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Data Modeling, Normalization and Denormalisation

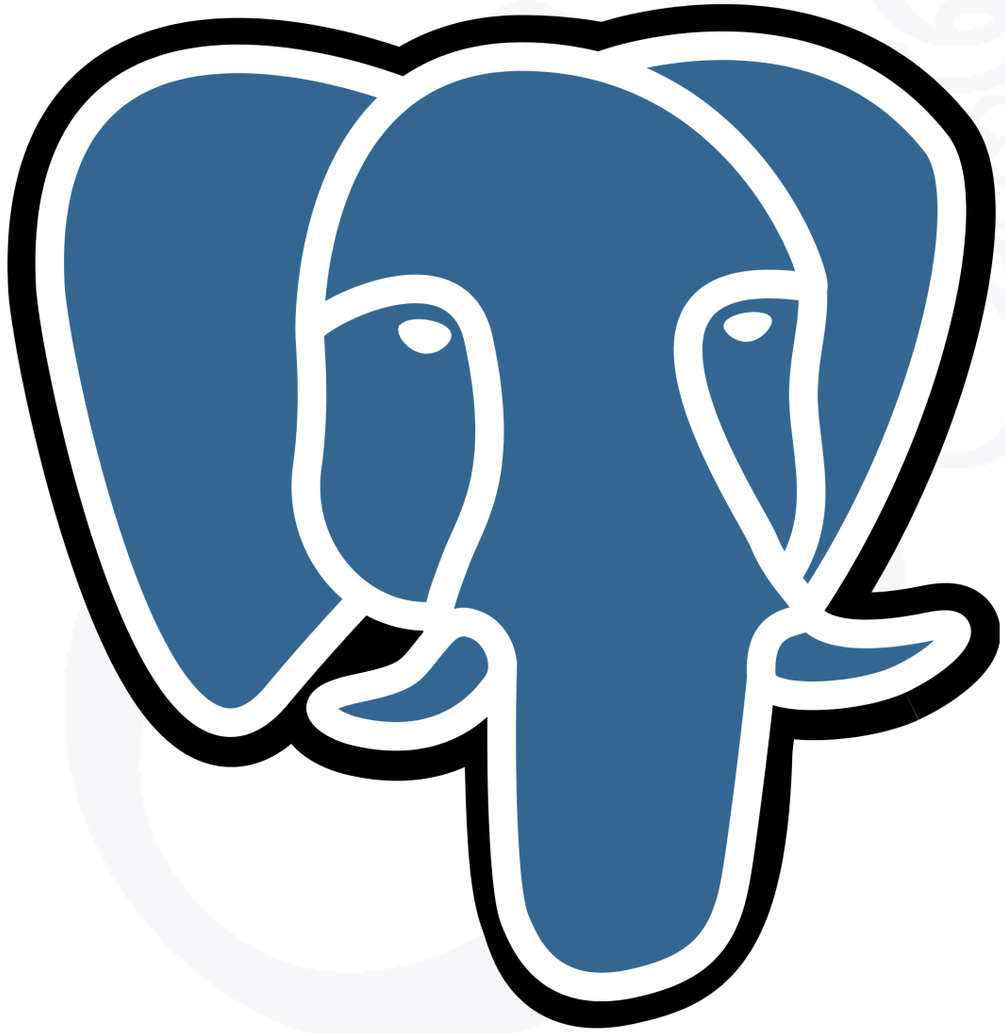
Dimitri Fontaine
Citus Data, now part of Microsoft
@tapoueh

