Temporal Data & Time Travel in PostgreSQL

Peter Vanroose

http://www.abis.eu/html/enindex.html

FOSDEM 2015 - PGDay

30 January 2015

Marriott Hotel, Brussels

Temporal tables in PostgreSQL

Outline :

- **Relational databases and historic (or versioned) data: what & why**
- **ISO SQL:2011 standards description**
- **new SELECT query syntax for “temporal” requests**
- **System-time (“versioning”) vs. Business-time (“validity”)**
- **implementation choices: details & arguments**
- **use cases & performance aspects**

Relational databases and historic (or versioned) data

PostgreSQL ==> very efficient *transactional data server* :

- **ACID: atomic (transactions) ==> commit / rollback**
  consistent ==> each visible DB state makes sense
  isolated ==> through locking & isolation levels
  durable ==> permanent changes
  BUT no notion of "keeping track of history"

Data warehouse & business intelligence :

- **often needs / wants historic data**
  ("how did the data look on 1 February?")
  (trend analysis: "predict future sales from past trends")
- **not typically a task for a transactional DB server**
  but can be integrated

What we miss: "what was the (ACID) state of my data on <time instant>" ?

Reasons for “temporal” data queries in a relational DB 1.1

- **Not really meant for BI or DW**
- **Tracability of data changes for *auditing* purposes:**
  - **“*What data was used in last month’s investment assessment?*”**
  - **“*Please re-run the tax computation of last 31 December*”**
  - **“*Since when are you giving a 5% price reduction to that client?*”**
  - **“*Please trace back <certain business data> over the last year.*”**
- **Tracability of data changes for *business tracing* purposes:**
  - **“*Where did we send that order to last week?*”**

    ==> What was the customer’s address on January 22 at 15:43 ?
- **Storing data *validity* information:**
  - **Customer: “*My address as of 1 September will be ...*”**
  - **Insurance record(s): “*covered time interval: 1 January -- 30 June*”**
  - **Promotional action: “*Price will be 20% off between ... and ...*”**
  - **Product availability period(s) (possibly with retroactive effect)**

Temporal tables and the ISO SQL:2011 standard

SQL:2011 published December 2011, replacing SQL:2008

official name: ISO/IEC 9075:2011

Most important "new SQL feature" in this standard's version (viz. in Part 2: SQL/Foundation):

"Temporal Data Support"

as an optional (non-mandatory) feature

What?

- **tables may have additional time-period (interval) information**

  ("ACID validity" periods; temporal versions; ...)
- **UPDATE / DELETE / INSERT must automatically maintain this info**

  (TRUNCATE not)
- **SELECT should add syntax to interrogate non-current time-period:**

  SELECT ... FROM t AS OF SYSTEM TIME <time indication>
- **not meant to be used as "application time"**

Transaction time versus business time

“Transaction time”: what was the (ACID) state of my data on `<time>` ?

- **also called “system time”**
- **should be system maintained: “system-versioned” tables**
- **useful for questions on auditing & tracing**
- **only supports history: time instants must never be future**
- **default is “now”; history should not burden “normal” activity**

“Business time”: validity time, application time:

- **should be application (user) maintained, not automatic**
- **useful for questions on “covered time interval” of business reality**

  e.g.: insurance contract, address, promotional action, membership
- **future dates could make sense**
- **time resolution decided by application (day / microsecond / year ...)**

SELECT query syntax for “temporal” requests

Example table: customers

id	name	address	telephone	amount_sold
1	Janssen	Singel 9	016/123456	1043.50
2	Dupont	A.Max 3	02/9876543	745.00
3	Thiery	Square 1	03/1234567	6100.00
8	Van Dijk	Dijk 8	0476/54321	75.25
9	Berends	Dorp 17	09/8765432	3201.43
10	Zander	Centre 4		123.45

```
SELECT * FROM customers WHERE id = 3 ;
```

id	name	address	telephone	amount_sold
3	Thiery	Square 1	03/1234567	6100.00

```
SELECT * FROM customers AS OF SYSTEM TIME '2015-01-22 15:45:00' WHERE id = 3 ;
```
(*)

