

CS307

Principles of Database Systems

Chapter 9 Procedure and Trigger

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Most contents are from Stéphane Faroult's slides

9.1 Procedure

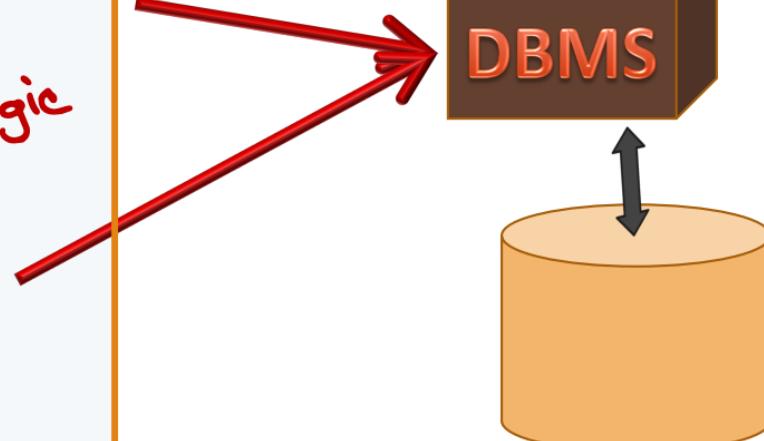
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Procedures

I have talked about functions, which return a value,
let's talk about procedures, which don't (PostgreSQL
only knows about functions, but it has void functions)

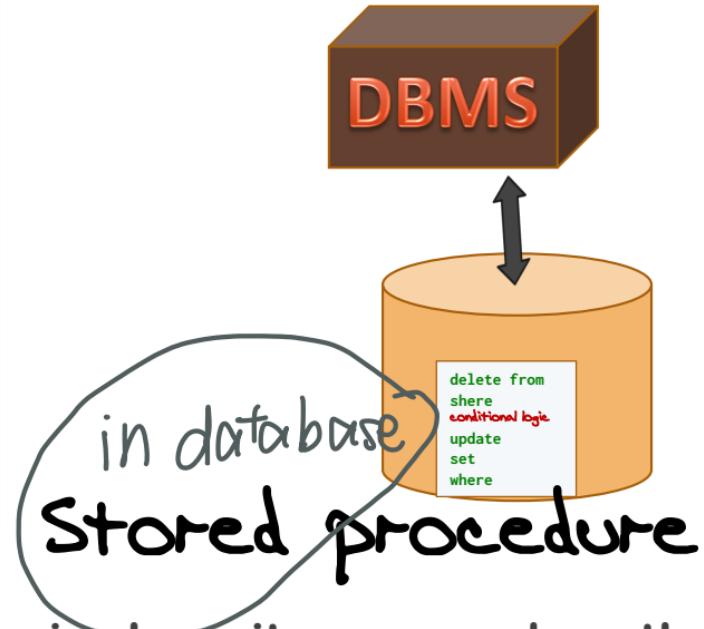
`delete from ...
where ...
+ Conditional logic
update ...
set ...
where ...`



Transactions (i.e. an "everything succeeds or fails" business operation) demand several steps, and may require some conditional logic.

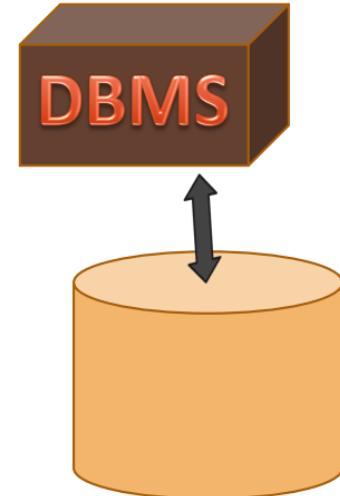
create procedure myproc

```
delete from ...  
where ...  
+ Conditional logic  
update ...  
set ...  
where ...
```



It makes sense to turn them into a single unit, a procedure that will be stored in the database.

`execute myproc`



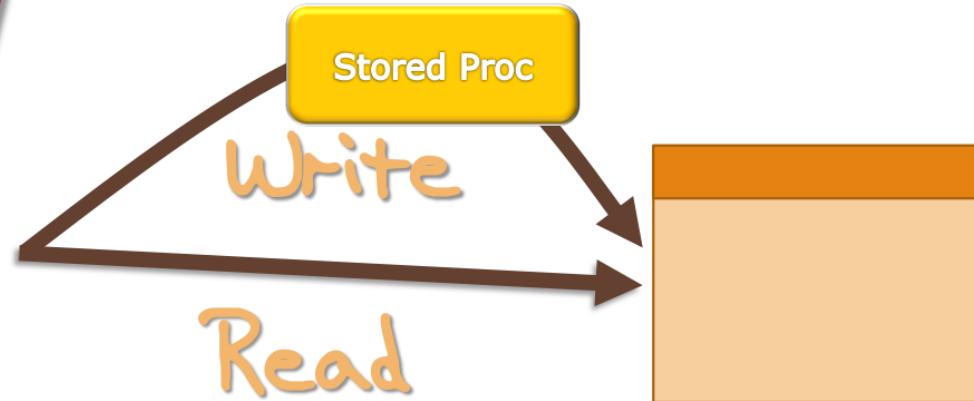
Instead of issuing several SQL statements, checking their outcome and so far, we can then issue a single command to execute everything on the server. Transaction management ("start transaction" and "commit"/"rollback") can be performed inside the procedure or outside it.

ONE call

There are many benefits to the approach. First of all calling the procedure is a single interaction with the database. When the database is located on a remote server (think "the cloud") you aren't going to waste time chatting over the network with the remote server.

Another significant benefit is **security**. We haven't talked about it yet, but you can prevent users from modifying data otherwise than by calling carefully written and well tested procedures.

Security



Adding a film to the database is a rather painful exercise. Let's do it with a procedure. The choice of parameters isn't very good but simpler.

Movie registration

Not too good

first name

surname

Title

Year

Country Name

Director

Actor1

Actor2

```
select country_code from countries  
...  
insert into movies  
...  
select peopleid from people  
...  
insert into credits  
...  
select peopleid from people  
...  
insert into credits  
...  
select peopleid from people  
...  
insert into credits  
...
```

get value of movieid

director

actor1

actor2

Lots of things to do

MINIMIZE the number of **STATEMENTS**

First of all, if we want to be relatively efficient we should try to minimize our interactions with the database. Running a stored procedure on the database is of course much better than issuing statements from afar, but context switches are always costly.

```
select country_code from countries  
...  
insert into movies  
...  
  
select peopleid from people  
...  
  
insert into credits  
...  
  
select peopleid from people  
...  
  
insert into credits  
...  
  
select peopleid from people  
...  
  
insert into credits  
...
```

```
insert into movies ...  
select country_code, ...  
from countries  
...  
  
insert into credits ...  
select peopleid, 'D', ...  
from people  
...  
  
insert into credits ...  
select peopleid, 'A', ...  
from people  
...  
  
insert into credits ...  
select peopleid, 'A', ...  
from people  
...
```

INSERT ... SELECT ...
is far better than
SELECT followed by
an INSERT.

But the three last
statements are
basically the same
one.

```
insert into movies ...
select country_code, ...
from countries
...
insert into credits ...
select peopleid, 'D!', ...
from peoplelet director, 'D', ...
... union all
    select actor1, 'A', ...
insert into credits ...
select peopleid, 'A', 'A'; ...) a
from peoplejoin people
:::
insert into credits ...
select peopleid, 'A', ...
from people
...
```

Check one row inserted
if not, generate error

Here is what we'll do.

Check rows inserted

```
create function movie_registration
    (p_title      varchar,
     p_country_name varchar,
     p_year       int,
     p_director_fn  varchar,
     p_director_sn  varchar,
     p_actor1_fn   varchar,
     p_actor1_sn   varchar,
     p_actor2_fn   varchar,
     p_actor2_sn   varchar)

returns void
as $$

declare
    n_rowcount int;
    n_movieid int;
    n_people int;

begin
    insert into movies(title, country, year_released)
        select p_title, country_code, p_year
        from countries
        where country_name = p_country_name;
```

PostgreSQL



And here is how we
can write it with
PostgreSQL.



```
insert into movies(title, country, year_released)
  select p_title, country_code, p_year
    from countries
   where country_name = p_country_name;
? cannot find country
return 0 rows.

get diagnostics n_rowcount = row_count;
if n_rowcount = 0
then
  raise exception 'country not found in table COUNTRIES';
end if;
n_movieid := lastval(); ☆ 返回上一个movieID ≠ select max
select count(surname)
  into n_people
from (select p_director_sn as surname
       union all
       select p_actor1_sn as surname
       union all
       select p_actor2_sn as surname) specified_people
  where surname is not null;
```

```

insert into credits(movieid, peopleid, credited_as)
select n_movieid, people.peopleid, provided.credited_as
from (select coalesce(p_director_fn, '*') as first_name,
            p_director_sn as surname,
            'D' as credited_as
        union all
        select coalesce(p_actor1_fn, '*') as first_name,
            p_actor1_sn as surname,
            'A' as credited_as
        union all
        select coalesce(p_actor2_fn, '*') as first_name,
            p_actor2_sn as surname,
            'A' as credited_as) provided
inner join people
    on people.surname = provided.surname
    and coalesce(people.first_name, '*') = provided.first_name
where provided.surname is not null;
get diagnostics n_rowcount = row_count;
if n_rowcount != n_people
    then
        raise exception 'Some people couldn''t be found';
    end if;
end;
$$ language plpgsql;

```



Check whether we
found everybody

插入姓名，返回 peopleId

In PostgreSQL you can call the procedure interactively by calling it from a SELECT statement (that will return nothing). Other products use "call", "execute", and so on. You can also call a procedure from within another procedure by using "perform".

```
select movie_registration('The Adventures of Robin Hood',
                          'United States', 1938,
                          'Michael', 'Curtiz',
                          'Errol', 'Flynn',
                          null, null);
```

PostgreSQL



When call from another procedure

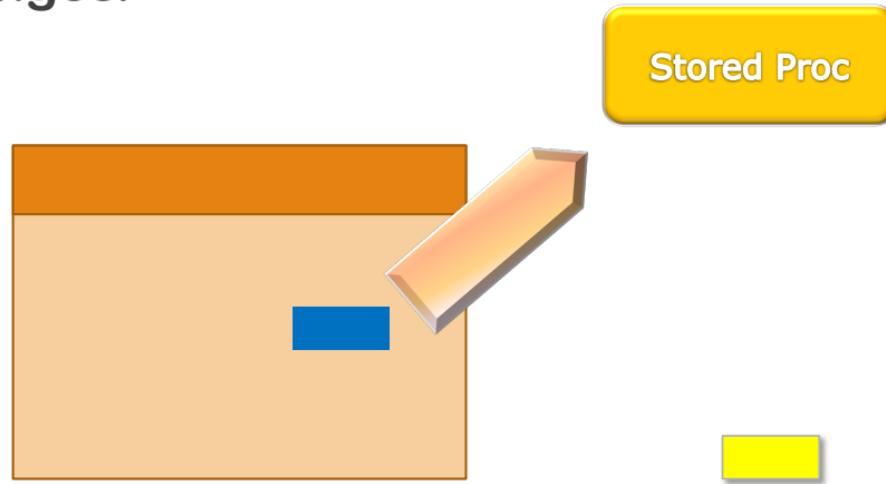
```
perform movie_registration('The Adventures of Robin Hood',
                           'United States', 1938,
                           'Michael', 'Curtiz',
                           'Errol', 'Flynn',
                           null, null);
```

9.2 Trigger

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You can attach to a table actions that will be executed automatically whenever the data in the table changes.

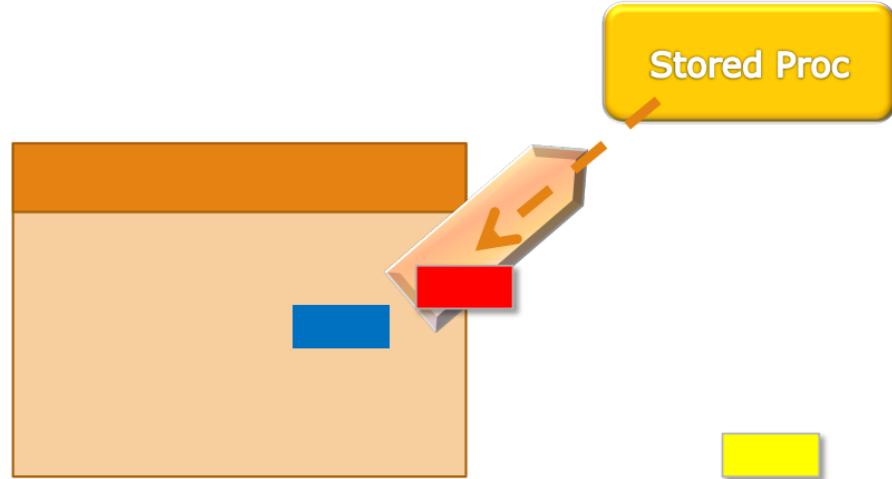


Note: a **SELECT** will never trigger anything.
Only write operations do.

PURPOSE

There are several purposes for triggers, some of which are more commendable than others. That said, we aren't living in an ideal world and there are cases when they can be useful for fixing things which are badly done in a program for which you haven't the source code.

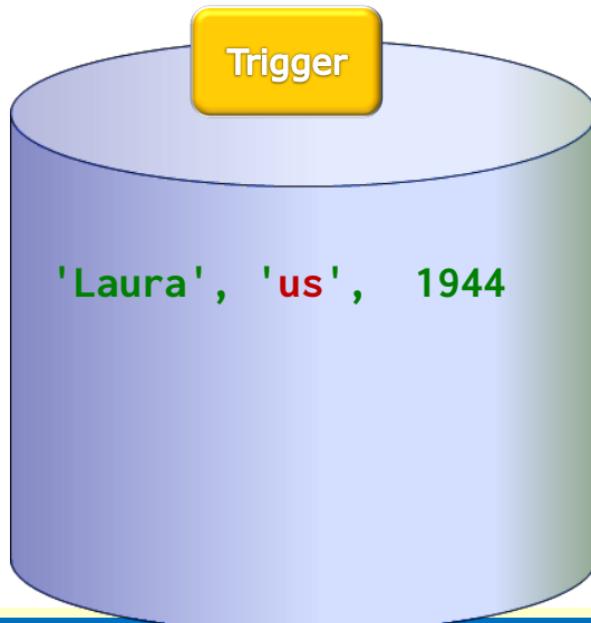
① Modify input on the fly



One thing that triggers may be used for is changing input on the fly. For instance, you want to make sure that data is always in lowercase but the data entry program doesn't enforce it, and you have no access to its source code. A trigger can force the case.

