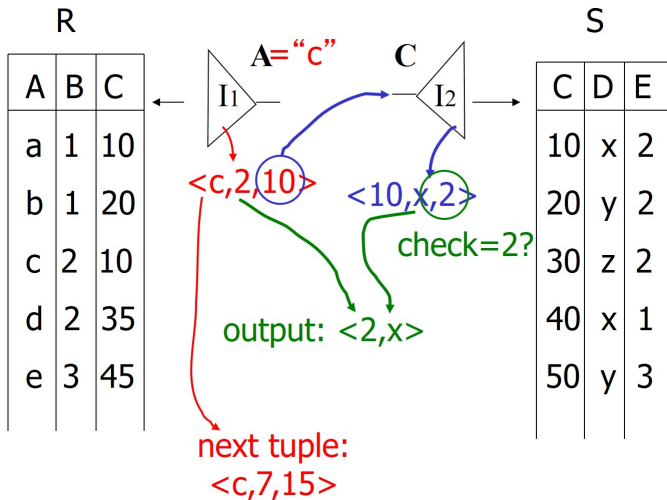
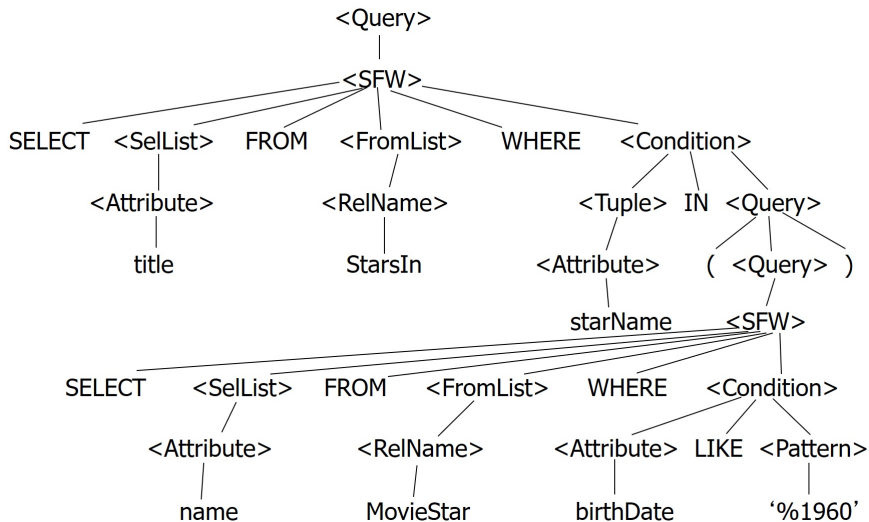# Overview of Query Optimization
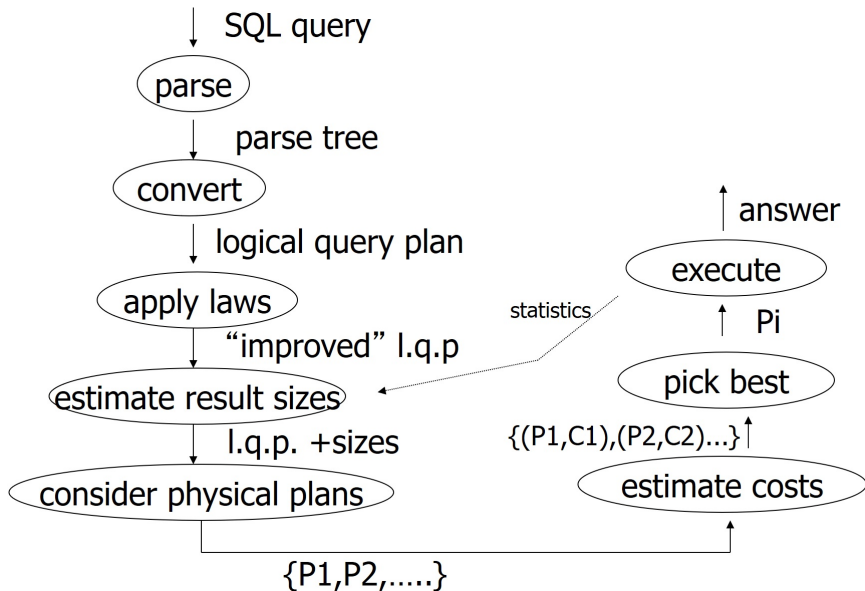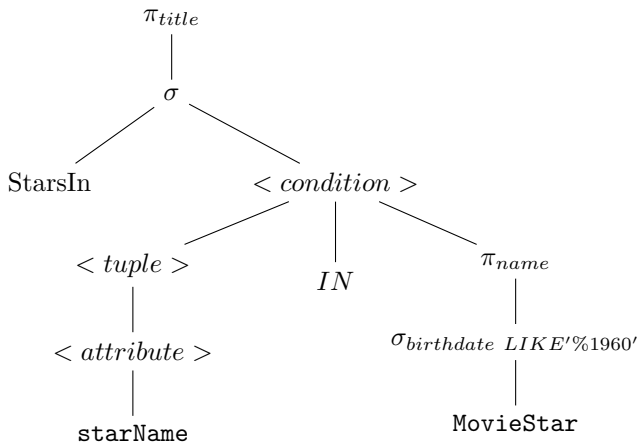
```
SELECT title
FROM   StarsIn
WHERE  starName  IN  (SELECT name
                      FROM MovieStar
                      WHERE birthdate LIKE '%1960');
```
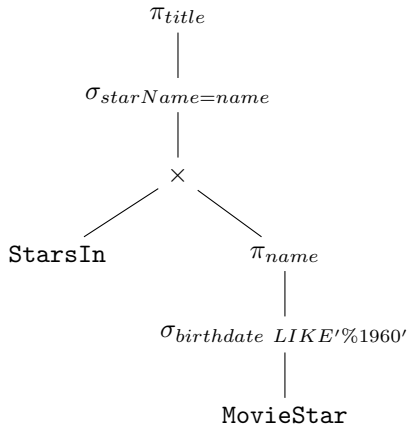
- Find the movies with stars born in 1960

