CS157A: Introduction to Database Management Systems

Chapter 8: Views and Indexes

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Views

- Virtual view
  - A relations that is the result of a query over other relations.
  - Virtual views are not stored in the databases
- Materialized views are periodically constructed from the database and stored there.
  - Enable efficient access to the database
  - Are most useful in data warehousing scenarios, where frequent queries of the actual base tables can be extremely expensive.

Declaring Views

```
DROP VIEW IF EXISTS SeniorUsers;
CREATE VIEW SeniorUsers AS
  SELECT uID, uName, age
  FROM User
  WHERE age >=60;
```

Querying Views

- A view is queried as if it was a stored table.
- The query processor replaces the view by its definition to process the query.

```
SELECT *
FROM SeniorUsers, Loan
WHERE SeniorUsers.uID = Loan.uID and overdue = 1;
```

```
SELECT *
FROM (SELECT uID, uName, age FROM User
        WHERE age >=60) SU, Loan
WHERE SU.uID = Loan.uID and overdue = 1;
```

View Removal

- DROP VIEW SeniorUsers;
  - Will not affect the base table User.
  - Can’t do any query involving SeniorUsers.
- DROP TABLE User;
  - Will remove the table User from the database and also make all views referring the User table unusable.

Modifying Views

- We can’t modify (insert, delete, update) a view like a table since a view is not stored.
- However, for the users who access the database only though views, there should be a way to modify views – modification to a view should be reflected on the base tables.
- Rewrite a query that modifies a view in a way that it modifies the base tables.

Example

```
DROP VIEW IF EXISTS YoungUsers;
CREATE VIEW YoungUsers AS
  SELECT uID, age
  FROM User
  WHERE age < 19;
```

YoungUsers

VIEW

uID	age
12	17
24	10

Insert Into YoungUsers
Values (77, 17);

How can we translate this query to modify the database ?

Insert into User Values (77, ?, 17); // so many different ways !

User

Base Table

Modifying Views

- Correctness of translation can be achieved but ambiguity issue should be resolved and it is not straightforward for some cases.

Two main approaches of translating modification to a view

1. INSTEAD-OF Triggers on Views

   e.g. SQLite, Postgres, Oracle

2. Automatically done by DBMS

   e.g. MySQL

INSTEAD OF Triggers on Views

- INSTEAND OF in place of BEFORE or AFTER.
- When an event occurs, the action of the trigger is done instead of the event.
- Translation is put in the action part of the trigger.
- All modifications can be handled.
- No guarantee of correctness

Automatic translation done by DBMS

- Translation to base table is automated by restricting views and modifications.
- No translation needs to be done by SQL programmers.
- Restrictions are significant.
- Adopted by the SQL standard

Example: Modifying a View

DROP VIEW if exists LateFeeUsers;
CREATE VIEW LateFeeUsers AS
SELECT uID, title, loanDate, overdue
FROM LOAN
WHERE overdue =**1**;

DELETE FROM LateFeeUsers WHERE uID = **135**;

SQLite complains that “LateFeeUsers a view and a view can’t be modified !”

Instead of Triggers: Delete

```
Drop trigger LateFeeUsersDelete;
Create Trigger LateFeeUsersDelete
instead of delete on LateFeeUsers
for each row
begin
  delete from LOAN
  where uID = OLD.uID and overdue = 1;
end;

delete from LateFeeUsers
where uID = 135;
```

- For each deleted row, the action is taken.
- The deleted row means a tuple that will be logically deleted from the view.
- The OLD variable is the tuple that Is asked to be delete from the view.
- Result: The user 135 is deleted from both LOAN and the view.

Instead of Triggers: Update

```
DROP Trigger LateFeeUsersUpdate;
CREATE Trigger LateFeeUsersUpdate
instead of update of title
ON LateFeeUsers
for each row
begin
  update LOAN
  set title=New.title
  where uID = Old.uID and title =
Old.title AND overdue = 1;
end;
```

```
update LateFeeUsers
set title = 'Bambi II'
WHERE uID = 24 AND
title = 'Bambi';
```

Result: The title of uID 24 with ‘Bambi II’ in both Loan and the view.

