Time Related Range Types Revisited

Real World use cases from the KOF and SwissPUG daily business

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Outline

Introduction

Myself And The Company I work for

- Senior DB Engineer at KOF ETH Zurich
  - KOF is the Center of Economic Research of the
  - ETHZ the Swiss Institute of Technology in Zurich, Switzerland
  - Independent economic research on business cycle tendencies for almost all sectors
  - Maintenance of all databases at KOF: PostgreSQL, Oracle, MySQL and MSSQL Server. Focus on migrating to PostgreSQL
  - Support in business process re-engineering
- Co-founder and treasurer of the SwissPUG, the Swiss PostgreSQL Users Group
- Member of the board of the Swiss PGDay

Outline

Range Types

Characteristics

PostgreSQL has support for ranges of various data types. The common denominator is that the base data type has a clear and unique natural order and that the values being part of a range have no missing values. Natural candidates are date or time related types and numbers as well as its derivates. Specifically PostgreSQL defines following range types:

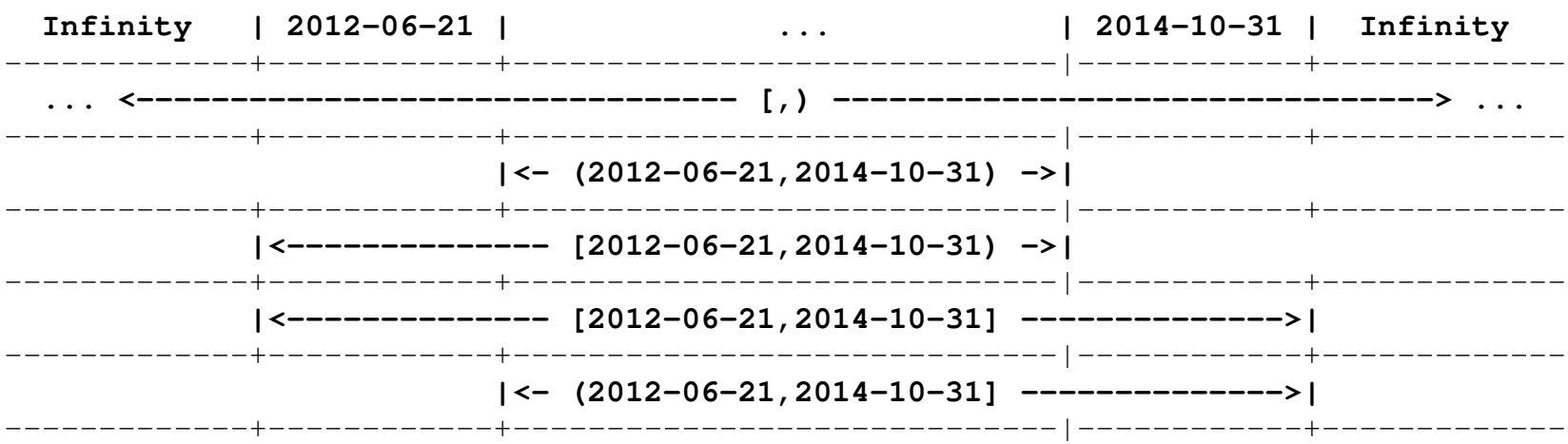
- INT4RANGE: Range of integer
- INT8RANGE: Range of bigint
- NUMRANGE: Range of numeric
- TSRANGE: Range of timestamp without time zone
- TSTZRANGE: Range of timestamp with time zone
- DATERANGE: Range of date

In this presentation we focus on the last two: `DATERANGE` and `TSTZRANGE`.

Range Types

Representation

Typically ranges are represented as a string containing the bounds and an indications if those bounds are included in the range or not. Example using `DATERANGE`



Analogue to the first example, you may have one of the bounds empty to create a range with only one open end.

Create Ranges 1/2

To create a range type you may type cast a text representation of it to the corrensponding type or use one of the built in functions. In both cases the type creation will make sure that your entry is valid.

```
db=> SELECT '[2012-06-21,2014-10-31)'::DATERANGE;
 [2012-06-21,2014-10-31)

db=> SELECT daterange('2012-06-21','2014-10-31','[)');
 [2012-06-21,2014-10-31)

db=> SELECT '[2015-06-21,2014-10-31)'::DATERANGE;
ERROR:  range lower bound must be less than or equal to range upper bound
```

In the documentation you will find the list of the range type creation functions. General format:

```
name_of_range_type(lower_bound,upper_bound,bounds);
```

lower and upper bound can be NULL for open ends. Bounds is a 2 char string containig the representation of the bounds. If not provided the default is "`[)`".

Create Ranges 2/2

A recommendation: Get used to operate with the default representation of ranges, unless you have a very good reason to do it differently. Consider the following:

```
db=> SELECT daterange('2012-06-21','2014-10-30','()') AS from_function,
            '(2012-06-21,2014-10-30]'::DATERANGE AS from_typecast;
-[ RECORD 1 ]-+------------------------
from_function | [2012-06-22,2014-10-31)
from_typecast | [2012-06-22,2014-10-31)
```

The range creation process returns the default representation if the values are scaled ordinally.

```
db=> CREATE TABLE test (dr DATERANGE);
db=> INSERT INTO test VALUES ('(2012-06-21,2014-10-30]'::DATERANGE);
db=> SELECT * FROM test;
-[ RECORD 1 ]--------------
dr | [2012-06-22,2014-10-31)
```

This can be confusing when you start retrieving the bounding values for whatever operation that you want to perform.

