CSE 444: Database Internals

Lecture 11

Query Optimization (part 2)

Query Optimizer Overview

- **Input**: A logical query plan
- **Output**: A good physical query plan
- **Basic query optimization algorithm**
  - Enumerate alternative plans (logical and physical)
  - Compute estimated cost of each plan
    - Compute number of I/Os
    - Optionally take into account other resources
  - Choose plan with lowest cost
  - This is called cost-based optimization

The Three Parts of an Optimizer

- Cost estimation
  - Based on cardinality estimation
- Search space
  - Algebraic laws, restricted types of join trees
- Search algorithm
  - Will discuss next

Search Algorithm

- Dynamic programming (in class)
  - Based on System R (aka Selinger) style optimizer[1979]
  - Limited to joins: *join reordering algorithm*
  - Bottom-up
- Rule-based algorithm (will not discuss)
  - Database of rules (=algebraic laws)
  - Usually: dynamic programming
  - Usually: top-down

Dynamic Programming

Originally proposed in System R [1979]

- Only handles single block queries:

```
SELECT list
FROM   R1, …, Rn
WHERE cond_1 AND cond_2 AND . . . AND cond_k
```

- Some heuristics for search space enumeration:
  - Selections down
  - Projections up
  - Avoid cartesian products

```
SELECT list
FROM   R1, …, Rn
WHERE  cond1 AND cond2 AND . . . AND condk
```

Dynamic Programming

- For each subquery Q ⊆{R1, …, Rn} compute the following:
  - T(Q) = the estimated size of Q
  - Plan(Q) = a best plan for Q
  - Cost(Q) = the estimated cost of that plan

SELECT list
FROM R1, …, Rn
WHERE $cond_1$ AND $cond_2$ AND . . . AND $cond_k$

Dynamic Programming

- **Step 1**: For each $\{R_i\}$ do:
  - $T(\{R_i\}) = T(R_i)$
  - Plan($\{R_i\}$) = access method for R_i
  - Cost($\{R_i\}$) = cost of access method for R_i

```
SELECT list
FROM    R1, …, Rn
WHERE cond1 AND cond2 AND . . . AND condk
```

Dynamic Programming

- **Step 2**: For each Q $\subseteq\{R_1, \ldots, R_n\}$ of size k do:
  - T(Q) = use estimator
  - Consider all partitions Q = Q' ∪ Q''
    compute cost(Plan(Q') ⋈ Plan(Q''))
  - Cost(Q) = the smallest such cost
  - Plan(Q) = the corresponding plan

- Note
  - If we restrict to left-linear trees: Q'' = single relation
  - May want to avoid cartesian products

```
SELECT list
FROM   R1, …, Rn
WHERE cond1 AND cond2 AND . . . AND condk
```

Dynamic Programming

- **Step 3**: Return Plan($\{R_1, \ldots, R_n\}$)

Example

```
SELECT *
FROM    R, S, T, U
WHERE cond1 AND cond2 AND . . .
```

- $R \bowtie S \bowtie T \bowtie U$
- Assumptions:

$$T(R) = 2000$$
$$T(S) = 5000$$
$$T(T) = 3000$$
$$T(U) = 1000$$

- Every join selectivity is 0.001

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000		
S	5000		
T	3000		
U	1000		
RS			
RT			
RU			
ST			
SU			
TU			
RST			
RSU			
RTU			
STU			
RSTU			

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000		
S	5000		
T	3000		
U	1000		
RS	10000		
RT	6000		
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000		
T	3000		
U	1000		
RS	10000		
RT	6000		
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000		
U	1000		
RS	10000		
RT	6000		
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000		
RT	6000		
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

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Join selectivity is 0.001

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000	R ⋈ S nested loop join	…
RT	6000		
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

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Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000	R ⋈ S nested loop join	…
RT	6000	R ⋈ T index join	…
RU	2000		
ST	15000		
SU	5000		
TU	3000		
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

T(R) = 2000
T(S) = 5000
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T(U) = 1000

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000	R ⋈ S nested loop join	…
RT	6000	R ⋈ T index join	…
RU	2000	R ⋈ U index join	
ST	15000	S ⋈ T hash join	
SU	5000	. . .	
TU	3000	. . .	
RST	30000		
RSU	10000		
RTU	6000		
STU	15000		
RSTU	30000		

Assume
B(..) = T(..)/10

Join selectivity is 0.001

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000	R ⋈ S nested loop join	…
RT	6000	R ⋈ T index join	…
RU	2000	R ⋈ U index join	
ST	15000	S ⋈ T hash join	
SU	5000	. . .	
TU	3000	. . .	
RST	30000	(RT) ⋈ S hash join	…
RSU	10000	(SU) ⋈ R merge join	
RTU	6000	…	
STU	15000		
RSTU	30000		