The Art of PostgreSQL

Turn Thousands of Lines
of Code into Simple Queries

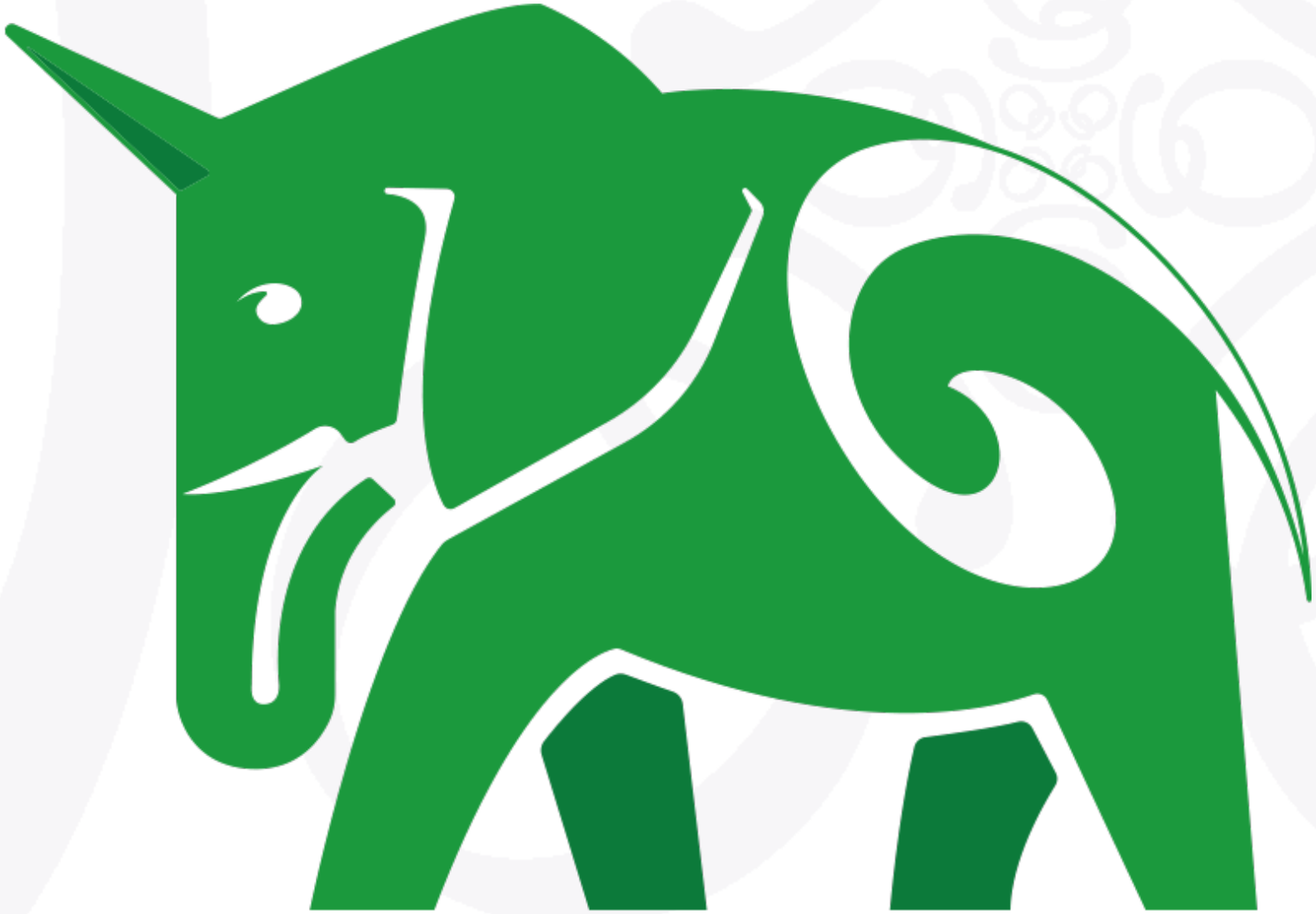
POSTGRESQL MAJOR CONTRIBUTOR

PostgreSQL



CURRENTLY WORKING AT

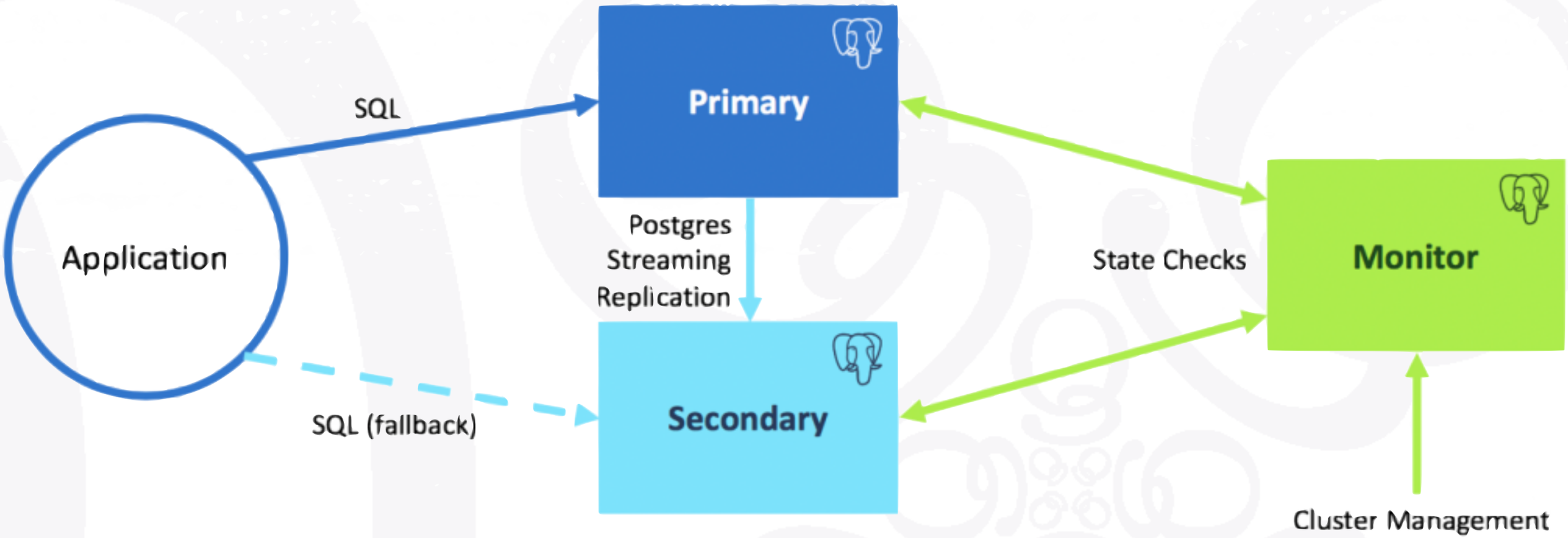
Citus Data



Join us!

