Bitemporality:

Tracking Reproducible Revisions in PostgreSQL Using RANGE Types

Miroslav Šedivý

solute GmbH, Karlsruhe, Germany · solute.de

Bitemporality: Tracking Reproducible Revisions in PostgreSQL Using RANGE Types

- INSERT, UPDATE and DELETE without losing information
  - Time-versioning entities with attributes
  - RANGE types in PostgreSQL 9.x+
  - GiST extension
  - Python and Psycopg2
  - Modifying data (concurrently)
  - Reading data (consistently)

Miroslav Šedivý

['mɪrɔslaʊ 'ʃɛɟɪviː]

- born in Bratislava, Czechoslovakia
- M.Sc. at INSA Lyon, France
- used MySQL and Oracle before PostgreSQL
- came to Python 2.5 from Perl/Java in 2008
- Senior Software Developer at solute GmbH in Karlsruhe, Germany

A simple data model with records evolving over time

A simple data model with records evolving over time

```
 name             | city      | street         | house_number | apartment
------------------------------------------------------------------------------
 Nadya Shevelyova | Leningrad | 3rd Builders' | 25           | 12
 Zhenya Lukashin  | Moscow    | 3rd Builders' | 25           | 12
```

A simple data model with records evolving over time

```
 name             | city      | street        | house_number | apartment
------------------------------------------------------------------------
 Nadya Shevelyova | Leningrad | 3rd Builders' | 25           | 12
 Zhenya Lukashin  | Moscow    | 3rd Builders' | 25           | 12
```

```
 time_zone     | utc_offset | observes_dst
-----------------------------------------
 Europe/Moscow | +03:00     | False
 Europe/Paris  | +01:00     | True
```

A really simple data model

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT NOT NULL UNIQUE,
                       fee INTEGER NOT NULL);
```

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                       fee INTEGER NOT NULL);
```

```
SELECT * FROM customer;

 id | name  | fee
----------------
  1 | alice |  10
  2 | bob   |  20
```

A really simple data model

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CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT NOT NULL UNIQUE,
                       fee INTEGER NOT NULL);
```

```
SELECT * FROM customer;

 id | name  | fee
----------------
  1 | alice |  10
  2 | bob   |  20
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee
----------------
  1 | alice |  10
  2 | bob   |  20
  3 | carol |  30
```

A really simple data model

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT NOT NULL UNIQUE,
                       fee INTEGER NOT NULL);
```

```
SELECT * FROM customer;

 id | name  | fee
----------------
  1 | alice |  10
  2 | bob   |  20
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee
----------------
  1 | alice |  10
  2 | bob   |  20
  3 | carol |  30
```

- When did we insert the entry `id = 3`?

When did we insert an entry?

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT UNIQUE NOT NULL,
                       fee INTEGER NOT NULL,
                       inserted_on TIMESTAMPTZ NOT NULL DEFAULT NOW());
```

When did we insert an entry?

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT UNIQUE NOT NULL,
                       fee INTEGER NOT NULL,
                       inserted_on TIMESTAMPTZ NOT NULL DEFAULT NOW());
```

```
 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
```

When did we insert an entry?

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT UNIQUE NOT NULL,
                       fee INTEGER NOT NULL,
                       inserted_on TIMESTAMPTZ NOT NULL DEFAULT NOW());
```

```
 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
  3 | carol |  30 | 2019-02-05
```

When did we insert an entry?

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT UNIQUE NOT NULL,
                       fee INTEGER NOT NULL,
                       inserted_on TIMESTAMPTZ NOT NULL DEFAULT NOW());
```

```
 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
  3 | carol |  30 | 2019-02-05
```

- UPDATE with `updated_on`?

When did we insert an entry?

```
CREATE TABLE customer (id INTEGER PRIMARY KEY,
                       name TEXT UNIQUE NOT NULL,
                       fee INTEGER NOT NULL,
                       inserted_on TIMESTAMPTZ NOT NULL DEFAULT NOW());
```

```
 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee | inserted_on
--------------------------------
  1 | alice |  10 | 2019-01-01
  2 | bob   |  20 | 2019-01-01
  3 | carol |  30 | 2019-02-05
```

- UPDATE with `updated_on`?
- DELETE with ... ?

When is the entry valid?

```
CREATE TABLE customer (id INTEGER NOT NULL,                                  -- NOT PRIMARY KEY
                       name TEXT NOT NULL,                                   -- NOT UNIQUE
                       fee INTEGER NOT NULL,
                       valid_since TIMESTAMPTZ NOT NULL DEFAULT NOW(),
                       valid_until TIMESTAMPTZ NOT NULL DEFAULT NULL);   -- or infinity?
```

When is the entry valid?

```
CREATE TABLE customer (id INTEGER NOT NULL,                                  -- NOT PRIMARY KEY
                       name TEXT NOT NULL,                                   -- NOT UNIQUE
                       fee INTEGER NOT NULL,
                       valid_since TIMESTAMPTZ NOT NULL DEFAULT NOW(),
                       valid_until TIMESTAMPTZ NOT NULL DEFAULT NULL);   -- or infinity?
```

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
```

When is the entry valid?

```
CREATE TABLE customer (id INTEGER NOT NULL,                                  -- NOT PRIMARY KEY
                       name TEXT NOT NULL,                                   -- NOT UNIQUE
                       fee INTEGER NOT NULL,
                       valid_since TIMESTAMPTZ NOT NULL DEFAULT NOW(),
                       valid_until TIMESTAMPTZ NOT NULL DEFAULT NULL);   -- or infinity?
```

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
```

```
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
  3 | carol |  30 | 2019-02-05  | NULL
```