Assume
B(..) = T(..)/10

Join selectivity
is 0.001

T(R) = 2000
T(S) = 5000
T(T) = 3000
T(U) = 1000

Subquery	T	Plan	Cost
R	2000	Clustered index scan R.A	200
S	5000	Table scan	500
T	3000	Table scan	300
U	1000	Unclustered index scan U.F	1000
RS	10000	R ⋈ S nested loop join	…
RT	6000	R ⋈ T index join	…
RU	2000	R ⋈ U index join	
ST	15000	S ⋈ T hash join	
SU	5000	. . .	
TU	3000	. . .	
RST	30000	(RT) ⋈ S hash join	…
RSU	10000	(SU) ⋈ R merge join	
RTU	6000	…	
STU	15000		
RSTU	30000	(RT) ⋈ (SU) hash join	…

Assume
B(..) = T(..)/10

Join selectivity is 0.001

Discussion

- Need to consider both R ⋈ S and S ⋈ R
  - Because the cost may be different! (indexes etc)

- When computing the cheapest plan for
- (Q) ⋈ R, we may consider new access methods for R, e.g. an index look-up that makes sense only in the context of the join

```
SELECT list
FROM   R1, …, Rn
WHERE cond1 AND cond2 AND . . . AND condk
```

Discussion

Given a query with n relations R1, …, Rn

- How many entries do we have in the dynamic programming table?
- For each entry, how many alternative plans do we need to inspect?

```
SELECT list
FROM    R1, …, Rn
WHERE cond1 AND cond2 AND . . . AND condk
```

Discussion

Given a query with n relations R1, …, Rn

- How many entries do we have in the dynamic programming table?
  - A: $2^n - 1$
- For each entry, how many alternative plans do we need to inspect?
  - A: for each entry with k tables, examine $2^k – 2$ plans

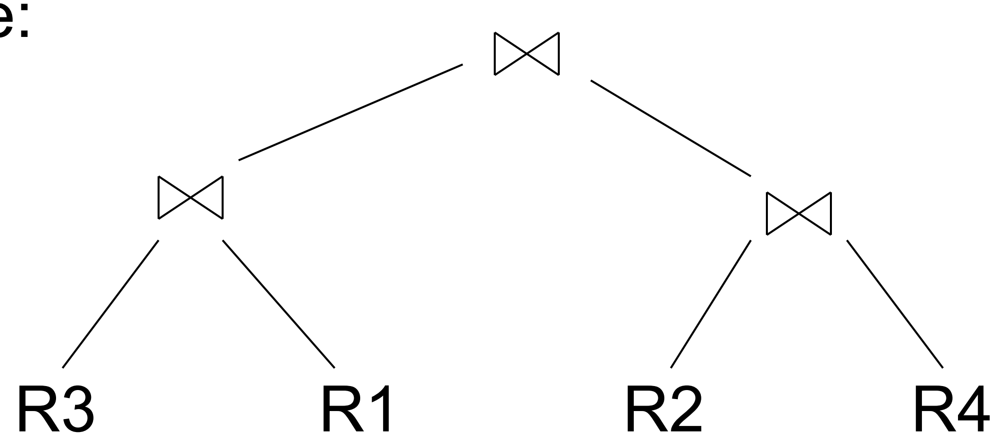
Reducing the Search Space

- Left-linear trees

- No cartesian products

Join Trees

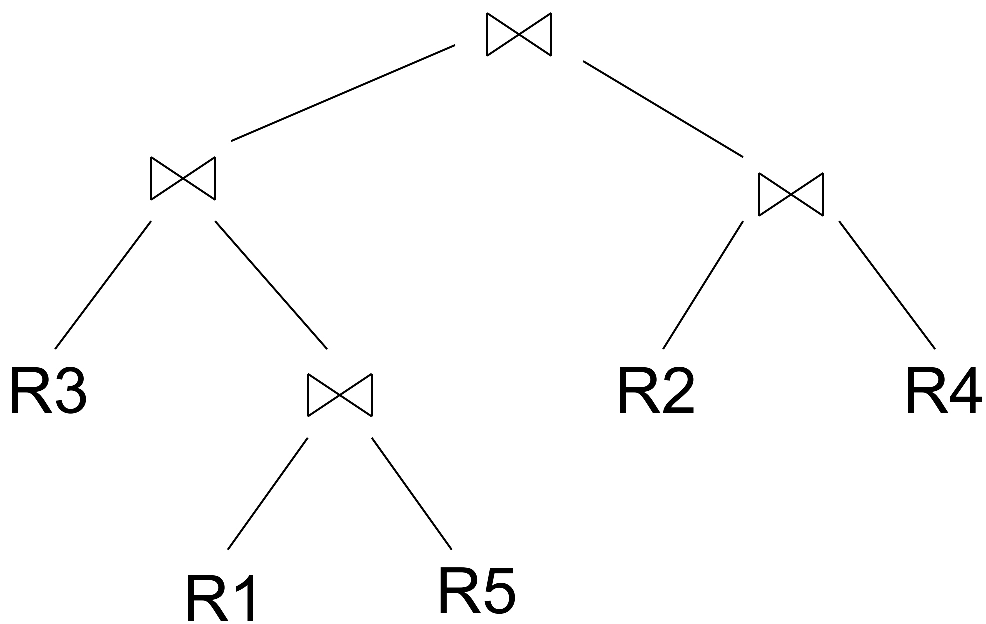
- R1 ⋈ R2 ⋈ …. ⋈ Rn
- Join tree:



