Databases 1

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Course Outline

1. ~~Introduction to database approach~~
2. ~~The database environment~~
3. ~~Introduction to The Relational Model~~
4. Views
5. Transactions
6. SQL Constraints
7. ~~Relational Database Design. Theory and practice~~
8. An Introduction to Database Performance. Indexing
9. JSON Support in Relational Database Management Systems
10. NoSQL Databases

Week 10

SQL Constraints

Views

SQL Constraints

- Define “rules” for data in the relational database
  - ensures data consistency and integrity
  - any data action that violates the constraint is rejected

- Classification of constraints
  - Column level
  - Table level

- Common SQL constraints are
  - NOT NULL
  - PRIMARY KEY
  - FOREIGN KEY
  - DEFAULT
  - UNIQUE
  - CHECK
  - INDEX

- Can be defined either at table creation time

```
CREATE TABLE Students (
        Id INT PRIMARY KEY,
        Name VARCHAR(100) NOT NULL,
        Address VARCHAR(256),
        MajorId INT NOT NULL
                FOREIGN KEY REFERENCES Major(Id),
        Active CHAR(1))
```

- Or later

```
ALTER TABLE Students
        MODIFY Active DEFAULT  ‘Y’;
```

Good coding practice: always give meaningful names to constraints

UNIQUE Constraint

- Ensures that all values in one (or more) column(s) are unique
- Useful to represent other candidate keys of the domain, when surrogate/auto-generated primary keys are used;
- These are the alternate keys, hence it is recommended that their starts with AK_
- While table may have only one PK, multiple unique constraints (alternate candidate keys) can be added
- Example:

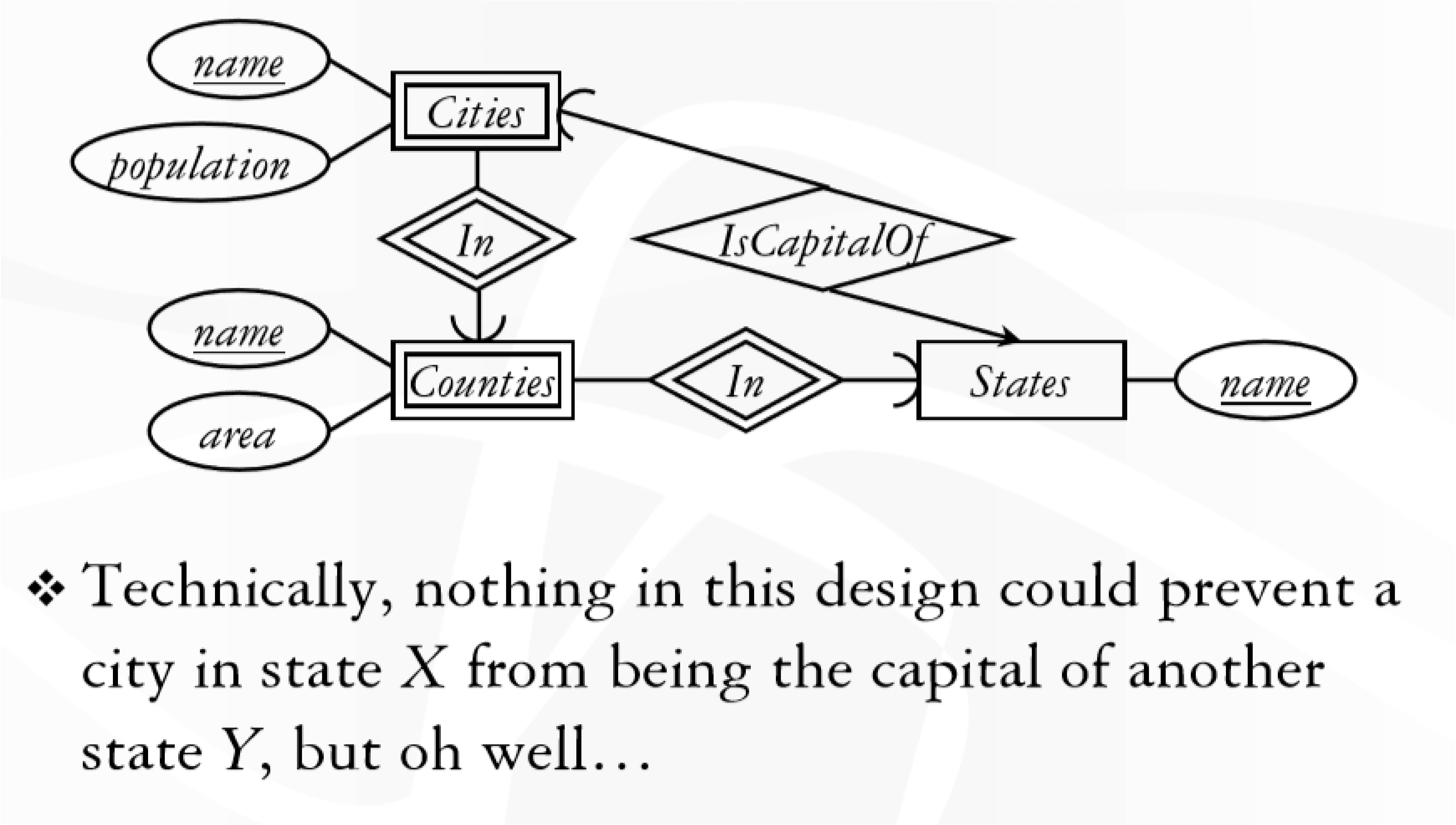
```
ALTER TABLE Students
      ADD CONSTRAINT AK_Students_Name_Address UNIQUE (Name, Address);
```