Let's update an entry

```
 id | name  | fee | valid_since | valid_until
-----------------------------------------------
  1 | alice |  10 | 2019-01-01  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
  3 | carol |  30 | 2019-02-05  | NULL



UPDATE customer SET valid_until = NOW() WHERE id = 1 and valid_until IS NULL;

INSERT INTO customer (id, name, fee) VALUES (1, 'alice', 15);

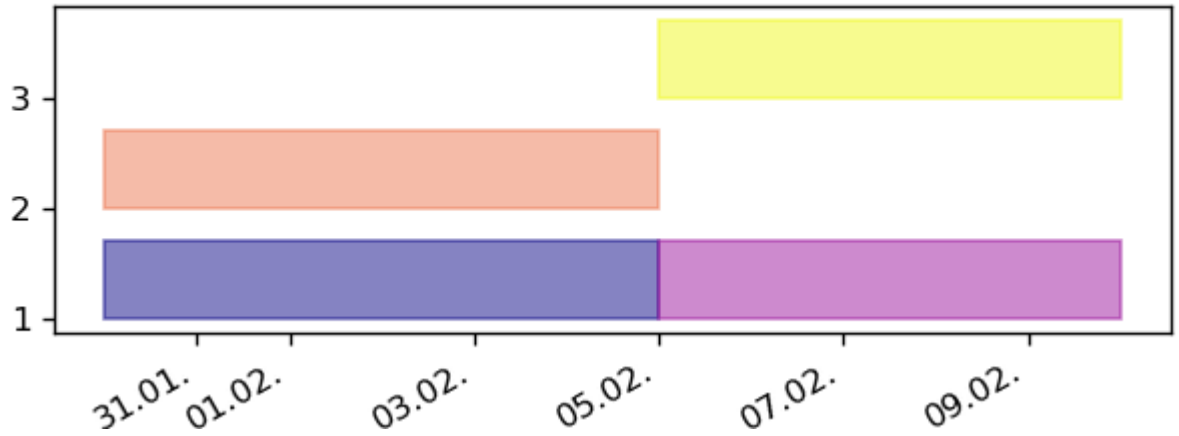

 id | name  | fee | valid_since | valid_until
-----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
  1 | alice |  15 | 2019-02-05  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
  3 | carol |  30 | 2019-02-05  | NULL
```

Let's delete (deactivate) an entry

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
  1 | alice |  15 | 2019-02-05  | NULL
  2 | bob   |  20 | 2019-01-01  | NULL
  3 | carol |  30 | 2019-02-05  | NULL
```

```
UPDATE customer SET valid_until = NOW() WHERE id = 2 and valid_until IS NULL;
```

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
  1 | alice |  15 | 2019-02-05  | NULL
  2 | bob   |  20 | 2019-01-01  | 2019-02-05
  3 | carol |  30 | 2019-02-05  | NULL
```




```
 id | name  | fee | valid_since | valid_until
-----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
  1 | alice |  15 | 2019-02-05  | NULL
  2 | bob   |  20 | 2019-01-01  | 2019-02-05
  3 | carol |  30 | 2019-02-05  | NULL
```

RANGES

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
```

```
 id | name  | fee | valid
-----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
```

RANGES

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
```

```
 id | name  | fee | valid
-----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
```

```
INT4RANGE | INT
INT8RANGE | BIGINT
NUMRANGE  | NUMERIC
TSRANGE   | TIMESTAMP
TSTZRANGE | TIMESTAMPTZ
DATERANGE | DATE
```

```
… or define your own range types!
```

RANGES

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
```

```
 id | name  | fee | valid
-----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
```

```
INT4RANGE | INT
INT8RANGE | BIGINT
NUMRANGE  | NUMERIC
TSRANGE   | TIMESTAMP
TSTZRANGE | TIMESTAMPTZ
DATERANGE | DATE
```

… or define your own range types!

```
[1, 4]: 1, 2, 3, 4
[1, 4): 1, 2, 3    ---> Pythonic range(1, 4)
(1, 4]:    2, 3, 4
(1, 4):    2, 3

(NULL,
     , NULL)
```

[…, NOW()) and [NOW(), …) are adjacent in µs!

RANGES

```
 id | name  | fee | valid_since | valid_until
----------------------------------------------
  1 | alice |  10 | 2019-01-01  | 2019-02-05
```

```
 id | name  | fee | valid
-----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
```

```
INT4RANGE | INT
INT8RANGE | BIGINT
NUMRANGE  | NUMERIC
TSRANGE   | TIMESTAMP
TSTZRANGE | TIMESTAMPTZ
DATERANGE | DATE
```

… or define your own range types!

```
[1, 4]: 1, 2, 3, 4
[1, 4): 1, 2, 3    ---> Pythonic range(1, 4)
(1, 4]:    2, 3, 4
(1, 4):    2, 3

(NULL,
     , NULL)
```

[…, NOW()) and [NOW(), …) are adjacent in µs!

```
=  <>  <  >  <=  >=  @>  &&  <<  >>  &<  &>  -|-  +  *  -  LOWER(  UPPER(  LOWER_INF(  UPPER_INF(
```

```
CREATE TABLE customer (id INTEGER NOT NULL, -- NO PRIMARY KEY
                       name TEXT NOT NULL,
                       fee INTEGER NOT NULL,
                       valid TSTZRANGE NOT NULL DEFAULT TSTZRANGE(NOW(), NULL));
```

```
CREATE TABLE customer (id INTEGER NOT NULL, -- NO PRIMARY KEY
                       name TEXT NOT NULL,
                       fee INTEGER NOT NULL,
                       valid TSTZRANGE NOT NULL DEFAULT TSTZRANGE(NOW(), NULL));
```

```
 id | name  | fee | valid
----------------------------------------
  1 | alice |  10 | [2019-01-01, NULL)
  2 | bob   |  20 | [2019-01-01, NULL)
```

```
CREATE TABLE customer (id INTEGER NOT NULL, -- NO PRIMARY KEY
                       name TEXT NOT NULL,
                       fee INTEGER NOT NULL,
                       valid TSTZRANGE NOT NULL DEFAULT TSTZRANGE(NOW(), NULL));
```

```
 id | name  | fee | valid
----------------------------------------
  1 | alice |  10 | [2019-01-01, NULL)
  2 | bob   |  20 | [2019-01-01, NULL)
```

```
-- insert
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

-- delete
UPDATE customer SET valid = TSTZRANGE(LOWER(valid), NOW()) WHERE id = 2 and UPPER_INF(valid);

-- update
UPDATE customer SET valid = TSTZRANGE(LOWER(valid), NOW()) WHERE id = 1 and UPPER_INF(valid);
INSERT INTO customer (id, name, fee) VALUES (1, 'alice', 15);
```

```
CREATE TABLE customer (id INTEGER NOT NULL, -- NO PRIMARY KEY
                       name TEXT NOT NULL,
                       fee INTEGER NOT NULL,
                       valid TSTZRANGE NOT NULL DEFAULT TSTZRANGE(NOW(), NULL));
```

