DM505 Database Design and Programming
DM576 Database Systems

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Real SQL Programming

SQL in Real Programs

- We have seen only how SQL is used at the generic query interface – an environment where we sit at a terminal and ask queries of a database
- Reality is almost always different: conventional programs interacting with SQL

Options

1. Code in a specialized language is stored in the database itself (e.g., PSM, PL/pgsql)
2. SQL statements are embedded in a *host language* (e.g., Java)
3. Connection tools are used to allow a conventional language to access a database (e.g., CLI, JDBC, psycopg2)

Stored Procedures

- PSM, or "*persistently stored modules*," allows us to store procedures as database schema elements
- PSM = a mixture of conventional statements (if, while, etc.) and SQL
- Let us do things we cannot do in SQL alone

Procedures in PostgreSQL

CREATE PROCEDURE <name>
([<arguments>]) AS $$
<program>$$ LANGUAGE <lang>;

- PostgreSQL only supports functions:

CREATE FUNCTION <name>
([<arguments>]) RETURNS VOID AS $$
<program>$$ LANGUAGE <lang>;

Procedu
now su

Parameters for Procedures

- Unlike the usual name-type pairs in languages like Java, procedures use mode-name-type triples, where the *mode* can be:
  - IN = function uses value, does not change
  - OUT = function changes, does not use
  - INOUT = both

Function RETURN Types

- VOID
- Traditional data type (e.g. INT, VARCHAR etc.)
- Composite Types (e.g. ROW and RECORD)
- SETOF (e.g ROWS/RECORDS)
- TABLE
- TRIGGER
- Etc.

Example: Stored Procedure

- Let's write a procedure that takes two arguments *b* and *p*, and adds a tuple to Sells(bar, beer, price) that has bar = 'C.Ch.', beer = *b*, and price = *p*
  - Used by Cafe Chino to add to their menu more easily

The Procedure

```
CREATE PROCEDURE ChinoMenu (
    IN b     CHAR(20),
    IN p     REAL
) AS $$
INSERT INTO Sells
VALUES('C.Ch.', b, p);
$$ LANGUAGE plpgsql;
```

Parameters are both read-only, not changed

The body --- a single insertion

Invoking Procedures

- Use SQL/PSM statement CALL, with the name of the desired procedure and arguments
- Example:

```
CALL ChinoMenu('Eventyr', 50);
```

- Functions used in SQL expressions wherever a value of their return type is appropriate
- PostgreSQL: CALL → SELECT

```
SELECT ChinoMenu('Eventyr', 50);
```

Kinds of PL/pgsql statements

- Return statement: RETURN <expression> returns value of a function
  - Like in Java, RETURN terminates the function execution
- Declare block: DECLARE <name> <type> used to declare local variables
- Groups of Statements: BEGIN . . . END
  - Separate statements by semicolons

Kinds of PL/pgsql statements

- Assignment statements:

  <variable> := <expression>;

  - Example: `b := 'Od.Cl.';`
- Statement labels: give a statement a label by prefixing a name and a colon

IF Statements

- Simplest form:

  IF <condition> THEN
  <statements(s)>
  END IF;

- Add ELSE <statement(s)> if desired, as

  IF . . . THEN . . . ELSE . . . END IF;

- Add additional cases by ELSEIF <statements(s)>: IF … THEN … ELSEIF … THEN … ELSEIF … THEN … ELSE … END IF;

Example: IF

- Let's rate bars by how many customers they have, based on Frequents(drinker,bar)
  - <100 customers: 'unpopular'
  - 100-199 customers: 'average'
  - >= 200 customers: 'popular'
- Function Rate(b) rates bar b

Example: IF

```
CREATE FUNCTION Rate (IN b CHAR(20))
        RETURNS CHAR(10) AS $$
        DECLARE cust INTEGER;
    BEGIN
        cust := (SELECT COUNT(*) FROM Frequents
                WHERE bar = b);
        IF cust < 100 THEN RETURN 'unpopular';
        ELSEIF cust < 200 THEN RETURN 'average';
        ELSE RETURN 'popular';
        END IF;
    END;
```

Number of customers of bar b

IF statement

Loops

- Basic form:

  <<<label>>> LOOP
  <statements>
  END LOOP;

- Exit from a loop by:

  EXIT <label> WHEN <condition>

Example: Exiting a Loop

```
<<loop1>> LOOP
        . . .
        EXIT loop1 WHEN ...;
        . . .
END LOOP;
```

If this statement is executed and the condition holds ...

