

Package ‘recmap’

March 24, 2018

Type Package

Title Compute the Rectangular Statistical Cartogram

Version 0.5.31

Author Christian Panse [aut, cre] (<<https://orcid.org/0000-0003-1975-3064>>)

Maintainer Christian Panse <Christian.Panse@gmail.com>

Description Provides an interface and a C++ implementation of the RecMap MP2 construction heuristic (see 'citation("`recmap`)" for details). This algorithm draws maps according to a given statistical value (e.g., election results, population or epidemiological data). The basic idea of the RecMap algorithm is that each map region (e.g., different countries) is represented by a rectangle. The area of each rectangle represents the statistical value given as input (maintain zero cartographic error). Documentation about RecMap is provided by a vignette included in this package.

License GPL-3

Depends R (>= 3.3), GA (>= 3.0.0), Rcpp (>= 0.12.4), sp

Suggests colorspace, doParallel, knitr, maps, noncensus, shiny, testthat

SystemRequirements C++11

LinkingTo Rcpp (>= 0.12.4)

VignetteBuilder knitr

NeedsCompilation yes

BugReports <https://github.com/cpanse/recmap/issues>

Repository CRAN

Date/Publication 2018-03-24 13:06:13 UTC

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as.recmapping.SpatialPolygonsDataFrame

Convert a SpatialPolygonsDataFrame Object to recmap Object

Description

The method generates a recmap class out of a [SpatialPolygonsDataFrame](#) object.

Usage

```
## S3 method for class 'SpatialPolygonsDataFrame'
as.recmapping(X)
```

Arguments

X a [SpatialPolygonsDataFrame](#) object.

Value

returns a [recmap](#) object.

Author(s)

Christian Panse

References

Roger S. Bivand, Edzer Pebesma, Virgilio Gomez-Rubio, 2013. Applied spatial data analysis with R, Second edition. Springer, NY. <http://www.asdar-book.org/>

See Also

- [sp](#)
- [as.SpatialPolygonsDataFrame](#)

Examples

```
SpDf <- as.SpatialPolygonsDataFrame(recmap(checkerboard(8)))

summary(SpDf)
spplot(SpDf)

summary(as.recmmap(SpDf))

# taken from https://github.com/sjewo/cartogram

## Not run:
  if (requireNamespace("maptools", quietly = TRUE)) {
library(maptools)
  data(wrld_simpl)

afr <- as.recmmap(wrld_simpl[wrld_simpl$REGION==2, ])
is.recmmap(afr)

afr$z <- afr$POP2005

is.recmmap(afr)
afr <- afr[afr$z > 0, ]

# make map overlap to generate a connected pseudo dual
afr$dx <- 2.0 * afr$dx
afr$dy <- 2.0 * afr$dy

# overview
plot(recmap(afr))

# use the GA
set.seed(1)
plot(recmapGA(afr))

  }

## End(Not run)
```

as.SpatialPolygonsDataFrame.recmmap

Convert a recmap Object to SpatialPolygonsDataFrame Object

Description

The method generates a SpatialPolygons object of a as input given `recmap` object. Both `data.frames` are merged by the index order.

Usage

```
## S3 method for class 'recmap'  
as.SpatialPolygonsDataFrame(x, df = NULL, ...)
```

Arguments

x	a recmap object.
df	a data.frame object. default is NULL.
...	...

Value

returns a [SpatialPolygonsDataFrame](#)

Note

This S3method has replaced the `recmap2sp` function since package version 0.5.22.

Author(s)

Christian Panse

References

Roger S. Bivand, Edzer Pebesma, Virgilio Gomez-Rubio, 2013. Applied spatial data analysis with R, Second edition. Springer, NY. <http://www.asdar-book.org/>

See Also

- [sp](#)

Examples

```
SpDf <- as.SpatialPolygonsDataFrame(recmap(checkerboard(8)))  
summary(SpDf)  
spplot(SpDf)
```

checkerboard

Create a Checkboard

Description

This function generates a [recmap](#) object.

Usage

```
checkerboard(n = 8, ratio = 4)
```

Arguments

<code>n</code>	defines the size of the map. default is 8 which will generate a map having 64 regions.
<code>ratio</code>	defines the ratio of the statistical value. As default, the black regions have a value which is four times higher.

Value

returns a checkerboard as `recmap` object.

Author(s)

Christian Panse

See Also

- [recmap](#).

Examples

```
checkerboard8x8 <- checkerboard(8)

plot(checkerboard8x8,
      col=c('white', 'white', 'white', 'black')[checkerboard8x8$z])
```

jss2711

jss2711 data

Description

jss2711 contains the recmap input for the Figures 4, 6, 7, 11, 12, 13.