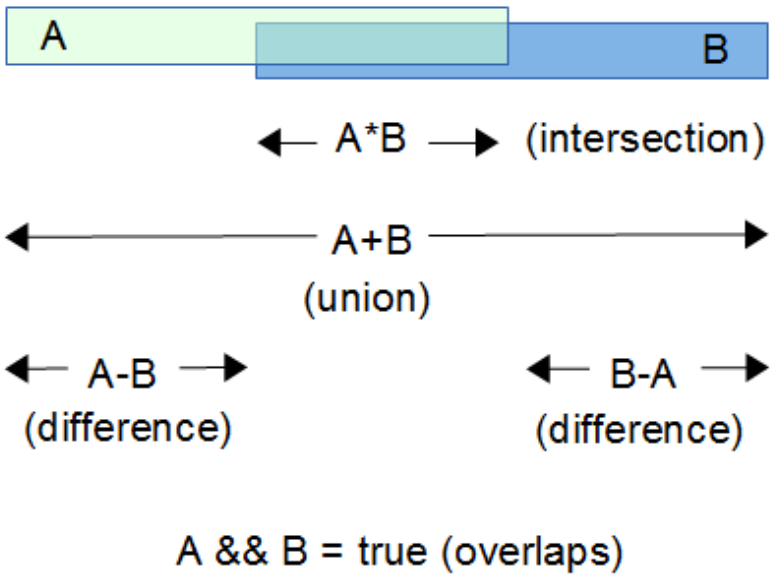
Operators 1/2

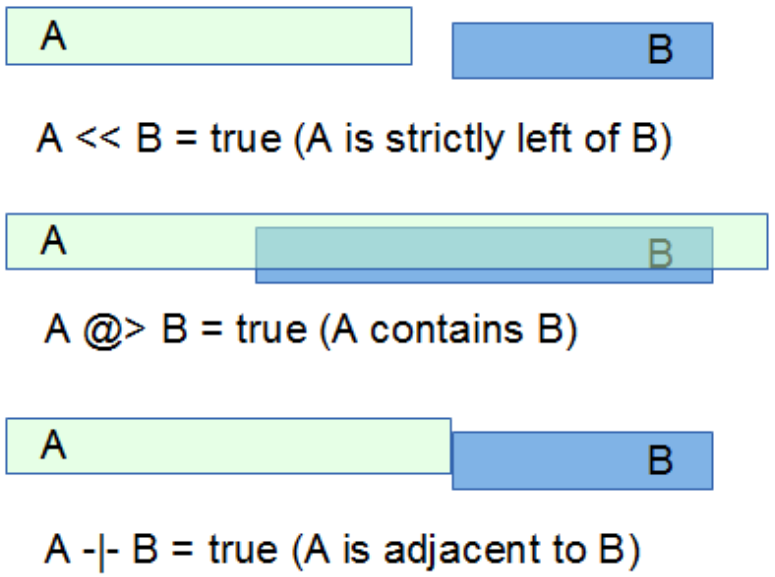
At the time of this writing (Version 9.6.1) range types are supplied with a set of 19 operators. From the official documentation:

- The simple comparison operators <, >, <=, and >= compare the lower bounds first, and only if those are equal, compare the upper bounds. **These comparisons are not usually very useful for ranges, but are provided to allow B-tree indexes to be constructed on ranges**.
- The left-of/right-of/adjacent operators always return false when an empty range is involved ; that is, **an empty range is not considered to be either before or after any other range**.
- The union and difference operators **will fail if the resulting range would need to contain two disjoint sub-ranges**, as such a range cannot be represented.

Operators 2/2

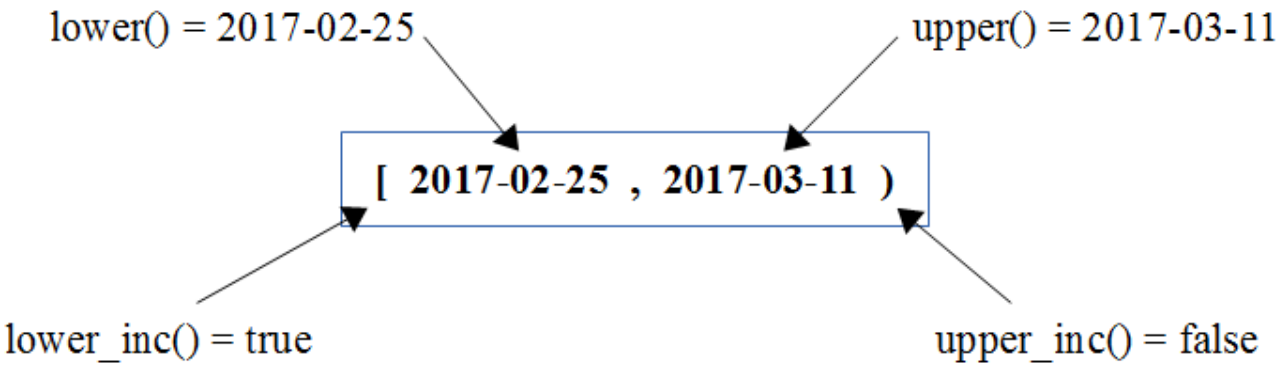
Let's focus on some range specific operators...





Functions

The built in functions for range types are helpful to request specific information on the type's characteristics.