id	name	address	telephone	amount_sold
3	Thiery	Zand 98	03/1234567	6100.00

New SELECT query syntax for “temporal” requests

- **New ANSI / ISO *SQL:2011 Standard* syntax:**
  ... FROM <table> AS OF SYSTEM TIME <timestamp> ...
- **DB2 syntax since version 10 (2010) (2 alternative forms):**
  ... FROM <table> FOR SYSTEM_TIME AS OF <timestamp> ...
  ... FROM <table> AS OF TIMESTAMP <timestamp> ...
- **Oracle syntax since version 10g (2005) (“Flashback Query”):**
  ... FROM <table> AS OF TIMESTAMP <timestamp> ...
- **Examples:**

```
SELECT * FROM customers AS OF SYSTEM TIME current_timestamp ;
SELECT * FROM customers AS OF SYSTEM TIME current_date - 3 days ;
SELECT * FROM customers AS OF SYSTEM TIME current_timestamp - 1 min ;
SELECT * FROM customers AS OF SYSTEM TIME TIMESTAMP '2015-01-22' ;
SELECT * FROM customers AS OF SYSTEM TIME :hv ;
```

Note: Oracle & DB2 also have similar syntax for “business time”;
the standard does not (yet) propose a syntax for this

DB2: **... FROM <table> FOR BUSINESS_TIME AS OF <timestamp>**
Oracle: **... FROM <table> AS OF PERIOD FOR <business_time> <timestamp>**

Temporal tables in PostgreSQL

Table setup for “system time” versioning

But ... tables are (still) not “versioned” by default !

Think about how you would implement “versioned data” manually:

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	
3	Thiery	Square 1	03/1234567	6100.00	2015-01-28 15:13:32	
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/1234567	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

Technical challenges:

store delta’s? duplicate PK values; query performance; complexity;
triggers for update & delete; default values for “hidden” columns; ...

Table setup for “system time” versioning: SQL:2011


```
CREATE TABLE customers
    (id             integer NOT NULL
    , name          varchar(64)
    , address       varchar(128)
    , telephone     varchar(32)
    , amount_sold   dec(9,2)
    , valid_from    timestamp     GENERATED ALWAYS AS SYSTEM VERSION START
    , valid_until   timestamp     GENERATED ALWAYS AS SYSTEM VERSION END
    , PRIMARY KEY (id)
    )
    WITH SYSTEM VERSIONING;
```

- may also ALTER existing table: ADD two columns & versioning:

```
ALTER TABLE customers
    ADD COLUMN s1 timestamp GENERATED ALWAYS AS SYSTEM VERSION START;
ALTER TABLE customers
    ADD COLUMN s2 timestamp GENERATED ALWAYS AS SYSTEM VERSION END;
ALTER TABLE customers
    ADD SYSTEM VERSIONING;
```

- may later drop the versioning again:

```
ALTER TABLE customers DROP SYSTEM VERSIONING;
```

Table setup for “system time” versioning: how DB2 does it

Available since 2010 (DB2 version 10)

```
CREATE TABLE customers
    (id             integer NOT NULL
    , name          varchar(64)
    , address       varchar(128)
    , telephone     varchar(32)
    , amount_sold   dec(9,2)
    , valid_from    timestamp(12)  GENERATED ALWAYS AS ROW BEGIN  NOT NULL
    , valid_until   timestamp(12)  GENERATED ALWAYS AS ROW END    NOT NULL
    , trans_id      timestamp(12)  GENERATED ALWAYS AS TRANSACTION START ID
    , PRIMARY KEY (id)
    , PERIOD SYSTEM_TIME (valid_from, valid_until)
    );

CREATE TABLE customers_history LIKE customers ;
ALTER TABLE customers
    ADD VERSIONING    USE HISTORY TABLE customers_history ;
```

- may also ALTER customers: ADD three columns & PERIOD spec
- the three columns *could* be declared as IMPLICITLY HIDDEN

