How Green Was My Valley

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Crunchy Data

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Agenda

Spatial Analytics

- Overview
- Ingesting Data
- Analytics

Full details of this talk available at:
`https://info.crunchydata.com/blog/spatial-analytics-with-postgres-postgis-plr`

Datasets

- Administrative shape data
- Geocoded data (not covered here)
- MOD13A1 NDVI
  - Normalized Difference Vegetation Index
  - global, spatial raster data

`https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod13a1`

Components

- PostgreSQL
  - The world's most advanced open source database.
- PostGIS
  - A spatial database extender for PostgreSQL. Adds support for geographic objects allowing location queries to be run in SQL.
- R
  - An open source language and environment for statistical computing and graphics.
- PL/R
  - R Procedural Language Handler for PostgreSQL. Enables user-defined SQL functions to be written in the R language. Actively developed since early 2003.

https://www.r-project.org
http://www.postgis.net
http://www.joeconway.com/plr

CRUNCHY Enterprise PostgreSQL

PostgreSQL and R Setup

- Install desired versions of PostgreSQL, PostGIS, R, and PL/R
- Create the database and install Postgres extensions
- Install variety of required/interesting R packages
- Be sure to install R packages as `root` or `postgres`

RPostgreSQL Compatibility

- Allows prototyping using R, move to PL/R for production
- Queries performed in current database
- Driver/connection parameters ignored; dbDriver, dbConnect, dbDisconnect, and dbUnloadDriver are no-ops

RPostgreSQL Compatibility Example

- PostgreSQL access from R

```
get_ndvi_mean<-function(rastfile) {

  library(cairoDevice); library(RGtk2); library(sp); library(raster); library(RPostgreSQL)

  ndvi <- brick(rastfile)
  ndvi_mn <- cellStats(ndvi, stat = 'mean')

  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)

  return(data.frame(ndvi_dt, ndvi_mn))

}
```

RPostgreSQL Compatibility Example

- Same function from PL/R

```
CREATE OR REPLACE FUNCTION get_ndvi_mean
  (rastfile text, OUT lyr_date date, OUT lyr_mean float8)
RETURNS setof RECORD AS $$
  library(cairoDevice); library(RGtk2); library(sp); library(raster); library(RPostgreSQL)

  ndvi <- brick(rastfile)
  ndvi_mn <- cellStats(ndvi, stat = 'mean')

  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)

  return(data.frame(ndvi_dt, ndvi_mn))
$$ LANGUAGE 'plr' STRICT;
```

Create Raw Image from SQL

```
CREATE OR REPLACE FUNCTION plot_ndvi_trend(rastfile text)
RETURNS bytea AS $$
  library(cairoDevice); library(RGtk2); library(sp); library(raster)
  pixmap <- gdkPixmapNew(w=1024, h=768, depth=24); asCairoDevice(pixmap)

  ndvi <- brick(rastfile)
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)
  ndvi_mn <- cellStats(ndvi, stat = 'mean')
  idx <- order(ndvi_dt)
  Data <- data.frame(ndvi_dt$lyr_date[idx], ndvi_mn[idx])
  plot(Data, type ="l", xlab = "Time", ylab = "NDVI")

  plot_pixbuf <- gdkPixbufGetFromDrawable(NULL, pixmap, pixmap$getColormap(),
                                          0, 0, 0, 0, 500, 500)
  gdkPixbufSaveToBufferv(plot_pixbuf, "png", character(0), character(0))$buffer
$$ LANGUAGE 'plr' STRICT;
```

Use of Raw Image from SQL

- Need screen buffer on typical server:

```
Xvfb :1 -screen 0 1024x768x24
export DISPLAY=:1.0
```

- Calling it from PHP

```
<?php
$dbconn = pg_connect("...");
$rs = pg_query( $dbconn,
      "SELECT plr_get_raw(plot_ndvi_trend('/usr/local/bda/modis/ndvi_cooked/ndvi.tif'))");
$hexpic = pg_fetch_array($rs);
$cleandata = pg_unescape_bytea($hexpic[0]);

header("Content-Type: image/png");
header("Last-Modified: " .
       date("r", filectime($_SERVER['SCRIPT_FILENAME'])));
header("Content-Length: " . strlen($cleandata));
echo $cleandata;
?>
```