```
 id | name  | fee | valid
----------------------------------------
  1 | alice |  10 | [2019-01-01, NULL)
  2 | bob   |  20 | [2019-01-01, NULL)
```

```
-- insert
INSERT INTO customer (id, name, fee) VALUES (3, 'carol', 30);

-- delete
UPDATE customer SET valid = TSTZRANGE(LOWER(valid), NOW()) WHERE id = 2 and UPPER_INF(valid);

-- update
UPDATE customer SET valid = TSTZRANGE(LOWER(valid), NOW()) WHERE id = 1 and UPPER_INF(valid);
INSERT INTO customer (id, name, fee) VALUES (1, 'alice', 15);
```

```
 id | name  | fee | valid
-----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
  1 | alice |  15 | [2019-02-05, NULL)
  2 | bob   |  20 | [2019-01-01, 2019-02-05)
  3 | carol |  30 | [2019-02-05, NULL)
```

```
CREATE EXTENSION btree_gist;              -- Generalized Search Tree
```

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```

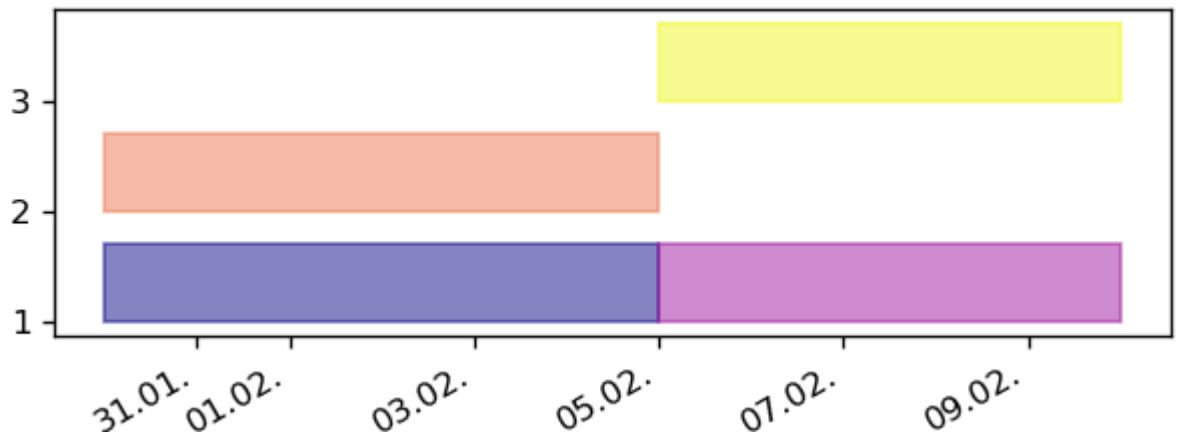
```
CREATE TABLE customer (
    id INTEGER NOT NULL,
    name TEXT NOT NULL,
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&)
);
```

```
 id | name  | fee | valid
----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
  1 | alice |  15 | [2019-02-05, NULL)
  2 | bob   |  20 | [2019-01-01, 2019-02-05)
  3 | carol |  30 | [2019-02-05, NULL)
```

```
CREATE EXTENSION btree_gist;              -- Generalized Search Tree
```

```
CREATE TABLE customer (
    id INTEGER NOT NULL,
    name TEXT NOT NULL,
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&)
);
```

```
 id | name  | fee | valid
----------------------------------------------
  1 | alice |  10 | [2019-01-01, 2019-02-05)
  1 | alice |  15 | [2019-02-05, NULL)
  2 | bob   |  20 | [2019-01-01, 2019-02-05)
  3 | carol |  30 | [2019-02-05, NULL)
```



Let's get that PRIMARY KEY back!

```
CREATE TABLE customer (
    id SERIAL PRIMARY KEY,
    name TEXT UNIQUE);
```

```
CREATE TABLE customer_rev (
    id INTEGER REFERENCES customer(id),
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&));
```

Let's get that PRIMARY KEY back!

```
CREATE TABLE customer (
    id SERIAL PRIMARY KEY,
    name TEXT UNIQUE);
```

```
CREATE TABLE customer_rev (
    id INTEGER REFERENCES customer(id),
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&));
```

```
 id | name
----------------
  1 | alice
  2 | bob
  3 | carol
```

```
 id | fee | valid
---------------------------------------
  1 |  10 | [2019-01-01, 2019-02-05)
  1 |  15 | [2019-02-05, NULL)
  2 |  20 | [2019-01-01, 2019-02-05)
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Let's get that PRIMARY KEY back!

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CREATE TABLE customer (
    id SERIAL PRIMARY KEY,
    name TEXT UNIQUE);
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CREATE TABLE customer_rev (
    id INTEGER REFERENCES customer(id),
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&));
```

```
 id | name
----------------
  1 | alice
  2 | bob
  3 | carol
```

```
 id | fee | valid
-------------------------------------
  1 |  10 | [2019-01-01, 2019-02-05)
  1 |  15 | [2019-02-05, NULL)
  2 |  20 | [2019-01-01, 2019-02-05)
  3 |  30 | [2019-02-05, NULL)
```

```
SELECT username
FROM customer JOIN customer_rev USING (id)
WHERE UPPER_INF(valid)                    -- WHERE valid @> '2019-01-15'
```

Let's get that PRIMARY KEY back!

```
CREATE TABLE customer (
    id SERIAL PRIMARY KEY,
    name TEXT UNIQUE);
```

```
CREATE TABLE customer_rev (
    id INTEGER REFERENCES customer(id),
    fee INTEGER NOT NULL,
    valid TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        valid WITH &&));
```

```
 id | name
----------------
  1 | alice
  2 | bob
  3 | carol
```

```
 id | fee | valid
-------------------------------------
  1 |  10 | [2019-01-01, 2019-02-05)
  1 |  15 | [2019-02-05, NULL)
  2 |  20 | [2019-01-01, 2019-02-05)
  3 |  30 | [2019-02-05, NULL)
```