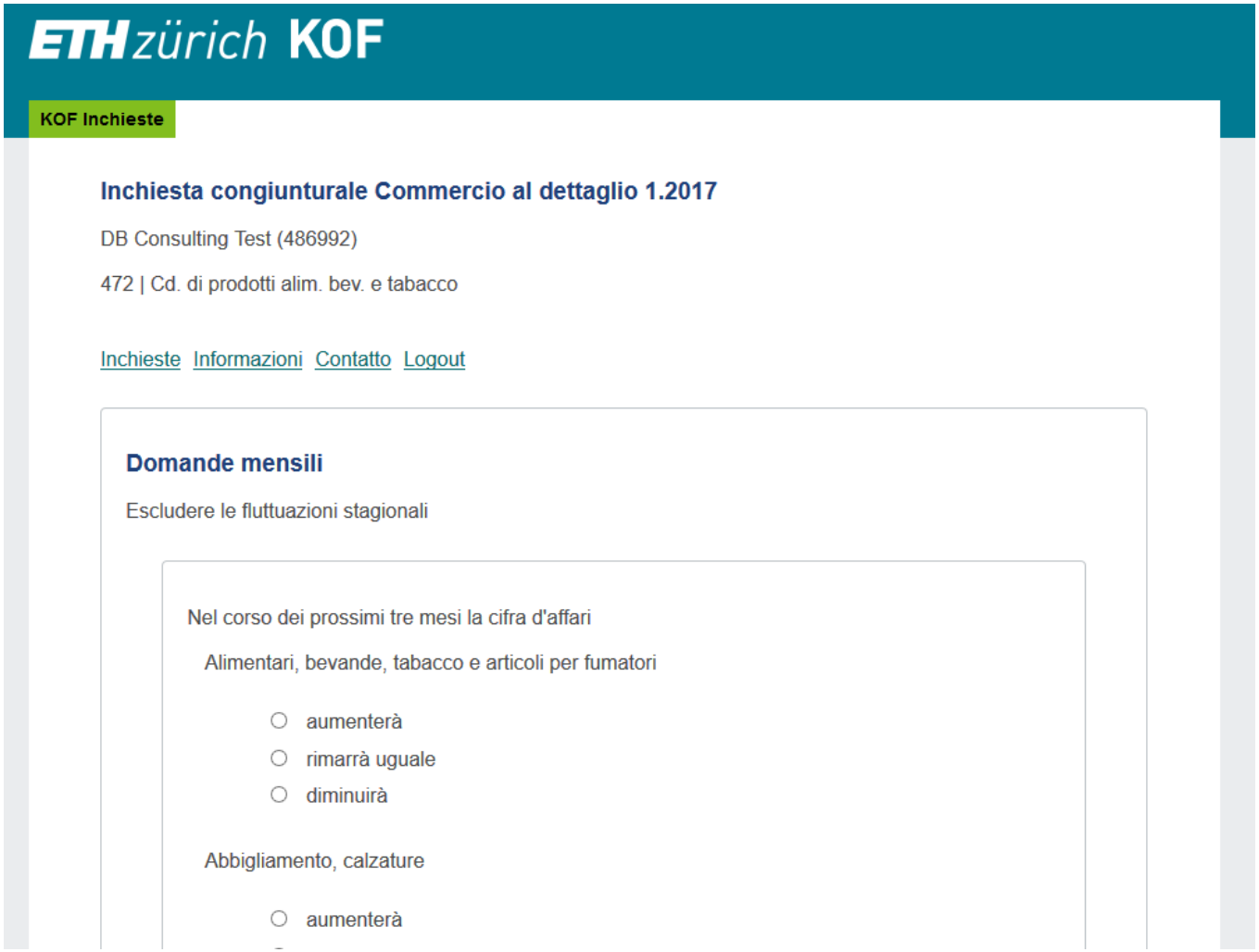
- `lower_inf(anyrange), upper_inf(anyrange)`: Return a boolean indicating if the requested bound is open ended.
- `isempty(anyrange)`: Return a boolean indicating if the range is empty. Notice that empty is not the same as NULL. In term of DATERANGE, for example, empty means as much as "never".
- `merge(anyrange,anyrange)`: The smallest range containing both range arguments. The difference to the union operator (+) it that the range parameters don't need to be at least contiguous.

Outline

Outline

Manage Questionnaires Versions

A KOF Questionnaire



Manage Questionnaires Versions

... is a JSON document

```
db=> SELECT * FROM operations.get_form_by_language('DHU','it',0);
{
  "version": "1.0",
  "survey": "DHU",
  "items": [{
    "meta": {
      "frequency": "month"
    },
    "title": {
      "it": "Domande mensili"
    },
    "description": {
      "it": "<em>Escludere le fluttuazioni stagionali</em>"
    },
    "items": [{
      "description": {
        "it": "Nel corso dei prossimi tre mesi la cifra d'affari"
      },
      "items": [{
        "id": "q_ql_exp_turnover_food_n3m",
        "type": "single_choice",
        "question": {
          "it": "Alimentari, bevande, tabacco e articoli per fumatori"
        },
        "answers": {
          "values": [{
    [...]
```

Manage Questionnaires Versions

... with a History

```
db=> \d web_form_templates
Table "operations.web_form_templates"
   Column    |   Type    | Modifiers
-------------+-----------+-----------
 survey_name | text      |
 survey_type | integer   |
 form_json   | json      |
 validity    | daterange |
Indexes:
    "web_form_templates_survey_name_type_validity_excl"
      EXCLUDE USING gist (survey_name WITH =, survey_type WITH =, validity WITH &&)
      DEFERRABLE

db=> SELECT survey_name, survey_type, validity
     FROM operations.web_form_templates
     WHERE (survey_name,survey_type) = ('DHU',0)
     ORDER BY validity;

 survey_name | survey_type |        validity
-------------+-------------+-------------------------
 DHU         |           0 | [2011-01-01,2015-02-01)
 DHU         |           0 | [2015-02-01,)
(2 rows)
```