Source and Ingest USA Counties

- Use `getData()` (`rgdal` package) to get shape layer for an administrative area
  - `GADM`: database of global administrative boundaries
    → `http://www.gadm.org`
- Create a PostGIS table and store it there

Create USA Counties Layer Table

```
CREATE OR REPLACE FUNCTION create_admin_layer(country text, level int, tablename text)
RETURNS text AS $$
  library(rgdal); library(RPostgreSQL)

  # download the requested administrative shapes and create the Postgres table
  dsn="PG:user='postgres' dbname='gis' host='localhost'"
  shapes = getData('GADM', country = country, level = level)
  writeOGR(shapes, dsn, tablename, "PostgreSQL")
  sql.str <- sprintf("CREATE INDEX %s_idx1 ON %s(name_1,name_2)", tablename, tablename)
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  dbGetQuery(conn, sql.str)

  return("OK")
$$ LANGUAGE plr;

DROP TABLE IF EXISTS counties;
SELECT create_admin_layer(country := 'USA', level := 2, tablename := 'counties');
```

Extract and Plot San Diego County

```
-- Note: might need to run "Xvfb :1 -screen 0 1024x768x24"
CREATE OR REPLACE FUNCTION plot_admin_layer(layername text, name1 text, name2 text)
RETURNS bytea AS $$
  library(rgeos); library(cairoDevice); library(RGtk2); library(RPostgreSQL)

  pixmap <- gdkPixmapNew(w=1024, h=768, depth=24); asCairoDevice(pixmap)

  proj_str <- "+proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0"
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- sprintf("SELECT st_astext(wkb_geometry) AS geom
                      FROM %s WHERE name_1 = '%s' AND name_2 = '%s'", layername, name1, name2)
  plot(readWKT(dbGetQuery(conn, sql.str), p4s=proj_str))

  plot_pixbuf <- gdkPixbufGetFromDrawable(NULL, pixmap, pixmap$getColormap(),
                                          0, 0, 0, 0, 500, 500)
  buffer <- gdkPixbufSaveToBufferv(plot_pixbuf, "png", character(0), character(0))$buffer
  return(buffer)
$$ LANGUAGE 'plr' STRICT;
```

San Diego County Administrative Boundaries

```
SELECT plr_get_raw(plot_admin_layer('counties', 'California', 'San Diego'));
```

San Diego County Administrative Boundaries - Reprojected

```
p4s <- "+proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0"
mp4s <- "+proj=laea +lat_0=45 +lon_0=-100 +x_0=0 +y_0=0 +a=6370997 +b=6370997 +units=m +no_defs"
plot(spTransform(readWKT(dbGetQuery(conn, sql.str), p4s=p4s), CRS(mp4s)))
```

Preprocessing

- Review downloaded files, eliminate anomolies (9 out of 1166)
- Run preprocessing function
  - Load area of interest (AoI) administrative boundaries
  - Reproject AoI to same projection as MOD13A1 raster data
  - Loop through the downloaded files
    - Unzip File of Interest (FoI)
    - Load NDVI, QA, and Acquisition rasters
    - Crop rasters to AoI (trim matrix to AoI extent)
    - Mask rasters to AoI (mark cells outside AoI as NA)
    - Use QA raster to mark cells with questionable data in NDVI raster as NA
    - Use Acquisition raster to calculate mean date (YYYY.pppp) of NDVI data
  - Capture NDVI rasters and Dates

Preprocessing Function

```
# loop through all the MODIS files and preprocess
CREATE OR REPLACE FUNCTION process_raw_ndvi
  (mywd text, layername text, name1 text, name2 text)
RETURNS bytea AS $$

  [...too long to cover...]

  return(data.frame(ndvi_i, ndvi_dt))
$$ LANGUAGE 'plr' STRICT;
```

Preprocessing Function

```
CREATE TABLE robjects(objname text primary key, obj bytea);

INSERT INTO robjects
SELECT 'ndvi_dt', process_raw_ndvi('/usr/local/bda/modis',
                                   'counties',
                                   'California',
                                   'San Diego');
--Time: 8010273.572 ms
```