CHECK Constraint

- Limit the values for a specified column or limit the values in certain columns based on other values in other columns of the same row
- The predicate cannot contain queries, but may call user-defined/system functions
- Example:

```
ALTER TABLE Students
      ADD CONSTRAINT CK_Students_Valid_Id_Name CHECK (Id >= 0 AND Name <> ‘’);
```

Example



- ❖ Technically, nothing in this design could prevent a city in state *X* from being the capital of another state *Y*, but oh well…

For demo purpose, assume the following structure for table CapitalOf
CapitalOf(CityId, StateName)
where CityId is a Foreign Key referencing Cities(Id)

Example

```
CREATE FUNCTION IsCityInState
(
    @CityId INT,
    @StateName VARCHAR(128)
)
RETURNS INT
AS
BEGIN
    IF @StateName = (SELECT StateName
                     FROM Counties CN
                     INNER JOIN Cities CT ON CN.Id = CT.CountyId
                     WHERE CT.Id = @CityId)
        return 1
    return 0
END

ALTER TABLE CapitalOf
    WITH CHECK ADD CONSTRAINT CK_ValidState
    CHECK (CityId IS NULL OR IsCityInState(CityId, StateName) = 1)
```

Week 10

Views

Scenario

The mobile dev team of our university develops a student-centred mobile application aiming at helping students to manage their enrollments. How should the app request the list of all enrollments for the logged-in student?

