Open Source, Scale and Reproducibility Using GIS: Discovering the World Beyond Point-and-Click and ArcGIS

Ömer Özak

Dept. Economics, SMU

Here's How I Do GIS

October 13, 2016

The Voyage of Homo-œconomicus into GIS

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Homo-œconomicus...or Economic Man

" the concept in many economic theories portraying humans as consistently rational and narrowly self-interested agents who usually pursue their subjectively-defined ends optimally."

Plan for today

1. The Big Bang
2. The Dark Ages
3. The Age of Discovery
4. The Modern Era
5. The Future
6. Q&A

Why GIS?

The question that started it all

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  - How to measure?
  - Measure for Pre-industrial era
  - Changes due to technology

Why a New Measure?

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- Common approach: Geodesic distances

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Country 1	Country 2	Distance	Country 1	Country 2	Distance
Costa Rica	Panama	514.3561	Germany	Poland	515.774
Phillipines	Brunei	1262.339	Yemen	Sudan	1254.947
Irak	Romania	2002.218	Ghana	Gambia	2002.745

Proposed Solution

Construct a measure that

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- Controls for

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Solution: The Voyage of Homo-œconomicus

Combine data on

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- Infantry movement

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- Human Mobility Index with Seafaring pre-steam engine (HMIOcean)

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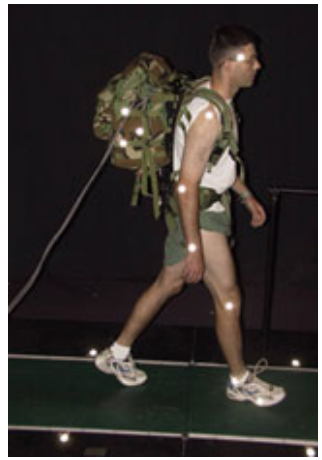

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- Historical data on seafaring in Old World (pre-1500CE) (Casson, 1951, 1989)
- Historical data on seafaring (pre-steam engine) (García-Herrera, Können, Wheeler, Prieto, Jones, and Koek, 2005)

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  - 200+ countries

Homo-œconomicus meets GIS

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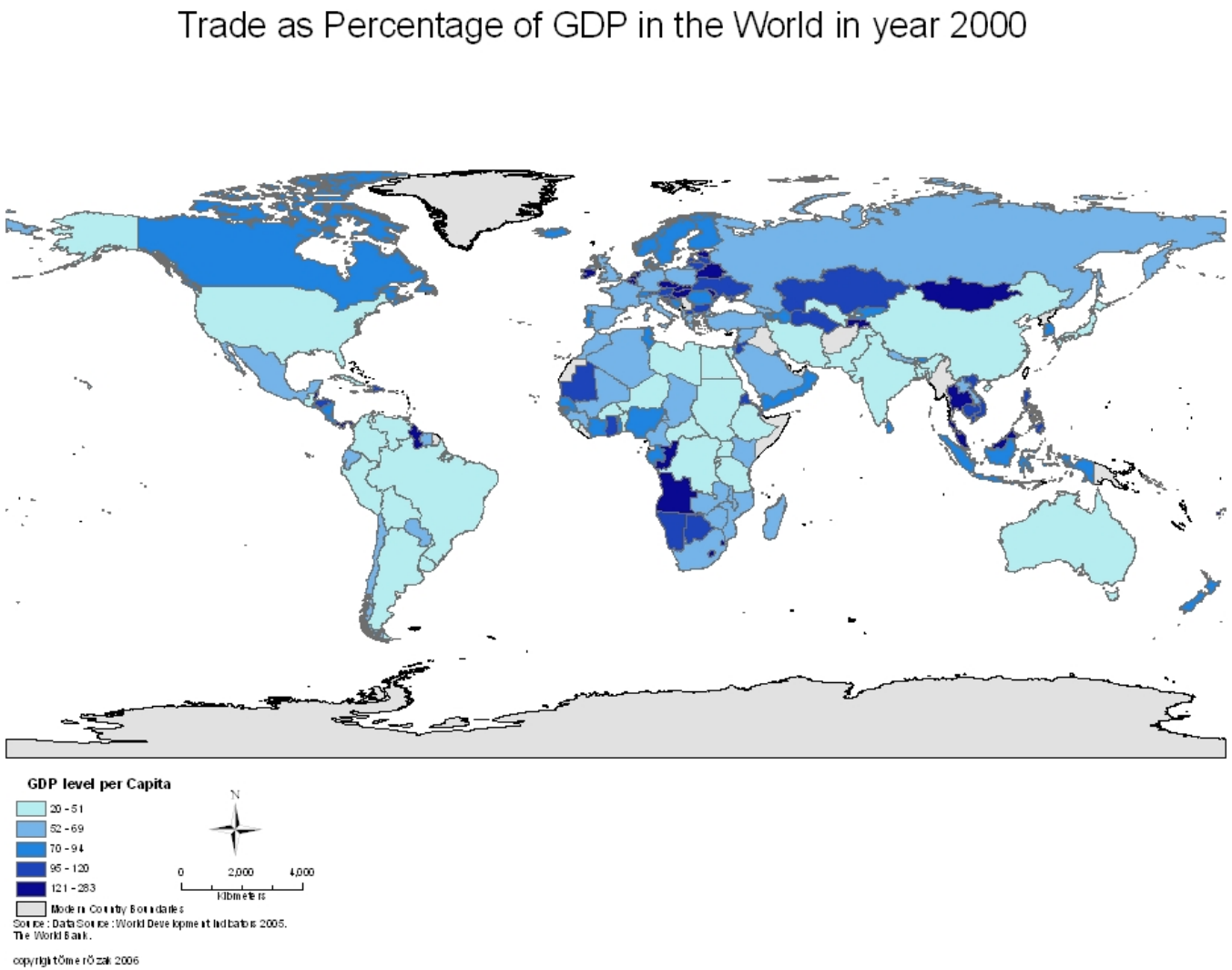
  - Some spatial stats (compute Moran I & II)

Trade as share of GDP



Homo-œconomicus meets GIS

Seems easy & straightforward...Thesis's gonna be ready in 2 weeks!

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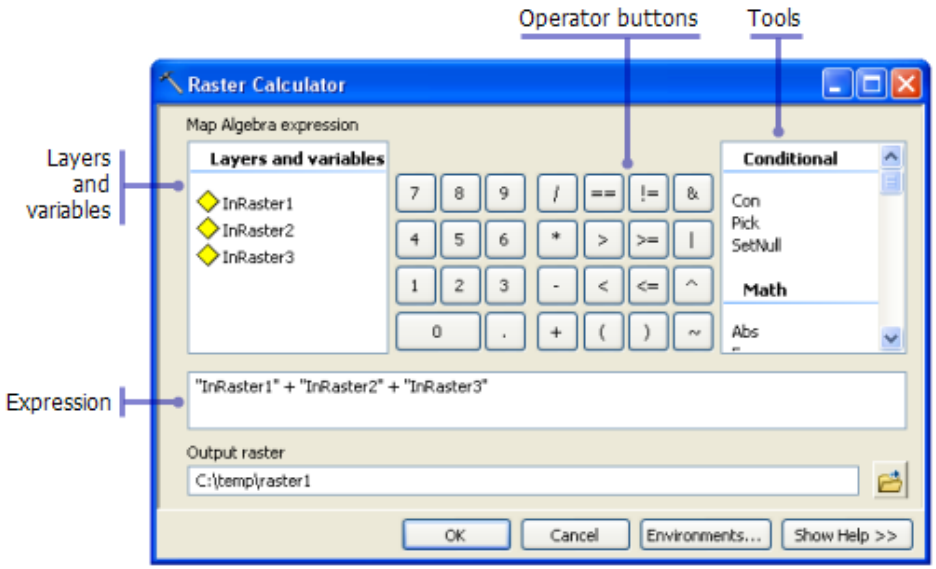
- Shapefile $\Longrightarrow$ points, lines, polygons, etc.