... control winds up here

Other Loop Forms

- WHILE <condition> LOOP
  <statements>
  END LOOP;
- Equivalent to the following LOOP:

```
LOOP
    EXIT WHEN NOT <condition>;
    <statements>
END LOOP;
```

Other Loop Forms

- FOR <name> IN <start> TO <end>
  LOOP
  <statements>
  END LOOP;
- Equivalent to the following block:

```
<name> := <start>;
LOOP  EXIT WHEN <name> > <end>;
    <statements>
    <name> := <name>+1;
END LOOP;
```

Other Loop Forms

- FOR <name> IN REVERSE <start> TO <end> LOOP
  <statements>
  END LOOP;
- Equivalent to the following block:

```
<name> := <start>;
LOOP  EXIT WHEN <name> < <end>;
    <statements>
    <name> := <name> - 1;
END LOOP;
```

Other Loop Forms

- FOR <name> IN <start> TO <end>
  BY <step> LOOP
      <statements>
  END LOOP;
- Equivalent to the following block:

```
<name> := <start>;
LOOP  EXIT WHEN <name> > <end>;
    <statements>
    <name> := <name>+<step>;
     END LOOP;
```

Queries

- General SELECT-FROM-WHERE queries are *not* permitted in PL/pgsql
- There are three ways to get the effect of a query:
  1. Queries producing one value can be the expression in an assignment
  2. Single-row SELECT ... INTO
  3. Cursors

Example: Assignment/Query

- Using local variable *p* and Sells(bar, beer, price), we can get the price Cafe Chino charges for Odense Classic by:

```
p := (SELECT price FROM Sells
   WHERE bar = 'C.Ch' AND
         beer = 'Od.Cl.');
```

SELECT ... INTO

- Another way to get the value of a query that returns one tuple is by placing INTO <variable> after the SELECT clause
- Example:

```
SELECT price INTO p FROM Sells
WHERE bar = 'C.Ch.' AND
      beer = 'Od.Cl.';
```

Cursors

- A *cursor* is essentially a tuple-variable that ranges over all tuples in the result of some query
- Declare a cursor *c* by:

DECLARE c CURSOR FOR <query>;

Opening and Closing Cursors

- To use cursor *c*, we must issue the command:

  OPEN c;

  - The query of *c* is evaluated, and *c* is set to point to the first tuple of the result
- When finished with *c*, issue command:

  CLOSE c;

Fetching Tuples From a Cursor

- To get the next tuple from cursor c, issue command:

  FETCH FROM c INTO x_1, x_2,…,x_n ;

- The *x*'s are a list of variables, one for each component of the tuples referred to by *c*
- c is moved automatically to the next tuple

Breaking Cursor Loops – (1)

- The usual way to use a cursor is to create a loop with a FETCH statement, and do something with each tuple fetched
- A tricky point is how we get out of the loop when the cursor has no more tuples to deliver

Breaking Cursor Loops – (2)

- Many operations return if a row has been found, changed, inserted, or deleted (SELECT INTO, UPDATE, INSERT, DELETE, FETCH)
- In plpgsql, we can get the value of the status in a variable called FOUND

Breaking Cursor Loops – (3)

- The structure of a cursor loop is thus:

```
<<cursorLoop>> LOOP
  …
  FETCH c INTO … ;
  IF NOT FOUND THEN EXIT cursorLoop;
  END IF;
  …
END LOOP;
```

Example: Cursor

- Let us write a procedure that examines Sells(bar, beer, price), and raises by 10 the price of all beers at Cafe Chino that are under 30
- Yes, we could write this as a simple UPDATE, but the details are instructive anyway

Declarations

```
CREATE FUNCTION RaisePrices()
   RETURNS VOID AS $$
   DECLARE theBeer CHAR(20);
           thePrice REAL;
           c CURSOR FOR
      (SELECT beer, price FROM Sells
       WHERE bar = 'C.Ch.');
```

Used to hold beer-price pairs when fetching through cursor c

Returns Cafe Chino's price list

Procedure Body

```
BEGIN
    OPEN c;
    <<menuLoop>> LOOP
        FETCH c INTO theBeer, thePrice;
        EXIT menuLoop WHEN NOT FOUND;
        IF thePrice < 30 THEN
            UPDATE Sells SET price = thePrice + 10
            WHERE bar = 'C.Ch.' AND beer = theBeer;
        END IF;
    END LOOP;
    CLOSE c;
END;$$ LANGUAGE plpgsql;
```

Check if the recent FETCH failed to get a tuple

If Cafe Chino charges less than 30 for the beer, raise its price at at Cafe Chino by 10

Database-Connection Libraries

Host/SQL Interfaces Via Libraries

- The third approach to connecting databases to conventional languages is to use library calls
  1. C + CLI
  2. Java + JDBC
  3. Python + psycopg2

Three-Tier Architecture

- A common environment for using a database has three tiers of processors:
  1. *Web servers* – talk to the user.
  2. *Application servers* – execute the business logic
  3. *Database servers* – get what the app servers need from the database

Example: Amazon

- Database holds the information about products, customers, etc.
- Business logic includes things like “what do I do after someone clicks ‘checkout’ ?”
  - Answer: Show the “how will you pay for this?” screen

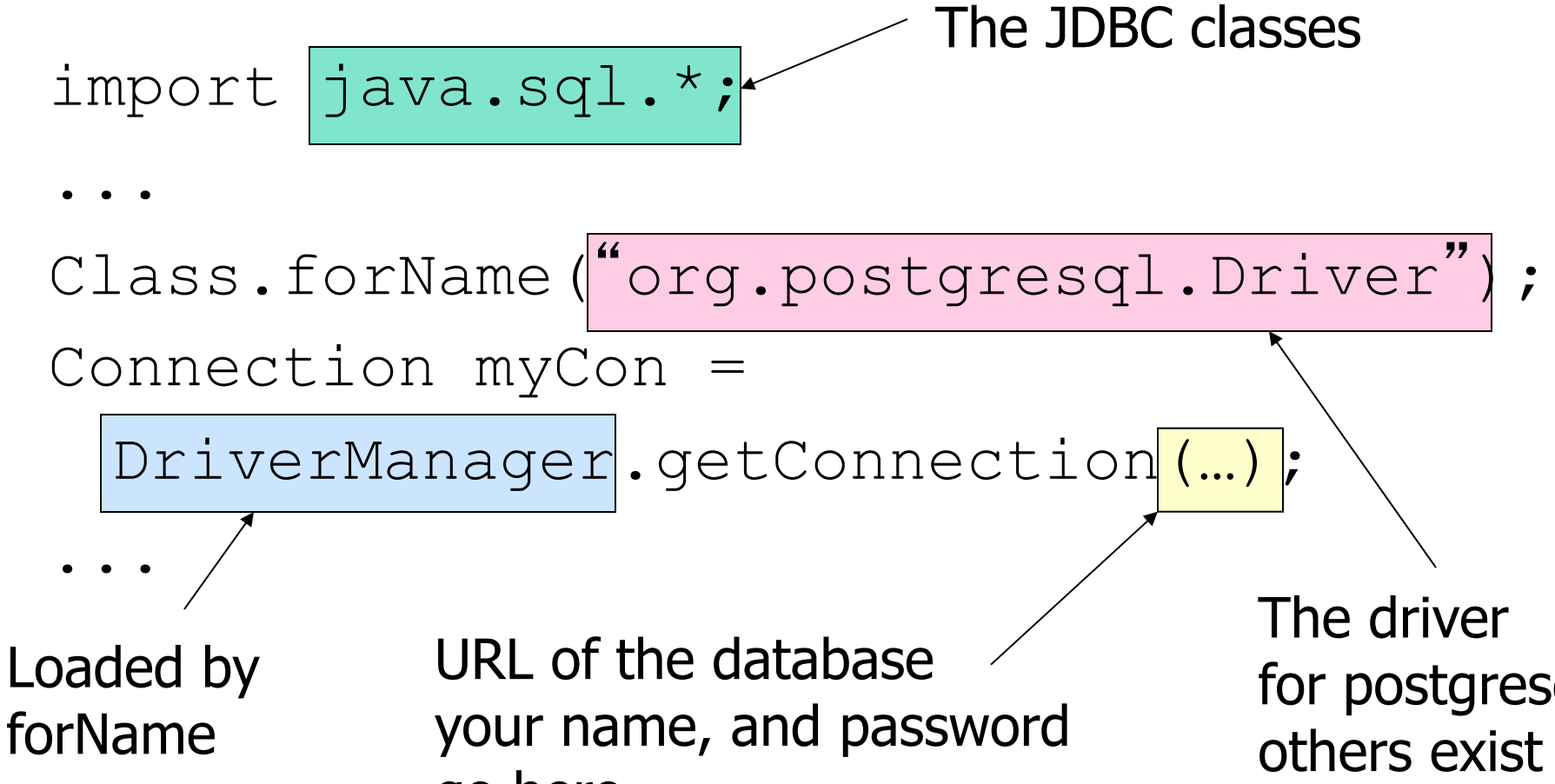
Environments, Connections, Queries

- The database is, in many DB-access languages, an *environment*
- Database servers maintain some number of *connections*, so app servers can ask queries or perform modifications
- The app server issues *statements:* queries and modifications, usually

