Stockage, manipulation et analyse de données matricielles avec PostGIS Raster

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Introducing PostGIS Raster

• Support for rasters in the PostGIS spatial database
  - RASTER is a new native base type like the PostGIS GEOMETRY type
  - Implemented very much like and as easy to use as the GEOMETRY type
    - One row = one raster
    - One table = one coverage
  - Integrated as much as possible with the GEOMETRY type
    - SQL API easy to learn for usual PostGIS users
    - Full raster/vector analysis capacity taking nodata value into account.
    - Seamless when possible.
  - First release with future PostGIS 2.0

• Development Team
  - Current: Bborie Park, Jorge Arevalo, Pierre Racine, Regina & Leo Obe
  - Past: Sandro Santilli, Mateusz Loskot, David Zwarg

• Founding
  - Steve Cumming through a Canada Foundation for Innovation grant
  - Deimos Space, Davis University, Cadcorp, Azavea, OSGeo

Chapter 13 on PostGIS Raster
Georeferenced, Multiband, Multiresolution and Tiled Coverages

- **Georeferenced**
  - Each tile/raster is **georeferenced**
  - Support for rotation (or skew)
- **Multiband**
  - Support for **band with different pixeltypes in the same raster**
    - 1BB, 8BSI, 8BUI, 16BSI, 16BUI, 32BSI, 32BUI, 32BF, 64BF
  - Full supports for **nodata values (one per band)**
  - No real limit on number of band
- **Tiled**
  - No real distinction between a tile and a raster
  - No real limit on size
    - 1 GB per tile, 32 TB per coverage (table)
    - Rasters are **compressed** (by PostgreSQL)
  - Support for **non-rectangular tiled coverage**
- **Multiresolution (or overviews)** are stored in different tables
- **List of raster columns available in a** **raster_columns** **table similar to the geometry_columns table**
Supports Many Raster Arrangements

- a) warehouse of untiled and unrelated images (4 images)
- b) irregularly tiled raster coverage (36 tiles)
- c) regularly tiled raster coverage (36 tiles)
- d) rectangular regularly tiled raster coverage (54 tiles)
- e) tiled images (2 tables of 54 tiles)
- f) rasterized geometries coverage (9 lines in the table)
What You Can Do Now?

Store and manage rasters in the database...

- Import a series of raster
  - `raster2pgsql.py -r "c:/temp/mytiffolder/*.tif" -t mytable -s 4326 -k 50x50 -I | psql -d testdb`
  - Very similar to shp2pgsql
  - Any raster format supported by GDAL

- Get details about the raster georeference
  - `ST_UpperLeftX()`, `ST_UpperLeftY()`, `ST_Height()`, `ST_Width()`, `ST_ScaleX()`, `ST_ScaleY()`, `ST_SkewX()`, `ST_SkewY()`, `ST_Georeference()`
  - `ST_SRID()`, `ST_NumBands()`
  - `ST_Metadata()`

- Get details about bands
  - `ST_BandPixelType()`, `ST_BandNodataValue()`, `ST_BandPath()`
  - `ST_BandMetaData()`
What You Can Do Now?
Store and manage rasters in the database…

• Change the **georeference** and the **spatial reference**
  - `ST_SetScale()`, `ST_SetSkew()`, `ST_SetUpperLeft()`, `ST_SetGeoReference`
  - `ST_SetSRID()`

• Change a **band nodata value**
  - `ST_SetBandNodataValue()`
  - `ST_SetBandNodataValue(rast, NULL)` — to unset nodata value

• **Reproject** rasters
  - `ST_Transform(rast, srid, algorithm, maxerr)`
  - NearestNeighbour, bilinear, cubic, cubic spline, lanczos
  - Done with GDAL
What You Can Do Now?

Store and manage rasters stored outside the database...

- Provides faster loading and export of files for desktop application
- Provides faster access for web applications (JPEGs)
- Avoid useless database backup of large datasets not requiring edition
- Avoid importation (copy) of large datasets into the database
- Provides an efficient SQL API to manipulate/analyse raster files
- All functions should eventually work seamlessly with out-db raster
- Data read/write with GDAL (many formats)
What You Can Do Now?
Dump rasters from the database…

• With the GDAL driver 'PostGISRaster'
  - Developed and maintained by Jorge Arévalo

• Read only and still needs optimization

• Two modes
  1. ONE_RASTER_PER_ROW
  2. ONE_RASTER_PER_TABLE (limited)

• `gdal_translate "PG:host='localhost' dbname='myDB' user='me' password='toto' table='myTable' mode='2' " outputFile.tif`
What You Can Do Now?
Get raster statistics…