Table setup for “system time” versioning: how Oracle does it 4.3

“Oracle Flashback Query” since Oracle 10g (2005):

- **Available for all tables (when Flashback is enabled)**
- **Pseudo-columns:**

  versions_starttime

  versions_endtime

  versions_xid
- **integrated with “ordinary” rollback mechanisms**

Table setup for “system time” versioning: configuration issues 4.4

- base and history table *must* have byte-compatible rows:
  - same column names, same data types, same order & NOT NULLs
  - exactly what “CREATE .. LIKE ..” provides
- no further similarities needed
  - may have different indexes
  - may have different check constraints and FKs
    (typically, the history table should have none)
  - may have different physical implementation
    (like, e.g., partitioning, compression, tablespace&buffer choices)
  - history table *should* have all direct DML blocked
    (since it should be completely transparent to applications)
- ALTER TABLE (column alterations or additions) on base table
  automatically updates the history table definition
- No necessity of having a PK !!

Table setup for “system time” versioning: sample data

customers table:

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	infinity
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	infinity
3	Thiery	Square 1	03/1234567	6100.00	2015-01-28 15:13:32	infinity
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	infinity
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	infinity
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	infinity

customers_history table:

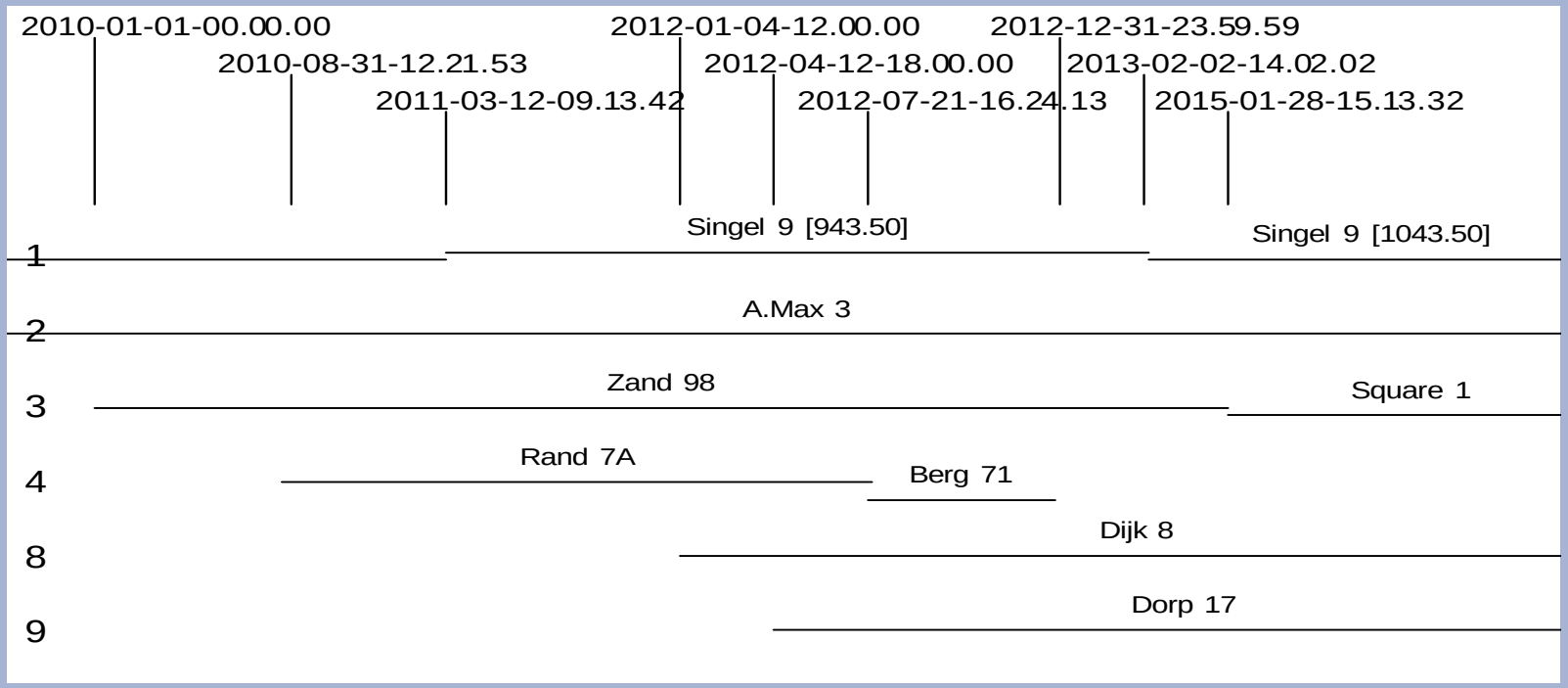
id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/1234567	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

