Reconciling Databases (using schemas, Slony, DBI-Link, pgTAP and other tools)

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Basic Problem

- Data-driven application
- Inputs (e.g., prices, market hours, inventory levels) processed by algorithmic models using GNU R to produce output (e.g. signals)
- Both inputs and models can change at any time
  - Bad data
  - Corrections/revisions to models
- How do we test/compare our changes?

Traditional solution for code development

- Development/Staging/Production servers
- Code developed only on dev server
- When developer ready, change pushed to staging server.
- Staging server = Production server + 1 change
- Regression tests on all servers/automated builds from source control/scripted deployment

But data is not static

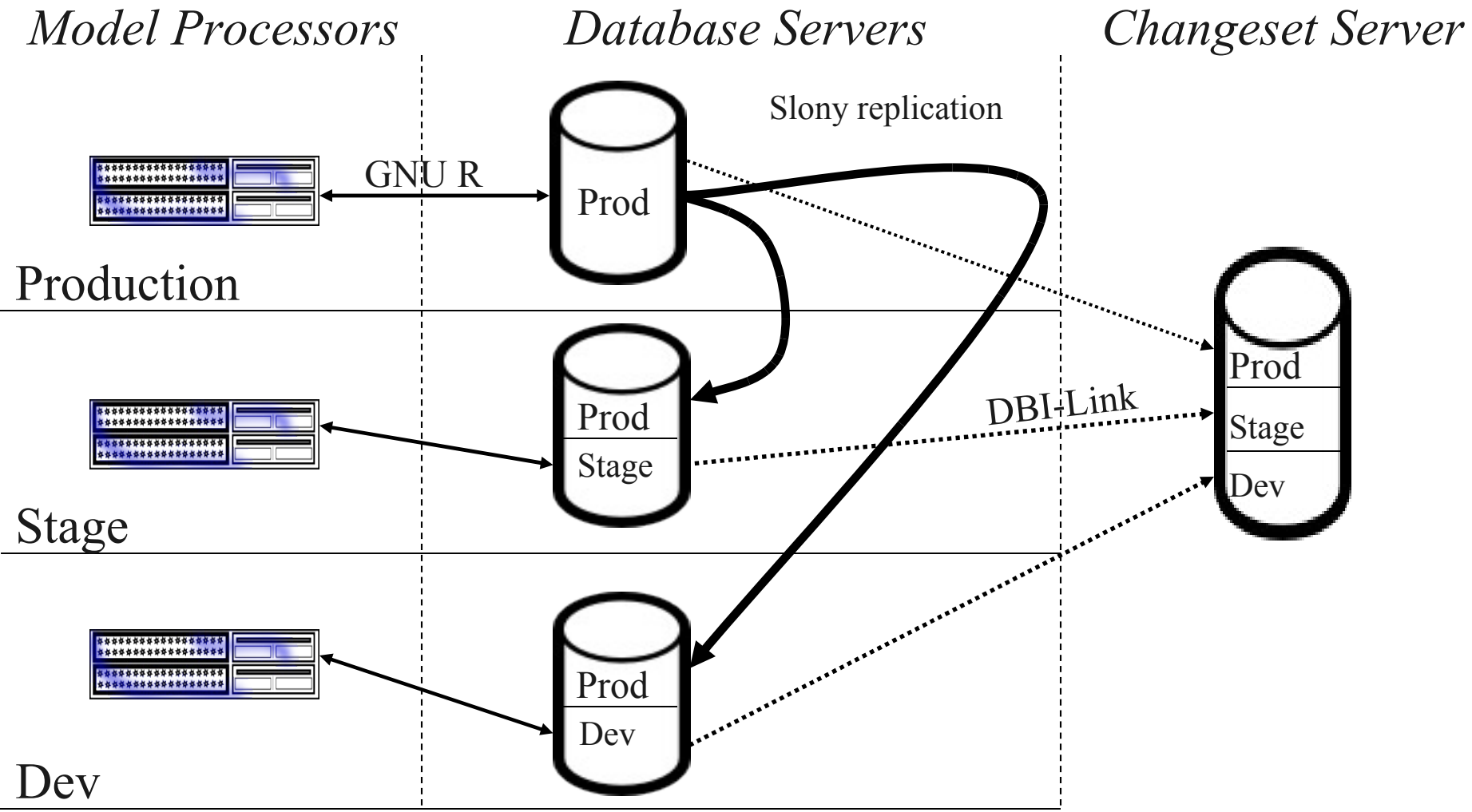
- Price data continually changes--corrections even to historical data
  - Different sources for prices may have different data
- For new markets, often real-time data best way to test
- Metadata for algorithmic models may change: sampling rate, number of inputs, etc…

