Practicum in Database Systems

Project 5 intro

Project 5 overview

- Bring together your work for P3 and P4
- Support query optimization:
  - gather data statistics
  - choose implementation of selection
  - choose join order
  - choose implementation of each join
- Contains algorithms/data structures you may not have seen or not seen in this exact format

Architecture/format changes

- Physical Plan Builder config file goes away
- Interpreter config file contains just input/output/temp sort directory
- You need to generate and print logical and physical plans as well as query answers
- See instructions for expected format of your logical/physical plan

Step 1: gather statistics

- Write code to collect basic stats on your relations:
  - number of tuples
  - for each attribute, min and max values
- Your interpreter should do this before running queries
- Should write stats out in a file that can be accessed by DB catalog

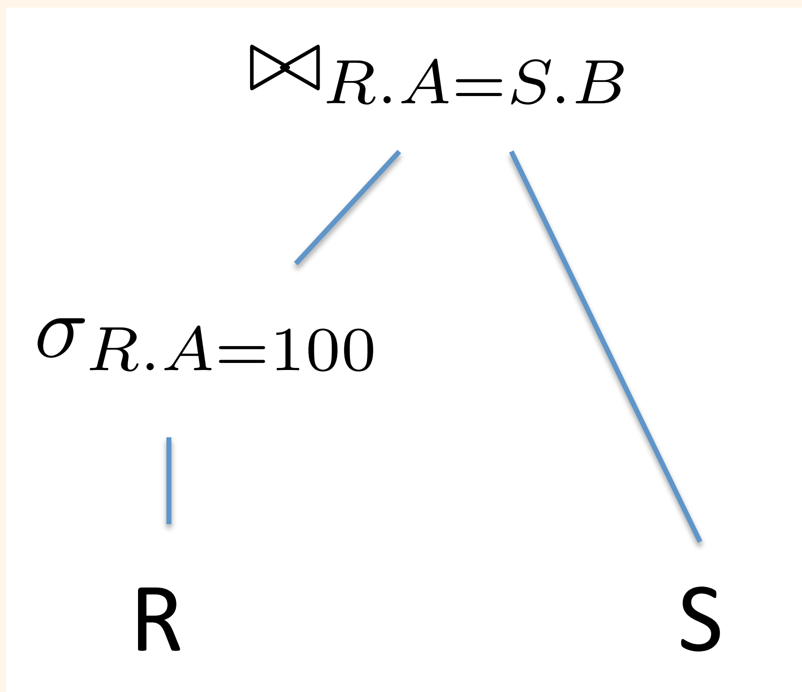
Step 2: push selections

- We already did some of this in P2
- But this time, we will push more aggressively

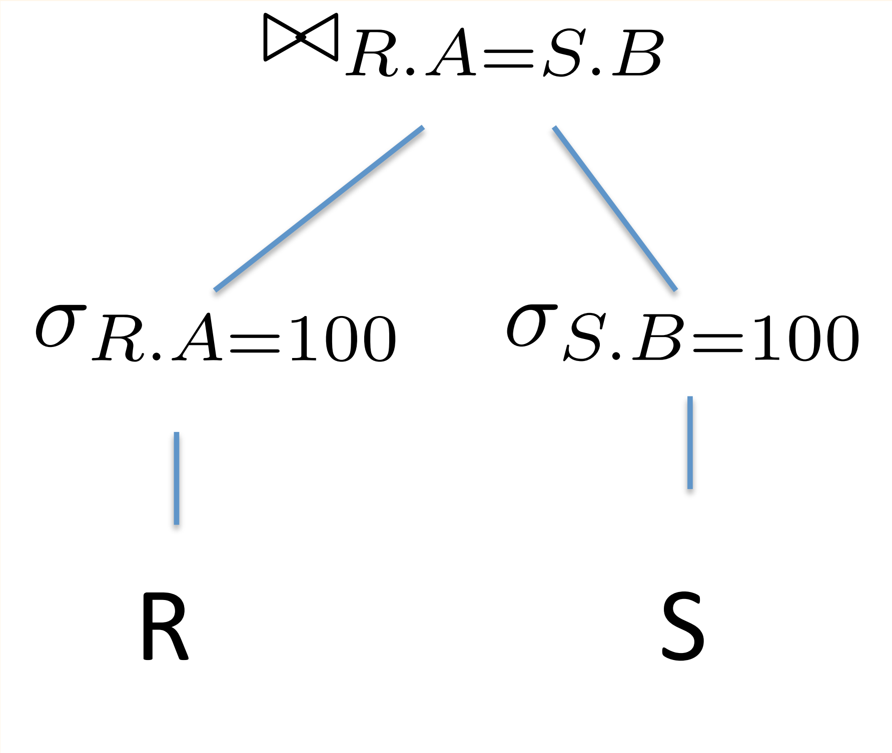
Example

SELECT * FROM R, S WHERE R.A = 100 AND R.A = S.B

- Your plan probably looks like this:



A better plan



First things first

- When to push selections?
- While building logical plan
  - Always advantageous in our implementation
  - Regardless of data stats

What does your logical plan look like?

