

Poisson_MGWR_univariate_check

May 19, 2020

Notebook Outline:

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0.0.1 Set up Cells

```
In [1]: import sys
        sys.path.append("C:/Users/msachde1/Downloads/Research/Development/mgwr")

In [2]: import warnings
        warnings.filterwarnings("ignore")
        import pandas as pd
        import numpy as np

        from mgwr.gwr import GWR
        from spglm.family import Gaussian, Binomial, Poisson
        from mgwr.gwr import MGWR
        from mgwr.sel_bw import Sel_BW
        import multiprocessing as mp
        pool = mp.Pool()
        from scipy import linalg
        import numpy.linalg as la
        from scipy import sparse as sp
        from scipy.sparse import linalg as spla
        from spreg.utils import spdots, spmultiply
        from scipy import special
        import libpysal as ps
        import seaborn as sns
        import matplotlib.pyplot as plt
        from copy import deepcopy
        import copy
        from collections import namedtuple
        import spglm
```

0.0.2 Fundamental equations for Poisson MGWR

$$y = \text{Poisson}[E_i \exp(\sum \beta_k x_{k,i})] - (1)$$

$$E_i = \text{Offset} - (2)$$

$$\hat{y} = \text{predicted}(y) - (3)$$

$$z = (\sum \beta_k x_{k,i}) + ((y - \hat{y})/\hat{y}) - (4)$$

$$(5)$$

0.0.3 Example Dataset

```
In [3]: data_p = ps.io.open(ps.examples.get_path('Tokyomortality.csv'))
        coords = list(zip(data_p.by_col('X_CENTROID'), data_p.by_col('Y_CENTROID')))
        off = np.array(data_p.by_col('eb2564')).reshape((-1,1))
        y = np.array(data_p.by_col('db2564')).reshape((-1,1))
        occ = np.array(data_p.by_col('OCC_TEC')).reshape((-1,1))
        own = np.array(data_p.by_col('OWNH')).reshape((-1,1))
        pop = np.array(data_p.by_col('POP65')).reshape((-1,1))
        unemp = np.array(data_p.by_col('UNEMP')).reshape((-1,1))
        X = np.hstack([occ, own, pop, unemp])
        x = unemp

        X_std = (X-X.mean(axis=0))/X.std(axis=0)
        x_std = (x-x.mean(axis=0))/x.std(axis=0)
        y_std = (y-y.mean(axis=0))/y.std(axis=0)
```

0.0.4 Helper functions

Hardcoded here for simplicity in the notebook workflow

Please note: A separate bw_func_p will not be required when changes will be made in the repository

```
In [5]: kernel='bisquare'
        fixed=False
        spherical=False
        search_method='golden_section'
        criterion='AICc'
        interval=None
        tol=1e-06
        max_iter=200
        X_glob=[]

In [6]: def gwr_func(y, X, bw, family=Gaussian(), offset=None):
        return GWR(coords, y, X, bw, family, offset, kernel=kernel,
                    fixed=fixed, constant=False,
                    spherical=spherical, hat_matrix=False).fit(
                    lite=True, pool=pool)
```

```

def bw_func_p(coords,y, X):
    selector = Sel_BW(coords,y, X,family=Poisson(),offset=off, X_glob=[],
                      kernel=kernel, fixed=fixed,
                      constant=False, spherical=spherical)
    return selector

def bw_func(coords,y,X):
    selector = Sel_BW(coords,y,X,X_glob=[],
                      kernel=kernel, fixed=fixed,
                      constant=False, spherical=spherical)
    return selector

def sel_func(bw_func, bw_min=None, bw_max=None):
    return bw_func.search(
        search_method=search_method, criterion=criterion,
        bw_min=bw_min, bw_max=bw_max, interval=interval, tol=tol,
        max_iter=max_iter, pool=pool, verbose=False)

```

0.0.5 Univariate example

GWPR model with independent variable, x = unemployment

```
In [7]: bw_gwpr=Sel_BW(coords,y_std,x_std,family=Poisson(),offset=off,constant=False).search()
```

```
In [8]: gwpr_model=GWR(coords,y_std,x_std,bw=bw_gwpr,family=Poisson(),offset=off,constant=False)
```

