PROCEDURAL LANGUAGE EXTENSIONS FOR THE PGSQL

PLpgSQL

(not covered in textbook)

More on SQL Queries

A section relation is
(course_id, sec_id, semester, year, building, room_no, time_slot_id)

Find courses that ran in Fall 2009 and in Spring 2010

```
(select course_id from section where sem = ‘Fall’ and year = 2009)
 intersect
(select course_id from section where sem = ‘Spring’ and year = 2010)
```

this is done via a SQL intersect operation

More on SQL Queries

A different way of specifying the query *“Find all courses taught in both the Fall 2009 semester and in the Spring 2010 semester”:*

```
Select course_id
from section as S
where semester = ’Fall’ and year = 2009 and
        exists (Select *
                from section as T
                where semester = ’Spring’ and year= 2010
                                      and S.course_id= T.course_id);
```

This is called a ***correlated subquery.***

More on SQL Queries

A ***correlated subquery*** is a type of subquery that refers to a column of a table that is not in its FROM clause.

Correlated subquery: outer query executes before the inner query

An ***uncorrelated subquery*** is a type of subquery where inner query doesn't depend upon the outer query for its execution.

Uncorrelated subquery: inner query executes before the outer query.

Can SQL do this?

Consider the **scenario:**

- Withdraw money at an ATM
- A bank customer attempts to withdraw funds in their account.
- An ATM interacts with a secure database with your banking details.

What can SQL do?(cont.)

Example: say a person with acctNum 1 is trying to withdraw 50 dollars

Imagine that this is the implementation for the bank withdraw scenario:

```
Select 'Insufficient Funds'
from Accounts
where acctNo = 1 and balance < 50;

Update Accounts
set balance = balance - Amount
where acctNo = 1 and balance >=  50;

Select 'New balance:' || balance
from Accounts
where acctNo = 1;
```

What can SQL do?(cont.)

We can feel that it implicitly defines two evaluation scenarios:

- Display ‘Insufficient Funds’, UPDATE has no effect, displays unchanged balance
- UPDATE occurs as required, displays changed balance

I.e. *If there is not enough funds, the ATM should indicate ‘Insufficient Funds’; otherwise, it should allow the withdrawal and update the account balance.*

What can SQL do?(cont.)

```
Select 'Insufficient Funds'
from Accounts
where acctNo = 1 and balance < 50;

Update Accounts
set balance = balance - Amount
where acctNo = 1 and balance >=
50;

Select 'New balance:' || balance
from Accounts
where acctNo = 1;
```

Some ***issues***:

1. There is no parameterisation (e.g. acctNum)
2. Will always attempt UPDATE, even when it knows it's invalid
3. Will always display “new” balance, even if it’s unchanged

To accurately express the “business logic“ of withdrawing money, we need facilities like **conditional controls**.

The Limitation of SQL

What we have seen from SQL:

- Data definition (create table(...))
- Query (select...from...where...)
- Constraints on values (domain, key, referential integrity)

And some useful functionalities..

- Views (giving names to SQL queries)

But this is not enough to support real applications. Therefore more **extensibility** and **programmability** needed.

SQL as a Programming Language

SQL is a powerful language for manipulating relational data, but it **is not meant to be a powerful programming language.**

What if at some point in developing complete database applications

- We will need to consider implement user interactions
- we need to control sequences of database operations
- we need to process query results in additional ways

How would SQL be able to handle these?

Extending SQL by PostgreSQL

Ways that SQL could be extended:

- new data types (incl. constraints, I/O, indexes, ...)
- more powerful constraint checking
- packaging/parameterizing queries
- more functions/aggregates for use in queries
- event-based triggered actions

All are required to **assist application development**.

Database Programming(cont.)

(Let’s return to the example of withdrawing money)

To returning one of the two possible text results :

- If *try to withdraw too much* → return *'Insufficient funds’*
- If *withdrawal ok* → return *'New balance: newAmount'*

Requires a combination of

- SQL code to access the database
- procedural code to control the process

Database Programming

Database programming requires a ***combination*** of

- manipulation of data in DB (via SQL)
- conventional programming (via procedural code)

This combination is realised in a number of ways:

- Passing SQL commands via a ***"call-level" interface***

  (PL is decoupled from DBMS; most flexible; e.g. Java/JDBC, PHP)
- ***Embedding SQL*** into augmented programming languages

  (requires PL pre-processor; typically DBMS-specific; e.g. SQL/C)
- …

A Stored Procedure Approach

Stored procedures

- procedures/functions that are stored in DB along with data
- written in a language combining SQL and procedural ideas
- provide a way to extend operations available in database
- executed **within the DBMS** (close coupling with query engine)

Benefits of using stored procedures:

- minimal data transfer cost SQL ↔ procedural code
- user-defined functions can be nicely integrated with SQL
- procedures are managed like other DBMS data (ACID)
- procedures and the data they manipulate are held together

SQL/PSM

SQL/PSM is a **1996 standard for SQL** stored procedures. (PSM = Persistent Stored Modules)

Syntax for PSM procedure/function dentitions:

```
CREATE PROCEDURE ProcName ( <ParamList> )
[ local declarations ]
procedure body ;
```

```
CREATE FUNCTION FuncName (<ParamList> )
RETURNS Type
[ local declarations ]
function body ;
```

Parameters have three modes: IN, OUT, INOUT

SQL/PSM

Example: Defining a procedure:

```
CREATE PROCEDURE AddNewPerson (
IN name CHAR(20),
IN id INTEGER
)
INSERT INTO People VALUES(name, id);
```

Example: Invoking a procedure using the SQL/PSM statement CAL

```
CALL AddNewPerson(‘Codd’, 000001);
```

The Status of PSM in Modern DB

Unfortunately, the PSM standard was ***developed after*** most DBMSs had their own stored procedure language -> No DBMS implements the PSM standard exactly.

1. IBM's DB2 and MySQL implement the SQL/PSM closely (but not exactly)
2. Oracle's PL/SQL is moderately close to the SQL/PSM standard
3. PostgreSQL's PLpgSQL is close to PL/SQL (95% compatible)

PostgreSQL

- We can pass SQL commands via a "call-level" interface (PL is decoupled from DBMS; most flexible; e.g. Java/JDBC, PHP)
- We can embed SQL into augmented programming languages (requires PL pre-processor; typically DBMS-specific; e.g. SQL/C)
- Database programming can also be realised via special-purpose programming language **in the DBMS**
  - integrated with DBMS;
  - enables extensibility;
  - e.g. PL/SQL, PL/pgSQL.

User-defined Data Types

SQL data definition language provides:

- atomic types: integer, float, character, Boolean
- ability to define tuple types (create table)

PostgreSQL also provides mechanisms to define new types:

- basic types: ***CREATE DOMAIN***
- tuple types: ***CREATE TYPE***

User-defined Data Types(cont.)

Syntax for defining a new atomic type (as specialisation of existing type):

```
CREATE DOMAIN DomainName [ AS ] DataType
[ DEFAULT expression ]
[ CONSTRAINT ConstrName constraint ]
```

Example

```
Create Domain UnswCourseCode as text
check ( value ~ '[A-Z]{4}[0-9]{4}' );
```

which can then be used like other SQL atomic types

```
Create Table Course (
        id integer,
        code UnswCourseCode, ...
);
```

~ is POSIX Regular Expressions

POSIX regular expressions provide a more powerful means for pattern matching than LIKE and SIMILAR TO.

User-defined Data Types(cont.)

Syntax for defining a new tuple type:

```
CREATE TYPE TypeName AS
( AttrName1 DataType1, AttrName2 DataType2, ...)
```

Example

```
Create type ComplexNumber as ( r float, i float );
```

```
Create type CourseInfo as (
        course UnswCourseCode ,
        syllabus text ,
        lecturer text
);
```

If attributes need constraints, can be supplied by using a DOMAIN.

User-defined Data Types(cont.)

CREATE TYPE is different from CREATE TABLE:

1. does not create a new (empty) table
2. does not provide for key constraints
3. does not have explicit specification of domain constraints

Used for specifying return types of functions that return tuples or sets.

PostgreSQL: SQL Functions

PostgreSQL allows users to define functions to be defined in SQL

```
CREATE OR REPLACE FUNCTION
        funcName(arg1type, arg2type, ....)
        RETURNS rettype
AS $$
        SQL statements
$$ LANGUAGE sql;
```

PostgreSQL: SQL Functions(cont.)