Instead of Trigger: Insert

```
DROP trigger LateFeeUsersInsert;
CREATE trigger LateFeeUsersInsert
instead of INSERT ON LateFeeUsers
for each row
begin
   INSERT INTO LOAN VALUES
  (New.uID, New.title,
New.loanDate,New.overdue);
END;
```

INSERT INTO LateFeeUsers VALUES (**888**, 'Gone With the Wind', '2000-12-25',1) ;

Result: The new tuple is inserted in both Loan and the view.

Wrong Translations

- DBMS can’t prevent an incorrect trigger (written with logical errors) from being triggered !

Example: Wrong Translations-delete

```
Drop trigger LateFeeUsersDelete;
Drop trigger WrongTrigger;

Create Trigger WrongTrigger
instead of delete on LateFeeUsers
for each row
begin
  delete from LOAN
  where uID = OLD.uID and overdue = 1
AND title = 'somebook' ;
end;

delete from LateFeeUsers
where uID =456;
```

Result: There is no change in the Loan Table and the View.

Example: Wrong Translations-update

```
DROP Trigger LateFeeUsersUpdate;
Drop Trigger WrongTrigger;

CREATE Trigger WrongTrigger
instead of update of title ON LateFeeUsers
for each row
begin
update LOAN
  set title=New.title
  where uID = Old.uID and title = Old.title  AND
loanDate >= datetime('2013-01-01 00:00:00');
end;

update LateFeeUsers
set title = 'Bambi II'
WHERE uID = 234 AND title = 'Bambi';
```

- Result: There is no change in the view, and a wrong tuple is updated in the Loan table.
- Reason: overdue = 1 is missing and a wrong condition is added in the where clause.

Example: Wrong Translation - insert

- With the LateFeeUsersInsert trigger, do

  INSERT INTO LateFeeUsers VALUES

  (**111**, 'Modern Database Systems', date('now'), **0**);
- Result: The tuple is inserted into the Loan table but doesn't show up in the view because it doesn't satisfy the condition of the view.
- User should not write an insert to a **view** that will change the base table but doesn't get reflected on the view.

Better LateFeeUsersInsert Trigger

```
DROP trigger LateFeeUsersInsert;
CREATE trigger LateFeeUsersInsert
instead of INSERT ON LateFeeUsers
for each row
WHEN New.overdue = 1
begin
 INSERT INTO LOAN VALUES
(New.uID, New.title, New.loanDate,New.overdue);
end;
```

INSERT INTO LateFeeUsers VALUES(**111**, 'Streaming Media', date('now'), **0**);

Result: No change in both Loan and the View !

View involving Joins

```
DROP VIEW UsersBeingOverdue;
CREATE View UsersBeingOverdue as
  SELECT USER.uID, USER.age, title, overdue
  FROM USER,LOAN
  WHERE USER.uID = LOAN.uID AND overdue = 1;
```

View involving Joins: Insert

```
DROP Trigger UsersBeingOverdueInsert;
CREATE Trigger UsersBeingOverdueInsert
 instead of INSERT ON UsersBeingOverdue
 for each row
 WHEN (New.uID IN (SELECT uID FROM USER)) AND New.overdue = 1
 BEGIN
   INSERT INTO LOAN VALUES (NEW.uID, New.title, NULL, New.overdue);
 END;

INSERT INTO UsersBeingOverdue VALUES(777, 30,'Lion King', 1); // will not add if
777 is not in the user relation.

INSERT INTO UsersBeingOverdue
    SELECT USER.uID, USER.age, 'Java Concepts', 1
    FROM USER
    WHERE USER.uID NOT IN (SELECT uID FROM LOAN);
```