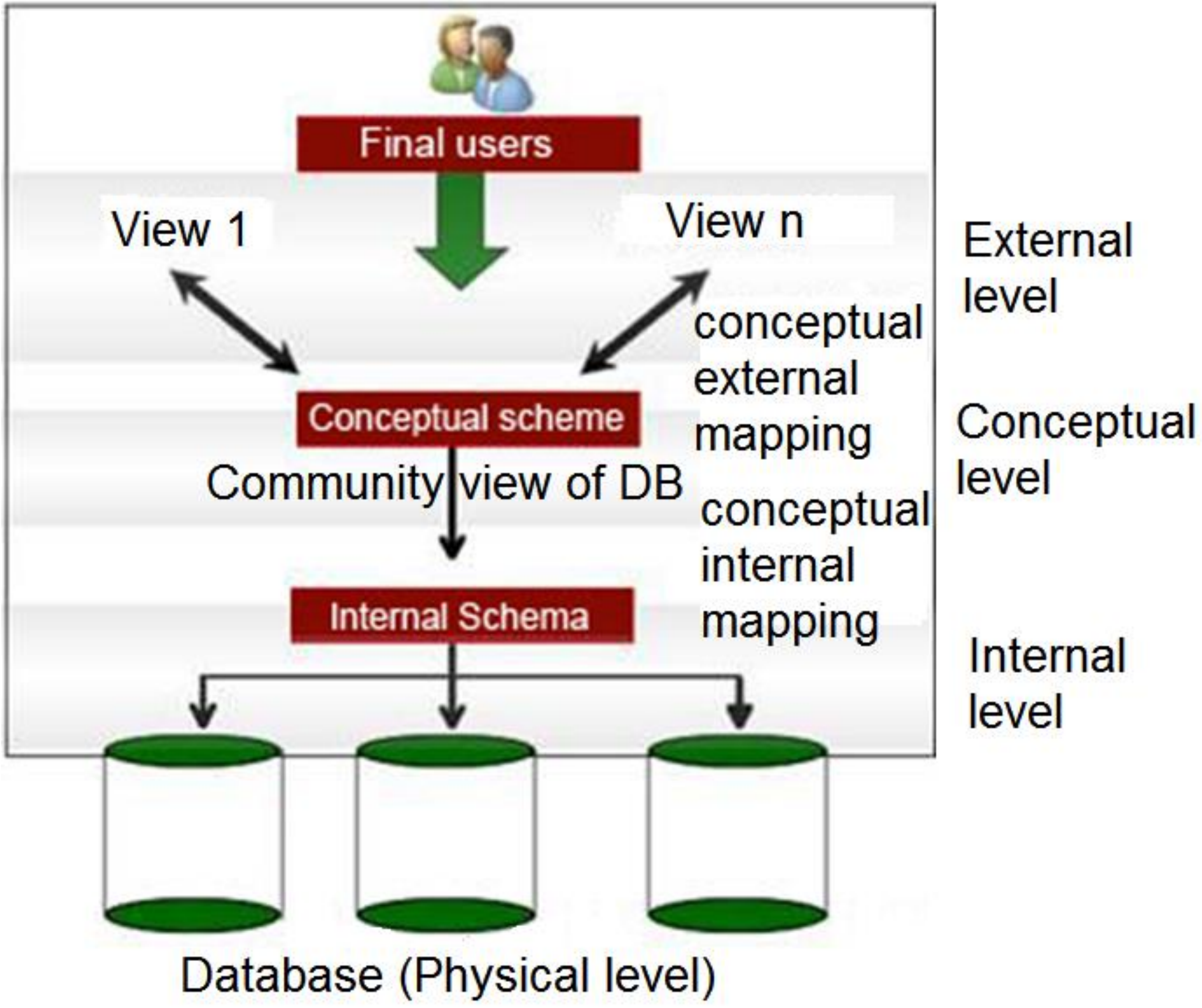
1/ Send a query, something like

```
SELECT *
FROM Enrollments E INNER JOIN Courses C ON E.CourseTitle = C.CourseTitle
WHERE StudId = @LoggedInStudentId
```

Issues:

- Mobile developers need to know the database schema + SQL? YES
- More details than needed are returned, possibly some sensitive data? YES
- What happens if the DA/DBA normalizes the schema, e.g. he/she decides that Departments must have their own table and replaces Department column of Courses with a surrogate FK to Departments table? NEED TO CHANGE + REPUBLISH THE APP (at least its back-end)

ANSI/X3 SPARC Architecture for databases



The ANSI/X3 SPARC DBMS Framework: Report of the Study Group on Database Management Systems (1977)

Views

- Physical, conceptual, logical levels

- Why Views?
  - Hide some data from some users
  - Make some queries easier
  - Modularity of database access (customized access = access to parts of the database)
  - Powerful and flexible security mechanism

The bigger the database, more views are used

Views

- A view is a ‘virtual relation’ that does not actually exist in the database but is produced upon request, at the time of the request.