(note: precision of timestamp columns: may contain fractional digits and/or time zone)

Table setup for “system time” versioning: effects on DML

- **customer_history rows: *never* inserted/updated/deleted manually !**
- **on INSERT in customer:**
  - **the three additional columns are auto-filled by the RDBMS:**
    - valid_from: with *current_timestamp*
    - valid_until: with ‘infinity’
- **on UPDATE of row(s) in customer:**
  - **original (unchanged) row is “moved” to customer_history**
    - where *valid_until* is changed to *current_timestamp*
  - **modified row: valid_from is modified to *current_timestamp***
- **on DELETE of row(s) in customer:**
  - **original (old) row is “moved” to customer_history**
    - where *valid_until* is changed to *current_timestamp*

Interpretation of system time validity intervals



PK temporal uniqueness: **for every time instant, there is at most one data row per PK value.**

Since e.g. 2011-03-12 09:13:42 is the commit timestamp of the update, it belongs to the middle time interval, *not* the left one.

In general, the "valid_from" (start) time is an *inclusive* boundary, while the "valid_until" (end) time is an *exclusive* boundary.

Temporal tables in PostgreSQL

System time: guarantees

- “Ordinary” SELECT queries never need to access the history table

  ==> base table looks exactly as before

  (except for additional columns)

  ==> no need to revisit existing applications

  (even with identical access paths)

- “Ordinary” INSERT/UPDATE/DELETE notice additional overhead

  similar to classical triggers

- History can only be forged by modifying the history table directly
  - base table START & END columns should be non-updatable
  - history table should be non-updatable

  ==> otherwise it would be possible to create inconsistent data

  (viz. violate temporal uniqueness on PK)

  & to forge the real history

  (DB2 allows this! => carefully set history table authorisations)

System time: additional DML possibilities

SELECT ... FROM customers AS OF SYSTEM TIME current_timestamp
is equivalent to
SELECT ... FROM customers
and should not need to access the history table (but it does in DB2!)

SELECT ... FROM customers AS OF SYSTEM TIME current_date
is *NOT* equivalent to the above!
==> it's equivalent to "last midnight"

SELECT ... FROM customers AS OF SYSTEM TIME current_date + INTERVAL '1 day'
is essentially *INVALID* (as is any future date), but will be accepted (by DB2, not Oracle)

SELECT ... FROM customers FOR SYSTEM_TIME FROM <ts1> TO <ts2>
- the time range is <ts1> *inclusive* but <ts2> *exclusive*
- might return multiple rows for the same PK
- makes sense to include (one of) the "valid_from" or "valid_until" columns in selection
- if <ts1> is larger than or equal to <ts2>, the result set is empty

SELECT ... FROM customers FOR SYSTEM_TIME BETWEEN <ts1> AND <ts2>
- the time range is <ts1> *inclusive* and also <ts2> *inclusive*

System time: performance considerations

The query

SELECT ... FROM customers AS OF SYSTEM TIME <ts> WHERE <cond>

is implemented as follows (as can be seen from EXPLAIN):

```
SELECT ... FROM customers
    WHERE <cond>
        AND valid_from <= <ts>
UNION ALL
    SELECT ... FROM customers_history
        WHERE <cond>
            AND valid_from <= <ts>
            AND valid_until  >  <ts>
```