MGWR Poisson loop with one independent variable, x = unemployment

Edited multi_bw function - original function in <https://github.com/pysal/mgwr/blob/master/mgwr/search.py>

```

In [9]: def multi_bw(init,coords,y, X, n, k, family=Gaussian(),offset=None, tol=1e-06, max_iter=
        verbose=False):

    if isinstance(family,spgml.family.Poisson):
        bw = sel_func(bw_func_p(coords,y,X))
        optim_model=gwr_func(y,X,bw,family=Poisson(),offset=offset)
        err = optim_model.resid_response.reshape((-1, 1))
        param = optim_model.params
        #This change for the Poisson model follows from equation (1) above
        XB = offset*np.exp(np.multiply(param, X))

    else:
        bw=sel_func(bw_func(coords,y,X))
        optim_model=gwr_func(y,X,bw)
        err = optim_model.resid_response.reshape((-1, 1))
        param = optim_model.params
        XB = np.multiply(param, X)

```

```

bw_gwr = bw
XB=XB

if rss_score:
    rss = np.sum((err)**2)
    iters = 0
    scores = []
    delta = 1e6
    Bws = []
    bw_stable_counter = np.ones(k)
    bws = np.empty(k)

try:
    from tqdm.auto import tqdm #if they have it, let users have a progress bar
except ImportError:

    def tqdm(x, desc=''): #otherwise, just passthrough the range
        return x

for iters in tqdm(range(1, max_iter + 1), desc='Backfitting'):
    new_XB = np.zeros_like(X)
    params = np.zeros_like(X)

    for j in range(k):
        temp_y = XB[:, j].reshape((-1, 1))
        temp_y = temp_y + err
        temp_X = X[:, j].reshape((-1, 1))

        #The step below will not be necessary once the bw_func is changed in the r
        if isinstance(family, spglm.family.Poisson):

            bw_class = bw_func_p(coords, temp_y, temp_X)

        else:
            bw_class = bw_func(coords, temp_y, temp_X)

    if np.all(bw_stable_counter == bws_same_times):
        #If in backfitting, all bws not changing in bws_same_times (default 3)
        bw = bws[j]
    else:
        bw = sel_func(bw_class, multi_bw_min[j], multi_bw_max[j])
        if bw == bws[j]:
            bw_stable_counter[j] += 1
        else:
            bw_stable_counter = np.ones(k)

#Changed gwr_func to accept family and offset as attributes

```

```

    optim_model = gwr_func(temp_y, temp_X, bw,family,offset)
    err = optim_model.resid_response.reshape((-1, 1))
    param = optim_model.params.reshape((-1, ))
    new_XB[:, j] = optim_model.predy.reshape(-1)
    params[:, j] = param
    bws[j] = bw

num = np.sum((new_XB - XB)**2) / n
den = np.sum(np.sum(new_XB, axis=1)**2)
score = (num / den)**0.5
XB = new_XB

if rss_score:
    predy = np.sum(np.multiply(params, X), axis=1).reshape((-1, 1))
    new_rss = np.sum((y - predy)**2)
    score = np.abs((new_rss - rss) / new_rss)
    rss = new_rss
    scores.append(deepcopy(score))
    delta = score
    BWs.append(deepcopy(bws))

if verbose:
    print("Current iteration:", iters, ",SOC:", np.round(score, 7))
    print("Bandwidths:", ', '.join([str(bw) for bw in bws]))

if delta < tol:
    break

print("iters = "+str(iters))
opt_bws = BWs[-1]
print("opt_bws = "+str(opt_bws))
return (opt_bws, np.array(BWs), np.array(scores), params, err, bw_gwr)

```

Running the function with family = Poisson() and offset

```

In [10]: bw_mgwpr = multi_bw(init=None,coords=coords,y=y_std, X=x_std, n=262, k=x.shape[1], fa

iters = 2
opt_bws = [178.]

```

Running without family and offset attributes runs the normal MGWR loop

```

In [11]: bw_mgwr = multi_bw(init=None,coords=coords,y=y_std, X=x_std, n=262, k=x.shape[1])

iters = 1
opt_bws = [73.]

```

0.0.6 Parameter check

Difference in parameters from the GWPR model and MGWPR model

```
In [12]: max(bw_mgwpr[3]-gwpr_model.params)
```

```
Out[12]: array([1.89357983e-05])
```

The parameters are not identical but the maximum difference in the parameters is to the order of $1e-05$

0.0.7 Bandwidths check

```
In [13]: bw_gwpr
```

```
Out[13]: 178.0
```

```
In [14]: bw_mgwpr[0]
```

```
Out[14]: array([178.])
```

Bandwidths from both models is the same