https://careers.microsoft.com/us/en/job/622968/Azure-Database-for-PostgreSQL-MySQL-MariaDB-Dev-Support-Engineer

pg_auto_failover



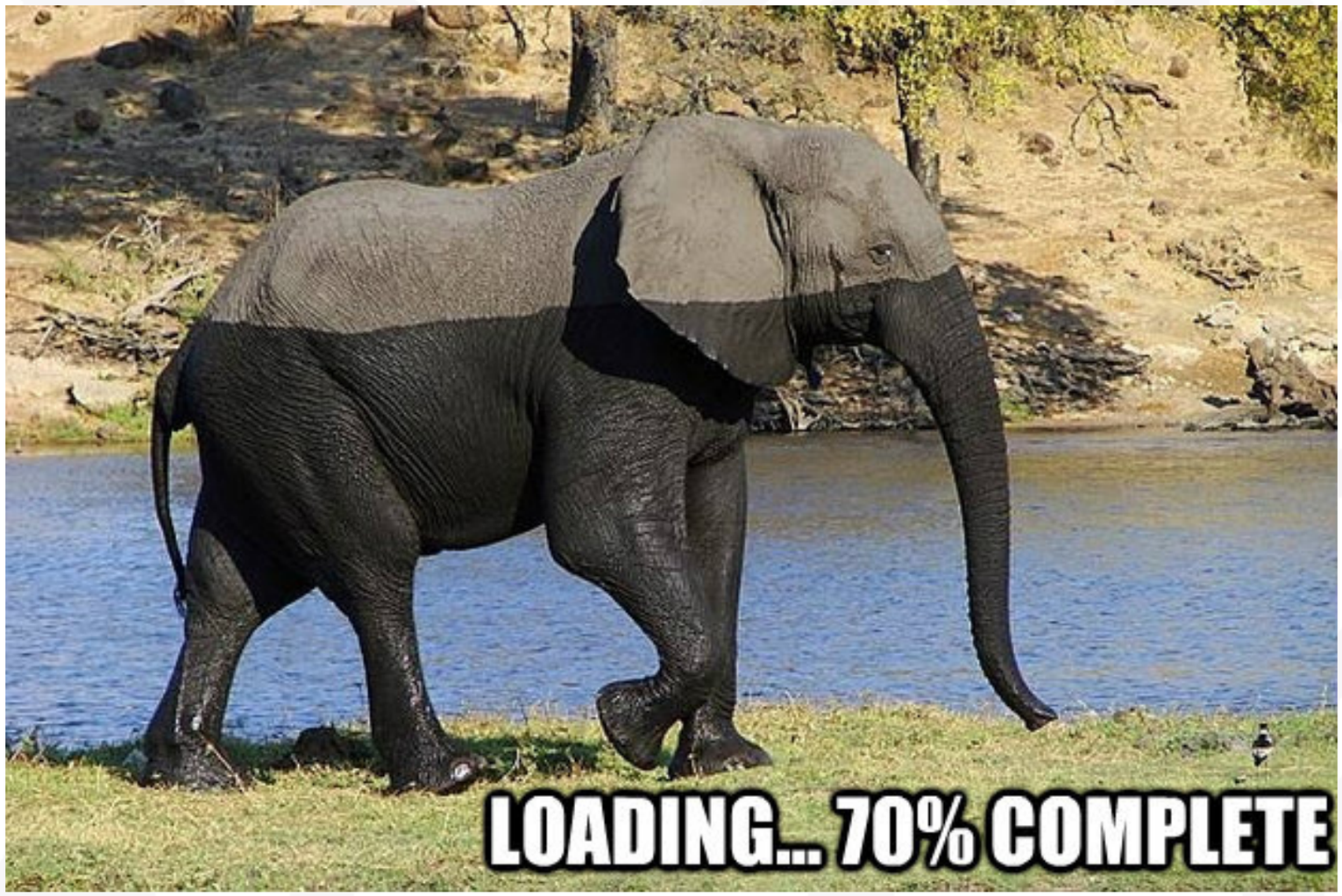
Automated Failover

PostgreSQL Licence, GitHub, fully open

Migrating to PostgreSQL

In a single command line!

