The Art of PostgreSQL

PostgreSQL

Turn Thousands of Lines
of Code into Simple Queries

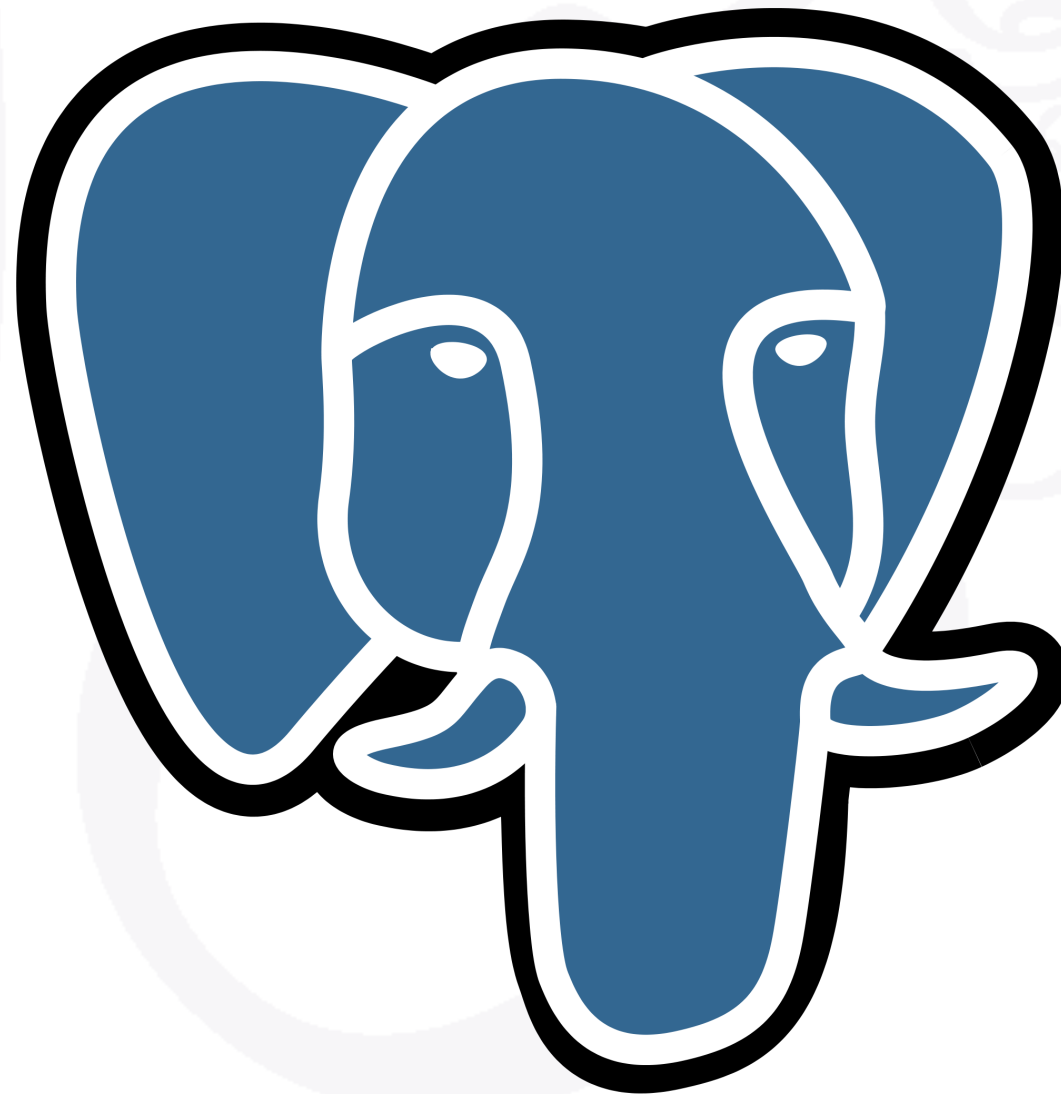# PostgreSQL for developers

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PostgreSQL Major Contributor

Citus Data

Mastering PostgreSQL In Application Development
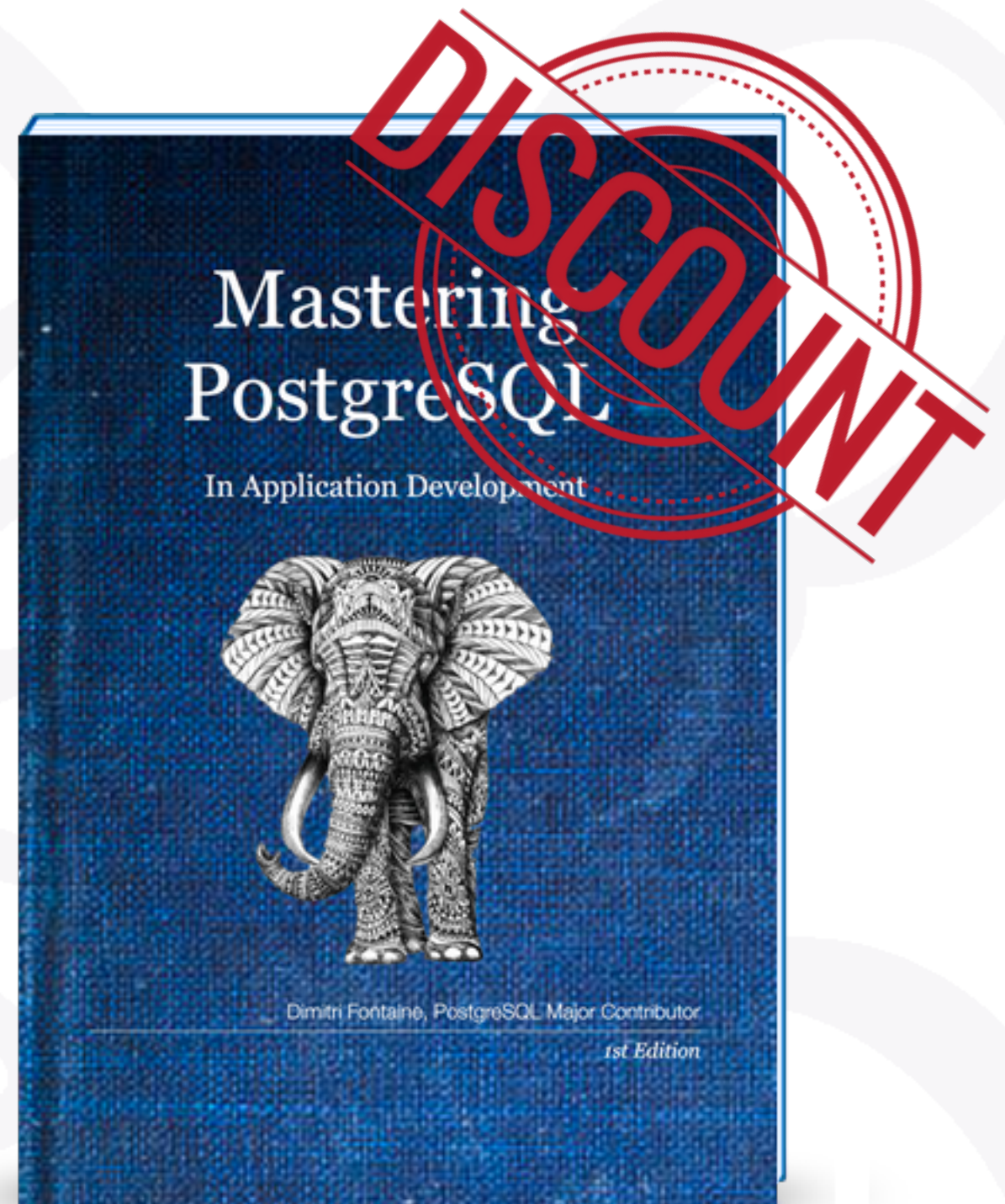
Why PostgreSQL?

Concurrency & Isolation

Atomic

Isolated

Consistent
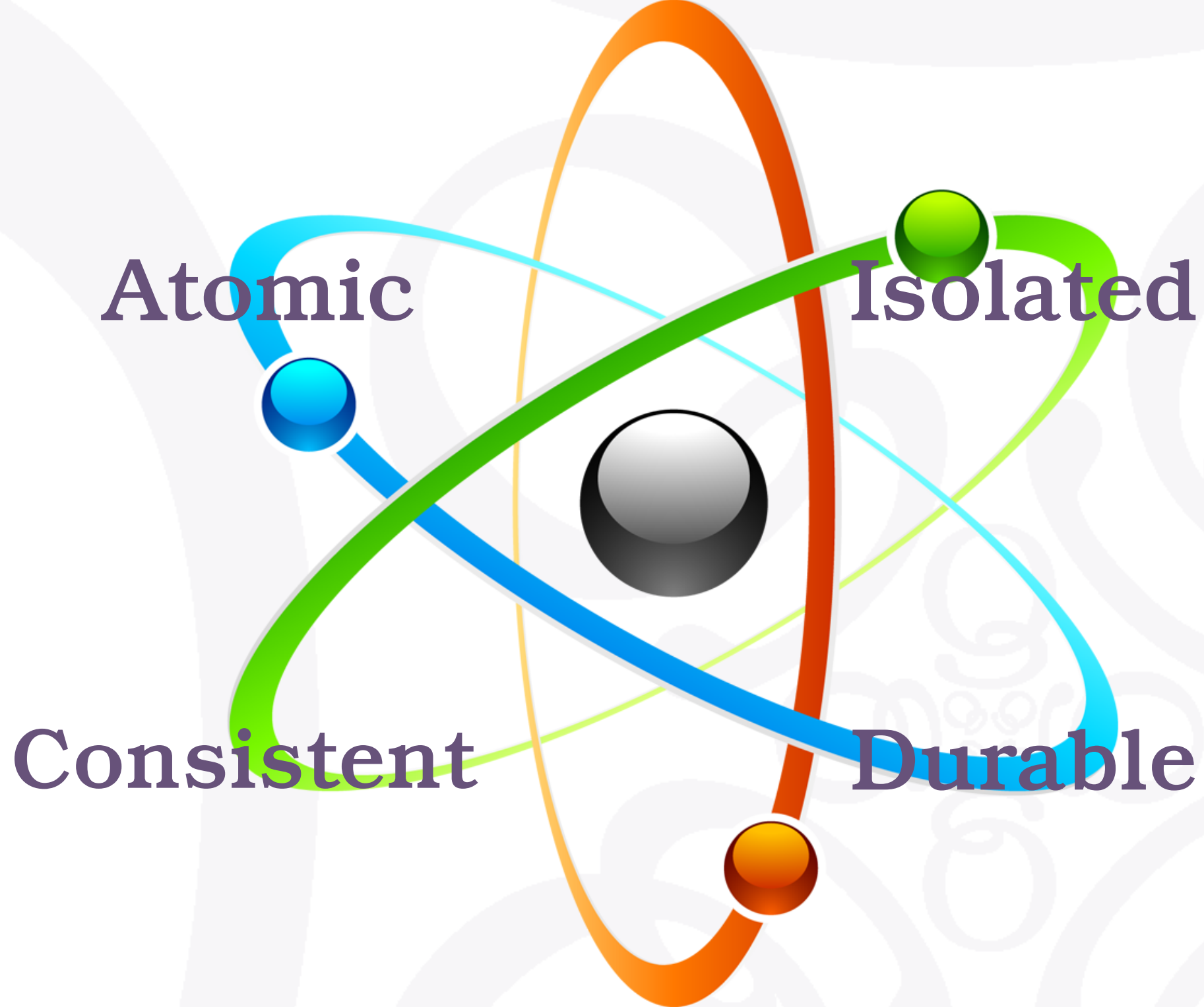
Durable

RDMBS are ACID

Concurrency and Isolation

Atomic

ROLLBACK;

Consistent

- Schema

```
create table foo
  (
    id int,
    f1 text
  );
```

- Data types
- Constraints
  check, not null,
  pkey, fkey
- Relations
- SQL

Isolated

`$ pg_dump`

Durable

PostgreSQL for Developers

- *Transactions*

- *SQL*

- *Object Oriented*

- *Extensions*

- *Rich data types*

- *Data Processing*

- *Advanced Indexing*

- *Arrays, XML, JSON*

Migrating to PostgreSQL

In a single command line!

pgloader.io
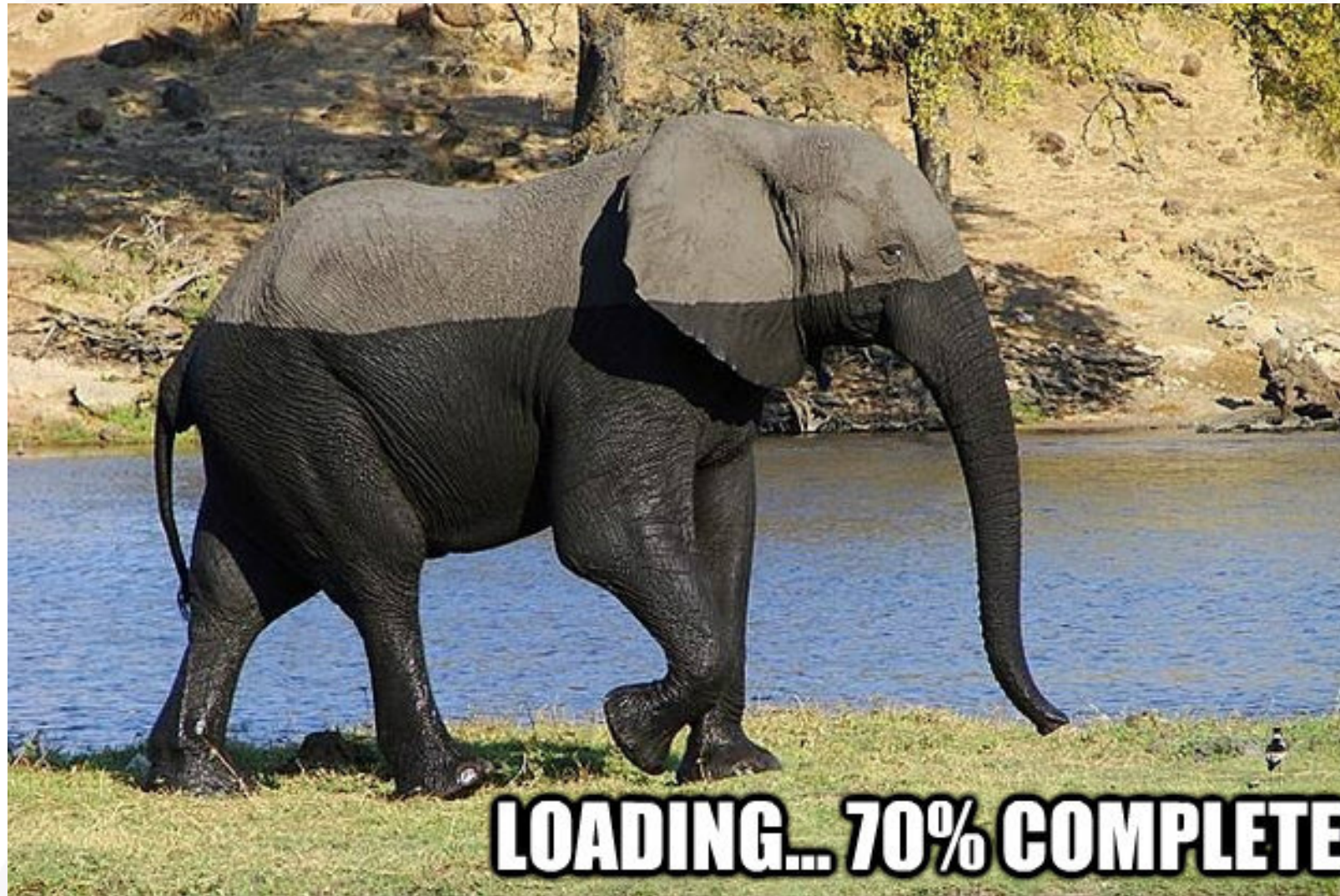
One-command migration

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

SQL for developers

New York Stock Exchange

Daily NYSE Group Volume in NYSE Listed, 2017

```
2010    1/4/2010   1,425,504,460      4,628,115 $38,495,460,645
2010    1/5/2010   1,754,011,750      5,394,016 $43,932,043,406
2010    1/6/2010   1,655,507,953      5,494,460 $43,816,749,660
2010    1/7/2010   1,797,810,789      5,674,297 $44,104,237,184
```

```
create table factbook
 (
   year    int,
   date    date,
   shares  text,
   trades  text,
   dollars text
 );
```

```
\copy factbook from 'factbook.csv' with delimiter E'\t' null ''
```

Daily NYSE Group Volume in NYSE Listed, 2017

```
alter table factbook
    alter shares
     type bigint
    using replace(shares, ',', '')::bigint,

    alter trades
     type bigint
    using replace(trades, ',', '')::bigint,

    alter dollars
     type bigint
    using substring(replace(dollars, ',', '') from 2)::numeric;
```

SQL and Algorithms

Top-N Heapsort, Python

```python
#! /usr/bin/env python3

import psycopg2
import heapq
import sys

PGCONNSTRING = "dbname=appdev application_name=cont"


def top(n):
    "Fetch data from the factbook table"

    conn = psycopg2.connect(PGCONNSTRING)
    curs = conn.cursor()
    sql = """
  SELECT date, dollars
    FROM factbook
   WHERE date is not null
"""
    curs.execute(sql)

    topn = [(0, None) for i in range(n)]
    heapq.heapify(topn)

    for date, dollars in curs.fetchall():
        heapq.heappushpop(topn, (dollars, date))

    return topn


if __name__ == '__main__':
    n = int(sys.argv[1])
    topn = top(n)

    for dollars, date in heapq.nlargest(n, topn):
        print("%s: %s" % (date, dollars))
```

```
2014-12-19: 124663932012
2015-09-18: 118869806099
2014-09-19: 118622863491
2013-12-20: 117924997250
2015-03-20: 115466468635
2016-06-24: 112434567771
2015-06-26: 110931465892
2010-06-25: 110901889417
2015-12-18: 110329938339
2014-03-21: 107923489435
```

Top-N Heapsort, SQL

```sql
select date, dollars
  from factbook
order by dollars desc
 limit 10;
```

date	dollars
2014-12-19	124663932012
2015-09-18	118869806099
2014-09-19	118622863491
2013-12-20	117924997250
2015-03-20	115466468635
2016-06-24	112434567771
2015-06-26	110931465892
2010-06-25	110901889417
2015-12-18	110329938339
2014-03-21	107923489435

(10 rows)

Top-N Heapsort, SQL

explain (analyze, verbose, buffers)

```
Limit  (cost=76.73..76.76 rows=10 width=12)
       (actual time=1.356..1.359 rows=10 loops=1)
   Output: date, dollars
   Buffers: shared hit=18
   ->  Sort  (cost=76.73..81.62 rows=1953 width=12)
            (actual time=1.354..1.354 rows=10 loops=1)
       Output: date, dollars
       Sort Key: factbook.dollars DESC
       Sort Method: top-N heapsort  Memory: 25kB
       Buffers: shared hit=18
       ->  Seq Scan on public.factbook
                (cost=0.00..34.53 rows=1953 width=12)
                (actual time=0.017..0.673 rows=1953 loops=1)
           Output: date, dollars
           Buffers: shared hit=15
 Planning time: 0.137 ms
 Execution time: 1.395 ms
(13 rows)
```

Monthly Reports

Monthly Report, SQL

```
\set start '2017-02-01'

  select date,
         to_char(shares, '99G999G999G999') as shares,
         to_char(trades, '99G999G999') as trades,
         to_char(dollars, 'L99G999G999G999') as dollars
    from factbook
   where date >= date :'start'
     and date  < date :'start' + interval '1 month'
order by date;
```

Monthly Report, SQL

date	shares	trades	dollars
2017-02-01	1,161,001,502	5,217,859	$ 44,660,060,305
2017-02-02	1,128,144,760	4,586,343	$ 43,276,102,903
2017-02-03	1,084,735,476	4,396,485	$ 42,801,562,275
2017-02-06	954,533,086	3,817,270	$ 37,300,908,120
2017-02-07	1,037,660,897	4,220,252	$ 39,754,062,721
2017-02-08	1,100,076,176	4,410,966	$ 40,491,648,732
2017-02-09	1,081,638,761	4,462,009	$ 40,169,585,511
2017-02-10	1,021,379,481	4,028,745	$ 38,347,515,768
2017-02-13	1,020,482,007	3,963,509	$ 38,745,317,913
2017-02-14	1,041,009,698	4,299,974	$ 40,737,106,101
2017-02-15	1,120,119,333	4,424,251	$ 43,802,653,477
2017-02-16	1,091,339,672	4,461,548	$ 41,956,691,405
2017-02-17	1,160,693,221	4,132,233	$ 48,862,504,551
2017-02-21	1,103,777,644	4,323,282	$ 44,416,927,777
2017-02-22	1,064,236,648	4,169,982	$ 41,137,731,714
2017-02-23	1,192,772,644	4,839,887	$ 44,254,446,593
2017-02-24	1,187,320,171	4,656,770	$ 45,229,398,830
2017-02-27	1,132,693,382	4,243,911	$ 43,613,734,358
2017-02-28	1,455,597,403	4,789,769	$ 57,874,495,227

(19 rows)