```
SELECT username
FROM customer JOIN customer_rev USING (id)
WHERE UPPER_INF(valid)                    -- WHERE valid @> '2019-01-15'
```

Let's add another time dimension!

Bitemporal database design

A method of storing data records to represent both the history of the reality and the history of updates to these records in the database.

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1. When the fact described by the record was known to the world
2. When the record was known to our database

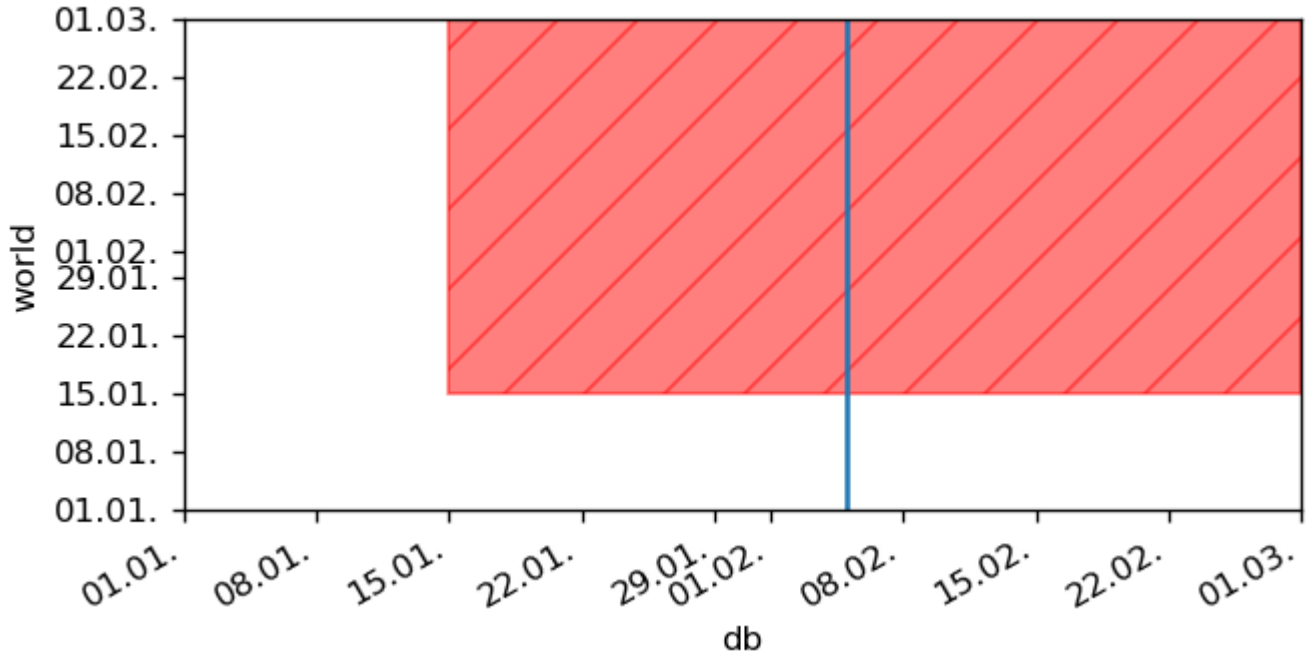
Bitemporal database design

A method of storing data records to represent both the history of the reality and the history of updates to these records in the database.

1. When the fact described by the record was known to the world
2. When the record was known to our database

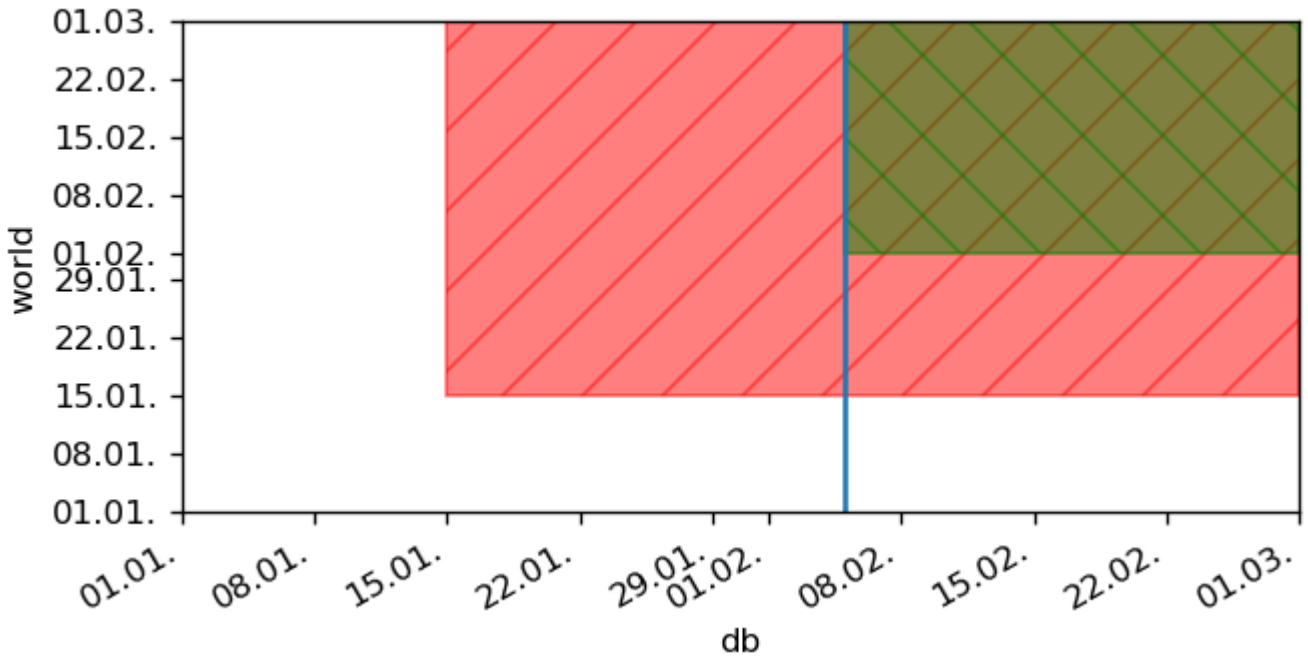
```
CREATE TABLE customer_rev (
    id INTEGER REFERENCES customer(id),
    fee INTEGER NOT NULL,
    tsr_world TSTZRANGE NOT NULL,
    tsr_db TSTZRANGE NOT NULL,
    EXCLUDE USING GIST (id WITH =,
                        tsr_world WITH &&,
                        tsr_db WITH &&));
```

