

Data Processing Inside PostgreSQL

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There are indisputable advantages of doing data processing in the database rather than in each application. This presentation explores the ability to push data processing into the database using SQL, functions, triggers, and the object-relational features of POSTGRESQL.

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Pre-SQL Data Access

No one wants to return to this era:

- Complex cross-table access
- Single index
- No optimizer
- Simple WHERE processing
- No aggregation



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SQL Data Access

You probably take these for granted:

- Easy cross-table access, with optimizer assistance
- Complex WHERE processing
- Transaction Control
- Concurrency
- Portable language (SQL)

Welcome to the
next generation
of data storage.



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Contents

1. SQL
2. Functions and Triggers
3. Customizing Database Features

1. SQL

Make full use of the SQL tools available.



2. Functions and Triggers

Put your programs
in the database.



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3. Customizing Database Features

Change the
database features.



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1. SQL



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Table Constraints

Table creation requires concentration.



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Unique Test in an Application

```
BEGIN;  
LOCK tab;  
SELECT ... WHERE col = key;  
if not found  
    INSERT (or UPDATE)  
COMMIT;
```

UNIQUE Constraint

```
CREATE TABLE tab  
(  
    col ... UNIQUE  
);
```

```
CREATE TABLE customer (id INTEGER UNIQUE);
```

Preventing NULLs

```
if (col != NULL)  
    INSERT/UPDATE;
```

NOT NULL Constraint

```
CREATE TABLE tab  
(  
    col ... NOT NULL  
);
```

```
CREATE TABLE customer (name TEXT NOT NULL);
```

Primary Key Constraint

- UNIQUE
- NOT NULL

```
CREATE TABLE customer (id INTEGER PRIMARY KEY);
```

Ensuring Table Linkage: Foreign → Primary

```
BEGIN;  
SELECT *  
FROM primary  
WHERE key = col  
FOR UPDATE;  
if found  
    INSERT (or UPDATE) INTO foreign;  
COMMIT;
```


Primary → Foreign

```
BEGIN;  
SELECT *  
FROM foreign WHERE col = key FOR UPDATE;  
if found      ?  UPDATE/DELETE primary;  
COMMIT;
```

Ensuring Table Linkage, Example

```
CREATE TABLE statename (  
    code CHAR(2) PRIMARY KEY,  
    name VARCHAR(30)  
);  
  
CREATE TABLE customer  
(  
    customer_id INTEGER,  
    name VARCHAR(30),  
    telephone VARCHAR(20),  
    street VARCHAR(40),  
    city VARCHAR(25),  
    state CHAR(2) REFERENCES statename,  
    zipcode CHAR(10),  
    country VARCHAR(20)  
);
```

Larger Example

```
CREATE TABLE customer
(
    customer_id INTEGER PRIMARY KEY,
    name        VARCHAR(30),
    telephone   VARCHAR(20),
    street      VARCHAR(40),
    city        VARCHAR(25),
    state       CHAR(2),
    zipcode     CHAR(10),
    country     VARCHAR(20)
);

CREATE TABLE employee
(
    employee_id INTEGER PRIMARY KEY,
    name        VARCHAR(30),
    hire_date   DATE
);
```

Larger Example

```
CREATE TABLE part (  
    part_id    INTEGER PRIMARY KEY,  
    name       VARCHAR(30),  
    cost       NUMERIC(8,2),  
    weight     FLOAT  
);  
  
CREATE TABLE salesorder (  
    order_id   INTEGER,  
    customer_id INTEGER REFERENCES customer,  
    employee_id INTEGER REFERENCES employee,  
    part_id    INTEGER REFERENCES part,  
    order_date DATE,  
    ship_date  DATE  
);
```

Prevent Change to Primary

```
BEGIN;  
SELECT ...  
FROM foreign  
WHERE col = key  
FOR UPDATE;  
if found  
    ABORT;  
UPDATE/DELETE primary;  
COMMIT;
```

REFERENCES Constraint, NO ACTION/RESTRICT (default)

```
CREATE TABLE foreign
(
    col ... REFERENCES primary (col)
        ON UPDATE NO ACTION -- not required
        ON DELETE NO ACTION -- not required
);
```

Cascade Change to Primary

```
BEGIN;  
SELECT ...  
FROM foreign  
WHERE col = key  
FOR UPDATE;  
if found  
    UPDATE/DELETE foreign;  
UPDATE/DELETE primary;  
COMMIT;
```