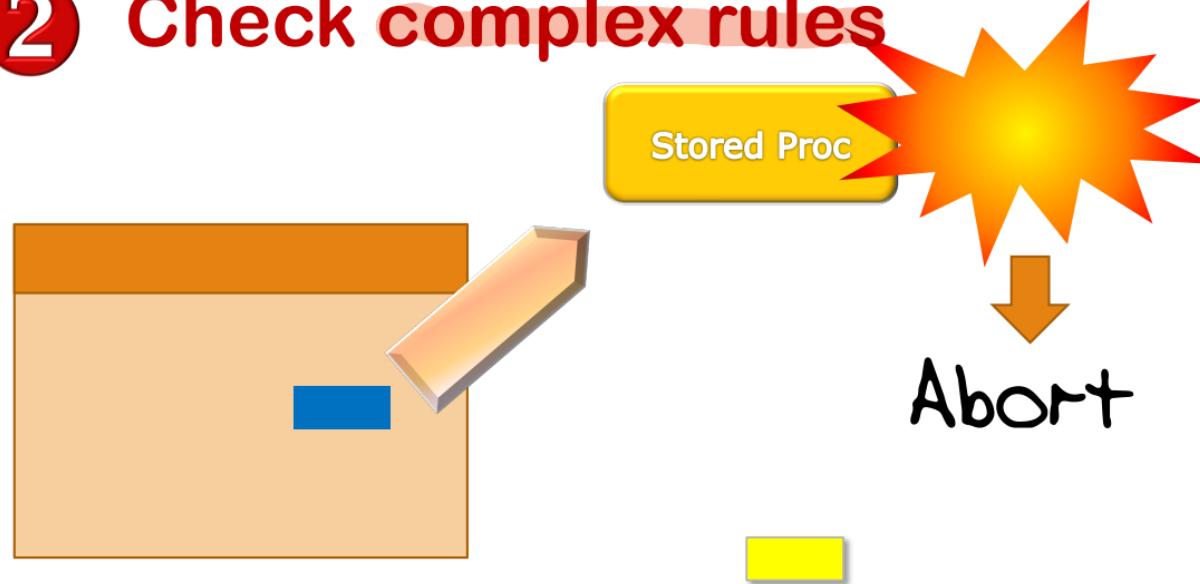
Note!

```
insert into movies(title, country, year_released)  
values ('Laura', 'US', 1944)
```



Much better
to have the
transformation
in input
programs

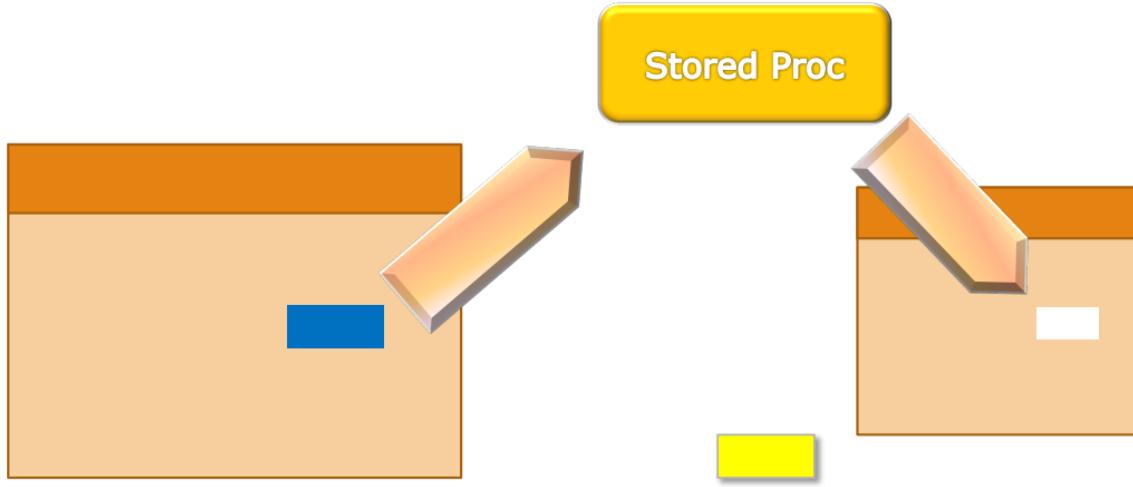
② Check complex rules



Another case is when you have business rules so complex (exceptions to rules, etc.) that they cannot be checked through declarative constraints. You can abort a transaction in a trigger, and return an error.