View involving Joins: delete

```
DROP Trigger UsersBeingOverdueDelete;
CREATE Trigger UsersBeingOverdueDelete
  instead of delete ON UsersBeingOverdue
  for each row
  begin
     delete FROM LOAN
     WHERE uID = Old.uID AND overdue = 1;
  end;

DELETE FROM  UsersBeingOverdue WHERE uID = 135;
```

View involving Joins: update

```
DROP Trigger UsersBeingOverdueUpdate;
CREATE Trigger UsersBeingOverdueUpdate
  instead of update ON UsersBeingOverdue
  for each row
  begin
    update LOAN
    set overdue = New.overdue
    WHERE title = NEW.title AND overdue = 1;
  END;

UPDATE UsersBeingOverdue
SET overdue = 0 WHERE title = 'Bambi';
```

View and Constraints

```
CREATE VIEW SeniorUsers AS
  SELECT uID, uName, age FROM User
  WHERE age >=60;
```

```
DROP TRIGGER IF EXISTS SeniorUsersInsert;
CREATE Trigger SeniorUsersInsert
 instead of insert ON SeniorUsers for each row
 when New.age >=60
 begin
INSERT INTO User VALUES(New.uID, New.uName, New.age, NULL);
 end;

INSERT INTO SeniorUsers VALUES(135,'Kim', 70); //error if 135
already exists in the User.
```

Ambiguous Translations

- Fundamentally, we could write a trigger for such a modification, but it does not make much sense to write a translation for this type of modification on the view.

Ambiguous Translations

- View involving aggregation

```
DROP VIEW IF EXISTS AvgAge;
CREATE VIEW AvgAge AS
SELECT uName, AVG(age) as avg
FROM User
GROUP BY uName;
```

- Consider the following query:

update AvgAge set avg = **50** where uName = ‘Kim’;

Ambiguous Translations

- View using distinct

```
DROP VIEW IF EXISTS UserNames;
CREATE VIEW UserNames AS
    SELECT DISTINCT uName FROM User;
```

- Consider the following query:

```
Insert into UserNames values ('Kim');
```

Ambiguous Translations

- View where the sub query references the same table of outer query

```
CREATE VIEW UserWithSameAge AS
   SELECT * FROM USER U1
   WHERE EXISTS (SELECT * FROM USER U2
         WHERE  U1.uID <> U2.uID AND U1.age =
         U2.age);
```

- Consider the following query:

```
delete from UserWithSameAge where uID =123;
```

Automatic View Modifications - MySQL

- Restrictions in SQL Standard for “updatable views”
  - SELECT (no DISTINCT) from a single table R (can’t be a join view)
  - Attributes not in SELECT can be NULL or can have a default value.
  - Where clause of a sub query must not involve R in the from clause of outer query (but allow to refer to other tables)
  - No group by or aggregation

Automatic View Modifications

DROP VIEW LateFeeUsers;

CREATE VIEW LateFeeUsers AS

SELECT uID, title, loanDate, overdue

FROM LOAN WHERE overdue =**1**;

INSERT INTO LateFeeUsers VALUES (1019, 'Bambi','2000-12-25' , 1); // inserted in both Loan and View without any trigger.

Example: Wrong Insert

INSERT INTO LateFeeUsers VALUES (1018, 'Bambi','2013-12-25' , 0);

Result: The tuple is inserted to Loan but the view doesn't reflect the change because overdue = 0.

Solution:

DROP VIEW LateFeeUsers;

CREATE VIEW LateFeeUsers AS

SELECT uID, title, loanDate, overdue FROM LOAN

WHERE overdue =**1** with check option; // the insert will fail.

