GRTS
Generalized Random Tessellation Stratified Sampling using the spsurvey package in R.

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Why

• Simple Random Sample designs can produce clumped sample points.
• First n sample points are spread out through sample area.
• GRTS is spatially balanced – sample points mimic the spatial density of the sampled resource (sample frame).
Data Types

• Can be used with:
  – Point Data (ex. Ponds)
  – Linear Data (ex. Streams)
  – Area Data (ex. Vegetation Types)
Tessellation

Repetition of a geometric shape with no overlaps or gaps - tiling

http://en.wikipedia.org/wiki/Tessellation
How it Works – Area Sample

Study Area is Tessellated in a regular grid. Each grid is assigned an identifier according to the hierarchical grid numbering. The grid ID is in a base four numbering system.

Figure 1. First Four Levels of a Quadrant-Recursive Partitioning of the Unit Square. The address associated with the cross-hatched cell is 213.

Reverse Hierarchical Order

<table>
<thead>
<tr>
<th>Original Order</th>
<th>Original order arranged by the base 4 ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<tr>
<td>15</td>
<td>32</td>
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<tr>
<td>16</td>
<td>33</td>
</tr>
</tbody>
</table>

Reverse the address:

<table>
<thead>
<tr>
<th>Original Order</th>
<th>Reversed ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>15</td>
<td>23</td>
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<td>16</td>
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</tbody>
</table>

Reorder:

<table>
<thead>
<tr>
<th>Original Order</th>
<th>Reversed ID</th>
<th>New Order</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
</tr>
<tr>
<td>2</td>
<td>01</td>
<td>2</td>
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<td>11</td>
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<td>16</td>
<td>33</td>
<td>16</td>
</tr>
</tbody>
</table>

- Then select sample sites as needed from the newly ordered set of sites. This is the process that produced the spatially balanced selection of sample sites.
• The reverse hierarchical series is mapped to 2 dimensions, then samples are selected via a systematic random sample.

• Strata can be given different selection probabilities by changing the length in 2D space.
To use GRTS you need:

- A .shp file of your study site (or a sp.object)
- R
- The spsurvey package


Note - There are other ways to run GRTS, but this is probably the easiest.
Single Strata Example

- You don’t have to have a stratified design to use GRTS – just run with one strata
seltype

• "Equal" selects all locations with equal probability.
• "Unequal" selects elements with equal probability within each category/strata
• "Continuous" selects elements with unequal probabilities proportional to continuous variables.
Unstratified, Equal Probability, GRTS Survey

```
library (spsurvey)

att = read.dbf("Utah")  #read attribute file of the shape file used to bound the study area
head (att)  # display the attribute file in R

# this code is sampling for only one real strata, the shape file is made up of multiple polygons
# (fragmented strata). If each polygon represented a different strata the code could be changed to reflect

Equaldsgn <- list(None=list
                 (panel=c(PanelOne=40),
                  over = 20,
                  seltype='Equal')
                 )

# a list named "None" that contains:
# panelOne => number of samples
# over => over sample, ie 20 extra points
# equal probability sample

seed <- sample(1000000000,1)  # run to get random seed
set.seed(seed)

Equalsites <- grts(design=Equaldsgn,
                 src.frame='shapefile',  # the sample frame is coming from a shape file
                 in.shape='Utah',  # the shape file used is poly_sage.shp
                 att.frame=att,  # attribute data frame
                 type.frame='area',  # type - area vs linear
                 DesignID='Sample',  # the prefix for each point name
                 shapefile=TRUE,  # output a shape file
                 prj='Utah',  # projection to use for the shape file - same as listed file
                 out.shape="UT_pts"  # name of output shape file
                   )
```
Unstratified, Equal Probability, GRTS Survey
Unstratified, Unequal Probability GRTS Survey Design

```r
att = read.dbf("FourCorrners")  # read attribute file of the shape file used to bound the study area
head(att)

Unequaldsgn <- list(None=list(panel=c(PanOne=90),
                          seltyp="Unequal",
                          caty.n=c("Arizona"=50,
                                    "Colorado"=25,
                                    "New Mexico"=10,
                                    "Utah"=5),
                      )

# Select the sample
Unequalsites <- g rtns(design=Unequaldsgn,
                       DesignID="UNEQUAL",
                       type.frame="area",
                       src.frame="shapefile",
                       in.shape="FourCorrners",
                       att.frame=att,
                       mdcaty="NAME",
                       shapefile=TRUE,
                       prj="FourCorrners",
                       out.shape="FourCorrner_pts"
)
```

# the grts call will reference the Unequaldsgn object
# unequal prob in each category
# area vs. linear or point
# spatial data to be imported from a .shp
# the shape file
# attribute data.frame
# the column in the .dbf file that has the categories
# output a shape file
# projection to use for the shape file - same as listed file
# name of output shape file
Unstratified, Unequal Probability GRTS Survey Design
Stratified, Equal Probability, GRTS Survey Design

```
att = read.dbf("FourCorrners")  # read attribute file of the shape file used to bound the study area
head (att)

Stratdsgn <- list("Arizona"=list(panel=c(PanelOne=25),
                              seltype="Equal"),
                  "Colorado"=list(panel=c(PanelOne=25),
                               seltype="Equal"),
                  "New Mexico"=list(panel=c(PanelOne=10),
                                     seltype="Equal"),
                  "Utah"=list(panel=c(PanelOne=10),
                               seltype="Equal"))

# Select the sample
Stratsites <- grts(design=Stratdsgn,
                    DesignID="STRATIFIED",
                    type.frame="area",
                    src.frame="shapefile",
                    in.shape="FourCorrners",
                    att.frame=att,
                    stratum="NAME",      # col containing stratum in .dbf
                    shapefile=TRUE,      # output a shape file
                    prj="FourCorrners", # projection to use for the shape file - same as listed file
                    out.shape="FourCorStrat_pts"
)
```
Stratified, Equal Probability, GRTS Survey Design
Messy Study Area...
Unstratified, Equal Probability, GRTS Survey

```r
att = read.dbf("poly_sage")  # read attribute file
head(att)  # display the attribute file

Equaldsgn <- list(None=list(panel=c(PanelOne=115),
               over = 50,
               seltype='Equal')
               )

seed <- sample(1000000000,1)  # run to get random seed
set.seed(seed)

Equalsites <- grts(design=Equaldsgn,
                src.frame='shapefile',
in.shape='poly_sage',
att.frame=att,
type.frame='area',
DesignID='Sage',
shapefile=TRUE,
prj='poly_sage',
out.shape='SB_Sample' )
```
Additional Resources

Tutorial:

Another good overview of GRTS:
Philippi, Tom. Topic 2(b) GRTS Spatial Sampling (for Monitoring), NPS Inventory and Monitoring, https://science.nature.nps.gov/im/datamgmt/statistics/r/advanced/grts.cfm#grts

More Examples:
From the US EPA - Specific Design Information - Illustrative Examples
http://www.epa.gov/nheerl/arm/designing/design_intro.htm

Package Documentation:

The theory behind it: