Functions in PGPLSQL

functions in psql
create or replace function funcName()
return **s** returntype as **$$**
begin
raise notice 'Hello Birb!';
end;
$$ language langName
The two $ are always necessary. Also note the returns with an s and the language at the end.
Which **MUST** be a **PROCEDURAL LANGUAGE**, so c++ doesn't work here.

Parameters are handled like in any language
func(x bigint, y bigint)
you can also define multiple return types
func(variadic a numeric[])
or a generic return
func(param anyelement)

Variable Declaration:
returns void as $$
DECLARE
x bigint; y bigint;
BEGIN ....

Variable manipulation: x := 6 + 4

if: IF n = 0 THEN RETURN 1;
(optional)ELSE RETURN 2; END IF;
ELSIF also possible (note elsif not elseif)

case x when 1, 2 then msg := 'one or two'; end case;
essentially this checks if x is 1 **OR** 2

case when x between 0 and 10 then ....
similar but with a range, both can be simulated by if else.

Exceptions: BEGIN z:= x / y;
EXCEPTION WHEN division-by-zero
THEN z:= 0; (or error rather) END;
if you want to catch all: WHEN others THEN
often used after exception: RAISE; (show error)

For Loop: For var IN query LOOP
statements END LOOP;
for r in SELECT * FROM ang LOOP
RETURN NEXT r; END LOOP; RETURN; END;
note that the return next doesn't return
you store it in a buffer
and return it at the end of the function.
for infinite loops: FOR i IN 1..max LOOP;

update and insert: INSERT INTO ANG VALUES(...);
UPDATE ang set salary = salary + 500
where name = 'dashie';
interestingly, after the where name = 'dashie'
you can use if not found then (handle error)
this allows for easier error handling.

queries: **execute** 'SELECT * from ang'
—— into result; return result; END;

comments are done by either – or /* */ for multiline

anonymous function: you can omit
the name and just write do $$ ...

cursor: declare curs CURSOR FOR query;
BEGIN OPEN curs; LOOP do something CLOSE curs; END;
Cursors are essentially just iterables.
cursors can also be unbound curs1 refcursor
or they can be parameterized curs3 cursor(arg)

PL/pgSQL: Datentypen

- PL/pgSQL übernimmt alle SQL Datentypen:
  - Boolean:
  - Zahlen: int, integer, number
  - Strings, Datum, etc.
  - Arrays: alle Datentypen gefolgt von „[]“, z.B. int[]
  - Weitere: JSON, etc.
- ... ergänzt mit zusätzlichen Datentypen:
  - var5 angestellter.id%type; -- abgeleiteter col.-Typ
  - var6 angestellter%rowtype; -- abgeleitet von Tabelle
  - var7 record; -- generischer Record (This is a simple entry inside a query aka 1 person)
  - var8 anyelement; -- generischer Typ gemäss Fn.-Argument, vgl. nachfolgend
  - curs1 refcursor; curs2 cursor ...; -- vgl. nachfolgend

arrays: SELECT '1,2,3'::int[]
or SELECT ARRAY[1,2,3]
var int[] only in variable declaration.
!!arrays start with 1 in psql !!

return types: all of the above AND void,
SETOF type (array of a type), TABLE, Trigger

Arrays: Accessoren

```
create table tictactoe as
  (select i as id,
          array[ ['z1','k1','z1','k2','],
                 ['z2','k1','z2','k2','],
                 ['z3','k1','z3','k2'] ] as board);
```

Index Query: intuitiv wie eine Koordinate (“1-basiert”: Start mit 1 nicht 0):
`select board[1][1] from tictactoe;`
`-- z1 k1`

Slice Query: “Untergrenze:Obergrenze” für jede Dimension:
`select board[2:3][1:1] from tictactoe;`
`-- {{z2 k1},{z3 k1}}`

Max-Bound-Abkürzung “[2]” **vermeiden** (Verwechslungsgefahr), besser [1:2]
`select board[2:3][2] from tictactoe;  -- [2]=>[1:2]`
`-- {{z2 k1,z2 k2},{z3 k1,z3 k2}}`