Our use case

- Input tables
  - Instrument – Corn
  - Contract – Corn January 2010
  - Price – Corn Jan 2010 on 5/22/2009
  - Models – Buy commodity if price yesterday > price 3 months ago
- Parameter tables
  - Roll schedule – when do we switch from one contract to the next?
  - Market – Corn (always using nearest contract)
  - Market models – apply models A, B & C to Corn
- Output tables
  - Price percent – continuous stream of price changes for given market
  - Signals (buy / sell) – results of applying models to market on given date
  - Simulated profits – what should have happened...

How do we test and stage our data-driven application?

Development Environment



Schemas and Slony

- Replication via Slony from production server to dev and stage
  - Slony provides asynchronous table replication; blocks writes on slave nodes
- Duplicate tables for metadata in another schema: stage has stage schema, dev has dev schema
  - Change search_path to see different results

Search Path gotchas

- SET search_path / SHOW search_path
- Foreign key constraints explicitly remember search path from time of creation
- Remember default search_path is $user,public (don’t create $user schema unless you really want it!)

Search Path gotchas (cont.)

- Functions cache query plan
  - If run same function in same connection twice with different search_path settings, connection will use first search_path setting for function
    - Can explicitly pass in set search_path to function, but may not be what you want
  - Simpler to reconnect
- If you create tables like this:

```
CREATE TABLE foo (LIKE prod.foo INCLUDING INDEXES
            INCLUDING CONSTRAINTS INCLUDING DEFAULTS)
```

  remember to drop default on any synthetic keys and explicitly re-create sequence in new schema; and to check path of foreign key constraints

Replication possibilities

- Synchronous replication
  - WAL shipping (but only warm standby)
  - Hot standby in 8.5?
- Asynchronous replication
  - Slony
  - Command Prompt Replicator (Mammoth)
  - Londiste
  - Golconde
  - Bucardo

Slony basics

- Adds triggers to replicated tables
  - System catalog hackery if Postgres version < 8.3
- Slave node tables are read-only
- Writes event log that tracks data changes on replicated tables into its own schema
- Replication sets can be made of one or many tables
- Different nodes can replicate different sets
- Requires one slon daemon per node to push/pull changes
- Nodes can be cascaded

Slony gotchas

- All schema changes on replicated tables must be added through EXECUTE DDL scripts
- Asynchronous replication means slaves can fall behind, especially on large deletes/copies. \copy on master node = inserts on slave node.
- Never truncate replicated tables!

Slony gotchas -- continued

- Foreign keys on non-replicated tables that references replicated tables must be dropped through Slonik EXECUTE DDL scripts
- All triggers on replicated tables are automatically disabled on slave nodes. To enable triggers on slave nodes, use Slonik STORE TRIGGER command (not true in Slony 2.x).
- Functions must be kept in sync manually!

Reconciling Databases

- Three different problems
  - Reconciling data
  - Reconciling table structures
  - Reconciling functions, indexes, constraints, triggers and views

Slony replication and different schemas give us prod/stage/dev database environments – but ...

Issue 1:

How do we reconcile data between the different databases and schemas?

Easy stuff

- Between stage and public and test and public, since both live in the same database
- But usually we need to compare test to stage, since we're pushing database changes this way...

