Stored Procedures

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❖ Limitations of Basic SQL

What we have seen of SQL so far:

- data definition language (`create table(...)`)
- constraints (domain, key, referential integrity)
- query language (`select...from...where...`)
- views (give names to SQL queries)

This provides powerful declarative data extraction mechanisms.

This is not sufficient to write complete applications.

More extensibility and programmability are needed.

❖ Extending SQL

Ways in which standard SQL might be extended:

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

All are required to *assist* in application development.

But still do not provide a solution to developing applications.

❖ SQL as a Programming Language

At some point in developing complete database applications

- we need to implement user interactions
- we need to control sequences of database operations
- we need to process query results in complex ways
- we need to build a web interface for users to access data

and SQL cannot do any of these.

SQL cannot even do something as simple as factorial!

Ok ... so PostgreSQL added a factorial operator ... but it's non-standard.

❖ SQL as a Programming Language (cont)

Consider the problem of withdrawal from a bank account:

If a bank customer attempts to withdraw more funds than they have in their account, then indicate "Insufficient Funds", otherwise update the account

An attempt to implement this in SQL:

```
select 'Insufficient Funds'
from   Accounts
where  acctNo = AcctNum and balance < Amount;
update Accounts
set    balance = balance - Amount
where  acctNo = AcctNum and balance >= Amount;
select 'New balance: '||balance
from   Accounts
where  acctNo = AcctNum;
```

❖ SQL as a Programming Language (cont)

Two possible evaluation scenarios:

- displays "Insufficient Funds", **`UPDATE`** has no effect, displays unchanged balance
- **`UPDATE`** occurs as required, displays changed balance

Some problems:

- SQL doesn't allow parameterisation (e.g. *AcctNum*)
- always attempts **`UPDATE`**, even when it knows it's invalid
- need to evaluate **`(balance <`** *Amount*`)` test twice
- always displays balance, even when not changed

To accurately express the "business logic", we need facilities like conditional execution and parameter passing.

❖ 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
  (prog lang is decoupled from DBMS; most flexible; e.g. Java/JDBC, PHP, Python)
- embedding SQL into augmented programming languages
  (requires pre-processor for language; typically DBMS-specific; e.g. SQL/C)
- special-purpose programming languages in the DBMS
  (closely integrated with DBMS; enable extensibility; e.g. PL/SQL, PLpgSQL)

Here we focus on the last: extending DBMS capabilities via programs stored in the DB

❖ Database Programming (cont)

Combining SQL and procedural code solves the "withdrawal" problem:

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

(This example is actually a stored procedure, using SQL/PSM syntax)

❖ Stored Procedures

Stored procedures are small programs ...

- stored in the database, alongside the stored data
- invoked in SQL queries, or automatically invoked in triggers

SQL/PSM is a standard for stored procedures, developed in 1996.
By then, most DBMSs had their own stored procedure languages.

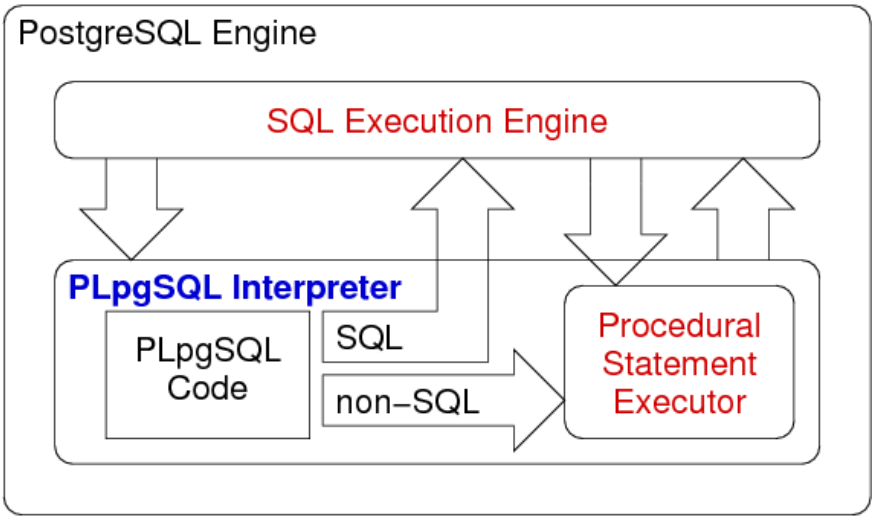
PostgreSQL supports stored procedures in a variety of languages

- PLpgSQL ... PostgreSQL-specific procedural language (cf. Oracle's PL/SQL)
- SQL ... functions that resemble parameterised views
- Python, Perl, Tcl, ... etc.

❖ Stored Procedures (cont)

The PLpgSQL interpreter

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



Embedded in DBMS engine, so efficient to execute with queries

❖ SQL Functions

PostgreSQL allows functions to be defined in SQL

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

Within the function, arguments are accessed as **$1**, **$2**, ...

Return value: result of the last SQL statement.

rettype can be any PostgreSQL data type (incl tuples,tables).

Function returning a table: **returns setof** *TupleType*

Details: PostgreSQL Documentation, Section 37.5

❖ SQL Functions (cont)

Example: info about bars from a given suburb

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

-- usage examples
select * from hotelsIn('The Rocks');
      name        |   addr     | license
------------------+------------+---------
 Australia Hotel | The Rocks |  123456
 Lord Nelson      | The Rocks |  123888

select * from hotelsIn('Randwick');
    name      |   addr    | license
--------------+-----------+---------
 Royal Hotel | Randwick |  938500
```

❖ SQL Functions (cont)

Example: Name of cheapest beer at each bar

```
create view Cheapest(bar, price) as
select bar, min(price) from Sells group by bar;

select s.*
from   Sells s
where  s.price =
         (select price from Cheapest where bar = s.bar);
```

Could be implemted by defining an SQL function **`LowestPriceAt(bar)`**

```
create or replace
    function LowestPriceAt(text) returns float
as $$
select min(price) from Sells where bar = $1;
$$ language sql;

select * from Sells where price = LowestPriceAt(bar);
```

❖ Functions vs Views

A parameterless function behaves similar to a view

E.g.

```
create or replace view EmpList
as
select given||' '||family as name,
       street||', '||town as addr
from   Employees;
```

which is used as

```
mydb=# select * from EmpList;
```

❖ Functions vs Views (cont)

Compared to its implementation as a function:

```
create type EmpRecord as (name text, addr text);

create or replace function
   EmpList() returns setof EmpRecord
as $$
select family||' '||given as name,
       street||', '||town as addr
from   Employees
$$ language sql;
```

which is used as

```
mydb=# select * from EmpList();
```

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