Manage Questionnaires Versions

And some fancy utilities

```
db=> SELECT question_text, answers_codes
     FROM operations.get_questions_from_form('DHU','it',0,'2012-05-25');
              question_text                |                 answers_codes
-------------------------------------[...]--+-----------------------------------------------
 Alimentari                                | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Bevande                                   | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Tabacco e articoli per fumatori           | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Abbigliamento, calzature                  | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Carburanti                                | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Altri gruppi di merci del commerc[...]    | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 [...]

db=> SELECT question_text, answers_codes
     FROM operations.get_questions_from_form('DHU','it',0,'2017-01-01');
                 question_text            |                 answers_codes
------------------------------------------+-----------------------------------------------
 Alimentari, bevande, tabacco e ar[...]   | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Abbigliamento, calzature                 | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Carburanti                               | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 Altri gruppi di merci del commerci[...]  | 1: aumenterà, 0: rimarrà uguale, -1: diminuirà
 [...]
```

Outline

History of Survey Participants

Rationale

The entries in table `survey_participants` are used to keep track of the information that is required for

- Creating and sending questionnaires or mail invitations (survey name, contact information).
- Sectors and weights for the calculation of macro economic indicators (economic sector, weighting information).

By its nature, contact information is relevant at the moment when mails and questionnaires are sent out. When it comes to the information used for computation, it is clear that we must keep the information that was valid at the time the survey was conducted. We need to know, e.g. how big the company was for any specific day that it delivered survey data.

History of Survey Participants

Short digression: The difference between audit and history (in this context)

- When you are investigating problems in a database (or mostly in the application built on top of it), you usually want to know exactly who did what and when. In such cases every single change may be relevant to your analysis. This is what we call an audit, i.e. an exact record of all changes in one or more tables.
- The KOF surveys are conducted every month and always start at the beginning of a month. If the information about a company is modified many times during a month, e.g. because of mistyped information or follow ups from the company itself, it is not relevant for the survey itself and its analysis. What is important is the information that was valid at the moment when the company was called to attend the survey. To keep record of this specific information is what we call the history of the company.
- In short, an audit would record all changes made to a record, while an history keeps track of changes that have an impact on the processes they support. Notice that the history does not even need to be a copy of an existing table. Finally what needs to be kept in the history, again, depends on the processes. An address is relevant at the time of sending out a Questionnaire or an E-Mail. It is not required (at least for us) to keep track of these changes. On the contrary, data used to weigh responses must match the values valid at the time when these responses were delivered.