```
 id | fee | tsr_world          | tsr_db
----------------------------------------------------
  1 |  10 | [2019-01-15, NULL) | [2019-01-15, NULL)
```

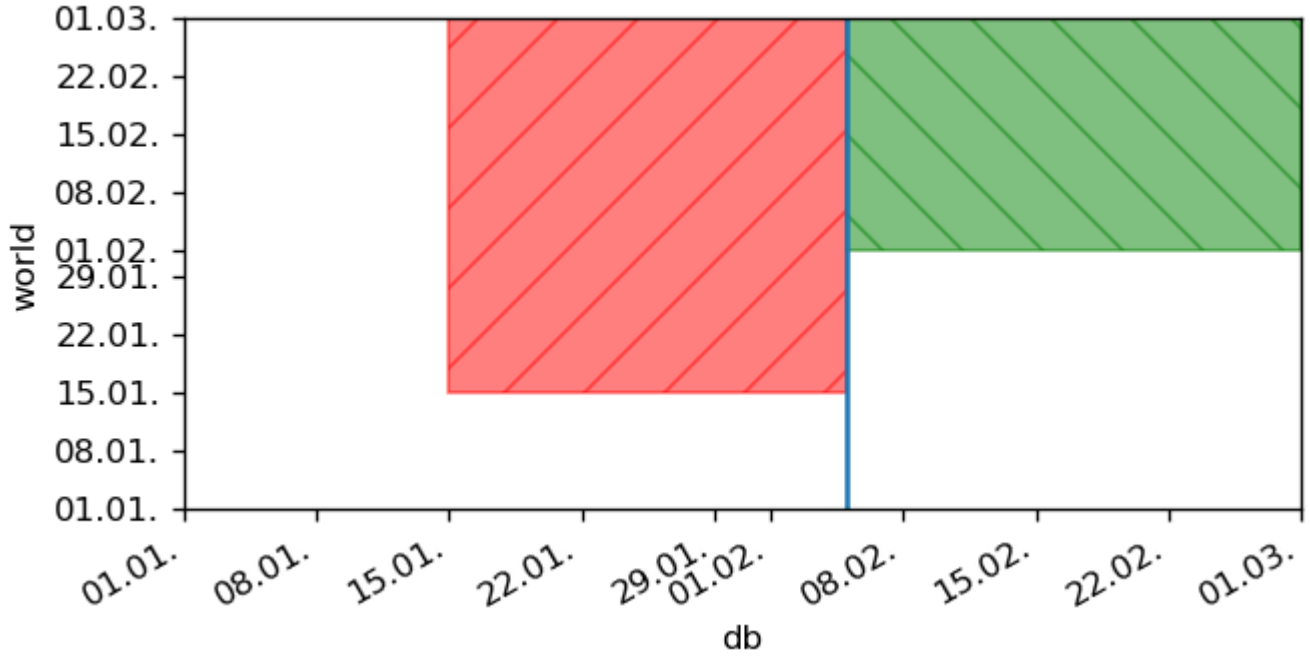