REFERENCES Constraint, CASCADE

```
CREATE TABLE foreign (  
    col ... REFERENCES primary (col)  
        ON UPDATE CASCADE  
        ON DELETE CASCADE  
);
```


Set Foreign to NULL on Change to Primary

```
BEGIN;  
SELECT ...  
FROM foreign  
WHERE col = key  
FOR UPDATE;  
if found  
    UPDATE foreign SET col = NULL;  
UPDATE/DELETE primary;  
COMMIT;
```

REFERENCES Constraint, SET NULL

```
CREATE TABLE foreign
(
    col ... REFERENCES primary (col)
        ON UPDATE SET NULL
        ON DELETE SET NULL
);
```

Set Foreign to DEFAULT on Change to Primary

```
BEGIN;  
SELECT ...  
FROM foreign  
WHERE col = key  
FOR UPDATE;  
if found  
    UPDATE foreign SET col = DEFAULT;  
UPDATE/DELETE primary;  
COMMIT;
```

REFERENCES Constraint, SET DEFAULT

```
CREATE TABLE foreign  
(  
    col ... REFERENCES primary (col)  
        ON UPDATE SET DEFAULT  
        ON DELETE SET DEFAULT  
);
```

```
CREATE TABLE order (cust_id INTEGER REFERENCES customer (id));
```

Controlling Data

```
if col > 0 ...  
  (col = 2 OR col = 7) ...  
  length(col) < 10 ...  
  INSERT/UPDATE tab;
```

CHECK Constraint

```
CREATE TABLE tab  
(  
    col ... CHECK (col > 0 ...  
);
```

```
CREATE TABLE customer (age INTEGER CHECK (age >= 0));
```

Check Constraint Example

```
CREATE TABLE friend2 (  
    firstname VARCHAR(15),  
    lastname  VARCHAR(20),  
    city      VARCHAR(15),  
    state     CHAR(2)      CHECK (length(trim(state)) = 2),  
    age       INTEGER      CHECK (age >= 0),  
    gender    CHAR(1)      CHECK (gender IN ('M','F')),  
    last_met  DATE         CHECK (last_met BETWEEN '1950-01-01'  
                                AND CURRENT_DATE),  
    CHECK (upper(trim(firstname)) != 'ED' OR  
          upper(trim(lastname)) != 'RIVERS')  
);
```

```
INSERT INTO friend2  
VALUES ('Ed', 'Rivers', 'Wibbleville', 'J', -35, 'S', '1931-09-23');
```

ERROR: ExecAppend: rejected due to CHECK constraint friend2_last_met

Default Column Values

```
if col not specified  
    col = DEFAULT;  
INSERT/UPDATE tab;
```


DEFAULT Constraint

```
CREATE TABLE tab  
(  
    quantity ... DEFAULT 1  
);
```

```
CREATE TABLE customer (created timestamp DEFAULT CURRENT_TIMESTAMP);
```

Auto-Numbering Column

```
CREATE TABLE counter (curr INTEGER);  
INSERT INTO counter VALUES (1);  
...  
BEGIN;  
val = SELECT curr FROM counter FOR UPDATE;  
UPDATE counter SET curr = curr + 1;  
COMMIT;  
INSERT INTO tab VALUES (... val ...);
```

SERIAL/Sequence

```
CREATE TABLE tab  
(  
    col SERIAL  
);
```

```
CREATE TABLE tab  
(  
    col INTEGER DEFAULT nextval('tab_col_seq')  
);
```

```
CREATE TABLE customer (id SERIAL);
```

```
CREATE SEQUENCE customer_id_seq;  
CREATE TABLE customer (id INTEGER DEFAULT nextval('customer_id_seq'));
```

Constraint Macros, DOMAIN

```
CREATE DOMAIN phone AS CHAR(12)
    CHECK (VALUE ~ '^[0-9]{3}-[0-9]{3}-[0-9]{4}$');
CREATE TABLE company ( ... phnum phone, ...);
```

Using SELECT's Features



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ANSI Outer Joins - LEFT OUTER

```
SELECT *  
FROM tab1, tab2  
WHERE tab1.col = tab2.col
```

```
UNION
```

```
SELECT *  
FROM tab1  
WHERE col NOT IN  
(  
    SELECT tab2.col  
    FROM tab2  
);
```

```
SELECT *  
FROM tab1 LEFT JOIN tab2 ON tab1.col = tab2.col;
```