Format

A set of nested list of data frames.

Author(s)

Christian Panse, 2018

Source

- Figure 11 – Switzerland: map data source: Swiss Federal Office of Topography using Landscape Models / Boundaries GG25, downloaded 2016-05-01; statistical data: Bundesamt für Statistik (BFS), Website Statistik Schweiz, downloaded file je-d-21.03.01.xls on 2016-05-26.
- Figure 12 – sbb: sbb.ch 2016-05-12
- Figure 13 – UK: Contains National Statistics data Crown copyright and database right 2016 Contains NRS data Crown copyright and database right 2016 Source: NISRA : Website: www.nisra.gov.uk Contains OS data Crown copyright [and database right] (2016)

References

<https://arxiv.org/abs/1606.00464>

Examples

```

data(package = "reemap")
data(jss2711)
options(warn = -1)

## Figure 4 - left
op <- par(mar=c(4, 4, 2, 2), mfrow = c(1, 2))

boxplot(number ~ size, data = mbb_check,
  subset = algorithm == "linear",
  xlab = 'number of map regions',
  ylab = 'number of MBB intersection calls',
  col = "red", log='y')

boxplot(number ~ size, data = mbb_check,
  subset = algorithm == "multiset",
  xlab = 'number of map regions',
  ylab = 'number of MBB intersection calls',
  log='y');

legend("bottomright", c("reemap > 0.2.1", "reemap <= 0.2.1"),
  col=c('black', 'red'), pch = 22, cex = 1.5)

## Figure 6 - right
op <- par(mar = c(4, 4, 2, 2), mfrow = c(1, 1), bg = 'white')

plot(cmp_GA_GRASP$GA[, 1], cmp_GA_GRASP$GA[, 2], type = 'b',
  xlab = 'elapsed time [in seconds]',
  ylab = 'reemap.fitness', pch = 22, lwd = 2)

lines(cmp_GA_GRASP$GRASP[, 1], cmp_GA_GRASP$GRASP[, 2], col = 'red', type = 'b', pch = 23)
legend("bottomright", c("GA", "GRASP"), col = c('black', 'red'),
  pch=c(22, 23), cex=1.5)

```

```

## Figure 7
## Not run:

res <- lapply(c(1, 1, 2, 2, 3, 3), function(seed){
  set.seed(seed);
  res <- recmapGA(Map = checkerboard(4), pmutation = 0.25)
  res$seed <- seed
  res})

op <- par(mfcol=c(2,4), bg='azure', mar=c(5, 5, 0.5, 0.5))

x <- recmap(checkerboard(4))
p <- paste(' = (', paste(1:length(x$z), collapse=", "), ')', sep='')
plot(x,
      sub=substitute(paste(Pi['forward'], p), list(p=p)),
      col = c('white', 'white', 'white', 'black')[x$z])

x <- recmap(checkerboard(4)[rev(1:16),])
p <- paste(' = (', paste(rev(1:length(x$z)), collapse=", "), ')', sep='')
plot(x,
      sub=substitute(paste(Pi[reverse], p), list(p=p)),
      col = c('white', 'white', 'white', 'black')[x$z])

rv <- lapply(res, function(x){
  p <- paste(' = (', paste(x$GA@solution[1,], collapse=", "), ')', sep='')
  plot(x$Cartogram,
        col = c('white', 'white', 'white', 'black')[x$Cartogram$z],
        sub=substitute(paste(Pi[seed], perm), list(perm=p, seed=x$seed)))
  })

## End(Not run)

# sanity check - reproducibility

identical.recmap <- function(x, y, plot.diff = FALSE){
  target <- x
  current <- y

  stopifnot(is.recmap(target))
  stopifnot(is.recmap(current))
  rv <- identical(x$x, y$x) && identical(x$y, y$y) && identical(x$dx, y$dx) && identical(x$dy, y$dy)
  if (plot.diff){
    rvtemp <- lapply(c('x', 'y', 'dx', 'dy'), function(cn){
      plot(sort(abs(target[, cn] - current[, cn])),
            ylab = 'absolute error',
            main = cn)
      abline(h = 0, col = 'grey')
    })
  }
}

rv