Example: Not-updatable Views

View with Aggregation

```
CREATE VIEW AvgAge AS
SELECT uName, AVG(age) as avg
FROM User
GROUP BY uName;
```

```
update AvgAge set avg = 50 where uName =
'Kim'; //error
```

Example: Not-updatable Views

- View with SELECT (distinct)

```
CREATE VIEW UserNames AS
    SELECT DISTINCT uName FROM User;
```

- Consider the following query:

```
Insert into UserNames values ('Kim'); // error
```

Example: Not-updatable Views

- View with a sub query that refers the same table from outer query.

```
DROP VIEW UserWithSameAge;
CREATE VIEW UserWithSameAge AS
  SELECT * FROM USER U1
  WHERE EXISTS (SELECT * FROM USER U2 WHERE
U1.uID <> U2.uID AND U1.age = U2.age);

Delete from UserWithSameAge where uID =123; // error
```

View involving a subquery that refers to another table

```
DROP VIEW IF EXISTS YoungLoaners;
Create VIEW YoungLoaners AS
  SELECT uID, uName, age from User
  WHERE age < 18 AND  User.uID in (select uID from Loan) ;

delete FROM YoungLoaners WHERE uID = 24;
```

- If the outer query refers a single table, which is required by standard, deletion will be done in the table of the outer query. (Thus, 24 will be removed from User not from Loan)
- If this deletion from the user violates a foreign key constraint, it will be rejected or handled according to a given policy.

View involving a subquery that refers to another table

- Consider

INSERT INTO YoungLoaners VALUES (187, 'Wu', **60**);

- Result: Wu will be inserted to User in the outer query but will not be shown in the view due to his age. This insertion to the user through the view YoungLoaners is not desirable.

- Solution: check with option. This insertion will be failed by the check option.

Join Views

- SQL Standard doesn’t allow to update Join Views.
- MySQL allows insert and update operations on join views, but not delete operations.

Why Join Views are not updatable by standard ?

```
CREATE VIEW MovieProd AS
    SELECT title, year, name
    FROM Movies, MovieExec
    WHERE producerC# = cert#;
```

Insert into MovieProd Values (‘Bambi’, 1969, ‘Max’,);

Translation:

Insert into Movies Values (‘Bambi’, 1969, null);

Insert into MovieExec (‘Max’, null);

MySQL: Join Views

```
Drop View if EXISTS BambiUsers;
Create view BambiUsers(uID, loanID, uName, overdue) AS
  Select User.uID, Loan.uID, User.uName, overdue
  From User, Loan
  Where User.uID = Loan.uID and title = 'Bambi'    ;
```

- update BambiUsers set overdue = **0** WHERE overdue = **1**;

Result: The system will modify the base table containing the attribute to be updated. (Loan in this case.)

- update BambiUsers set loanID = **111** WHERE loanID = **1011**;

Result: Without check option and without foreign key constraint, the uID in Loan is updated, but the corresponding uID in User is not changed.

With check option, it will CHECK OPTION fail if 111 doesn't exist in User.

Without check option and with foreign key constraint, it will fail due to the foreign key violation if 111 doesn't exist in User.

Indexes

- Index on an attribute A: A data structure that makes it faster to find those tuples that have specific column values
- A data structure of (key, value)
  - Key x: A value of attribute A → index key
  - Value: set of locations of the tuples that have x for the value of A.
- Index key can be any attribute or set of attributes
- Stored in database
- Underlying data structures
  - B tree/B+ tree
  - Hash table

Motivation

SELECT uID

FROM User, Loan

WHERE User.uID = Loan.uID and title = ‘Bambi’ ;

If we have an index on title of Loan, first get the tuples containing Bambi, and test uIDs of the tuples for equality.

Defining Indexes

CREATE INDEX TitleIndex ON Loan (title);

To serve the query in the previous slide,

the DBMS can quickly determine the position of tuples that contain ‘Babmi’ without having to look at all the data.