```sql
SELECT id, fee, tsr_world
FROM customer_rev
WHERE tsr_db @> '2018-02-05';
```

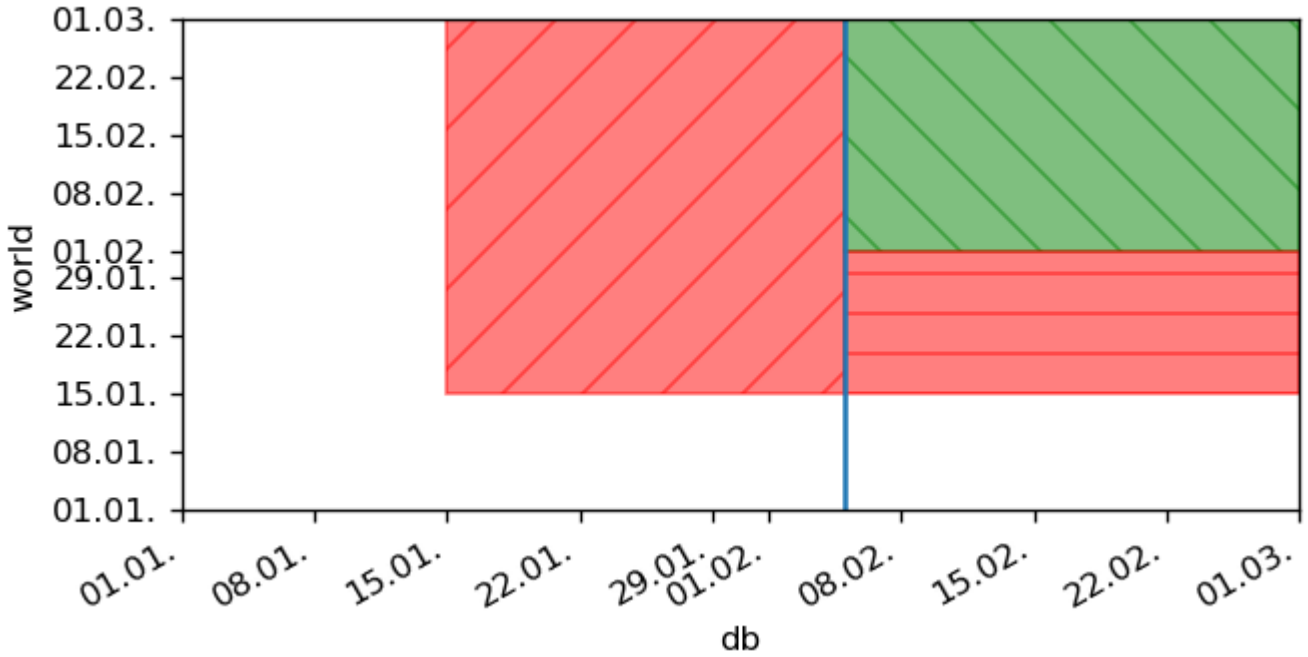
```
 id | fee | tsr_world                | tsr_db
----------------------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [2019-01-15, NULL)
  1 |  15 | [2019-02-01, NULL)       | [2019-02-05, NULL)
```



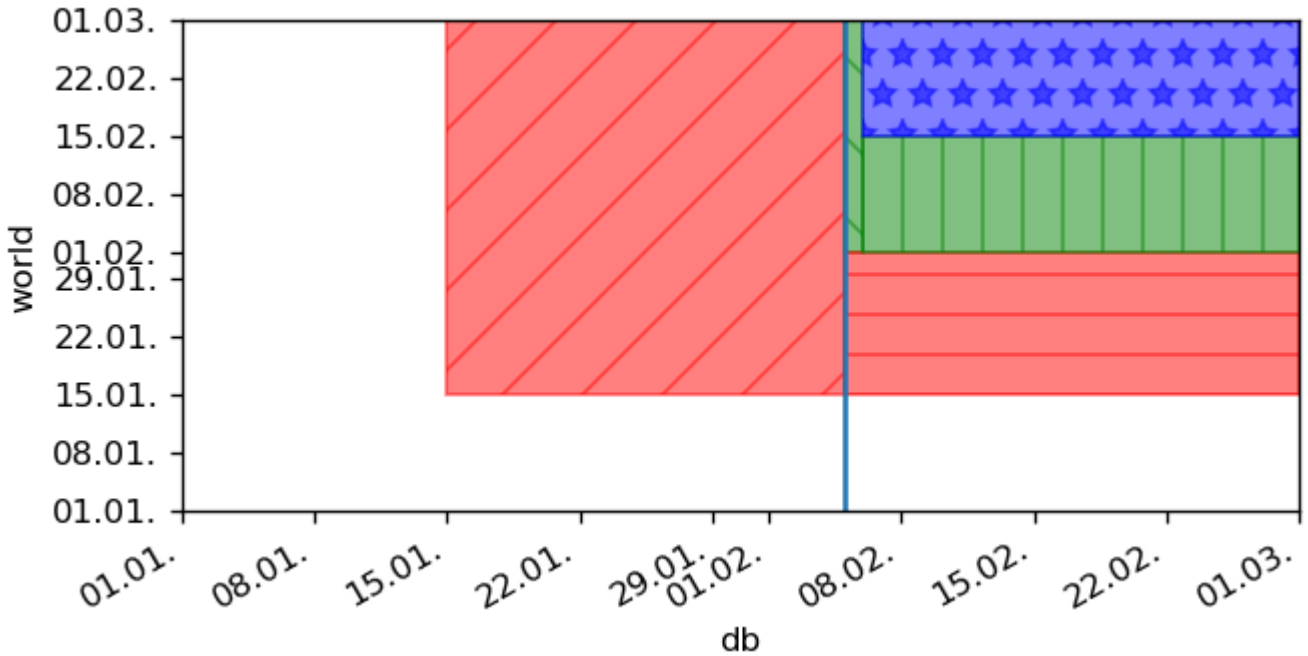
```
 id | fee | tsr_world                | tsr_db
----------------------------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [2019-01-15, 2019-02-05)
  1 |  15 | [2019-02-01, NULL)       | [2019-02-05, NULL)
```



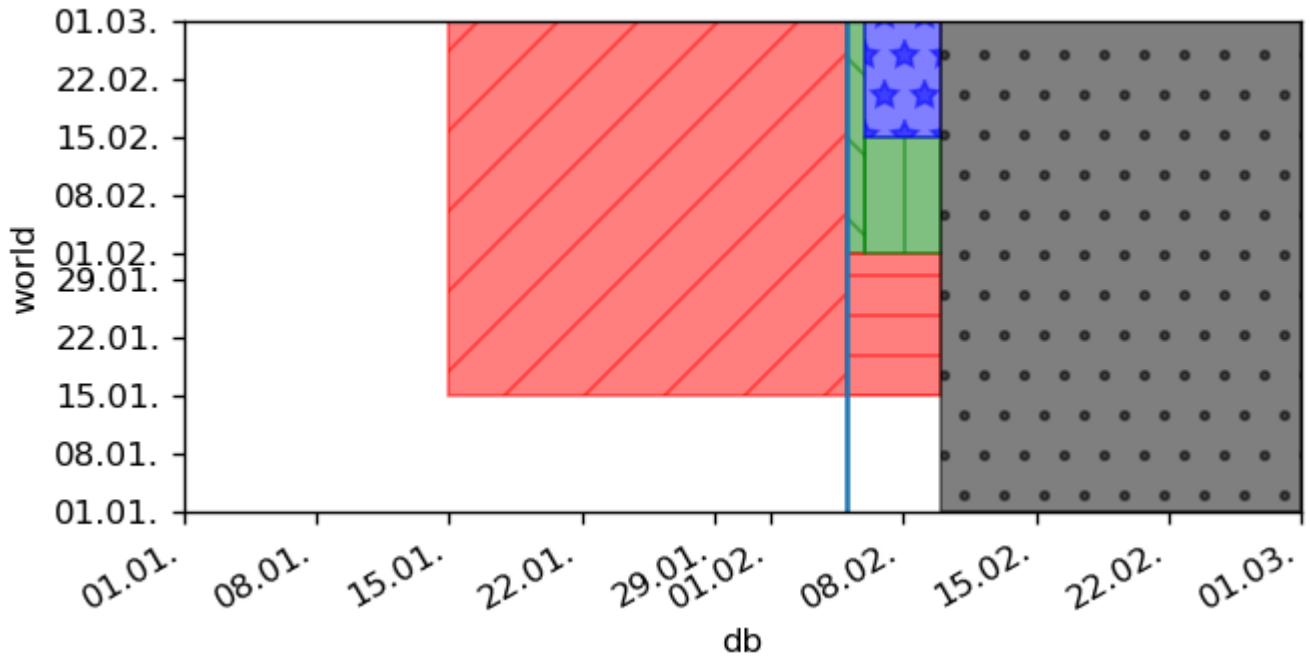
```
 id | fee | tsr_world                | tsr_db
----------------------------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [2019-01-15, 2019-02-05)
  1 |  10 | [2019-01-15, 2019-02-01) | [2019-02-05, NULL)
  1 |  15 | [2019-02-01, NULL)       | [2019-02-05, NULL)
```

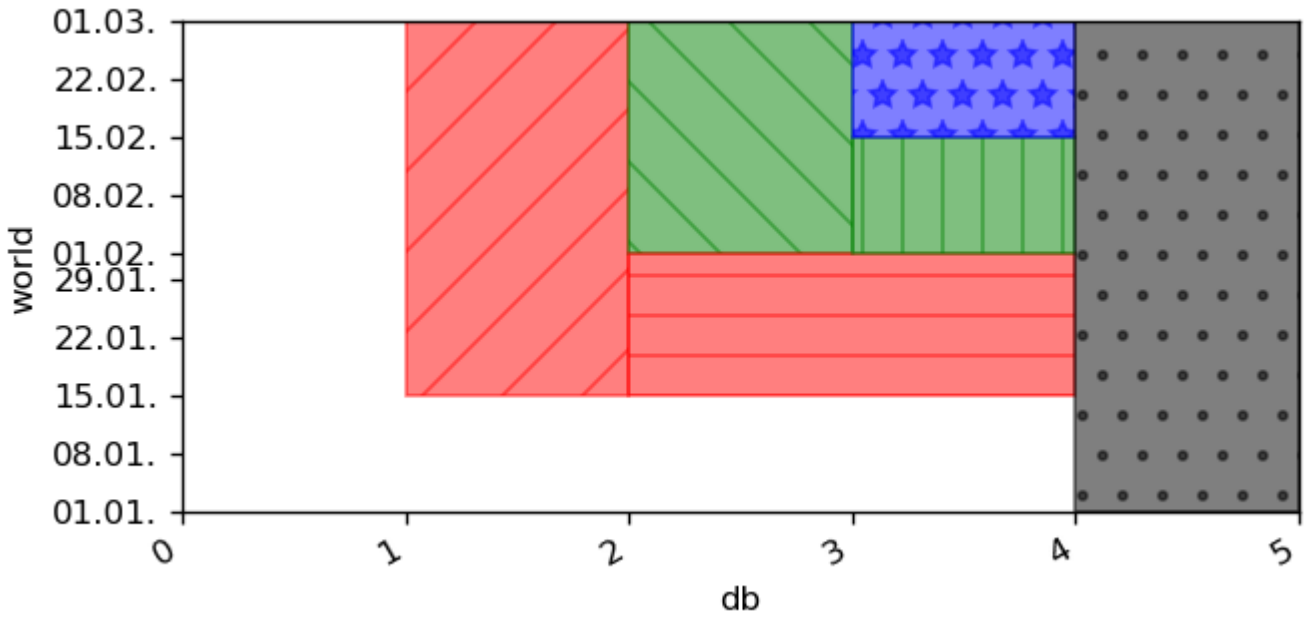


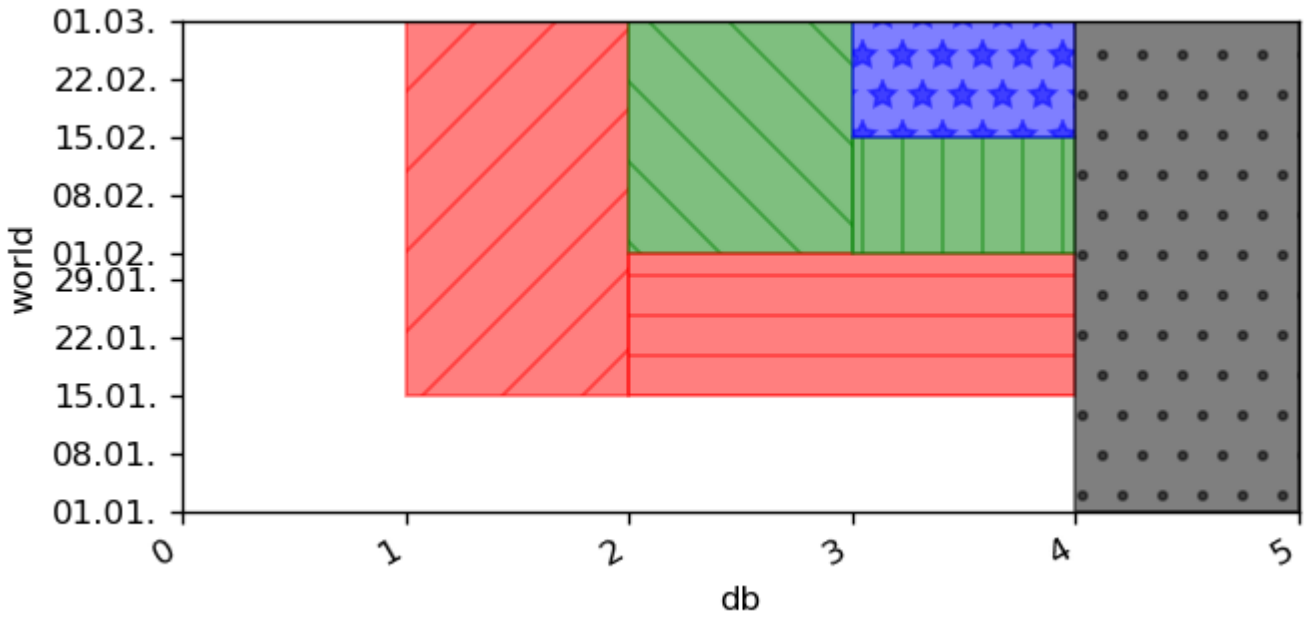
```
 id | fee | tsr_world                | tsr_db
----------------------------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [2019-01-15, 2019-02-05)
  1 |  10 | [2019-01-15, 2019-02-01) | [2019-02-05, NULL)
  1 |  15 | [2019-02-01, NULL)       | [2019-02-05, 2019-02-06)
  1 |  15 | [2019-02-01, 2019-02-15) | [2019-02-06, NULL)
  1 |  18 | [2019-02-15, NULL)       | [2019-02-06, NULL)
```



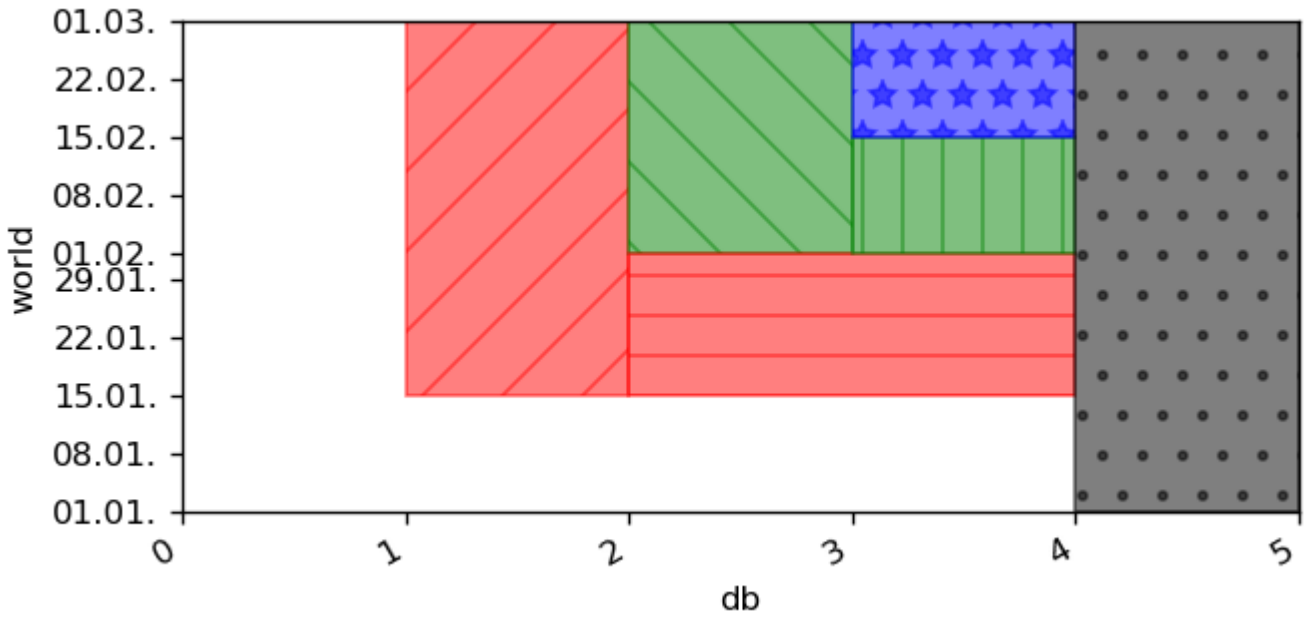
```
 id | fee | tsr_world                | tsr_db
----------------------------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [2019-01-15, 2019-02-05)
  1 |  10 | [2019-01-15, 2019-02-01) | [2019-02-05, 2019-02-10)
  1 |  15 | [2019-02-01, NULL)       | [2019-02-05, 2019-02-06)
  1 |  15 | [2019-02-01, 2019-02-15) | [2019-02-06, 2019-02-10)
  1 |  18 | [2019-02-15, NULL)       | [2019-02-06, 2019-02-10)
  1 |   0 | [NULL, NULL)             | [2019-02-10, NULL)
```




01.03.
22.02.
15.02.
08.02.
01.02.
29.01.
22.01.
15.01.
08.01.
01.01.
world
0
1
2
3
4
5
db