Suche mit **ANY**:
`select * from tictactoe where 'z2 k2' = any(board);`
`-- 1;{{z1 k1,z1 k2},{z2 k1,z2 k2},{z3 k1,z3 k2}}`

Arrays: Operatoren

- «Is equal»: =
  - SELECT ARRAY[1,2,3] = ARRAY[1,2,3]; true
  - SELECT ARRAY[3,2,1] = ARRAY[1,2,3]; false
- «Contains»: @>
  - SELECT ARRAY[1,7,4,2,6] @> ARRAY[2,7];
- «Is contained by»: <@
  - SELECT ARRAY[2,7] <@ ARRAY[1,7,4,2,6];
- «Overlaps»: &&
  - SELECT ARRAY[1,4,3] && ARRAY[2,1]

hstore / map:
Create und Insert:

```
CREATE TABLE test (id integer, col2 hstore, col3 text);

INSERT INTO test VALUES (1, 'a=>123, b=>foo, c=>bar'::hstore, NULL);

SELECT * FROM test;
id | col2                                | col3
---+-------------------------------------+------
1 | "a"=>"123", "b"=>"foo", "c"=>"bar" | null
(1 row)
```

Queries:
- List all keys
  `SELECT akeys(mykvpfield) FROM ...`
- Get all key-value pairs
  `SELECT each(mykvpfield) FROM ...`
- Get key value (as text)
  `SELECT mykvpfield->'name' FROM ...`
- Test if left hstore is contained in right hstore:
  `... WHERE mykvpfield @> 'tourism=>zoo'; -- or hstore('tourism','zoo')`

Operatoren:
- “->” get value for key : SELECT 'a=>x, b=>y'::hstore -> 'a'
- „@>“, etc. ... ähnlich wie Array-Operator

hstore supports GIST/GIN indexing

	FUNCTION	PROCEDURE
Use in an expression	✔	✘
Return a value	✔	✘
Return values as OUT parameters	✔ (PG Spezialität)	✔ (PG v14)
Return a single result set	✔ (as table fn.)	✔
Return multiple result sets	✘	✔
Contain transactions	✘	✔
Make it run using ...	EXECUTE	CALL

also note that type%rowtype is used like this:
r ang%rowtype -> for r in select * from ang;

important to know, you can always use these functions to manipulate queries, for example
select upper(name) from ang;
depending on the function you can also
select generatetab(1,10)

- Es gibt zusätzlich IN, OUT, INOUT
  `create function foo(IN p1 type)...`
  - IN: call by value; Variablen oder Ausdrücke als Argument
  - OUT: call by reference; nur Variablen als Argument
  - INOUT: beides

cast: cast(input as type);
cast(record.id as text);

stored procedures are nothing but a chaining of functions:
- Schritt 1 in PL/pgSQL: siehe Beispiel 3 (SP-Funktion mit in/out –Parametern)
- Schritt 2: Deklaration in Java/JPA (aka Registrierung in JPA):

```
@NamedStoredProcedureQuery(
  name = "MySum", -- JPA-Objekt
  procedureName = "mysum", -- Name der SP-Fn. (DB-Objekt)
  parameters = {
    @StoredProcedureParameter(mode = ParameterMode.IN, type = Double.class, name =
"x"),
    @StoredProcedureParameter(mode = ParameterMode.IN, type = Double.class, name =
"y"),
    @StoredProcedureParameter(mode = ParameterMode.OUT, type = Double.class, name =
"sum")
  }
)
```

- Schritt 3: Call it!

```
StoredProcedureQuery query = this.em.createNamedStoredProcedureQuery("MySum");
query.setParameter("x", 1.23d);
query.setParameter("y", 4.56d);
query.execute();
Double sum = (Double) query.getOutputParameterValue("sum");
```

some good to know things: plain SQL is more efficient.
write variables lower case for sql
use cast over typename -> not select date '2022-06-07'

Triggers

- sind DB-Objekte und immer einer Tabelle zugeordnet
- werden in Stored Procedures programmiert
- haben keine Parameter
- können nicht direkt aufgerufen werden
- werden vom DBMS beim Eintreten eines Events aufgerufen
- haben bei der Ausführung die Rechte ihres Owners

- Trigger can pass parameters to function
- FOR EACH [statement | row]
- Events: INSERT, UPDATE, DELETE, TRUNCATE, INSTEAD OF
- Function executes BEFORE or AFTER changes

statement is once, row means once per row, aka for the entire table.