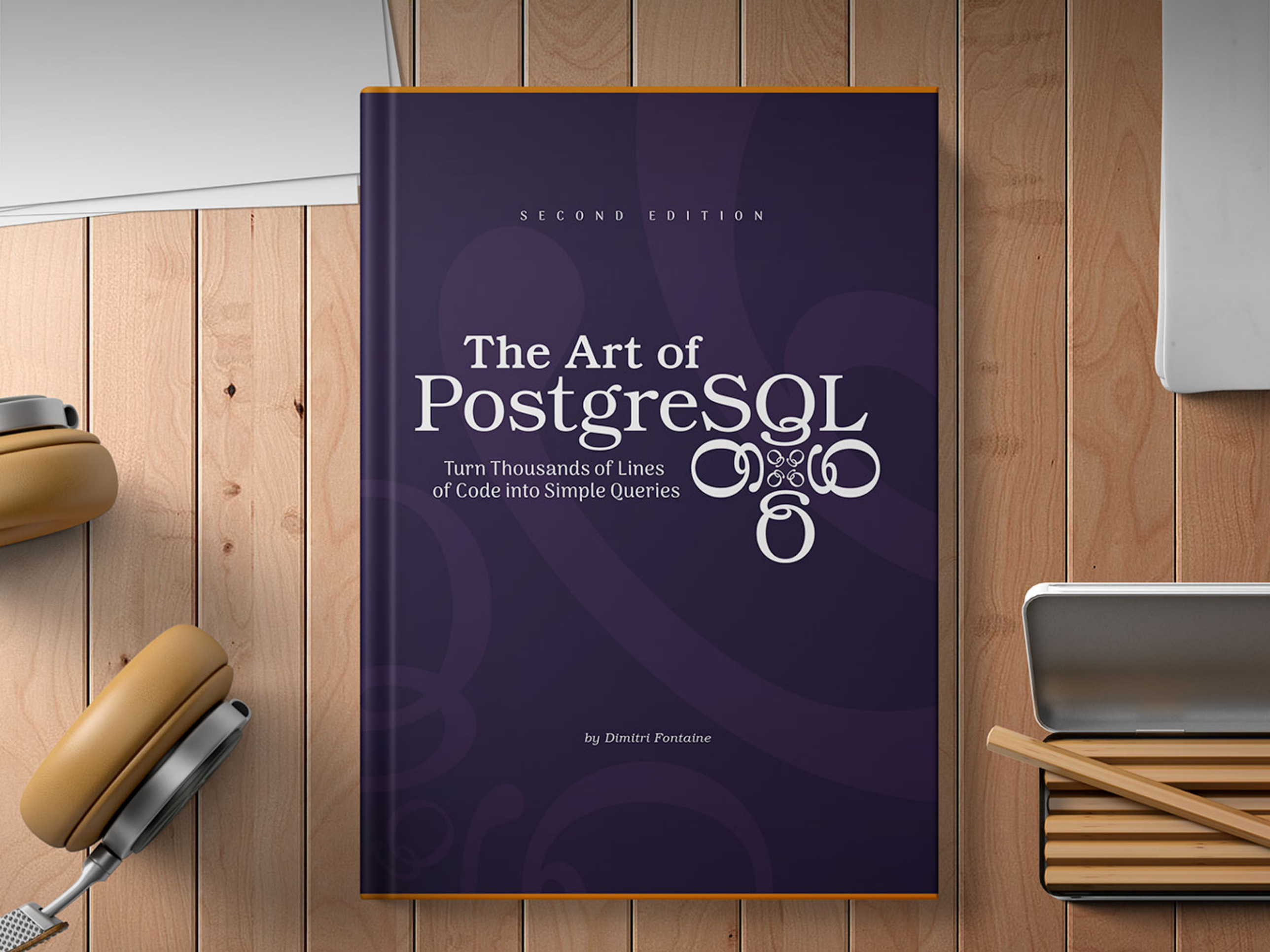
pgloader.io



One-command migration

```
$ pgloader mysql://root@localhost/f1db?useSSL=false \
    pgsql://f1db@localhost/f1db
```

```
$ pgloader ./test/mysql/f1db.load
2019-06-19T11:24:36.014000+02:00 LOG pgloader version "3.6.26cc9ca"
2019-06-19T11:24:36.154000+02:00 LOG Migrating from #<MYSQL-CONNECTION mysql://root@localhost:3306/f1db {100620ACC3}>
2019-06-19T11:24:36.155000+02:00 LOG Migrating into #<PGSQL-CONNECTION pgsql://dim@UNIX:5432/plop {100620B583}>
2019-06-19T11:24:41.001000+02:00 LOG report summary reset
                table name     errors       rows      bytes      total time
-------------------------  ---------  ---------  ---------  --------------
           fetch meta data          0         33                     0.413s
            Create Schemas          0          0                     0.002s
          Create SQL Types          0          0                     0.005s
             Create tables          0         26                     0.174s
            Set Table OIDs          0         13                     0.007s
-------------------------  ---------  ---------  ---------  --------------
              f1db.circuits          0         73     8.5 kB          0.024s
    f1db.constructorresults          0      11142   186.2 kB          0.089s
          f1db.constructors          0        208    15.0 kB          0.113s
f1db.constructorstandings          0      11896   249.3 kB          0.242s
               f1db.drivers          0        842    79.8 kB          0.175s
              f1db.laptimes          0     426633    11.2 MB          2.148s
       f1db.driverstandings          0      31726   719.1 kB          0.456s
             f1db.pitstops           0       6251   209.6 kB          0.351s
                f1db.races           0        997   100.6 kB          0.353s
              f1db.seasons           0         69     3.9 kB          0.384s
            f1db.qualifying          0       7516   286.4 kB          0.094s
               f1db.results          0      23777     1.3 MB          0.276s
                f1db.status          0        134     1.7 kB          0.023s
-------------------------  ---------  ---------  ---------  --------------
    COPY Threads Completion          0          4                     2.549s
             Create Indexes          0         20                     2.396s
     Index Build Completion          0         20                     1.322s
            Reset Sequences          0         10                     0.105s
               Primary Keys          0         13                     0.020s
      Create Foreign Keys            0          0                     0.000s
           Create Triggers           0          0                     0.001s
           Set Search Path           0          1                     0.001s
          Install Comments           0          0                     0.000s
-------------------------  ---------  ---------  ---------  --------------
          Total import time          ✓     521264    14.3 MB          6.394s
```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Data Modeling