Function arguments: accessed as $1, $2, ...

Return value: result of **the last** SQL statement.

- *rettype* can be any PostgreSQL data type.
- Rettype can be a table: *returns setof TupleType*

PostgreSQL: SQL Functions(cont.)

Example1:

```
-- max price of specified beer
create or replace function
        maxPrice(text) returns float
as $$
        select max(price) from Sells where beer = $1;
$$ language sql;
```

PostgreSQL: SQL Functions(cont.)

```
-- usage examples
select maxPrice('New’);
```

```
maxprice
----------
2.8
```

```
select bar, price from sells
where beer='New' and price=maxPrice('New’);
```

```
bar              price
---------------- -------
Marble Bar       2.8
```

PostgreSQL: SQL Functions(cont.)

Example2:

```
-- set of Bars from specified suburb
create or replace function
        hotelsIn(text) returns setof Bars
as $$
        select * from Bars where addr = $1;
$$ language sql;
```

PostgreSQL: SQL Functions(cont.)

```
-- usage examples
select * from hotelsIn('The Rocks');
```

```
name                addr                license
------------        --------------      -----------
Australia Hotel     The Rocks           123456
Lord Nelson         The Rocks           123888
```

PL/pgSQL (PostgreSQL Manual: Chapter 40)

Procedural **L**anguage extensions to **P**ost**g**re**SQL**

A *PostgreSQL-specific language* integrating features of:

- procedural programming
- SQL programming

PL/pgSQL Function

PLpgSQL functions are created in the db :

```
CREATE OR REPLACE FUNCTION
    funcName(param1, param2, ....)
    RETURNS rettype
AS $$
    DECLARE
        variable declarations
    BEGIN
        code for function
    END;
$$ LANGUAGE plpgsql;
```

Note: the entire function body is a single SQL string.

PL/pgSQL Function Parameters

All parameters are passed by value in PL/pgSQL.

Within a function, parameters can be referred:

- using positional notation ($1, $2, ...)

OR

- via aliases, supplied either
  - as part of the function header (e.g. f(a int, b int))
  - as part of the declarations (e.g. a alias for $1; b alias for $2)

PL/pgSQL Function Parameters(cont.)

Example: new-style function

```
CREATE OR REPLACE FUNCTION
        add(x text, y text) RETURNS text
AS $$
DECLARE
        result text; -- local variable
BEGIN
        result := x||""||y;
        return result;
END;
$$ LANGUAGE 'plpgsql';
```

Beware: never give aliases the same names as attributes.

PL/pgSQL Function Parameters(cont.)

Example: old-style function exists

```
CREATE OR REPLACE FUNCTION
        cat(text, text) RETURNS text
AS ‘
DECLARE
        x alias for $1; -- alias for parameter
        y alias for $2; -- alias for parameter
        result text; -- local variable
BEGIN
        result := x||''''''||y;
        return result;
END;
‘ LANGUAGE ‘plpgsql’;
```

Beware: never give aliases the same names as attributes.

PL/pgSQL Function Parameters(cont.)

Restrictions: requires x and y to have values of the same “addable" type.

```
CREATE OR REPLACE FUNCTION
        add ( x any_element , y any_element ) RETURNS any_element
AS $$
BEGIN
        return x + y ;
END ;
$$ LANGUAGE plpgsql ;
```

PL/pgSQL Function Parameters(cont.)

PLpgSQL allows ***function overloading*** (i.e. same name, different arg types)

Example

```
CREATE FUNCTION add ( int , int ) RETURNS int AS
$$ BEGIN return $1 + $2 ; END ; $$ LANGUAGE plpgsql ;

CREATE FUNCTION add ( int , int , int ) RETURNS int AS
$$ BEGIN return $1 + $2 + $3 ; END ; $$ LANGUAGE plpgsql ;

CREATE FUNCTION add ( char (1) , int ) RETURNS int AS

$$ BEGIN return ascii ( $1 )+ $2 ; END ; $$ LANGUAGE plpgsql ;
```

But must differ in arg types, so cannot also define:

```
CREATE FUNCTION add ( char (1) , int ) RETURNS char AS

$$ BEGIN return chr ( ascii ( $1 )+ $2 ); END ; $$ LANGUAGE plpgsql ;
```

i.e. cannot have two functions that look like add(char(1), int).