ANSI Outer Joins - RIGHT OUTER

```
SELECT *  
FROM tab1, tab2  
WHERE tab1.col = tab2.col
```

```
UNION
```

```
SELECT *  
FROM tab2  
WHERE col NOT IN  
(  
    SELECT tab1.col  
    FROM tab1  
);
```

```
SELECT *  
FROM tab1 RIGHT JOIN tab2 ON tab1.col = tab2.col;
```

ANSI Outer Joins - FULL OUTER

```
SELECT *
FROM tab1, tab2
WHERE tab1.col = tab2.col
UNION
SELECT *
FROM tab1
WHERE col NOT IN
(
    SELECT tab2.col
    FROM tab2
)
UNION
SELECT *
FROM tab2
WHERE col NOT IN
(
    SELECT tab1.col
    FROM tab1
);

SELECT *
FROM tab1 FULL JOIN tab2 ON tab1.col = tab2.col;
```


ANSI Outer Join Example

```
SELECT *  
FROM customer LEFT JOIN order ON customer.id = order.cust_id;
```

Aggregates

SUM()

```
total = 0
FOREACH val IN set
    total = total + val;
END FOREACH

SELECT SUM(val) FROM tab;
```

Aggregates

MAX()

```
max = MIN_VAL;  
FOREACH val IN set  
    if (val > max)  
        max = val;  
END FOREACH
```

```
SELECT MAX(val) FROM tab;
```

```
SELECT MAX(cost) FROM part;
```

Aggregates

GROUP BY SUM()

```
qsort(set)
```

```
save = '';
```

```
total = 0;
```

```
FOREACH val IN set
```

```
    if val != save and save != ''
```

```
    {
```

```
        print save, total;
```

```
        save = val;
```

```
        total = 0;
```

```
    }
```

```
    total = total + amt;
```

```
END FOREACH
```

```
if save != ''
```

```
    print save, total;
```

```
SELECT val, SUM(amt) FROM tab GROUP BY val;
```

Aggregates, GROUP BY MAX()

```
save = '';
max = MIN_VAL;
FOREACH val IN set
    if val != save and save != ''
    {
        print save, max;
        save = val;
        max = MIN_VAL;
    }
    if (amt > max)
        max = amt;
END FOREACH
if save != ''
    print save, max;

SELECT val, MAX(amt) FROM tab GROUP BY val;
```

GROUP BY Examples

```
SELECT part, COUNT(*)  
FROM order  
ORDER BY part;
```

```
SELECT cust_id, SUM(due)  
FROM order  
GROUP BY cust_id  
ORDER BY 2 DESC;
```

Merging SELECTs, UNION

```
SELECT * INTO TEMP out FROM ...  
INSERT INTO TEMP out SELECT ...  
INSERT INTO TEMP out SELECT ...  
SELECT DISTINCT ...
```

```
SELECT *  
UNION  
SELECT *  
UNION  
SELECT *;
```

Joining SELECTs, INTERSECT

```
SELECT * INTO TEMP out;  
DELETE FROM out WHERE out.* NOT IN (SELECT ...);  
DELETE FROM out WHERE out.* NOT IN (SELECT ...);
```

```
SELECT *  
INTERSECT  
SELECT *  
INTERSECT  
SELECT *;
```


Subtracting SELECTs, EXCEPT

```
SELECT * INTO TEMP out;  
DELETE FROM out WHERE out.* IN (SELECT ...);  
DELETE FROM out WHERE out.* IN (SELECT ...);
```

```
SELECT *  
EXCEPT  
SELECT *  
EXCEPT  
SELECT *;
```

Controlling Rows Returned, LIMIT/OFFSET

```
DECLARE limdemo CURSOR FOR SELECT ...  
FOR i = 1 to 5  
    FETCH IN limdemo  
END FOR
```

```
SELECT *  
LIMIT 5;
```

```
DECLARE limdemo CURSOR FOR SELECT ...  
MOVE 20 IN limdemo  
FOR i = 1 to 5  
    FETCH IN limdemo;  
END FOR
```

```
SELECT *  
OFFSET 20 LIMIT 5;
```

Controlling Rows Returned, LIMIT/OFFSET Example

```
SELECT order_id, balance  
FROM order  
ORDER BY balance DESC  
LIMIT 10;
```

