Database tuning and Course review

Lecture 11
2ID35, Spring 2015

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Agenda

- Mini-lecture on DB Tuning
- Review of course and prep for final exam

DB tuning

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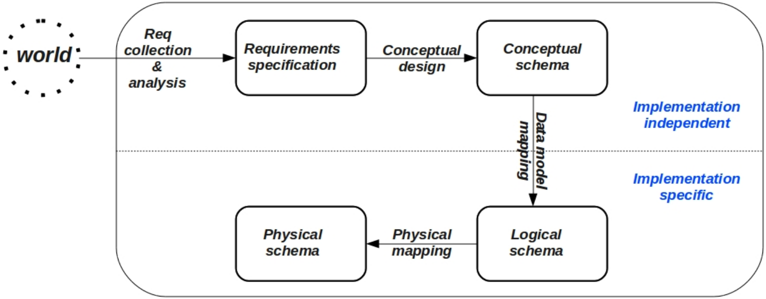
DB design



DB design process

DB design

“Goodness” in DB design

- Conceptual. Accurately reflect the semantics of use in the modeled domain.
- Logical. Accurately reflect conceptual model and disallow redundancies and update anomalies, as best possible.

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The distinction between design and tuning is somewhat fuzzy

- design is about *semantics*
- tuning is about *efficient use*

Job of the DBA: design, tuning, protection, maintenance

DB tuning

Tuning is driven by observed and/or expected workload

- list of queries and updates, and their frequencies
  - relations involved
  - attributes involved
  - selection and join predicates

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Let's consider tuning the basic components: buffers, indexes, schemas, queries

Tuning buffers and indexes

Six guidelines.

(1) Two types of cache:

- page cache
- procedure cache, for recent query plans

DBA can usually tweak cache size and replacement policy

Tuning buffers and indexes

Six guidelines.

(1) Two types of cache:

- page cache
- procedure cache, for recent query plans

DBA can usually tweak cache size and replacement policy

(2) To index or not to index: don't create indexes unnecessarily

- wasted space
- confuses query optimizer
- cost of maintenance can outweigh benefits

Tuning buffers and indexes

(3) Choice of search key: based on workload

- exact match vs. range selection
- multi-attribute

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(4) Hash-based vs. tree-based

- usually B+tree
- except when
  - frequent join – index on join attributes of inner relation
  - equality selections in query

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(6) To cluster or not to cluster: not always necessary on primary key (often the default) as this grouping might not give you much

- look at workload

Tuning buffers and indexes

Example.

```
SELECT M.ID, M.DeptID
FROM Managers M
WHERE M.Name = "Pointy-Haired Boss"
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Default is a clustered index on primary key `Managers.ID`

- not useful for this query
- if manager names are fairly unique, build unclustered index on `Managers.Name`, or, if warranted, build clustered index

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- not useful for this query
- if manager names are fairly unique, build unclustered index on `Managers.Name`, or, if warranted, build clustered index
- also holds for `Managers.Age` and `Managers.Salary`
- Hash-based or Ordered index?

Tuning buffers and indexes

Example.

ProjectPart(projectID, partID)
PartSupplier(partID, supplierID)

```
SELECT P.projID, S.supplierID
FROM ProjectPart P, PartSupplier S
WHERE P.partID = S.partID
```

Tuning buffers and indexes

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SELECT P.projID, S.supplierID
FROM ProjectPart P, PartSupplier S
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It seems natural to build an index on `PartSupplier.partID` to help out index nested loops join with `PartSupplier` as inner relation.

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```

It seems natural to build an index on `PartSupplier.partID` to help out index nested loops join with `PartSupplier` as inner relation.

However, potentially many rows of `PartSupplier` will join with each row of `ProjectPart`, leading to large result size!

- need to use some other join algorithm
- hence, we should not build this index!

Tuning schemas

Three basics.

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  ProjectPartSupplier(projectID, partID, supplierID)

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  ProjectPartSupplier(projectID, partID, supplierID)

2: vertical partitioning. place infrequently used columns in a separate table (smaller tuples = smaller pages = more records per I/O)

- for example, place rarely accessed attributes such as `hireDate` and `hireReferral` in separate table from `Managers`
- cf. column stores such as MonetDB

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- for example, place fired or retired managers in a separate table from `Managers`
- cf. google file system; distributed DB design

Tuning queries

Five heuristics.

(1) avoid sorts: `DISTINCT`, `UNION`, `INTERSECT`, `EXCEPT`.

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(1) avoid sorts: `DISTINCT`, `UNION`, `INTERSECT`, `EXCEPT`.
for example, in the query

