CS W186 - Spring 2020
Guerrilla Section 3
Joins and Query Optimization

Sunday, March 15, 2020

Joins

We will be joining two tables: a table of students, and a table of assignment submissions; and we will be joining by the student ID:

```
CREATE TABLE Students (
    student_id INTEGER PRIMARY KEY,
    ...
);

CREATE TABLE AssignmentSubmissions(
    assignment_number INTEGER,
    student_id INTEGER REFERENCES Students(student_id),
    ...
);

SELECT *
FROM Students, AssignmentSubmissions
WHERE Students.student_id = AssignmentSubmissions.student_id;
```

We also have:

- `Students` has $[S] = 20$ pages, with $p_S = 200$ records per page
- `AssignmentSubmissions` has $[A] = 40$ pages, with $p_A = 250$ records per page

Questions:

1. What is the I/O cost of a simple nested loop join for `Students` $\bowtie$ `AssignmentSubmissions`?

2. What is the I/O cost of a simple nested loop join for `AssignmentSubmissions` $\bowtie$ `Students`?

3. What is the I/O cost of a block nested loop join for `Students` ⋈ `AssignmentSubmissions`?

   Assume our buffer size is $B = 12$ pages.

4. What about block nested loop join for `AssignmentSubmissions` ⋈ `Students`?

   Assume our buffer size is $B = 12$ pages.

5. What is the I/O cost of an Index-Nested Loop Join for `Students` ⋈ `AssignmentSubmissions`?

   Assume we have a **clustered** alternative 2 index on `AssignmentSubmissions.student_id`, in the form of a height 2 B+ tree. Assume that index node and leaf pages are not cached; all hits are on the same leaf page; and all hits are also on the same data page.

6. Now assume we have a **unclustered** alternative 2 index on `AssignmentSubmissions.student_id`, in the form of a height 2 B+ tree. Assume that index node pages and leaf pages are never cached, and we only need to read the relevant leaf page once for each record of `Students`, and all hits are on the same leaf page.

   What is the I/O cost of an Index-Nested Loop Join for `Students` ⋈ `AssignmentSubmissions`?

   HINT: The foreign key in `AssignmentSubmissions` may play a role in how many accesses we do per record.

7. What is the cost of an unoptimized sort-merge join for `Students` ⋈ `AssignmentSubmissions`?

   Assume we have $B = 12$ buffer pages.

8. What is the cost of an **optimized** sort-merge join for `Students` $\bowtie$ `AssignmentSubmissions`?

   Assume we have $B = 12$ buffer pages.

9. In the previous question, we had a buffer of $B = 12$ pages. If we shrank B enough, the answer we got might change.

   How small can the buffer B be without changing the I/O cost answer we got?

10. What is the I/O cost of Grace Hash Join on these tables?

    Assume we have a buffer of $B = 6$ pages.

Query Optimization 1

(Modified from Fall 2017)

For the following question, assume the following:

- Column values are uniformly distributed and independent from one another

- Use System R defaults (1/10) when selectivity estimation is not possible
- Primary key IDs are sequential, starting from 1
- Our optimizer does not consider interesting orders

We have the following schema:

Table Schema	Records	Pages	Indices
CREATE TABLE Student (sid INTEGER PRIMARY KEY, name VARCHAR(32), major VARCHAR(64)), semesters_completed INTEGER)	25,000	500	• Index 1: Clustered(major). There are 130 unique majors • Index 2: Unclustered(semesters completed). There are 11 unique values in the range [0, 10]
CREATE TABLE Application (sid INTEGER REFERENCES Student, cid INTEGER REFERENCES Company, status TEXT, (sid, cid) PRIMARY KEY)	100,000	10,000	• Index 3: Clustered(cid, sid). • Given: status has 10 unique values
CREATE TABLE Company (cid INTEGER PRIMARY KEY, open_roles INTEGER))	500	100	• Index 4: Unclustered(cid) • Index 5: Clustered(open roles). There are 500 unique values in the range [1, 500]

Consider the following query:

```
SELECT Student.name, Company.open_roles, Application.referral
FROM Student, Application, Company
WHERE Student.sid = Application.sid                      -- (Selectivity 1)
AND Application.cid = Company.cid                        -- (Selectivity 2)
AND Student.semesters_completed > 6                      -- (Selectivity 3)
AND (Student.major='EECS' OR Company.open_roles <= 50)   -- (Selectivity 4)
AND NOT Application.status = 'limbo'                     -- (Selectivity 5)
ORDER BY Company.open_roles;
```

1. For the following questions, calculate the selectivity of each of the labeled Selectivities above.

   (a) Selectivity 1

   (b) Selectivity 2

   (c) Selectivity 3

(d) Selectivity 4

(e) Selectivity 5

2. For each predicate, which is the first pass of Selinger's algorithm that uses its selectivity to estimate output size? (Pass 1, 2 or 3?)