- Base relation = a named relation corresponding to an entity in the conceptual schema, whose tuples are physically stored in the database.

- View = The dynamic result of one ore more relational operations operating on the base relations to produce another relation.

Defining and using views

- View V = Query(R_1, R_2, …, R_n) where R_i is a table or another view.
- Schema of V = schema of query result
- “Temporary table”
- In reality, the DBMS re-writes the query Q to use R_1, R_2, …, R_n instead of V

Views in SQL

- CREATE VIEW ViewName AS Query
- CREATE VIEW ViewName(A_1, A_2, …, A_n) AS Query
  - Query – SQL SELECT query
  - Creates the view as an object in the database catalogue; query is run every time the view is opened / used

- ALTER VIEW – modifies an existing view

- DROP VIEW ViewName;
  - Some DBMS returns an error if View is used in other queries; others returns the error only when the query involving the view is run.

- SELECT * FROM ViewName - queries an existing view

Scenario

The mobile dev team of our university develops a student-centred mobile application aiming at helping students to manage their enrollments. How should the app request the list of all enrollments for the logged-in student?

1/ Send a query, something like

```
SELECT *
FROM Enrollments E INNER JOIN Courses C ON E.CourseTitle = C.CourseTitle
WHERE StudId = @LoggedInStudentId
```

Issues:

- Mobile developers need to know the database schema + SQL? YES
- More details than needed are returned, possibly some sensitive data? YES
- What happens if the DA/DBA normalizes the schema, e.g. he/she decides that Departments must have their own table and replaces Department column of Courses with a surrogate FK to Departments table? NEED TO CHANGE + REPUBLISH THE APP (at least its back-end)

Scenario

The mobile dev team of our university develops a student-centred mobile application aiming at helping students to manage their enrollments. How should the app request the list of all enrollments for the logged-in student?

2/ Expose data needed by the app through a view

```
SELECT *
FROM MobileAppView
WHERE Id = @LoggedInStudentId
```

Issues:

- Mobile developers need to know the database schema + SQL? NO
- More details than needed are returned, possibly some sensitive data? NO
- What happens if the DA/DBA normalizes the schema, e.g. he/she decides that Departments must have their own table and replaces Department column of Courses with a surrogate FK to Departments table? THE APP IS NOT TOUCHED

Scenario

Courses(CourseTitle:CHAR(50), Department:CHAR(20), Credits:INTEGER)

Students(StudID:INTEGER, StudName:CHAR(50), DoB:DATE, PoB:CHAR(50), Major:CHAR(40), TotalCredits:INTEGER)

Enrollments(StudID:INTEGER, CourseTitle:CHAR(50), EnrollmentDate:DATE, Decision:BOOLEAN)

```
CREATE VIEW MobileAppView AS
SELECT StudID AS Id, C.CourseTitle AS Title,
EnrollmentDate, Decision, Department AS DeptName, Credits
    FROM Enrollments E
        INNER JOIN Courses C ON C.CourseTitle=E.CourseTitle
```

```
ALTER VIEW MobileAppView AS
SELECT StudID AS Id, C.CourseTitle AS Title,
EnrollmentDate, Decision, D.Name AS DeptName, Credits
    FROM Enrollments E
        INNER JOIN Courses C ON E.CourseTitle=E.CourseTitle
        INNER JOIN Departments D ON C.DeptID=D.Id
```

Examples

```
Courses(CourseTitle:CHAR(50), Department:CHAR(20),
Credits:INTEGER)

Students(StudID:INTEGER, StudName:CHAR(50), DoB:DATE,
PoB:CHAR(50), Major:CHAR(40), TotalCredits:INTEGER)

Enrollments(StudID:INTEGER, CourseTitle:CHAR(50),
EnrollmentDate:DATE, Decision:BOOLEAN)

CREATE VIEW DBAccepted AS
     SELECT StudID, EnrollmentDate FROM Enrollments
     WHERE CourseTitle=‘Database’ AND Decision=‘Y’

CREATE VIEW DBAccepted2 AS
     SELECT Students.StudID, StudName, Major, TotalCredits
     FROM Students, DBAccepted
     WHERE Students.StudID = DBAccepted.StudID
```

