Package ‘BalancedSampling’

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Title Balanced and Spatially Balanced Sampling

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Description Select balanced and spatially balanced probability samples in multi-dimensional spaces with any prescribed inclusion probabilities. It contains fast (C++ via Rcpp) implementations of the included sampling methods. The local pivotal method by Grafström, Lundström and Schelin (2012) <doi:10.1111/j.1541-0420.2011.01699.x> and spatially correlated Poisson sampling by Grafström (2012) <doi:10.1016/j.jspi.2011.07.003> are included. Also the cube method (for balanced sampling) and the local cube method (for doubly balanced sampling) are included, see Grafström and Tillé (2013) <doi:10.1002/env.2194>.

License GPL (>= 2)

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`BalancedSampling-package` *Balanced and Spatially Balanced Sampling*

Description

Select balanced and spatially balanced probability samples in multi-dimensional spaces with any prescribed inclusion probabilities. It contains fast (C++ via Rcpp) implementations of the included sampling methods. The local pivotal method by Grafström, Lundström and Schelin (2012) and spatially correlated Poisson sampling by Grafström (2012) are included. Also the cube method (for balanced sampling) and the local cube method (for doubly balanced sampling) are included, see Grafström and Tillé (2013).

Author(s)

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References

Deville, J. C. and Tillé, Y. (2004). Efficient balanced sampling: the cube method. Biometrika, 91(4), 893-912.

Deville, J.-C. and Tillé, Y. (1998). Unequal probability sampling without replacement through a splitting method. Biometrika 85, 89-101.

Grafström, A. (2012). Spatially correlated Poisson sampling. Journal of Statistical Planning and Inference, 142(1), 139-147.

Grafström, A. and Lundström, N.L.P. (2013). Why well spread probability samples are balanced. Open Journal of Statistics, 3(1).

Grafström, A. and Schelin, L. (2014). How to select representative samples. Scandinavian Journal of Statistics.

Grafström, A., Lundström, N.L.P. and Schelin, L. (2012). Spatially balanced sampling through the Pivotal method. Biometrics 68(2), 514-520.

Grafström, A. and Tillé, Y. (2013). Doubly balanced spatial sampling with spreading and restitution of auxiliary totals. Environmetrics, 24(2), 120-131.

Examples

```
# ********************************************************
# check inclusion probabilities
# ********************************************************
set.seed(1234567);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9);
N = length(p);
X = cbind(runif(N),runif(N));
p1 = p2 = p3 = p4 = rep(0,N);
nrs = 1000; # increase for more precision
for(i in 1:nrs){
  # lpm1
  s = lpm1(p,X);
  p1[s]=p1[s]+1;

  # lpm2
  s = lpm2(p,X);
  p2[s]=p2[s]+1;

  # scps
  s = scps(p,X);
  p3[s]=p3[s]+1;

  # lcube
  s = lcube(p,X,cbind(p));
  p4[s]=p4[s]+1;
}
print(p);
print(p1/nrs);
print(p2/nrs);
print(p3/nrs);
print(p4/nrs);

# ********************************************************
# check spatial balance
# ********************************************************
set.seed(1234567);
N = 500;
n = 70;
p = rep(n/N,N);
X = cbind(runif(N),runif(N));
```

```
nrs = 10; # increase for more precision
b1 = b2 = b3 = b4 = b5 = rep(0,nrs);

for(i in 1:nrs){
  # lpm1
  s = lpm1(p,X);
  b1[i] = sb(p,X,s);

  # lpm2
  s = lpm2(p,X);
  b2[i] = sb(p,X,s);

  # scps
  s = scps(p,X);
  b3[i] = sb(p,X,s);

  # lcube
  s = lcube(p,X,cbind(p));
  b4[i] = sb(p,X,s);

  # srs
  s = sample(N,n);
  b5[i] = sb(p,X,s);
}
print(mean(b1));
print(mean(b2));
print(mean(b3));
print(mean(b4));
print(mean(b5));

# *********************************************************
# stratification
# *********************************************************
set.seed(1234567);
N = 10;
n = 4;
p = rep(n/N,N);
stratum1 = c(1,1,1,1,1,0,0,0,0,0); # stratum 1 indicator
stratum2 = c(0,0,0,0,0,1,1,1,1,1); # stratum 2 indicator
stratum3 = c(0,0,1,1,1,1,1,0,0,0); # overlapping 1 and 2
s = lpm1(p,cbind(stratum1,stratum2,stratum3));

# *********************************************************
# plot spatially balanced sample
# *********************************************************
set.seed(1234567);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
s = lpm1(p,X); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample
```

```
# *********************************************************
# check cpu time (for simulation)
# *********************************************************
set.seed(1234567);
N = 2000;
n = 100;
X = cbind(runif(N),runif(N));
p = rep(n/N,N);
system.time(for(i in 1:10){lpm1(p,X)});
system.time(for(i in 1:10){lpm2(p,X)});
```

---

cube *Cube method (Balanced sampling)*

Description

This is a fast implementation of the cube method. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer. Landing is done by dropping balancing variables (from rightmost column, so keep inclusion probabilities in first column to guarantee fixed size).

Usage

```
cube(prob,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns

Value

Returns a vector of selected indexes in 1,2,...,N.

References

Deville, J. C. and Tillé, Y. (2004). Efficient balanced sampling: the cube method. Biometrika, 91(4), 893-912.

Chauvet, G. and Tillé, Y. (2006). A fast algorithm for balanced sampling. Computational Statistics, 21(1), 53-62.

Examples

```
## Not run:
# Example 1
# Select sample
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(p,runif(N),runif(N)); # matrix of auxiliary variables
s = cube(p,X); # select sample


# Example 2
# Check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = cube(p,cbind(p));
  ep[s]=ep[s]+1;
}
print(ep/nrs);

# Example 3
# How fast is it?
# Let's check with N = 100 000 and 5 balancing variables
set.seed(12345);
N = 100000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
# matrix of 5 auxiliary variables
X = cbind(p,runif(N),runif(N),runif(N),runif(N));
system.time(cube(p,X));

## End(Not run)
```

`cubestratified` *Stratified balanced sampling with pooling of landing phases*

Description

This is a fast implementation of stratified balanced sampling. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer (within each stratum).

Usage

```
cubestratified(prob,Xbal,integerStrata)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns
`integerStrata`	vector of length N with stratum number

Value

Returns a vector of length N with sampling indicators.

References

Chauvet, G. (2009). Stratified balanced sampling. Survey Methodology, 35, 115-119.

Examples

```
## Not run:
# Example 1
N = 10;
n = 5;
p = rep(n/N,N);
strata = c(1,1,2,2,3,3,4,4,5,5);
indicators = cubestratified(p,cbind(p),strata);
s = (1:N)[indicators==1];

## End(Not run)
```

`flightphase` *Flight phase of the cube method*

Description

This is a fast implementation of the flight phase of the cube method. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer.

Usage

```
flightphase(prob,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xbal`	matrix of balancing auxiliary variables of N rows and q columns

Value

Returns a vector of length N with new probabilities, where at most q are non-integer.

References

Deville, J. C. and Tillé, Y. (2004). Efficient balanced sampling: the cube method. Biometrika, 91(4), 893-912.

Chauvet, G. and Tillé, Y. (2006). A fast algorithm for balanced sampling. Computational Statistics, 21(1), 53-62.

Examples

```
## Not run:
# Example 1
# Select sample and check balance
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(p,runif(N),runif(N)); # matrix of auxiliary variables

pflight = flightphase(p,X);

