

# Package ‘GWmodel’

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**Description** In GWmodel, we introduce techniques from a particular branch of spatial statistics, termed geographically-weighted (GW) models. GW models suit situations when data are not described well by some global model, but where there are spatial regions where a suitably localised calibration provides a better description. GWmodel includes functions to calibrate: GW summary statistics, GW principal components analysis, GW discriminant analysis and various forms of GW regression; some of which are provided in basic and robust (outlier resistant) forms.

**Author** Binbin Lu[aut], Paul Harris[aut], Martin Charlton[aut], Chris Brunsdon[aut], Tomoki Nakaya[aut], Isabella Gollini[ctb]

**Maintainer** Binbin Lu <binbinlu@whu.edu.cn>

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GWmodel-package	<i>Geographically-Weighted Models</i>
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## Description

In GWmodel, we introduce techniques from a particular branch of spatial statistics, termed geographically-weighted (GW) models. GW models suit situations when data are not described well by some global model, but where there are spatial regions where a suitably localised calibration provides a better description. GWmodel includes functions to calibrate: GW summary statistics, GW principal components analysis, GW discriminant analysis and various forms of GW regression; some of which are provided in basic and robust (outlier resistant) forms.

## Details

Package:	GWmodel
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Version:	2.0-5
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License:	GPL (>=2)
LazyLoad:	yes

## Note

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Beta versions can always be found at <https://github.com/lbb220/GWmodel>, which includes all the newly developed functions for GW models.

For latest tutorials on using GWmodel please go to: <https://rpubs.com/gwmodel>

## Author(s)

Binbin Lu, Paul Harris, Martin Charlton, Chris Brunsdon, Tomoki Nakaya, Isabella Gollini  
 Maintainer: Binbin Lu <binbinlu@whu.edu.cn>

## References

Gollini I, Lu B, Charlton M, Brunsdon C, Harris P (2015) GWmodel: an R Package for exploring Spatial Heterogeneity using Geographically Weighted Models. *Journal of Statistical Software*, 63(17):1-50, <http://www.jstatsoft.org/v63/i17/>

Lu B, Harris P, Charlton M, Brunsdon C (2014) The GWmodel R Package: further topics for exploring Spatial Heterogeneity using Geographically Weighted Models. *Geo-spatial Information Science* 17(2): 85-101, <http://www.tandfonline.com/doi/abs/10.1080/10095020.2014.917453>

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bw.ggwr	<i>Bandwidth selection for generalised geographically weighted regression (GWR)</i>
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### Description

A function for automatic bandwidth selection to calibrate a generalised GWR model

### Usage

```
bw.ggwr(formula, data, family = "poisson", approach = "CV",
kernel = "bisquare", adaptive = FALSE, p = 2, theta = 0, longlat = F, dMat)
```

### Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <a href="#">sp</a>
family	a description of the error distribution and link function to be used in the model, which can be specified by "poisson" or "binomial"
approach	specified by CV for cross-validation approach or by AIC corrected (AICc) approach
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

### Value

Returns the adaptive or fixed distance bandwidth

**Note**

For a discontinuous kernel function, a bandwidth can be specified either as a fixed (constant) distance or as a fixed (constant) number of local data (i.e. an adaptive distance). For a continuous kernel function, a bandwidth can be specified either as a fixed distance or as a 'fixed quantity that reflects local sample size' (i.e. still an 'adaptive' distance but the actual local sample size will be the sample size as functions are continuous). In practise a fixed bandwidth suits fairly regular sample configurations whilst an adaptive bandwidth suits highly irregular sample configurations. Adaptive bandwidths ensure sufficient (and constant) local information for each local calibration. This note is applicable to all GW models

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

 bw.gwda

*Bandwidth selection for GW Discriminant Analysis*


---

**Description**

A function for automatic bandwidth selection for GW Discriminant Analysis using a cross-validation approach only

**Usage**

```
bw.gwda(formula, data, COV.gw = T, prior.gw = T, mean.gw = T,
        prior = NULL, wqda = F, kernel = "bisquare", adaptive
        = FALSE, p = 2, theta = 0, longlat = F,dMat)
```

**Arguments**

formula	Model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame for training, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
COV.gw	if true, localised variance-covariance matrix is used for GW discriminant analysis; otherwise, global variance-covariance matrix is used
mean.gw	if true, localised mean is used for GW discriminant analysis; otherwise, global mean is used
prior.gw	if true, localised prior probability is used for GW discriminant analysis; otherwise, fixed prior probability is used
prior	a vector of given prior probability
wqda	if TRUE, a weighted quadratic discriminant analysis will be applied; otherwise a weighted linear discriminant analysis will be applied

kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

Returns the adaptive or fixed distance bandwidth.

**Note**

For a discontinuous kernel function, a bandwidth can be specified either as a fixed (constant) distance or as a fixed (constant) number of local data (i.e. an adaptive distance). For a continuous kernel function, a bandwidth can be specified either as a fixed distance or as a 'fixed quantity that reflects local sample size' (i.e. still an 'adaptive' distance but the actual local sample size will be the sample size as functions are continuous). In practise a fixed bandwidth suits fairly regular sample configurations whilst an adaptive bandwidth suits highly irregular sample configurations. Adaptive bandwidths ensure sufficient (and constant) local information for each local calibration. This note is applicable to all GW models

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

bw.gwpca

*Bandwidth selection for Geographically Weighted Principal Components Analysis (GWPCA)*

---

**Description**

A function for automatic bandwidth selection to calibrate a basic or robust GWPCA via a cross-validation approach only

**Usage**

```
bw.gwpca(data,vars,k=2, robust=FALSE, kernel="bisquare", adaptive=FALSE, p=2,
          theta=0, longlat=F, dMat)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be evaluated
k	the number of retained components, and it must be less than the number of variables
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

Returns the adaptive or fixed distance bandwidth

**Note**

For a discontinuous kernel function, a bandwidth can be specified either as a fixed (constant) distance or as a fixed (constant) number of local data (i.e. an adaptive distance). For a continuous kernel function, a bandwidth can be specified either as a fixed distance or as a 'fixed quantity that reflects local sample size' (i.e. still an 'adaptive' distance but the actual local sample size will be the sample size as functions are continuous). In practise a fixed bandwidth suits fairly regular sample configurations whilst an adaptive bandwidth suits highly irregular sample configurations. Adaptive bandwidths ensure sufficient (and constant) local information for each local calibration. This note is applicable to all GW models

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris P, Clarke A, Juggins S, Brunson C, Charlton M (2015) Enhancements to a geographically weighted principal components analysis in the context of an application to an environmental data set. *Geographical Analysis* 47: 146-172

---

 bw.gwr

*Bandwidth selection for basic GWR*


---

### Description

A function for automatic bandwidth selection to calibrate a basic GWR model

### Usage

```
bw.gwr(formula, data, approach="CV", kernel="bisquare",
        adaptive=FALSE, p=2, theta=0, longlat=F, dMat)
```

### Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <a href="#">sp</a>
approach	specified by CV for cross-validation approach or by AIC corrected (AICc) approach
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

### Value

Returns the adaptive or fixed distance bandwidth

### Note

For a discontinuous kernel function, a bandwidth can be specified either as a fixed (constant) distance or as a fixed (constant) number of local data (i.e. an adaptive distance). For a continuous kernel function, a bandwidth can be specified either as a fixed distance or as a 'fixed quantity that reflects local sample size' (i.e. still an 'adaptive' distance but the actual local sample size will be the sample size as functions are continuous). In practise a fixed bandwidth suits fairly regular sample



configurations whilst an adaptive bandwidth suits highly irregular sample configurations. Adaptive bandwidths ensure sufficient (and constant) local information for each local calibration. This note is applicable to all GW models

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

---

bw.gwr.lcr

*Bandwidth selection for locally compensated ridge GWR (GWR-LCR)*

---

### Description

A function for automatic bandwidth selection for [gwr.lcr](#) via a cross-validation approach only

### Usage

```
bw.gwr.lcr(formula, data, kernel="bisquare",
           lambda=0, lambda.adjust=FALSE, cn.thresh=NA,
           adaptive=FALSE, p=2, theta=0, longlat=F, dMat)
```

### Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a <code>Spatial*DataFrame</code> , i.e. <code>SpatialPointsDataFrame</code> or <code>SpatialPolygonsDataFrame</code> as defined in package <code>sp</code>
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
lambda	option for a globally-defined (constant) ridge parameter. Default is $\lambda=0$ , which gives a basic GWR fit
lambda.adjust	a locally-varying ridge parameter. Default FALSE, refers to: (i) a basic GWR without a local ridge adjustment (i.e. $\lambda=0$ , everywhere); or (ii) a penalised GWR with a global ridge adjustment (i.e. $\lambda$ is user-specified as some constant, other than 0 everywhere); if TRUE, use <code>cn.tresh</code> to set the maximum condition number. For locations with a condition number (for its local design matrix), above this user-specified threshold, a local ridge parameter is found
cn.thresh	maximum value for condition number, commonly set between 20 and 30
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)

theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

Returns the adaptive or fixed distance bandwidth

**Note**

For a discontinuous kernel function, a bandwidth can be specified either as a fixed (constant) distance or as a fixed (constant) number of local data (i.e. an adaptive distance). For a continuous kernel function, a bandwidth can be specified either as a fixed distance or as a 'fixed quantity that reflects local sample size' (i.e. still an 'adaptive' distance but the actual local sample size will be the sample size as functions are continuous). In practise a fixed bandwidth suits fairly regular sample configurations whilst an adaptive bandwidth suits highly irregular sample configurations. Adaptive bandwidths ensure sufficient (and constant) local information for each local calibration. This note is applicable to all GW models

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Gollini I, Lu B, Charlton M, Brunsdon C, Harris P (2015) GWmodel: an R Package for exploring Spatial Heterogeneity using Geographically Weighted Models. *Journal of Statistical Software* 63(17): 1-50

---

bw.gwss.average      *Bandwidth selection for GW summary averages*

---

**Description**

A function for automatic bandwidth selections to calculate GW summary averages, including means and medians, via a cross-validation approach.

**Usage**

```
bw.gwss.average(data, summary.locat, vars, kernel = "bisquare", adaptive = FALSE,
                p = 2, theta = 0, longlat = F, dMat)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
summary.locat	a Spatial*DataFrame object for providing summary locations, i.e. SpatialPoints-DataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be summarized
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

Returns the adaptive or fixed distance bandwidths (in a two-column matrix) for calculating the averages of each variable.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

DubVoter

*Voter turnout data in Greater Dublin(SpatialPolygonsDataFrame)*

---

**Description**

Voter turnout and social characters data in Greater Dublin for the 2002 General election and the 2002 census. Note that this data set was originally thought to relate to 2004, so for continuity we have retained the associated variable names.

**Usage**

data(DubVoter)

**Format**

A SpatialPolygonsDataFrame with 322 electoral divisions on the following 11 variables.

**DED\_ID** a vector of ID

**X** a numeric vector of x coordinates

**Y** a numeric vector of y coordinates

**DiffAdd** percentage of the population in each ED who are one-year migrants (i.e. moved to a different address 1 year ago)

**LARent** percentage of the population in each ED who are local authority renters

**SC1** percentage of the population in each ED who are social class one (high social class)

**Unempl** percentage of the population in each ED who are unemployed

**LowEduc** percentage of the population in each ED who are with little formal education

**Age18\_24** percentage of the population in each ED who are age group 18-24

**Age25\_44** percentage of the population in each ED who are age group 25-44

**Age45\_64** percentage of the population in each ED who are age group 45-64

**GenEl2004** percentage of population in each ED who voted in 2004 election

**Details**

Variables are from DubVoter.shp.

**References**

Kavanagh A (2006) Turnout or turned off? Electoral participation in Dublin in the early 21st Century. *Journal of Irish Urban Studies* 3(2):1-24

Harris P, Brunsdon C, Charlton M (2011) Geographically weighted principal components analysis. *International Journal of Geographical Information Science* 25 (10):1717-1736

**Examples**

```
data(DubVoter)
ls()
## Not run:
spplot(Dub.voter, names(Dub.voter)[4:12])

## End(Not run)
```

---

EWHP

*House price data set (DataFrame) in England and Wales*

---

### Description

A house price data set for England and Wales from 2001 with 9 hedonic (explanatory) variables.

### Usage

```
data(EWHP)
```

### Format

A data frame with 519 observations on the following 12 variables.

**Easting** a numeric vector, X coordinate

**Northing** a numeric vector, Y coordinate

**PurPrice** a numeric vector, the purchase price of the property

**BldIntWr** a numeric vector, 1 if the property was built during the world war, 0 otherwise

**BldPostW** a numeric vector, 1 if the property was built after the world war, 0 otherwise

**Bld60s** a numeric vector, 1 if the property was built between 1960 and 1969, 0 otherwise

**Bld70s** a numeric vector, 1 if the property was built between 1970 and 1979, 0 otherwise

**Bld80s** a numeric vector, 1 if the property was built between 1980 and 1989, 0 otherwise

**TypDetch** a numeric vector, 1 if the property is detached (i.e. it is a stand-alone house), 0 otherwise

**TypSemiD** a numeric vector, 1 if the property is semi detached, 0 otherwise

**TypFlat** a numeric vector, if the property is a flat (or 'apartment' in the USA), 0 otherwise

**FlrArea** a numeric vector, floor area of the property in square metres

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

Fotheringham, A.S., Brunson, C., and Charlton, M.E. (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.

### Examples

```
###  
data(EWHP)  
head(ewhp)  
houses.spdf <- SpatialPointsDataFrame(ewhp[, 1:2], ewhp)  
###Get the border of England and Wales  
data(EWOutline)  
plot(ewoutline)  
plot(houses.spdf, add = TRUE, pch = 16)
```

---

 EWOutline

*Outline of England and Wales for data [EWHP](#)*


---

**Description**

Outline (SpatialPolygonsDataFrame) of the England and Wales house price data [EWHP](#).

**Usage**

```
data(EWOutline)
```

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

Georgia

*Georgia census data set (csv file)*


---

**Description**

Census data from the county of Georgia, USA

**Usage**

```
data(Georgia)
```

**Format**

A data frame with 159 observations on the following 13 variables.

**AreaKey** An identification number for each county

**Latitude** The latitude of the county centroid

**Longitud** The longitude of the county centroid

**TotPop90** Population of the county in 1990

**PctRural** Percentage of the county population defined as rural

**PctBach** Percentage of the county population with a bachelors degree

**PctEld** Percentage of the county population aged 65 or over

**PctFB** Percentage of the county population born outside the US

**PctPov** Percentage of the county population living below the poverty line

**PctBlack** Percentage of the county population who are black

**ID** a numeric vector of IDs

**X** a numeric vector of x coordinates

**Y** a numeric vector of y coordinates

**Details**

This data set can also be found in GWR 3 and in spgwr.

**References**

Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.

**Examples**

```
data(Georgia)
ls()
coords <- cbind(Gedu.df$X, Gedu.df$Y)
educ.spdf <- SpatialPointsDataFrame(coords, Gedu.df)
splot(educ.spdf, names(educ.spdf)[4:10])
```

---

GeorgiaCounties

*Georgia counties data (SpatialPolygonsDataFrame)*

---

**Description**

The Georgia census data with boundaries for mapping

**Usage**

```
data(GeorgiaCounties)
```

**Details**

This data set can also be found in GWR 3 and in spgwr.

**Examples**

```
data(GeorgiaCounties)
plot(Gedu.counties)
data(Georgia)
coords <- cbind(Gedu.df$X, Gedu.df$Y)
educ.spdf <- SpatialPointsDataFrame(coords, Gedu.df)
plot(educ.spdf, add=TRUE)
```

ggwr.basic

*Generalised GWR models with Poisson and Binomial options***Description**

This function implements generalised GWR

**Usage**

```
ggwr.basic(formula, data, regression.points, bw, family =
           "poisson", kernel = "bisquare", adaptive = FALSE, cv =
           T, tol = 1e-05, maxiter = 20, p = 2, theta = 0,
           longlat = F, dMat, dMat1)

## S3 method for class 'ggwr'
print(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
regression.points	a Spatial*DataFrame object, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
bw	bandwidth used in the weighting function, possibly calculated by <code>bw.ggwr()</code> ; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
family	a description of the error distribution and link function to be used in the model, which can be specified by “poisson” or “binomial”
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
cv	if TRUE, cross-validation data will be calculated
tol	the threshold that determines the convergence of the IRLS procedure
maxiter	the maximum number of times to try the IRLS procedure
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance



theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix between regression points and observations, it can be calculated by the function <a href="#">gw.dist</a>
dMat1	a square distance matrix between each pair of observations, it can be calculated by the function <a href="#">gw.dist</a>
x	an object of class “ggwr”, returned by the function <a href="#">gwr.generalised</a>
...	arguments passed through (unused)

### Value

A list of class “ggwr”:

GW.arguments	a <a href="#">list</a> class object including the model fitting parameters for generating the report file
GW.diagnostic	a <a href="#">list</a> class object including the diagnostic information of the model fitting
glm.res	an object of class inheriting from “glm” which inherits from the class “lm”, see <a href="#">glm</a> .
SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package “sp”) integrated with fit.points,GWR coefficient estimates, y value,predicted values, coefficient standard errors and t-values in its "data" slot.
CV	a data vector consisting of the cross-validation data

### Note

Note that this function calibrates a Generalised GWR model via an approximating algorithm, which is different from the back-fitting algorithm used in the GWR4 software by Tomoki Nakaya.

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

- Nakaya, T., A. S. Fotheringham, C. Brunson & M. Charlton (2005) Geographically weighted Poisson regression for disease association mapping. *Statistics in Medicine*, 24, 2695-2717.
- Nakaya, T., M. Charlton, S. Fotheringham & C. Brunson. 2009. How to use SGWRWIN (GWR4.0). Maynooth, Ireland: National Centre for Geocomputation.
- Fotheringham S, Brunson, C, and Charlton, M (2002), *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*, Chichester: Wiley.

## Examples

```
data(LondonHP)
## Not run:
DM<-gw.dist(dp.locat=coordinates(londonhp))
bw.f1 <- bw.ggwr(BATH2~FLOORSZ,data=londonhp, dMat=DM)
res.poisson<-ggwr.basic(BATH2~FLOORSZ, bw=bw.f1,data=londonhp, dMat=DM)
bw.f2 <- bw.ggwr(BATH2~FLOORSZ,data=londonhp, dMat=DM,family ="binomial")
res.binomial<-ggwr.basic(BATH2~FLOORSZ, bw=bw.f2,data=londonhp, dMat=DM,
                        family ="binomial")

## End(Not run)
```

---

ggwr.cv

*Cross-validation score for a specified bandwidth for generalised GWR*


---

## Description

This function finds the cross-validation score for a specified bandwidth for generalised GWR. It can be used to construct the bandwidth function across all possible bandwidths and compared to that found automatically.

## Usage

```
ggwr.cv(bw, X, Y,family="poisson", kernel="bisquare",adaptive=F, dp.locat,
        p=2, theta=0, longlat=F,dMat)
```

## Arguments

bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
X	a numeric matrix of the independent data with an extra column of “ones” for the 1st column
Y	a column vector of the dependent data
family	a description of the error distribution and link function to be used in the model, which can be specified by “poisson” or “binomial”
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
dp.locat	a two-column numeric array of observation coordinates

p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV.score	cross-validation score
----------	------------------------

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

ggwr.cv.contrib	<i>Cross-validation data at each observation location for a generalised GWR model</i>
-----------------	---

---

**Description**

This function finds the individual cross-validation score at each observation location, for a generalised GWR model, for a specified bandwidth. These data can be mapped to detect unusually high or low cross-validation scores.

**Usage**

```
ggwr.cv.contrib(bw, X, Y, family="poisson", kernel="bisquare", adaptive=F,
               dp.locat, p=2, theta=0, longlat=F, dMat)
```

**Arguments**

bw	bandwidth used in the weighting function; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
X	a numeric matrix of the independent data with an extra column of "ones" for the 1st column
Y	a column vector of the dependent data
family	a description of the error distribution and link function to be used in the model, which can be specified by "poisson" or "binomial"
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise

adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
dp.locat	a two-column numeric array of observation coordinates
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV	a data vector consisting of squared residuals, whose sum is the cross-validation score for the specified bandwidth
----	--

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gw.dist

*Distance matrix calculation*

---

**Description**

Calculate a distance vector(matrix) between any GW model calibration point(s) and the data points.

**Usage**

```
gw.dist(dp.locat, rp.locat, focus=0, p=2, theta=0, longlat=F)
```

**Arguments**

dp.locat	a numeric matrix of two columns giving the coordinates of the data points
rp.locat	a numeric matrix of two columns giving the coordinates of the GW model calibration points
focus	an integer, indexing to the current GW model point, if focus=0, all the distances between all the GW model calibration points and data points will be calculated and a distance matrix will be returned; if 0<focus<length(rp.locat), then the distances between the 'focus'th GW model points and data points will be calculated and a distance vector will be returned
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated

**Value**

Returns a numeric distance matrix or vector; matrix with its rows corresponding to the observations and its columns corresponds to the GW model calibration points.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**See Also**

[dist](#) in *stats*

**Examples**

```
dp<-cbind(sample(100),sample(100))
rp<-cbind(sample(10),sample(10))
#Euclidean distance metric is used.
dist.v1<-gw.dist(dp.locat=dp, focus=5, p=2, theta=0, longlat=FALSE)
#Manhattan distance metric is used.
#The coordinate system is rotated by an angle 0.5 in radian.
dist.v2<-gw.dist(dp.locat=dp, focus=5, p=1, theta=0.5)
#Great Circle distance metric is used.
dist.v3<-gw.dist(dp.locat=dp, focus=5, longlat=TRUE)
#A generalized Minkowski distance metric is used with p= 0.75 .
#The coordinate system is rotated by an angle 0.8 in radian.
dist.v4<-gw.dist(dp.locat=dp,rp.locat=rp, focus=5, p=0.75,theta=0.8)
#####
#matrix is calculated
#Euclidean distance metric is used.
dist.m1<-gw.dist(dp.locat=dp, p=2, theta=0, longlat=FALSE)
#Manhattan distance metric is used.
#The coordinate system is rotated by an angle 0.5 in radian.
dist.m2<-gw.dist(dp.locat=dp, p=1, theta=0.5)
#Great Circle distance metric is used.
#dist.m3<-gw.dist(dp.locat=dp, longlat=TRUE)
#A generalized Minkowski distance metric is used with p= 0.75 .
#The coordinate system is rotated by an angle 0.8 in radian.
dist.m4<-gw.dist(dp.locat=dp,rp.locat=rp, p=0.75,theta=0.8)
```

---

gw.pcplot

*Geographically weighted parallel coordinate plot for investigating multivariate data sets*

---

**Description**

This function provides a geographically weighted parallel coordinate plot for locally investigating a multivariate data set. It has an option that weights the lines of the plot with increasing levels of transparency, according to their observation's distance from a specified focal/observation point.

**Usage**

```
gw.pcplot(data,vars,focus,bw,adaptive = FALSE, ylim=NULL,ylab="",fixtrans=FALSE,
          p=2, theta=0, longlat=F,dMat,...)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be evaluated
focus	an integer, indexing to the observation point
bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
ylim	the y limits of the plot
ylab	a label for the y axis
fixtrans	if TRUE, the transparency of the neighbouring observation plot lines increases with distance; If FALSE a standard (non-spatial) parallel coordinate plot is returned.
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
...	other graphical parameters, (see <a href="#">par</a> )

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Harris P, Brunson C, Charlton M, Juggins S, Clarke A (2014) Multivariate spatial outlier detection using robust geographically weighted methods. *Mathematical Geosciences* 46(1) 1-31
- Harris P, Clarke A, Juggins S, Brunson C, Charlton M (2015) Enhancements to a geographically weighted principal components analysis in the context of an application to an environmental data set. *Geographical Analysis* 47: 146-172

gw.weight

*Weight matrix calculation***Description**

Calculate a weight vector(matrix) from a distance vector(matrix).

**Usage**

```
gw.weight(vdist,bw,kernel,adaptive=FALSE)
```

**Arguments**

vdist	a distance matrix or vector
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)

**Value**

Returns a numeric weight matrix or vector; matrix with its rows corresponding to the observations and its columns corresponds to the GW model calibration points.

**Note**

The gaussian and exponential kernel functions are continuous and valued in the interval (0,1]; while bisquare, tricube and boxcar kernel functions are discontinuous and valued in the interval [0,1]. Notably, the upper limit of the bandwidth is exactly the number of observations when the adaptive kernel is used. In this function, the adaptive bandwidth will be specified as the number of observations even though a larger number is assigned. The function will be the same as a global application function (i.e. all weights are 1) when the adaptive bandwidth is equal to or larger than the number of observations when using the boxcar kernel function.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

gwda

*GW Discriminant Analysis***Description**

This function implements GW discriminant analysis.