Examples

```
Courses(CourseTitle:CHAR(50), Department:CHAR(20),
Credits:INTEGER)

Students(StudID:INTEGER, StudName:CHAR(50), DoB:DATE,
PoB:CHAR(50), Major:CHAR(40), TotalCredits:INTEGER)

Enrollments(StudID:INTEGER, CourseTitle:CHAR(50),
EnrollmentDate:DATE, Decision:BOOLEAN)

CREATE VIEW DBAccepted AS
     SELECT StudID, EnrollmentDate FROM Enrollments
     WHERE CourseTitle=‘Database’ AND Decision=‘Y’

// With Query re-write (v1)
CREATE VIEW DBAccepted2 AS
     SELECT Students.StudID, StudName, Major, TotalCredits
     FROM Students,
          (SELECT StudID, EnrollmentDate FROM Enrollments
           WHERE CourseTitle=‘Database’ AND Decision=‘Y’)
               AS DBAccepted
     WHERE Students.StudID = DBAccepted.StudID
```

Examples

```
Courses(CourseTitle:CHAR(50), Department:CHAR(20),
Credits:INTEGER)

Students(StudID:INTEGER, StudName:CHAR(50), DoB:DATE,
PoB:CHAR(50), Major:CHAR(40), TotalCredits:INTEGER)

Enrollments(StudID:INTEGER, CourseTitle:CHAR(50),
EnrollmentDate:DATE, Decision:BOOLEAN)

CREATE VIEW DBAccepted AS
     SELECT StudID, EnrollmentDate FROM Enrollments
     WHERE CourseTitle=‘Database’ AND Decision=‘Y’

// With Query re-write (v2)
CREATE VIEW DBAccepted2 AS
     SELECT Students.StudID, StudName, Major, TotalCredits
     FROM Students, Enrollments
     WHERE CourseTitle=‘Database’ AND Decision=‘Y’ AND
           Students.StudID = Enrollments.StudID
```

Examples

```
Courses(CourseTitle:CHAR(50), Department:CHAR(20),
Credits:INTEGER)

Students(StudID:INTEGER, StudName:CHAR(50), DoB:DATE,
PoB:CHAR(50), Major:CHAR(40), TotalCredits:INTEGER)

Enrollments(StudID:INTEGER, CourseTitle:CHAR(50),
EnrollmentDate:DATE, Decision:BOOLEAN)

CREATE VIEW DBAccepted AS
     SELECT StudID, EnrollmentDate FROM Enrollments
     WHERE CourseTitle=‘Database’ AND Decision=‘Y’

// Using views
SELECT * FROM DBAccepted WHERE EnrollmentDate < ‘01-nov-2015’
```

View modification

- Can a view V be modified (insert/delete/update) as any other table?
  - Remember, V is not stored => doesn't make much sense
  - Some users only see the views => it should be possible
- SOLUTION: Modification of V is rewritten (automatically by the system) to modify the base tables.
- Ambiguities: there may be multiple rewrites; which one the one user wanted? Example.

View modification approaches

- Restrict modifications so that the translation to base table modifications is meaningful and unambiguous
  - (+) No user intervention
  - (-) Restrictions may be significant
  - Imposed by SQL standard

- View creator specifies the rewriting process, i.e. what happens in case of delete/update/insert
  - (+) Can handle all modifications
  - (-) No guarantee of correctness
  - Enabled by INSTEAD OF triggers
  - Trigger definition is vendor-specific, not covered by SQL standard

View modification using automatic view modification

- Restrictions in SQL standard for ‘updatable views’:
  - SELECT (no DISTINCT) on a single table T
  - Attributes of T not part of the view should be NULLable or have a default value constraint defined
  - Sub-queries must not refer to T
  - No GROUP BY or HAVING