# check balance after flight
colSums(X)
colSums(X/p*pflight)

# select final sample as indicators
indicators = landingphase(p,pflight,X);

# check final balance
colSums(X)
colSums(X/p*indicators)

# final sample as indexes
s = (1:N)[indicators==1];

## End(Not run)
```

`hlpm` *Hierarchical local pivotal method*

Description

Hierarchical local pivotal method (hlpm) selects an initial sample using the local pivotal method and then splits the sample into subsamples of given sizes using a successive (hierarchical) selection with the local pivotal method. Can be used with any prescribed inclusion probabilities that sum to an integer n. The sizes of the subsamples must also sum to n. It is used to select several subsamples such that each subsample is spatially balanced and the combined sample (the union of the subsamples) is also spatially balanced. Licence (GPL >=2).

Usage

```
hlpm(p,X,sizes)
```

Arguments

`p`	vector of inclusion probabilities for initial sample.
`X`	matrix of auxiliary variables.
`sizes`	vector of sizes of subsamples whose sum must match the sum of the initial inclusion probabilities.

Value

Returns a list with population indexes of initial sample S and a vector sampleNumber indicating the number of the subsample of each unit.

Examples

```
## Not run:
############
## Example with two subsamples
############

N = 100; # population size
X = cbind(runif(N),runif(N)); # auxiliary variables
n = 10; # size of initial sample
p = rep(n/N,N); # inclusion probabilities of initial sample
sizes = c(7,3); # sizes of the two subsamples
hlpm(p,X,sizes) # selection of samples using hierarchical local pivotal method


## End(Not run)
```

`landingphase` *Landing phase of the cube method*

Description

Landing is done by dropping balancing variables (from rightmost column).

Usage

```
landingphase(prob,probflight,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`probflight`	vector of length N obtained from the flightphase
`Xbal`	matrix of balancing auxiliary variables of N rows and q columns

Value

Returns a vector of length N with inclusion indicators.

References

Deville, J. C. and Tillé, Y. (2004). Efficient balanced sampling: the cube method. Biometrika, 91(4), 893-912.

Chauvet, G. and Tillé, Y. (2006). A fast algorithm for balanced sampling. Computational Statistics, 21(1), 53-62.

Examples

```
## Not run:
# Example 1
# Select sample
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(p,runif(N),runif(N)); # matrix of auxiliary variables
pflight = flightphase(p,X); # flight
indicators = landingphase(p,pflight,X); # landing
# final sample
s = (1:N)[indicators==1];

## End(Not run)
```

`lcps` *Locally correlated Poisson samling*

Description

Selects spatially balanced sampling with prescribed inclusion probabilites from a finite population using Locally correlated Poisson sampling, a variant of SCPS (`scps()`).

Usage

```
lcps(prob, x)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`x`	matrix of (standardized) auxiliary variables of N rows and q columns

Details

`lcps` uses euclidean distance on auxiiary variables to calculate distance between units.

Value

Returns a vector of selected indices in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Prentius, W. (2022). Locally correlated Poisson sampling. Manuscript.

Examples

```
## Not run:
  N = 1000L; # size of the population
  prob = runif(N, 0.1, 0.3); # Inclusion probabilities
  x = matrix(rnorm(3*N), ncol = 3L); # N * 3 matrix of auxiliary variables
  s = lcps(prob, x); # sample indices

## End(Not run)
```

---

lcube *Local cube method (Doubly balanced sampling)*

Description

Select doubly balanced samples with prescribed inclusion probabilities from a finite population. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer. This is a simplified (optimized for speed) implementation of the local cube method (doubly balanced sampling). Landing is done by dropping balancing variables (from rightmost column, so keep inclusion probabilities in first column to guarantee fixed size). Euclidean distance is used in the `Xspread` space.

Usage

```
lcube(prob,Xspread,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xspread`	matrix of (standardized) auxiliary variables of N rows and q columns
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns

Value

Returns a vector of selected indexes in 1,2,...,N.