Point-and-click and more in ArcGIS

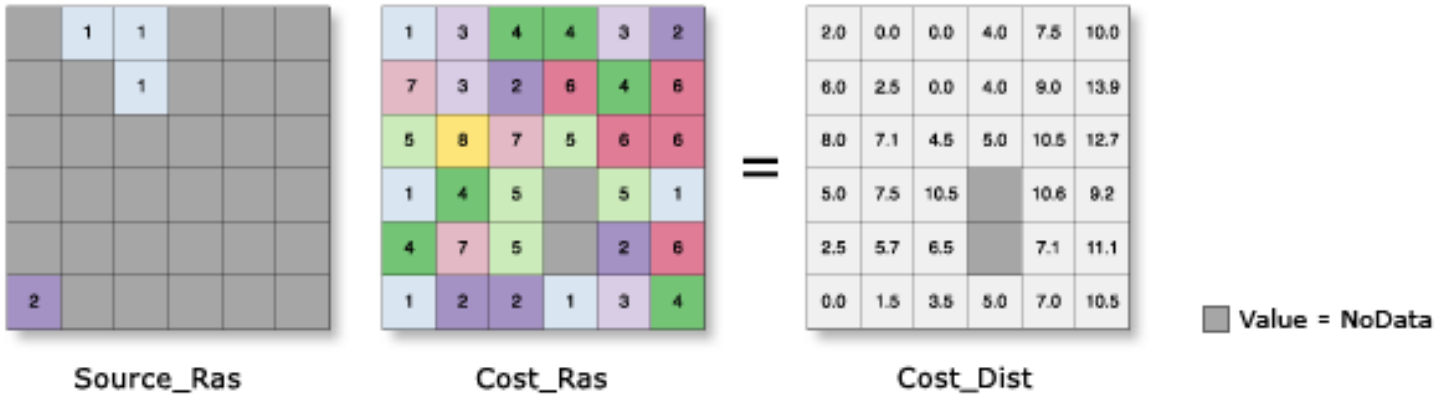
To solve my problem I need more tools...

- Raster Calculator



Point-and-click and more in ArcGIS

- Cost Distance Function



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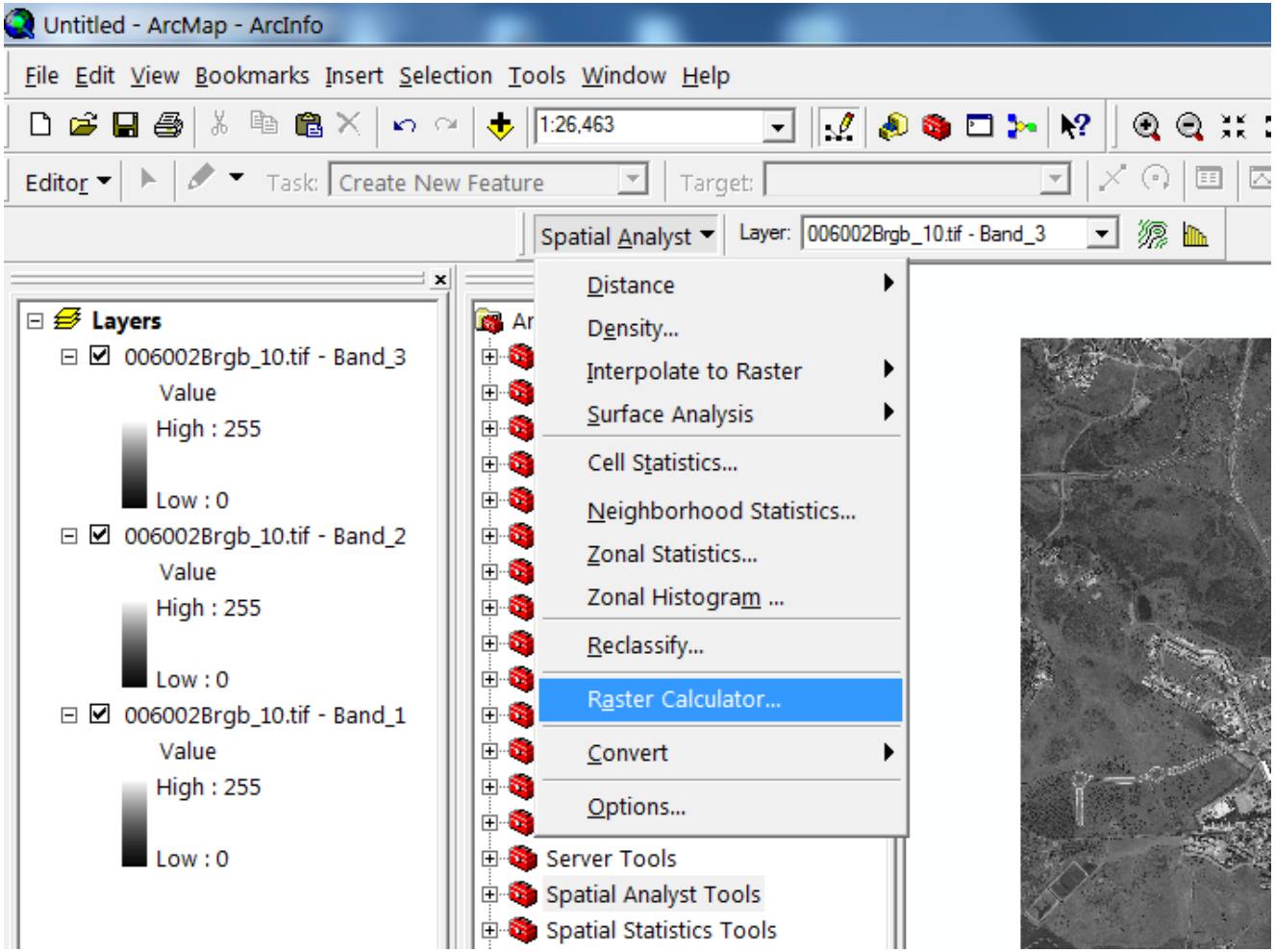
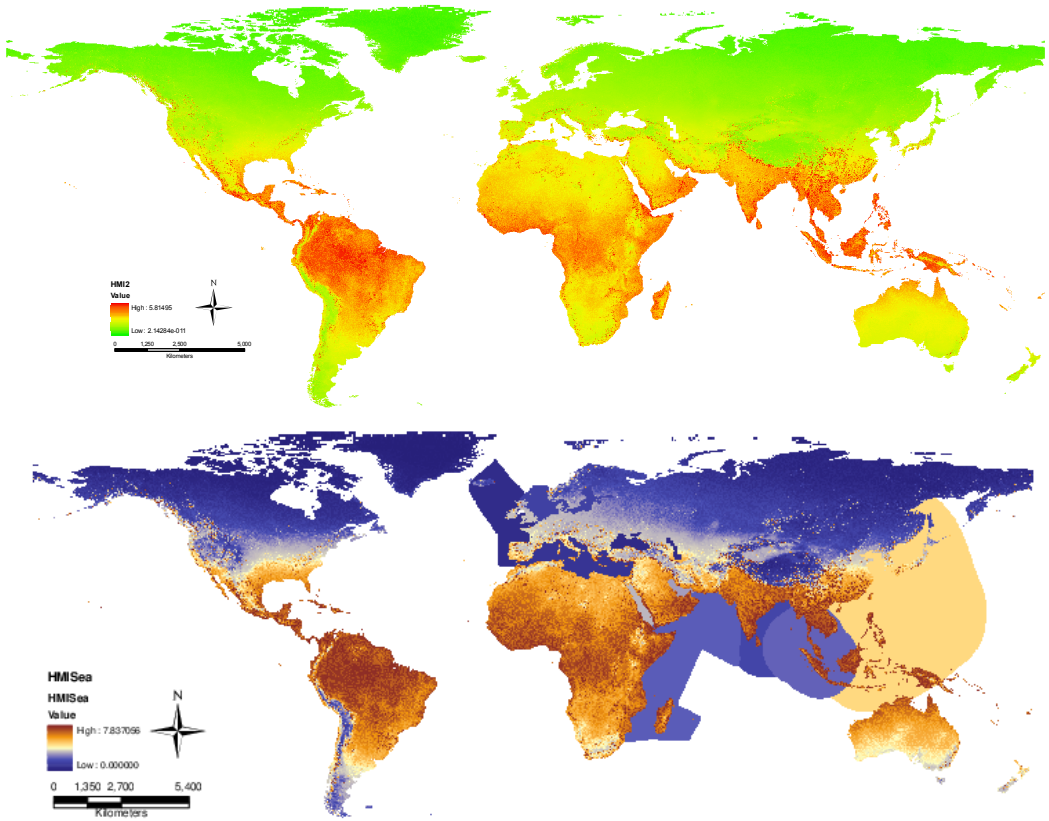
  - Get access to 1 computer...