• **ST_SummaryStats**(raster)
  - Return a set of (min, max, sum, mean, stddev, count (of
    withdata pixels)) records
  - 10 seconds for one SRTM tile of 3600 x 3600 pixels, 70MB

• **ST_Histogram**(raster, bin, width[ ])
  - Return a set of (min, max, count, percent)
    records for an array of bins

• **ST_Quantile**(raster, quantiles[ ])
  - Return a set of values for an array of quantile

• **ST_ValueCount**(raster, values[ ])
  - Return the frequency for an array of value

All stats function have:

• A **exclude_nodata_value**
  parameter

• A version working on a **coverage** of many tiles

• A **sample_percent**
  parameter (except
  **ST_ValueCount()**)
What You Can Do Now?
Display rasters...

• Display the true raster
  - QGIS plugin by Maurício de Paulo (mauricio.dev@gmail.com)
  - gvSIG plugin by Nacho Brodin (ibrodin@prodevelop.es)
  - MapServer
  - Normally any software using GDAL to read raster and allowing passing database connection parameters to GDAL

• Display a vectorization of the raster
  - OpenJump
    ■ SELECT ST_AsBinary((ST_DumpAsPolygons(rast)).geom),
           (ST_DumpAsPolygons(rast)).val
    FROM srtm_tiled
    WHERE rid=1869;
  - ArcGIS 10
    ■ Add Query Layer (same as OpenJump but without ST_AsBinary())
  - Any software displaying vector PostGIS queries
What You Can Do Now?
Edit rasters...

- **ST_SetValue**(raster, x, y, newval)
  - ST_SetValue(raster, x, y, pt geometry)
  - More ways to set raster values are planned

- **ST_Reclass**(raster, reclassexpr, pixelttype, nodataval)
  - reclassexpr is a text string like '0-87:1-10, 88-254:11-15'
    meaning map 0 to 87 to 1 to 10 and 88 to 254 to 11 to 15
  - You can reset the nodata value
  - You can pass an array of reclassexpr to reclass a multi-band raster
  - Reclass a SRTM tile to a grayscale three band '8BUI' raster (JPEG)

```
SELECT ST_Addband(ST_Addband(ST_AddBand(ST_MakeEmptyRaster(rast),
ST_Reclass(rast, '-100-2000:0-255', '8BUI'))),
ST_Reclass(rast, '-100-2000:0-255', '8BUI')),
ST_Reclass(rast, '-100-2000:0-255', '8BUI'))
FROM srtm_22_03
```
What You Can Do Now? Edit rasters...

- **ST_MapAlgebra**(raster, band, expression, nodatavalueexpr, pixeltype)

- Expressions are evaluated by the PostgreSQL parser
  - Any, really any, complex SQL expression
  - e.g. 'SQRT(rast)/POWER(rast, 3) + ACOS(rast/(rast+1))'
  - e.g. 'CASE WHEN rast < 0 THEN rast+10 ELSE NULL END'

- A **nodatavalueexpr** allow specifying an alternative expression when the pixel is nodata

- **SELECT ST_MapAlgebra**(rast, 'rast/2', '32BF', '0') FROM srtm_22_03

```
   -4  2  0
  -1 -4  2
  -2  0  1
```

```
   6
  -9 -6
   8
```
What You Can Do Now?
Convert rasters to any GDAL format with SQL…

- **ST_GDALDrivers()**
  - Display the list of GDAL driver available with your version of GDAL
  - SELECT (ST_GDALDrivers()).*

- **ST_AsGDALRaster(rast, format, options[])**
  - SELECT ST_AsGDALRaster(rast, 'JPEG') FROM srtm_22_03

- **ST_AsTIFF(raster, nbands[], compression)**
  - Compression % can be specified after the compression 'JPEG80'

- **ST_AsJPEG(raster, nbands[], quality)**

- **ST_AsPNG(raster, nbands[], compression)**
What You Can Do Now?
Do raster/vector analysis...

• Extract ground elevation values for lidar points…
  - SELECT lidarPtID, ST_Value(rast, geom) elevation
    FROM lidar, srtm WHERE ST_Intersects(geom, rast)

• Intersect a road network and extract elevation values for each road segment
  - SELECT roadID,
    (ST_Intersection(geom, rast)).geom road, (ST_Intersection(geom, rast)).val elevation
    FROM roadNetwork, srtm WHERE ST_Intersects(geom, rast)
What You Can Do Now?
Do raster/vector analysis...