```

```

}

## Not run:
op <- par(mfcol = c(4, 4), mar = c(4, 4, 4, 1));
identical.recmmap(res[[1]]$Cartogram, res[[2]]$Cartogram, TRUE)
identical.recmmap(res[[3]]$Cartogram, res[[4]]$Cartogram, TRUE)
identical.recmmap(res[[5]]$Cartogram, res[[6]]$Cartogram, TRUE)
identical.recmmap(res[[1]]$Cartogram, res[[6]]$Cartogram, TRUE)

## End(Not run)

## Figure 11
## Not run: plot(recmap(Switzerland$map[Switzerland$solution,]))

op <- par(mfrow=c(1, 1), mar=c(0,0,0,0));

C <- Switzerland$cartogram
class(C) <- c('recmap', 'data.frame')

plot(C)

idx <- rev(order(C$z))[1:50];

text(C$x[idx], C$y[idx], C$name[idx], col = 'red',
      cex = C$dx[idx] / strwidth(as.character(C$name[idx])))

# text(C$x[idx], C$y[idx], iconv(as.character(C$name[idx]),
# "latin1", "UTF-8"), col='red',
# cex = C$dx[idx]/strwidth(as.character(C$name[idx])))

## Figure 12
SBB.Map <- SBB$Map

# make input map overlapping
S <- SBB$Map
S <- S[!is.na(S$x),]
S$dx <- 0.1; S$dy <- 0.1; S$z <- S$DTV
S$name <- S$Bahnhof_Haltestelle

op <- par(mfrow = c(2, 1), mar = c(0, 0, 0, 0))
plot.recmap(S)
idx <- rev(order(S$z))[1:10]
text(S$x[idx], S$y[idx], S$name[idx], col='red', cex=0.7)
idx <- rev(order(S$z))[11:30]
text(S$x[idx], S$y[idx], S$name[idx], col = 'red', cex = 0.5)

Cartogram.recomp <- recmap(S[sol <- SBB$GA@solution[1, ], ])
plot(Cartogram.recomp)

idx <- rev(order(Cartogram.recomp$z))[1:40]
text(Cartogram.recomp$x[idx],Cartogram.recomp$y[idx],
      Cartogram.recomp$name[idx],

```



```

col = 'red',
cex = 1.25 * Cartogram.recomp$dx[idx] / strwidth(Cartogram.recomp$name[idx]))

# sanity check - reproducibility cross platform
op <- par(mfrow=c(2,2), mar=c(5,5,5,5))
identical.recmmap(Cartogram.recomp, SBB$Cartogram, TRUE)

## Figure 13

DF <- data.frame(Pct_Leave = UK$Map$Pct_Leave, row.names = UK$Map$name)
splot(as.SpatialPolygonsDataFrame(UK$Map, DF),
      main="Input England/Wales/Scotland")

UK.recmmap <- recmmap(UK$Map)
splot(as.SpatialPolygonsDataFrame(UK.recmmap , DF))

# sanity check - reproducibility cross platform
op <- par(mfrow=c(2,2), mar=c(5,5,5,5))
identical.recmmap(UK.recmmap, UK$Cartogram, TRUE)

```

plot.recmmap

Prints a recmmap object.

Description

plots input and output of the [recmmap](#) function. The function requires column names (x, y, dx, dy).

Usage

```

## S3 method for class 'recmmap'
plot(x, col='#00000011', col.text = 'grey', border = 'darkgreen', ...)

```

Arguments

x	recmmap object - can be input or output of recmmap.
col	a vector of colors.
border	This parameter is passed to the rect function. color for rectangle border(s). The default means par("fg"). Use border = NA to omit borders. If there are shading lines, border = TRUE means use the same colour for the border as for the shading lines. The default value is set to 'darkgreen'.
col.text	a vector of colors.
...	whatsoever

Value

graphical output

Author(s)

Christian Panse

See Also[recmap](#) or `vignette("recmap")`**Examples**

```
Cartogram <- recmap(Map <- checkerboard(2))

plot(Map)
plot(Cartogram)
```

 recmap

Compute a Rectangular Statistical Cartogram

Description

The input consists of a map represented by overlapping rectangles. The algorithm requires as input for each map region:

- a tuple of (x, y) values corresponding to the (longitude, latitude) position,
- a tuple of (dx, dy) of expansion along (longitude, latitude),
- and a statistical value z.

The (x, y) coordinates represent the center of the minimal bounding boxes (MBB). The coordinates of the MBB are derived by adding or subtracting the (dx, dy) / 2 tuple accordingly. The tuple (dx, dy) defines also the ratio of the map region. The statistical values define the desired area of each map region.

The output is a rectangular cartogram where the map regions are:

- Non-overlapping,
- connected,
- ratio and area of each rectangle correspond to the desired areas,
- rectangles are placed parallel to the axes.

The construction heuristic places each rectangle in a way that important spatial constraints, in particular

- the topology of the pseudo dual graph,
- the relative position of MBB centers.

are tried to be preserved.

