Databases

Lecture 9 - Trigger, Integrity and Security

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Contents

1. Introduction

1.1 Where are we right now?

- Last time, we looked at the basics of subqueries and views
- Today, we'll be discussing
  - how we can use transactions to increase the safety of our data manipulation statements,
  - how transactions are executed and
  - what triggers are and how we can use them.

1.1 Where are we right now?

1. Introduction
2. Basics
3. SQL
4. Entity-Relationship-Model
5. Relationships
6. Constraints
8. Subqueries & Views
9. Transactions
10. Database Applications
11. Integrity, Trigger & Security

1.2 What is the goal of this chapter?

- At the end of this lesson, you should be able to
  - create and define functions being run certain events using triggers
  - use transactions to make safe changes, that can be undone if necessary.

2. Repetition

Updating Views

- Views are Relations, just like tables!
- Should make no difference to users

? Question

Can we modify the view's data?

- Depends on type of view!

2.1 Views

Basics

- Classify views based on the select:
  - Projection View
    - `SELECT a, b, c ...`
  - Selection View
    - `... WHERE <condition> ...`
  - Join View
    - `FROM tab_a JOIN tab_b ...`
    - Aggregation View
      - `SELECT MAX(x) ...`
- Other types and combinations exist

2.1 Views

Basics

- A view with a single defining table is updatable if
  - the view attributes contain the primary key of the base relation,
  - as well as all attributes with the NOT NULL constraint that have a default value specified
- Views defined on multiple tables using joins are only updatable in special cases
  - E.g., INSERT and UPDATE for Join Views, if join condition is based on PK-FK
- Views defined using grouping and aggregate functions are not updatable

Generated Tables

```sql
CREATE TABLE <name> AS SELECT
```

SQL

- Can create new table based on query
- New table is independent from old table
- Use cases:
  - Copy table
  - Copy parts of table

> **Memorize**
>
> New table does not have all constraints of the parent table!

Generated Tables

Example

```sql
INSERT INTO Underpaid ( lname , fname )
  SELECT lname , fname **FROM** Employee WHERE salary < 1000 ;
```

- `WHERE` clause belongs to `SELECT`

2.2 Transactions

Operations

- A transaction bundles several operations into one logical unit
  - Unit of Work
- Includes one or more database access operations E.g., `INSERT`, `DELETE`, `UPDATE`, `SELECT`
- Operations must be executed all or none
- Example: Order a hotel room over the internet
  - Choose and reserve room
  - Payment
  - Final booking of the hotel room

2.2 Transactions

ACID

- Key features of transactions
  - Atomicity: Transaction is executed in whole or not at all
  - Consistency: State of the DB is consistent before and after a transaction
  - Isolation: Transactions do not interfere with other concurrent transactions
  - Durability: Changes are stored permanently in the database and will not get lost

2.2 Transactions

ACID - Atomicity

- Begin of Transaction (BoT)
  - SQL99: START TRANSACTION
  - PostgresQL:

```sql
BEGIN;
```

- Commit a transaction: `COMMIT;`
  - All operations are made persistent
  - All changes are visible to other users
- Rollback transaction: `ROLLBACK;`
  - DB is in state at BoT again

2.2 Transactions

ACID - Consistency

- DB: in consistent state before transaction Also, in consistent state after transaction
- Integrity constraints assure that
- Constraints can be defined as
  - `IMMEDIATE` (default in mySQL)
    - are checked immediately after operation
  - `DEFERRED`
    - Check at time of commit

2.2 Transactions

ACID - Isolation

- Transactions are isolated from other concurrent transactions
- Concurrent transactions shall behave well

ACID - Isolation: Concurrency Control

- Concurrent operations can lead to problems
  - Lost Update
  - Dirty Read
    - Unrepeatable read
    - Phantom tuples