References

Grafström, A. and Tillé, Y. (2013). Doubly balanced spatial sampling with spreading and restitution of auxiliary totals. Environmetrics, 24(2), 120-131.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
s = lcube(p,X,cbind(p)); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
X = cbind(runif(N),runif(N)); # some artificial auxiliary variables
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = lcube(p,X,cbind(p));
  ep[s]=ep[s]+1;
}
print(ep/nrs);


## End(Not run)
```

`lcubeflightphase` *Flight phase for the local cube method*

Description

Flight phase for the local cube method. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer. This is a simplified (optimized for speed) implementation of the flight phase of the local cube method (doubly balanced sampling). Euclidean distance is used in the `Xspread` space.

Usage

```
lcubeflightphase(prob,Xspread,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xspread`	matrix of (standardized) auxiliary variables of N rows and q columns
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns

Value

Returns a vector of length N with new probabilities, where at most r are non-integer.

References

Grafström, A. and Tillé, Y. (2013). Doubly balanced spatial sampling with spreading and restitution of auxiliary totals. Environmetrics, 24(2), 120-131.

Examples

```
## Not run:
# Example 1
# Select sample
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
pflight = lcubeflightphase(p,X,cbind(p,X));
# check balance
colSums(X)
colSums(X/p*pflight)


## End(Not run)
```

lcubelandingphase *Landing phase for the local cube method*

Description

Landing is done by dropping balancing variables (from rightmost column). Euclidean distance is used in the `Xspread` space.

Usage

```
lcubelandingphase(prob,probflight,Xspread,Xbal)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`probflight`	vector of length N with probabilities from flightphase
`Xspread`	matrix of (standardized) auxiliary variables of N rows and q columns
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns

Value

Returns a vector of length N with indicators.

References

Grafström, A. and Tillé, Y. (2013). Doubly balanced spatial sampling with spreading and restitution of auxiliary totals. Environmetrics, 24(2), 120-131.

Examples

```
## Not run:
# Example 1
# Select sample
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
pflight = lcubeflightphase(p,X,cbind(p,X)); # flight
indicators = lcubelandingphase(p,pflight,X,cbind(p,X)); # landing
# final sample
s = (1:N)[indicators==1];

## End(Not run)
```

`lcubestratified` *Stratified doubly balanced sampling with pooling of landing phases*

Description

This is a fast implementation of stratified doubly balanced sampling. To have a fixed sample size, include the inclusion probabilities as a balancing variable in `Xbal` and make sure the inclusion probabilities sum to a positive integer (within each stratum). Euclidean distance is used in the `Xspread` space.

Usage

```
lcubestratified(prob,Xspread,Xbal,integerStrata)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`Xspread`	matrix of (standardized) auxiliary variables of N rows and q columns
`Xbal`	matrix of balancing auxiliary variables of N rows and r columns
`integerStrata`	vector of length N with stratum number

Value

Returns a vector of length N with sampling indicators.

References

Chauvet, G. (2009). Stratified balanced sampling. Survey Methodology, 35, 115-119.

Grafström, A. and Tillé, Y. (2013). Doubly balanced spatial sampling with spreading and restitution of auxiliary totals. Environmetrics, 24(2), 120-131.

Examples

```
## Not run:
# Example 1
N = 10;
n = 5;
p = rep(n/N,N);
Xspread = cbind(1:N);
strata = c(1,1,1,1,1,1,2,2,2,2);
indicators = lcubestratified(p,Xspread,cbind(p),strata);
s = (1:N)[indicators==1];

## End(Not run)
```

`lpm` *Local pivotal method (sub-optimal)*

Description

Select spatially balanced samples with prescribed inclusion probabilities from a finite (large) population using a sub-optimal implementation of the local pivotal method. Euclidean distance is used in the `x` space.