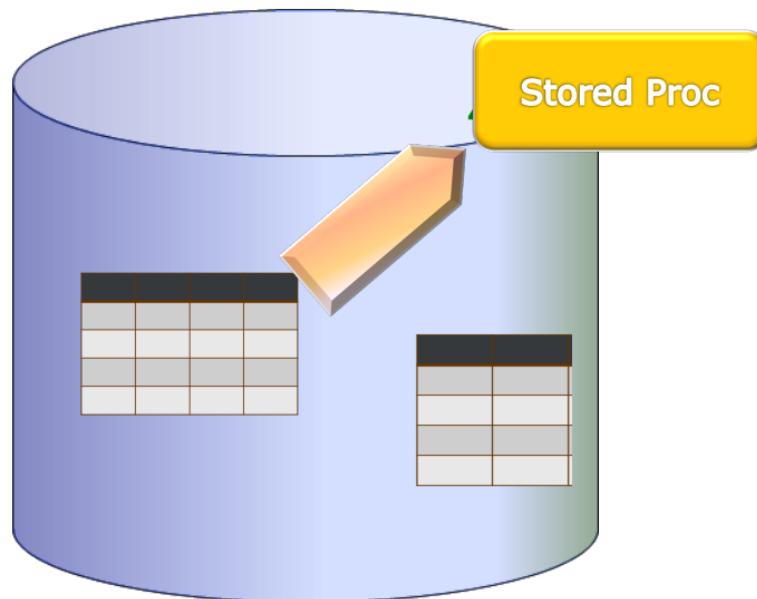
③

Manage data redundancy



A third case is managing some data redundancy. A trigger can write in your back to another table. In the film database, this is done for titles: words are automatically isolated and added to **MOVIE_TITLE_FT_INDEX** whenever you add a row to **MOVIES** or **ALT_TITLES** (not for Chinese titles)

```
insert into movies(title, country, year_released)  
values ('Monty Python and the Holy Grail', 'gb', 1975)
```



Trigger Activation

When are triggers fired? "During the change" is not a proper answer. In fact, depending on what the trigger is designed to achieve, it may be fired by various events and at various possible precise moments.

films_francais

titre	title
annee	year

Let's say that we have uploaded from an external file and into a table called FILMS_FRANCAIS (film is film in French) storing only two columns, title and year.

```
insert into movies(title, country, year_released)  
select titre, 'fr', annee  
from films_francais
```

One statement

Several rows

If we use an **INSERT ... SELECT ...** statement, we have **ONE** statement that inserts **SEVERAL** rows. If we activate a procedure, what will happen? Some DBMS products give you a choice.

```
insert into movies(title, country, year_released)
select titre, 'fr', annee
from films_francais
```



4	Casablanca	us	1942
5	Citizen Kane	us	1941
12	Ladri di biciclette	it	1948
23	The Third Man	gb	1949
25	Notorious	us	1946
61	Les Enfants du Paradis	fr	1945
62	Pierrot le Fou	fr	1965
63	Les 400 coups	fr	1959
64	Le Salaire de la Peur	fr	1953
65	Le Fabuleux Destin d'Amélie Poulain	fr	2001

LekeEnEnfantdudBaPadàdis	f#94\$945
PiÙteotielèoGou	f#96\$965
Leke40000coups	f#95\$959
LeLàSalairéderkàlBeleur	f#95\$953
LeLàBabouleuReDésid'mmobilisMoRèlain	f#002001

One thing you can sometimes do is fire the procedure only once for the statement, either BEFORE the first row is inserted, or AFTER the last row is inserted.

```
insert into movies(title, country, year_released)
select titre, 'fr', annee
from films_francais
```



4	Casablanca	us	1942
5	Citizen Kane	us	1941
12	Ladri di biciclette	it	1948
23	The Third Man	gb	1949
25	Notorious	us	1946
61	Les Enfants du Paradis	fr	1945
62	Pierrot le Fou	fr	1965
63	Les 400 coups	fr	1959
64	Le Salaire de la Peur	fr	1953
65	Le Fabuleux Destin d'Amélie Poulain	fr	2001

LekeEnEnfantdudBaPadàdis	f#94\$945
PiBieentoileBou	f#96\$965
Leke40000coups	f#95\$959
LeLàSalinàredkàlBeleur	f#95\$953
LeLàBabouleuReDésid'mAbbàiliBoRàlain	f#002001

OR (and it's sometimes the only option) you can call the procedure before or after you insert EACH row, in which case it will be executed a far greater number of times.

```
insert into movies(title, country, year_released)
select titre, 'fr', annee
from films_francais
```



before/after insert
for each row
trigger

4	Casablanca	us	1942
5	Citizen Kane	us	1941
12	Ladri di biciclette	it	1948
23	The Third Man	gb	1949
25	Notorious	us	1946
61	Les Enfants du Paradis	fr	1945
62	Pierrot le Fou	fr	1965
63	Les 400 coups	fr	1959
64	Le Salaire de la Peur	fr	1953
65	Le Fabuleux Destin d'Amélie Poulain	fr	2001

LeEnEnfantdudBaPadàdis	f#94\$945
PiRieentoileBou	f#96\$965
Lebe4000coups	f#959959
LeLaSalairédekalBeleur	f#953953
LeFabuleuxDestinid'méliePoulain	f2002001

Same thing after each row ...

PostgreSQL



ORACLE®

IBM® DB2®

before statement
before each row
after each row
after statement



IBM DB2®

old table
new table

MySQL®

SQLite

Time

Microsoft®
SQL Server®

before each row
after each row

after statement

old

new

deleted

inserted

Options vary with DBMS products. Virtual rows or tables give you access to before change/after change values.