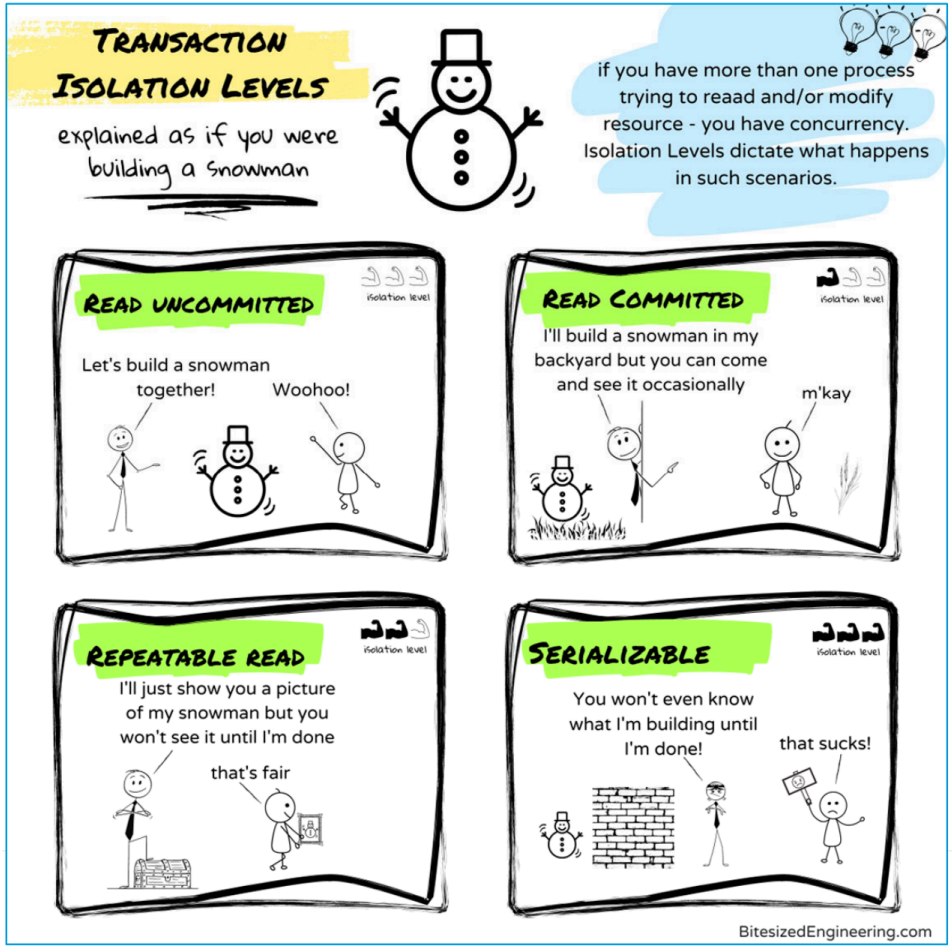
2.2 Transactions

ACID - Isolation: Concurrency Control

- Lost Update is prevented by SQL
- Transactions: may choose Isolation Level
  - `SERIALIZABLE`
    - no problems
    - `REPEATABLE READ` (default in mySQL)
      - Open for phantom tuples
    - `READ COMMITTED` (default in Oracle, SQL Server)
      - Open for phantom tuples and unrepeatable read
    - `READ UNCOMMITTED`
      - Open for all problems