Locking SELECT Rows, FOR UPDATE

```
BEGIN;  
LOCK tab;  
SELECT * FROM CUSTOMER WHERE id = 4452;  
UPDATE customer SET balance = 0 WHERE id = 4452;  
COMMIT;  
  
BEGIN;  
SELECT *  
FROM customer  
WHERE id = 4452  
FOR UPDATE;  
  
...  
UPDATE customer  
SET balance = 0  
WHERE id = 4452;  
COMMIT;
```

Temporary Tables

```
CREATE TABLE tab (...);
```

```
...
```

```
DROP TABLE tab;
```

```
CREATE TEMP TABLE tab (...);
```

```
SELECT *
```

```
INTO TEMPORARY hold
```

```
FROM tab1, tab2, tab3
```

```
WHERE ...
```

Automatically Modify SELECT, VIEW - One Column

```
SELECT col4  
FROM tab;
```

```
CREATE VIEW view1 AS  
SELECT col4  
FROM tab;
```

```
SELECT * FROM view1;
```

Automatically Modify SELECT, VIEW - One Row

```
SELECT *  
FROM tab  
WHERE col = 'ISDN';
```

```
CREATE VIEW view2 AS  
SELECT *  
FROM tab  
WHERE col = 'ISDN';
```

```
SELECT * FROM view2;
```

Automatically Modify SELECT, VIEW - One Field

```
SELECT col4  
FROM tab  
WHERE col = 'ISDN';
```

```
CREATE VIEW view3 AS  
SELECT col4  
FROM tab  
WHERE col = 'ISDN';
```

```
SELECT * FROM view3;
```


Automatically Modify, INSERT/UPDATE/DELETE Rules

```
INSERT INTO tab1 VALUES (...);
```

```
INSERT INTO tab2 VALUES (...);
```

```
CREATE RULE insert_tab1 AS ON INSERT TO tab1 DO
```

```
INSERT INTO tab2 VALUES (...);
```

```
INSERT INTO tab1 VALUES (...);
```

Automatically Modify INSERT/UPDATE/DELETE Rules Example

```
CREATE TABLE service_request
(
    customer_id INTEGER,
    description text,
    cre_user text DEFAULT CURRENT_USER,
    cre_timestamp timestamp DEFAULT CURRENT_TIMESTAMP
);
```

```
CREATE TABLE service_request_log
(
    customer_id INTEGER,
    description text,
    mod_type char(1),
    mod_user text DEFAULT CURRENT_USER,
    mod_timestamp timestamp DEFAULT CURRENT_TIMESTAMP
);
```

Rules Example - Rule Definition

```
CREATE RULE service_request_update AS -- UPDATE rule  
ON UPDATE TO service_request  
DO  
    INSERT INTO service_request_log (customer_id, description, mod_type)  
    VALUES (old.customer_id, old.description, 'U');
```

```
CREATE RULE service_request_delete AS -- DELETE rule  
ON DELETE TO service_request  
DO  
    INSERT INTO service_request_log (customer_id, description, mod_type)  
    VALUES (old.customer_id, old.description, 'D');
```

Multi-User Consistency

- Atomic Changes
- Atomic Visibility
- Atomic Consistency
- Reliability

Notification, LISTEN/NOTIFY

`signal()/kill()`

`LISTEN myevent;`

`NOTIFY myevent;`

Application Walk-through



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2. Functions and Triggers

Placing Code
Into the Database:
Server-Side Functions



Single-Parameter Built-In Functions/Operator

```
SELECT factorial(10);
```

```
factorial
```

```
-----
```

```
3628800
```

```
SELECT 10!;
```

```
?column?
```

```
-----
```

```
3628800
```


Two-Parameter Built-in Function/Operator

```
SELECT date_mi('2003-05-20'::date, '2001-10-13'::date);
```

```
date_mi
```

```
-----
```

```
584
```

```
SELECT '2003-05-20'::date - '2001-10-13'::date;
```

```
?column?
```

```
-----
```

```
584
```

```
psql \dfS
```

```
psql \doS
```

Custom Server-Side Functions

- Create function
- Call function, manually or automatically

Compute Sales Tax

```
total = cost * 1.06;  
INSERT ... VALUES ( ... total ... );  
  
INSERT ... VALUES ( ... cost * 1.06, ... );  
  
CREATE FUNCTION total(float)  
RETURNS float  
AS 'SELECT $1 * 1.06;'  
LANGUAGE 'sql';  
  
INSERT ... VALUES ( ... total(cost) ... )
```