- A plan = a join tree
- A partial plan = a subtree of a join tree

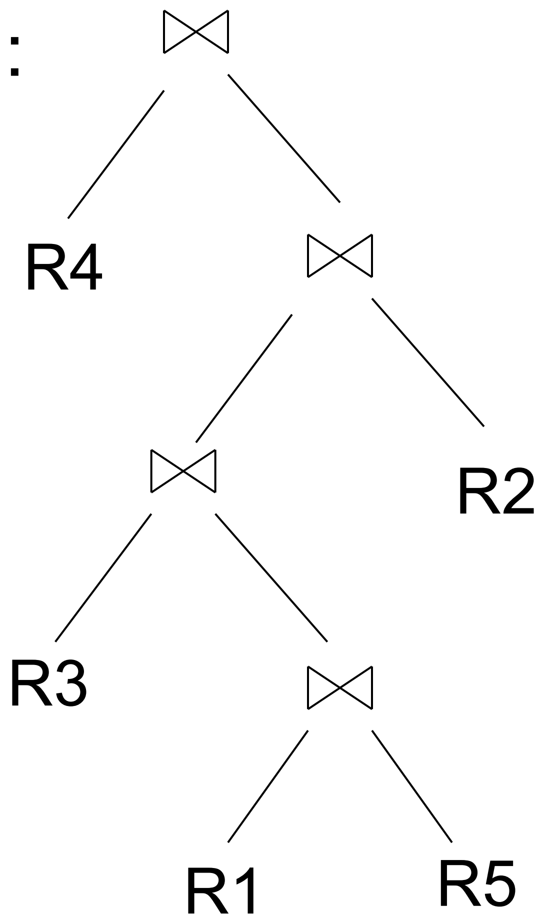
Types of Join Trees

- Bushy:



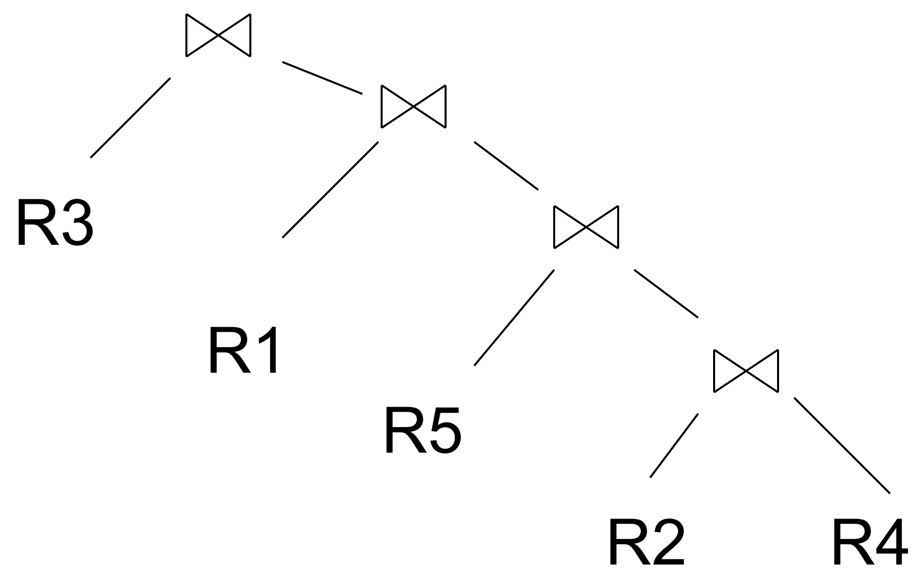
Types of Join Trees

- Linear :



Types of Join Trees

- Right deep:



Types of Join Trees

- Left deep:
  - Work well with existing join algos
    - Nested-loop and hash-join
  - Facilitate pipelining
  - Dynamic programming can be used with all trees