Produce Raster in ArcGIS

- Construct HMI data



HMI & HMISea


HMI2
Value
High : 5.81495
Low : 2.14284e-011
0 1,250 2,500 5,000
Kilometers
N
HMISea
HMISea
Value
High : 7.837096
Low : 0.000000
0 1,350 2,700 5,400
Kilometers
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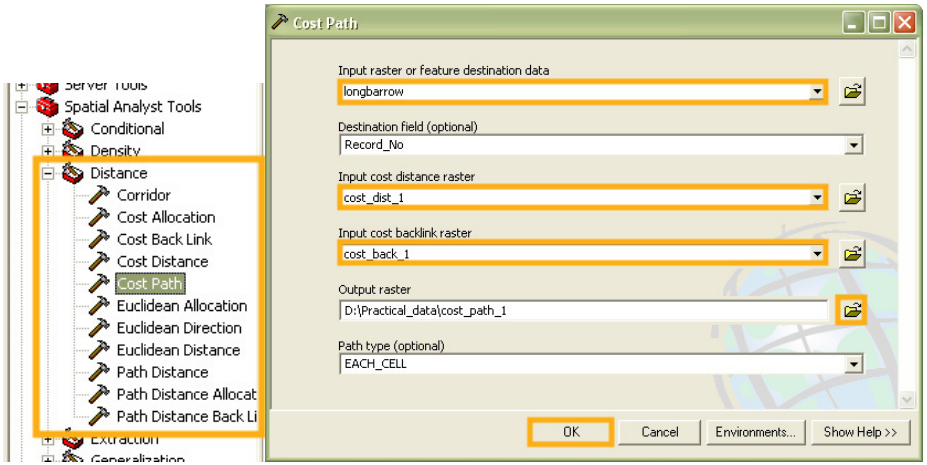
ArcGIS headache II

- Construct Optimal Routes and Times



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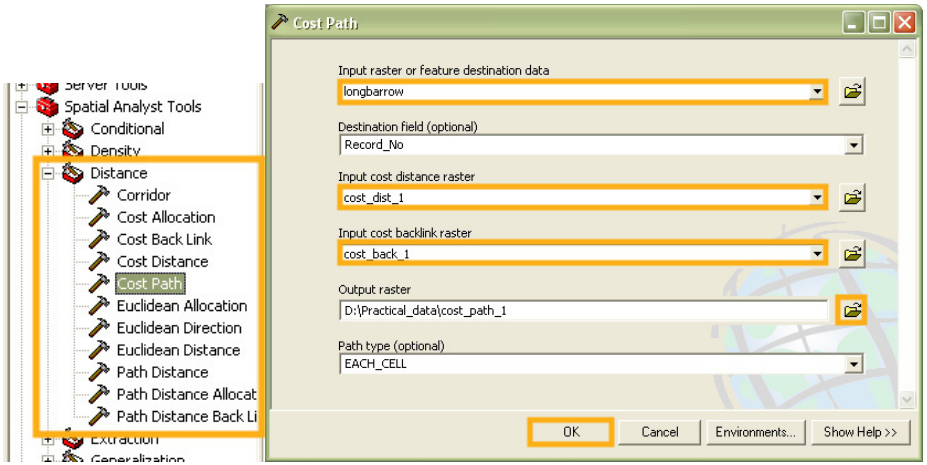

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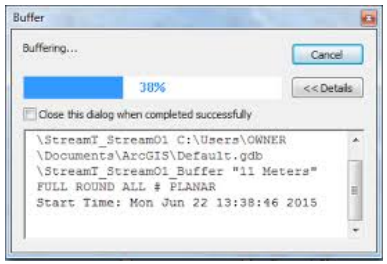

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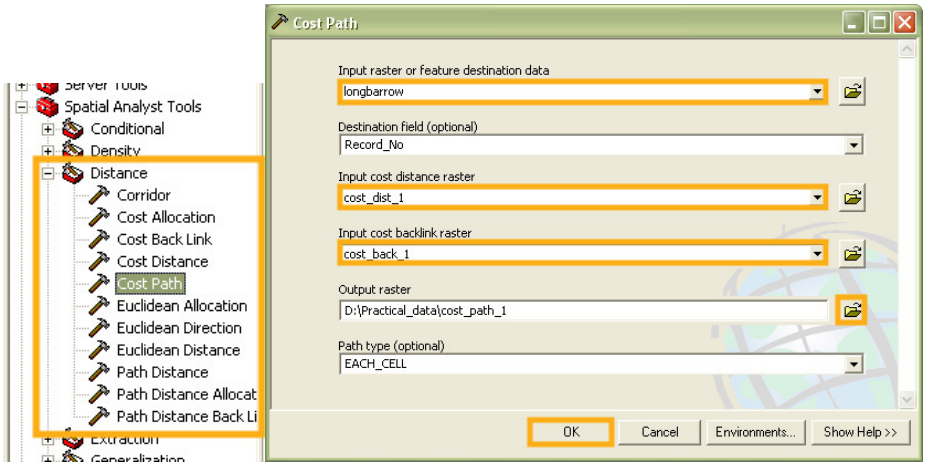

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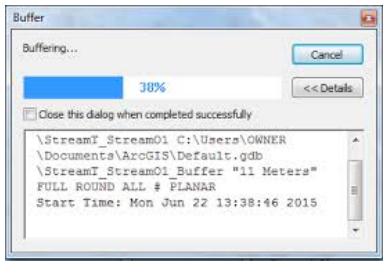

$\Longrightarrow$ $>$ 1 year to compute data!!!

Solution...Parallelize!

- Find multiple computers and **repeat exact same** process for different sources

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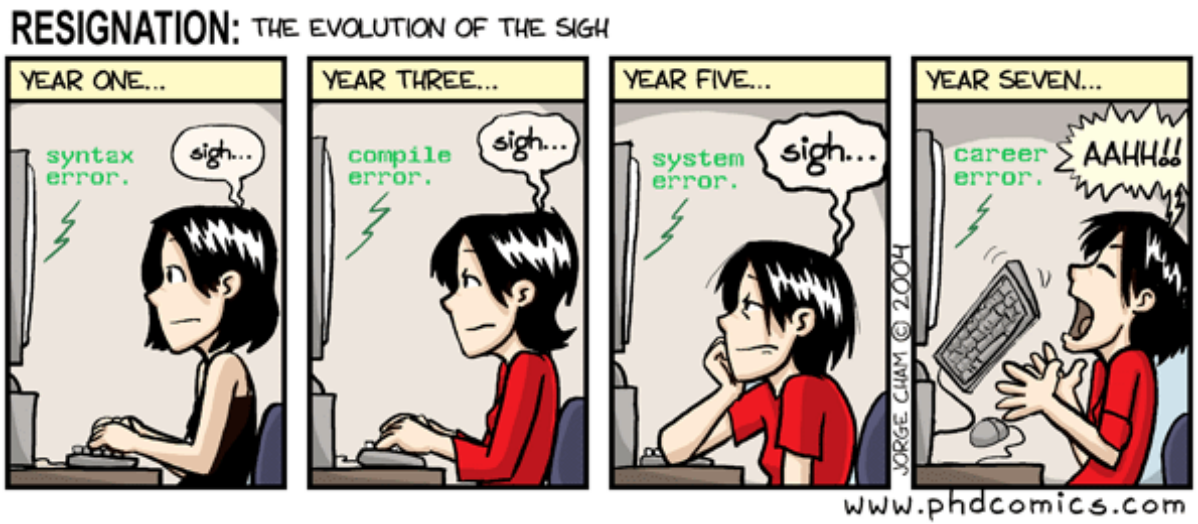
- Need scripting...still slow in ArcGIS!

OMG...Now what???!!!


HOW'S THE DEBUGGING GOING?
JORGE CHAM © 2005
www.phdcomics.com


RESIGNATION: THE EVOLUTION OF THE SIGH
YEAR ONE...
syntax error.
sigh...
YEAR THREE...
compile error.
sigh...
YEAR FIVE...
system error.
sigh...
YEAR SEVEN...
career error.
AAHH!!
JORGE CHAM © 2004
www.phdcomics.com

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$\Longrightarrow$ Time to try something different

Can I overcome disadvantages?

Free Point-and-click solutions

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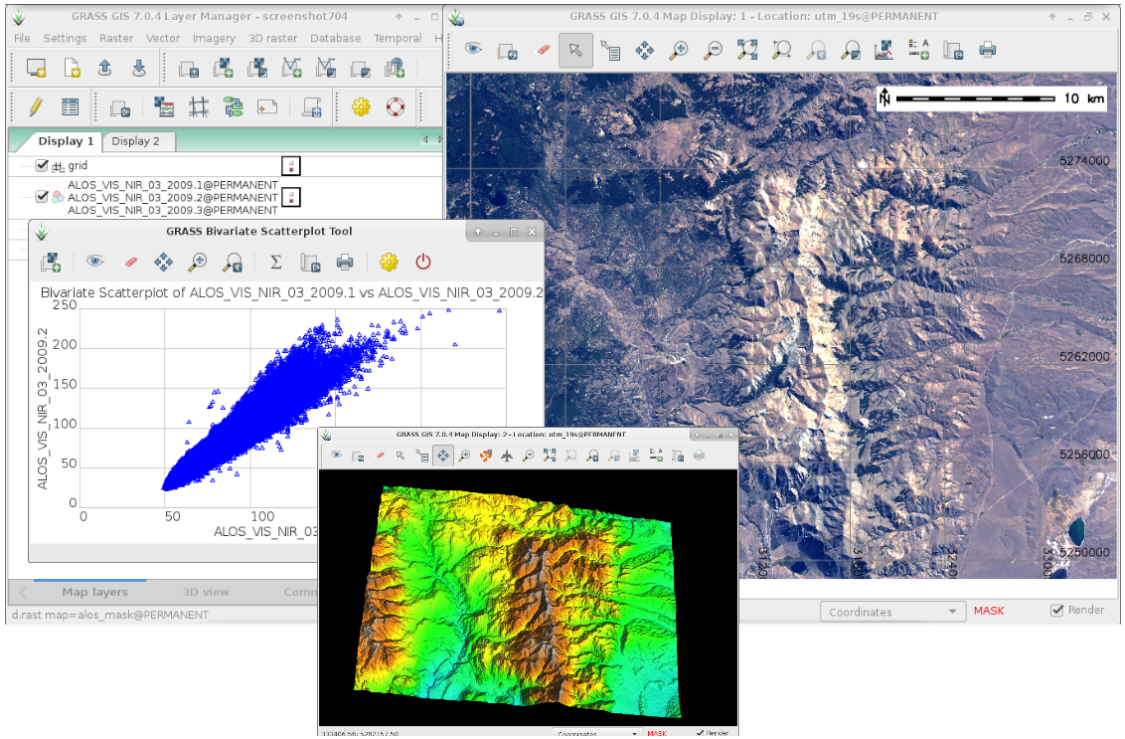