- Before triggers can change contents of new row
- After triggers can only respond to what has happened
  e.g. Foreign Keys
- Return values of AFTER triggers will be ignored
- Triggers execute in alphabetical order

```
The INSTEAD Trigger can be use
to avoid crashes:
-> INSTEAD OF UPDATE
-> ON UPDATE DO INSTEAD
for example, trying to update
a read-only view -> INSTEAD OF
UDPATE
```

- DDL für Triggers

```
CREATE | DROP | ALTER TRIGGER
  mytrigger …
  ON mytable …
```

- Syntax-Beispiel CREATE TRIGGER:

```
CREATE TRIGGER mytrigger
  AFTER INSERT OR UPDATE
  ON mytable
  FOR EACH ROW
  EXECUTE PROCEDURE mytriggerfn();
```

Syntax-Beispiel Trigger-Fn. passend zu Trigger:

```
CREATE FUNCTION mytriggerfn()
RETURNS TRIGGER --
AS $$
  <<body>>
$$ language plpgsql;
```

- Eine Trigger-Fn. hat keine Fn.-Parameter
- Diese werden über Trigger-Fn.-Variablen übergeben, u.a.:
  - TG_NARGS Anzahl Parameter
  - TG_ARGV[] Array von Parametern als TEXT

PL/pgSQL: Trigger-Fn.-Variablen

- TG_NAME Name des Triggers (TG)
- TG_WHEN BEFORE oder AFTER
- TG_LEVEL ROW od. STATEMENT
- TG_OP INSERT, UPDATE, DELETE, (TRUNCATE)
- TG_RELID OID der Tabelle
- TG_RELNAME Name der Tabelle
- TG_TABLE_SCHEMA Schema der Tabelle

```
CREATE OR REPLACE FUNCTION dt_trigger_func()
  RETURNS TRIGGER AS $$
BEGIN
  IF (TG_OP = 'INSERT') THEN
    NEW.creation_date := now();
  ELSIF (TG_OP = 'UPDATE') THEN
    NEW.modification_date := now();
  END IF;
  RETURN NEW;
END
$$ LANGUAGE plpgsql;

CREATE TRIGGER dt_trigger
BEFORE INSERT OR UPDATE
ON mytable
FOR EACH ROW
EXECUTE PROCEDURE dt_trigger_func();
```

BEFORE-Trigger : Falls RETURN null → wird Operation abgebrochen

Return types: RETURN NEW -> returns a new table/row
RETURN OLD -> returns the old table/row
(but could change other rows!)
RETURN NULL -> cancel operation.

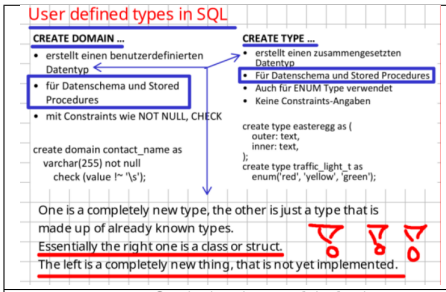
running order: before statement, before row, after row, after statement ->
and of course alphabetically.

inside the Trigger functions you can use the variables that don't matter aka can be ANY -> user
or the entered user from the trigger -> NEW.user
or explicitly the old one -> OLD.user
and last user defined stuff like -> SELECT 'I'
which just places an I as the variable
or something like now() for timestamps.

Triggers make the database slower and harder to maintain.
some databases therefore let you disable them if you want.
On a table basis.
Also watch out for cascading effects of triggers
they might cause something else to be deleted.

Stored Procedures are really helpful for security
They have all the prviliges, but only
allow the user to do what the
creator has predefined.

User defined types in SQL



Optimization and indexing

The basics of indexing is that is saves
time on queries, but it uses more space,
and needs to be redone on udpate/insert.