- Not supported by all DBMS

View modification using automatic view modification

Example: (an updateable view)

```
CREATE VIEW DBAccepted(ID, Curs, EDate) AS
   SELECT StudID, CourseTitle, EnrollmentDate
      FROM Enrollments
      WHERE CourseTitle=‘Database’ AND Decision=‘Y’
```

- `DELETE FROM DBAccepted WHERE ID=1234`
  - Applies the predicate from view’s WHERE AND the predicate from DELETE

- `UPDATE DBAccepted SET EDate = ’12-dec-2014’ WHERE ID=1234`
- `UPDATE DBAccepted SET Curs = ’Algebra’ WHERE ID=1234`
  - Applies the predicate from view’s WHERE AND the predicate from UPDATE

-
  ```
  INSERT INTO DBAccepted (ID, Curs, EDate)
                 VALUES  (101, ‘Networks’, ’15-nov-2020’)
  ```
  - Record inserted, but the value for Decision column is not set according to the view definition (it is given the default value / NULL)

View modification using automatic view modification

- To avoid insertion of undesired tuples, use WITH CHECK OPTION in view definition and then the previous INSERT is flagged as erroneous

- WITH CHECK OPTION also prevents rows from migrating out of the view, as in UPDATE … SET Curs = ‘Algebra’ …

- WITH [LOCAL/CASCADE] CHECK OPTION – apply /not check on underlying views

View modification using automatic view modification

Example: (an updateable checked view)

```
CREATE VIEW DBAcceptedChecked(ID, Curs, EDate) AS
   SELECT StudID, CourseTitle, EnrollmentDate
      FROM Enrollments
      WHERE CourseTitle=‘Database’ AND Decision=‘Y’
      WITH CHECK OPTION;
```

Statement	-	WITH CHECK

DELETE FROM DBAccepted
WHERE ID=1234
	OK	OK

UPDATE DBAccepted
SET EDate = ’12-dec-2014’
WHERE ID=123
	OK	OK

UPDATE DBAccepted
SET Curs = ’Algebra’
WHERE ID=1234
	OK	ERROR

INSERT INTO DBAccepted
VALUES
(101, ‘Networks’, ’2020-01-01’)
	OK	ERROR

Exercise

Given the following views
CREATE VIEW **LowSalary** AS SELECT * FROM Staff WHERE salary > 9000

CREATE VIEW **HighSalary** AS SELECT * FROM LowSalary
WHERE salary > 10000
WITH LOCAL CHECK OPTION;

CREATE VIEW **Manager3Staff** AS SELECT * FROM HighSalary WHERE branch=10;

which of the following updates will be rejected/accepted by the DBMS?

a) UPDATE Manager3Staff SET salary = 9500 WHERE EmpId = 1234

b) UPDATE Manager3Staff SET salary = 8000 WHERE EmpId = 1234

c) UPDATE Manager3Staff SET salary = 11000 WHERE EmpId=1234

Exercise

Given the following views
CREATE VIEW **LowSalary** AS SELECT * FROM Staff WHERE salary > 9000

CREATE VIEW **HighSalary** AS SELECT * FROM LowSalary
WHERE salary > 10000
WITH LOCAL CHECK OPTION;

CREATE VIEW **Manager3Staff** AS SELECT * FROM HighSalary WHERE branch=10;

which of the following updates will be rejected/accepted by the DBMS?

a) UPDATE Manager3Staff SET salary = 9500 WHERE EmpId = 1234
(Rejected)

b) UPDATE Manager3Staff SET salary = 8000 WHERE EmpId = 1234
(Accepted)

c) UPDATE Manager3Staff SET salary = 11000 WHERE EmpId=1234
(Accepted)

Exercise

- Which of the following views are updateable?

```
a) CREATE VIEW View2 AS
   SELECT StudName, Major, AVG(TotalCredits)
   FROM Students
   GROUP BY Major;
```

```
b) CREATE VIEW View3 AS
     SELECT DISTINCT Major FROM Students;
```