A single index on multiple attributes

- Suppose title and year form a primary key for Movie. Then consider

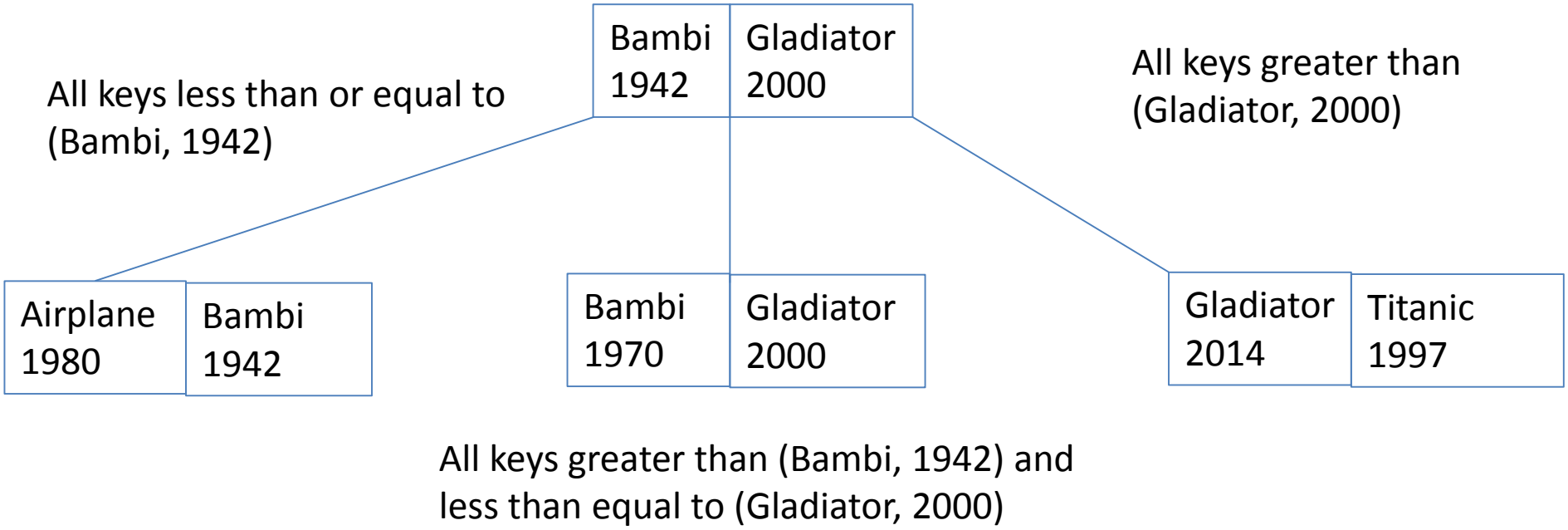
```
SELECT *
FROM Movie
Where title = 'Star Wars' and year = 1990;
```

- With `CREATE INDEX KeyIndex Movie(title,year)`
  The index will find only one tuple.
- With `CREATE INDEX YearIndex Movie(year)`
  First find all movies made on 1990 using the index and check through them for the given title.
- `(title, year)` vs. `(year, title)`

Composite Index Key

- The ordering of the composite index key values is lexicographic ordering. That is, (a1, a2) < (b1, b2) if either a1< b1 or (a1=b1 and a2 < b2)
- The order of the individual attributes in the composite key is important.

Composite Index Key



The above index may be used to search for (title, year) or (title),but not for (year).

Selection of Indexes

- Benefits: faster query execution
- Costs: space, index creation, maintenance
  - Maintenance is the most expensive overhead: Insertions, deletions and updates to that relation become more complex and time-consuming.

Selection of Indexes

- The most useful index on a relation is an index on its key (key index)
  - Queries involving the key are very common.
  - At most one disk page needs to be retrieved because a key is associated with at most one tuple.
- If the index key is not the key of a relation
  - The index key needs to be almost a key

    (e.g. title instead of the key (title, year) for Movies)

  or
  - The tuples needs clustered on the index key

  in order to minimize the time to retrieve tuples from the disk.

Example: Selection of Index

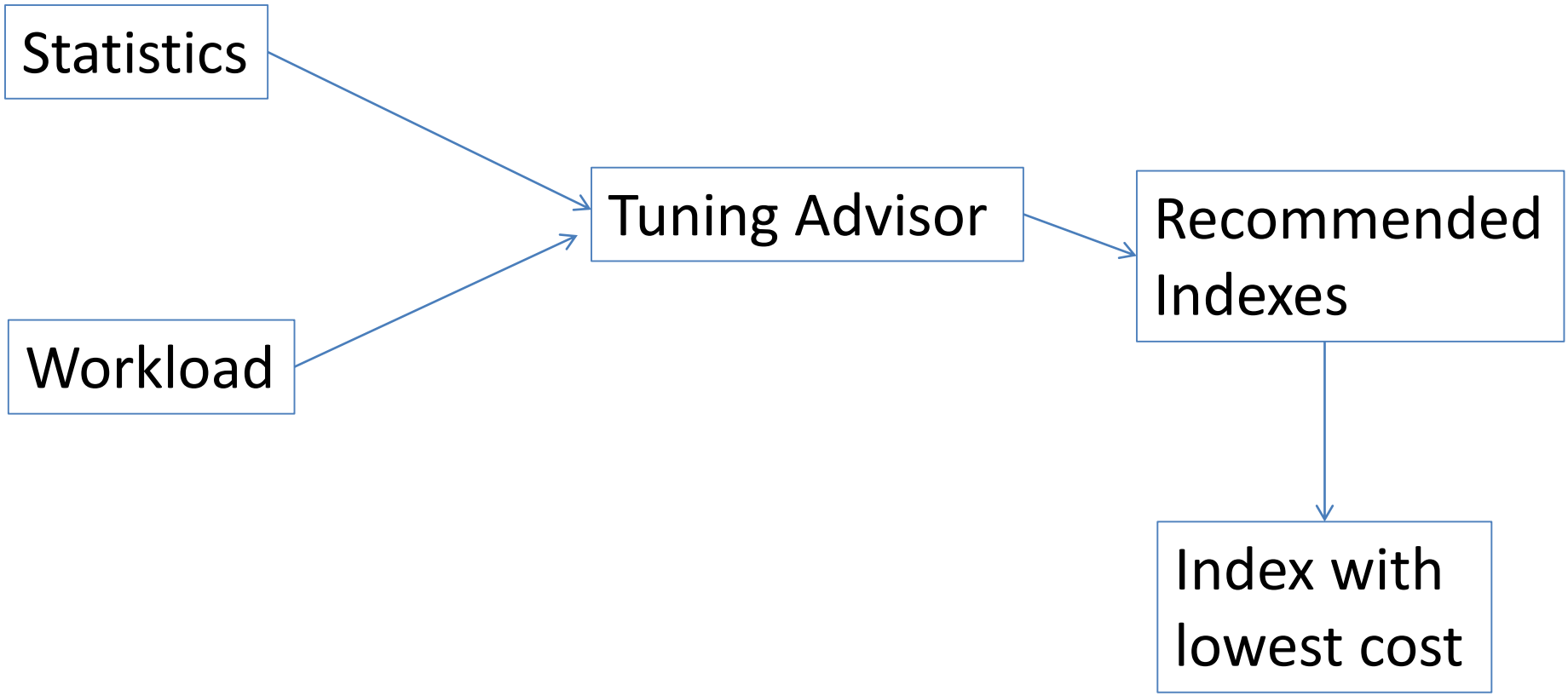
- With `CREATE INDEX YearIndex Movie(year)`
- Consider

```
select * from Movies where year= 1990;
```

- What if Movies are not clustered by year ?

  There will be little gain from the index on year. Imagine a scenario where movie tuples made on 1990 are spread all over the places on the disk.