So it could be important to create index(es)

on columns valid_from and/or valid_until,

possibly composite with other columns

System time in PostgreSQL

There are some partial implementations & proposals:

1. **Vladislav Arkhipov (Dec. 2012): Pg extension "temporal_tables"**

   (see `pgxn.org/dist/temporal_tables/1.0.1/`)

   ==> working implementation for the "auto-archive" part (triggers)

   ==> does not modify the SELECT or CREATE TABLE syntax

2. **Miroslav Šimulcik**

   (see `wiki.postgresql.org/wiki/SQL2011Temporal`)

   ==> is only a design proposal: implementation not (yet) public

Technical choices -- important aspects to consider:

- **preferably use the TSTZRANGE type ? (see next page)**
- **is there need for a TRANS_ID ?**
- **performance considerations: the triggers; GiST & GIN indexes; ...**
- **visibility/accessibility of the history table ?**

Intermezzo - range data types in PostgreSQL

Since Pg 9.2; non-standard

Range value = a pair of values of a certain (ordinal) base type

Interpretation: is the “range” of all values between those end points

CREATE TYPE <name> AS RANGE (SUBTYPE = <type>)

e.g.: CREATE TYPE tsrange AS RANGE (SUBTYPE = timestamp)
==> is a predefined type, together with tstzrange, int4range, daterange, ...

Notation for range constants: (mix of inclusive / exclusive the end points)

'[3, 7]' '[2015-01-01, 2016-01-01)' '(3.1415 , 3.1416)' '[2015-01-01,)'

New predicates for range columns: (beware: need explicit casts ...)

“contains”: '[3, 7]' @> 4

“intersects”: '[2015-01-01, 2016-01-01)' && '(2014-12-31, 2015-01-01]'
isempty('(4, 5)')

New operators:

'[3,7]' * '[5,9]' *(returns '[5,8)')* '[3,7]' + '[5,9]' *(=> '[3,10)')* '[3,7]' - '[5,9]' *(=>'[3,5)')*
upper('[3,8)') *(returns 8)* lower('[3,8)') *(returns 3)*

System time: some use cases

1. Compliance & auditing:
   - never need to use “AS OF” queries
   - history table functions as a “change log”
2. Business Intelligence related to time evolution of data:
   - “who was our best customer at the end of last month?”
   - application could directly query the base + history tables
   - or: take summary snapshots at several time instants: eg:

```
WITH RECURSIVE dates(t) AS (
    SELECT cast('2014-01-01' AS timestamp)
    UNION ALL
    SELECT t + INTERVAL '1 month' FROM dates WHERE t < current_date
)
SELECT SUM(amount_sold) FROM dates d, customers AS OF SYSTEM TIME d.t
GROUP BY d.t
-- (although this won’t work syntactically: “AS OF” needs host variable or constant)
```

System time: some use cases

3. Compare data at two times in the past (or current)

- **detailed:**

```
SELECT a.id, a.address AS old, b.address AS new
FROM  customers AS OF SYSTEM TIME :date1  a
        FULL OUTER JOIN
         customers AS OF SYSTEM TIME :date2  b
        ON a.id = b.id
WHERE a.address is distinct from b.address
```

- **summaries:**

```
SELECT SUM(amount_sold), :date1
FROM  customers AS OF SYSTEM TIME :date1
UNION ALL
SELECT SUM(amount_sold), :date2
FROM customers AS OF SYSTEM TIME :date2
```

Resembles use case of versioning systems (git, subversion, CVS)

4. Point in time recovery

```
UPDATE customers c
SET address = (SELECT address FROM customers AS OF SYSTEM TIME :x
                    WHERE id = c.id)
```

Business time: data validity time period

Want more control over the “valid_from” and “valid_until” values

- time instant of UPDATE is not necessarily
  time instant of when this new fact becomes valid
- example: address change should become active on 1 September

No longer about “transaction time” but about “effective” timespans.