- Compute the mean temperature around a series of point

  1. CREATE TABLE pointBuffers AS
     SELECT pointID, ST_Buffer(geom, 200) FROM pointTable
  2. SELECT pointID, (gv).geom pointBuffer, (gv).val temp
     FROM (SELECT pointID, ST_Intersection(geom, rast) gv
          FROM pointBuffers, temperature
          WHERE ST_Intersects(geom, rast)

- Results must be summarized per buffer afterward
- All analysis functions take nodata values into account
- See the tutorial in the wiki
What You Can Do Now?
Create a high resolution analysis grid for a large area…

Compute the quantities of many variables for each raster cell

- Road length, mean temperature, population, water surface, river length, Etc…
- Easy in vector mode (1 cell = 1 polygon) but what about all of France at 10m?
  
  \[100\,000 \times 100\,000\]
  
  =
  
  way too many polygons!

- Manageable in raster format!
  1. Intersect your layers with an index raster
  2. Summarize per pixel
  3. Assign results to new bands
What You Can Do Now?
Create a specialised web or desktop GIS application…

• With the raster API, PostGIS is now a very complete SQL GIS
  - All data are implicitly tiled and spatially indexed
  - No need to write complex C,C++, Python or JAVA code to manipulate complex geographical datasets.
  - Use SQL: The most used, most easy and most minimalist though complete language to work with data in general. Easily extensible (PL/pgSQL)
  - Keep the processes close to the data where the data should be: in a database!

• Lightweight multi-users specialized desktop and web GIS applications
  - All the (geo)processing is done in the database
  - Applications become simple SQL query builders and data (results) viewers
What You Can Do Now?
Implement a WPS server raster/vector geoprocessor...

Desktop or Web
WPS Client

WPS query
WPS answer

WPS Server

SQL

PostGIS
(geoprocessing)

table, vector, raster
What You Can Do Now?
Develop new raster processing functions…

- **ST_MakeEmptyRaster()**
- **ST_AddBand()**
  - Empty band or copy a band from another raster
- **All georeference setters**
  - ST_SetScale(), ST_SetSkew(), ST_SetUpperLeft(), ST_SetGeoReference()
- **ST_SetBandNodataValue**
- **ST_SetValue()**
- **Coordinates transformation helpers**
  - ST_World2RasterCoordX(), ST_World2RasterCoordY(),
    ST_Raster2WorldCoordX(), ST_Raster2WorldCoordY()
- **ST_Intersection() & ST_intersects()**
  - To interact with vector data
- Many more…
What You Can Do Now?
Develop new raster processing functions…

• PL/pgSQL example for `ST_DeleteBand`

```sql
CREATE OR REPLACE FUNCTION ST_DeleteBand(rast raster, band int)
RETURNS raster AS $$
DECLARE
    numband int := ST_NumBands(rast);
    newrast raster := ST_MakeEmptyRaster(rast);
BEGIN
    FOR b IN 1..numband LOOP
        IF b != band THEN
            newrast := ST_AddBand(newrast, rast, b, NULL);
        END IF;
    END LOOP;
    RETURN newrast;
END; $$ LANGUAGE 'plpgsql';
```
Performance?

- Import of **900MB** of uncompressed 16BSI GeoTIFF SRTM
  - 13 SRTM files
  - tiled to 48373 100x100 pixels tiles: 3 minutes
  - tiled to 525213 30x30 pixels tiles: 6 minutes

- **ST_Intersection()** of **814 buffers** with the 30x30 900 MB SRTM coverage
  - 4 minutes

- **ST_Intersection()** of **100 000 lines** with a **300 MB landsat image**
  - 8 minutes
Comparison with Oracle GeoRaster

Oracle GeoRaster

• Stored as a one to many relation between two types, in two different tables
  - SDO_GEORASTER (raster)
  - SDO_RASTER (tile)
  - Only SDO_RASTER is georeferenced
• Supports (too) many raster features for any kind of raster application
  - bitmap mask, two compression schemes, three interleaving types, multiple dimensions, embedded metadata (colour table, statistics, etc…), lots of unimplemented features
• Hard to load data
• Designed for raster storage

PostGIS Raster

• Stored as a unique type, in one table
  - RASTER (or tile)
  - Each raster is georeferenced
• Supports the minimal set of characteristics for the geospatial industry
  - georeference, multiband, tiling, pyramids, nodata values
• Easy to load data
• Designed for raster/vector analysis
What You Can Do Soon?
Write to PostGIS raster with GDAL…

• A write GDAL driver do not exist yet.