Function Return Types

A PostgreSQL function can return a value which is

- an atomic data type (e.g. integer, text, ...)
- a tuple (e.g. table record type or tuple type)
- a set of atomic values (like a table column)
- a set of tuples (i.e. a table)
- ***void*** (i.e. no return value)

A function returning a set of tuples is similar to a view.

Function Return Types(cont)

Examples of different function return types:

```
create type Employee as (id integer, name text, salary float, ...);
```

```
create function factorial(integer)
        returns integer ...
create function EmployeeOfMonth(date)
        returns Employee ...
create function allSalaries()
        returns setof float ...
create function OlderEmployees()
        returns setof Employee ...
```

Function Return Types(cont)

Different kinds of functions are invoked in different ways:

```
select factorial(5);
          -- returns one integer
select EmployeeOfMonth('2008-04-01');
          -- returns (x,y,z,...)
```

```
select * from EmployeeOfMonth('2008-04-01');
          -- one-row table
select * from allSalaries();
          -- single-column table
select * from OlderEmployees();
          -- subset of Employees
```

Using PL/pgSQL Functions

PLpgSQL functions can be invoked in several ways:

as part of a SELECT statement

```
select myFunction ( arg1 , arg2 );
select * from myTableFunction ( arg1 , arg2 );
```

as part of the execution of another PLpgSQL function

```
PERFORM myVoidFunction ( arg1 , arg2 );
result := myOtherFunction ( arg1 );
```

automatically, via an insert/delete/update trigger

```
create trigger T before update on R
for each row execute procedure myCheck ();
```

Declaring Data Types

Variables can also be defined in terms of:

- the type of an existing variable or table column
- the type of an existing table row (implicit RECORD type)

Declaring Data Types

The variable of a composite type is called a row-type variable.
A row-type variable can hold one row from a SELECT query result.

You can declare a variable to have the same type as a row from an table using <table_name>***%ROWTYPE***, e.g.

```
account Accounts%ROWTYPE ;
```

You may also refer to an attributes type using and specifying <table_name>**.** <column_name>***%TYPE***, e.g.

```
account.branchName%TYPE
```

Declaring Data Types

Examples of declaring data types (in a pl/pgsql function)

- quantity INTEGER ;
- start_quantity quantity%TYPE ;
- employee Employees%ROWTYPE ;
- name Employees.name%TYPE ;

Control Structures in Pl/pgsql

Assignment

- variable := expression;

Example:

```
tax := subtotal * 0.06;
my_record.user_id := 20;
```

Conditionals

- IF … THEN
- IF … THEN … ELSE
- IF … THEN … ELSIF … THEN … ELSE

Example

```
IF v_user_id > 0 THEN
UPDATE users SET email = v_email WHERE user_id = v_user_id; END IF;
```

Control Structures(cont.)

Iteration

```
LOOP
        Statement
END LOOP ;
```

Example

```
LOOP
        IF count > 0 THEN
                -- some computations
        END IF;
END LOOP;
```

Control Structures(cont.)

Iteration

```
FOR int_var IN low .. high LOOP
        Statement
END LOOP ;
```

Example

```
FOR i IN 1..10 LOOP
        -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the loop
END LOOP;
```

Control Structures(cont.)