Application should be able to insert into or update the validity dates

But still want “temporal uniqueness” guarantees from the RDBMS

Careful: without an “AS OF”: returns the full history (all versions):

... FROM <table> ...

Table setup for “business time” versioning: how DB2 does it


```
CREATE TABLE customers
    (id             integer NOT NULL
    , name          varchar(64)
    , address       varchar(128)
    , telephone     varchar(32)
    , amount_sold   decimal(9,2)
    , valid_from    timestamp       NOT NULL
    , valid_until   timestamp       NOT NULL
    , PERIOD BUSINESS_TIME (valid_from, valid_until)          -- no “FOR” ...
    , PRIMARY KEY (id, BUSINESS_TIME WITHOUT OVERLAPS)
    );
```

- No history table!
- “id” could now have duplicates

  ==> need a composite primary key
- New uniqueness concept: *temporal uniqueness*
- Enforced by a new type of unique index (standards compliant?) :

```
CREATE UNIQUE INDEX <name>
    ON <table> (<cols>, BUSINESS_TIME WITHOUT OVERLAPS) ;
```

Table setup for “business time” versioning: how Oracle does it

Since Oracle 12c (2013):

```
CREATE TABLE customers
    (id             integer NOT NULL
    , name          varchar(64)
    , address       varchar(128)
    , telephone     varchar(32)
    , amount_sold   decimal(9,2)
    , valid_from    timestamp DEFAULT current_timestamp
    , valid_until   timestamp DEFAULT to_timestamp('31.12.9999')
    , PERIOD FOR business_time (valid_from, valid_until)
    );
```

- “No overlaps” must be manually guaranteed, it seems ...
- should not declare “id” as primary key, of course ...

Business time: inserting data

- No defaults for “valid_from” and “valid_until”

  ==> application *must* explicitly state the validity period

  (if these columns are NOT NULL, which they shouldn’t be)

==> “valid_until” could still be set to e.g. 2999-12-31 or ‘infinity’

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	infinity
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	infinity
3	Thiery	Square 1	03/1234567	6100.00	2015-01-28 15:13:32	infinity
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	infinity
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	infinity
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	infinity
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/1234567	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

Business time: updating data

- **Update statements without “temporal” specification will update ALL rows, not just the ones “as of now”:**

UPDATE customers SET telephone = '03/7654321' WHERE id = 3

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	infinity
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	infinity
3	Thiery	Square 1	03/7654321	6100.00	2015-01-28 15:13:32	infinity
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	infinity
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	infinity
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	infinity
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/7654321	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

Business time: updating data

- **Update statements with “temporal” specification:**

```
UPDATE customers FOR PORTION OF BUSINESS_TIME
                    FROM TIMESTAMP '2015-09-01 00:00:00' TO TIMESTAMP 'infinity'
   SET telephone = '03/7654321' WHERE id = 3
```

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	infinity
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	infinity
3	Thiery	Square 1	03/7654321	6100.00	2015-09-01 00:00:00	infinity
3	Thiery	Square 1	03/1234567	6100.00	2015-01-28 15:13:32	2015-09-01 00:00:00
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	infinity
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	infinity
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	infinity
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/1234567	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

==> automatic row split when necessary!

Business time: deleting data

- **Delete statements with “temporal” specification:**

```
DELETE FROM customers FOR PORTION OF BUSINESS_TIME
                      FROM TIMESTAMP '2016-01-01 00:00:00' TO TIMESTAMP 'infinity'
    WHERE id = 3
```