2.2 Transactions

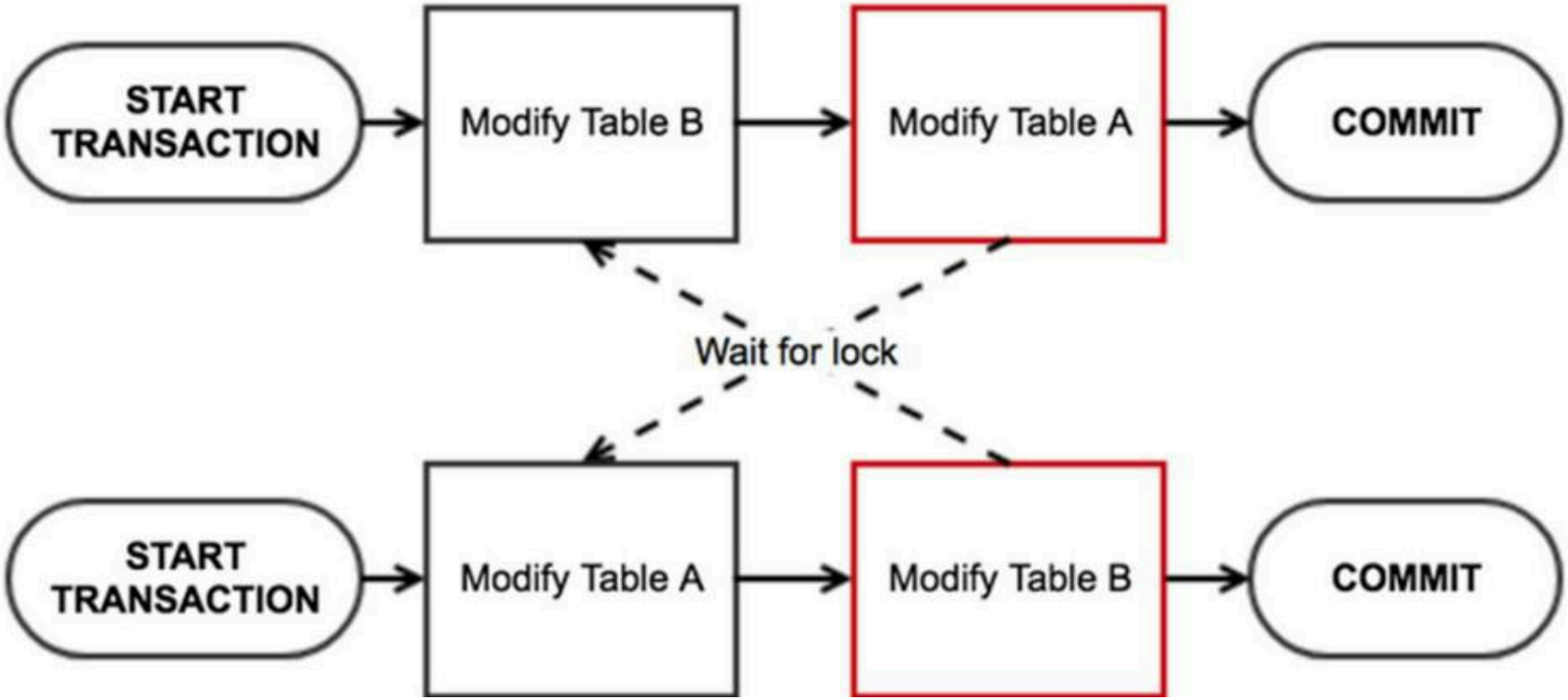
ACID - Isolation: Concurrency Control



2.2 Transactions

ACID - Isolation: Concurrency Control

- Deadlocks may occur!
  - Usually are resolved automatically by aborting one transaction



ACID - Durability

- Once committed, changed data is safe
- Error types
  1. Computer failure
  2. Transaction or system error (constraint violation, $\frac{x}{0}$, blackout, system crash)
  3. Local Errors
  4. Concurrency control enforcement
  5. Disk error (harddisk broken)
  6. Physical problems and catastrophes (fire, earthquake, robbery, …)

ACID - Durability: Error Handling

- Recovery from transaction failures usually means that the database is restored to the most recent consistent state just before the time of failure
- Minor damages due to error types 1-4 from slide “ACID – Durability”
  - DBMS provides handling
    - Recovery strategy is to identify any changes that may cause an inconsistency in the database
      - Changes are first written to redo logs (files on disk)
      - Written to database files after commit

ACID - Durability: Error Handling

- Extensive damage due to error types 5-6 from slide “ACID – Durability”
  - Recovery handling restores a past copy of the database from archival storage
  - Reconstructs a more current state by redoing the operations
  - Last transactions are lost!
- Solution: Redundancy
  - RAID (r edundant a rray of i ndependent d isks)
    - Data Replication by DBMS

ACID - Durability: Error Handling

- Changes are performed on (replicated to) several database instances
- Master/Slave
  - Updates only on one instance (master)
  - Slave: Read only vs. Standby
- Multi-Master
  - Updates on different instances
  - Needs conflict resolution strategy

ACID - Durability: Error Handling

- Synchronous
  - Transaction valid only when committed on all DBs
  - Safest, but performance impact
  - May reduce availability of the system
- Asynchronous
  - Transaction valid when committed locally