**Usage**

```
gwda(formula, data, predict.data, validation = T, COV.gw=T,
      mean.gw=T, prior.gw=T, prior=NULL, wqda =F,
      kernel = "bisquare", adaptive = FALSE, bw,
      p = 2, theta = 0, longlat = F, dMat)
## S3 method for class 'gwda'
print(x, ...)
```

**Arguments**

formula	Model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame for training, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
predict.data	a Spatial*DataFrame object for prediction, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b> ; if it is not given, the training data will be predicted using leave-one-out cross-validation.
validation	If TRUE, the results from the prediction will be validated and the correct proportion will be calculated.
COV.gw	if true, localised variance-covariance matrix is used for GW discriminant analysis; otherwise, global variance-covariance matrix is used
mean.gw	if true, localised mean is used for GW discriminant analysis; otherwise, global mean is used
prior.gw	if true, localised prior probability is used for GW discriminant analysis; otherwise, fixed prior probability is used
prior	a vector of given prior probability
wqda	if TRUE, weighted quadratic discriminant analysis will be applied; otherwise weighted linear discriminant analysis will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)



bw	bandwidth used in the weighting function, possibly calculated by <code>bw.gwpca</code> ; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>
x	an object of class "gwda"
...	arguments passed through (unused)

**Value**

A class of object "gwda"

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Brunsdon, C, Fotheringham S, and Charlton, M (2007), Geographically Weighted Discriminant Analysis, *Geographical Analysis* 39:376-396

Lu B, Harris P, Charlton M, Brunsdon C (2014) The GWmodel R Package: further topics for exploring Spatial Heterogeneity using Geographically Weighted Models. *Geo-spatial Information Science* 17(2): 85-101

---

gwpca	<i>GWPCA</i>
-------	--------------

---

**Description**

This function implements basic or robust GWPCA.

**Usage**

```
gwpca(data, elocat, vars, k = 2, robust = FALSE, kernel = "bisquare",
      adaptive = FALSE, bw, p = 2, theta = 0, longlat = F, cv = T,
      dMat)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
elocat	a two-column numeric array or Spatial*DataFrame object for providing evaluation locations, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>

vars	a vector of variable names to be evaluated
k	the number of retained components; k must be less than the number of variables
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
bw	bandwidth used in the weighting function, possibly calculated by <code>bw.gw pca</code> ; fixed (distance) or adaptive bandwidth(number of nearest neighbours)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
cv	If TRUE, cross-validation data will be found that are used to calculate the cross-validation score for the specified bandwidth.
dMat	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>

### Value

A list of components:

loadings	The localised loadings
var	The local amount of variance accounted for by each component
GW.arguments	A list of geographically weighted arguments supplied to the function call
CV	Vector of cross-validation data

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

- Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.
- Harris P, Brunson C, Charlton M (2011) Geographically weighted principal components analysis. International Journal of Geographical Information Science 25:1717-1736
- Harris P, Brunson C, Charlton M, Juggins S, Clarke A (2014) Multivariate spatial outlier detection using robust geographically weighted methods. Mathematical Geosciences 46(1) 1-31

Harris P, Clarke A, Juggins S, Brunson C, Charlton M (2014) Geographically weighted methods and their use in network re-designs for environmental monitoring. *Stochastic Environmental Research and Risk Assessment* 28: 1869-1887

Harris P, Clarke A, Juggins S, Brunson C, Charlton M (2015) Enhancements to a geographically weighted principal components analysis in the context of an application to an environmental data set. *Geographical Analysis* 47: 146-172

## Examples

```
## Not run:
if(require("mvoutlier") && require("RColorBrewer"))
{
  data(bsstop)
  Data.1 <- bsstop[, 1:14]
  colnames(Data.1)
  Data.1.scaled <- scale(as.matrix(Data.1[5:14])) # standardised data...
  rownames(Data.1.scaled) <- Data.1[, 1]
  #compute principal components:
  pca <- princomp(Data.1.scaled, cor = FALSE, scores = TRUE)
  # use covariance matrix to match the following...
  pca$loadings
  data(bss.background)
  backdrop <- function()
  plot(bss.background, asp = 1, type = "l", xaxt = "n", yaxt = "n",
       xlab = "", ylab = "", bty = "n", col = "grey")
  pc1 <- pca$scores[, 1]
  backdrop()
  points(Data.1$XC00[pc1 > 0], Data.1$YC00[pc1 > 0], pch = 16, col = "blue")
  points(Data.1$XC00[pc1 < 0], Data.1$YC00[pc1 < 0], pch = 16, col = "red")

  #Geographically Weighted PCA and mapping the local loadings
  # Coordinates of the sites
  Coords1 <- as.matrix(cbind(Data.1$XC00,Data.1$YC00))
  d1s <- SpatialPointsDataFrame(Coords1,as.data.frame(Data.1.scaled))
  pca.gw <- gw pca(d1s,vars=colnames(d1s@data),bw=1000000,k=10)
  local.loadings <- pca.gw$loadings[, , 1]

  # Mapping the winning variable with the highest absolute loading
  # note first component only - would need to explore all components..

  lead.item <- colnames(local.loadings)[max.col(abs(local.loadings))]
  df1p = SpatialPointsDataFrame(Coords1, data.frame(lead = lead.item))
  backdrop()
  colour <- brewer.pal(8, "Dark2")[match(df1p$lead, unique(df1p$lead))]
  plot(df1p, pch = 18, col = colour, add = TRUE)
  legend("topleft", as.character(unique(df1p$lead)), pch = 18, col =
       brewer.pal(8, "Dark2"))
  backdrop()

  #Glyph plots give a view of all the local loadings together
  glyph.plot(local.loadings, Coords1, add = TRUE)
```

```

#it is not immediately clear how to interpret the glyphs fully,
#so inter-actively identify the full loading information using:
check.components(local.loadings, Coords1)

# GWPCA with an optimal bandwidth
bw.choice <- bw.gwpca(d1s,vars=colnames(d1s@data),k=2)
pca.gw.auto <- gwpca(d1s,vars=colnames(d1s@data),bw=bw.choice,k=2)
# note first component only - would need to explore all components..
local.loadings <- pca.gw.auto$loadings[, , 1]

lead.item <- colnames(local.loadings)[max.col(abs(local.loadings))]
df1p = SpatialPointsDataFrame(Coords1, data.frame(lead = lead.item))
backdrop()
colour <- brewer.pal(8, "Dark2")[match(df1p$lead, unique(df1p$lead))]
plot(df1p, pch = 18, col = colour, add = TRUE)
legend("topleft", as.character(unique(df1p$lead)), pch = 18,
col = brewer.pal(8, "Dark2"))

# GWPCPLOT for investigating the raw multivariate data
gw.pcpplot(d1s, vars=colnames(d1s@data),focus=359, bw = bw.choice)
}

## End(Not run)

```

---

gw pca.check.components

*Interaction tool with the GWPCA glyph map*

---

## Description

The function interacts with the multivariate glyph plot of GWPCA loadings.

## Usage

```
gw pca.check.components(ld,loc)
```

## Arguments

ld	GWPCA loadings returned by <a href="#">gw pca</a>
loc	a 2-column numeric array of GWPCA evaluation locations

## Note

The function “check.components” (in the early versions of GWmodel) has been renamed as “gw-pca.check.components”, while the old name is still kept valid.

## Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

**See Also**[gw pca.glyph.plot](#)

gw pca.cv

*Cross-validation score for a specified bandwidth for GWPCA***Description**

This function finds the cross-validation score for a specified bandwidth for basic or robust GWPCA. It can be used to construct the bandwidth function across all possible bandwidths and compared to that found automatically.

**Usage**

```
gw pca.cv(bw, x, loc, k=2, robust=FALSE, kernel="bisquare", adaptive=FALSE, p=2,
          theta=0, longlat=F, dMat)
```

**Arguments**

bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
x	the variable matrix
loc	a two-column numeric array of observation coordinates
k	the number of retained components; k must be less than the number of variables
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV.score      cross-validation score

**Author(s)**

Binbin Lu &lt;binbinlu@whu.edu.cn&gt;

gw pca.cv.contrib

*Cross-validation data at each observation location for a GWPCA***Description**

This function finds the individual cross-validation score at each observation location, for a GWPCA model, for a specified bandwidth. These data can be mapped to detect unusually high or low cross-validation scores.

**Usage**

```
gw pca.cv.contrib(x, loc, bw, k=2, robust=FALSE, kernel="bisquare", adaptive=FALSE,
                 p=2, theta=0, longlat=F, dMat)
```

**Arguments**

x	the variable matrix
loc	a two-column numeric array of observation coordinates
bw	bandwidth used in the weighting function; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
k	the number of retained components; k must be less than the number of variables
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV a data vector consisting of squared residuals, whose sum is the cross-validation score for the specified bandwidth (bw) and component (k).

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gwpcg.glyph.plot

*Multivariate glyph plots of GWPCA loadings*

---

**Description**

This function provides a multivariate glyph plot of GWPCA loadings at each output location.

**Usage**

```
gwpcg.glyph.plot(ld, loc, r1=50, add=FALSE, alpha=1, sep.contrasts=FALSE)
```

**Arguments**

ld	GWPCA loadings returned by <a href="#">gwpcg</a>
loc	a two-column numeric array for providing evaluation locations of GWPCA calibration
r1	argument for the size of the glyphs, default is 50; glyphs get larger as r1 is reduced
add	if TRUE, add the plot to the existing window.
alpha	the level of transparency of glyph from function <code>rgb()</code> and ranges from 0 to max (fully transparent to opaque)
sep.contrasts	allows different types of glyphs and relates to whether absolute loadings are used (TRUE) or not

**Note**

The function “glyph.plot” (in the early versions of GWmodel) has been renamed as “gwpcg.glyph.plot”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris P, Brunsdon C, Charlton M (2011) Geographically weighted principal components analysis. *International Journal of Geographical Information Science* 25:1717-1736

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gw pca.montecarlo.1      *Monte Carlo (randomisation) test for significance of GWPCA eigenvalue variability for the first component only - option 1*

---

### Description

This function implements a Monte Carlo (randomisation) test for a basic or robust GW PCA with the bandwidth pre-specified and constant. The test evaluates whether the GW eigenvalues vary significantly across space for the first component only.

### Usage

```
gw pca.montecarlo.1(data, bw, vars, k = 2, nsims=99, robust = FALSE, kernel = "bisquare",
                    adaptive = FALSE, p = 2, theta = 0, longlat = F, dMat)
## S3 method for class 'mcsims'
plot(x, sname="SD of local eigenvalues from randomisations", ...)
```

### Arguments

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gw pca</a> ; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
vars	a vector of variable names to be evaluated
k	the number of retained components; k must be less than the number of variables
nsims	the number of simulations for Monte Carlo test
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
x	an object of class "mcsims", returned by the function <a href="#">gw pca.montecarlo.1</a> or <a href="#">gw pca.montecarlo.2</a>
sname	the label for the observed value on the plot
...	arguments passed through (unused)



**Value**

A list of components:

actual	the observed standard deviations (SD) of eigenvalues
sims	a vector of the simulated SDs of eigenvalues

**Note**

The function “montecarlo.gwpca.1” (in the early versions of GWmodel) has been renamed as “gwpca.montecarlo.1”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris P, Brunsdon C, Charlton M (2011) Geographically weighted principal components analysis. *International Journal of Geographical Information Science* 25:1717-1736

**Examples**

```
## Not run:
data(DubVoter)
DM<-gw.dist(dp.locat=coordinates(Dub.voter))
gmc.res<-gwpca.montecarlo.1(data=Dub.voter, vars=c("DiffAdd", "LARent",
"SC1", "Unempl", "LowEduc"), bw=20, dMat=DM, adaptive=TRUE)
gmc.res
plot(gmc.res)

## End(Not run)
```

---

gwpca.montecarlo.2	<i>Monte Carlo (randomisation) test for significance of GWPCA eigenvalue variability for the first component only - option 2</i>
--------------------	--

---

**Description**

This function implements a Monte Carlo (randomisation) test for a basic or robust GW PCA with the bandwidth automatically re-selected via the cross-validation approach. The test evaluates whether the GW eigenvalues vary significantly across space for the first component only.

**Usage**

```
gwpca.montecarlo.2(data, vars, k = 2, nsims=99, robust = FALSE, kernel = "bisquare",
  adaptive = FALSE, p = 2, theta = 0, longlat = F, dMat)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be evaluated
k	the number of retained components; k must be less than the number of variables
nsims	the number of simulations for MontCarlo test
robust	if TRUE, robust GWPCA will be applied; otherwise basic GWPCA will be applied
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

A list of components:

actual	the observed standard deviations (SD) of eigenvalues
sims	a vector of the simulated SDs of eigenvalues

**Note**

The function “montecarlo.gwpca.2” (in the early versions of GWmodel) has been renamed as “gw-pca.montecarlo.2”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris P, Brunsdon C, Charlton M (2011) Geographically weighted principal components analysis. *International Journal of Geographical Information Science* 25:1717-1736

**Examples**

```
## Not run:
data(DubVoter)
DM<-gw.dist(dp.locat=coordinates(Dub.voter))
gmc.res.autow<-gwpca.montecarlo.2(data=Dub.voter, vars=c("DiffAdd", "LAREnt",
"SC1", "Unempl", "LowEduc"), dMat=DM,adaptive=TRUE)
gmc.res.autow
plot.mcsims(gmc.res.autow)

## End(Not run)
```

gwr.basic

*Basic GWR model***Description**

This function implements basic GWR

**Usage**

```
gwr.basic(formula, data, regression.points, bw, kernel="bisquare",
adaptive=FALSE, p=2, theta=0, longlat=F,dMat,F123.test=F,cv=T, W.vect=NULL)
## S3 method for class 'gwrn'
print(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
regression.points	a Spatial*DataFrame object, i.e. SpatialPointsDataFrame or SpatialPolygons-DataFrame as defined in package <b>sp</b>
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance

<code>theta</code>	an angle in radians to rotate the coordinate system, default is 0
<code>longlat</code>	if TRUE, great circle distances will be calculated
<code>dMat</code>	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>
<code>F123.test</code>	If TRUE, conduct three separate F-tests according to Leung et al. (2000).
<code>cv</code>	if TRUE, cross-validation data will be calculated and returned in the output <code>Spatial*DataFrame</code>
<code>W.vect</code>	default NULL, if given it will be used to weight the distance weighting matrix
<code>x</code>	an object of class "gwr", returned by the function <code>gwr.basic</code>
<code>...</code>	arguments passed through (unused)

### Value

A list of class "gwr":

<code>GW.arguments</code>	a list class object including the model fitting parameters for generating the report file
<code>GW.diagnostic</code>	a list class object including the diagnostic information of the model fitting
<code>lm</code>	an object of class inheriting from "lm", see <code>lm</code> .
<code>SDF</code>	a <code>SpatialPointsDataFrame</code> (may be gridded) or <code>SpatialPolygonsDataFrame</code> object (see package "sp") integrated with <code>fit.points,GWR</code> coefficient estimates, <code>y</code> value, predicted values, coefficient standard errors and t-values in its "data" slot.
<code>timings</code>	starting and ending time.
<code>this.call</code>	the function call used.
<code>Ftest.res</code>	results of Leung's F tests when <code>F123.test</code> is TRUE.

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

- Brunsdon, C, Fotheringham, S, Charlton, M (1996), Geographically Weighted Regression: A Method for Exploring Spatial Nonstationarity. *Geographical Analysis* 28(4):281-298
- Charlton, M, Fotheringham, S, and Brunsdon, C (2007), GWR3.0, <http://gwr.nuim.ie/>.
- Fotheringham S, Brunsdon, C, and Charlton, M (2002), *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*, Chichester: Wiley.
- Leung, Y, Mei, CL, and Zhang, WX (2000), Statistical tests for spatial nonstationarity based on the geographically weighted regression model. *Environment and Planning A*, 32, 9-32.
- Lu, B, Charlton, M, Harris, P, Fotheringham, AS (2014) Geographically weighted regression with a non-Euclidean distance metric: a case study using hedonic house price data. *International Journal of Geographical Information Science* 28(4): 660-681

**Examples**

```

data(LondonHP)
DM<-gw.dist(dp.locat=coordinates(londonhp))
##Compare the time consumed with and without a specified distance matrix
## Not run:
system.time(gwr.res<-gwr.basic(PURCHASE~FLOORSZ, data=londonhp, bw=1000,
                              kernel = "gaussian"))
system.time(DM<-gw.dist(dp.locat=coordinates(londonhp)))
system.time(gwr.res<-gwr.basic(PURCHASE~FLOORSZ, data=londonhp, bw=1000,
                              kernel = "gaussian", dMat=DM))

## specify an optimum bandwidth by cross-validation approach
bw1<-bw.gwr(PURCHASE~FLOORSZ, data=londonhp, kernel = "gaussian",dMat=DM)
gwr.res1<-gwr.basic(PURCHASE~FLOORSZ, data=londonhp, bw=bw1, kernel = "gaussian",
                   dMat=DM)

gwr.res1
## End(Not run)
data(LondonBorough)

nsa = list("SpatialPolygonsRescale", layout.north.arrow(), offset = c(561900,200900),
          scale = 500, col=1)
## Not run:
if(require("RColorBrewer"))
{
  mypalette<-brewer.pal(6,"Spectral")
  x11()
  spplot(gwr.res1$SDF, "FLOORSZ", key.space = "right", cex=1.5, cuts=10,
         ylim=c(155840.8,200933.9), xlim=c(503568.2,561957.5),
         main="GWR estimated coefficients for FLOORSZ with a fixed bandwidth",
         col.regions=mypalette, sp.layout=list(nsa, londonborough))}

## End(Not run)
## Not run:
bw2<-bw.gwr(PURCHASE~FLOORSZ,approach="aic",adaptive=TRUE, data=londonhp,
            kernel = "gaussian", dMat=DM)
gwr.res2<-gwr.basic(PURCHASE~FLOORSZ, data=londonhp, bw=bw2,adaptive=TRUE,
                   kernel = "gaussian", dMat=DM)

gwr.res2
if(require("RColorBrewer"))
{
  x11()
  spplot(gwr.res2$SDF, "FLOORSZ", key.space = "right", cex=1.5, cuts=10,
         ylim=c(155840.8,200933.9), xlim=c(503568.2,561957.5),
         main="GWR estimated coefficients for FLOORSZ with an adaptive bandwidth",
         col.regions=mypalette, sp.layout=list(nsa,londonborough))}

## End(Not run)

```

## Description

This function implements bootstrap methods to test for coefficient variability found from GWR under model assumptions for each of four null hypotheses: MLR, ERR, SMA and LAG models. Global test statistic results are found, as well local observation-specific test results that can be mapped.

## Usage

```
gwr.bootstrap(formula, data, kernel="bisquare", approach="AIC", R=99, k.nearneigh=4,
              adaptive=FALSE, p=2, theta=0, longlat=FALSE, dMat, verbose=FALSE)
## S3 method for class 'gwrbsm'
print(x, ...)
```

## Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a <code>Spatial*DataFrame</code> , i.e. <code>SpatialPointsDataFrame</code> or <code>SpatialPolygonsDataFrame</code> as defined in package <code>sp</code>
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
approach	specified by CV for cross-validation approach or by AIC corrected (AICc) approach
R	number of random samples reaped in the bootstrap procedure
k.nearneigh	number of nearest neighbours concerned in calibrating ERR, SMA and LAG models
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
verbose	if TRUE and bandwidth selection is undertaken, the bandwidth searches are reported
x	an object of class "gwrbsm", returned by the function <a href="#">gwr.bootstrap</a>
...	arguments passed through (unused)

**Value**

A list of class “gwrbsm”:

formula	Regression model formula of a <a href="#">formula</a> object
results	modified statistics reported from comparisons between GWR and MLR, ERR, SMA and LAG
SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package “sp”) integrated with fit.points, GWR coefficient estimates, y value, predicted values, coefficient standard errors and bootstrap p-values in its “data” slot.
timings	starting and ending time.
this.call	the function call used.

**Note**

This function implements the bootstrap methods introduced in Harris et al. (2017). It provides a global test statistic (the modified one given in Harris et al. 2017) and a complementary localised version that can be mapped. The bootstrap methods test for coefficient variability found from GWR under model assumptions for each of four null hypotheses: i) multiple linear regression model (MLR); ii) simultaneous autoregressive error model (ERR); iii) moving average error model (SMA) and iv) simultaneous autoregressive lag model (LAG).

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris, P., Brunson, C., Lu, B., Nakaya, T., & Charlton, M. (2017). Introducing bootstrap methods to investigate coefficient non-stationarity in spatial regression models. *Spatial Statistics*, 21, 241-261.

**Examples**

```
## Not run:
#Example with the Georgia educational attainment data
data(Georgia)
data(GeorgiaCounties)
coords <- cbind(Gedu.df$X, Gedu.df$Y)
Gedu.spdf <- SpatialPointsDataFrame(coords, Gedu.df)
#Make a SpatialPolygonsDataFrame
require(RColorBrewer)
gSRDF <- SpatialPolygonsDataFrame(polygons(Gedu.counties), over(Gedu.counties,
                                                                Gedu.spdf), match.ID=T)

mypalette.1 <- brewer.pal(11, "Spectral")
X11(width=9,height=8)
spplot(gSRDF, names(gSRDF)[c(5,7:9)], col.regions=mypalette.1,
cuts=10, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Georgia educational attainment predictor data")))
```

```

bsm.res <- gwr.bootstrap(PctBach~PctRural+PctEld+PctFB+PctPov, gSRDF,
                        R=999, longlat=T)

bsm.res
#local bootstrap tests with respect to: MLR, ERR, SMA and LAG models.
mypalette.local.test <- brewer.pal(10,"Spectral")
X11(width=12,height=16)
spplot(bsm.res$SDF, names(bsm.res$SDF)[14:17], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the MLR model
                        null hypothesis")))

X11(width=12,height=16)
spplot(bsm.res$SDF, names(bsm.res$SDF)[19:22], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the ERR model
                        null hypothesis")))

X11(width=12,height=16)
spplot(bsm.res$SDF, names(bsm.res$SDF)[24:27], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the SMA model null
                        hypothesis")))

X11(width=12,height=16)
spplot(bsm.res$SDF, names(bsm.res$SDF)[29:32], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the LAG model null
                        hypothesis")))
#####
#Example with Dublin voter data
data(DubVoter)
X11(width=9,height=8)
spplot(Dub.voter, names(Dub.voter)[c(5,7,9,10)], col.regions=mypalette.1,
cuts=10, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Dublin voter turnout predictor data")))
bsm.res1 <- gwr.bootstrap(GenEl2004~LARent+Unempl+Age18_24+Age25_44, Dub.voter
                        , R=999)

bsm.res1

#local bootstrap tests with respect to: MLR, ERR, SMA and LAG models.
X11(width=11,height=8)
spplot(bsm.res1$SDF, names(bsm.res1$SDF)[14:17], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the MLR model null
                        hypothesis")))

X11(width=11,height=8)
spplot(bsm.res1$SDF, names(bsm.res1$SDF)[19:22], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the ERR model null
                        hypothesis")))

X11(width=11,height=8)
spplot(bsm.res1$SDF, names(bsm.res1$SDF)[24:27], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the SMA model

```



```

                                null hypothesis"))))
X11(width=11,height=8)
spplot(bsm.res1$SDF, names(bsm.res1$SDF)[29:32], col.regions=mypalette.local.test,
cuts=9, par.settings=list(fontsize=list(text=15)),
main=expression(paste("Local p-values for each coefficient of the LAG model
                                null hypothesis"))))

## End(Not run)

```

---

`gwr.collin.diagno`      *Local collinearity diagnostics for basic GWR*

---

## Description

This function provides a series of local collinearity diagnostics for the independent variables of a basic GWR model.

## Usage

```
gwr.collin.diagno(formula, data, bw, kernel="bisquare",
                  adaptive=FALSE, p=2, theta=0, longlat=F,dMat)
```

## Arguments

<code>formula</code>	Regression model formula of a <a href="#">formula</a> object
<code>data</code>	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <a href="#">sp</a>
<code>bw</code>	bandwidth used in the weighting function, probably calculated by <code>bw.gwr</code> or <code>bw.gwr.lcr</code> ; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
<code>kernel</code>	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
<code>adaptive</code>	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
<code>p</code>	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
<code>theta</code>	an angle in radians to rotate the coordinate system, default is 0
<code>longlat</code>	if TRUE, great circle distances will be calculated
<code>dMat</code>	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

corr.mat	Local correlation matrix
VIF	Local Variance inflation factors (VIFs) matrix
local_CN	Local condition numbers
VDP	Local variance-decomposition proportions
SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package “sp”) integrated with VIF, local_CN, VDP and corr.mat

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Wheeler D, Tiefelsdorf M (2005) Multicollinearity and correlation among local regression coefficients in geographically weighted regression. *Journal of Geographical Systems* 7:161-187
- Wheeler D (2007) Diagnostic tools and a remedial method for collinearity in geographically weighted regression. *Environment and Planning A* 39:2464-2481
- Gollini I, Lu B, Charlton M, Brunsdon C, Harris P (2015) GWmodel: an R Package for exploring Spatial Heterogeneity using Geographically Weighted Models. *Journal of Statistical Software*, 63(17):1-50

---

gwr.cv

*Cross-validation score for a specified bandwidth for basic GWR*

---

**Description**

This function finds the cross-validation score for a specified bandwidth for basic GWR. It can be used to construct the bandwidth function across all possible bandwidths and compared to that found automatically.

**Usage**