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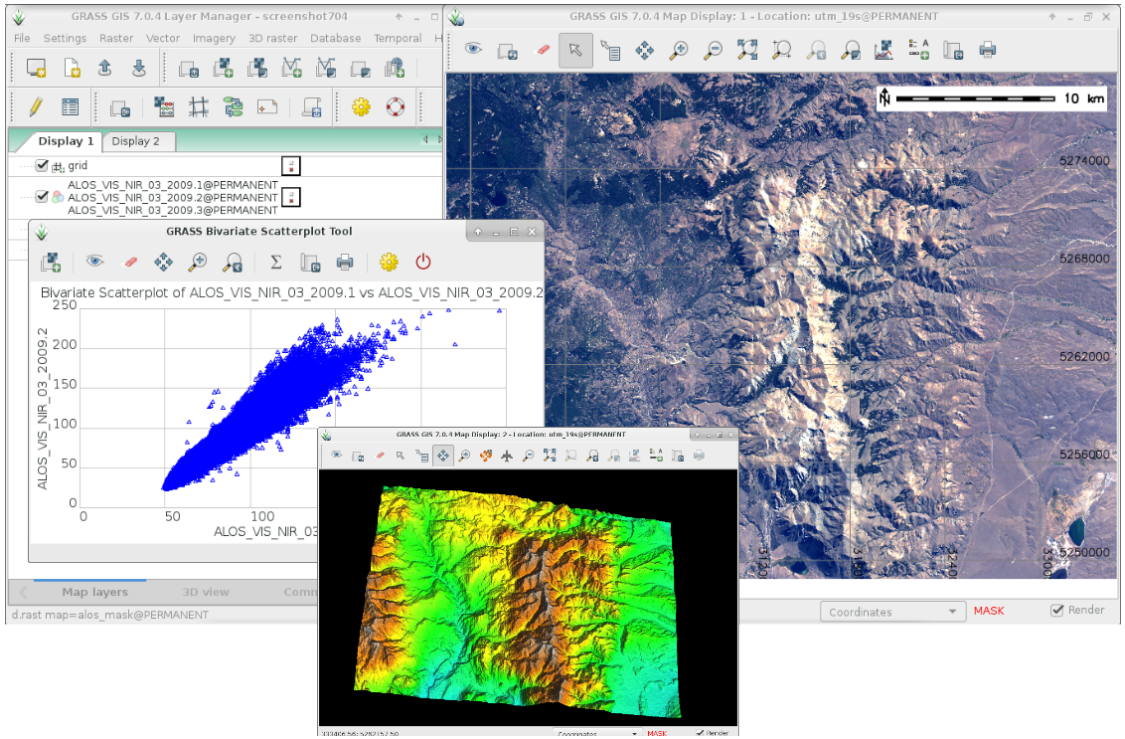

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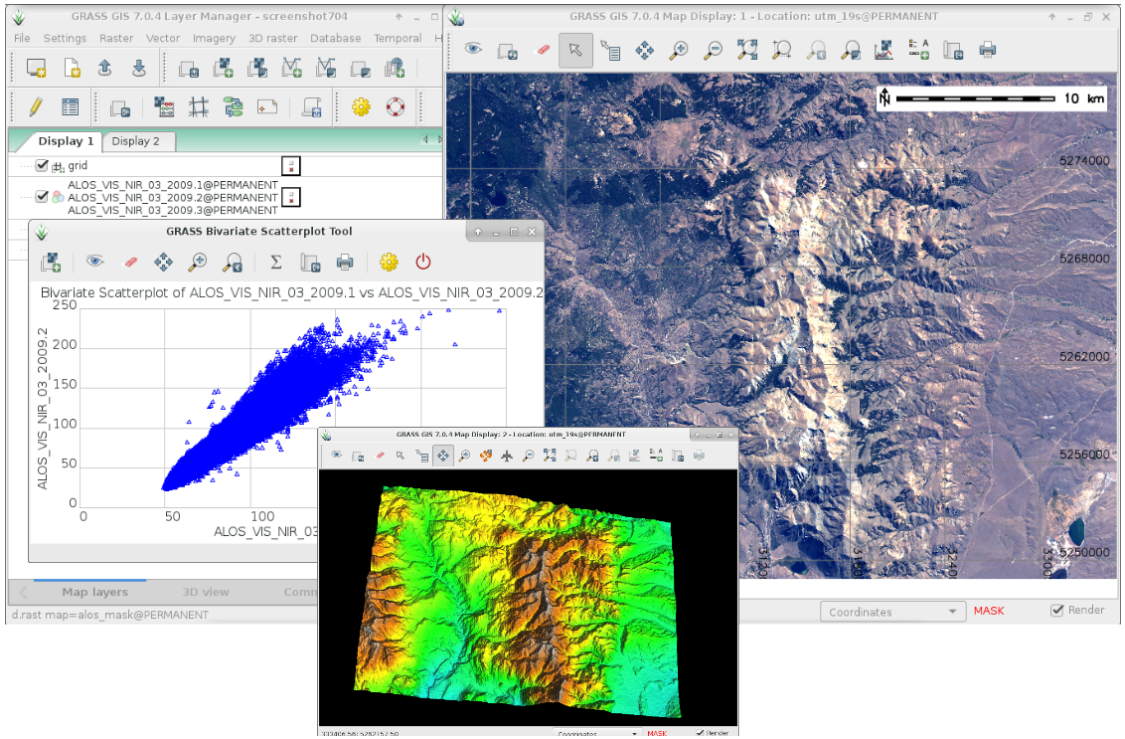

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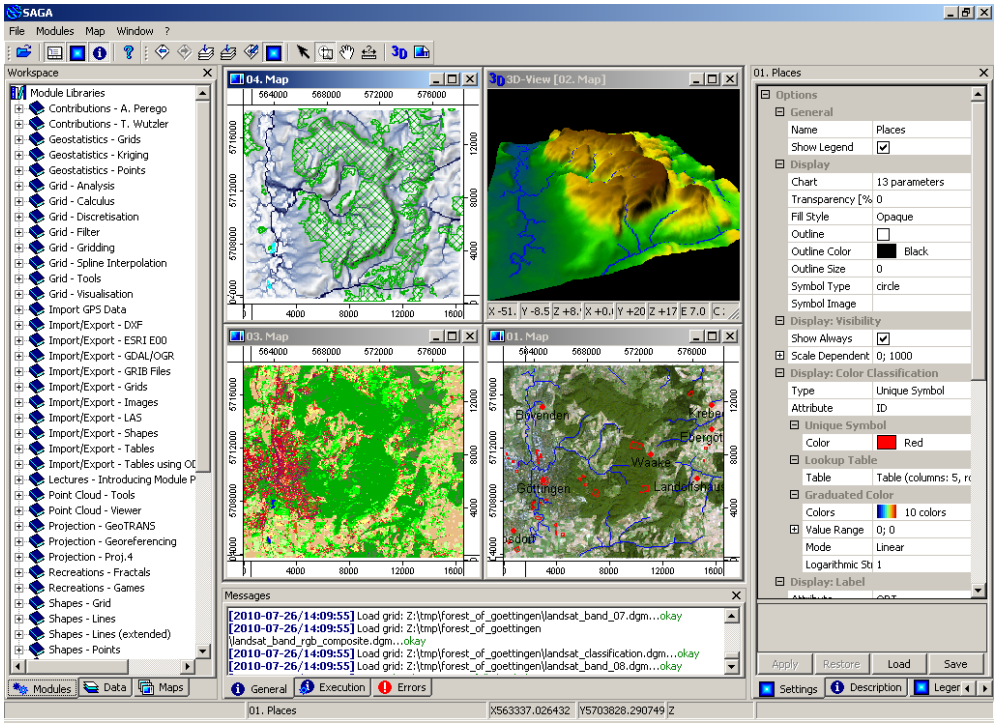