  Oh oh... no cross-database queries...

How to do cross-database queries?

- Outside database:
  - pg_comparator (http://www.coelho.net/pg_comparator/)
  - Home-grown
- Inside database:
  - Dblink
  - DBI-Link

DBI-Link

- David Fetter's project (http://pgfoundry.org/projects/dbi-link/) to treat heterogenous data sources as tables within Postgres
- Uses plperlu + DBI to connect to other datasources; uses empty tables and rules to make other datasources seem like different schema in host database

DBI-Link setup

- CREATELANG plperlu linkdb
- Install DBD::Pg on database server
- psql -d linkdb -f dbi_link.sql

```
SELECT make_accessor_functions(
    'dbi:Pg:devdb:dev_server',
    'username','password",
     '--
AutoCommit:1
RaiseError:1
--'::dbi_link.yaml,  --YAML for DBI connection attributes
NULL::dbi_link.yaml, --YAML for DBI connection environment
    'dev',           --Remote schema name
     NULL::text,     --Remote catalog name
    'dev')           --Local schema name
```

DBI-Link setup (continued)

- Should now be able to run simple queries on remote tables as if in link database
- If remote schema changes, must do the following:
  - DROP SCHEMA dev CASCADE;
  - SELECT dbi_link.refresh_schema(data_source_id) FROM dbi_link.dbi_connection WHERE local_schema = ’dev';

DBI-Link gotchas

- Can’t use indexes; must load entire contents of table into memory
- Currently, no real support for arrays

How do we figure out what's changed?

- EXCEPT queries between same tables in different schemas?
  - Gets inserts or deletes -- but how do we figure out updates?
  - Dynamic query that compares contents of fields will break when one schema's field has a null and the other doesn't
    - If master.foo is null and slave.foo = 3, then (master.foo = slave.foo) = NULL!

Use ROW(*) comparison

- SELECT sf.ROW(*),pf.ROW(*)
  from stage.foo sf
  full outer join public.foo pf
  on sf.pkey = pf.pkey
  WHERE sf.ROW(*) IS DISTINCT
  FROM pf.ROW(*)
  - Handles nulls for you: (null compared to non-null) = false, not null!

Create changeset from ROW(*) query

- Cast ROW back up to recordset
- If right side is null, need to insert row
- If left side is null, need to delete row
- If both sides have content, need to update row
  - Easy to make reversal set at same time

Sample SQL

```
-- reconciling test.foo v. stage.foo
(bar_int int,baz_text text, primary key bar_int)

SELECT
       --rename fields so easier to distinguish master vs. slave field
       master_row.bar_int AS bar_int_m,
       master_row.baz_text AS baz_text_m,
       slave_row.bar_int AS bar_int_s,
       slave_row.baz_test AS baz_text_s,
       CASE WHEN slave_row IS NULL
            THEN 'I'::varchar
            WHEN master_row IS NULL
            THEN 'D'::varchar
            ELSE 'U'::varchar END AS ddl_action
    FROM
    (
     SELECT ROW(m.*)::foo as master_row,
     ROW(s.*)::foo as slave_row
     FROM test.foo m
             FULL OUTER JOIN stage.foo s
               ON m.bar_int = s.bar_int
     WHERE row(m.*)::foo IS DISTINCT FROM row(s.*)::foo
    ) as x;
```

Problem: Must verify changesets

- Changes to metadata tables not all promoted at same time
- Changesets can get out of sync--need to verify content in changeset is still in database

Use digest to vet changeset / reverse changeset

- Before applying changeset, regenerate all differences. Take MD5() of DDL statements.
  - Strict commit: if any line in changeset is missing md5 entry in current set of differences, throw out whole set
  - OR
  - Relaxed commit: if any line in changeset is missing md5 entry, throw out line

Edge cases

- Sometimes metadata tables need to be combined or need to overlap:
  - Edge case 1: discrete additions added to large table
  - Edge case 2: overlapping/conflicting data to replace records in large table