```
CREATE TABLE revision (
    revision_id INTEGER PRIMARY KEY,
    tsr_db TSTZRANGE DEFAULT TSTZRANGE(NOW(), NULL),
    desc TEXT NOT NULL UNIQUE,
    EXCLUDE USING GIST (tsr_db WITH &&));
```

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```
 revision_id | tsr_db       | desc
-------------------------------------------------------------------------------
           0 | [NULL, NULL) | In the beginning, the Earth was without form, and void…
```

```
customer_rev

 id | fee | tsr_world                | revs
----------------------------------------------
  1 |  10 | [2019-01-15, NULL)       | [1, 2)
  1 |  10 | [2019-01-15, 2019-02-01) | [2, 4)
  1 |  15 | [2019-02-01, NULL)       | [2, 3)
  1 |  15 | [2019-02-01, 2019-02-15) | [3, 4)
  1 |  18 | [2019-02-15, NULL)       | [3, 4)
  1 |   0 | [NULL, NULL)             | [4, NULL)
```

```
revision

 revision_id | tsr_db                   | desc
-------------------------------------------------------------------------------------------------
           0 | [NULL, 2019-01-15)       | In the beginning, the Earth was without form, and void…
           1 | [2019-01-15, 2019-02-05) | Start at 10
           2 | [2019-02-05, 2019-02-06) | Increase to 15
           3 | [2019-02-06, 2019-02-10) | Increase to 18
           4 | [2019-02-10, NULL)       | Give for free!
```

Writing into DB

- table `revision`
  - close previous `tsr_db`
  - insert a new one
- other tables
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  - insert new rows

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```
with Revision(desc='update from #123') as rev:
    rev.modify(…)
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```

```
class Revision:
    def __init__(self, desc):
        self.desc = desc
        self.revision_id = None
        self.todos = []
        self.conn = psycopg.connect('postgres://USER@HOST:PORT/DBNAME')

    def __enter__(self):
        with self.conn.cursor() as cur:
            cur.execute("""UPDATE revision SET tsr_db = TSTZRANGE(LOWER(tsr_db), NOW())
                           WHERE UPPER_INF(tsr_db) RETURNING revision_id""")
            self.revision_id = next(cur)[0] + 1  # raise StopIteration?
            cur.execute("""INSERT INTO revision (revision_id, desc) VALUES (%s, %s)""",
                        (self.revision_id, self.desc))
        return self

    def __exit__(self, exc_type, exc_value, exc_traceback):
        if exc_type is None and self.todos:
            while True:
                confirm = input(f'{len(self.todos)} todos. commit? (yes/no)')
                if confirm == 'yes':
                    self.conn.commit()
                    return
                elif confirm == 'no':
                    break
        self.conn.rollback()

    def modify(self, …):
        …
```

Reading from DB

- consistent at any time

```
SELECT MAX(revision_id)
FROM revision;
```

```
SELECT …
FROM customer_rev
WHERE revs @> %(revision_id)s
  AND …
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- direct SQL or service?
  - logging, usage statistics (upgrades?)
  - caching
  - updates in service?

Consistent serial reading

What is “now”?

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today = datetime.datetime.utcnow()
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```
revision_id, data = service.method_one(*args)
revision_id, data = service.method_one(*args, revision_date=datetime(2019, 2, 1, 13, …))
revision_id, data = service.method_one(*args, revision_id=17)

_, data = service.method_two(*args, revision_id=revision_id)
```

Revisions like commits in VCS?

- single branch
- “test” branches through clones?

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- psycopg2 blocking transactions on modified rows
- use context managers for “transactions” in code
- read external sources (time, DB, …) independently from your runtime
- Python3, psycopg2 and PostgreSQL are cool

```
 name             | city      | street        | house_number | apartment
------------------------------------------------------------------------
 Nadya Shevelyova | Leningrad | 3rd Builders' | 25           | 12
 Zhenya Lukashin  | Moscow    | 3rd Builders' | 25           | 12
```

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 Europe/Moscow | +03:00     | False
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