Rule 5. Data dominates.

"If you've chosen the right data structures and organized things well, the algorithms will almost always be self-evident. Data structures, not algorithms, are central to programming."

(Brooks p. 102)

Data Modeling Examples

- *Data Types*
- *Constraints*
- *Primary keys, Foreign Keys, Check, Not Null*
- *Partial unique indexes*
- *Exclusion Constraints*

Data Modeling

```
create table sandbox.article
  (
    id          bigserial primary key,
    category    integer references sandbox.category(id),
    pubdate     timestamptz,
    title       text not null,
    content     text
);
```

Partial Unique Index

```
CREATE TABLE toggles
(
  user_id      integer   NOT NULL,
  type         text      NOT NULL,
  enabled_at   timestamp NOT NULL,
  disabled_at timestamp,
);

CREATE UNIQUE INDEX ON toggles (user_id, type)
        WHERE disabled_at IS NULL;
```

Constraints are Guarantees

```
create table rates
 (
  currency text,
  validity daterange,
  rate     numeric,

  exclude using gist (currency with =,
                      validity with &&)
);
```

Avoiding Database Anomalies

Update Anomaly

Employees' Skills

Employee ID	Employee Address	Skill
426	87 Sycamore Grove	Typing
426	87 Sycamore Grove	Shorthand
519	94 Chestnut Street	Public Speaking
519	96 Walnut Avenue	Carpentry

Insertion Anomaly

Faculty and Their Courses

Faculty ID	Faculty Name	Faculty Hire Date	Course Code
389	Dr. Giddens	10-Feb-1985	ENG-206
407	Dr. Saperstein	19-Apr-1999	CMP-101
407	Dr. Saperstein	19-Apr-1999	CMP-201
424	Dr. Newsome	29-Mar-2007	?

Deletion anomaly

Faculty and Their Courses

Faculty ID	Faculty Name	Faculty Hire Date	Course Code
389	Dr. Giddens	10-Feb-1985	ENG-206
407	Dr. Saperstein	19-Apr-1999	CMP-101
407	Dr. Saperstein	19-Apr-1999	CMP-201

DELETE

ANOTHER QUOTE FROM FRED BROOKS

Database Design and User Workflow

“Show me your flowcharts and conceal your tables, and I shall continue to be mystified. Show me your tables, and I won’t usually need your flowcharts; they’ll be obvious.”

Tooling for Database Modeling

```
BEGIN;

create schema if not exists sandbox;

create table sandbox.category
 (
   id    serial primary key,
   name  text not null
 );

insert into sandbox.category(name)
     values ('sport'),('news'),('box office'),('music');

ROLLBACK;
```

Object Relational Mapping

- *The **R** in ORM stands for **relation***
- *Every SQL query result set is a relation*

Object Relational Mapping

When mapping base tables, you end up trying to solve different complex issues at the same time

- User Workflow
- Consistent view of the whole world at all time

Normalization

Basics of the Unix Philosophy: principles

Clarity

- *Clarity is better than cleverness*

Simplicity

- *Design for simplicity; add complexity only where you must.*

Transparency

- *Design for visibility to make inspection and debugging easier.*

Robustness

- *Robustness is the child of transparency and simplicity.*

DRY

1st Normal Form, Codd, 1970

- There are no duplicated rows in the table.
- Each cell is single-valued (no repeating groups or arrays).
- Entries in a column (field) are of the same kind.

2nd Normal Form, Codd, 1971

"A table is in 2NF if it is in 1NF and if it has no partial dependencies."

"A table is in 2NF if it is in 1NF and if all non-key attributes are dependent on all of the key. A partial dependency occurs when a non-key attribute is dependent on only a part of the composite key."

Third Normal Form, Codd, 1971
BCNF, Boyce-Codd, 1974

- *A table is in 3NF if it is in 2NF and if it has no transitive dependencies.*
- *A table is in BCNF if it is in 3NF and if every determinant is a candidate key.*

More Normal Forms

- Each level builds on the previous one.
- A table is in **4NF** if it is in BCNF and if it has no multi-valued dependencies.
- A table is in **5NF**, also called “Projection-join Normal Form” (**PJNF**), if it is in 4NF and if every join dependency in the table is a consequence of the candidate keys of the table.
- A table is in **DKNF** if every constraint on the table is a logical consequence of the definition of keys and domains.

Database Constraints

Primary Keys

```
create table sandbox.article
  (
    id          bigserial primary key,
    category    integer references sandbox.category(id),
    pubdate     timestamptz,
    title       text not null,
    content     text
);
```

Surrogate Keys

Artificially generated key is named a surrogate key because it is a **substitute** for natural key.

A natural key would allow preventing duplicate entries in our data set.

Surrogate Keys

```
insert into sandbox.article
    (category, pubdate, title)
    values (2, now(), 'Hot from the Press'),
           (2, now(), 'Hot from the Press')
returning *;
```

Oops. Not a Primary Key.

```
-[ RECORD 1 ]--------------------------
id       | 3
category | 2
pubdate  | 2018-03-12 15:15:02.384105+01
title    | Hot from the Press
content  |
-[ RECORD 2 ]--------------------------
id       | 4
category | 2
pubdate  | 2018-03-12 15:15:02.384105+01
title    | Hot from the Press
content  |

INSERT 0 2
```

Natural Primary Key

```
create table sandboxpk.article
 (
   category   integer references sandbox.category(id),
   pubdate    timestamptz,
   title      text not null,
   content    text,

   primary key(category, pubdate, title)
);
```

Update Foreign Keys

```
create table sandboxpk.comment
 (
   a_category integer     not null,
   a_pubdate  timestamptz not null,
   a_title    text        not null,
   pubdate    timestamptz,
   content    text,

   primary key(a_category, a_pubdate, a_title, pubdate, content),

   foreign key(a_category, a_pubdate, a_title)
    references sandboxpk.article(category, pubdate, title)
);
```

Natural and Surrogate Keys

```
create table sandbox.article
 (
   id          integer      generated always as identity,
   category    integer      not null references sandbox.category(id),
   pubdate     timestamptz  not null,
   title       text         not null,
   content     text,

   primary key(category, pubdate, title),
   unique(id)
);
```

Other Constraints

Normalisation Helpers

- *Primary Keys*
- *Foreign Keys*
- *Not Null*
- *Check Constraints*
- *Domains*
- ***Exclusion Constraints***

```
create table rates
 (
  currency text,
  validity daterange,
  rate     numeric,

  exclude using gist
  (
     currency with =,
     validity with &&
  )
);
```

Denormalization

Rules of Optimization

@pleb

Rules of Optimization:
Rule 1: Don't do it.
Rule 2: Don't do it yet(experts only)

DONALD KNUTH

Premature Optimization...

“Programmers waste enormous amounts of time thinking about, or worrying about, the speed of noncritical parts of their programs, and these attempts at efficiency actually have a strong negative impact when debugging and maintenance are considered. We should forget about small efficiencies, say about 97% of the time: **premature optimization is the root of all evil**. Yet we should not pass up our opportunities in that critical 3%.”

"Structured Programming with Goto Statements”
Computing Surveys 6:4 (December 1974), pp. 261–301, §1.

Denormalization: cache

- Duplicate data for faster access
- Implement cache invalidation

Denormalization example

```
\set season 2017

  select drivers.surname as driver,
         constructors.name as constructor,
         sum(points) as points

    from results
         join races using(raceid)
         join drivers using(driverid)
         join constructors using(constructorid)

   where races.year = :season

group by grouping sets(drivers.surname, constructors.name)
  having sum(points) > 150
order by drivers.surname is not null, points desc;
```

Denormalization example

```
create view v.season_points as
  select year as season, driver, constructor, points
    from seasons left join lateral
         (
            select drivers.surname as driver,
                   constructors.name as constructor,
                   sum(points) as points
             from results
                  join races using(raceid)
                  join drivers using(driverid)
                  join constructors using(constructorid)
               where races.year = seasons.year
          group by grouping sets(drivers.surname, constructors.name)
          order by drivers.surname is not null, points desc
          )
          as points on true
order by year, driver is null, points desc;
```

Materialized View

```
create materialized view cache.season_points as
  select * from v.season_points;

create index on cache.season_points(season);
```

Materialized View

```
refresh materialized view cache.season_points;
```

Application Integration

```
select driver, constructor, points
  from cache.season_points
 where season = 2017
   and points > 150;
```

Denormalization: audit trails

- Foreign key references to other tables won't be possible when those reference change and you want to keep a history that, by definition, doesn't change.
- The schema of your main table evolves and the history table shouldn’t rewrite the history for rows already written.