JDBC

- *Java Database Connectivity* (JDBC) is a library for accessing a DBMS using Java as the host language
- >200 drivers available: PostgreSQL, MySQL, Oracle, ODBC, ...
- `http://jdbc.postgresql.org/`

Making a Connection



URL for PostgreSQL database

- jdbc:postgresql://<host>[:<port>]/<database>?user=<user>&password=<password>
- Alternatively use getConnection variant:
- getConnection("jdbc:postgresql://<host>[:<port>]/<database>", <user>, <password>);
- DriverManager.getConnection("jdbc:postgresql://10.110.4.32:5434/postgres", "peter", "geheim");

Statements

- JDBC provides two classes:
  1. *Statement* = an object that can accept a string that is a SQL statement and can execute such a string
  2. *PreparedStatement* = an object that has an associated SQL statement ready to execute

Creating Statements

- The Connection class has methods to create Statements and PreparedStatements

```
Statement stat1 = myCon.createStatement();
PreparedStatement stat2 =
    myCon.createStatement(
        ”SELECT beer, price FROM Sells ” +
        ”WHERE bar = ’C.Ch.’ ”
    );
```

createStatement with no argument returns a Statement; with one argument it returns a PreparedStatement

Executing SQL Statements

- JDBC distinguishes queries from modifications, which it calls “updates”
- Statement and PreparedStatement each have methods executeQuery and executeUpdate
  - For Statements: one argument – the query or modification to be executed
  - For PreparedStatements: no argument

Example: Update

- stat1 is a Statement
- We can use it to insert a tuple as:

```
stat1.executeUpdate(
  ”INSERT INTO Sells ” +
  ”VALUES(’C.Ch.’,’Eventyr’,30)”
);
```

Example: Query

- stat2 is a PreparedStatement holding the query ”SELECT beer, price FROM Sells WHERE bar = ’C.Ch.’ ”
- executeQuery returns an object of class ResultSet – we’ll examine it later
- The query:

```
ResultSet menu = stat2.executeQuery();
```

Accessing the ResultSet

- An object of type ResultSet is something like a cursor
- Method next() advances the "cursor" to the next tuple
  - The first time next() is applied, it gets the first tuple
  - If there are no more tuples, next() returns the value false

Accessing Components of Tuples

- When a ResultSet is referring to a tuple, we can get the components of that tuple by applying certain methods to the ResultSet
- Method get*X*(*i*), where *X* is some type, and *i* is the component number, returns the value of that component
  - The value must have type *X*

Example: Accessing Components

- Menu = ResultSet for query "SELECT beer, price FROM Sells WHERE bar = 'C.Ch.' "
- Access beer and price from each tuple by:

```
while (menu.next()) {
  theBeer = menu.getString(1);
  thePrice = menu.getFloat(2);
     /*something with theBeer and
       thePrice*/
}
```

Important Details

- Reusing a Statement object results in the ResultSet being closed
  - Always create new Statement objects using createStatement() or explicitly close ResultSets using the close method
- For transactions, for the Connection con use con.setAutoCommit(false) and explicitly con.commit() or con.rollback()
  - If AutoCommit is false and there is no commit: closing the connection = rollback

Python and Databases

- many different modules for accessing databases
- commercial: mxodbc, …
- open source: pygresql, psycopg2, …
- we use psycopg2
  - install using `pip install psycopg2`
  - import with `import psycopg2`

Connection String

- Database connection described by a connection string
- Example: `con_str = """`

```
host=10.110.4.32
port=5434
dbname=postgres
user=peter
password=geheim
"""
```

Making a Connection

- With the DB library imported and the connection string `con_str` available:

```
con = psycopg2.connect(con_str);
```

Function connect
in the DB API

Class is connection
because it is returned
by psycopg2.connect(…)

Cursors in Python

- Queries are executed for a cursor
- A cursor is obtained from connection
- Example:

```
cursor = con.cursor()
```

- Queries or modifications are executed using the `execute(…)` method
- Cursors can then be used in a `for`-loop

Example: Executing a Query

- Find all the bars that sell a beer given by the variable `beer`

```
beer = 'Od.Cl.'
cursor = con.cursor()
cursor.execute(
   "SELECT bar FROM Sells" +
   "WHERE beer = '%s';" % beer);
```

Remember this variable is replaced by the value of `beer`

Example: Tuple Cursors

```
bar = 'C.Ch.'
cur = con.cursor()
cur.execute("SELECT beer, price" +
" FROM Sells" +
" WHERE bar = " + bar + ";")
for row in cur:
  print row[0] + “ for “ + row[1]
```

Summary 12

More things you should know:

- Stored Procedures, PL/pgsql
- Declarations, Statements, Loops,
- Cursors, Tuple Variables
- Three-Tier Approach, JDBC, psycopg2