Usage

```
lpm(prob,x,h)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`x`	matrix of (standardized) auxiliary variables of N rows and q columns
`h`	positive integer, size of window in the list to search for nearest neighbor

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
h = 100; # size of search window (for finding nearest neighbor)
s = lpm(p,X,h); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
X = cbind(runif(N),runif(N)); # some artificial auxiliary variables
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = lpm(p,X,10);
  ep[s]=ep[s]+1;
}
print(ep/nrs);

## End(Not run)
```

---

lpm1 *Local pivotal method 1*

Description

Select spatially balanced samples with prescribed inclusion probabilities from a finite population. Euclidean distance is used in the x space.

Usage

```
lpm1(prob,x)
```

Arguments

prob	vector of length N with inclusion probabilities
x	matrix of (standardized) auxiliary variables of N rows and q columns

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Grafström, A., Lundström, N.L.P. and Schelin, L. (2012). Spatially balanced sampling through the Pivotal method. Biometrics 68(2), 514-520.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
s = lpm1(p,X); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
X = cbind(runif(N),runif(N)); # some artificial auxiliary variables
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = lpm1(p,X);
  ep[s]=ep[s]+1;
}
print(ep/nrs);

## End(Not run)
```

`lpm2` *Local pivotal method 2*

Description

Select spatially balanced samples with prescribed inclusion probabilities from a finite population. Euclidean distance is used in the `x` space.

Usage

```
lpm2(prob,x)
```

Arguments

prob	vector of length N with inclusion probabilities
x	matrix of (standardized) auxiliary variables of N rows and q columns

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Grafström, A., Lundström, N.L.P. and Schelin, L. (2012). Spatially balanced sampling through the Pivotal method. Biometrics 68(2), 514-520.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
s = lpm2(p,X); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
X = cbind(runif(N),runif(N)); # some artificial auxiliary variables
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = lpm2(p,X);
  ep[s]=ep[s]+1;
}
print(ep/nrs);


## End(Not run)
```

`probabilities` *Inclusion probabilities*

Description

Computes the first-order inclusion probabilities from a vector of positive numbers (for a probability proportional-to-size sampling design). This function is borrowed from the package "sampling" by Alina Matei and Yves Tillé. Licence (GPL >=2).

Usage

```
probabilities(a,n)
```

Arguments

a	vector of positive numbers
n	sample size

Examples

```
## Not run:
############
## Example
############
# a vector of positive numbers
a=1:20
# computation of the inclusion probabilities for a sample size n=12
pik=probabilities(a,12)
pik

## End(Not run)
```

---

rpm *Random pivotal method*

Description

Select samples with prescribed inclusion probabilities from a finite population. This design has high entropy. In each of the (at most) N steps, two undecided units are selected at random to compete.

Usage

```
rpm(prob)
```

Arguments

prob	vector of length N with inclusion probabilities

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
s = rpm(p); # select sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = rpm(p);
  ep[s]=ep[s]+1;
}
print(ep/nrs);

## End(Not run)
```

---

sb *Spatial balance*

Description

Calculates spatial balance of a sample subject to inclusion probabilities and auxiliary space

Usage

```
sb(p,x,s)
```

Arguments

p	vector of length N with inclusion probabilities
x	matrix of (standardized) auxiliary variables of N rows and q columns
s	the sample, vector of length n

Value

Number, the spatial balance

References

Grafström, A., Lundström, N.L.P. and Schelin, L. (2012). Spatially balanced sampling through the Pivotal method. Biometrics 68(2), 514-520.

Examples

```
## Not run:
# check spatial balance
set.seed(1234567);
N = 500;
n = 70;
p = rep(n/N,N);
X = cbind(runif(N),runif(N));

# select lpm1 sample
s = lpm1(p,X);
# calculate balance
B = sb(p,X,s);


## End(Not run)
```

`scps` *Spatially correlated Poisson sampling*

Description

Select spatially balanced samples with prescribed inclusion probabilities from a finite population. This implementation uses the maximal weight strategy and Euclidean distance.

Usage

```
scps(prob,x)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`x`	matrix of (standardized) auxiliary variables of N rows and q columns

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Grafström, A. (2012). Spatially correlated Poisson sampling. Journal of Statistical Planning and Inference, 142(1), 139-147.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
s = scps(p,X); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
N = length(p); # population size
X = cbind(runif(N),runif(N)); # some artificial auxiliary variables
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = scps(p,X);
  ep[s]=ep[s]+1;
}
print(ep/nrs);

## End(Not run)
```

---

scps_coord *Spatially correlated Poisson sampling with coordination*

Description

Select spatially balanced samples with prescribed inclusion probabilities from a finite population. This implementation uses the maximal weight strategy and Euclidean distance. To be used with permanent random numbers.

Usage

```
scps_coord(prob,x,rand)
```

Arguments

prob	vector of length N with inclusion probabilities
x	matrix of (standardized) auxiliary variables of N rows and q columns
rand	vector of length N with permanent random numbers

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Grafström, A. (2012). Spatially correlated Poisson sampling. Journal of Statistical Planning and Inference, 142(1), 139-147.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 1000; # population size
n = 100; # sample size
p = rep(n/N,N); # inclusion probabilities
X = cbind(runif(N),runif(N)); # matrix of auxiliary variables
u = runif(N);
s = scps_coord(p,X,u); # select sample
plot(X[,1],X[,2]); # plot population
points(X[s,1],X[s,2], pch=19); # plot sample

## End(Not run)
```

`scps_getrand` *Spatially correlated Poisson sampling*

Description

Retrieves a vector of random numbers resulting in the provided scps sample

Usage

```
scps_getrand(prob,x,s)
```

Arguments

`prob`	vector of length N with inclusion probabilities
`x`	matrix of (standardized) auxiliary variables of N rows and q columns
`s`	vector of length N with inclusion indicators

Value

Retrieves a vector of length N with random numbers resulting in the provided scps sample

References

Grafström, A. (2012). Spatially correlated Poisson sampling. Journal of Statistical Planning and Inference, 142(1), 139-147.

`spm` *Sequential pivotal method (also known as ordered pivotal sampling and Deville's systematic sampling)*

Description

Select samples with prescribed inclusion probabilities from a finite population. The resulting samples are well spread in the list (similar to systematic sampling). In each of the (at most) N steps, two undecided units with smallest index are selected to compete.

Usage

```
spm(prob)
```

Arguments

`prob`	vector of length N with inclusion probabilities

Value

Returns a vector of selected indexes in 1,2,...,N. If the inclusion probabilities sum to n, where n is integer, then the sample size is fixed (n).

References

Deville, J.-C. and Tillé, Y. (1998). Unequal probability sampling without replacement through a splitting method. Biometrika 85, 89-101.

Chauvet, G. (2012). On a characterization of ordered pivotal sampling. Bernoulli, 18(4), 1320-1340.

Examples

```
## Not run:
# Example 1
set.seed(12345);
N = 100; # population size
n = 10; # sample size
p = rep(n/N,N); # inclusion probabilities
s = spm(p); # select sample

# Example 2
# check inclusion probabilities
set.seed(12345);
p = c(0.2, 0.25, 0.35, 0.4, 0.5, 0.5, 0.55, 0.65, 0.7, 0.9); # prescribed inclusion probabilities
```

```
N = length(p); # population size
ep = rep(0,N); # empirical inclusion probabilities
nrs = 10000; # repetitions
for(i in 1:nrs){
  s = spm(p);
  ep[s]=ep[s]+1;
}
print(ep/nrs);

## End(Not run)
```

---

vsb *Variance estimator for spatially balanced sample*

Description

Variance estimator of HT estimator of population total of target variable y

Usage

```
vsb(probs,ys,xs)
```

Arguments

`probs`	vector of length n (sample) with inclusion probabilities
`ys`	vector of target variable y of length n (sample)
`xs`	matrix of (standardized) auxiliary variables of n rows (sample) and q columns

Value

Number, the estimated variance

References

Grafström, A., and Schelin, L. (2014). How to select representative samples. Scandinavian Journal of Statistics.

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