Time + Event

The other important parameter is WHAT fires the trigger. You don't need to fire a trigger that changes the case when you delete a row.

Several possible triggers

insert
update
delete



PostgreSQL



ORACLE®

IBM | DB2.

insert
update
delete

Several possible events
can fire one trigger



PostgreSQL



ORACLE®



```
create trigger trigger_name  
before insert or update or delete  
on table_name  
for each row  
as  
begin  
...  
end
```

Some products let you have several different events that fire the same trigger (timing must be identical)



ORACLE®



```
create trigger trigger_name  
before delete  
on table_name  
for each row  
as  
begin  
    ...  
end
```



Other products allow only one trigger per event/timing, and one event per trigger.

```
create trigger trigger_name  
on table_name  
after insert, update, delete  
as  
begin  
    ...  
end
```

SQL Server is a bit special. Triggers are always after the statement, and syntax is different from other products. But several events can fire one trigger.



1

Modify input on the fly

before insert / update
for each row



modify by joining on inserted

As I have told you, which trigger you use depends on what you want to do. To modify data on the fly, the trigger must operate on each row, and be fired BEFORE the value is inserted (SQL Server forces you to "fix" things after the row was inserted)

1

Modify input on the fly

2

Check complex rules

before insert / update / delete
for each row



Microsoft®
SQL Server®

check by joining on inserted
and deleted.

Roll back if something wrong.

Similar story with complex rules. SQL Server is the only product that allows a rollback in a trigger.

1 Modify input on the fly

2 Check complex rules

3 Manage data redundancy

after insert / update / delete
for each row



Microsoft[®]
SQL Server

deleted/inserted

Data redundancy is only handled when the triggering event was successful, therefore AFTER.

9.3 Auditing

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Auditing 审计

One good example of managing some data redundancy is keeping an audit trail. It won't do anything for people who steal data (remember that SELECT cannot fire a trigger – although with the big products you can trace all queries), but it may be useful for checking people who modify data that they aren't supposed to modify. We'll do it with PostgreSQL.

This is what an audit table might look like. We'll store one row per changed column in the PEOPLE table.

PostgreSQL



```
create table people_audit(auditid      serial,  
                          peopleid       int not null,  
                          type_of_change char(1),  
                          column_name    varchar,  
                          old_value      varchar,  
                          new_value      varchar,  
                          changed_by     varchar,  
                          time_changed   datetime);
```

Multiple ways to do it ...

Another option might be to have one big string storing all the changes in XML or JSON format for instance.

```
create or replace function people_audit_fn()
returns trigger
as $$
begin
if tg_op = 'UPDATE'
then
insert into people_audit(peopleid,
                         type_of_change,
                         column_name,
                         old_value,
                         new_value,
                         changed_by,
                         time_changed);
select peopleid, 'U', column_name, old_value, new_value,
       current_user || '@'
          || coalesce(cast(inet_client_addr() as varchar, 'localhost'),
       current_timestamp
```

With PostgreSQL (only)
you need to create a
special function that
returns a trigger.

TG_OP is a system variable that says which operation fired the trigger (with other products you might say "when updating then")

```
from (select old.peopleid,
            'first_name' column_name,
            old.first_name old_value,
            new.first_name new_value
       where coalesce(old.first_name, '*')
             <> coalesce(new.first_name, '*'))
union all
    select old.peopleid,
            'surname' column_name,
            old.surname old_value,
            new.surname new_value
       where old.surname <> new.surname
union all
    select old.peopleid,
            'born' column_name,
            cast(old.born as varchar) old_value,
            cast(new.born as varchar) new_value
       where old.born <> new.born
union all
    select old.peopleid,
            'died' column_name,
            cast(old.died as varchar) old_value,
            cast(new.died as varchar) new_value
       where coalesce(old.died, -1) <> coalesce(new.died, -1)) modified;
```

Painful statement
checking column by
column if it was
changed.

```
create or or replace function people_audit_fn()
returns trigger
as
$$
begin
  if tg_op = 'UPDATE'
  then
    insert into people_audit(...)
    ...
  elsif tg_op = 'INSERT' then
    insert into people_audit(...)
    ...
  else
    insert into people_audit(...)
    ...
  end if;
  return null;
end;
$$ language plpgsql;
```

Rinse, repeat

It's easier for inserts and for deletes because every not null column should be recorded. For inserts values are in the NEW dummy row, and for deletes in the OLD one.