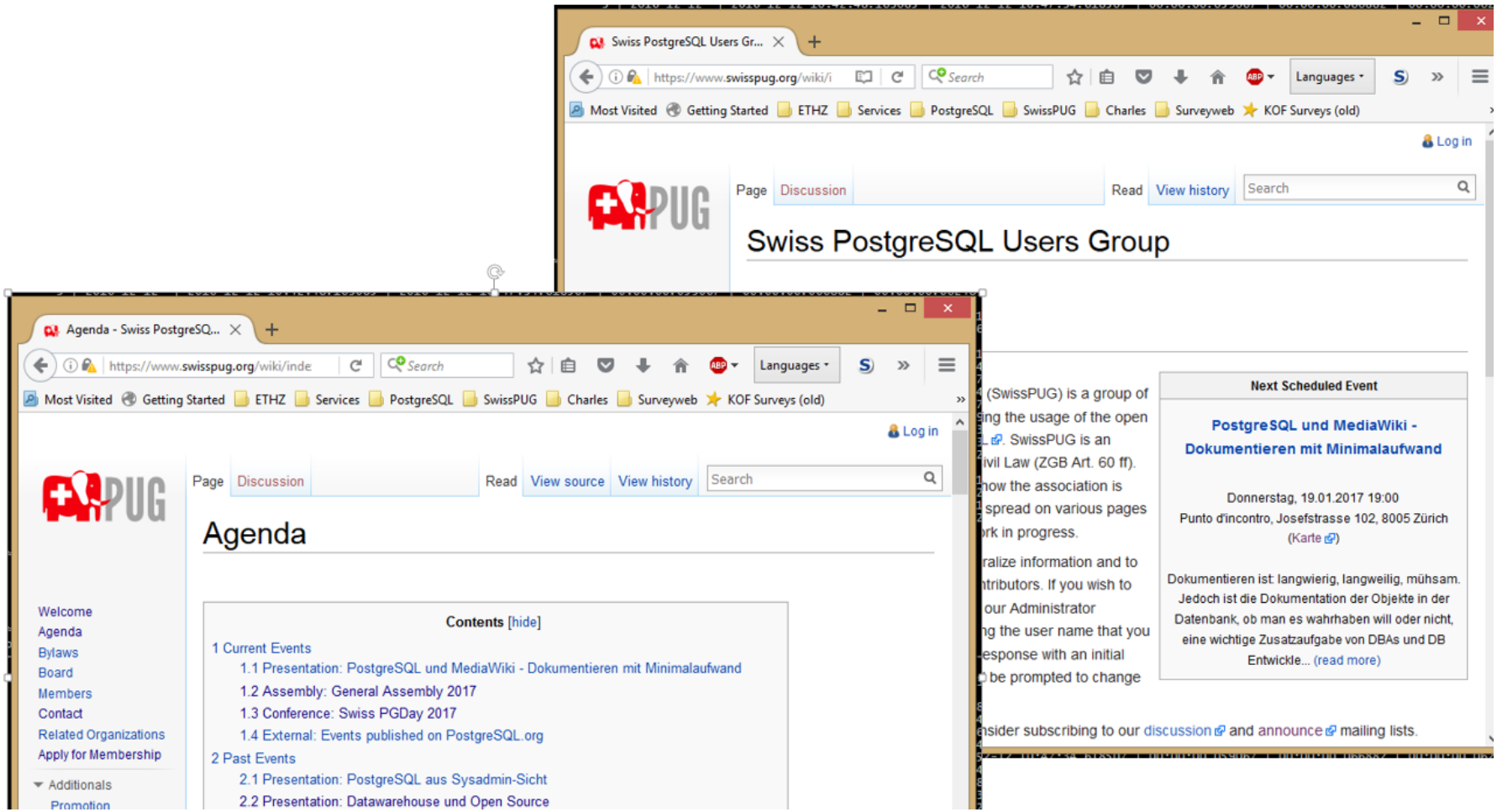
History of Survey Participants

Implementation

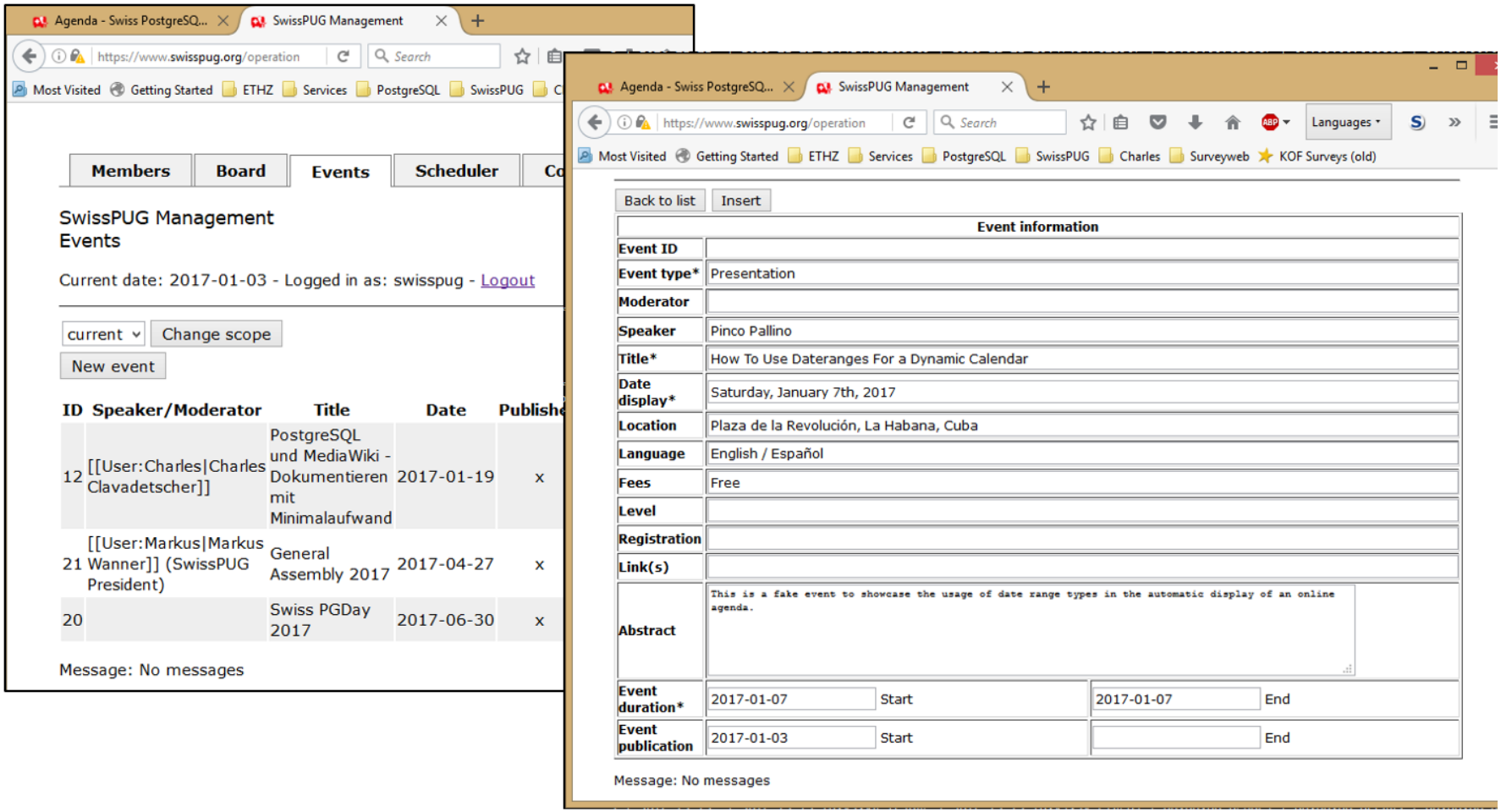
```
FROM operations.company_weights:

 survey_name | company_id | contact_id | sector_class | sector_code | fte
-------------+------------+------------+--------------+-------------+-----
 BAU         |     550611 |     486992 | NA608        | 4213        |   9
(1 row)

FROM operations.company_weights_history:

-[ RECORD 1 ]+----------------------
survey_name  | BAU
company_id   | 550611
contact_id   | 486992
sector_class | NA608
sector_code  | 4213
fte          | 5
validity     | [2012-03-01,2016-06-01)
-[ RECORD 2 ]+----------------------
survey_name  | BAU
company_id   | 550611
contact_id   | 486992
sector_class | NA608
sector_code  | 4213
fte          | 9
validity     | [2016-06-01,)
```