Convert Fahrenheit to Centigrade

```
cent = (faren - 32.0) * 5.0 / 9.0  
INSERT ... VALUES ( ... cent ... )
```

```
INSERT ... VALUES ( ... (faren - 32.0) * 5.0 / 9.0, ... )
```

```
CREATE FUNCTION ftoc(float)  
RETURNS float  
AS 'SELECT ($1 - 32.0) * 5.0 / 9.0;'  
LANGUAGE 'sql';
```

```
INSERT ... VALUES ( ... ftoc(faren) ... )
```

Compute Shipping Cost

```
if cost < 2
    shipping = 3.00
else if cost < 4
    shipping = 5.00
else shipping = 6.00
```

```
INSERT ... VALUES ( ... cost + shipping ... );
```

Shipping Cost Function

```
CREATE FUNCTION shipping(numeric)
RETURNS numeric
AS 'SELECT CASE
    WHEN $1 < 2 THEN CAST(3.00 AS numeric(8,2))
    WHEN $1 >= 2 AND $1 < 4 THEN CAST(5.00 AS numeric(8,2))
    WHEN $1 >= 4 THEN CAST(6.00 AS numeric(8,2))
END;'
LANGUAGE 'sql';

INSERT ... VALUES ( ... cost + shipping(cost) ... );
```

String Processing — PL/pgSQL

```
CREATE FUNCTION spread(text)
RETURNS text
AS $$
DECLARE
    str text;
    ret text;
    i integer;
    len integer;
BEGIN
    str := upper($1);
    ret := ''; -- start with zero length
    i := 1;
    len := length(str);
    WHILE i <= len LOOP
        ret := ret || substr(str, i, 1) || ' ';
        i := i + 1;
    END LOOP;
    RETURN ret;
END;
$$
LANGUAGE 'plpgsql';

SELECT spread('Major Financial Report');
      spread
-----
M A J O R   F I N A N C I A L   R E P O R T
```

State Name Lookup SQL Language Function

```
SELECT name  
FROM statename  
WHERE code = 'AL';
```

```
CREATE FUNCTION getstatename(text)  
RETURNS text  
AS 'SELECT name  
    FROM statename  
    WHERE code = $1;'  
LANGUAGE 'sql';
```

```
SELECT getstatename('AL');
```


State Name Lookup From String PL/pgSQL Language Function

```
CREATE FUNCTION getstatecode(text)
RETURNS text
AS $$
DECLARE
    state_str statename.name%TYPE;
    statename_rec record;
    i integer;
    len integer;
    matches record;
    search_str text;
BEGIN
    state_str := initcap($1); -- capitalization match column
    len := length(trim($1));
    i := 2;
    SELECT INTO statename_rec * -- first try for an exact match
    FROM statename
    WHERE name = state_str;
    IF FOUND
    THEN RETURN statename_rec.code;
    END IF;
```

State Name Lookup From String PL/pgSQL Language Function (Cont.)

```
WHILE i <= len LOOP -- test 2,4,6,... chars for match
    search_str = trim(substr(state_str, 1, i)) || '%';
    SELECT INTO matches COUNT(*)
    FROM statename
    WHERE name LIKE search_str;
    IF matches.count = 0 -- no matches, failure
    THEN RETURN NULL;
    END IF;
    IF matches.count = 1 -- exactly one match, return it
    THEN
        SELECT INTO statename_rec *
        FROM statename
        WHERE name LIKE search_str;
        IF FOUND
        THEN RETURN statename_rec.code;
        END IF;
    END IF;
    i := i + 2; -- >1 match, try 2 more chars
END LOOP;
RETURN '';
END;
$$
LANGUAGE 'plpgsql';
```

State Name Maintenance

```
CREATE FUNCTION change_statename(char(2), char(30))  
RETURNS boolean  
AS $$  
DECLARE  
    state_code ALIAS FOR $1;  
    state_name ALIAS FOR $2;  
    statename_rec RECORD;
```

State Name Maintenance (Cont.)

```
BEGIN
  IF length(state_code) = 0 -- no state code, failure
  THEN RETURN 'f';
  ELSE
    IF length(state_name) != 0 -- is INSERT or UPDATE?
    THEN
      SELECT INTO statename_rec *
      FROM statename
      WHERE code = state_code;
      IF NOT FOUND -- is state not in table?
      THEN INSERT INTO statename
        VALUES (state_code, state_name);
      ELSE UPDATE statename
        SET name = state_name
        WHERE code = state_code;
      END IF;
      RETURN 't';
    
```