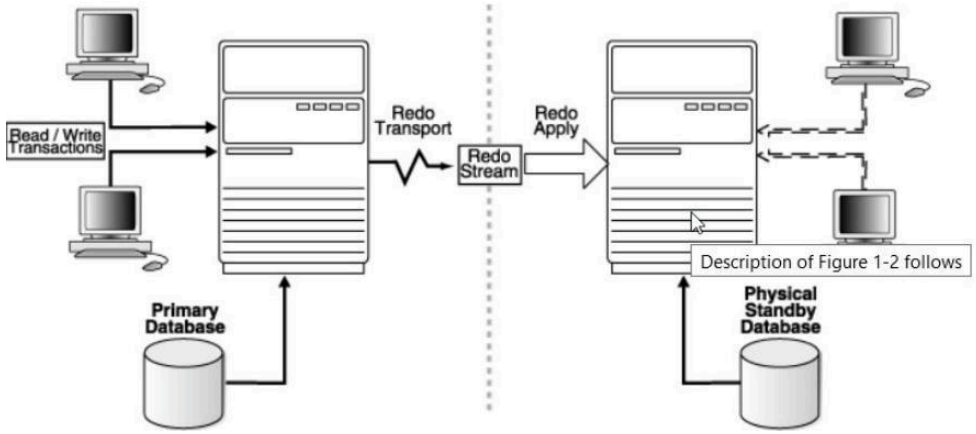
ACID - Durability: Error Handling

- Low level (disk device)
- Trigger based
  - Update triggers the replication (SQL level)
- Logfile shipping
  - Changes are stored in redo logs (as usual)
  - redo logs are copied to standby DB

2.2 Transactions

ACID - Durability: Error Handling

- Oracle
  - Data Guard
    - Replication on second server, can be used to answer Read-Only queries

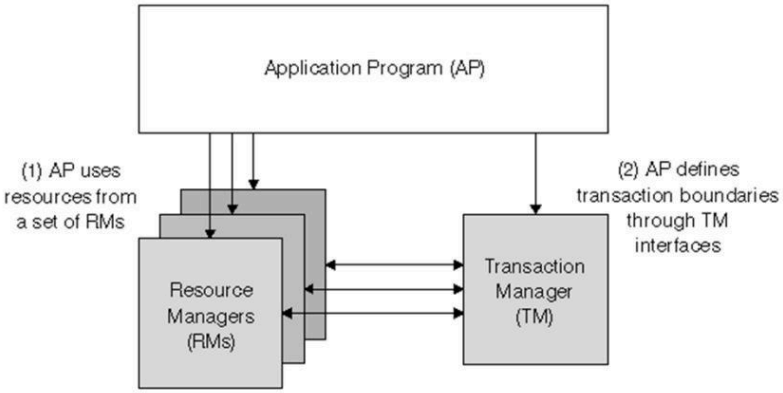


- Real Application Cluster (RAC)
  - Several servers share the same DB

2.2 Transactions

Distributed Transactions

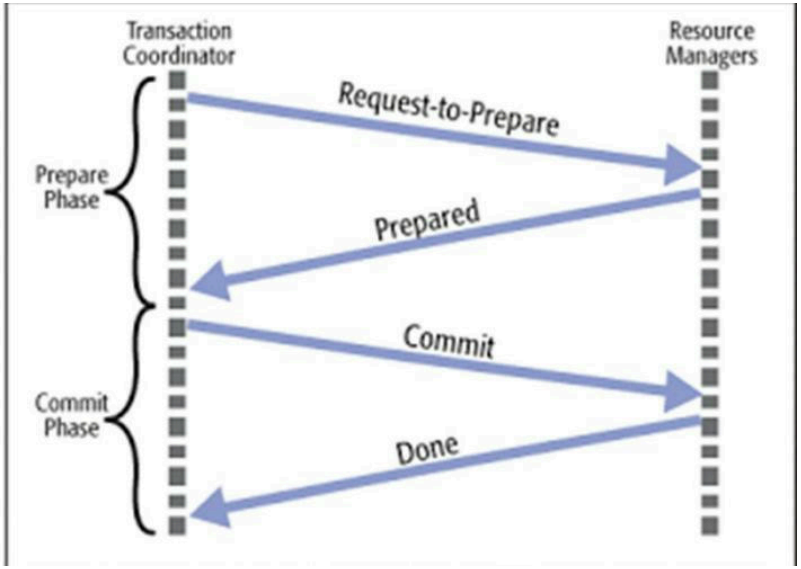
- Transactions not only in a single DBS
- Standardized by X/Open
  - Transaction Manager: A software component that guarantees transaction properties
  - Resource Manager: Every resource (e.g., DBS, GUI) that is able to work in a transactional mode without providing a transaction control structure itself
- The Transaction manager coordinates the Resource Manager that take part in the transaction. E.g., different DBS (distributed transactions) that appear as one DBS from outside (transparency!)