```
gwr.cv(bw, X, Y, kernel="bisquare", adaptive=FALSE, dp.locat, p=2, theta=0,
       longlat=F, dMat, verbose=T)
```

**Arguments**

bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
X	a numeric matrix of the independent data with an extra column of “ones” for the 1st column
Y	a column vector of the dependent data

kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
dp.locat	a two-column numeric array of observation coordinates
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
verbose	if TRUE (default), reports the progress of search for bandwidth

**Value**

CV.score      cross-validation score

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gwr.cv.contrib	<i>Cross-validation data at each observation location for a basic GWR model</i>
----------------	---

---

**Description**

This function finds the individual cross-validation score at each observation location, for a basic GWR model, for a specified bandwidth. These data can be mapped to detect unusually high or low cross-validations scores.

**Usage**

```
gwr.cv.contrib(bw, X, Y, kernel="bisquare", adaptive=FALSE, dp.locat, p=2,
              theta=0, longlat=F, dMat)
```

**Arguments**

bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
X	a numeric matrix of the independent data with an extra column of “ones” for the 1st column
Y	a column vector of the dependent data
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
dp.locat	a two-column numeric array of observation coordinates
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV	a data vector consisting of squared residuals, whose sum is the cross-validation score for the specified bandwidth.
----	---

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gwr.hetero

*Heteroskedastic GWR*

---

**Description**

This function implements a heteroskedastic GWR model

**Usage**

```
gwr.hetero(formula, data, regression.points, bw, kernel="bisquare",
            adaptive=FALSE, tol=0.0001,maxiter=50,verbose=T,
            p=2, theta=0, longlat=F,dMat)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
regression.points	a Spatial*DataFrame object, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
tol	the threshold that determines the convergence of the iterative procedure
maxiter	the maximum number of times to try the iterative procedure
verbose	logical, if TRUE verbose output will be made from the iterative procedure
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package "sp") integrated with coefficient estimates in its "data" slot.
-----	---

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.
- Harris P, Fotheringham AS, Juggins S (2010) Robust geographically weighed regression: a technique for quantifying spatial relationships between freshwater acidification critical loads and catchment attributes. *Annals of the Association of American Geographers* 100(2): 286-306
- Harris P, Brunson C, Fotheringham AS (2011) Links, comparisons and extensions of the geographically weighted regression model when used as a spatial predictor. *Stochastic Environmental Research and Risk Assessment* 25:123-138

gwr.lcr

*GWR with a locally-compensated ridge term***Description**

To address possible local collinearity problems in basic GWR, GWR-LCR finds local ridge parameters at affected locations (set by a user-specified threshold for the design matrix condition number).

**Usage**

```
gwr.lcr(formula, data, regression.points, bw, kernel="bisquare",
        lambda=0, lambda.adjust=FALSE, cn.thresh=NA,
        adaptive=FALSE, p=2, theta=0, longlat=F, cv=T, dMat)
## S3 method for class 'gwrlcr'
print(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
regression.points	a Spatial*DataFrame object, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b> , or a two-column numeric array
bw	bandwidth used in the weighting function, possibly calculated by <code>bw.gwr.lcr</code> ; fixed (distance) or adaptive bandwidth(number of nearest neighbours)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
lambda	option for a globally-defined (constant) ridge parameter. Default is <code>lambda=0</code> , which gives a basic GWR fit
lambda.adjust	a locally-varying ridge parameter. Default <code>FALSE</code> , refers to: (i) a basic GWR without a local ridge adjustment (i.e. <code>lambda=0</code> , everywhere); or (ii) a penalised GWR with a global ridge adjustment (i.e. <code>lambda</code> is user-specified as some constant, other than 0 everywhere); if <code>TRUE</code> , use <code>cn.tresh</code> to set the maximum condition number. Here for locations with a condition number (for its local design matrix) above this user-specified threshold, a local ridge parameter is found
cn.thresh	maximum value for condition number, commonly set between 20 and 30

adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
cv	if TRUE, 'cross-validation data will be calculated and returned in the output Spatial*DataFrame
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
x	an object of class "gwrlcr", returned by the function <a href="#">gwr.lcr</a>
...	arguments passed through (unused)

**Value**

A list of class "rgwr":

SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package "sp") with coordinates of regression.points in its "data" slot.
GW.arguments	parameters used for the LCR-GWR calibration
GW.diagnostic	diagnostic information is given when data points are also used as regression locations
timings	timing information for running this function
this.call	the function call used.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Wheeler D (2007) Diagnostic tools and a remedial method for collinearity in geographically weighted regression. *Environment and Planning A* 39:2464-2481
- Brunsdon C, Charlton M, Harris P (2012) Living with collinearity in Local Regression Models. GISRUK 2012, Lancaster, UK
- Brunsdon C, Charlton M, Harris P (2012) Living with collinearity in Local Regression Models. Spatial Accuracy 2012, Brazil
- Gollini I, Lu B, Charlton M, Brunsdon C, Harris P (2015) GWmodel: an R Package for exploring Spatial Heterogeneity using Geographically Weighted Models. *Journal of Statistical Software* 63(17): 1-50

**Examples**

```
data(DubVoter)
require(RColorBrewer)

# Function to find the global condition number (CN)
BKW_cn <- function (X) {
```

```

p <- dim(X)[2]
Xscale <- sweep(X, 2, sqrt(colSums(X^2)), "/")
Xsvd <- svd(Xscale)$d
cn <- Xsvd[1] / Xsvd[p]
cn
}
#
X <- cbind(1,Dub.voter@data[,3:10])
head(X)
CN.global <- BKW_cn(X)
CN.global
## Not run:
# gwr.lcr function with a global bandwidth to check that the global CN is found
gwr.lcr1 <- gwr.lcr(GenEl2004~DiffAdd+LARent+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64, data=Dub.voter, bw=10000000000)
summary(gwr.lcr1$SDF$Local_CN)

# Find and map the local CNs from a basic GWR fit using the lcr-gwr function
#(note this is NOT the locally-compensated ridge GWR fit as would need to set
#lambda.adjust=TRUE and cn.thresh=30, say)

bw.lcr2 <- bw.gwr.lcr(GenEl2004~DiffAdd+LARent+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64, data=Dub.voter, kernel="bisquare", adaptive=TRUE)
gwr.lcr2 <- gwr.lcr(GenEl2004~DiffAdd+LARent+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64, data=Dub.voter, bw=bw.lcr2, kernel="bisquare", adaptive=TRUE)
if(require("RColorBrewer"))
  spplot(gwr.lcr2$SDF,"Local_CN",col.regions=brewer.pal(9,"Yl0rRd"),cuts=8,
  main="Local CN")

## End(Not run)

```

---

gwr.lcr.cv

---

*Cross-validation score for a specified bandwidth for GWR-LCR model*


---

## Description

This function finds the cross-validation score for a specified bandwidth for GWR-LCR. It can be used to construct the bandwidth function across all possible bandwidths and compared to that found automatically.

## Usage

```

gwr.lcr.cv(bw,X,Y,locs,kernel="bisquare",
           lambda=0,lambda.adjust=FALSE,cn.thresh=NA,
           adaptive=FALSE,p=2,theta=0, longlat=F,dMat)

```

## Arguments

**bw** bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)



X	a numeric matrix of the independent data with an extra column of “ones” for the 1st column
Y	a column vector of the dependent data
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisphere: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
locs	a two-column numeric array of observation coordinates
lambda	option for a globally-defined (constant) ridge parameter. Default is $lambda=0$ , which gives a basic GWR fit
lambda.adjust	a locally-varying ridge parameter. Default FALSE, refers to: (i) a basic GWR without a local ridge adjustment (i.e. $lambda=0$ , everywhere); or (ii) a penalised GWR with a global ridge adjustment (i.e. $lambda$ is user-specified as some constant, other than 0 everywhere); if TRUE, use <code>cn.tresh</code> to set the maximum condition number. Here for locations with a condition number (for its local design matrix) above this user-specified threshold, a local ridge parameter is found
cn.tresh	maximum value for condition number, commonly set between 20 and 30
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>

**Value**

CV.score	cross-validation score
----------	------------------------

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

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gwr.lcr.cv.contrib	<i>Cross-validation data at each observation location for the GWR-LCR model</i>
--------------------	---

---

### Description

This function finds the individual cross-validation score at each observation location, for a GWR-LCR model, for a specified bandwidth. These data can be mapped to detect unusually high or low cross-validations scores.

### Usage

```
gwr.lcr.cv.contrib(bw,X,Y,locs,kernel="bisquare",
                  lambda=0,lambda.adjust=FALSE,cn.thresh=NA,
                  adaptive=FALSE, p=2, theta=0, longlat=F,dMat)
```

### Arguments

bw	bandwidth used in the weighting function;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
X	a numeric matrix of the independent data with an extra column of “ones” for the 1st column
Y	a column vector of the dependent data
locs	a two-column numeric array of observation coordinates
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
lambda	option for a globally-defined (constant) ridge parameter. Default is $\lambda=0$ , which gives a basic GWR fit
lambda.adjust	a locally-varying ridge parameter. Default FALSE, refers to: (i) a basic GWR without a local ridge adjustment (i.e. $\lambda=0$ , everywhere); or (ii) a penalised GWR with a global ridge adjustment (i.e. $\lambda$ is user-specified as some constant, other than 0 everywhere); if TRUE, use cn.tresh to set the maximum condition number. Here for locations with a condition number (for its local design matrix) above this user-specified threshold, a local ridge parameter is found
cn.thresh	maximum value for condition number, commonly set between 20 and 30
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance

theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

CV	a data vector consisting of squared residuals, whose sum is the cross-validation score for the specified bandwidth.
----	---

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gwr.mink.approach	<i>Minkovski approach for GWR</i>
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---

**Description**

This function implements the Minkovski approach to select an 'optimum' distance metric for calibrating a GWR model.

**Usage**

```
gwr.mink.approach(formula, data, criterion="AIC", bw, bw.sel.approach = "AIC", adaptive=F,
                  kernel="bisquare", p.vals=seq(from=0.25, to=8, length.out=32), p.inf = T,
                  theta.vals = seq(from=0, to=0.5*pi, length.out=10), verbose=F,
                  nlower = 10)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <a href="#">sp</a>
criterion	the criterion used for distance metric selection, AICc ("AICc") or cross-validation ("CV") score; default is "AICc"
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ; fixed (distance) or adaptive bandwidth(number of nearest neighbours)
bw.sel.approach	approach used to select an optimum bandwidth for each calibration if no bandwidth (bw) is given; specified by CV for cross-validation approach or by AIC corrected (AICc) approach
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)

kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
p.vals	a collection of positive numbers used as the power of the Minkowski distance
p.inf	if TRUE, Chebyshev distance is tried for model calibration, i.e. p is infinity
theta.vals	a collection of values used as angles in radians to rotate the coordinate system
verbose	if TRUE and bandwidth selection is undertaken, the bandwidth searches are reported
nlower	the minimum number of nearest neighbours if an adaptive kernel is used

**Value**

A list of:

diag.df	a data frame with four columns (p, theta, bandwidth, AICc/CV), each row corresponds to a calibration
coefs.all	a list class object including all the estimated coefficients

**Note**

The function “mink.approach” (in the early versions of GWmodel) has been renamed as “gwr.mink.approach”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Lu, B, Charlton, M, Brunsdon, C & Harris, P(2016). The Minkowski approach for choosing the distance metric in Geographically Weighted Regression. *International Journal of Geographical Information Science*, 30(2): 351-368.

---

gwr.mink.matrixview    *Visualisation of the results from [gwr.mink.approach](#)*

---

**Description**

This function visualises the AICc/CV results from the [gwr.mink.approach](#).

**Usage**

```
gwr.mink.matrixview(diag.df, znm=colnames(diag.df)[4], criterion="AIC")
```

**Arguments**

diag.df	the first part of a list object returned by <code>gwr.mink.approach</code>
znm	the name of the forth column in diag.df
criterion	the criterion used for distance metric selection in <code>gwr.mink.approach</code>

**Note**

The function “mink.matrixview” (in the early versions of GWmodel) has been renamed as “gwr.mink.matrixview”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Lu, B, Charlton, M, Brunson, C & Harris, P(2016). The Minkowski approach for choosing the distance metric in Geographically Weighted Regression. *International Journal of Geographical Information Science*, 30(2): 351-368.

---

gwr.mink.pval	<i>Select the values of p for the Minkovski approach for GWR</i>
---------------	--

---

**Description**

These functions implement heuristics to select the values of p from two intervals: (0, 2] in a 'backward' direction and (2, Inf) in a 'forward' direction.

**Usage**

```
gwr.mink.pval(formula, data, criterion="AIC", bw, bw.sel.approach = "AIC",
              adaptive=F, kernel="bisquare", left.interval=0.25,
              right.interval=0.5, drop.tol=3, theta0=0, verbose=F, nlower = 10)
gwr.mink.pval.forward(formula, data, bw, bw.sel.approach = "AIC",
                      adaptive=F, kernel="bisquare", p.max=Inf, p.min=2,
                      interval=0.5, drop.tol=3, theta0=0, verbose=F, nlower = 10)
gwr.mink.pval.backward(formula, data, bw, bw.sel.approach = "AIC",
                       adaptive=F, kernel="bisquare", p.max=2, p.min=0.1,
                       interval=0.5, drop.tol=3, theta0=0, verbose=F, nlower = 10)
## S3 method for class 'pvalas'
plot(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
criterion	the criterion used for distance metric selection, AICc ("AICc") or cross-validation ("CV") score; default is "AICc"
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ; fixed (distance) or adaptive bandwidth(number of nearest neighbours)
bw.sel.approach	approach used to select an optimum bandwidth for each calibration if no bandwidth (bw) is given; specified by CV for cross-validation approach or by AIC corrected (AICc) approach
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
left.interval	the step-size for searching the left interval (0, 2] in a 'backward' direction
right.interval	the step-size for searching the right interval (2, Inf) in a 'forward' direction
p.max	the maximum value of p
p.min	the minimum value of p
interval	the step-size for searching the given interval in a 'backward' or 'forward' direction
drop.tol	an AICc difference threshold to define whether the values of p to be dropped or not
theta0	a fixed rotation angle in radians
verbose	if TRUE and bandwidth selection is undertaken, the bandwidth searches are reported
nlower	the minimum number of nearest neighbours if an adaptive kernel is used
x	an object of class "pvlas", returned by these functions
...	arguments passed through (unused)

**Value**

A list of:

p.vals	a vector of tried values of p
criterion.vals	a vector of criterion values (AICc or CV) for tried values of p
p.dropped	a vector of boolean to label whether a value of p to be dropped or not: TRUE means to be dropped and FALSE means to be used for the Minkovski approach

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Lu, B, Charlton, M, Brunsdon, C & Harris, P(2016). The Minkowski approach for choosing the distance metric in Geographically Weighted Regression. *International Journal of Geographical Information Science*, 30(2): 351-368.

---

gwr.mixed

*Mixed GWR*

---

**Description**

This function implements mixed (semiparametric) GWR

**Usage**

```
gwr.mixed(formula, data, regression.points, fixed.vars,
          intercept.fixed=FALSE, bw, diagnostic=T, kernel="bisquare",
          adaptive=FALSE, p=2, theta=0, longlat=F, dMat)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
regression.points	a Spatial*DataFrame object, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
fixed.vars	independent variables that appeared in the formula that are to be treated as global
intercept.fixed	logical, if TRUE the intercept will be treated as global
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ; fixed (distance) or adaptive bandwidth(number of nearest neighbours)
diagnostic	logical, if TRUE the diagnostics will be calculated
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise

adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

### Value

A list of class “mgwr”:

GW.arguments	a list class object including the model fitting parameters for generating the report file
aic	AICc value from this calibration
df.used	effective degree of freedom
rss	residual sum of squares
SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package “sp”) integrated with coefficient estimates in its "data" slot.
timings	starting and ending time.
this.call	the function call used.

### Note

For an alternative formulation of mixed GWR, please refer to GWR 4, which provides useful tools for automatic bandwidth selection. This windows-based software also implements generalised mixed GWR.

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

- Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.
- Brunson C, Fotheringham AS, Charlton ME (1999) Some notes on parametric significance tests for geographically weighted regression. *Journal of Regional Science* 39(3):497-524
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- Nakaya T, Fotheringham AS, Brunson C, Charlton M (2005) Geographically Weighted Poisson Regression for Disease Association Mapping, *Statistics in Medicine* 24: 2695-2717
- Nakaya T et al. (2011) GWR4.0, <http://gwr.nuim.ie/>.



---

`gwr.model.selection`    *Model selection for GWR with a given set of independent variables*

---

### Description

This function selects one GWR model from many alternatives based on the AICc values.

### Usage

```
gwr.model.selection(DeVar=NULL, InDeVars=NULL, data=list(), bw=NULL, approach="CV",
  adaptive=F, kernel="bisquare", dMat=NULL, p=2, theta=0, longlat=F)
```

### Arguments

<code>DeVar</code>	dependent variable
<code>InDeVars</code>	a vector of independent variables for model selection
<code>data</code>	a <code>Spatial*DataFrame</code> , i.e. <code>SpatialPointsDataFrame</code> or <code>SpatialPolygonsDataFrame</code> as defined in package <code>sp</code>
<code>bw</code>	bandwidth used in the weighting function, possibly calculated by <code>bw.gwr</code>
<code>approach</code>	specified by <b>CV</b> ( <b>cv</b> ) for cross validation approach or <b>AIC</b> ( <b>aic</b> ) for selecting bandwidth by AICc values
<code>adaptive</code>	if TRUE calculate an adaptive kernel where the bandwidth ( <code>bw</code> ) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
<code>kernel</code>	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
<code>dMat</code>	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>
<code>p</code>	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
<code>theta</code>	an angle in radians to rotate the coordinate system, default is 0
<code>longlat</code>	if TRUE, great circle distances will be calculated

### Value

A list of:

<code>model.list</code>	a list of all the tried GWR models consisted of formulas and variables.
<code>GWR.df</code>	a data frame consisted of four columns: bandwidth, AIC, AICc, RSS

**Note**

The algorithm for selecting GWR models consists of the following four steps:

Step 1. Start by calibrating all the possible bivariate GWR models by sequentially regressing a single independent variable against the dependent variable;

Step 2. Find the best performing model which produces the minimum AICc value, and permanently include the corresponding independent variable in subsequent models;

Step 3. Sequentially introduce a variable from the remaining group of independent variables to construct new models with the permanently included independent variables, and determine the next permanently included variable from the best fitting model that has the minimum AICc value;

Step 4. Repeat step 3 until all the independent variables are permanently included in the model.

In this procedure, the independent variables are iteratively included into the model in a "forward" direction. Note that there is a clear distinction between the different number of involved variables in a selection step, which can be called model levels.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Lu, B, Charlton, M, Harris, P, Fotheringham, AS (2014) Geographically weighted regression with a non-Euclidean distance metric: a case study using hedonic house price data. *International Journal of Geographical Information Science* 28(4): 660-681

**See Also**

[gwr.model.view](#), [gwr.model.sort](#)

---

`gwr.model.sort`

*Sort the results of the GWR model selection function*  
[gwr.model.selection](#).

---

**Description**

Sort the results from the GWR model selection function [gwr.model.selection](#)

**Usage**

```
gwr.model.sort(Sorting.list , numVars, ruler.vector)
```

**Arguments**

<code>Sorting.list</code>	a list returned by function <a href="#">gwr.model.selection</a>
<code>numVars</code>	the number of independent variables involved in model selection
<code>ruler.vector</code>	a numeric vector as the sorting basis

**Note**

The function sorts the results of model selection within individual levels.

The function “model.sort.gwr” (in the early versions of GWmodel) has been renamed as “gwr.model.sort”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**See Also**

[gwr.model.selection](#), [gwr.model.view](#)

---

`gwr.model.view`

*Visualise the GWR models from [gwr.model.selection](#)*

---

**Description**

This function visualises the GWR models from [gwr.model.selection](#).

**Usage**

```
gwr.model.view(DeVar, InDeVars, model.list)
```

**Arguments**

DeVar	dependent variable
InDeVars	a vector of independent variables for model selection
model.list	a list of all GWR model tried in <a href="#">gwr.model.selection</a>

**Note**

The function “model.view.gwr” (in the early versions of GWmodel) has been renamed as “gwr.model.view”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**See Also**

[gwr.model.selection](#), [gwr.model.sort](#)

## Examples

```
## Not run:
data(LondonHP)
DM<-gw.dist(dp.locat=coordinates(londonhp))
DeVar<-"PURCHASE"
InDeVars<-c("FLOORSZ", "GARAGE1", "BLDPWW1", "BLDPOSTW")
model.sel<-gwr.model.selection(DeVar, InDeVars, data=londonhp,
kernel = "gaussian", dMat=DM, bw=5000)
model.list<-model.sel[[1]]
gwr.model.view(DeVar, InDeVars, model.list=model.list)

## End(Not run)
```

---

gwr.montecarlo	<i>Monte Carlo (randomisation) test for significance of GWR parameter variability</i>
----------------	---

---

## Description

This function implements a Monte Carlo (randomisation) test to test for significant (spatial) variability of a GWR model's parameters or coefficients.

## Usage

```
gwr.montecarlo(formula, data = list(), nsims=99, kernel="bisquare", adaptive=F, bw,
p=2, theta=0, longlat=F, dMat)
```

## Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a <code>Spatial*DataFrame</code> , i.e. <code>SpatialPointsDataFrame</code> or <code>SpatialPolygonsDataFrame</code> as defined in package <code>sp</code>
nsims	the number of randomisations
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a>
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>

**Value**

pmat                    A vector containing p-values for all the GWR parameters

**Note**

The function “montecarlo.gwr” (in the early versions of GWmodel) has been renamed as “gwr.montecarlo”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Brunsdon C, Fotheringham AS, Charlton ME (1998) Geographically weighted regression - modelling spatial non-stationarity. *Journal of the Royal Statistical Society, Series D-The Statistician* 47(3):431-443

Fotheringham S, Brunsdon, C, and Charlton, M (2002), *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*, Chichester: Wiley.

Charlton, M, Fotheringham, S, and Brunsdon, C (2007), *GWR3.0*.

**Examples**

```
## Not run:
data(LondonHP)
DM<-gw.dist(dp.locat=coordinates(londonhp))
bw<-bw.gwr(PURCHASE~FLOORSZ,data=londonhp,dMat=DM, kernel="gaussian")
#See any difference in the next two commands and why?
res.mont1<-gwr.montecarlo(PURCHASE~PROF+FLOORSZ, data = londonhp,dMat=DM,
nsim=99, kernel="gaussian", adaptive=FALSE, bw=3000)
res.mont2<-gwr.montecarlo(PURCHASE~PROF+FLOORSZ, data = londonhp,dMat=DM,
nsim=99, kernel="gaussian", adaptive=FALSE, bw=300000000000)

## End(Not run)
```

---

gwr.predict

*GWR used as a spatial predictor*

---

**Description**

This function implements basic GWR as a spatial predictor. The GWR prediction function is able to do leave-out-one predictions (when the observation locations are used for prediction) and predictions at a set-aside data set (when unobserved locations are used for prediction).

