COMP9311 Week 07 Lecture

Triggers

Triggers (review)

Triggers are actions invoked by DB modifications.

They allow programmers to

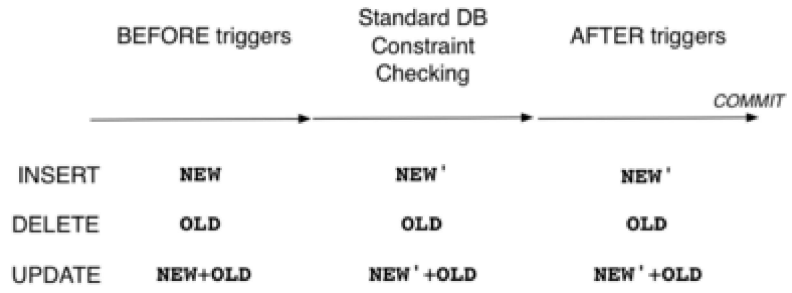
- implement global constraint (assertion) checking
- maintain summary values (cross-table dependencies)

They achieve this by

- invoking functions before/after insert/delete/update
- using/manipulating OLD/NEW values of changed tuples

... Triggers (review)

Sequence of activities during database update:



Note: BEFORE trigger can modify value of new tuple

Triggers in PostgreSQL

PostgreSQL triggers provide a mechanism for

- INSERT, DELETE or UPDATE events
- to automatically activate PLpgSQL functions

Syntax for PostgreSQL trigger definition:

```
CREATE TRIGGER TriggerName
{AFTER|BEFORE}  Event1 [OR Event2 ...]
ON TableName
[ WHEN ( Condition ) ]
FOR EACH {ROW|STATEMENT}
EXECUTE PROCEDURE FunctionName(args...);
```

... Triggers in PostgreSQL

There is no restriction on what code can go in the function.

However a BEFORE function must contain one of:

RETURN old; or RETURN new;

depending on which version of the tuple is to be used.

If BEFORE trigger returns old, no change occurs.

If exception is raised in trigger function, no change occurs.

Trigger Example #1

Consider a database of people in the USA:

```
create table Person (
   id      integer primary key,
   ssn     varchar(11) unique,
   ... e.g. family, given, street, town ...
   state   char(2), ...
);
create table States (
   id      integer primary key,
   code    char(2) unique,
   ... e.g. name, area, population, flag ...
);
```

Constraint: Person.state ∈ (select code from States), or
exists (select id from States where code=Person.state)

... Trigger Example #1

Example: ensure that only valid state codes are used:

```
create trigger checkState before insert or update
on Person for each row execute procedure checkState();

create function checkState() returns trigger as $$
begin
   -- normalise the user-supplied value
   new.state = upper(trim(new.state));
   if (new.state !~ '^[A-Z][A-Z]$') then
      raise exception 'Code must be two alpha chars';
   end if;
   -- implement referential integrity check
   select * from States where code=new.state;
   if (not found) then
      raise exception 'Invalid code %',new.state;
   end if;
   return new;
end;
$$ language plpgsql;
```

... Trigger Example #1

Examples of how this trigger would behave:

```
insert into Person
   values('John',...,'Calif.',...);
-- fails with 'Statecode must be two alpha chars'

insert into Person
   values('Jane',...,'NY',...);
-- insert succeeds; Jane lives in New York

update Person
   set town='Sunnyvale',state='CA'
         where name='Dave';
-- update succeeds; Dave moves to California

update Person
   set state='OZ' where name='Pete';
-- fails with 'Invalid state code OZ'
```

Trigger Example #2

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Example: department salary totals

Scenario:

```
Employee(id, name, address, dept, salary, ...)
Department(id, name, manager, totSal, ...)
```

An assertion that we wish to maintain:

```
create assertion TotalSalary check (
   not exists (
       select d.id from Department d
       where  d.totSal <>
              (select sum(e.salary)
               from Employee e
               where e.dept = d.id)
    )
)
```

... Trigger Example #2

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Events that might affect the validity of the database

- a new employee starts work in some department
- an employee gets a rise in salary
- an employee changes from one department to another
- an employee leaves the company

A single assertion could check for this after each change.