2.2 Transactions

Distributed Transactions

- To ensure interoperability between the participating resource managers the 2-phase commit protocol is realized
- It defines the final synchronization of different parts of a transaction of a global transaction
- In the first phase the transaction manager asks participating resource managers to announce the results of their local transaction part
- This leads to a global result (commit or rollback) that is then in the second phase announced to the participants



Savepoints

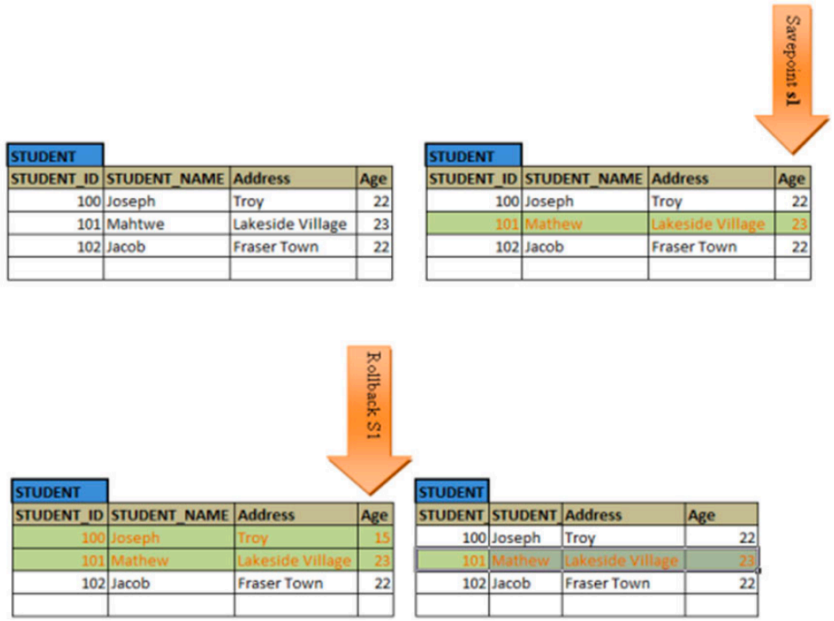
- There are operations that may be expensive to execute time consuming
- If certain constraints fail within transaction execution, then maybe these constraints may not fail in a second attempt (e.g., time dependent)
- So “fall back” points can be defined, which are called savepoints
- It is possible to rollback up to a savepoint and restart transaction execution from this point on

2.2 Transactions

Savepoints

Code

```
UPDATE STUDENT SET STUDENT_NAME = 'Mathew' WHERE STUDENT_NAME = 'Mahtwe';
SAVEPOINT S1;
UPDATE STUDENT SET AGE = 15 WHERE STUDENT_ID = 100;
ROLLBACK to S1;
```



STUDENT

STUDENT_ID	STUDENT_NAME	Address	Age
100	Joseph	Troy	22
101	Mahtwe	Lakeside Village	23
102	Jacob	Fraser Town	22

STUDENT

STUDENT_ID	STUDENT_NAME	Address	Age
100	Joseph	Troy	22
101	Mathew	Lakeside Village	23
102	Jacob	Fraser Town	22

STUDENT

STUDENT_ID	STUDENT_NAME	Address	Age
100	Joseph	Troy	15
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STUDENT

STUDENT	STUDENT	Address	Age
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3. Integrity, Trigger and Security

Integrity Constraints

- Static Constraints
  - Conditions on states
  - Conditions must be fulfilled before and after operations
  - Used until now
    - Primary Key
    - Foreign Key
    - `UNIQUE`, `NOT NULL`, `CHECK`
- Dynamic Constraints (Assertions)
  - Integrity conditions that affect multiple tables
  - Conditions on state transitions