**Usage**

```
gwr.predict(formula, data, predictdata, bw, kernel="bisquare", adaptive=FALSE, p=2,
            theta=0, longlat=F, dMat1, dMat2)
## S3 method for class 'gwr.pred'
print(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a <a href="#">Spatial*DataFrame</a> , i.e. <a href="#">SpatialPointsDataFrame</a> or <a href="#">SpatialPolygonsDataFrame</a> as defined in package <a href="#">sp</a>
predictdata	a <a href="#">Spatial*DataFrame</a> object to provide prediction locations, i.e. <a href="#">SpatialPointsDataFrame</a> or <a href="#">SpatialPolygonsDataFrame</a> as defined in package <a href="#">sp</a>
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ; fixed (distance) or adaptive bandwidth (number of nearest neighbours)
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat1	a pre-specified distance matrix between data points and prediction locations; if not given, it will be calculated by the given parameters
dMat2	a pre-specified symmetric distance matrix between data points; if not given, it will be calculated by the given parameters
x	an object of class "gwr.pred", returned by the function <a href="#">gwr.predict</a>
...	arguments passed through (unused)

**Value**

A list of class "gwr.pred":

GW.arguments	a list of geographically weighted arguments
SDF	a <a href="#">SpatialPointsDataFrame</a> (may be gridded) or <a href="#">SpatialPolygonsDataFrame</a> object (see package "sp") with GWR coefficients, predictions and prediction variances in its "data" slot.
this.call	the function call used.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Harris P, Fotheringham AS, Crespo R, Charlton M (2010) The use of geographically weighted regression for spatial prediction: an evaluation of models using simulated data sets. *Mathematical Geosciences* 42:657-680

Harris P, Juggins S (2011) Estimating freshwater critical load exceedance data for Great Britain using space-varying relationship models. *Mathematical Geosciences* 43: 265-292

Harris P, Brunson C, Fotheringham AS (2011) Links, comparisons and extensions of the geographically weighted regression model when used as a spatial predictor. *Stochastic Environmental Research and Risk Assessment* 25:123-138

Gollini I, Lu B, Charlton M, Brunson C, Harris P (2015) GWmodel: an R Package for exploring Spatial Heterogeneity using Geographically Weighted Models. *Journal of Statistical Software*, 63(17):1-50

**Examples**

```
## Not run:
data(LondonHP)
gwr.pred<-gwr.predict(PURCHASE~FLOORSZ, data=londonhp, bw=2000, kernel = "gaussian")
gwr.pred
#####Global OLS regression results and comparison with gstat functions
if(require("gstat"))
{
  mlr.g <- gstat(id = "xx1", formula = PURCHASE~FLOORSZ,data=londonhp)
  mlr.g1 <- predict(mlr.g, newdata = londonhp, BLUE = TRUE)
  mlr.g1
}
#####
ols.pred<-gwr.predict(PURCHASE~FLOORSZ, data=londonhp, bw=100000000000000000000000)
ols.pred$SDF

## End(Not run)
```

---

gwr.psdm

---

*GWR with parameter-specific distance metrics*


---

**Description**

This function implements GWR with parameter-specific distance metrics to detect variations in regression relationships across different spatial scales.

**Usage**

```
gwr.psdm(formula, data, kernel="bisquare", adaptive=FALSE, criterion="dCVR",
         max.iterations=1000, threshold=0.000001, dMats, p.vals, theta.vals,
         longlat=FALSE, bws0, bw.seled=rep(F, length(bws0)), approach = "AIC",
         bws.thresholds=rep(1, length(dMats)), verbose=F, nlower = 10)
## S3 method for class 'psdmgwr'
print(x, ...)
```

**Arguments**

formula	Regression model formula of a <a href="#">formula</a> object
data	a <a href="#">Spatial*DataFrame</a> , i.e. <a href="#">SpatialPointsDataFrame</a> or <a href="#">SpatialPolygonsDataFrame</a> as defined in package <a href="#">sp</a>
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
criterion	criterion for determining the convergence of the back-fitting procedure, could be "CVR" or "dCVR", which correspond to the changing value of RSS (CVR) and the differential version (dCVR), respectively; and "dCVR" is used as default.
max.iterations	maximum number of iterations in the back-fitting procedure
threshold	threshold value to terminate the back-fitting iterations
dMats	a <a href="#">list</a> of distance matrices used for estimating each specific parameter
p.vals	a collection of positive numbers used as the power of the Minkowski distance
theta.vals	a collection of values used as angles in radians to rotate the coordinate system
longlat	if TRUE, great circle distances will be calculated
bws0	a <a href="#">vector</a> of initializing bandwidths for the back-fitting procedure, of which the length should equal to the number of parameters if specified
bw.seled	a <a href="#">vector</a> of boolean variables to determine whether the corresponding bandwidth should be re-selected or not: if TRUE, the corresponding bandwidths for the specific parameters are supposed to be given in bws0; otherwise, the bandwidths for the specific parameters will be selected within the back-fitting iterations.
approach	specified by CV for cross-validation approach or by AIC corrected (AICc) approach
bws.thresholds	threshold values to define whether the bandwidth for a specific parameter has converged or not
verbose	if TRUE and bandwidth selection is undertaken, the bandwidth searches are reported



nlower	the minimum number of nearest neighbours if an adaptive kernel is used
x	an object of class “psdmgwr”, returned by the function <a href="#">gwr.psdm</a>
...	arguments passed through (unused)

**Value**

A list of class “psdmgwr”:

SDF	a SpatialPointsDataFrame (may be gridded) or SpatialPolygonsDataFrame object (see package “sp”) integrated with data locations, coefficient estimates from the PSDM GWR model, predicted y values, residuals, coefficient standard errors and t-values in its “data” slot.
GW.arguments	a list class object including the model fitting parameters for generating the report file
GW.diagnostic	a list class object including the diagnostic information of the model fitting
lm	an object of class inheriting from “lm”, see <a href="#">lm</a> .
bws.vars	bandwidths used for all the parameters within the back-fitting procedure
AICc.vals	AICc values calculated within the back-fitting procedure
timings	starting and ending time.
this.call	the function call used.

**Note**

This function calibrates a GWR model with parameter-specific distance metrics, which by construction also implements a GWR model with parameter-specific bandwidths. Thus, GWR with flexible bandwidths (FBGWR) and mixed GWR are both special cases of PSDM GWR (as are basic GWR and the global regression). Specifically, an FBGWR model will be calibrated if no “dMats” and “p.vals” are specified; a mixed GWR model will be calibrated if an infinite bandwidth and another regular bandwidth are used for estimating the global and local parameters (again when no “dMats” and “p.vals” are specified). In other words, the [gwr.psdm](#) function is specified with Euclidean distances in both cases. Note that the results from this function for a mixed GWR model and [gwr.mixed](#) might be different, as a back-fitting algorithm is used in [gwr.psdm](#), while an approximating algorithm is applied in [gwr.mixed](#). The [gwr.mixed](#) performs better in computational efficiency, but poorer in prediction accuracy.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Yang, W. (2014). An Extension of Geographically Weighted Regression with Flexible Bandwidths. St Andrews, St Andrews, UK.
- Lu, B., Harris, P., Charlton, M., & Brunson, C. (2015). Calibrating a Geographically Weighted Regression Model with Parameter-specific Distance Metrics. *Procedia Environmental Sciences*, 26, 109-114.

Lu, B., Brunson, C., Charlton, M., & Harris, P. (2017). Geographically weighted regression with parameter-specific distance metrics. *International Journal of Geographical Information Science*, 31, 982-998.

### Examples

```
data(LondonHP)
EUDM <- gw.dist(coordinates(londonhp))
#No bandwidth is selected, and bws0 values are used
## Not run:
res1<- gwr.psdm(PURCHASE~FLOORSZ+PROF, data=londonhp, criterion="CVR",kernel="gaussian",
  adaptive=T, bws0=c(100, 100, 100),bw.seled=rep(T, 3), dMats=list(EUDM,EUDM,EUDM))
#FBGWR
res1<- gwr.psdm(PURCHASE~FLOORSZ+PROF, data=londonhp, criterion="dCVR",kernel="gaussian")
#Mixed GWR
res3<- gwr.psdm(PURCHASE~FLOORSZ+PROF, data=londonhp, bws0=c(Inf, 100, 100, Inf),
  bw.seled=rep(T, 3),kernel="gaussian", dMats=list(EUDM,EUDM,EUDM))
#PSDM GWR
res4<- gwr.psdm(PURCHASE~FLOORSZ+PROF, data=londonhp, kernel="gaussian", p.vals=c(1,2,3))

## End(Not run)
```

---

gwr.robust

*Robust GWR model*

---

### Description

This function implements two robust GWR models.

### Usage

```
gwr.robust(formula, data, bw,filtered=FALSE,
  kernel = "bisquare",adaptive = FALSE, p = 2,
  theta = 0, longlat = F, dMat, F123.test = F,
  maxiter=20,cut.filter= 3, cut1=2,cut2=3,delta=1.0e-5)
```

### Arguments

formula	Regression model formula of a <a href="#">formula</a> object
data	a <code>Spatial*DataFrame</code> , i.e. <code>SpatialPointsDataFrame</code> or <code>SpatialPolygonsDataFrame</code> as defined in package <code>sp</code>
bw	bandwidth used in the weighting function, possibly calculated by <a href="#">bw.gwr</a> ;fixed (distance) or adaptive bandwidth(number of nearest neighbours)
filtered	default FALSE, the automatic approach is used, if TRUE the filtered data approach is employed, as that described in Fotheringham et al. (2002 p.73-80)

kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
F123.test	default FALSE, otherwise calculate F-test results (Leung et al. 2000)
maxiter	default 20, maximum number of iterations for the automatic approach
cut.filter	If filtered is TRUE, it will be used as the residual cutoff for filtering data; default cutoff is 3
cut1	default 2, first cutoff for the residual weighting function. $wr(e)=1$ if $lel \leq cut1 * \sigma$
cut2	default 3, second cutoff for the residual weighting function. $wr(e)=(1-(lel-cut1)^2)^2$ if $cut1 * \sigma < lel < cut2 * \sigma$ , and $wr(e)=0$ if $lel \geq cut2 * \sigma$ ; cut 1 and cut2 refer to the automatic approach
delta	default 1.0e-5, tolerance of the iterative algorithm

## Value

A list of class “gwr”:

GW.arguments	a <b>list</b> class object including the model fitting parameters for generating the report file
GW.diagnostic	a <b>list</b> class object including the diagnostic information of the model fitting
lm	an object of class inheriting from “lm”, see <a href="#">lm</a> .
SDF	a <b>SpatialPointsDataFrame</b> (may be gridded) or <b>SpatialPolygonsDataFrame</b> object (see package “sp”) integrated with <code>fit.points,GWR</code> coefficient estimates, y value, predicted values, coefficient standard errors and t-values in its “data” slot. Notably, <code>E_weights</code> will be also included in the output SDF which represents the residual weighting when automatic approach is used; When the filtered approach is used, <code>E_weight</code> is a vector consisted of 0 and 1, where 0 means outlier to be excluded from calibration.
timings	starting and ending time.
this.call	the function call used.
Ftest.res	results of Leung’s F tests when <code>F123.test</code> is TRUE.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.

Harris P, Fotheringham AS, Juggins S (2010) Robust geographically weighed regression: a technique for quantifying spatial relationships between freshwater acidification critical loads and catchment attributes. *Annals of the Association of American Geographers* 100(2): 286-306

**Examples**

```
## Not run:
data(DubVoter)
bw.a <- bw.gwr(GenEl2004~DiffAdd+LAREnt+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64,
data=Dub.voter, approach="AICc", kernel="bisquare", adaptive=TRUE)
bw.a
gwr.res <- gwr.basic(GenEl2004~DiffAdd+LAREnt+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64,
data=Dub.voter, bw=bw.a, kernel="bisquare", adaptive=TRUE, F123.test=TRUE)
print(gwr.res)

# Map of the estimated coefficients for LowEduc
names(gwr.res$SDF)
if(require("RColorBrewer"))
{
  mypalette<-brewer.pal(6,"Spectral")
  X11(width=10,height=12)
  spplot(gwr.res$SDF,"LowEduc",key.space = "right",
col.regions=mypalette,at=c(-8,-6,-4,-2,0,2,4),
main="Basic GW regression coefficient estimates for LowEduc")
}
# Robust GW regression and map of the estimated coefficients for LowEduc
rgwr.res <- gwr.robust(GenEl2004~DiffAdd+LAREnt+SC1+Unempl+LowEduc+Age18_24
+Age25_44+Age45_64, data=Dub.voter, bw=bw.a, kernel="bisquare",
adaptive=TRUE, F123.test=TRUE)
print(rgwr.res)
if(require("RColorBrewer"))
{
  X11(width=10,height=12)
  spplot(rgwr.res$SDF, "LowEduc", key.space = "right",
col.regions=mypalette,at=c(-8,-6,-4,-2,0,2,4),
main="Robust GW regression coefficient estimates for LowEduc")
}

## End(Not run)
```

---

`gwr.t.adjust`*Adjust p-values for multiple hypothesis tests in basic GWR*

---

**Description**

Given a set of p-values from the pseudo t-tests of basic GWR outputs, this function returns adjusted p-values using: (a) Bonferroni, (b) Benjamini-Hochberg, (c) Benjamini-Yekutieli and (d) Fotheringham-Byrne procedures.

**Usage**