Example: Generating Relational Algebra
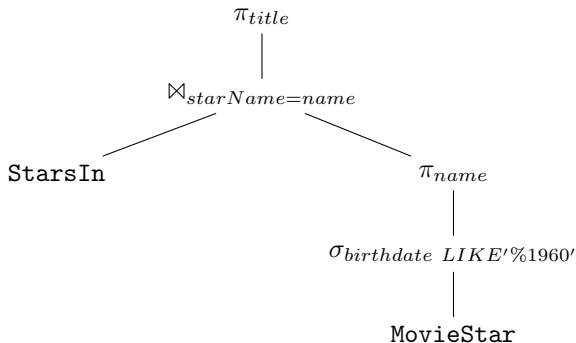
Example: Logical Query Plan

π_{title}

$\sigma_{starName=name}$

$\times$

StarsIn

π_{name}

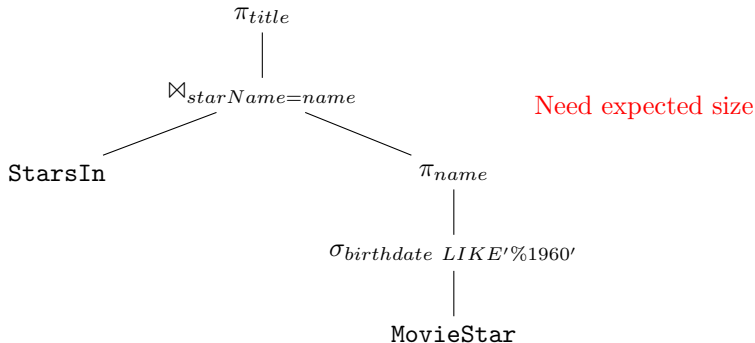$\sigma_{birthdate\ LIKE'\%1960'}$

MovieStar

- May consider "IN" elimination as a rewriting in the logical plan generator or may consider it a task of the converter
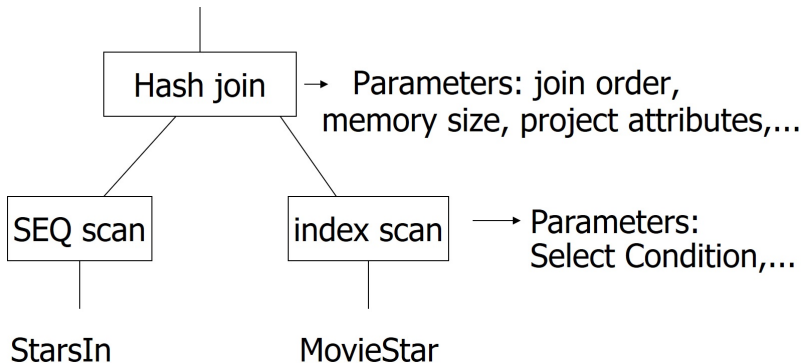
Example: Improved Logical Query Plan

$$\pi_{title}$$

$$|$$

$$\bowtie_{starName=name}$$

StarsIn

$$\pi_{name}$$

$$\sigma_{birthdate\ LIKE'\%1960'}$$

MovieStar

Result sizes are important for selecting physical plans

Estimate Result Sizes

π_{title}

$\bowtie_{starName=name}$

StarsIn

π_{name}

$\sigma_{birthdate\ LIKE'\%1960'}$

MovieStar

Need expected size

Pick best!