State Name Maintenance (Cont.)

```
ELSE -- is DELETE
    SELECT INTO statename_rec *
    FROM statename
    WHERE code = state_code;
    IF FOUND
    THEN    DELETE FROM statename
            WHERE code = state_code;
            RETURN 't';
    ELSE RETURN 'f';
    END IF;
END IF;
END;
$$
LANGUAGE 'plpgsql';

SELECT change_statename('AL','Alabama');
SELECT change_statename('AL','Bermuda');
SELECT change_statename('AL','');
SELECT change_statename('AL',''); -- row was already deleted
```

SELECT Inside FROM

```
SELECT *  
FROM (SELECT * FROM tab) AS tab;
```

```
SELECT *  
FROM (  SELECT 1,2,3,4,5 UNION  
        SELECT 6,7,8,9,10 UNION  
        SELECT 11,12,13,14,15) AS tab15;
```

col		col		col		col		col
----	+	----	+	----	+	----	+	----
1		2		3		4		5
6		7		8		9		10
11		12		13		14		15

Function Returning Multiple Values

```
CREATE FUNCTION func5() RETURNS  
TABLE (x1 INT, x2 INT, x3 INT, x4 INT, x5 INT) AS  
'SELECT 1,2,3,4,5;'  
LANGUAGE SQL;
```

```
SELECT * FROM func5();  
  x1 | x2 | x3 | x4 | x5  
-----+-----+-----+-----+-----  
   1 |  2 |  3 |  4 |  5
```

Function Returning a Table Result

```
CREATE FUNCTION func15() RETURNS  
TABLE (x1 INT, x2 INT, x3 INT, x4 INT, x5 INT) AS  
'  SELECT 1,2,3,4,5 UNION  
    SELECT 6,7,8,9,10 UNION  
    SELECT 11,12,13,14,15;'  
LANGUAGE SQL;
```

```
SELECT * FROM func15() ORDER BY x1;
```

x1	x2	x3	x4	x5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15

Automatic Function Calls Trigger

- BEFORE/AFTER ROW
- INSERT/UPDATE/DELETE
- OLD/NEW

Trigger on Statename

```
CREATE FUNCTION trigger_insert_update_statename()  
RETURNS trigger  
AS $$  
BEGIN  
    IF new.code !~ '^[A-Za-z][A-Za-z]$'  
    THEN RAISE EXCEPTION 'State code must be two alphabetic characters.';  
    END IF;  
    IF new.name !~ '^[A-Za-z ]*$'  
    THEN RAISE EXCEPTION 'State name must be only alphabetic characters.';  
    END IF;  
    IF length(trim(new.name)) < 3  
    THEN RAISE EXCEPTION 'State name must longer than two characters.';  
    END IF;  
    new.code = upper(new.code); -- uppercase statename.code  
    new.name = initcap(new.name); -- capitalize statename.name  
    RETURN new;  
END;  
$$  
LANGUAGE 'plpgsql';
```

Install Trigger On Statename

```
CREATE TRIGGER trigger_statename
BEFORE INSERT OR UPDATE
ON statename
FOR EACH ROW
EXECUTE PROCEDURE trigger_insert_update_statename();

INSERT INTO statename VALUES ('a', 'alabama');
INSERT INTO statename VALUES ('a1', 'alabama2');
INSERT INTO statename VALUES ('a1', 'a1');
INSERT INTO statename VALUES ('a1', 'alabama');
```

Function Languages

- SQL
- PL/pgSQL
- PL/Perl
- PL/Python
- PL/Java
- PL/TCL
- PL/sh
- C

Function Examples

- `/contrib/earthdistance`
- `/contrib/fuzzystringmatch`
- `/contrib/pgcrypto`



<https://www.flickr.com/photos/brapke/>

3. Customizing Database Features

Adding New Data and Indexing Features



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Creation

- **CREATE FUNCTIONS** in C
- **CREATE TYPE**
- **CREATE OPERATOR**
- **CREATE OPERATOR CLASS** (index type)

Create New Data Type With Operator and Index Support

- Write input/output functions
- Register input/output functions with CREATE FUNCTION
- Register type with CREATE TYPE
- Write comparison functions
- Register comparison functions with CREATE FUNCTION
- Register comparison functions with CREATE OPERATOR
- Register operator class for indexes with CREATE OPERATOR CLASS

Create New Data Type Examples

- `/contrib/chkpass`
- `/contrib/isn`
- `/contrib/cube`
- `/contrib/ltree`
- `/src/backend/utils/ad`



Conclusion



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