• It should allows
  - loading raster in the database using `gdal_translate`
  - loading many raster at the same time
  - any application writing to GDAL to write to PostGIS raster
  - tiling a raster to any tile size
  - to create overviews
What You Can Do Soon?
Convert geometries to raster…
Resample/retile a raster coverage…

• **ST_AsRaster**(geometry)
  - Alignment and pixelsize can be determined from:
    1. Parameters
    2. The extent of the geometry
    3. The first encountered segment length
       (to quickly rasterize previously vectorized rasters)
    4. A provided existing raster

• **ST_Resample**(raster)
  - Only realign
  - Resample and realign
  - From parameters or an existing raster

• **ST_Intersection**(raster, raster) -> raster
  - Equivalent to **ST_Clip**(raster, **ST_AsRaster**(geometry))
  - Useful for retiling an existing coverage to a new one
What You Can Do Soon?
Complex MapAlgebra analyses...

- Already available: One raster version of ST_MapAlgebra()
- Soon: Faster user-defined function version
  - Function taking a pixel value and some parameters and returning a computed value
  
  CREATE FUNCTION polynomial(x float, VARIADIC args TEXT[])

  RETURNS FLOAT AS $$
  DECLARE
    m FLOAT;
    b FLOAT;
  BEGIN
    m := args[1]::FLOAT;
    b := args[2]::FLOAT;
    return m * x + b;
  END; $$ LANGUAGE 'plpgsql';

  SELECT ST_MapAlgebra(raster, 'polynomial', ARRAY['1.34', '5.2'])
What You Can Do Soon?
Complex MapAlgebra analyses...

• One raster neighbor version
  - User function taking a 3x3, 5x5, 7x7, or more raster and optional parameters and returning a value
  - Useful to implement any focal function (“moving window”)
  - Possibility to pass the name of a coverage where to get out-of-bound pixel values

• Two rasters version
  - SELECT ST_MapAlgebra(elev1.rast, elev2.rast, 'rast1 + rast2) / 2', '32BF', 'INTERSECTION')
    FROM elev1, elev2 WHERE ST_Intersects(elev1.rast, elev2.rast)
  - Useful to implement most overlay functions and more
    - ST_Union(raster, raster) -> raster
    - ST_Intersection(raster, raster) -> raster
    - ST_BurnToRaster(raster, geometry, value)...
  - Resample/realign on the fly. Takes care of nodata values.
  - Resulting extent can be FIRST, SECOND, UNION or INTERSECTION.
What You Can Do Soon?
Aggregate many tiles into one raster… (or merge)

• Use ST_Union as an aggregate function
  - Taking a state, a temporary and a final function specifying how to aggregate pixel values in a state, a temporary and a final raster
  - User can defines their own expressions or use predefined functions like FIRST, LAST, MIN, MAX, SUM, MEAN, COUNT

• Ex. SELECT ST_Union(raster, 'MEAN')
  - Compute the mean pixel value of many overlapping pixels
  - The state function 'SUM' accumulate pixel values
  - The temporary function 'COUNT' count the number of pixels
  - The final function 'state raster/temporary raster' divide the sum by the count
  - See pl/pgsql code in raster/script/plpgsql/st_union.sql
What You Can Do (maybe not too) Soon?
Interpolate a raster coverage from a point coverage...

- **ST_Interpolate**(pts geometry)
  - Should be an aggregate returning one raster (or a set of tiles)
  - Implementing many different interpolation algorythms
    - Nearest neighbor, linear, polynomial
  - Very useful to convert lidar data to raster

- **ST_AsDensity**(geometry)
  - Count the number of features touching each pixel and then smooth the surface using a moving window (neighbor map algebra)
What You Can Do (maybe not too) Soon?
Create a clean raster coverage... from a messy one...

1. Load a bunch of **unaligned overlapping** rasters (e.g. landsat)

2. **ST_SetBrightness() & ST_SetContrast()**
   - or **ST_NormalizeColor('table', 'rasterColumn')**

3. **ST_MakeEmptyRasterCoverage()**
   - Create a vector grid or an empty raster coverage based on a set of parameters

4. **ST_MapAlgebra(emptyRaster, messyRaster, 'MEAN', 'FIRST')** -> raster
What You Can Do (maybe not too) Soon?
Recognize forms from images stored in the DB…

• And **automatically** convert them to **geometries**
• Need more research…
Summary

- **PostGIS Raster is multiband, tiled, multiresolution**
  - Each band supports one nodata value, one pixel type.
  - One row = one raster, one table = one coverage.
  - Supports many tile arrangement.
  - Very much like a vector coverage.
  - Import is done the same way as usual with PostGIS: raster2pgsql

- **There are plenty of functions to…**
  - manipulate,
  - edit,
  - do raster and raster/vector analysis,
  - get raster statistics,
  - create new rasters
  - Write web and desktop applications in a client-server context
Thanks!

http://trac.osgeo.org/postgis/wiki/WKTRaster