id	name	address	telephone	amount_sold	valid_from	valid_until
1	Janssen	Singel 9	016/123456	1043.50	2013-02-02 14:02:02	infinity
2	Dupont	A.Max 3	02/9876543	745.00	2004-08-20 11:11:11	infinity
3	Thiery	Square 1	03/7654321	6100.00	2015-09-01 00:00:00	2016-01-01 00:00:00
3	Thiery	Square 1	03/1234567	6100.00	2015-01-28 15:13:32	2015-09-01 00:00:00
8	Van Dijk	Dijk 8	0476/54321	75.25	2012-01-04 12:00:00	infinity
9	Berends	Dorp 17	09/8765432	3201.43	2012-04-12 18:00:00	infinity
10	Zander	Centre 4		123.45	2012-11-15 09:00:00	infinity
1	Janssen	Singel 9	016/123456	943.50	2011-03-12 09:13:42	2013-02-02 14:02:02
1	Janssen	Singel 9		943.50	2004-03-30 15:13:42	2011-03-12 09:13:42
3	Thiery	Zand 98	03/1234567	6100.00	2010-01-01 00:00:00	2015-01-28 15:13:32
4	Pieters	Rand 7A		100.00	2010-08-31 12:21:53	2012-07-21 16:24:13
4	Pieters	Berg 71		100.00	2012-07-21 16:24:13	2012-12-31 23:59:59

==> automatic row split when necessary!

Business time: guarantees & caveats

- "Ordinary" SELECT always accesses the full table

  ==> including history!

  ==> unless including the necessary WHERE predicates on columns `valid_from` & `valid_until` ...

  OR by using the "new" AS OF syntax (similar to system time):

- DB2 syntax for querying a "business temporal" table:

  ... FROM <table> **FOR BUSINESS_TIME AS OF** <timestamp or date> ...

- Oracle syntax: ... FROM <table> AS OF PERIOD FOR <business_time> <timestamp>

- no SQL ANSI/ISO standard (yet) ?

- "Ordinary" INSERT/UPDATE/DELETE: all versions (incl. history) !

  ==> unless with WHERE on `valid_from` or `valid_until`

- INSERTs and "temporal" UPDATEs sometimes refused:

  ==> "duplicate" error from unique index

  when time intervals would overlap

  ==> ***temporal uniqueness** should be guaranteed by the RDBMS*

Business time: additional DML possibilities in DB2

7.7

SELECT ... FROM customers FOR BUSINESS_TIME AS OF current_timestamp
is *NOT* equivalent to
SELECT ... FROM customers

SELECT ...
FROM customers FOR BUSINESS_TIME AS OF current_date + INTERVAL '1 day'
is totally *VALID* (as is any future date)

SELECT ... FROM customers FOR BUSINESS_TIME FROM <ts1> TO <ts2>
- the time range is <ts1> *inclusive* but <ts2> *exclusive*
- might return multiple rows for the same id
- if <ts1> is larger than or equal to <ts2>, or one is NULL, the result set is empty

SELECT ... FROM customers FOR BUSINESS_TIME BETWEEN <ts1> AND <ts2>
- the time range is <ts1> *inclusive* and also <ts2> *inclusive*

Temporal tables in PostgreSQL

Business time in PostgreSQL

No additional infrastructure needed, except for (ideally):

- new “WITHOUT OVERLAP” indexes / UNIQUE constraints
- new “temporal” table expression syntax to be added to SELECT:

  SELECT ... FROM <t> **AS OF** <time_period_spec> <timestamp>

  SELECT ... FROM <t> **FOR** <time_period_spec> **BETWEEN** <ts1> **AND** <ts2>
- possibly support mixed syntax for the “time range” column pair:
  - separate columns, ordinary timestamp predicates (< >= etc)
  - tsrange syntax:

    “contains”: e.g. '[2015-01-01, 2015-07-01)' @> current_timestamp

    “intersects”: e.g. '[2015-01-01, 2015-07-01)' && '[2014-11-01, 2015-02-01]'

    “intersection”: e.g. '[2015-01-01, 2015-07-01)' * '[2014-11-01, 2015-02-01]'

Business time: use case

Product price & availability

```
CREATE TABLE products
( prid          INTEGER NOT NULL
, price         DEC(9,2)
, valid_from    date    NOT NULL
, valid_until   date    NOT NULL
, PERIOD FOR BUSINESS_TIME (valid_from, valid_until)
, PRIMARY KEY (prid, BUSINESS_TIME WITHOUT OVERLAPS)
);

CREATE UNIQUE INDEX prid          --  not necessary: is automatically created !
    ON products (prid, BUSINESS_TIME WITHOUT OVERLAPS) ;
```

prid	price	valid_from	valid_until
101	250.00	2004-01-01	infinity
102	750.00	2012-01-01	infinity
103	150.00	2012-01-01	2015-07-01
103	120.00	2015-07-01	2015-09-01
103	3201.43	2016-01-01	infinity