Iteration

```
FOR int_var IN low .. high LOOP
        Statement
END LOOP ;
```

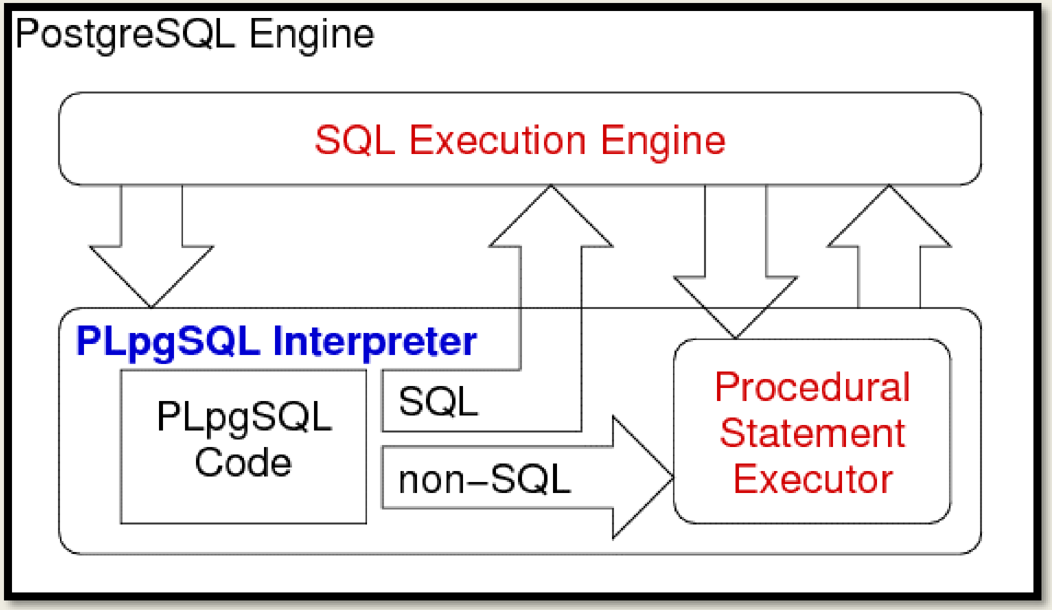
Example

```
FOR i IN 1..10 LOOP
        -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the loop
END LOOP;
```

PL/pgSQL(cont)

The PL/pgSQL interpreter

- executes procedural code and manages variables
- calls PostgreSQL engine to evaluate SQL statements



PL/pgSQL

Provided a means for extending DBMS functionality, e.g.

- implementing constraint checking (triggered functions)
- complex query evaluation (e.g. recursive)
- complex computation of column values
- detailed control of displayed results

PL/pgSQL Function

Stored-procedure approach (PLpgSQL):

```
create function
    withdraw(acctNum text, amount integer) returns text as $$
declare bal integer;
begin
    select balance into bal
    from Accounts
    where acctNo = acctNum;
    if (bal < amount) then
        return 'Insufficient Funds';
    else
        update Accounts
        set balance = balance - amount
        where acctNo = acctNum;
        select balance into bal
        from Accounts where acctNo = acctNum;
        return 'New Balance: ' || bal;
    end if;
end;
$$ language plpgsql;
```

SELECT … INTO

Can capture query results via:

SELECT Exp_1 , Exp_2 , … , Exp_n

INTO Var_1 , Var_2 , … , Var_n

FROM TableList

WHERE Condition …

The semantics:

1. execute the query as usual
2. return “projection list" (Exp_1 , Exp_2 , …) as usual
3. assign each Exp_i to corresponding Var_i

SELECT ... INTO(cont.)

Assigning a simple value via SELECT ... INTO:

```
-- cost is local var , price is attr

SELECT price INTO cost

FROM StockList

WHERE item = ' Cricket Bat ';

cost := cost * (1 + tax_rate );

total := total + cost ;
```

Exceptions

Syntax of exceptions

```
BEGIN
    Statements ...
EXCEPTION
    WHEN Exceptions1 THEN
            StatementsForHandler1
    WHEN Exceptions2 THEN
            StatementsForHandler2
    ...
END ;
```

Each Exceptionsi could be an OR list of exception names, e.g.,

- division_by_zero OR floating_point_exception OR ...

Exceptions(cont.)

Example:

```
-- table T contains one tuple ( ' Tom ' , ' Jones ')
DECLARE
        x INTEGER := 3;
BEGIN
        UPDATE T SET firstname = ' Joe ' WHERE lastname = ' Jones ';
        -- table T now contains ( ' Joe ' , ' Jones ')
        x := x + 1;
        y := x / 0;
EXCEPTION
        WHEN division_by_zero THEN
        -- update on T is rolled back to ( ' Tom ' , ' Jones ')
        RAISE NOTICE ' Caught division_by_zero ';
        RETURN x ;
        -- value returned is 4
END ;
```

Exceptions(cont.)

The ***RAISE*** operator generates server log entries, e.g.

- RAISE DEBUG ' Simple message ';
- RAISE NOTICE ' User = % ' , user_id ;
- RAISE EXCEPTION ' Fatal : value was % ' , value ;

There are several levels of severity:

- DEBUG, LOG, INFO, NOTICE, WARNING, and EXCEPTION
- not all severities generate a message to the client