With triggers, we have to program each case separately.

Each program implements updates to ensure assertion holds.

... Trigger Example #2

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Implement the Employee update triggers from above in PostgreSQL:

Case 1: new employees arrive

```
create trigger TotalSalary1
after insert on Employees
for each row execute procedure totalSalary1();

create function totalSalary1() returns trigger
as $$
begin
    if (new.dept is not null) then
        update Department
        set    totSal = totSal + new.salary
        where  Department.id = new.dept;
    end if;
    return new;
end;
$$ language plpgsql;
```

... Trigger Example #2

Case 2: employees change departments/salaries

```
create trigger TotalSalary2
after update on Employee
for each row execute procedure totalSalary2();

create function totalSalary2() returns trigger
as $$
begin
    update Department
    set    totSal = totSal + new.salary
    where  Department.id = new.dept;
    update Department
    set    totSal = totSal - old.salary
    where  Department.id = old.dept;
    return new;
end;
$$ language plpgsql;
```

... Trigger Example #2

Case 3: employees leave

```
create trigger TotalSalary3
after delete on Employee
for each row execute procedure totalSalary3();

create function totalSalary3() returns trigger
as $$
begin
    if (old.dept is not null) then
        update Department
        set    totSal = totSal - old.salary
        where  Department.id = old.dept;
```

```
    end if;
    return old;
end;
$$ language plpgsql;
```

Exercise: Triggers (1)

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Requirement: maintain assets in bank branches

- each branch has assets based on the accounts held there
- whenever an account changes, the assets of the corresponding branch should be updated to reflect this change

Some possible changes:

- a new account is opened
- the amount of money in an account changes
- an account moves from one branch to another
- an account is closed

Implement triggers to maintain Branch.assets

Exercise: Triggers (2)

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Consider a simple airline flights/bookings database:

```
Airports(id, code, name, city)
Planes(id, craft, nseats)
Flights(id, fltNum, plane, source, dest
        departs, arrives, price, seatsAvail)
Passengers(id, name, address, phone)
Bookings(pax, flight, paid)
```

Write triggers to ensure that Flights.seatsAvail is consistent with number of Bookings on that flight.

Assume that we never UPDATE a booking (only insert/delete)

Programming with DBs

Programming with Databases

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So far, we have seen ...

- accessing data via SQL queries
- packaging SQL queries as views/functions
- building functions to return tables
- implementing assertions via triggers

All of the above programming

- is very close to the data
- takes place inside the DBMS

... Programming with Databases

Complete applications require code outside the DBMS

- to handle the user interface (GUI or Web)
- to interact with other systems (e.g. other DBs)
- to perform compute-intensive work (vs. data-intensive)

"Conventional" programming languages (PLs) provide these.

... Programming with Databases

Requirements of an interface between PL and RDBMS:

- mechanism for connecting to the DBMS
- mapping betwen tuples and PL objects
- mechanism for mapping PL "requests" to queries
- mechanism for iterating over query results

Distance between PL and DBMS is variable, e.g.

- libpq allows C programs to use PG structs
- JDBC transmits SQL strings, retrieves tuples-as-objects

PL/DB Interface

Common DB access API used in programming languages

```
db = connect_to_dbms(DBname,User/Password);
query = build_SQL("SqlStatementTemplate",values);
results = execute_query(db,query);
while (more_tuples_in(results))
{
   tuple = fetch_row_from(results);
   // do something with values in tuple ...
}
```

This pattern is used in many different libraries:

- Java/JDBC, PHP/PDO, Perl/DBI, Python/dbapi2, Tcl, ...

... PL/DB Interface

DB access libraries have similar overall structure.

However, they differ in the details:

- whether specific to one database or generic
- whether object-oriented or procedural flavour
- function/method names and parameters
- how to get data from program into SQL statements
- how to get data from tuples to program variables

We use PHP to illustrate the idea in this lecture.