```
SELECT DISTINCT M.ID, M.DeptID
FROM Managers M
WHERE M.Name = "Pointy-Haired Boss"
```

the `DISTINCT` is unnecessary, as `ID` is a key for `Managers`, so is also a key for any subset of `Managers`

Tuning queries

(1, cont.) consider next

```
SELECT DISTINCT M.ID, D.Phone
FROM Managers M, Departments D
WHERE M.DID = D.DID
```

Tuning queries

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```
SELECT DISTINCT M.ID, D.Phone
FROM Managers M, Departments D
WHERE M.DID = D.DID
```

Is `DISTINCT` necessary?

Tuning queries

(1, cont.) consider next

```
SELECT DISTINCT M.ID, D.Phone
FROM Managers M, Departments D
WHERE M.DID = D.DID
```

Is `DISTINCT` necessary? No, since `DID` is a key for `Departments` (and `ID` is a key for `Managers`)

Tuning queries

(1, cont.) consider next

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SELECT DISTINCT M.ID, D.Phone
FROM Managers M, Departments D
WHERE M.DID = D.DID
```

Is `DISTINCT` necessary? No, since `DID` is a key for `Departments` (and `ID` is a key for `Managers`)

The relationship among `DISTINCT`, keys and joins can be generalized:

- Call a table T *privileged* if the fields returned by the `SELECT` contain a key of T.

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The relationship among `DISTINCT`, keys and joins can be generalized:

- Call a table T *privileged* if the fields returned by the `SELECT` contain a key of T.
- Let R be an unprivileged table. Suppose that R is joined on equality by its key field to some other table S, then we say R *reaches* S.
- Now, define reaches to be transitive. So, if R_1 reaches R_2 and R_2 reaches R_3, then say that R_1 reaches R_3.

Tuning queries

(1, cont.) Reaches Theorem.

There will be no duplicates among the records returned by a selection, even in the absence of `DISTINCT`, if one of the two following conditions hold:

- Every table mentioned in the `FROM` clause is privileged.
- Every unprivileged table reaches at least one privileged table.

Tuning queries

(2) avoid unnecessary scans: "$\neq$" in selection condition can often be rewritten

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(3) instead of creating new indexes, check for usage of existing indexes

- for example, `Name = ‘‘Fred’’ OR Salary = 4000`
- if separate indexes exist on `Name` and `Salary`, compiler might not catch this
- instead, rewrite as union of two queries

Tuning queries

(4) help the optimizer reuse procedure cache. for example,

```
SELECT P.Name
FROM Professor P
WHERE P.DeptID = ‘Math’
```

and we will also want profs from EE, ME, IE, ...

Tuning queries

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and we will also want profs from EE, ME, IE, ...

The optimizer most likely won't reuse the plan for the first query in these later queries, even though that plan is cached. Instead, we should use a host variable:
...`WHERE P.DeptID = :deptID` ...

Tuning queries

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SELECT P.Name
FROM Professor P
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                     P.DeptID = D.ID )
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Typical optimizer will generate a plan which executes the inner correlated query for each Profs tuple! We should decorrelate if possible.

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Typical optimizer will generate a plan which executes the inner correlated query for each Profs tuple! We should decorrelate if possible.

```
SELECT P.Name
FROM Professor P
WHERE P.DeptID IN ( SELECT D.ID
                    FROM department D
                    WHERE D.Name = ‘Mathematics’ )
```

Tuning queries

(5, cont.) However, optimizer won't recognize the implicit join here, and won't make use of available indexes. Hence, we should unnest if possible

```
SELECT P.Name
FROM Professor P, Department D
WHERE P.DeptID = D.ID AND D.Name = 'Mathematics'
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Tuning queries

(5, cont.) However, optimizer won't recognize the implicit join here, and won't make use of available indexes. Hence, we should unnest if possible

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In general, optimizers don't recognize equivalence of such plans, and so it is up to the client/DBA to tune.