- Single relation case – same as before
- Multi-relation case – don't fix the join order
  - This will be done in the physical plan builder based on data stats
  - So you only have one join operator, with multiple children
  - Children are selections or base tables

How to push selections

- Want to "propagate" numerical constraints through equalities between attributes
- Details and scope of what you should do are specified in the instructions

The union-find data structure

- Should propagate constraints using a *union-find* data structure
  - Also sometimes called *disjoint-set*
- A union-find has a collection of elements
- Every element is a set of attributes which are constrained to be equal to each other
- May also contain numerical bounds

Example WHERE clause

R.A < 100 AND

R.A = R.B AND

R.B = S.C AND

S.C > 50 AND

S.D = 42 AND

S.D = T.F

Corresponding union-find

Attributes:
R.A, R.B, S.C

lower bound: 51
upper bound: 99
equality constraint: null

Attributes:
S.D, T.F

lower bound: 42
upper bound: 42
equality constraint: 42

Using the union-find

- Process the WHERE clause and build a union-find that captures all the equality and numerical constraints

Union-find API

- Given an attribute, ***find*** the union-find element that contains it
- Given two union-find elements, ***union*** them into a single element
- Given a union-find element, adjust its numerical constraints

What to do with this union-find?

- Use it to generate selection conditions for every individual relation in the join
  - Any numerical constraints on an attribute of a relation are translated to a selection
  - Also, equality constraints like R.A = R.B
- Also store the union-find in the logical plan for future use
  - Will use it to generate join conditions once you fix join order