Data stored in Pages / Heap (Collection of Pages)
Indexing on either can be possible.
ex: Page index -> Primary key index
ex: Heap Index -> index on tables
PSQL does table cluster indexing
instead of integrated indexing -> key value (both indexed)

B-Tree: the default, can index multiple entries (only btree!)
CREATE UNIQUE INDEX name ON table (column [1,2...])

Hash Index: just like hashmap in programming
good for single or small multiple queries
bad for entire tables etc -> collision
hashing might take a long time with a lot of data.
B-tree almost always better!

GiST: balanced/treelike , Range/neighbor/fulltext search
used for geometric datatypes. SP-Gist for unbalanced trees.

GIN: General Inverted Index ”list of words
that point to documents” wtf?. Good for duplicates.
Good for hstore,Json,Arrays
Vergleich zu GiST:
- Ca. 3x schnellerer Zugriff
- Ca. 2 – 3x mehr Diskplatz
- Ca. 2 – 3x länger bis Index erstellt ist
- Ca. 10x langsamer bei Update

Bitmap indexing: Bitmap -> 0 1 stores Booleans/Enums
very fast read / slow update
in postgres **only implicit** use Brin instead.

BRIN: Block Range Index, stores min/max values as blocks
good for range search, sorted data, small disk usage
data is naturally sorted, address next to postal code.

Bloom Index -> equality search,
Trigram Index -> Full text search
RUM , non-default-GIN jsonb-path-ops

creating index:
CREATE INDEX <indexname> ON <table(attribute)>;
and: DROP INDEX <indexname>;

default index order for psql is btree,ASC,NULL first

Index-Variationen

- Zusammengesetzter Index
  - Bsp.: CREATE INDEX idx_addr ON addr(phone,name); kann für Queries auf phone und "phone AND name" genutzt werden, sowie für bestimmte Q. auf name; jedoch nicht für Suffix-Q. "... LIKE %name;"
- Index mit INCLUDE
  - Bsp.: CREATE INDEX idx_addr ON addr(phone) INCLUDE (name) ;

Index-Variationen ff.

- Partieller Index
  - Bsp.: CREATE INDEX idx_addr ON addr(status) WHERE status='active';
- Indexe mit Funktionen / Ausdrücke ("Funktionaler I.")
  - Bsp.: CREATE INDEX idx_addr ON addr(lower(name));
- Nicht nur PostgreSQL!

PG planner join strategies: Nested Loop,Merge,Hash
-Nested Loop: for r in right row r == for l in left row....
good for small tables, easy to setup
-Merge: Merge rows one after the other
higher starting cost, good for bigger tables
-Hash: Hash the row then compare to other row
only == check possible, high starting cost, low execution cost

PG planner scans: Full,Index,Index Only, Bitmap
-full scans the entire table
-index scans index and more (if necessary)
-index only only scans index
-Bitmap scans the bitmap generated by an index.

The steps of optimization
1. generate the plan of transaction
2. reform the term to optimize perfomance
without knowledge of the internal structure.
-> all values are considered equal
3. optimization based on: available indexes, analysis and costs
4. generate all possible plans to calculate cost
5. analyze said plans -> how many tuples, what kind...
6. profit?

selectivety this is the ratio of tuples a query returns
low selectivety would mean high number of rows
an example is select * from table where sex='Male'
the opposite would be high selectivety.

density this is the ratio of duplicates a query returns
the more duplicates the higher the density.
you can therefore also make graphs about the distribution
of density -> names a-c low g-l high

best practices: index only when selectivety over 10%
numeric comparison over text, join over subquery,
use short attributes, understand the query -> user,
don't select * from, don't use cross products.

distributed database systems
the advantages and disadvantages are obvious:
+ better performance – more complex
+better reliability + better management

homogeneous database system:
> all nodes have identical software
> all nodes know about each other and work toghether
> shows itself to the user as one big system

heterogeneous database system:
> nodes can have different software
> as well as different schemas -> can lead to problems
> nodes might NOT know about each other.

fragmentation: this is the splitting of schemas
into multiple Nodes -> table 1 in node1
table 2 in node 2.