Example

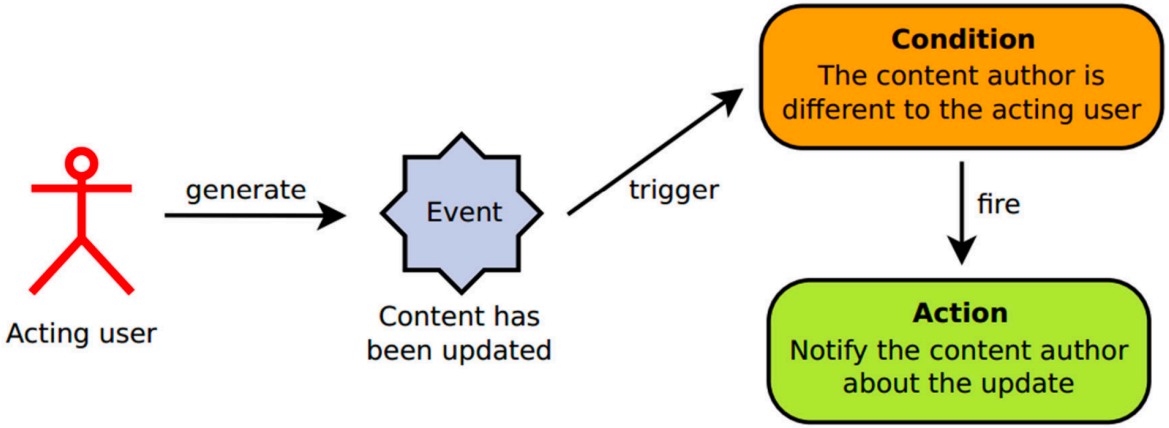
status of order → new → payed → processing → shipped

Integrity Constraints

- Assertions have been part of the SQL since SQL-92 (DDL)
- Not supported by most DBMS (e.g., MySQL, Postgres and Oracle)
- If the concept of assertions is to be simulated `TRIGGER`
- Concept:
  - Whenever anything is modified in the database, the assertion checks its condition
  - If the `SELECT`-statement gives a non-empty result, the operation that has triggered the assertion is denied

Integrity Constraints - ECA

- ECA rules
  - on event (E)
  - under certain conditions (C)
  - perform actions (A)



Trigger Syntax

SQL

```sql
CREATE
    [DEFINER = user]
    TRIGGER trigger_name
    trigger_time trigger_event
    ON tbl_name FOR EACH ROW
    [trigger_order]
    trigger_body
trigger_time: { BEFORE | AFTER }
trigger_event: { INSERT | UPDATE | DELETE }
trigger_order: { FOLLOWS | PRECEDES } other_trigger_name
```

Excursion Delimiter

- A PostgresQL client program such as pgadmin or psql program uses the delimiter (“;”) to separate statements and executes each statement separately
- However, a stored procedure consists of multiple statements separated by a semicolon (“;”)
- If you use a PostgresQL client program to define a stored procedure that contains semicolon characters, the PostgresQL client program will not treat the whole stored procedure as a single statement, but many statements.
- Therefore, you must redefine the delimiter temporarily so that you can pass the whole stored procedure to the server as a single statement.
- To redefine the default delimiter, you use the delimiter command

Excursion Delimiter

- In short: A delimiter is a separator between commands

Example

```sql
delimiter |
…
|
delimiter ;
```

In the code block between “delimiter” and “delimiter;” the delimiter is changed to “|” (instead of “;”)

Excursion Delimiter: Example

```SQL
delimiter |
CREATE TRIGGER SALARY_VIOLATION
BEFORE INSERT ON EMPLOYEE
FOR EACH ROW
   BEGIN
       IF NEW.SALARY > (SELECT SALARY
                        FROM EMPLOYEE
                        WHERE SSN = NEW.SUPER_SSN )
       THEN SET NEW.Salary = (SELECT SALARY
                              FROM EMPLOYEE
                             WHERE SSN = NEW.SUPER_SSN )-1;
       END IF;
END;
|
delimiter;
```

Events

- Triggers can react on events
  - DML: `INSERT`, `UPDATE`, `DELETE`
    - Most common trigger types
  - DDL: `CREATE`, `ALTER`, `DROP`
  - DB: startup, shutdown, logon of a user
- No `COMMIT` triggers

Types

- Time of execution, relative to event
  - `BEFORE`
  - `AFTER`
- `INSTEAD OF`
- Statement trigger
  - Once per statement
  - Even if no row is affected!
  - Default trigger type
- Row trigger
- For every affected row

3.1 Basics

- Syntax: `FOR EACH ROW`

Order of Trigger

- Before Statement Trigger (once!)
- For every row affected:
  - Before row trigger
  - DML operation
  - Immediate integrity checks
  - After row trigger
- After Statement Trigger (once!)