Plotting NDVI

```
CREATE OR REPLACE FUNCTION plot_ndvi(rastfile text, bricklayer int, plotfile text,
                        poilayer text, aoilayer text, aoiname1 text, aoiname2 text)
RETURNS text AS $$
  library(sp); library(raster); library(rgeos); library(rgdal); library(RPostgreSQL)
  Sys.setenv("DISPLAY"=":0.0")

  # required in R, noop in PL/R
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")

  # CRS of the MODIS raster
  mp4str <- "+proj=laea +lat_0=45 +lon_0=-100 +x_0=0
             +y_0=0 +a=6370997 +b=6370997 +units=m +no_defs"

  # plot to file if destination filename given
  if (plotfile != "") png(plotfile, width = 1024, height = 768)

  [...]
```

Plotting NDVI

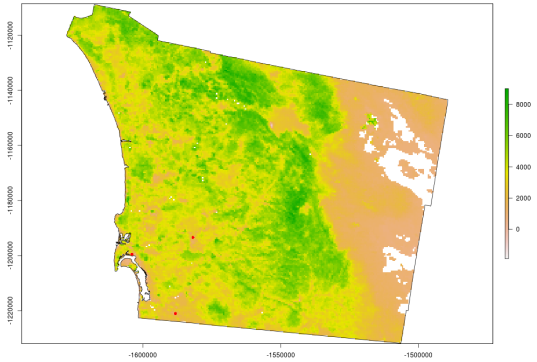
```
[...]

# retrieve boundaries for requested admin area
p4str <- "+proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0"
sql.str <- sprintf("SELECT st_astext(wkb_geometry) AS geom
                    FROM %s WHERE name_1 = '%s' and name_2 = '%s'",
                    aoilayer, aoiname1, aoiname2)
sdc <- readWKT(dbGetQuery(conn, sql.str), p4s=p4str)

# reproject the boundary to the CRS of the MODIS raster and add to plot
plot(spTransform(sdc, CRS(mp4str)))

# read and plot requested raster layer
ndvi <- brick(rastfile)
ndvi_layer <- ndvi[[bricklayer]]
plot(ndvi_layer, add = TRUE)

[...]
```

Plotting NDVI

```
  [...]

  # retrieve points of interest
  dsn <- "PG:user='postgres' dbname='gis' host='localhost'"
  poi <- readOGR(dsn=dsn, poilayer, stringsAsFactors = FALSE)

  # reproject the poi to the CRS of the MODIS raster
  poi <- spTransform(poi, CRS(mp4str))

  # add poi to plot
  plot(poi, col = "red", pch = 16, add = TRUE)

  if (plotfile != "") dev.off()
  return("OK")
$$ LANGUAGE 'plr' STRICT;
```

Plotting NDVI

```
SELECT plot_ndvi('/usr/local/bda/modis/ndvi_cooked/ndvi.tif', 42, '/tmp/airports2.png',
        'airports', 'counties', 'California', 'San Diego');
```



NDVI - Average over Time

```
CREATE OR REPLACE FUNCTION get_ndvi_mean
  (rastfile text, OUT lyr_date date, OUT lyr_mean float8)
RETURNS setof RECORD AS $$
  library(sp); library(raster); library(RPostgreSQL)

  ndvi <- brick(rastfile)
  ndvi_mn <- cellStats(ndvi, stat = 'mean')

  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)

  return(data.frame(ndvi_dt, ndvi_mn))
$$ LANGUAGE 'plr' STRICT;
```