Outline

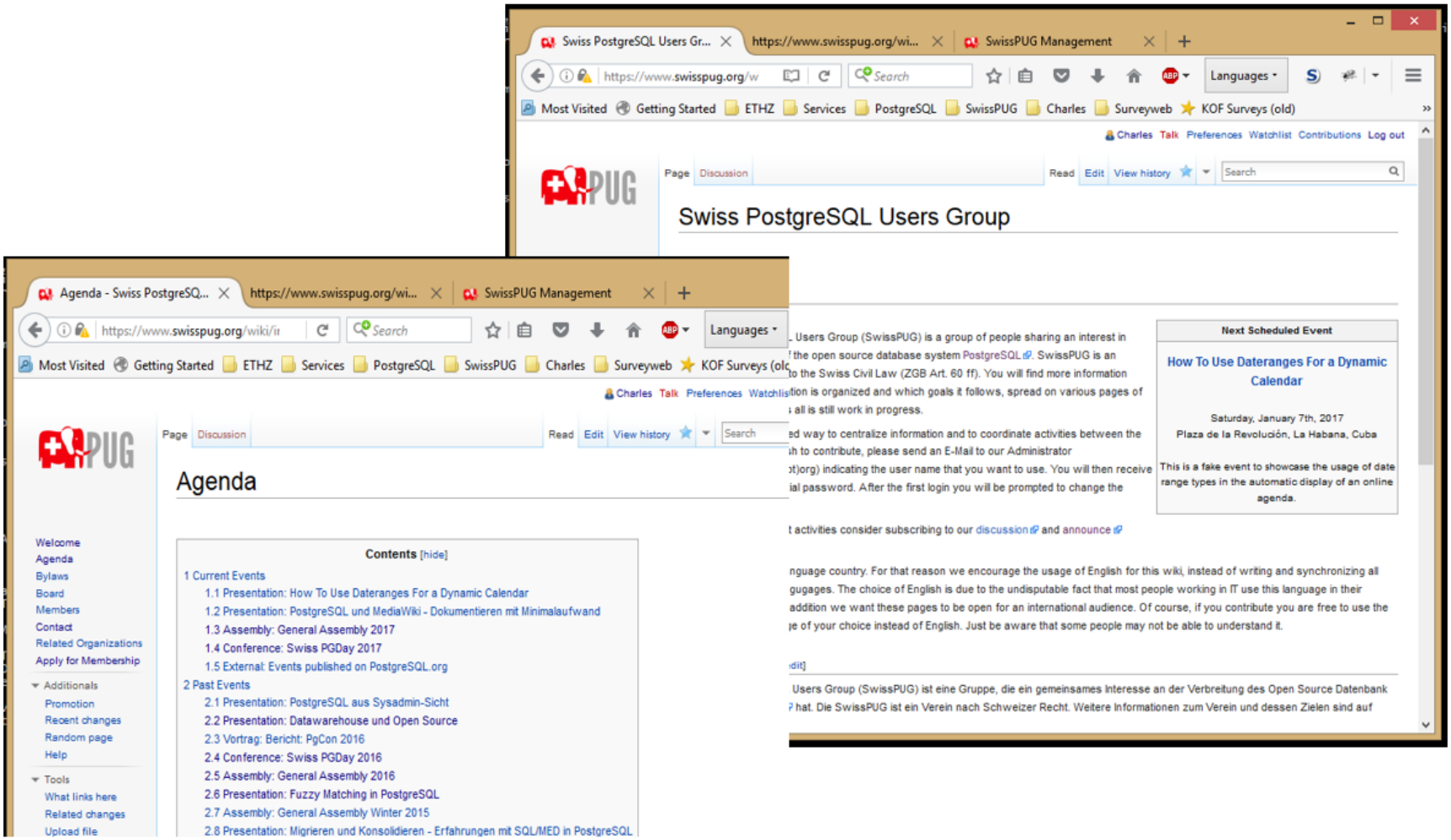
Dynamic Agenda Display



Dynamic Agenda Display



Dynamic Agenda Display



Dynamic Agenda Display

The entry in the DB

```
swisspug@swisspug=> SELECT * FROM events WHERE event_id = 22;
-[ RECORD 1 ]+-----------------------------------------------------------
event_id     | 22
event_type   | Presentation
moderator    |
speaker      | Pinco Pallino
title        | How To Use Dateranges For a Dynamic Calendar
date_display | Saturday, January 7th, 2017
location     |
language     |
fees         |
level        |
registration |
links        |
abstract     | This is a fake event to showcase the usage of date range types
             | in the automatic display of an online agenda.
publication  | [2017-01-03,)
duration     | [2017-01-07,2017-01-08)
```

Dynamic Agenda Display

The display function code

```
CREATE OR REPLACE FUNCTION public.mw_next_event()
RETURNS TEXT
AS $$
DECLARE
  v_event operations.events;
  v_wiki_text TEXT := '';
BEGIN
  SELECT * FROM operations.events
  INTO v_event
  WHERE CURRENT_DATE <@ publication      -- is open for publication
  AND CURRENT_DATE <= upper(duration)    -- has not finished yet
  ORDER BY lower(duration) ASC           -- put the newest on top of list
  LIMIT 1;                               -- take only the most recent
  IF v_event.event_id IS NOT NULL THEN
    -- Format wiki text for output.
  END IF;
  RETURN v_wiki_text;
END;
$$ LANGUAGE plpgsql
SECURITY DEFINER;
```