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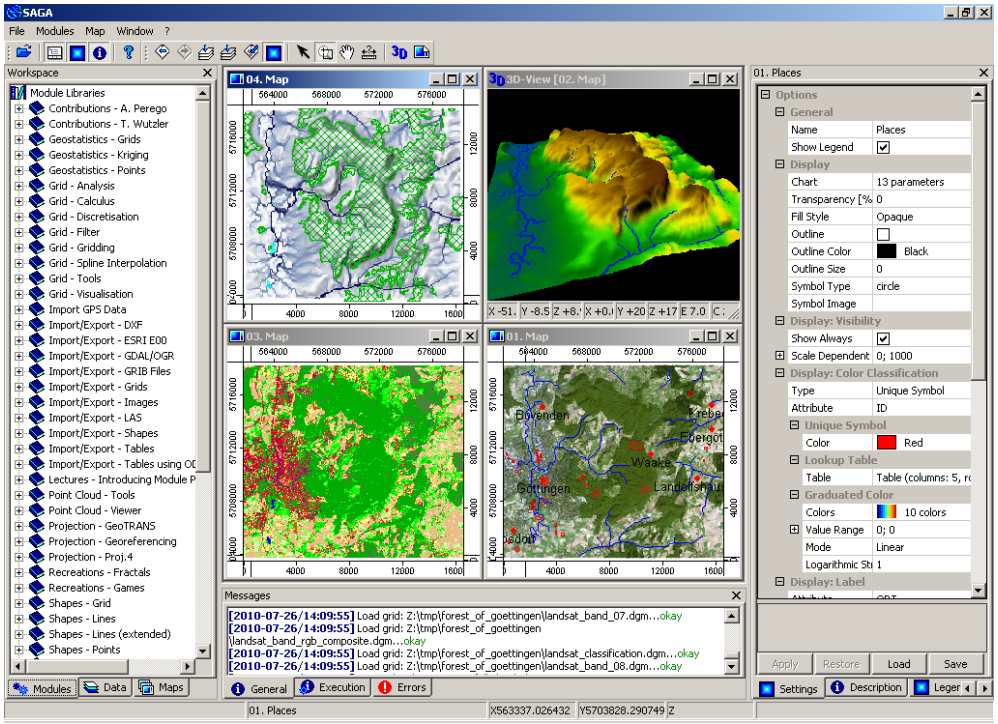

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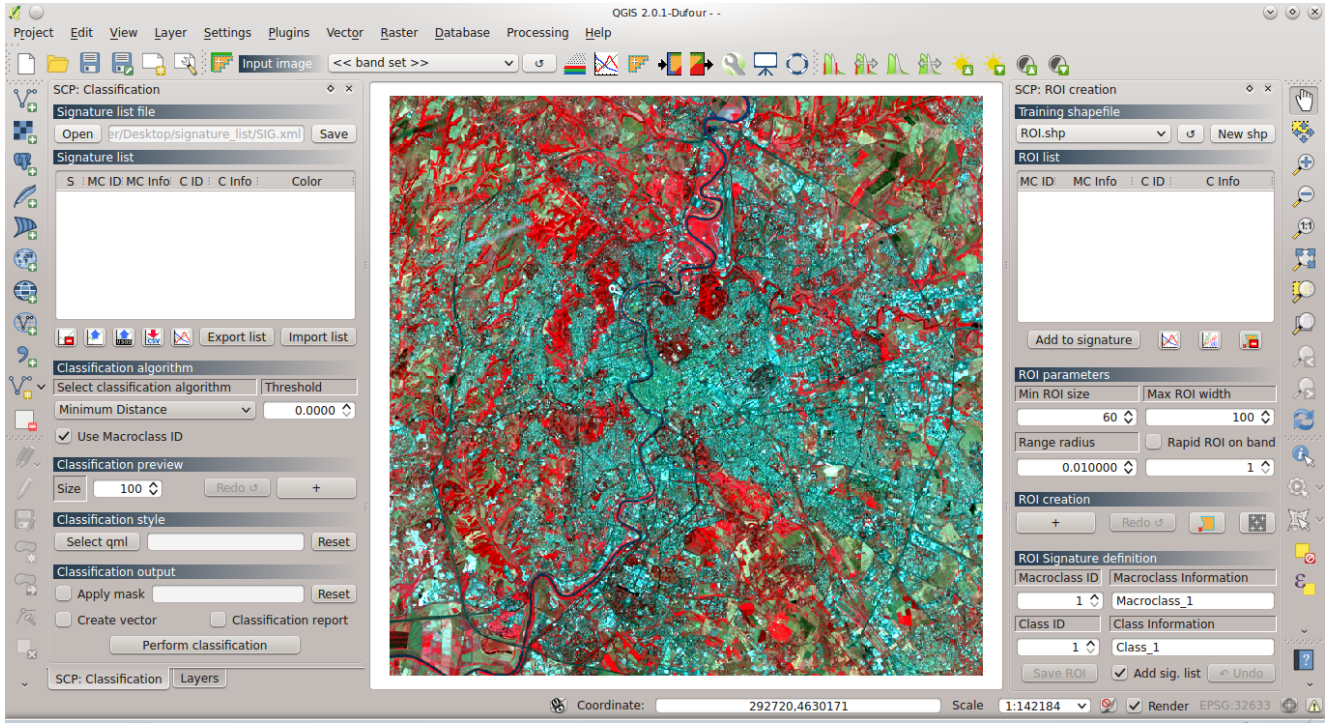

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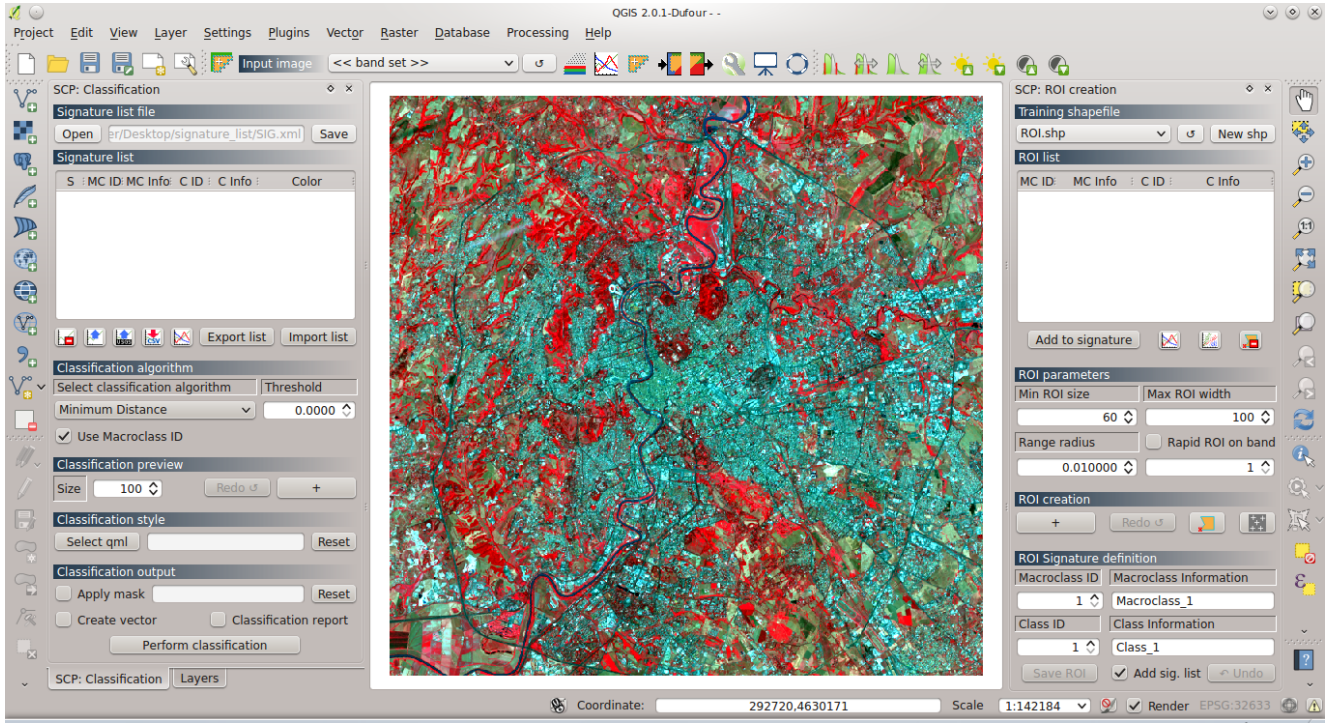

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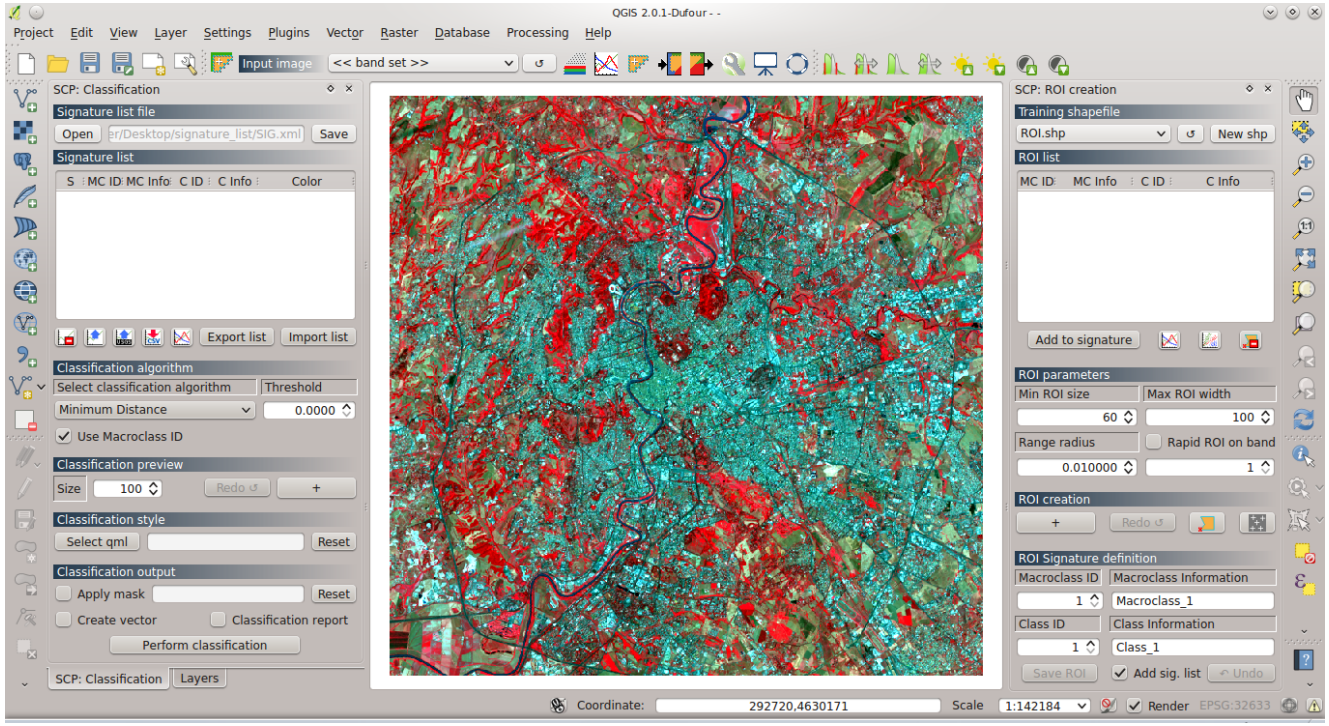

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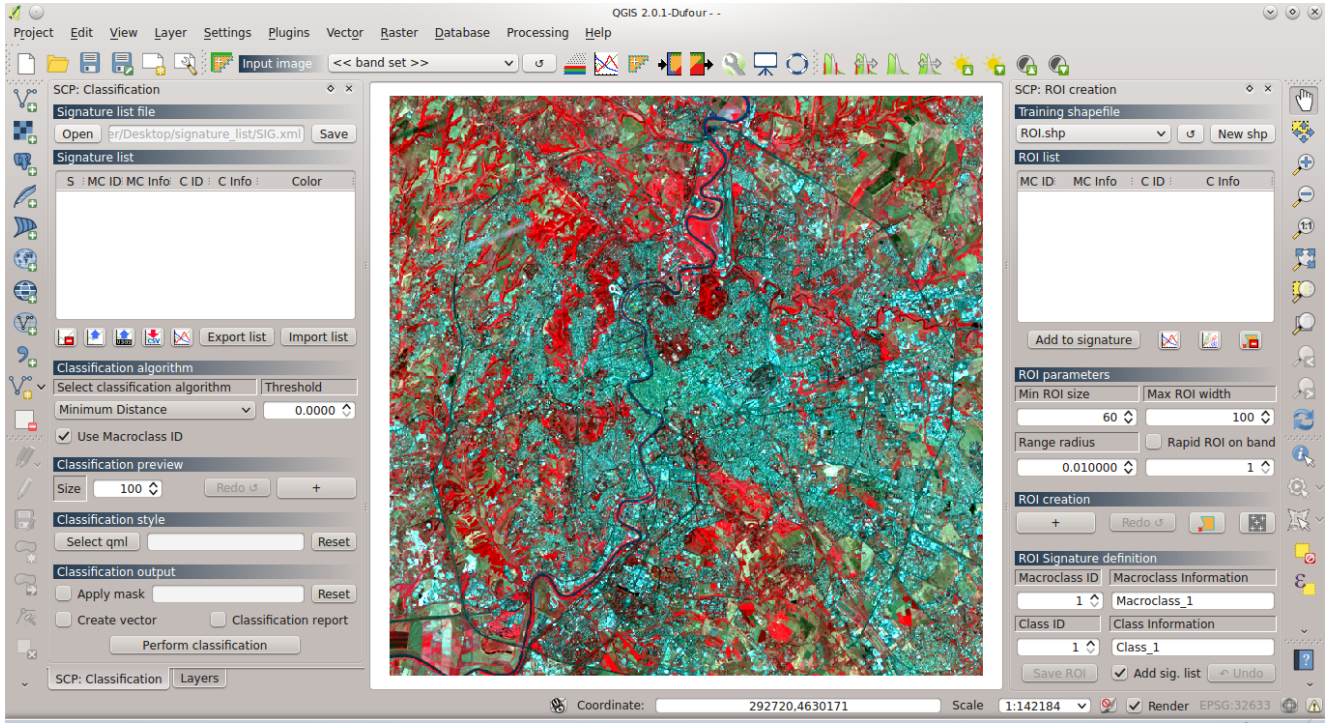

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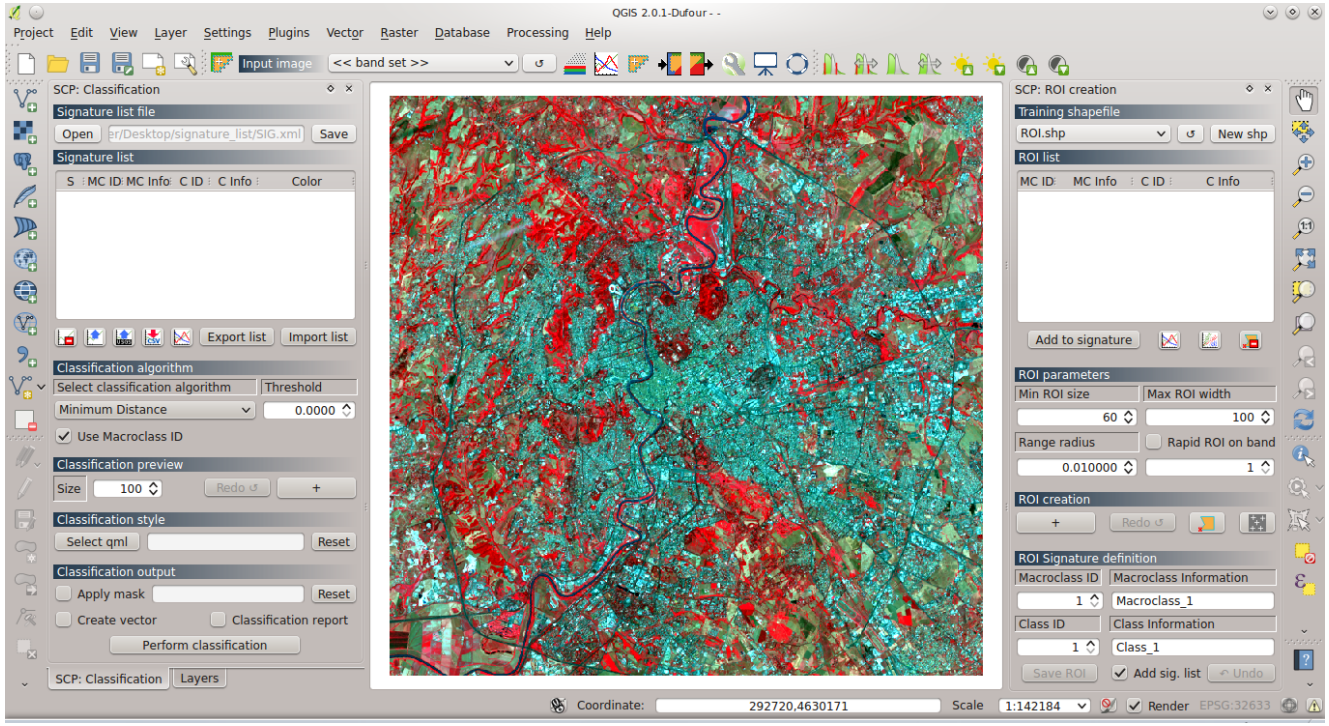

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  - Change code
  - Propose plug-ins, features, etc.