An AFTER/FOR EACH ROW trigger doesn't need to return anything; a BEFORE/FOR EACH ROW trigger must return a (usually modified) "row variable" which will be what the SQL engine will use for the operation



Once the function is ready you call it in the trigger.
With other products you could have the whole
code in the trigger body (between **begin ... end**),
or call there a regular stored procedure.

```
create trigger people_trg
after insert or update or delete on people
for each row
execute procedure people_audit_fn();
```



not "function" ...

```
insert into people(first_name, surname, born)  
values('Ryan', 'Gosling', 1980);
```

With the trigger, every new, not null value will be recorded.

people_audit

auditid	peopleid	type_of_change	column_name	old_value	new_value	changed_by	time_changed
1	95	I	first_name	NULL	Ryan	root@localhost	... 23:05:01
2	95	I	surname	NULL	Gosling	root@localhost	... 23:05:01
3	95	I	born	NULL	1980	root@localhost	... 23:05:01

```
insert into people(first_name, surname, born)
values('George', 'Clooney', 1961);
```

people_audit

auditid	peopleid	type_of_change	column_name	old_value	new_value	changed_by	time_changed
1	95	I	first_name	NULL	Ryan	root@localhost	... 23:05:01
2	95	I	surname	NULL	Gosling	root@localhost	... 23:05:01
3	95	I	born	NULL	1980	root@localhost	... 23:05:01
4	96	I	first_name	NULL	George	root@localhost	... 23:05:02
5	96	I	surname	NULL	Clooney	root@localhost	... 23:05:02
6	96	I	born	NULL	1961	root@localhost	... 23:05:02

```
insert into people(first_name, surname, born)
values('Frank', 'Capra', 1897);
```

people_audit

auditid	peopleid	type_of_change	column_name	old_value	new_value	changed_by	time_changed
1	95	I	first_name	NULL	Ryan	root@localhost	... 23:05:01
2	95	I	surname	NULL	Gosling	root@localhost	... 23:05:01
3	95	I	born	NULL	1980	root@localhost	... 23:05:01
4	96	I	first_name	NULL	George	root@localhost	... 23:05:02
5	96	I	surname	NULL	Clooney	root@localhost	... 23:05:02
6	96	I	born	NULL	1961	root@localhost	... 23:05:02
8	97	I	first_name	NULL	Frank	root@localhost	... 23:05:03
9	97	I	surname	NULL	Capra	root@localhost	... 23:05:03
			born	NULL	1897	root@localhost	... 23:05:03

```
update people
set died = 1991
where first_name = 'Frank'
and surname = 'Capra';
```

people_audit

auditid	peopleid	type_of_change	column_name	old_value	new_value	changed_by	time_changed
1	95	I	first_name	NULL	Ryan	root@localhost	... 23:05:01
2	95	I	surname	NULL	Gosling	root@localhost	... 23:05:01
3	95	I	born	NULL	1980	root@localhost	... 23:05:01
4	96	I	first_name	NULL	George	root@localhost	... 23:05:02
5	96	I	surname	NULL	Clooney	root@localhost	... 23:05:02
6	96	I	born	NULL	1961	root@localhost	... 23:05:02
7	97	I	first_name	NULL	Frank	root@localhost	... 23:05:03
8	97	I	surname	NULL	Capra	root@localhost	... 23:05:03
9	97	I	born	NULL	1897	root@localhost	... 23:05:03
10	97	U	died	NULL	1991	root@localhost	... 23:05:04

```
delete from people
where first_name = 'Ryan'
and surname = 'Gosling';
```

people_audit

auditid	peopleid	type_of_change	column_name	old_value	new_value	changed_by	time_changed
1	95	I	first_name	NULL	Ryan	root@localhost	... 23:05:01
2	95	I	surname	NULL	Gosling	root@localhost	... 23:05:01
3	95	I	born	NULL	1980	root@localhost	... 23:05:01
4	96	I	first_name	NULL	George	root@localhost	... 23:05:02
5	96	I	surname	NULL	Clooney	root@localhost	... 23:05:02
6	96	I	born	NULL	1961	root@localhost	... 23:05:02
7	97	I	first_name	NULL	Frank	root@localhost	... 23:05:03
8	97	I	surname	NULL	Capra	root@localhost	... 23:05:03
9	97	I	born	NULL	1897	root@localhost	... 23:05:03
10	97	U	died	NULL	1991	root@localhost	... 23:05:04
11	95	D	first_name	Ryan	NULL	root@localhost	... 23:05:05
12	95	D	surname	Gosling	NULL	root@localhost	... 23:05:05
13	95	D	born	1980	NULL	root@localhost	... 23:05:05



CAUTION

for each row

triggers

Beware of FOR EACH ROW triggers, you cannot do anything in them.

```
SQL> create table test(id int, label varchar(20), unique(id));
```

Table created.

```
SQL> insert into test(id, label) values(1, 'This is line 1');
```

1 row created.

Take note!

```
SQL> insert into test(id, label) values(2, 'This is line 2');
```

1 row created.

```
SQL> select * from test;
```

ID LABEL

```
-----  
1 This is line 1  
2 This is line 2
```

SQL>

```
SQL> update test set id = case id when 1 then 2 else 1 end;
```

2 rows updated.

```
SQL> select * from test;
```

ID	LABEL
2	This is line 1
1	This is line 2

```
SQL>
```

If I switch the values between the two columns, it works
(same behaviour with all DBMS products except PostgreSQL)

Value of id in the other row when you update one row?

Constraint?

STABLE CONSISTENT STATE

What happens is that consistency and constraints are checked AFTER the update, not DURING. During the update, the state is undefined.

during update, constraints 不起作用



**STABLE
CONSISTENT
STATE**

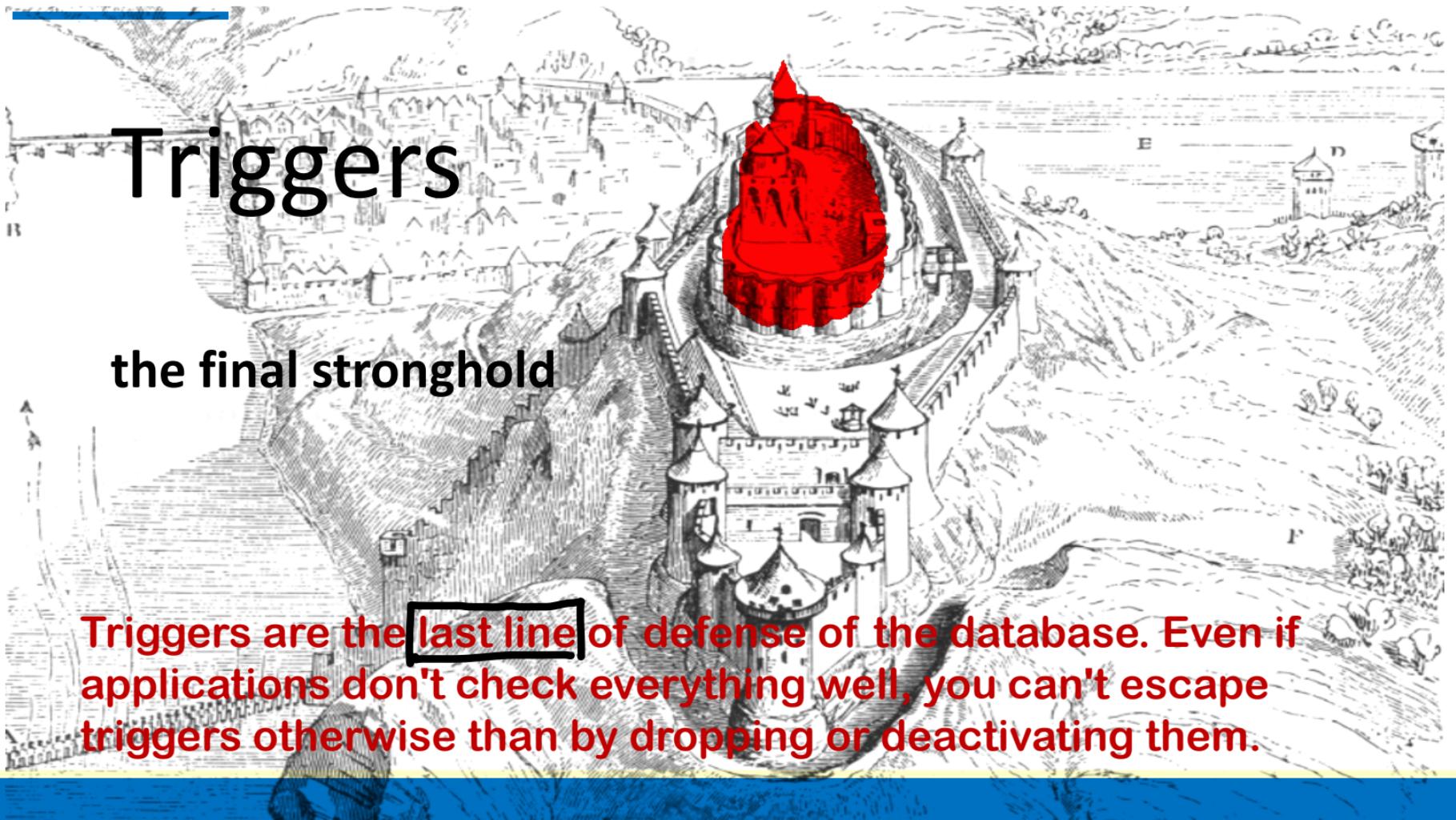


DON'T
look at
other rows
of the
modified table
in
for each row
triggers

Triggers

the final stronghold

Triggers are the **last line** of defense of the database. Even if applications don't check everything well, you can't escape triggers otherwise than by dropping or deactivating them.



Triggers = complexity

if you can,
AVOID
triggers

This being said, they add a lot of complexity, a simple operation may behave weirdly because of what a poorly written trigger does, and triggers are pretty much below the radar. Knowing whether a trigger is active or not requires special checks.

Additionally, they are often used to "fix" issues that should not have existed in the first place and often result of a poor database design.

if possible ...

Don't use triggers to fix design issues

Use stored procedures preferably to triggers

However, if users can access the database otherwise than through your programs ...

Use triggers if there are multiple access points

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Triggers: the last line of defense.

Only when you can't do otherwise.