Exercise

- Which of the following views are updateable?

```
a) CREATE VIEW View2 AS
   SELECT StudName, Major, AVG(TotalCredits)
   FROM Students
   GROUP BY Major;
```

```
b) CREATE VIEW View3 AS
     SELECT DISTINCT Major FROM Students;
```

A: None

View modification using triggers

```
CREATE VIEW DBAcceptedUnmodifiable(ID, Name, EDate) AS
SELECT S.StudID, StudName, EnrollmentDate
FROM Enrollments E JOIN Students S ON E.StudID = S.StudID
WHERE CourseTitle='Databases' AND Decision='Y';


DELETE FROM DBAcceptedUnmodifiable WHERE StudID=1234
      => error
```

View modification using triggers

```
CREATE TRIGGER DBAcceptedUnmodifiable_OnDelete
INSTEAD OF DELETE ON DBAcceptedUnmodifiable
REFERENCING OLD ROW AS OldRow
FOR EACH ROW
DELETE FROM Enrollments
     WHERE StudID = OldRow.StudID AND
           EnrollmentDate = OldRow.EnrollmentDate AND
           CourseTitle=‘Database’ AND
           Decision=‘Y’
```

- The WHERE clause in trigger **MUST** match the records to be deleted AND add the expressions of view’ WHERE clause (e.g., CourseTitle=‘Database’)
- Tuples of DBAcceptedUnmodifiable don’t physically exist, but the Old variable **is** bind to those that need to be logically deleted!
- The above trigger will only allow deletions; to support UPDATEs more trigger(s) are needed!

CAUTION: Writing incorrect trigger will modify/delete unexpected tuples that may even not be part of the view!

Materialized views

- View V = Query(R_1, R_2, …, R_n) where R_i is a table or another view.
- Create a physical table V with schema of query result
- **Execute Query and put results in V**
- Queries refer to V as if it is a table
- (+) Advantage of materialized view: improved query performance
- (-) V can be very large
- (-) Modifications to R_1, R_2, …, R_n => recompute/modify V

Advantages of materialized views

- Hide some data from some users
- Make some queries more natural to express
- Modularity of database access
- Improve query performance

Example

-
  ```
  CREATE MATERIALIZED VIEW MV1
    SELECT StudName, Enrollments.CourseTitle, Credits
    FROM Courses, Students, Enrollments
    WHERE Enrollments.StudID = Students.StudID AND
          Enrollments.CourseTitle = Courses.CourseTitle AND
          Students.Major = ‘CS’
  ```

Note: this is Oracle / PostreSQL syntax for triggers

Materialized views and modifications

- Modifications to base relations invalidate the view (example)

- DBMS need to maintain the view status

- Modifications on materialized view
  - Just update the stored table
  - Base tables need to be synchronized => same issue with virtual views

- Materialized views are often used to improve performance, hence users will not be allowed to modify them

Design of materialized views

- Which materialized views to create?

- **Efficiency benefits** of materialized views depend on:
  - Size of data
  - Complexity of the view
  - Number of queries using view
  - Number of modifications affecting the view
  - Incremental maintenance vs. Full re-computation

- Analyse the workload using above criteria

- Materialized views generalize the concept of index

- Automatic query rewriting to use materialized views
  - DBMS transparently use existing materialized views to rewrite users' queries, without users even knowing that

Example

```
CREATE MATERIALIZED VIEW CSEnrollments
 SELECT StudID, CourseTitle, Decision FROM Enrollments
 WHERE StudID IN (SELECT StudID FROM Students WHERE
Major=‘CS’)
```

Try to re-write the following query using `CSEnrollments` :

```
SELECT DISTINCT StudID, TotalCredits
FROM Courses, Students, Enrollments
WHERE Courses.CourseTitle=Enrollments.CourseTitle AND
      Students.StudID=Enrollments.StudID AND
      Courses.Department=‘INFO’ AND Students.Major=‘CS’
```

Example

```
CREATE MATERIALIZED VIEW CSEnrollments
 SELECT StudID, CourseTitle, Decision FROM Enrollments
 WHERE StudID IN (SELECT StudID FROM Students WHERE
Major=‘CS’)
```