   (a) Selectivity 1
   (b) Selectivity 2
   (c) Selectivity 3
   (d) Selectivity 4
   (e) Selectivity 5

3. Mark the choices for all access plans that would be considered in pass 2 of the Selinger algorithm.

   (a) Student ⋈ Application (800 IOs)
   (b) Application ⋈ Student (750 IOs)
   (c) Student ⋈ Company (470 IOs)
   (d) Company ⋈ Student (525 IOs)
   (e) Application ⋈ Company (600 IOs)
   (f) Company ⋈ Application (575 IOs)

4. Which choices from the previous question for all access plans would be chosen at the end of pass 2 of the Selinger algorithm?

5. Which plans that would be considered in pass 3?

   (a) Company ⋈ (Application ⋈ Student) (175,000 IOs)
   (b) Company ⋈ (Student ⋈ Application) (150,000 IOs)
   (c) Application ⋈ (Company ⋈ Student) (155,000 IOs)

(d) Application $\bowtie$ (Company $\bowtie$ Student) (160,000 IOs)
(e) Student $\bowtie$ (Company $\bowtie$ Application) (215,000 IOs)
(f) (Company $\bowtie$ Application) $\bowtie$ Student (180,000 IOs)
(g) (Application $\bowtie$ Company) $\bowtie$ Student (200,000 IOs)
(h) (Application $\bowtie$ Student) $\bowtie$ Company (194,000 IOs)
(i) (Student $\bowtie$ Application) $\bowtie$ Company (195,000 IOs)
(j) (Student $\bowtie$ Company) $\bowtie$ Application (165,000 IOs)

6. Which choice from the previous question for all plans would be chosen at the end of pass 3?

Query Optimization 2

(Modified from Spring 2016)

1. True or False

   - When evaluating potential query plans, the set of left deep join plans are always guaranteed to contain the best plan.
   - As a heuristic, the System R optimizer avoids cross-products if possible.
   - A plan can result in an interesting order if it involves a sort-merge join.
   - The System R algorithm is greedy because for each pass, it only keeps the lowest cost plan for each combination of tables.

2. For the following parts assume the following:

   - The System R assumptions about uniformity and independence from lecture hold
   - Primary key IDs are sequential, starting from 1

   We have the following schema:

CREATE TABLE Flight (fid INTEGER PRIMARY KEY, from_id INTEGER REFERENCES City, to_id INTEGER REFERENCES City, aid INTEGER REFERENCES Airline)	NTuples: 100K, NPages: 50 Index: (I) unclustered B+-tree on aid. 20 leaf pages. (II) clustered B+-tree on (from_cid, fid). 10 leaf pages.
CREATE TABLE City (cid INTEGER PRIMARY KEY, name VARCHAR(16), state VARCHAR(16), population INTEGER)	NTuples: 50K, NPages: 20 Index: (III) clustered B+-tree on population. 10 leaf pages. (IV) unclustered index on cid. 5 leaf pages. Statistics: state in [1, 50], population in [10^6, $8*10^6$]
CREATE TABLE Airline (aid INTEGER PRIMARY KEY, hq_cid INTEGER REFERENCES City, name VARCHAR(16))	NTuples: 5K, NPages: 2

Consider the following query:

```
SELECT *
FROM Flight F, City C, Airline A
WHERE F.to_cid = C.cid
AND F.aid = A.aid
AND F.aid >= 2500
AND C.population > 5e6
AND C.state = 'California';
```

Considering each predicate in the WHERE clause separately, what is the selectivity for each?

(a) `R1: C.state='California'`

(b) `R2: F.to_id = C.cid`

(c) `R3: F.aid >= 2500`

(d) `R4: C.population > 5 * 10^6`

3. For each blank in the System R DP table for Pass 1. Assume this is before the optimizer discards any rows it isn't interested in keeping and note that some blanks may be N/A. Additionally, assume it takes 2 I/Os to reach the leaf nodes.

Table(s)	Plans	Interesting Orders from Plan (N/A if none)	Cost (I/Os)
Flight	Index (I)		
City	Filescan		
City	Index (III)		

4. After Pass 2, which of the following plans could be in the DP table?
   (a) City [Index(III)] JOIN Airline [File scan]
   (b) City [Index (III)] JOIN Flight [Index (I)]
   (c) Flight [Index (II)] JOIN City [Index (III)]

5. Suppose we want to optimize for queries similar to the query above in part 2, which of the following suggestions could reduce I/O cost?
   (a) Change Index (III) to be unclustered
   (b) Store City as a sorted file on population