Index Creation



Example: Index Creation

`StarIn(movieTitle,movieYear,starName)`

Assumptions:

- StarIn occupies 10 disk pages
- A star has appeared in 3 movies
- A movie has 3 stars
- One disk access is assumed to read a page of the index every time we use that index.
- Modification on the index needs two disk accesses (one to read the page and another to write it back to disk)

Example: Index Creation

```
Q1:
SELECT movieTitle, movieYear
FROM StarsIn
WHERE starName = s;
```

No Index	Star Index	Movie Index	Both Index
10	4 (1 index access + 3 tuple accesses)	10	4 (movie index doesn't help)

Example: Index Creation

```
Q2:
SELECT starName
FROM StarsIn
WHERE movieTitle=t AND movieYear = y;
```

No Index	Star Index	Movie Index	Both Index
10	10	4	4 (star index doesn't help)

Example: Index Creation

```
I:
INSERT INTO StarIn VALUES(t,y,s);
```

No Index	Star Index	Movie Index	Both Index
2	4 (2 for modifying data and 2 for modifying index)	4	6

Example: Index Creation

	No Index	Star Index	Movie Index	Both Index
Average	$8P_1+8P_2+2$	$6P_2+4$	$6P_1+4$	$6-2P_1-2P_2$

P_1: Fraction of time doing Q1
P_2: Fraction of time doing Q2
I: $1 - P_1 - P_2$

If insertions are dominant: No Index
If queries are dominant: Both Index

Materialized Views

- Stored in database
- Benefits of using Virtual Views + faster query performance.
- In principle, we need to re-compute a materialized view every time one of its base tables changes
- Make changes to the materialized view incremental.

Incremental Changes to Materialized Views

```
CREATE MATERIALIZED VIEW MovieProd AS
    SELECT title, year, name
    FROM Movies, MovieExec
    WHERE producerC# = cert#;
```

Movies(title, year, producerC#)

MovieExec(name, cert#)

Example: Incremental Changes to Materialized Views

INSERT INTO Movies VALUES (‘Kill Bill’, 2003, 23456);

→

SELECT name

FROM MovieExec

where cert# = 23456; // only one name, say Smith, returns because cert# is the key

INSERT INTO MovieProd VALUES (‘Kill Bill’, 2003, ‘Smith’);

Example: Incremental Changes to Materialized Views

DELETE FROM Movies WHERE title = ‘Bambi’ and year = 1994;

→

DELETE FROM MovieProd

WHERE title = ‘Bambi’ and year = 1994;

Example: Incremental Changes to Materialized Views

INSERT INTO MovieExec VALUES ('Max', 34567);

→

INSERT INTO MovieProd

SELECT title, year, 'Max'

FROM Movies

WHERE prodecerC# = 34567;

Example: Incremental Changes to Materialized Views

DELETE FROM MovieExec WHERE cert#=45678;