Monthly Report, Python

```python
def fetch_month_data(year, month):
    "Fetch a month of data from the database"
    date = "%d-%02d-01" % (year, month)
    sql = """
  select date, shares, trades, dollars
    from factbook
   where date >= date %s
     and date  < date %s + interval '1 month'
order by date;
"""
    pgconn = psycopg2.connect(CONNSTRING)
    curs = pgconn.cursor()
    curs.execute(sql, (date, date))

    res = {}
    for (date, shares, trades, dollars) in curs.fetchall():
        res[date] = (shares, trades, dollars)

    return res
```

```python
def list_book_for_month(year, month):
    """List all days for given month, and for each
    day list fact book entry.
    """
    data = fetch_month_data(year, month)

    cal = Calendar()
    print("%12s | %12s | %12s | %12s" %
          ("day", "shares", "trades", "dollars"))
    print("%12s-+-%12s-+-%12s-+-%12s" %
          ("-" * 12, "-" * 12, "-" * 12, "-" * 12))

    for day in cal.itermonthdates(year, month):
        if day.month != month:
            continue
        if day in data:
            shares, trades, dollars = data[day]
        else:
            shares, trades, dollars = 0, 0, 0

        print("%12s | %12s | %12s | %12s" %
              (day, shares, trades, dollars))
```
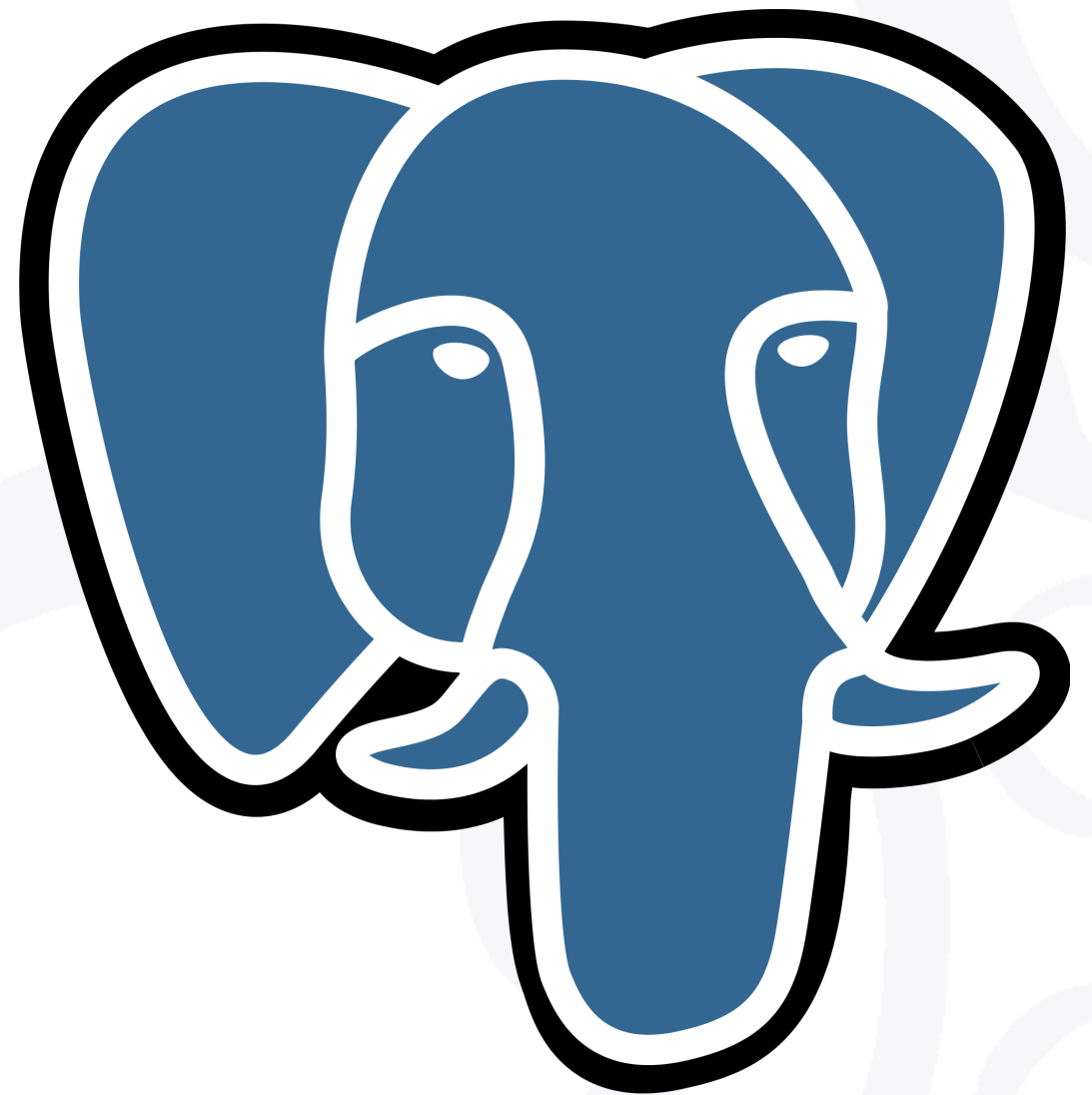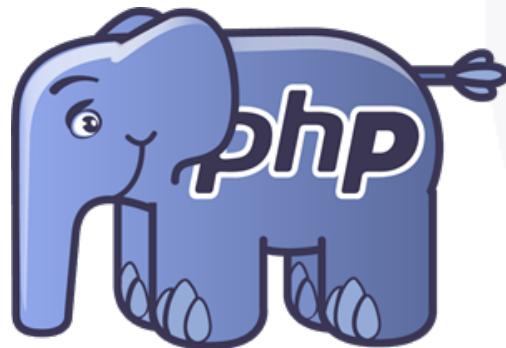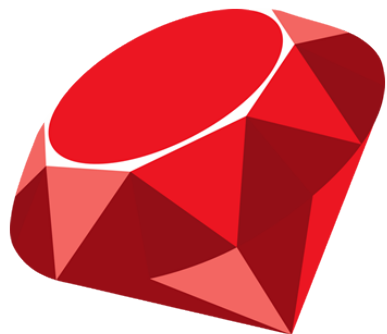
Monthly Report, Python

```
$ ./factbook-month.py 2017 2
        day |       shares |      trades |      dollars
------------+--------------+-------------+-------------
 2017-02-01 |   1161001502 |     5217859 |  44660060305
 2017-02-02 |   1128144760 |     4586343 |  43276102903
 2017-02-03 |   1084735476 |     4396485 |  42801562275
 2017-02-04 |            0 |           0 |            0
 2017-02-05 |            0 |           0 |            0
 2017-02-06 |    954533086 |     3817270 |  37300908120
 2017-02-07 |   1037660897 |     4220252 |  39754062721
 2017-02-08 |   1100076176 |     4410966 |  40491648732
 2017-02-09 |   1081638761 |     4462009 |  40169585511
 2017-02-10 |   1021379481 |     4028745 |  38347515768
 2017-02-11 |            0 |           0 |            0
 2017-02-12 |            0 |           0 |            0
 2017-02-13 |   1020482007 |     3963509 |  38745317913
 2017-02-14 |   1041009698 |     4299974 |  40737106101
 2017-02-15 |   1120119333 |     4424251 |  43802653477
 2017-02-16 |   1091339672 |     4461548 |  41956691405
 2017-02-17 |   1160693221 |     4132233 |  48862504551
 2017-02-18 |            0 |           0 |            0
 2017-02-19 |            0 |           0 |            0
 2017-02-20 |            0 |           0 |            0
 2017-02-21 |   1103777644 |     4323282 |  44416927777
 2017-02-22 |   1064236648 |     4169982 |  41137731714
 2017-02-23 |   1192772644 |     4839887 |  44254446593
 2017-02-24 |   1187320171 |     4656770 |  45229398830
 2017-02-25 |            0 |           0 |            0
 2017-02-26 |            0 |           0 |            0
 2017-02-27 |   1132693382 |     4243911 |  43613734358
 2017-02-28 |   1455597403 |     4789769 |  57874495227
```

Where is that code used?

Frontend, Back Office, Finance, Accounting, Invoicing, ...

Days with no activity, SQL

Monthly Report, Fixed, SQL

```sql
  select cast(calendar.entry as date) as date,
         coalesce(shares, 0) as shares,
         coalesce(trades, 0) as trades,
         to_char(
             coalesce(dollars, 0),
             'L99G999G999G999'
         ) as dollars
    from /*
          * Generate the target month's calendar then LEFT JOIN
          * each day against the factbook dataset, so as to have
          * every day in the result set, whether or not we have a
          * book entry for the day.
          */
         generate_series(date :'start',
                         date :'start' + interval '1 month'
                                       - interval '1 day',
                         interval '1 day'
         )
         as calendar(entry)
         left join factbook
               on factbook.date = calendar.entry
order by date;
```

Monthly Report, Fixed, SQL

date	shares	trades	dollars
2017-02-01	1161001502	5217859	$ 44,660,060,305
2017-02-02	1128144760	4586343	$ 43,276,102,903
2017-02-03	1084735476	4396485	$ 42,801,562,275
2017-02-04	0	0	$ 0
2017-02-05	0	0	$ 0
2017-02-06	954533086	3817270	$ 37,300,908,120
2017-02-07	1037660897	4220252	$ 39,754,062,721
2017-02-08	1100076176	4410966	$ 40,491,648,732
2017-02-09	1081638761	4462009	$ 40,169,585,511
2017-02-10	1021379481	4028745	$ 38,347,515,768
2017-02-11	0	0	$ 0
2017-02-12	0	0	$ 0
2017-02-13	1020482007	3963509	$ 38,745,317,913
2017-02-14	1041009698	4299974	$ 40,737,106,101
2017-02-15	1120119333	4424251	$ 43,802,653,477
2017-02-16	1091339672	4461548	$ 41,956,691,405
2017-02-17	1160693221	4132233	$ 48,862,504,551
2017-02-18	0	0	$ 0
2017-02-19	0	0	$ 0
2017-02-20	0	0	$ 0
2017-02-21	1103777644	4323282	$ 44,416,927,777
2017-02-22	1064236648	4169982	$ 41,137,731,714
2017-02-23	1192772644	4839887	$ 44,254,446,593
2017-02-24	1187320171	4656770	$ 45,229,398,830
2017-02-25	0	0	$ 0
2017-02-26	0	0	$ 0
2017-02-27	1132693382	4243911	$ 43,613,734,358
2017-02-28	1455597403	4789769	$ 57,874,495,227

(28 rows)

Marketing dept wants Week on Week Evolution

Monthly Report, WoW%, SQL

date	day	dollars	WoW %
2017-02-01	**Wed**	**$ 44,660,060,305**	**-2.21**
2017-02-02	Thu	$ 43,276,102,903	1.71
2017-02-03	Fri	$ 42,801,562,275	10.86
2017-02-04	Sat	$ 0	¤
2017-02-05	Sun	$ 0	¤
2017-02-06	**Mon**	**$ 37,300,908,120**	**-9.64**
2017-02-07	Tue	$ 39,754,062,721	-37.41
2017-02-08	**Wed**	**$ 40,491,648,732**	**-10.29**
2017-02-09	Thu	$ 40,169,585,511	-7.73
2017-02-10	Fri	$ 38,347,515,768	-11.61
2017-02-11	Sat	$ 0	¤
2017-02-12	Sun	$ 0	¤
2017-02-13	**Mon**	**$ 38,745,317,913**	**3.73**
2017-02-14	Tue	$ 40,737,106,101	2.41
2017-02-15	**Wed**	**$ 43,802,653,477**	**7.56**
2017-02-16	Thu	$ 41,956,691,405	4.26
2017-02-17	Fri	$ 48,862,504,551	21.52
2017-02-18	Sat	$ 0	¤
2017-02-19	Sun	$ 0	¤
2017-02-20	**Mon**	**$ 0**	**¤**
2017-02-21	Tue	$ 44,416,927,777	8.28
2017-02-22	**Wed**	**$ 41,137,731,714**	**-6.48**
2017-02-23	Thu	$ 44,254,446,593	5.19
2017-02-24	Fri	$ 45,229,398,830	-8.03
2017-02-25	Sat	$ 0	¤
2017-02-26	Sun	$ 0	¤
2017-02-27	**Mon**	**$ 43,613,734,358**	**¤**
2017-02-28	Tue	$ 57,874,495,227	23.25

(28 rows)

Monthly Report, WoW%, SQL

```sql
with computed_data as
(
  select cast(date as date)   as date,
         to_char(date, 'Dy')  as day,
         coalesce(dollars, 0) as dollars,
         lag(dollars, 1)
           over(
             partition by extract('isodow' from date)
               order by date
           )
         as last_week_dollars
    from /*
         * Generate the month calendar, plus a week
         * before so that we have values to compare
         * dollars against even for the first week
         * of the month.
         */
         generate_series(date :'start' - interval '1 week',
                         date :'start' + interval '1 month'
                                       - interval '1 day',
                         interval '1 day'
         )
         as calendar(date)
         left join factbook using(date)
)
select date, day,
       to_char(
         coalesce(dollars, 0),
         'L99G999G999G999'
       ) as dollars,
       case when dollars is not null
            and dollars <> 0
            then round(  100.0
                       * (dollars - last_week_dollars)
                       / dollars
                      , 2)
         end
       as "WoW %"
  from computed_data
 where date >= date :'start'
 order by date;
```

Monthly Report, WoW%, SQL

```sql
with computed_data as
(
  select cast(date as date)   as date,
         to_char(date, 'Dy')  as day,
         coalesce(dollars, 0) as dollars,
         lag(dollars, 1)
           over(
             partition by extract('isodow' from date)
                 order by date
           )
         as last_week_dollars
    from /*
         * Generate the month calendar, plus a week
         * before so that we have values to compare
         * dollars against even for the first week
         * of the month.
         */
         generate_series(date :'start' - interval '1 week',
                         date :'start' + interval '1 month'
                                       - interval '1 day',
                         interval '1 day'
         )
         as calendar(date)
         left join factbook using(date)
)

  select date, day,
         to_char(
             coalesce(dollars, 0),
             'L99G999G999G999'
         ) as dollars,
         case when dollars is not null
              and dollars <> 0
              then round(  100.0
                         * (dollars - last_week_dollars)
                         / dollars
                         , 2)
         end
         as "WoW %"
    from computed_data
   where date >= date :'start'
order by date;
```