NDVI - Average over Time

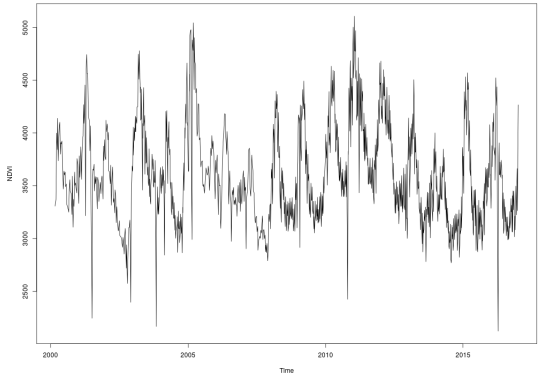
```
SELECT lyr_date, lyr_mean
FROM get_ndvi_mean('/usr/local/bda/modis/ndvi_cooked/ndvi.tif') LIMIT 3;
  lyr_date  |     lyr_mean
------------+------------------
 2000-02-29 | 3307.52445819025
 2000-03-09 | 3358.51562339221
 2000-03-11 | 3372.62659753491
(3 rows)
```

NDVI - Average over Time

```
CREATE OR REPLACE FUNCTION plot_ndvi_trend(rastfile text)
RETURNS bytea AS $$
  library(cairoDevice); library(RGtk2); library(sp); library(raster); library(RPostgreSQL)
  pixmap <- gdkPixmapNew(w=1024, h=768, depth=24); asCairoDevice(pixmap)

  ndvi <- brick(rastfile)
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")
  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)
  ndvi_mn <- cellStats(ndvi, stat = 'mean')
  idx <- order(ndvi_dt)
  Data <- data.frame(ndvi_dt$lyr_date[idx], ndvi_mn[idx])
  plot(Data, type ="l", xlab = "Time", ylab = "NDVI")

  plot_pixbuf <- gdkPixbufGetFromDrawable(NULL, pixmap, pixmap$getColormap(),
                                          0, 0, 0, 0, 500, 500)
  gdkPixbufSaveToBufferv(plot_pixbuf, "png", character(0), character(0))$buffer
$$ LANGUAGE 'plr' STRICT;
```

NDVI - Average over Time

```
SELECT plr_get_raw(plot_ndvi_trend('/usr/local/bda/modis/ndvi_cooked/ndvi.tif'));
```



NDVI - Visualize Average by Month

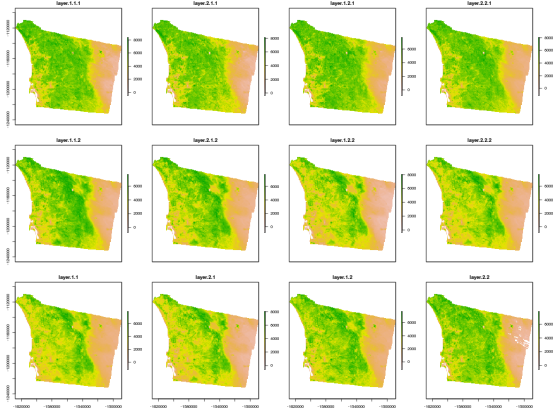
```
# Pure R code here
plot_ndvi_year <- function(rastfile, layeryr, plotfile)
{
  library(sp); library(raster); library(RPostgreSQL)
  Sys.setenv("DISPLAY"=":0.0")

  # required in R, noop in PL/R
  conn <- dbConnect(dbDriver("PostgreSQL"), user="postgres", dbname="gis", host="localhost")

  # plot to file if destination filename given
  if (plotfile != "") png(plotfile, width = 1024, height = 768)

  sql.str <- "SELECT lyr_date FROM ndvi_dates(get_robj('ndvi_dt'))"
  ndvi_dt <- dbGetQuery(conn, sql.str)

  [...]
```

NDVI - Visualize Average by Month

```
  [...]

  # read and plot requested raster layer
  ndvi <- brick(rastfile)
  ndvi_rast <- raster()
  for (i in 1:12)

  {

    fmt_str <- paste(layeryr, sprintf("%02d", i), sep = "-")
    ndvi_layer <- mean(ndvi[[which(format(ndvi_dt, "%Y-%m") == fmt_str)]], na.rm = TRUE)
    ndvi_rast <- addLayer(ndvi_rast, ndvi_layer)

  }

  plot(ndvi_rast)

  if (plotfile != "") dev.off()
}
```

NDVI - Visualize Average by Month

```
plot_ndvi_year("/usr/local/bda/modis/ndvi_cooked/ndvi.tif", 2011, "/tmp/ndvi-2011.png")
```



Questions?

Thank You!

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