COMP9311/3311 PHP/DB Interface

Standard pattern for extracting data from DB:

```
$db = dbConnect("dbname=myDB");
...
$query = "select a,b,c from R where c >= %d";
$result = dbQuery($db, mkSQL($query, $min));
while ($tuple = dbNext($result)) {
   $tmp = $tuple["a"] - $tuple["b"] - $tuple["c"];
   # or ...
   list($a,$b,$c) = $tuple;
   $tmp = $a - $b - $c;
}
...
```

COMP9311/3311 DB Library

Functions in the COMP9311 database library:

- dbConnect(conn): establish connection to DB
- dbQuery(db,sql): send SQL statement for execution
- dbNext(res): fetch next tuple from result set
- dbUpdate(db,sql): send SQL insert/delete/update
- ...

Most functions terminate with message if error occurs.

... COMP9311/3311 DB Library


```
$t = dbNext(resource $r);
```

- $t is assigned next tuple from result set $r
- $t contains two copies of values from tuple
  - one set of values is indexed by position in SELECT clause
  - one set of values is indexed by name in SELECT clause

Example:

```
$q = "select name,max(mark) from Enrolments ...";
$r = dbQuery($db,$q);
$t = dbNext($r);
# results in $t with value
array(0=>'John', "name"=>'John', 1=>95, "max"=>95)
```

Example PHP code (actual code)


```
$db_handle = pg_connect("dbname=bpsimple");
$query = "SELECT title, fname, lname FROM customer";
$result = pg_exec($db_handle, $query);
if ($result) {
  echo "The query executed successfully.\n";
```

```
  for ($row = 0; $row < pg_numrows($result); $row++) {
    $fullname = pg_result($result, $row, 'title') . " ";
    $fullname .= pg_result($result, $row, 'fname') . " ";
    $fullname .= pg_result($result, $row, 'lname');
    echo "Customer: $fullname\n";
  }
} else {
  echo "The query failed with the following error:\n";
  echo pg_errormessage($db_handle);
}
pg_close($db_handle);
```

DB/PL Mismatch

There is a tension between PLs and DBMSs

- DBMSs deal efficiently with sets of tuples
- PLs encourage dealing with single tuples/objects

If not handled carefully, can lead to inefficient use of DB.

Note: relative costs of DB access operations:

- establishing a DBMS connection ... very high
- initiating an SQL query ... high
- accessing individual tuple ... low

... DB/PL Mismatch

Consider the PL/DBMS access method, phrased in PHP:

```
--  establish connection to DBMS
$db = dbAccess("DB");
$query = "select a,b from R,S where ... ";
--  invoke query and get handle to result set
$results = dbQuery($db, $query);
--  for each tuple in result set
while ($tuple = dbNext($results)) {
    --  process next tuple
    process($tuple['a'], $tuple['b']);
}
```

... DB/PL Mismatch

Example: find mature-age students

```
$query = "select * from Student";
$results = dbQuery($db,$query);
while ($tuple = dbNext($results)) {
    if ($tuple["age"] >= 40) {
        --  process mature-age student
    }
}
```

If 10000 students, and only 500 of them are over 40, we transfer 9500 unnecessary tuples from DB.

... DB/PL Mismatch

E.g. should be implemented as:

```
$query = "select * from Student where age >= 40";
$results = dbQuery($db,$query);
while ($tuple = dbNext($results)) {
    --  process mature-age student
}
```

Transfers only the 500 tuples that are needed.

... DB/PL Mismatch

Example: find info about all marks for all students

```
$query1 = "select id,name from Student";
$res1 = dbQuery($db,$query1);
while ($tuple1 = dbNext($res1)) {
    $query2 = "select course,mark from Marks".
              " where student = $tuple1['id']";
    $res2 = dbQuery($db,$query2);
    while ($tuple2 = dbNext($res2)) {
        --  process student/course/mark info
    }
}
```

If 10000 students, we invoke 10001 queries on the database.

... DB/PL Mismatch

E.g. should be implemented as:

```
$query = "select id,name,course,mark".
         " from Student s, Marks m".
         " where s.id = m.student";
$results = dbQuery($db,$query);
while ($tuple = dbNext($results)) {
    --  process student/course/mark info
}
```

We invoke 1 query, and transfer same number of tuples.

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