History tables with JSONB

```
create schema if not exists archive;

create type archive.action_t
    as enum('insert', 'update', 'delete');
```

```
create table archive.older_versions
 (
   table_name text,
   date       timestamptz default now(),
   action     archive.action_t,
   data       jsonb
 );
```

Validity Periods

```
create table rates
 (
  currency text,
  validity daterange,
  rate     numeric,

  exclude using gist (currency with =,
                      validity with &&)
);
```

Validity Periods

```
select currency, validity, rate
  from rates
 where currency = 'Euro'
       and validity @> date '2017-05-18';

-[ RECORD 1 ]--------------------
currency | Euro
validity | [2017-05-18,2017-05-19)
rate     | 1.240740
```

Denormalization Helpers: Data Types

Composite Data Types

- *Composite Type*
- *Arrays*
- *JSONB*
- *Enum*
- *Domains*

- `hstore`
- `ltree`
- `intarray`
- `hll`

Partitioning

Partitioning Improvements

PostgreSQL 10

- ~~*Indexing*~~
- ~~*Primary Keys*~~
- ~~*On conflict*~~
- ~~*Update Keys*~~

PostgreSQL 11

- *Indexing, Primary Keys, Foreign Keys*
- *Hash partitioning*
- *Default partition*
- *On conflict support*
- *Update Keys*

NotOnlySQL

http://blog.wjauthority.com

Schemaless with JSONB

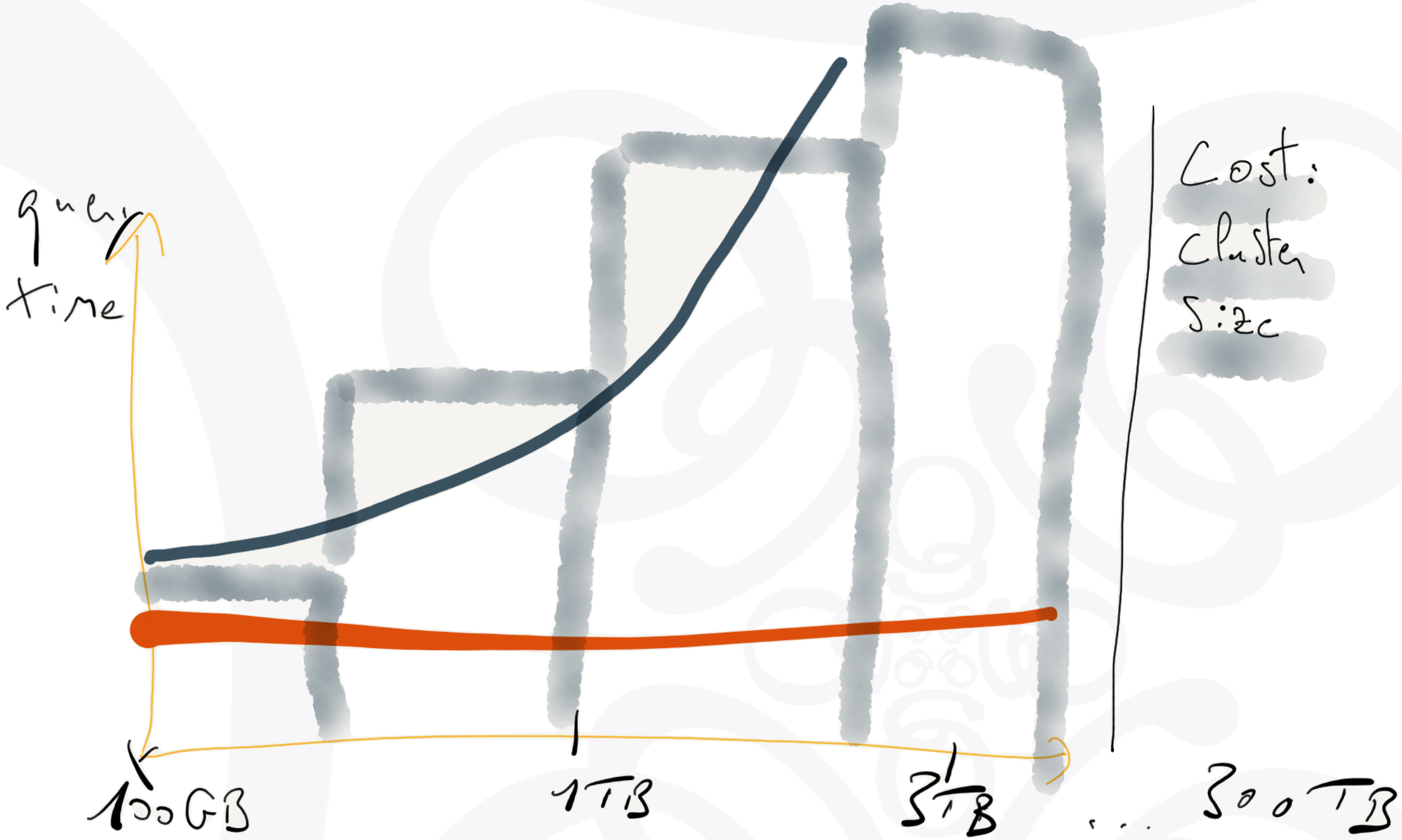
```
select jsonb_pretty(data)
  from magic.cards
 where data @> '{"type":"Enchantment",
  "artist":"Jim Murray",
  “colors":["Blue"]
}';
```