→

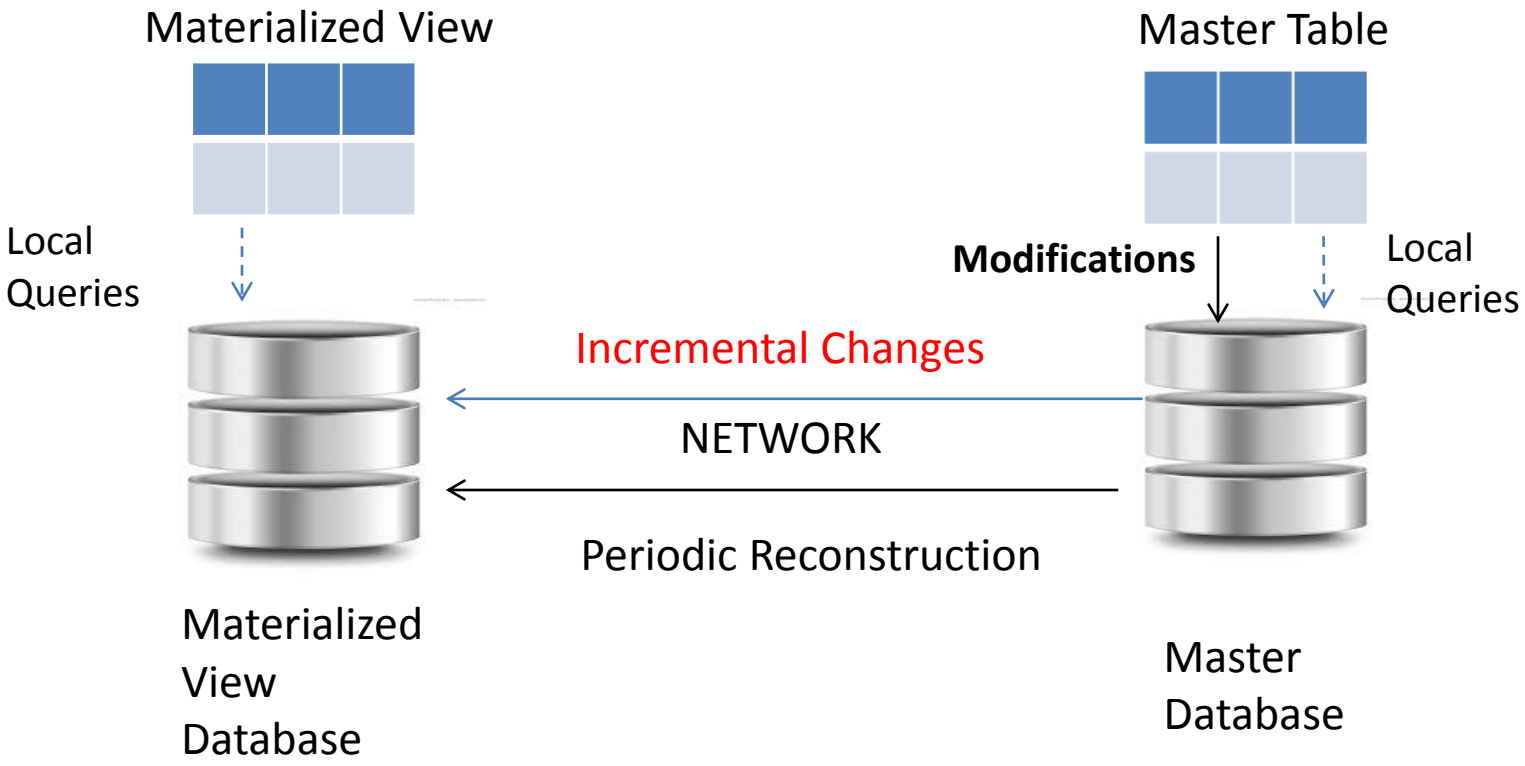
DELETE FROM MovieProd

WHERE (title, year) IN

(SELECT title, year FROM Movies

WHERE producerC# = 45678);

Periodic Maintenance of Materialized Views



Rewriting Queries to Use Materialized Views

Materialized View

SELECT Lv
FROM Rv
WHERE Cv

(3) Lq that come from Rv are on Lv

(1) All Rv appear in Rq

(2) Cq = Cv AND C
If C refers attributes of Rv, they should be on Lv

Query to be rewritten

SELECT Lq
FROM Rq
WHERE Cq

```
SELECT title, year, name
FROM Movies, MovieExec
WHERE producer#=cert#;
```

```
SELECT starName
FROM StarIn, Movies, MovieExec
WHERE movieTitle = title AND movieYear=year
AND producer#=cert# AND name = 'Max';
```

Movies(title,year,length,genre,studioName,producerC#)
StarIn(movieTitle, movieYear, starName)
MovieExec(name, address, cert#, netWorth)

Rewriting Queries to Use Materialized Views

Materialized View

```
SELECT title, year, name
FROM Movies, MovieExec
WHERE producer#=cert#;
```

Query to be rewritten

```
SELECT starName
FROM StarIn, Movies, MovieExec
WHERE movieTitle = title AND movieYear=year
AND producer#=cert# AND name = 'Max';
```

Rewritten Query

```
SELECT starName
FROM StarIn, MovieProd
WHERE movieTitle=title AND movieYear = year AND name = 'Max';
```

The same result but faster!