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- SQLite analyzer, from SQLite.
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Configuration:

- `PRAGMA cacheSize`
- `PRAGMA cacheSpill` to set steal/no-steal cache policy.
- `PRAGMA walAutocheckpoint`, to set checkpoint policy for the write-ahead log.
- `ANALYZE`, `REINDEX`, and `VACUUM`, to rebuild/clean the DB and stats
- `EXPLAIN`, to view query plan in virtual machine code

DB tuning: recap

- DB tuning is not about changing data semantics.
- Tuning is driven by observed and/or expected workload which is never truly random
- basic tuning components: buffers, indexes, schemas, queries
- every DB system has many, many tuning knobs, and lots of tool support for tuning

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Nice book on DB tuning. *Database Tuning: principles, experiments, and troubleshooting techniques.* Shasha and Bonnet, 2002.

Exercise

SalesPerson(<u>personID</u>, regionID, pName, address, age, hireDate, taxCode, healthCode, parkingSpot, ...)
Region(<u>regionID</u>, rName, area, rCode, history, taxOffice, ...)
Sales(<u>personID</u>, <u>regionID</u>, amount)

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Very common query:

```
SELECT DISTINCT P.personID, P.address, P.pName, R.rName
FROM SalesPerson P, Region R, Sales S
WHERE P.personID = S.personID AND R.regionID = S.regionID
      AND P.regionID = R.regionID
```

Can we tune the schema and/or query to improve response time?

Course review

Recap

Major topics

Relational data in external memory (lectures 1-4)

- storage, sorting, indexing

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- Histograms, reasoning about views

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Relational data in external memory (lectures 1-4)

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Query processing (lecture 5)

- Implementing σ, π, $\bowtie$, $\cup$, $-$

Views (lecture 6)

- Histograms, reasoning about views

Query optimization (lecture 7)

- logical plans, physical plans, dynamic programming

Recap

Major topics, cont.

Distributed query processing (lecture 8)

- parallel, distributed, and mediator systems; acyclic queries

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- ACID, 2PL, S2PL

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Major topics, cont.

Distributed query processing (lecture 8)

- parallel, distributed, and mediator systems; acyclic queries

Transaction management (lecture 9)

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Tuning and recap (lecture 11)

Old final exam

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(1) Consider the following conjunctive query Q:

$$result(A, B, C, D, E, F) \quad \leftarrow \quad r(A, B, C), s(A, F, E), t(E, D, C), u(A, C, E)$$

1. Give the hypergraph representation of Q.
2. Is Q acyclic? If so, can it be made cyclic by removing one hyperedge? Otherwise, can it be made acyclic by removing one hyperedge?

Old final exam

(2) Given a schedule S over transactions $\{T_1, \ldots, T_n\}$, the "strong graph" associated with S is the directed graph $\mathrm{sg}(S)$ having exactly one node for each transaction of S and an edge from T_i to T_j (for $i \neq j$) if and only if in S, for some object X there is an action $\alpha_i(X)$ of T_i on X which appears before an action $\alpha_j(X)$ of T_j on X.
Prove or disprove the following claims.

1. If $\mathrm{sg}(S)$ is acyclic, then S is conflict serializable.
2. If S is conflict serializable, then $\mathrm{sg}(S)$ is acyclic.

Old final exam

(3) Consider the following conjunctive queries.

$$
\begin{array}{lrcl}
Q_1: & \mathit{result}(A) & \leftarrow & r(A,B), r(A,C), s(B,D,E), s(B,F,F) \\
Q_2: & \mathit{result}(X) & \leftarrow & r(X,Y), r(X,W), s(Y,W,W), t(X)
\end{array}
$$

Is it the case that $Q_2 \subseteq Q_1$? Prove your answer.

Old final exam

(4) Consider the "semi-difference" relational algebra operator, defined as

$$
\begin{aligned}
R \rhd S &= \{r \in R \mid \neg\exists s \in S (r \bowtie s \in R \bowtie S)\} \\
&= R - (R \ltimes S).
\end{aligned}
$$

Formally prove or disprove the following proposals for relational algebra equivalences.

1. $\sigma_\theta(R \rhd S) = \sigma_\theta(R) \rhd S$, where θ is a standard single-table selection condition which mentions only attributes in R (i.e., $atts(\theta) \subseteq atts(R) - atts(S)$).
2. $R \ltimes S = R \rhd (R \rhd S)$.