Window Function, SQL'92

Monthly Report, WoW%, SQL

date	day	dollars	WoW %
2017-02-01	**Wed**	**$ 44,660,060,305**	**-2.21**
2017-02-02	Thu	$ 43,276,102,903	1.71
2017-02-03	Fri	$ 42,801,562,275	10.86
2017-02-04	Sat	$ 0	¤
2017-02-05	Sun	$ 0	¤
2017-02-06	**Mon**	**$ 37,300,908,120**	**-9.64**
2017-02-07	Tue	$ 39,754,062,721	-37.41
2017-02-08	**Wed**	**$ 40,491,648,732**	**-10.29**
2017-02-09	Thu	$ 40,169,585,511	-7.73
2017-02-10	Fri	$ 38,347,515,768	-11.61
2017-02-11	Sat	$ 0	¤
2017-02-12	Sun	$ 0	¤
2017-02-13	**Mon**	**$ 38,745,317,913**	**3.73**
2017-02-14	Tue	$ 40,737,106,101	2.41
2017-02-15	**Wed**	**$ 43,802,653,477**	**7.56**
2017-02-16	Thu	$ 41,956,691,405	4.26
2017-02-17	Fri	$ 48,862,504,551	21.52
2017-02-18	Sat	$ 0	¤
2017-02-19	Sun	$ 0	¤
2017-02-20	**Mon**	**$ 0**	**¤**
2017-02-21	Tue	$ 44,416,927,777	8.28
2017-02-22	**Wed**	**$ 41,137,731,714**	**-6.48**
2017-02-23	Thu	$ 44,254,446,593	5.19
2017-02-24	Fri	$ 45,229,398,830	-8.03
2017-02-25	Sat	$ 0	¤
2017-02-26	Sun	$ 0	¤
2017-02-27	**Mon**	**$ 43,613,734,358**	**¤**
2017-02-28	Tue	$ 57,874,495,227	23.25

(28 rows)

The SQL Standard

SQL:2016

Thinking in SQL

- Structured Query Language

- Declarative Programming Language

- Relational Model

  - Unix: *everything is a file*

  - Java: *everything is an object*

  - Python: *packages, modules, classes, methods*

  - SQL: ***relations***

SQL Relations

- SELECT describes the type of the relation
  - Named a *projection* operator
  - Defines SQL Query Attribute domains
- FROM introduces base relations
- Relational Operators compute new relations
  - INNER JOIN
  - OUTER JOIN
  - LATERAL JOIN
  - set operators: UNION, EXECPT, INTERSECT

SQL Relations

```sql
with decades as
(
    select extract('year' from date_trunc('decade', date)) as decade
      from races
 group by decade
)
select decade,
       rank() over(partition by decade order by wins desc) as rank,
       forename, surname, wins

   from decades
        left join lateral
        (
           select code, forename, surname, count(*) as wins
             from drivers
                  join results
                    on results.driverid = drivers.driverid
                   and results.position = 1
                  join races using(raceid)

             where   extract('year' from date_trunc('decade', races.date))
                   = decades.decade

         group by decades.decade, drivers.driverid
         order by wins desc
            limit 3
        )
        as winners on true

order by decade asc, wins desc;
```

Top-3 Pilots by decade

decade	rank	forename	surname	wins
1950	1	Juan	**Fangio**	**24**
1950	2	Alberto	Ascari	13
1950	3	Stirling	Moss	12
1960	1	Jim	**Clark**	**25**
1960	2	Graham	Hill	14
1960	3	Jack	Brabham	11
1970	1	Niki	**Lauda**	**17**
1970	2	Jackie	Stewart	16
1970	3	Emerson	Fittipaldi	14
1980	1	Alain	**Prost**	**39**
1980	2	Nelson	Piquet	20
1980	2	Ayrton	Senna	20
1990	1	Michael	**Schumacher**	**35**
1990	2	Damon	Hill	22
1990	3	Ayrton	Senna	21
2000	1	Michael	**Schumacher**	**56**
2000	2	Fernando	Alonso	21
2000	3	Kimi	Räikkönen	18
2010	1	Lewis	**Hamilton**	**45**
2010	2	Sebastian	Vettel	40
2010	3	Nico	Rosberg	23

(21 rows)

SQL is Code

SQL & Developer Tooling

```
with computed_data as
(
  select cast(date as date)   as date,
         to_char(date, 'Dy')  as day,
         coalesce(dollars, 0) as dollars,
         lag(dollars, 1)
           over(
             partition by extract('isodow' from date)
                 order by date
           )
         as last_week_dollars
    from /*
         * Generate the month calendar, plus a week before
         * so that we have values to compare dollars against
         * even for the first week of the month.
         */
         generate_series(date :'start' - interval '1 week',
                         date :'start' + interval '1 month'
                                       - interval '1 day',
                         interval '1 day'
         )
         as calendar(date)
         left join factbook using(date)
)
  select date, day,
         to_char(
             coalesce(dollars, 0),
             'L99G999G999G999'
         ) as dollars,
         case when dollars is not null
               and dollars <> 0
              then round(  100.0
                         * (dollars - last_week_dollars)
                         / dollars
                        , 2)
          end
         as "WoW %"
    from computed_data
   where date >= date :'start'
order by date;
```

- Code Integration
  - SQL Queries in .sql files
  - Parameters
  - Result Set To Objects
  - A Result Set *is a* Relation

- Testing
  - Unit Testing
  - Regression Testing

Object Relational Mapping

- *The **R** in ORM stands for **relation***

- *Every SQL query result set is a relation*

- *Alternatives: JOOQ, POMM*

CoolClips.com

Integration of SQL as code

YeSQL for Clojure

https://github.com/krisajenkins/yesql

Also exists for:

- *Python*

- *PHP*

- *C#*

- *Javascript*

- *Erlang*

- *Ruby*

Python AnoSQL

```
$ cat queries.sql

-- name: get-all-greetings
-- Get all the greetings in the database
SELECT * FROM greetings;


-- name: $select-users
-- Get all the users from the database,
-- and return it as a dict
SELECT * FROM USERS;
```

Python AnoSQL

```python
import anosql
import psycopg2
import sqlite3

# PostgreSQL
conn = psycopg2.connect('...')
queries = anosql.load_queries('postgres', 'queries.sql')

queries = queries.get_all_users(conn)
# [{"id": 1, "name": "Meghan"}, {"id": 2, "name": "Harry"}]

queries = queries.get_all_greetings(conn)
# => [(1, 'Hi')]
```

RegreSQL

```
$ regresql test
Connecting to 'postgres:///chinook?sslmode=disable'… ✓
TAP version 13
ok 1 — src/sql/album-by-artist.1.out
ok 2 — src/sql/album-tracks.1.out
ok 3 — src/sql/artist.1.out
ok 4 — src/sql/genre-topn.top-3.out
ok 5 — src/sql/genre-topn.top-1.out
ok 6 — src/sql/genre-tracks.out
```

RegreSQL

```
$ tree regresql/
regresql/
├── expected
│   └── src
│       └── sql
│           ├── album-by-artist.1.out
│           ├── album-tracks.1.out
│           ├── artist.1.out
│           ├── genre-topn.1.out
│           ├── genre-topn.top-1.out
│           ├── genre-topn.top-3.out
│           └── genre-tracks.out
├── out
│   └── src
│       └── sql
│           ├── album-by-artist.1.out
│           ├── album-tracks.1.out
│           ├── artist.1.out
│           ├── genre-topn.1.out
│           ├── genre-topn.top\ 1.out
│           ├── genre-topn.top\ 3.out
│           ├── genre-topn.top-1.out
│           ├── genre-topn.top-3.out
│           └── genre-tracks.out
├── plans
│   └── src
│       └── sql
│           ├── album-by-artist.yaml
│           ├── album-tracks.yaml
│           ├── artist.yaml
│           └── genre-topn.yaml
└── regress.yaml

9 directories, 21 files
```

PostgreSQL Extensions

Geolocation: ip4r

```sql
select *
  from geolite.blocks
  join geolite.location
       using(locid)
 where iprange
        >>=
        '74.125.195.147';
```

Constraint Exclusion

```
create table geolite.blocks
(
   iprange      ip4r,
   locid        integer,

   exclude using gist (iprange with &&)
);
```

Geolocation & earthdistance

```sql
with geoloc as
 (
  select location as l
    from location
    join blocks using(locid)
   where iprange
         >>=
         '212.58.251.195'
 )
  select name,
         pos <@> l miles
    from pubnames, geoloc
order by pos <-> l
  limit 10;
```

name	miles
The Windmill	0.238820308117723
County Hall Arms	0.343235607674773
St Stephen's Tavern	0.355548630092567
The Red Lion	0.417746499125936
Zeitgeist	0.395340599421532
The Rose	0.462805636194762
The Black Dog	0.536202634581979
All Bar One	0.489581827372222
Slug and Lettuce	0.49081531378207
Westminster Arms	0.42400619117691

(10 rows)

NBA Games Statistics

"An interesting factoid: the team that recorded the fewest defensive rebounds in a win was the 1995-96 Toronto Raptors, who beat the Milwaukee Bucks 93-87 on 12/26/1995 despite recording only 14 defensive rebounds."

NBA Games Statistics

```sql
with stats(game, team, drb, min) as (
    select ts.game, ts.team, drb, min(drb) over ()
      from team_stats ts
           join winners w on w.id = ts.game
                          and w.winner = ts.team
)
select game.date::date,
       host.name || ' -- ' || host_score as host,
       guest.name || ' -- ' || guest_score as guest,
       stats.drb as winner_drb
  from stats
       join game on game.id = stats.game
       join team host on host.id = game.host
       join team guest on guest.id = game.guest
 where drb = min;
```

NBA Games Statistics

```
-[ RECORD 1 ]----------------------------
date       | 1995-12-26
host       | Toronto Raptors -- 93
guest      | Milwaukee Bucks -- 87
winner_drb | 14
-[ RECORD 2 ]----------------------------
date       | 1996-02-02
host       | Golden State Warriors -- 114
guest      | Toronto Raptors -- 111
winner_drb | 14
-[ RECORD 3 ]----------------------------
date       | 1998-03-31
host       | Vancouver Grizzlies -- 101
guest      | Dallas Mavericks -- 104
winner_drb | 14
-[ RECORD 4 ]----------------------------
date       | 2009-01-14
host       | New York Knicks -- 128
guest      | Washington Wizards -- 122
winner_drb | 14

Time: 126.276 ms
```

Pure SQL Histograms

```sql
with drb_stats as (
    select min(drb) as min,
           max(drb) as max
      from team_stats
),
    histogram as (
   select width_bucket(drb, min, max, 9) as bucket,
          int4range(min(drb), max(drb), '[]') as range,
          count(*) as freq
     from team_stats, drb_stats
 group by bucket
 order by bucket
)
 select bucket, range, freq,
        repeat('▪',
               (   freq::float
                 / max(freq) over()
                 * 30
               )::int
        ) as bar
   from histogram;
```

Pure SQL Histograms

```
 bucket |   range   |  freq  |                    bar
--------+-----------+--------+-----------------------------------------
      1 | [10,15)   |     52 |
      2 | [15,20)   |   1363 | █▉
      3 | [20,25)   |   8832 | ████████████████
      4 | [25,30)   |  20917 | ████████████████████████████████████████
      5 | [30,35)   |  20681 | ████████████████████████████████████████
      6 | [35,40)   |   9166 | ████████████████
      7 | [40,45)   |   2093 | ███▉
      8 | [45,50)   |    247 |
      9 | [50,54)   |     20 |
     10 | [54,55)   |      1 |
(10 rows)
```

The Art of PostgreSQL

Turn Thousands of Lines
of Code into Simple Queries