Geostatistics examples in R: ordinary kriging, universal kriging and inverse distance weighted

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1 author:

Fernando Antonanzas
Universidad de La Rioja (Spain)

Geostatistics examples in R: ordinary kriging, universal kriging and inverse distance weighted

F. Antonanzas-Torres*
Edmans Group
ETSII, University of La Rioja, Logroño, Spain

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Techniques described in this paper have been implemented using the free software environment `R` [R Development Core Team, 2013] and various contributed packages:

- `raster` [Hijmans and van Etten, 2013] for spatial data manipulation and analysis.
- `gstat` [Pebesma and Graeler, 2013] and `sp` [Pebesma et al., 2013] for geostatistical analysis.
- `rasterVis` [Perpinan-Lamigueiro and Hijmans, 2013] for spatial data visualization methods.

For a wide explanation on the basis of geo-statistics, the author refers to [Hengl, 2009]. Other applied examples with free `R` code and data are provided in [Antonanzas-Torres et al., 2013, 2014]. Hereinafter, I will explain basic concepts with examples for beginners in this matter.

1 Ordinary kriging

Kriging in general is based on the spatial variance of a variable. This spatial variance is modeled throughout the variogram, which represents the semi-variances along distance. Since, semi-variances are represented as points in the variogram, it is necessary to model these points with simple models to describe the variation with distance. Different variogram models have been proposed (pure nugget- in which variance is independent of distance, spherical- in which variance has a nugget value-variance inherent to each measure and also a sill- distance from which model variance behaves as pure nugget, Gaussian, exponential, etc.).

In this case, if we think of a variable such as rainfall and we have records in different meteorological stations, a pure nugget variogram indicates variance of rain between

*Corresponding author: antonanzas.fernando@gmail.com

stations is independent on the distance between these station, no matter the distance between them. However, a spherical variogram shows that as we get further in distance from the station the variance increases based on a spherical model.

1.1 Example

```
## load data available at https://github.com/EDMANSolar/downscaling/blob/master
    /Stations.RData
R> load('Stations.RData')

## where GHImed is the variable measured and known.
R> UTM <- SpatialPointsDataFrame(Stations[,c(2,3)], Stations[,-c(2,3)],
                        proj4string=CRS('+proj=utm␣+zone=30␣+ellps=WGS84'))

## we do the variogram
R> vgm_ok <- variogram(GHImed~1, UTM)

## we fit the variogram with a spheric model as an example.
R> fitvgm_ok <- fit.variogram(vgm_ok, vgm(12000, "Sph", 20000, nugget= 5000))
R> plot(vgm_ok, model=fitvgm_ok, as.table=TRUE)

## using the gstat function we create the spatial model.
R> gModel_ok <- gstat(NULL, id='G0yKrig_ok',
             formula= GHImed ~ 1,
             locations=UTM, model=fitvgm_ok)

## load of the spatial grid to perform the kriging from
## https://github.com/EDMANSolar/downscaling/tree/master/data
GHI2005a<-raster('GHI2005a')

## interpolation and mapping
R> G0y_ok <- interpolate(GHI2005a, gModel_ok, xyOnly=FALSE)
R> levelplot(G0y_ok)
```

2 Universal kriging

The universal kriging, also denoted as kriging with external drift is useful when the variable to map is related to other spatially known variables. One example could be measurements of temperatures, which are commonly related to elevation (at a known rate of °C by m difference). By means of digital elevation model (our explicative variable) we could map temperatures with universal kriging. For other examples of universal kriging the author refers to previous works on solar mapping [Antonanzas-Torres et al., 2013, 2014].

2.1 Example

```
## we do the variogram of the variable measured (GHImed) with the explicative
    variable (GHIcmsaf).
R> vgmCMSAF <- variogram(GHImed~GHIcmsaf, UTM)

## the variogram is adjusted with a pure nugget model as example.
R> fitvgmCMSAF <- fit.variogram(vgmCMSAF, vgm(model='Nug'))
R> plot(vgmCMSAF, model=fitvgmCMSAF, as.table=TRUE)

## the model is performed for universal kriging.
R> gModel <- gstat(NULL, id='G0yKrig',
             formula= GHImed ~ GHIcmsaf,
             locations=UTM, model=fitvgmCMSAF)

## we load the explicative variable spatially known.
R> names(GHI2005a) <- 'GHIcmsaf'

## interpolation
R> G0y_uk <- interpolate(GHI2005a, gModel, xyOnly=FALSE)
R> levelplot(G0y_uk)
```

3 Inverse distance weighted

This technique is not widely used for its simplicity although not being a kriging technique. Variance decays inversally to the distance with a weight factor denoted as `idp`.

3.1 Example

```
## the weight factor is set to 0.5.
R> gModel_idw <- gstat(NULL, id='G0yKrig_idw',
               formula= GHImed ~ 1,set=list(idp = .5),
               locations=UTM)

## interpolation in the spatial grid of GHI2005a
R> G0y_idw <- interpolate(GHI2005a, gModel_idw)

## plot the map
levelplot(G0y_idw)
```

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