Business time: use case

select * from products where prid=103;

```
PRID        PRICE       VALID_FROM VALID_UNTIL
----------- ----------- ---------- -----------
        103      150.00 01/01/2012 07/01/2015
        103      120.00 07/01/2015 09/01/2015
        103     3201.43 01/01/2016 12/30/9999

  3 record(s) selected.
```

select * from products for business_time as of current_date where prid=103;

```
PRID        PRICE       VALID_FROM VALID_UNTIL
----------- ----------- ---------- -----------
        103      150.00 01/01/2012 07/01/2015

  1 record(s) selected.
```

select * from products for business_time from '01.01.2015' to '01.01.2016' where prid=103;

```
PRID        PRICE       VALID_FROM VALID_UNTIL
----------- ----------- ---------- -----------
        103      150.00 01/01/2012 07/01/2015
        103      120.00 07/01/2015 09/01/2015

  2 record(s) selected.
```

select * from products for business_time between '01.01.2015' and '01.07.2015' where prid=103;

```
PRID        PRICE       VALID_FROM VALID_UNTIL
----------- ----------- ---------- -----------
        103      150.00 01/01/2012 07/01/2015
        103      120.00 07/01/2015 09/01/2015
```

Bi-temporal tables

Contain both a system time indication (system maintained)
and a business time indication (application maintained)

“What is valid at time instant X, and when did we know that?”

Necessary to answer questions like:

- **When did we decide on the 20% off promotional price?**
- **What prices did our customers see last week?**

```
ALTER TABLE products
  ADD start       GENERATED ALWAYS AS ROW BEGIN  NOT NULL  implicitly hidden
  ADD end         GENERATED ALWAYS AS ROW END    NOT NULL  implicitly hidden
  ADD trans_id  GENERATED ALWAYS AS TRANSACTION START ID implicitly hidden
;
ALTER TABLE products    ADD PERIOD SYSTEM_TIME(start,end) ;
CREATE TABLE products_history LIKE products ;
ALTER TABLE products  ADD VERSIONING USE HISTORY TABLE products_history;
```

Bi-temporal tables: use cases

What was the 20% reduction timespan, as seen last week?

```
SELECT  prid, valid_from, valid_until
FROM    products AS OF SYSTEM TIME current_timestamp - 7 days  p
WHERE   price = ( SELECT 0.8*price FROM products WHERE prid = p.prid) ;
```

What price(s) did we announce last week for the summer months?

```
SELECT  prid, price
FROM    products AS OF SYSTEM TIME current_timestamp - 7 days
                FOR BUSINESS_TIME FROM '2015-07-01' TO '2015-09-01' ;
```

Further reading

Wikipedia: http://en.wikipedia.org/wiki/Temporal_database
http://en.wikipedia.org/wiki/SQL:2011

SIGMOD 2012 paper (41:3, pp. 34-43) by Kulkarni & Michels (IBM)

http://www.sigmod.org/publications/sigmod-record/1209/pdfs/07.industry.kulkarni.pdf

Presentation by K. Kulkarni (IBM) on temporal features in SQL:2011

http://metadata-standards.org/Document-library/Documents-by-number/WG2-N1501-N1550/WG2_N1536_koa046-Temporal-features-in-SQL-standard.pdf

ISO SQL:2011 final draft:

http://jtc1sc32.org/doc/N1951-2000/32N1964T-text_for_ballot-FCD_9075-2.pdf

Questions, remarks, feedback, ... ?

Thank you!

Peter Vanroose

ABIS Training & Consulting

pvanroose@abis.be

http://www.abis.be/html/enindex.html