Dynamic Agenda Display

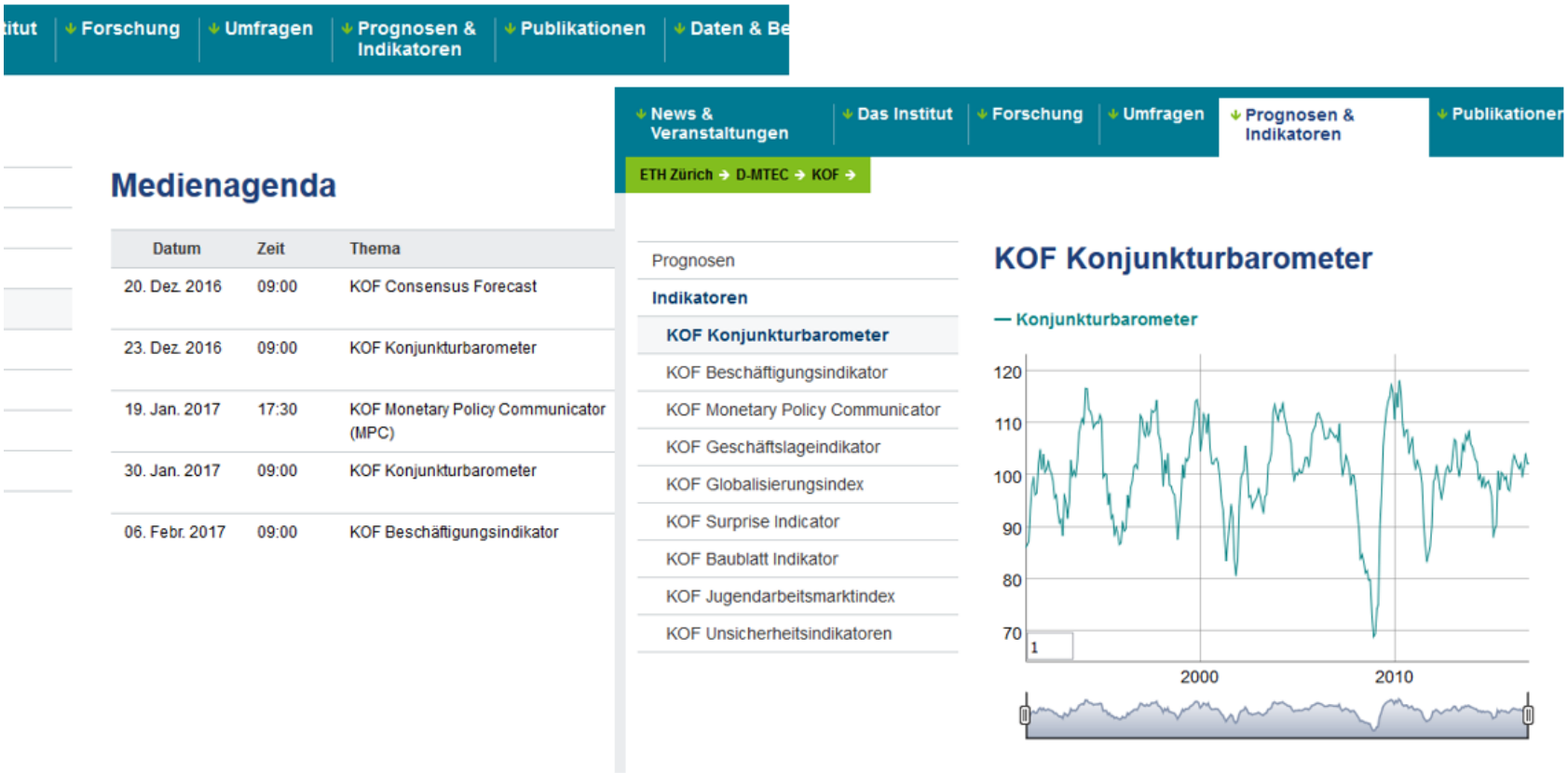
The display function in action

```
swisspug@swisspug=> SELECT * FROM public.mw_next_event();

{| class="wikitable" style="float: right;  clear: right; font-size: 88%; width: 300px"
|-
! Next Scheduled Event
|- style="text-align: center"
| <h3>[[Agenda#Presentation: How To Use Dateranges For a Dynamic Calendar|
        How To Use Dateranges For a Dynamic Calendar]]</h3><br/>
  Saturday, January 7th, 2017<br/>
  <br/><br/>This is a fake event to showcase the usage of date range types
           in the automatic display of an online agenda.
|}
```

Outline

Publication Of Indicators

The KOF Barometer



Publication Of Indicators

Requirements on Publication

- Publication date and time are published on the KOF website.
- Everybody should get access to the data at the same point in time.

Publication Of Indicators

The timeseries data table

```
        Table "public.timeseries_main"
    Column    |       Type        | Modifiers
--------------+-------------------+-----------
 ts_key       | character varying | not null
 ts_data      | hstore            |
 ts_frequency | integer           |
 validity     | tstzrange         | not null
Indexes:
    "timeseries_main_pkey" PRIMARY KEY, btree (ts_key, validity)
    "timeseries_main_ts_key_validity_excl"
       EXCLUDE USING gist (ts_key WITH =, validity WITH &&)

charles@charles=# SELECT * FROM public.timeseries_main WHERE ts_key = 'kofbarometer';
-[ RECORD 1 ]+-----------------------------------------------------------------
ts_key       | kofbarometer
ts_data      | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933"
ts_frequency | 12
validity     | ["2016-12-01 09:00:00+01",)

charles@charles=# SELECT (each(ts_data)).* FROM public.timeseries_main
                  WHERE ts_key = 'kofbarometer';
    key     |      value
------------+-----------------
 2016-11-01 | 102.162463328593
 2016-12-01 | 102.161371136933
```

Publication Of Indicators

The Publication Process 1/2

Modify the current valid entry to end at the time of publication.

```
BEGIN;

UPDATE public.timeseries_main
SET validity = tstzrange(lower(validity),now())
WHERE ts_key = 'kofbarometer'
AND validity @> now();
```

Create a new current entry accessible from the time of publication.

```
INSERT INTO public.timeseries_main
SELECT ts_key,
       ts_data||'2017-01-01=>100.00'::HSTORE,
       ts_frequency,
       tstzrange(now(),NULL)
FROM public.timeseries_main
WHERE ts_key = 'kofbarometer'
AND upper(validity) = now();

COMMIT;
```

For this examples we use `now()` but in real life you would obviously use a specific timestamp in the future.