How I Learned to Stop Clicking and Love the Code

Finally started using

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- General Purpose Programming Language
  - Open source
  - Easy to learn and code
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IP[y]: IPython
Interactive Computing

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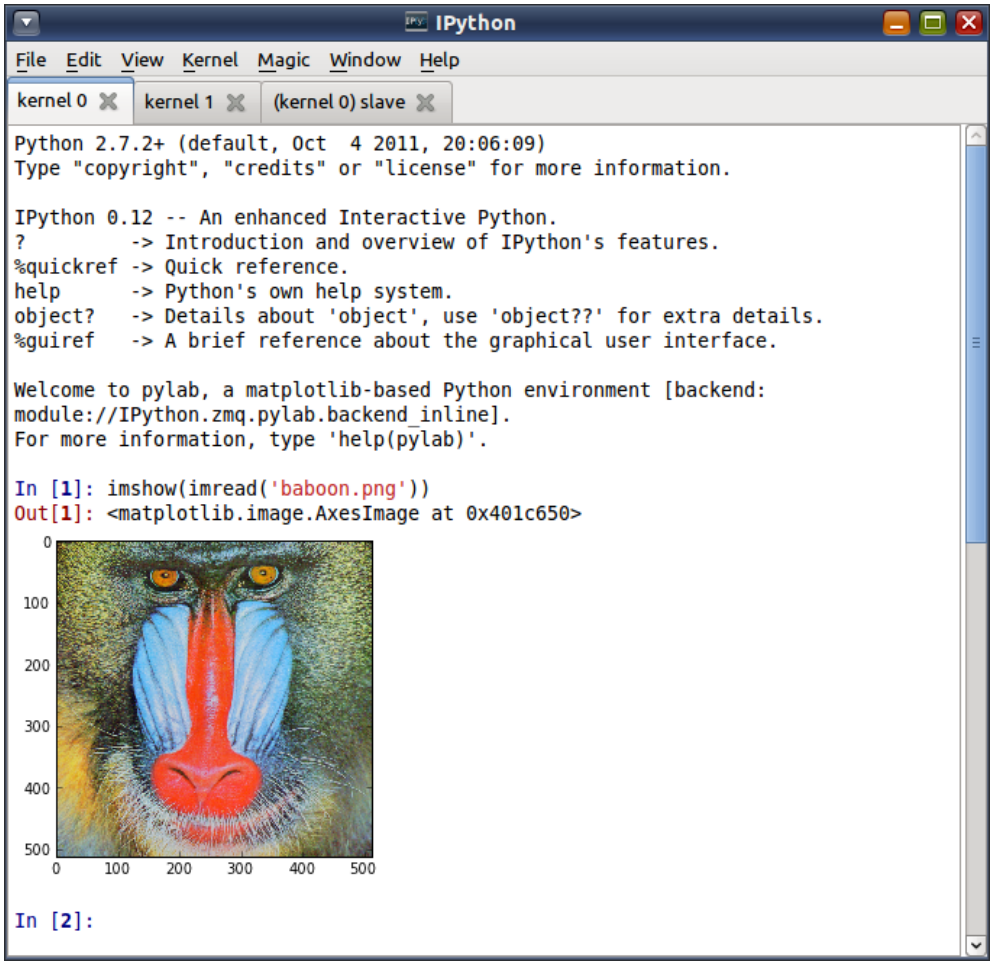
IP[y]: IPython
Interactive Computing

- Terminal/Command Line

```
Python 2.7.3 (default, Jul 10 2012, 18:48:25)
Type "copyright", "credits" or "license" for more information.

IPython 0.13.1 -- An enhanced Interactive Python.
?         -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help      -> Python's own help system.
object?   -> Details about 'object', use 'object??' for extra details.

In [1]: import numpy as np

In [2]: N = 3000

In [3]: a = np.random.randn(N,N)

In [4]: b = np.random.randn(N,N)

In [5]: np.do
np.dot     np.double

In [5]: np.dot(a, b)
Out[5]:
array([[  65.45670109,   64.96918252, -120.2955101 , ...,   46.52919413,
           1.62384273, -117.27453077],
       [ 103.8332094 ,  -63.19741333,   25.63850851, ...,   10.43730591,
         -98.22728902,   -9.16795735],
       [ -36.45095805,   44.32128353,  -17.58969917, ..., -125.12907291,
         -70.58206964,  -32.85757429],
       ...,
       [ -42.46168724,   36.45522834,   28.8765628 , ...,   39.40943867,
         -16.43199427,  -63.08194364],
       [ -84.46717927,   28.06738004,   32.09026395, ...,  -42.127647  ,
        -116.20291034,   32.02266909],
       [  56.79843374,   23.60837948,   52.24793136, ...,  -35.53881726,
         -21.19119431, -151.71414646]])

In [6]: %timeit np.dot(a,b)
1 loops, best of 3: 2.17 s per loop

In [7]: np.
Display all 551 possibilities? (y or n)
np.ALLOW_THREADS          np.convolve               np.iscomplex              np.ravel
np.BUFSIZE                np.copy                   np.iscomplexobj           np.ravel_multi_index
```

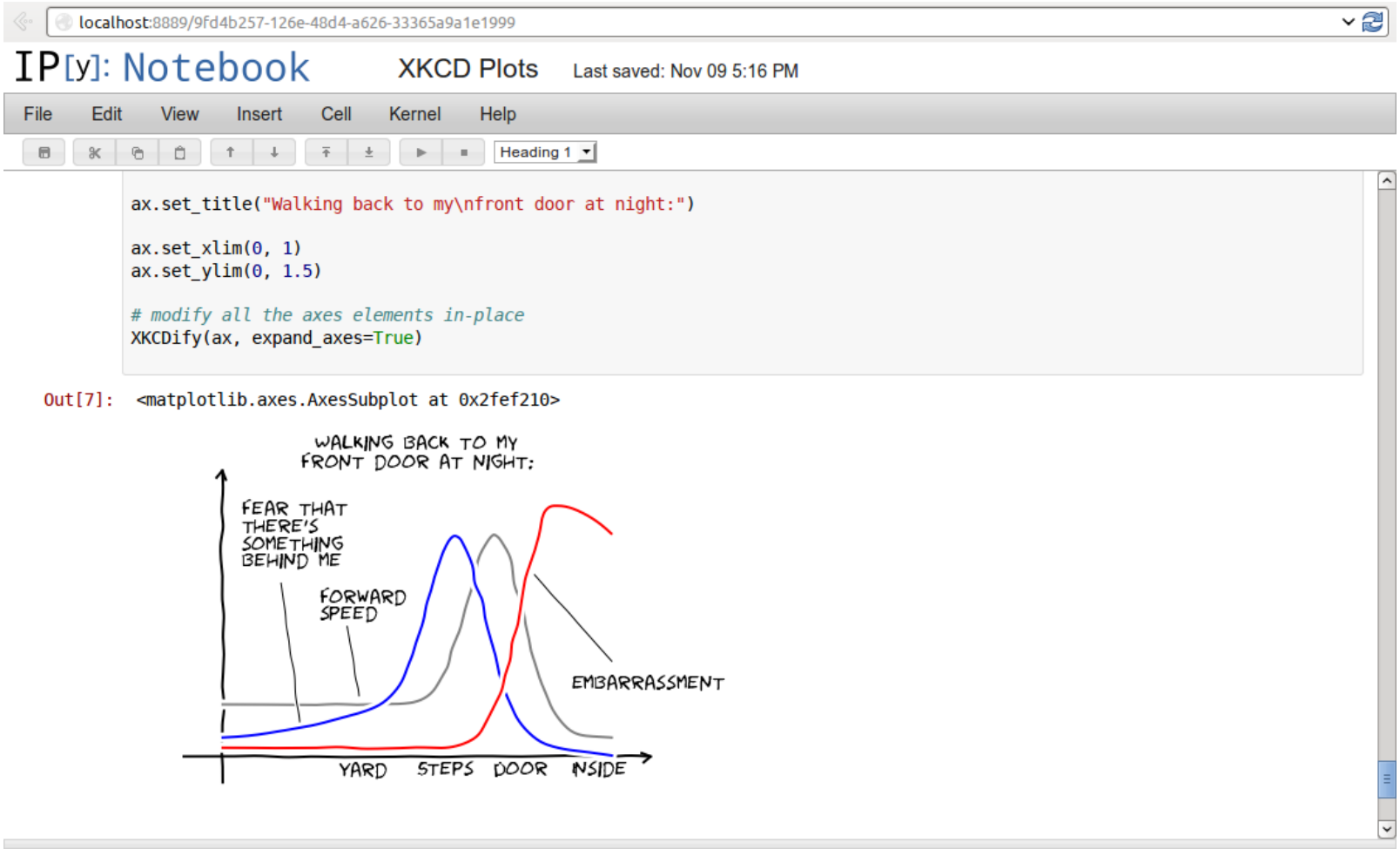
IP[y]: IPython
Interactive Computing

- QtConsole



IP[y]: IPython
Interactive Computing

- Notebook (Web Application)



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- Use multiple language simultaneously (e.g. Python & R)

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$\Longrightarrow$ Scary!