Durability Trade-Offs

```
create role dbowner with login;
create role app with login;

create role critical  with login in role app inherit;
create role notsomuch with login in role app inherit;
create role dontcare  with login in role app inherit;

alter user critical  set synchronous_commit to remote_apply;
alter user notsomuch set synchronous_commit to local;
alter user dontcare  set synchronous_commit to off;
```

Per Transaction Durability

```
SET demo.threshold TO 1000;

CREATE OR REPLACE FUNCTION public.syncrep_important_delta()
  RETURNS TRIGGER
  LANGUAGE PLpgSQL
AS
$$ DECLARE
  threshold integer := current_setting('demo.threshold')::int;
  delta integer := NEW.abalance - OLD.abalance;
BEGIN
  IF delta > threshold
  THEN
    SET LOCAL synchronous_commit TO on;
  END IF;
  RETURN NEW;
END;
$$;
```

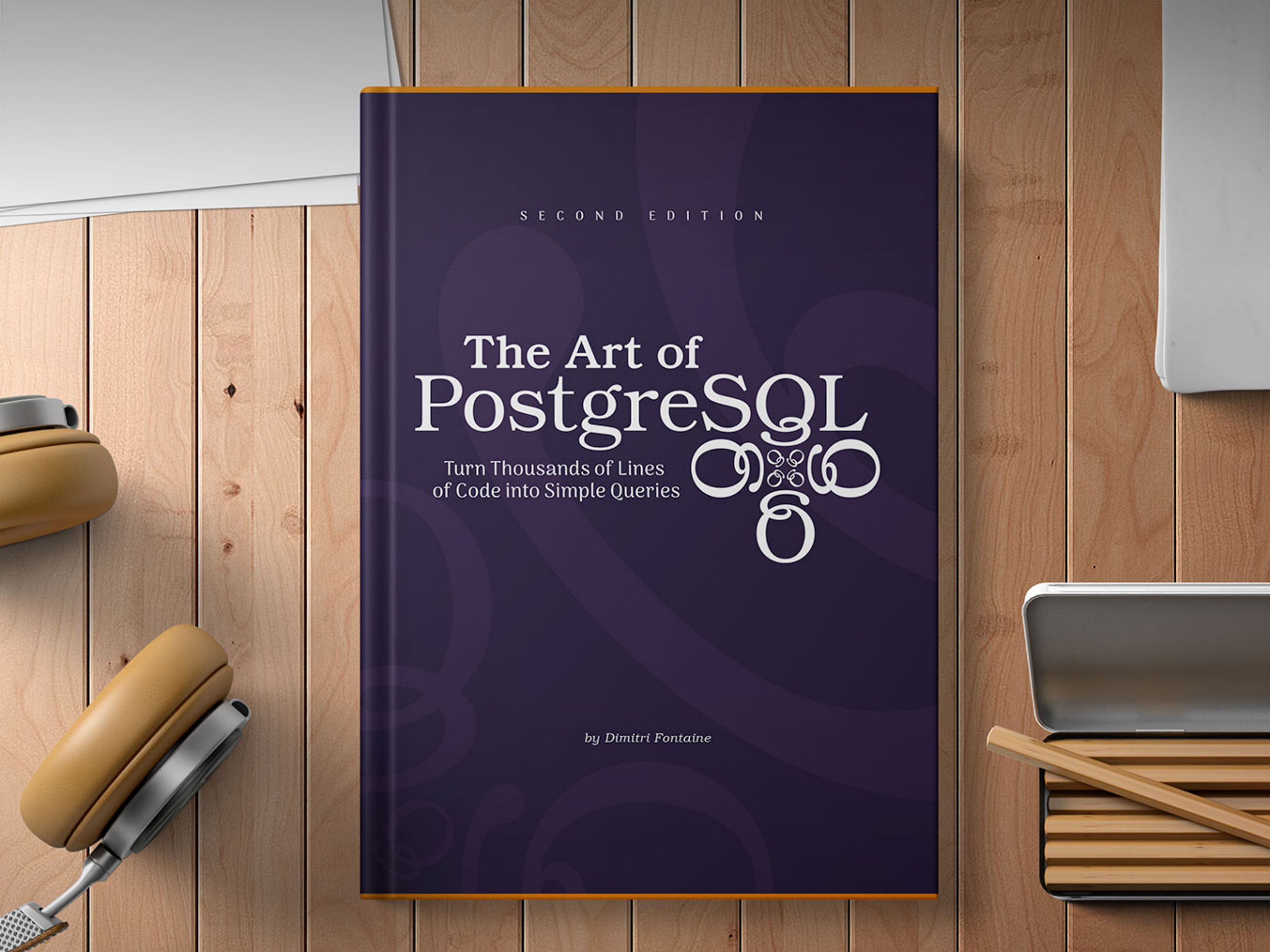


Horizontal Scaling

Sharding with Citus

Five Sharding Data Models and which is right?

- *Sharding by Geography*
- *Sharding by EntityId*
- *Sharding a graph*
- *Time Partitioning*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Ask Me Two Questions!

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