Try to re-write the following query using `CSEnrollments` :

```
SELECT DISTINCT StudID, TotalCredits
FROM Courses, Students, Enrollments
WHERE Courses.CourseTitle=Enrollments.CourseTitle AND
      Students.StudID=Enrollments.StudID AND
      Courses.Department=‘INFO’ AND Students.Major=‘CS’
```

```
SELECT DISTINCT StudID, TotalCredits
FROM Courses, CSEnrollments
WHERE Courses.CourseTitle=CSEnrollments.CourseTitle AND
      Courses.Department=‘INFO’
```

‘Parameterized’ views

- Standard-wise, does not exist

- In general, not available

- MS SQL Server Functions
  - scalar functions: return only scalar/single value; used in SELECT clauses

  - table valued functions (TVF): return a table (set of rows) -> alternative to views (parameterized views)

  - Inline table valued functions (iTVF): contains only one (return) statement that defines the rows/columns to be returned

Inline table valued functions

- Unlike Stored Procedures / multi-statement TVF, the database engine handles this inline TVF as a VIEW
- It computes the execution plan using the statistics on the tables used by this function (similar to views)
- There is no extra load of creating a table variable
- Better in performance than SP / multi-statement TVF

Inline table valued function - Example

```
-- Definition
CREATE FUNCTION EnrolledStudents (@CourseTitle VARCHAR(50))
RETURNS TABLE
AS
RETURN
SELECT S.*, E.EnrollmentDate, E.Decision
FROM Students S
INNER JOIN Enrollments E ON S.StudID = E.StudID
WHERE E.CourseTitle = @CourseTitle

-- Usage
SELECT * FROM EnrolledStudents(‘Database’) WHERE Decision=‘Y’

-- Removal
DROP FUNCTION EnrolledStudents
```

Bibliography (recommended)

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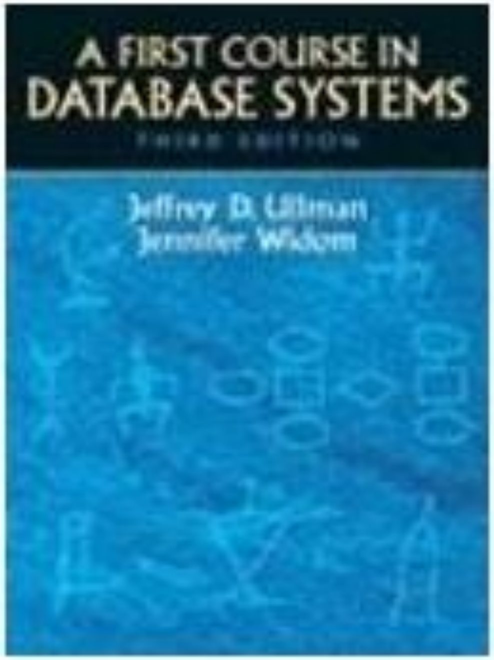
Cap 11.2.5



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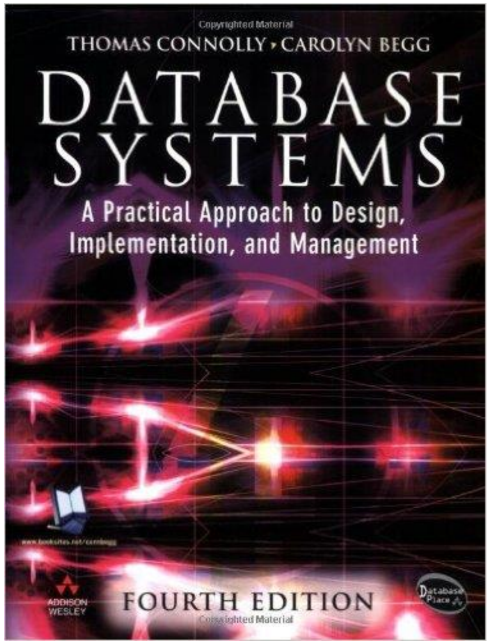
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