In Psql the horizontal fragmentation happens in 3 ways:
> 1 or more attributes for "partitioning key"
> "list" explicit designation
> hash function (ex: Modulo)

In Graph stores this would be called "sharding"
an example for this is the MongoDB
horizontal paritioning and allocation within a single node

replication: this is the duplication of data in schemas
this means table 1 might be on node1 and 2.
vertical -¿ splitting of columns
row1 in node1, row2 in node2
horizontal -¿ splitting of rows
part of column in node1 part of column in node2

unidirectional:

bidirectional:

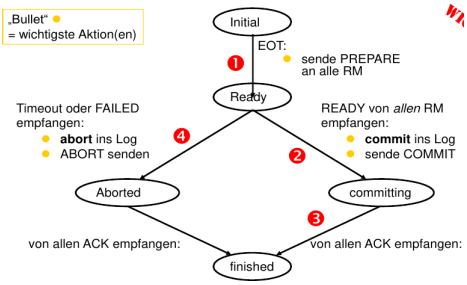
synchronous:

asynchronous:

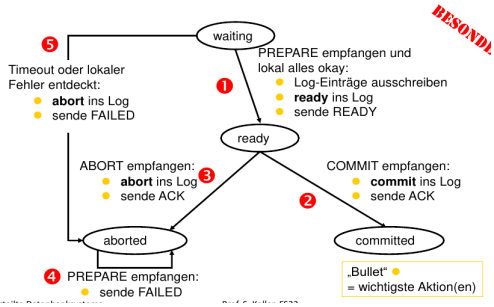
allocation: this is the distribution of work to the nodes
node1 might handle query or part of query1
while node2 handles something else.

as already stated above, the user doesn't see anything about
fragmentation or similar, the user simply interacts
with the schema and executes transactions.
these **transactions are always local**
This means that the user will talk to **Transaction Manager**
that will handle the transaction and call the necessary
functions on the **Resource Managers** (inside nodes).

Zustandsübergänge 2PC: Transaction Manager (TM)



Zustandsübergänge 2PC ff.: Resource Manager (RM)



case TM failed/restart:
> if the TM crashes before the commit message -> abort
> if the TM crashes after RM respond ready -> block RM
this is one of the main problems btw...

case RM failed/restart:
> if no entry in log, RM aborts
> if READY-Entry available -> RM asks TM what to do.
> if COMMIT-Entry available -> RM redoes transaction

case message dropped:
> if the prepare statement gets lost,
or the RM doesn't respond, then the TM
simply aborts the transaction for all.
> if RM doesn't get a response in READY state
then the RM will remind the TM until it gets one.

easiest way to convert PSQL to JSON is a temporary table.

```
create temporary table angprojj as
select
  ang.persnr,                    joins are omitted,
  jsonb_build_object(            would be below...
    'persnr', ang.persnr,
    'name', min(ang.name),
    'projects', jsonb_agg(trim(proj.bezeichnung))
  ) as angwithproj
```

you can also directly **select json_build_object**
or **select json_build_object(jsonb_agg(tmp))**
also note the jsonb_agg(trim (proj.bezeichnung))
for simplicity, the joins on the picture are removed.

The jsonb agg is necessary for aggregation
otherwise the join wouldn't work for JSON.

JSON-Daten abfragen

```
select persnr, angwithproj
from angprojj
where angwithproj->>'persnr' = 1001::text;

select persnr, angwithproj
from angprojj
where (angwithproj->>'name') like 'Marxer%'

select persnr, jsonb_pretty(angwithproj)
from angprojj
where angwithproj->'projects' @>
      to_jsonb('Uranus'::text)
```

Get as text:

```
select persnr, angwithproj->'projects' as projects
from angprojj;
```

=> 23 rows

CROSS JOIN zweier Tabellen. jsonb_array_elements_text() gibt „setof text" zurück:

```
select persnr, angwithproj->>'name' as persname, value as projname
from angprojj, jsonb_array_elements_text(angwithproj->'projects');
```

=> 29 rows

JOIN LATERAL = CROSS JOIN und Boolean: Output identisch mit oben :

```
select persnr, angwithproj->>'name' as persname, value as projname
from angprojj
cross join lateral jsonb_array_elements_text(angwithproj->'projects');
```

=> 29 rows