Edge Case I -- Discrete additions to large table

- Want to test 100K new prices for new market
  - No overlap with current data
  - Don’t want to add to public schema if not useful
- Use inheritance and schemas
  - Set search_path to dev, public;
  - ALTER TABLE public.price INHERITS dev.price
  - Hides dev.price if search_path=public; shows dev.price + public.price if search_price=dev,public
- Simple select * from price will worrk

Edge Case II -- Replacing prices

- Want to test replacing 100K prices for already existing market -- some dates are accurate in production
- Since prices are different between schema, normal query will show both series of prices
- Have to create custom accessor function or view

Example of accessor function

```
-- Price table:
-- (price_id serial primary key not null,
--  contract_id int not null, sampletime_id int not null,
--  dte timestamp, open numeric, high numeric,
--  low numeric, settle numeric, volume numeric, open_interest numeric)
--  with candidate key (contract_id,sampletime_id,dte);
CREATE OR REPLACE FUNCTION get_prices(wk_contract_id int, wk_sampletime_id
    int) AS
$$
    SELECT price_id,dte, open, high, low, settle, volume, open_interest
        FROM ONLY test.price t_pub
        WHERE contract_id = $1
        AND sampletime_id = $2
   UNION
    SELECT price_id, dte, open, high, low, settle, volume, open_interest
        FROM only public.price p_pub
        WHERE contract_id = $1
        AND sampletime_id = $2
        AND NOT EXISTS (SELECT NULL
                        FROM ONLY test.price
                        WHERE contract_id = $1
                        AND sampletime_id = $2
                        AND dte = p_pub.dte)
$$ LANGUAGE 'SQL';
```

Problems with these approaches

- If using synthetic primary keys, sequences may have to adjusted to avoid overlap
- Changing inheritance of public table will break identity of schema across nodes
- Accessor functions hurt performance

Limitations

- Changesets can’t be used to promote changes in column definitions, defaults, constraints or triggers for tables.
- Changesets can’t be used to promote functions or views
- Changesets can’t validate trigger function equality

Limitations (continued)

- Inserts and updates in public schema may need to trigger events in other schemas
  - Same trigger function wants to write to different table based on search_path of connection. Because of caching of function plans, may have to do the following:

```
DECLARE
    l_savesearchpath text;
    l_newsearchpath text;
BEGIN
    raise notice 'aggregate_updates (... with schema)';
    select into l_savesearchpath current_setting('search_path');
    raise notice 'Current search path is %', l_savesearchpath;
    select into l_newsearchpath set_config('search_path','' || $1 || '','f');
    raise notice 'Using search path %', l_newsearchpath;
    perform aggregate_updates();
    select into l_newsearchpath set_config('search_path','' ||
l_savesearchpath || '','f');
    raise notice 'Restored search path is %', l_newsearchpath;
```

Triggers vs. Messages

- Could use messages
  - Simplifies event handling
  - Alternatives:
    - LISTEN/NOTIFY (but can only take a NAME (no other payload)
    - PgQ
    - External message queue
      - ActiveMQ
      - RabbitMQ
      - WebsphereMQ

Issues 2 and 3:

How do we 2) reconcile DDL and 3) functions, triggers and views between databases and schemas?

Possible ideas

- Issue 2:
  - Script promotion of DDL changes, function changes via external application (e.g., Robert Brewer's post facto – http://post-facto.org/)
- Issue 3:
  - Functions in source control; automated checkout and deployment
  - Test table definition, constraints, and function behavior and expected signatures via David Wheeler's pgTAP (http://pgtap.projects.postgresql.org/)
    - PL/pgSQLversion of TAP (Test Anything Protocol)
    - has_column(), col_not_null(), col_has_default() for column definitions; has_fk() for column constraints
    - has_trigger(), trigger_is() to test trigger unity
    - can(), can_ok() to test function behavior and signatures

Questions?