Publication Of Indicators

The Publication Process 2/2

We have 2 entries with the same key and and order in time.

```
SELECT ts_key, ts_data, validity
FROM public.timeseries_main
WHERE ts_key = 'kofbarometer';
-[ RECORD 1 ]-----------------------------------------------------------------
ts_key   | kofbarometer
ts_data  | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933"
validity | ["2016-12-01 09:00:00+01","2017-01-03 15:07:40.416938+01")
-[ RECORD 2 ]-----------------------------------------------------------------
ts_key   | kofbarometer
ts_data  | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933",
         | "2017-01-01"=>"100.00"
validity | ["2017-01-03 15:07:40.416938+01",)
```

Querying with a time filter only delivers the current entry.

```
SELECT (each(ts_data)).*
FROM public.timeseries_main
WHERE ts_key = 'kofbarometer'
AND validity @> clock_timestamp();

    key     |       value
------------+-------------------
 2016-11-01 | 102.162463328593
 2016-12-01 | 102.161371136933
 2017-01-01 | 100.00
(3 rows)
```

Publication Of Indicators

Using Row Level Security

We have seen that filtering is done in the WHERE clause. We can achieve the same result using RLS.

```
CREATE POLICY public_access
ON public.timeseries_main
FOR SELECT
TO public
USING (validity @> clock_timestamp());

ALTER TABLE timeseries_main ENABLE ROW LEVEL SECURITY;
```

```
         Table "public.timeseries_main"
    Column     |       Type        | Modifiers
---------------+-------------------+-----------
 ts_key        | character varying | not null
 ts_data       | hstore            |
 ts_frequency  | integer           |
 validity      | tstzrange         | not null
Indexes:
    "timeseries_main_pkey" PRIMARY KEY, btree (ts_key, validity)
    "timeseries_main_ts_key_validity_excl"
      EXCLUDE USING gist (ts_key WITH =, validity WITH &&)
Policies:
    POLICY "public_access" FOR SELECT
      USING ((validity @> clock_timestamp()))
```

Publication Of Indicators

Testing RLS Settings

Table owner sees all entries.

```
SELECT CURRENT_USER;
-[ RECORD 1 ]+--------
current_user | charles

SELECT ts_key, ts_data, validity
FROM public.timeseries_main
WHERE ts_key = 'kofbarometer';

-[ RECORD 1 ]-----------------------------------------------------------------
ts_key   | kofbarometer
ts_data  | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933"
validity | ["2016-12-01 09:00:00+01","2017-01-03 15:07:40.416938+01")
-[ RECORD 2 ]-----------------------------------------------------------------
ts_key   | kofbarometer
ts_data  | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933",
         | "2017-01-01"=>"100.00"
validity | ["2017-01-03 15:07:40.416938+01",)
```

Publication Of Indicators

Testing RLS Settings

Any other user without any specific policy defined is public and only sees the currently valid row.

```
SET ROLE public_reader;

SELECT CURRENT_USER;
-[ RECORD 1 ]+--------------
current_user | public_reader

SELECT ts_key, ts_data, validity
FROM public.timeseries_main
WHERE ts_key = 'kofbarometer';

-[ RECORD 1 ]-----------------------------------------------------------------
ts_key   | kofbarometer
ts_data  | "2016-11-01"=>"102.162463328593", "2016-12-01"=>"102.161371136933",
         | "2017-01-01"=>"100.00"
validity | ["2017-01-03 15:07:40.416938+01",)
```

Outline

Conclusions

Date and time based range types offer a solid and flexible solution for a wide variety of needs, including but not limited to:

- Historicize entries for archiving or documentation.
- Create time responsive entries, i.e. decouple database interactions of delivery and consumption.
- Can easily be integrated with capabilities of the database such as indexing.
- They integrate also very well with advanced features like Row Level Security.

Resources

Documentation

- These slides: http://www.artesano.ch/documents/04-publications/time_related_range_types_revisited_pdfa.pdf
- Description: https://www.postgresql.org/docs/current/static/rangetypes.html
- Functions/Operators: https://www.postgresql.org/docs/current/static/functions-range.html

Live examples

- Show Next Event: http://www.swispug.org
- Dynamic Agenda: https://www.swisspug.org/wiki/index.php/Agenda
- Just In Time Publishing: https://www.kof.ethz.ch/prognosen-indikatoren/indikatoren/kof-konjunkturbarometer.html

Related presentations

- Hubert ”depesz” Lubaczewski (2010): https://www.depesz.com/2010/10/22/grouping-data-into-time-ranges/
- Jonathan Katz (2012): https://wiki.postgresql.org/images/7/73/Range-types-pgopen-2012.pdf
- Magnus Hagander (2015): https://www.hagander.net/talks/tardis_orm.pdf

Contact

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Thank you

Thank you very much for your attention !

Feedback

Q&A