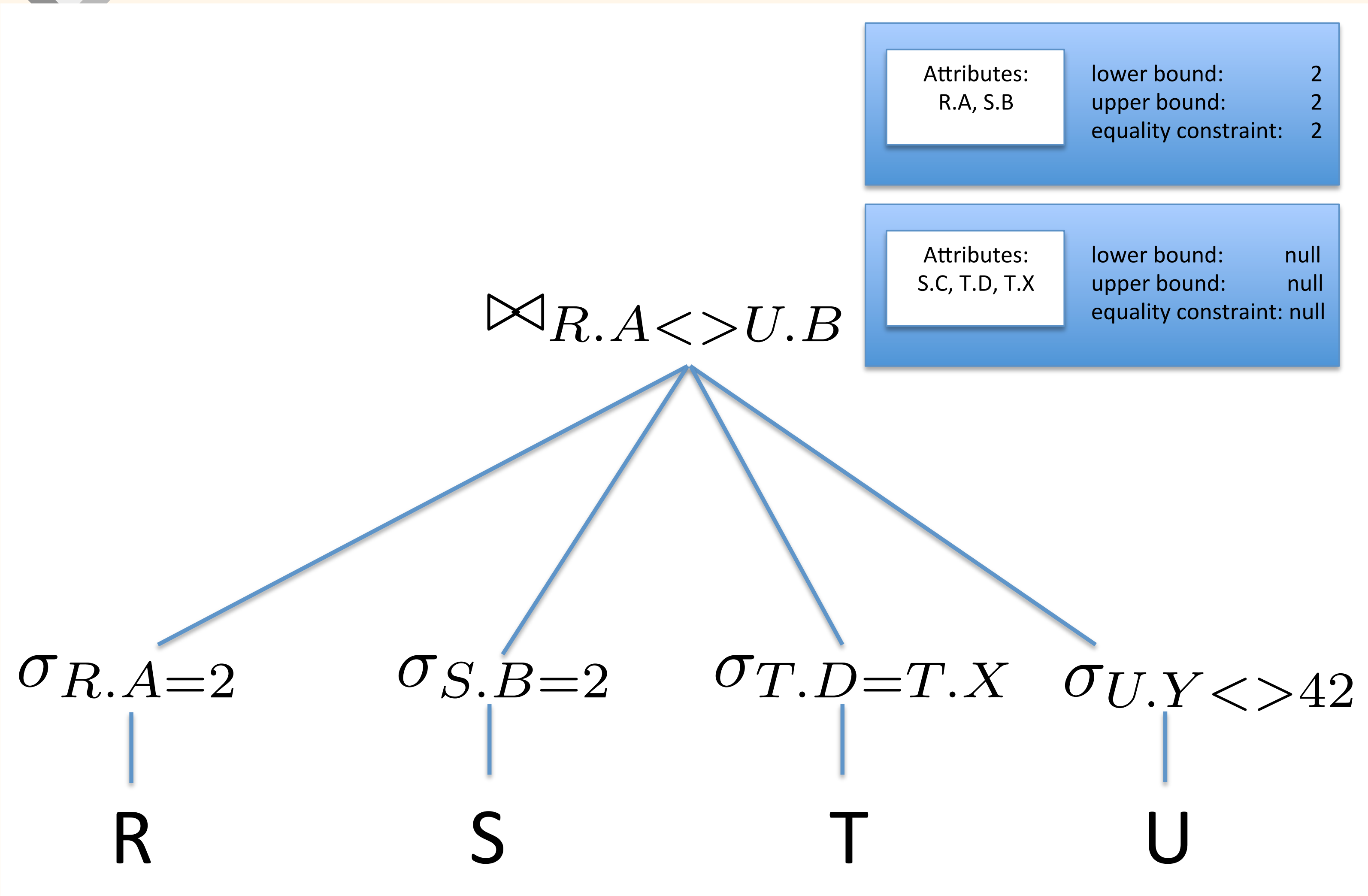
Leftovers

- Not all constraints go into the union-find
- E.g. R.A <> S.C
- So need to keep a "residual join expression" in your logical plan as well

Example query

```
SELECT *
FROM R, S, T, U
WHERE R.A <> U.B
      AND R.A = S.B
      AND S.C = T.D
      AND R.A = 2
      AND T.D = T.X
      AND U.Y <> 42
```

Logical query plan



Step 3: choose implementation for each selection

- In your Physical Plan Builder, when you visit() a logical selection op
- Use data statistics and available index info
- Calculate cost for every possible way to evaluate
- Choose lowest-cost alternative
- Formulas should be familiar from 4320

Step 4: choose a join order

- Left-deep tree, but need to chose ordering
- Similar to algorithm you saw in 4320 but simpler (?)
- See instructions of textbook by Garcia-Molina, Ullman and Widom for more details in instructions)

Dynamic programming algorithm

- Iterate over all subsets of relations, in increasing order of size
  - All subsets of size 2, all subsets of size 3, etc
- For each subset, find and retain only the lowest-cost join order
- This terminates with the lowest-cost join order for the entire set

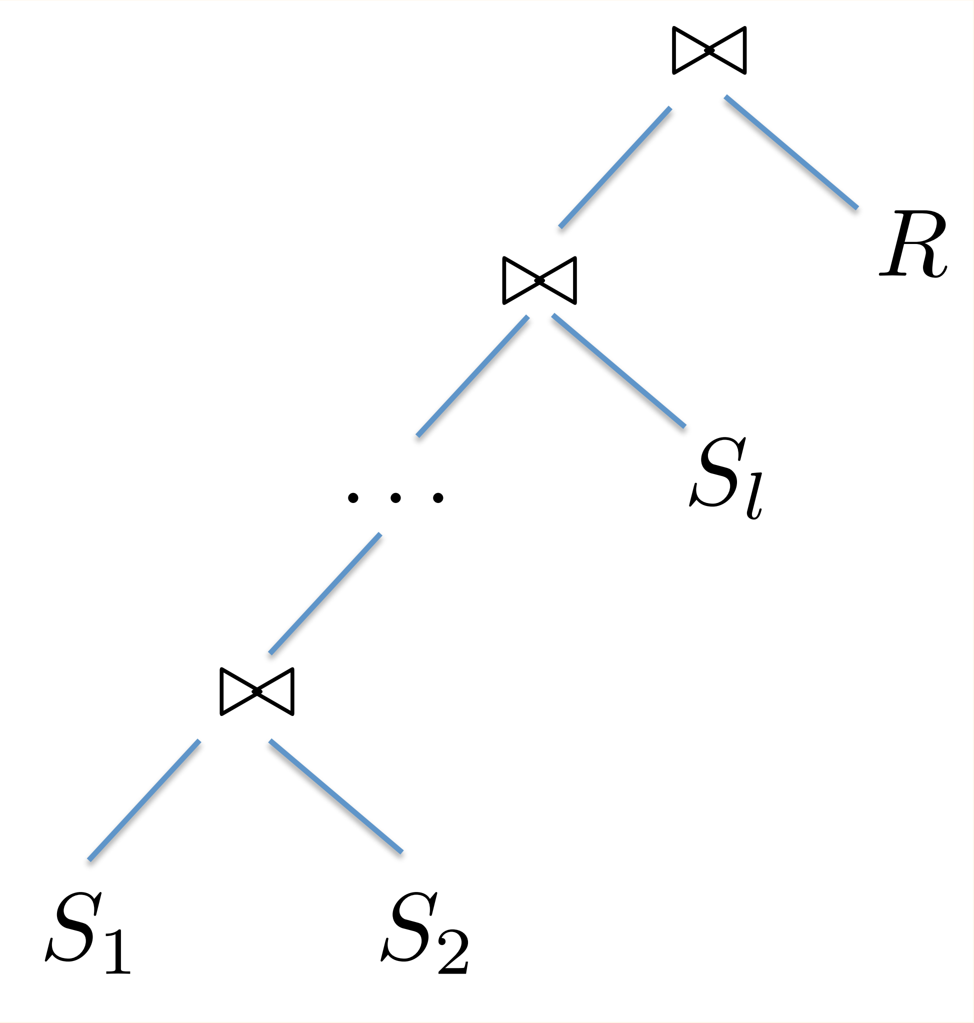
Finding the lowest cost plan

- If a subset has 2 relations, best (lowest cost) plan is the one with smaller relation as outer
- Whether you use BNLJ or SMJ, outer size influences overall cost

Cost for subsets of size >= *3*

- Cost of join order = sum of sizes of all intermediate relations, excluding final result
- Rationale: every intermediate relation we count is outer for some join

Calculating cost of a plan



Cost of plan

- Cost = size of last intermediate relation + cost of subplan to generate that relation
- (For a plan with 2 relations assume cost = 0)

How to compute relation sizes?

- Ok, so how do we compute intermediate relation sizes?
- Let's start with the join of 2 relations, R and S
- Size could theoretically vary from 0 to the cross product size
- We estimate it using statistics

V-values

- Given a relation R and attribute A, V(R, A) = number of distinct values A takes in R
- You can compute this for each relation and each attribute from your statistics
- Assume uniform distribution
- If you have a selection, include the reduction factor in your calculations

Join size

- Joining R and S on R.A = S.A
- Make some assumptions about R.A and S.A:

if $V(R,A) \le V(S,A)$ then every value of R.A appears as a value of S.A

if $V(R,A) \ge V(S,A)$ then every value of S.A appears as a value of R.A

- Intuition from primary key/foreign key joins

Computing join size

- Suppose V(R.A) <= V(S.A)
- Every tuple in R has a chance 1/V(S,A) of joining with a tuple from S
- So joins with |S|/V(S,A) tuples
- So expected join size is |R| |S|/V(S,A)
- If V(R.A) >= V(S.A) analogous argument shows join has size |R| |S|/V(R,A)

Conclusion

- If joining R and S on R.A = S.A, join size is

$$\frac{|R||S|}{max(V(R,A),V(S,A))}$$

- See instructions for discussion of more complex join conditions

Putting it all together

- You need to iterate over all subsets of relations
- Note: relations really means "relation instances" (may have FROM Reserves R1, Reserves R2 -> 2 instances)
- For every subset, compute:
  - best join order
  - cost of this plan
  - size of resulting relation
  - V-values for resulting relation
- The best join order for the (unique) largest subset is your answer

Step 5: choose an implementation for each join

- Make some choice between BNLJ and SMJ
- Don't use a "trivial" policy that always uses BNLJ (or always uses SMJ)
  - Unless of course you have not been able to implement one of these joins in P3
- Find and state some criterion for choosing between the two

Must-have requirements

- Pretty much need to implement everything the way we described it
- If you want to diverge from the instructions, need to get permission (Piazza, office hours, email)
- Will need to explain why your version is better than our suggested approach/algorithm

How we will grade

- Your stats file must match ours
- Your logical plans must match ours
- Your physical plans must be "reasonable" given the data and any special features of your implementation (that you mention in your README)
- Your query answers must still be correct