Transition Variables

- Row triggers can access old and new tuples
  - PostgresQL
    - `old` ⟶ `NULL` for `INSERT`
    - `new` ⟶ `NULL` for `DELETE`
- Oracle
  - `:new` and `:old`
  - Before row triggers:
    - Can even modify new!

Use Cases

- Constraints on state transitions
- Audit
  - When was a record last modified?
- Integrity checks with error correction
  - Change `new`
- Maintain redundant data
- Updateable views
  - `INSTEAD OF`

Trigger: Example

- Audit insertion of new persons

```sql
CREATE OR REPLACE FUNCTION f_trg_emp_log() RETURNS TRIGGER
$$
BEGIN
-- Statement here
END;
$$ LANGUAGE plpgsql;

DROP TRIGGER IF EXISTS emp_insert;
CREATE TRIGGER emp_insert AFTER INSERT ON employee
FOR EACH ROW EXECUTE FUNCTION f_trg_emp_log();
```

Trigger: Example

- Salary of new persons

```SQL
delimiter |
CREATE PROCEDURE output
   (in ssn char(9), in old_sal DECIMAL(10,2),
    in new_sal DECIMAL(10,2), in diff_sal DECIMAL(10,2))
BEGIN
   INSERT INTO EMPLOYEE_SALDIFF VALUES ( ssn , old_sal , new_sal, diff_sal);
END
|
delimiter;
```

Problems

- Cascading triggers
  - Trigger actions cause other triggers to fire
- Execution order
  - Result of high-level operation must be independent hereof!
- “Mutating Tables”

Problems

- Hard to implement
  - Transaction save!
  - Multi-session save
- Hard to debug
  - Update may lead to insert in another table
  - … can cause for example constraint violation
  - Which statement failed?

Assignment: Webshop

- Suppose the following relations in your database
- In the table `Price_History` we want to track on how the prices of the products of table Product develop over time. Table `Price_History` has four attributes:
  - The record ID `PHID`
  - The reference to table Product with the foreign key `PID`
  - The current price `Price`
  - The date `Change_Date`, where we store the date of the change

Table `Product`

PID	Price	Description
1	0.50	red apple
2	0.60	green apple
3	1.20	red pepper
4	1.10	green pepper
…	…	…

Table `Product_History`

PHID	PID (FK)	Price	Change_Date
1	1	0.50	02.06.2021
2	3	1.20	02.06.2021
3	2	0.60	03.06.2021
4	4	1.10	04.06.2021
…	…	…	…

Assignment: Webshop

1. `INSERT` trigger: We want to get an `INSERT` with the current (start) price in table `Price_History` when we do an `INSERT` in the table `Product`. This is triggered when an `INSERT` on our table product is done (`AFTER`).
2. `DELETE` trigger: Furthermore, in case of a `DELETE`, all records of the deleted product in the table `Price_History` should be deleted as well.
3. `UPDATE` trigger: If a price of a product is changed, this change should also result in an entry in the table `Price_History`.

Table `Product`

PID	Price	Description
1	0.50	red apple
2	0.60	green apple
3	1.20	red pepper
4	1.10	green pepper
…	…	…

Table `Product_History`

PHID	PID (FK)	Price	Change_Date
1	1	0.50	02.06.2021
2	3	1.20	02.06.2021
3	2	0.60	03.06.2021
4	4	1.10	04.06.2021
…	…	…	…

Permissions

- DBMS are multi-user systems
- You need permissions to do anything with the DB:
  - login
  - `CREATE` table, `DROP` table, etc.
  - `SELECT`
  - `INSERT`, `UPDATE`, `DELETE`
- Permissions can be `GRANT`ed and `REVOKE`d

GRANT and REVOKE

- Permissions can be GRANTed and REVOKEd

```SQL
GRANT <privilege_name> ON <object_name>
TO { <user_name> | PUBLIC | <role_name>} [ WITH GRANT OPTION ] ;
```

- GRANT

```SQL
GRANT SELECT ON tab_a TO user_a;
GRANT UPDATE ON tab_b TO user_a;
```

- REVOKE

```SQL
REVOKE SELECT ON tab_a FROM user_a;
```

Least Privilege Principle

- A user should have exactly the permissions necessary to do the work
  - … and not more!
- Important for web applications
  - anonymous end users
  - not trustworthy
- Limit the possible damage of attacks

Assignment: Webshop

1. Create a user student which is allowed to query and insert the table Product.
2. Revoke the insert privilege from a user student.

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