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- Get results and analyze in Stata (soon to be replaced by R o StatsModels)

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- Write & Test Code using IPython QtConsole or Notebook
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- Get results and analyze in Stata (soon to be replaced by R o StatsModels)
- Write paper in LaTeX

Examples

- Ömer's intro to GIS with IPython

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- CSI

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- CSI
- Google Location History

Example: Compute Zonal Stats I

```
#!/usr/bin/env python
# coding: utf-8
'''
============================================================
Author:  Ömer Özak, 2014 (ozak at smu.edu)
Website: http://omerozak.com
GitHub:  https://github.com/ozak/
============================================================
Python Script Template
'''
from __future__ import division
import sys, os, time
# Math, data
import numpy as np
import pandas as pd
pd.set_option('display.width', 140)

# GIS packages
#from osgeo import  ogr, osr, gdal, gdalnumeric
#from gdalconst import *
```

Example: Compute Zonal Stats II

```
#from PIL import Image, ImageDraw
#from pyGDsandbox.dataIO import df2dbf, dbf2df
#from rasterstats import zonal_stats
#import shutil, glob
#import pysal as ps
#from pysal.contrib import shapely_ext
#import shapely
from shapely.geometry import Polygon, Point
#from shapely.wkt import loads, dumps
#from shapely.ops import cascaded_union
import pyproj
#import georasters as gr
import hmi
#import fiona
import geopandas as gp
#import geopandas.tools as gpt
#from geopandas.tools import sjoin
from geopy.distance import great_circle
import geostats

# Various other packages
```

Example: Compute Zonal Stats III

```
import isounidecode          # Decode and encode text

# Directory
try:
    %cd Islam
except:
    path = os.path.abspath(__file__)
    dir_path = os.path.dirname(path)
    os.chdir(dir_path)
    %bookmark Islam

# Buffer size in meters
buf = 50000

# Set paths
path='../../data/'
if not os.path.exists(path):
    os.mkdir(path)
pathout='../../data/GIS/Cities/'
if not os.path.exists(pathout):
    os.mkdir(pathout)
```

Example: Compute Zonal Stats IV

```
# Geographical characteristics of each Ethnicity in a Buffer of buffer kms
cities = pd.read_stata(path+'AllCities.dta')
cities['geometry'] = cities.apply(lambda x: Point(x.lon, x.lat), axis=1)
cities.drop('aaanameofcity',axis=1,inplace=True)
cities = gp.GeoDataFrame(cities, crs=geostats.wgs84)
cities['city']=cities.city.apply(lambda x: isounidecode.unidecode(x[:x.find(' (')])
cities.to_file(pathout+'AllCities.shp')
cities = cities.to_crs(geostats.cea)
cities.to_file(pathout+'AllCitiesCyl.shp')
cities.geometry = cities.geometry.buffer(buf)

# Create geostats object and compute statistics
Stats = geostats.geostats(cities)
Stats.geostats()

# Export data
Stats.df.to_csv(path+'/AllCities'+str(int(buf/1000))+'.csv', index=False)
```

Example: HMI Distances with MP I

```
# coding: utf-8
# #Import packages
'''
=====================================================
Author:  Ömer Özak, 2014 (ozak at smu.edu)
Website: http://omerozak.com
GitHub:  https://github.com/ozak/
=====================================================
Program to create HMIdata for Islam Project using MultiProcessing to accelerate comp
Michalopoulos and Özak (2016)
'''
from __future__ import division
# Parallel
from IPython.parallel import Client
## Setup the clients, direct views, and balanced views
c = Client()
c.ids
dview = c[:]
view = c.load_balanced_view()
dview.activate()
```

Example: HMI Distances with MP II

```
%%px --local
import sys, os, time
# Math, data
import numpy as np
import pandas as pd
pd.set_option('display.width', 140)
from scipy.interpolate import griddata
import scipy.interpolate as interpolate
from scipy.spatial import cKDTree as KDTree
# GIS packages
from osgeo import  ogr, osr, gdal, gdalnumeric
from gdalconst import *
from PIL import Image, ImageDraw
#from pyGDsandbox.dataIO import df2dbf, dbf2df
from rasterstats import zonal_stats
import shutil, glob
import pysal as ps
import shapely
from shapely.geometry import Polygon, Point
from shapely.wkt import loads, dumps
```

Example: HMI Distances with MP III

```
from pysal.contrib import shapely_ext
from shapely.ops import cascaded_union
import pyproj
import geopandas as gp
import georasters as gr
from geopy.distance import great_circle
import fiona
import hmi
import isounidecode          # Decode and encode text
import datetime
import matplotlib.pyplot as plt

# Set directories
try:
    %cd Islam
    %matplotlib inline
except:
    path = os.path.abspath(__file__)
    dir_path = os.path.dirname(path)
    os.chdir(dir_path)
# Set paths
```

Example: HMI Distances with MP IV

```
path='../../data/'
if not os.path.exists(path):
    os.mkdir(path)
pathout='../../data/HMI/'
if not os.path.exists(pathout):
    os.mkdir(pathout)
# Import Cities shapefile using GeoPandas
cities = pd.read_stata(path+'/AllCities.dta')
cities['LAT']=cities['lat']
cities['LON']=cities['lon']
cities['city']=cities.city.apply(lambda x: isounidecode.unidecode(x[:(x.find(' (')=
cities = cities[['LAT','LON','code','city','ID']]

# Define a function that calls HMI, HMISea, HMIOcean with start point only one row i
#start_points=pd.DataFrame([cities.loc[0,:]], columns=cities.columns.values)

def computeHMI(row):
    """Compute HMI for starting at row and ending in all of cities"""
    A = hmi.HMI(pd.DataFrame([row[1]], columns=cities.columns.values), cities, lat=
    A.HMIdistance(export_shape=True, path=pathout+str(row[1]['code']+str(row[0])))
    return A.hmidist
```

Example: HMI Distances with MP V

```
def computeHMISea(row):
    """Compute HMI for starting at row and ending in all of cities"""
    A = hmi.HMISea(pd.DataFrame([row[1]], columns=cities.columns.values), cities, l
    A.HMIdistance(export_shape=True, path=pathout+str(row[1]['code']+str(row[0])))
    return A.hmidist

def computeHMIOcean(row):
    """Compute HMI for starting at row and ending in all of cities"""
    A = hmi.HMIOcean(pd.DataFrame([row[1]], columns=cities.columns.values), cities,
    A.HMIdistance(export_shape=True, path=pathout+str(row[1]['code']+str(row[0])))
    return A.hmidist

# Now compute all distances in parallel, merge GeoPandas Frames
dfhmi = view.map_async(computeHMI, cities.iterrows())
dfhmisea = view.map_async(computeHMISea, cities.iterrows())
dfhmiocean = view.map_async(computeHMIOcean, cities.iterrows())
# Get results
dfhmi = dfhmi.get()
dfhmisea = dfhmisea.get()
dfhmiocean = dfhmiocean.get()
```

Example: HMI Distances with MP VI

```
# Concatenate the results
dfhmi = pd.concat(dfhmi)
dfhmisea = pd.concat(dfhmisea)
dfhmiocean = pd.concat(dfhmiocean)
# Convert to GeoPandas again
dfhmi = gp.GeoDataFrame(dfhmi, crs=hmi.cea)
dfhmisea = gp.GeoDataFrame(dfhmisea, crs=hmi.cea)
dfhmiocean = gp.GeoDataFrame(dfhmiocean, crs=hmi.cea)
# Export Shape files
dfhmi.to_file(path+'HMI10.shp')
dfhmisea.to_file(path+'HMISea10.shp')
dfhmiocean.to_file(path+'HMIOcean10.shp')

# Merge Distances and export them
cols=dfhmi.columns
cols=cols.drop('geometry')
dfout = dfhmi[cols].copy()
dfout = dfout.merge(dfhmisea[['city_1','city_2','HMISea10dist','HMISea10Iso']], how
dfout = dfout.merge(dfhmiocean[['city_1','city_2','HMIOcean10dist','HMIOcean10Iso']
dfout.sort(['city_1','city_2'], inplace=True)
dfout.to_stata('../../data/HMI10dists.dta', write_index=False)
```

Example: Extension of Original Project

New Project...similar to original one but using city data

- 4669 cities

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- 9 versions of HMI*10

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- Using 149 cores on server

Example: Extension of Original Project

New Project...similar to original one but using city data

- 4669 cities
- 9 versions of HMI*10
- Using 149 cores on server
- Less than 1 day for full results (data, networks, MST, etc.)

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- Support

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- Point-and-click

When should you use?

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  - Fast or simple tasks/analyses

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The Voyage of Homo-œconomicus into GIS

Ömer Özak

Dept. Economics, SMU

Here's How I Do GIS

October 13, 2016