```
gwr.t.adjust(gwm.Obj)
```

**Arguments**

`gwm.Obj` an object of class “gwr”, returned by the function [gwr.basic](#)

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Byrne, G., Charlton, M. and Fotheringham, S., 2009. Multiple dependent hypothesis tests in geographically weighted regression. In: Lees, B. and Laffan, S. eds. 10th International conference on geocomputation. Sydney.

---

`gwr.write`*Write the GWR results into files*

---

**Description**

This function writes the calibration result of function [gwr.basic](#) to a text file and shape files

**Usage**

```
gwr.write(x, fn="GWRresults")  
gwr.write.shp(x, fn="GWRresults")
```

**Arguments**

`x` an object of class “gwr”, returned by the function [gwr.basic](#)  
`fn` file name for the written results, by default the output files can be found in the working directory, “GWRresults.txt”, “GWRresults(.shp, .shx, .dbf)”

**Note**

The projection file is missing for the written shapefiles.

The functions “writeGWR” and “writeGWR.shp” (in the early versions of GWmodel) have been renamed respectively as “gwr.write” and “gwr.write.shp”, while the old names are still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

gwss

*Geographically weighted summary statistics (GWSS)*

---

**Description**

This function calculates basic and robust GWSS. This includes geographically weighted means, standard deviations and skew. Robust alternatives include geographically weighted medians, inter-quartile ranges and quantile imbalances. This function also calculates basic geographically weighted covariances together with basic and robust geographically weighted correlations.

**Usage**

```
gwss(data, summary.locat, vars, kernel="bisquare", adaptive=FALSE, bw, p=2,
      theta=0, longlat=F, dMat, quantile=FALSE)
## S3 method for class 'gwss'
print(x, ...)
```

**Arguments**

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
summary.locat	a Spatial*DataFrame object for providing summary locations, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be summarized
bw	bandwidth used in the weighting function
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate an adaptive kernel where the bandwidth (bw) corresponds to the number of nearest neighbours (i.e. adaptive distance); default is FALSE, where a fixed kernel is found (bandwidth is a fixed distance)
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance

theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <code>gw.dist</code>
quantile	if TRUE, median, interquartile range, quantile imbalance will be calculated
x	an object of class "gwss", returned by the function <code>gwss</code>
...	arguments passed through (unused)

**Value**

A list of class "lss":

SDF	a <code>SpatialPointsDataFrame</code> (may be gridded) or <code>SpatialPolygonsDataFrame</code> object (see package "sp") with local means, local standard deviations, local variance, local skew, local coefficients of variation, local covariances, local correlations (Pearson's), local correlations (Spearman's), local medians, local interquartile ranges, local quantile imbalances and coordinates.
...	other information for reporting

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

Fotheringham S, Brunson, C, and Charlton, M (2002), *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*, Chichester: Wiley.

Brunson C, Fotheringham AS, Charlton ME (2002) Geographically weighted summary statistics - a framework for localised exploratory data analysis. *Computers, Environment and Urban Systems* 26:501-524

Harris P, Clarke A, Juggins S, Brunson C, Charlton M (2014) Geographically weighted methods and their use in network re-designs for environmental monitoring. *Stochastic Environmental Research and Risk Assessment* 28: 1869-1887

**Examples**

```
## Not run:
data(EWHP)
data(EWOutline)
head(ewhp)
houses.spdf <- SpatialPointsDataFrame(ewhp[, 1:2], ewhp)
localstats1 <- gwss(houses.spdf, vars = c("PurPrice", "FlrArea"), bw = 50000)
head(data.frame(localstats1$SDF))
localstats1
##A function for mapping data
if(require("RColorBrewer"))
{
  quick.map <- function(spdf,var,legend.title,main.title)
  {
```

```

x <- spdf@data[,var]
cut.vals <- pretty(x)
x.cut <- cut(x,cut.vals)
cut.levels <- levels(x.cut)
cut.band <- match(x.cut,cut.levels)
colors <- brewer.pal(length(cut.levels), "YlOrRd")
colors <- rev(colors)
par(mar=c(1,1,1,1))
plot(ewoutline,col="olivedrab",bg="lightblue1")
title(main.title)
plot(spdf,add=TRUE,col=colors[cut.band],pch=16)
legend("topleft",cut.levels,col=colors,pch=16,bty="n",title=legend.title)
}
quick.map(localstats1$SDF, "PurPrice_LM", "1000's Uk Pounds",
"Geographically Weighted Mean")
par(mfrow = c(1, 2))
quick.map(localstats1$SDF, "PurPrice_LSkE", "Skewness Level", "Local Skewness")
quick.map(localstats1$SDF, "PurPrice_LSD", "1000's Pounds", "Local Standard Deviation")
#Exploring Non-Stationarity of Relationships
quick.map(localstats1$SDF, "Corr_PurPrice.FlArea", expression(rho),
"Geographically Weighted Pearson Correlation")
#Robust, Quantile Based Local Summary Statistics
localstats2 <- gwss(houses.spdf, vars = c("PurPrice", "FlrArea"),
bw = 50000, quantile = TRUE)
quick.map(localstats2$SDF, "PurPrice_Median", "1000 UK Pounds",
"Geographically Weighted Median House Price")
}

## End(Not run)

```

---

gwss.montecarlo

*Monte Carlo (randomisation) test for gwss*


---

## Description

This function implements Monte Carlo (randomisation) tests for the GW summary statistics found in [gwss](#).

## Usage

```

gwss.montecarlo(data, vars, kernel = "bisquare",
                adaptive = FALSE, bw, p = 2, theta = 0, longlat = F,
                dMat, quantile=FALSE,nsim=99)

```

## Arguments

data	a Spatial*DataFrame, i.e. SpatialPointsDataFrame or SpatialPolygonsDataFrame as defined in package <b>sp</b>
vars	a vector of variable names to be summarized



bw	bandwidth used in the weighting function
kernel	function chosen as follows: gaussian: $wgt = \exp(-.5*(vdist/bw)^2)$ ; exponential: $wgt = \exp(-vdist/bw)$ ; bisquare: $wgt = (1-(vdist/bw)^2)^2$ if $vdist < bw$ , $wgt=0$ otherwise; tricube: $wgt = (1-(vdist/bw)^3)^3$ if $vdist < bw$ , $wgt=0$ otherwise; boxcar: $wgt=1$ if $dist < bw$ , $wgt=0$ otherwise
adaptive	if TRUE calculate the adaptive kernel, and bw correspond to the number of nearest neighbours, default is FALSE.
p	the power of the Minkowski distance, default is 2, i.e. the Euclidean distance
theta	an angle in radians to rotate the coordinate system, default is 0
longlat	if TRUE, great circle distances will be calculated
dMat	a pre-specified distance matrix, it can be calculated by the function <a href="#">gw.dist</a>
quantile	if TRUE, median, interquartile range, quantile imbalance will be calculated
nsim	default 99, the number of randomisations

**Value**

test	probability of the test statistics of the GW summary statistics; if $p < 0.025$ or if $p > 0.975$ then the true local summary statistics can be said to be significantly different (at the 0.95 level) to such a local summary statistics found by chance.
------	--

**Note**

The function “montecarlo.gwss” (in the early versions of GWmodel) has been renamed as “gwss.montecarlo”, while the old name is still kept valid.

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

**References**

- Fotheringham S, Brunson, C, and Charlton, M (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.
- Brunson C, Fotheringham AS, Charlton ME (2002) Geographically weighted summary statistics - a framework for localised exploratory data analysis. Computers, Environment and Urban Systems 26:501-524
- Harris P, Brunson C (2010) Exploring spatial variation and spatial relationships in a freshwater acidification critical load data set for Great Britain using geographically weighted summary statistics. Computers & Geosciences 36:54-70

**Examples**

```
## Not run:
data(LondonHP)
DM<-gw.dist(dp.locat=coordinates(londonhp))
test.lss<-gwss.montecarlo(data=londonhp, vars=c("PURCHASE","FLOORSZ"), bw=5000,
  kernel ="gaussian", dMat=DM,nsim=99)
test.lss

## End(Not run)
```

---

LondonBorough	<i>London boroughs data</i>
---------------	-----------------------------

---

**Description**

Outline (SpatialPolygonsDataFrame) of London boroughs for the [LondonHP](#) data.

**Usage**

```
data(LondonBorough)
```

**Author(s)**

Binbin Lu <binbinlu@whu.edu.cn>

---

LondonHP	<i>London house price data set (SpatialPointsDataFrame)</i>
----------	---

---

**Description**

A house price data set with 18 hedonic variables for London in 2001.

**Usage**

```
data(LondonHP)
```

**Format**

A SpatialPointsDataFrame object (proj4string set to "+init=epsg:27700 +datum=OSGB36").

The "data" slot is a data frame with 372 observations on the following 21 variables.

**X** a numeric vector, X coordinate

**Y** a numeric vector, Y coordinate

**PURCHASE** a numeric vector, the purchase price of the property

**FLOORSZ** a numeric vector, floor area of the property in square metres

- TYPEDETC** a numeric vector, 1 if the property is detached (i.e. it is a stand-alone house), 0 otherwise
- TPSEMIDTCH** a numeric vector, 1 if the property is semi detached, 0 otherwise
- TYPETRRD** a numeric vector, 1 if the property is in a terrace of similar houses (commonly referred to as a 'row house' in the USA), 0 otherwise
- TYPEBNGLW** a numeric vector, 1 if the property is a bungalow (i.e. it has only one floor), 0 otherwise
- TYPEFLAT** a numeric vector, 1 if the property is a flat (or 'apartment' in the USA), 0 otherwise
- BLDPWW1** a numeric vector, 1 if the property was built prior to 1914, 0 otherwise
- BLDPOSTW** a numeric vector, 1 if the property was built between 1940 and 1959, 0 otherwise
- BLD60S** a numeric vector, 1 if the property was built between 1960 and 1969, 0 otherwise
- BLD70S** a numeric vector, 1 if the property was built between 1970 and 1979, 0 otherwise
- BLD80S** a numeric vector, 1 if the property was built between 1980 and 1989, 0 otherwise
- BLD90S** a numeric vector, 1 if the property was built between 1990 and 2000, 0 otherwise
- BATH2** a numeric vector, 1 if the property has more than 2 bathrooms, 0 otherwise
- GARAGE** a numeric vector, 1 if the house has a garage, 0 otherwise
- CENTHEAT** a numeric vector, 1 if the house has central heating, 0 otherwise
- BEDS2** a numeric vector, 1 if the property has more than 2 bedrooms, 0 otherwise
- UNEMPLOY** a numeric vector, the rate of unemployment in the census ward in which the house is located
- PROF** a numeric vector, the proportion of the workforce in professional or managerial occupations in the census ward in which the house is located

### Author(s)

Binbin Lu <binbinlu@whu.edu.cn>

### References

- Fotheringham, A.S., Brunson, C., and Charlton, M.E. (2002), Geographically Weighted Regression: The Analysis of Spatially Varying Relationships, Chichester: Wiley.
- Lu, B, Charlton, M, Harris, P, Fotheringham, AS (2014) Geographically weighted regression with a non-Euclidean distance metric: a case study using hedonic house price data. International Journal of Geographical Information Science 28(4): 660-681

### Examples

```
data(LondonHP)
data(LondonBorough)
ls()
plot(londonborough)
plot(londonhp, add=TRUE)
```

---

USelect	<i>Results of the 2004 US presidential election at the county level (SpatialPolygonsDataFrame)</i>
---------	--

---

### Description

Results of the 2004 US presidential election at the county level, together with five socio-economic (census) variables. This data can be used with GW Discriminant Analysis.

### Usage

```
data(USelect)
```

### Format

A SpatialPolygonsDataFrame with 3111 electoral divisions on the following 6 variables.

**winner** Categorical variable with three classes: i) Bush, ii) Kerry and iii) Borderline (supporting ratio for a candidate ranges from 0.45 to 0.55)

**unemploy** percentage unemployed

**pctcoled** percentage of adults over 25 with 4 or more years of college education

**PEROVER65** percentage of persons over the age of 65

**pcturban** percentage urban

**WHITE** percentage white

### References

Robinson, A. C. (2013). Geovisualization of the 2004 Presidential Election. In: NATIONAL INSTITUTES OF HEALTH, P. S. U. (ed.). Penn State: <http://www.personal.psu.edu/users/a/c/acr181/election.html>.

Foley, P. & Demsar, U. (2012). Using geovisual analytics to compare the performance of geographically weighted discriminant analysis versus its global counterpart, linear discriminant analysis. International Journal of Geographical Information Science, 27, 633-661.

### Examples

```
data(USelect)  
ls()
```

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