The ratios are preserved and the area of each region corresponds to the as input given statistical value z.

Usage

```
recmap(V, E = data.frame(u=integer(), v=integer()))
```

Arguments

- V defines the input map regions formatted as `data.frame` having the column names `c('x', 'y', 'dx', 'dy', 'z', 'name')` as described above. V could also be considered as the nodes of the pseudo dual.
- E defines the edges of the map region's pseudo dual graph. If E is not provided, this is the default; the pseudo dual graph is composed of overlapping rectangles. If used, E must be a `data.frame` containing two columns named `c('u', 'v')` of type `integer` referencing the row number of V.

Details

The basic idea of the current recmap *implementation*:

1. Compute the pseudo dual out of the overlapping map regions.
2. Determine the *core region* by `index <- int(n / 2)`.
3. Place region by region along DFS skeleton of pseudo dual starting with the *core region*.

Note: if a rectangle can not be placed, accept a non-*feasible solution* (avoid solutions having a topology error higher than 100) Solving this constellation can be intensive in the computation and due to the assumably low fitness value the candidate cartogram will be likely rejected by the metaheuristic.

Time Complexity: The time complexity is $O(n^2)$, where n is the number of regions. DFS is visiting each map region only once and therefore has time complexity $O(n)$. For each placement, a constant number of MBB intersection are called (max 360). MBB check is implemented using `std::set`, `insert`, `upper_bound`, `upper_bound` costs are $O(\log(n))$. However, worst case for a range query is $O(n)$, if and only if dx or dy cover the whole x or y range. Q.E.D.

Performance: In praxis, computing on a 2.4 GHz Intel Core i7 machine (using only one core), using the 50 state U.S. map example, recmap can compute approximately 100 cartograms in one second. The number of MBB calls were (Min., Median, Mean, Max) = (1448, 2534, 3174, 17740), using in each run a different index order using the (`sample`) method.

Geodetic datum: the recmap algorithm is not transforming the geodetic datum, e.g., WGS84 or Swissgrid.

Value

Returns a recmap S3 object of the transformed map with new coordinates (x, y, dx, dy) plus additional columns containing information for topology error, relative position error, and the DFS number. The error values are thought to be used for fitness function of the metaheuristic.

Author(s)

Christian Panse, 2016

References

- Roland Heilmann, Daniel Keim, Christian Panse, and Mike Sips (2004). "RecMap: Rectangular Map Approximations." InfoVis 2004, IEEE Symposium on Information Visualization, Austin, Texas, 33-40. <http://dx.doi.org/10.1109/INFVIS.2004.57>.
- Christian Panse (2016). "Rectangular Statistical Cartograms in R: The recmap Package." <https://arxiv.org/abs/1606.00464>.

See Also

- S3 class methods: [plot.recmap](#) and [summary.recmap](#).
- the metaheuristic glue methods: [recmapGA](#) and [recmapGRASP](#).
- The package vignette <https://CRAN.R-project.org/package=recmap/vignettes/recmap.html> or by calling `vignette("recmap")` on the R command prompt.
- A shiny web application https://recmap.shinyapps.io/state_x77/.

Examples

```
map <- checkerboard(2)
cartogram <- recmap(map)

map
cartogram

op <- par(mfrow = c(1, 2))
plot(map)
plot(cartogram)

## US example
usa <- data.frame(x = state.center$x,
  y = state.center$y,
  # make the rectangles overlapping by correcting
  # lines of longitude distance.
  dx = sqrt(state.area) / 2
    / (0.8 * 60 * cos(state.center$y * pi / 180)),
  dy = sqrt(state.area) / 2 / (0.8 * 60),
  z = sqrt(state.area),
  name = state.name)

usa$z <- state.x77[, 'Population']
US.Map <- usa[match(usa$name,
  c('Hawaii', 'Alaska'), nomatch = 0) == 0, ]

plot.recmap(US.Map)
plot(recmap(US.Map))
par(op)

# define a fitness function
recmap.fitness <- function(idxOrder, Map, ...){
  Cartogram <- recmap(Map[idxOrder, ])
  # a map region could not be placed;
```

```

# accept only feasible solutions!
if (sum(Cartogram$topology.error == 100) > 0){return (0)}
1 / sum(Cartogram$z / (sqrt(sum(Cartogram$z^2))))
  * Cartogram$relpos.error)
}

## Not run:

## use Genetic Algorithms (GA >=3.0.0) as metaheuristic

M <- US.Map

reemapGA <- ga(type = "permutation",
  fitness = reemap.fitness,
  Map = M,
  monitor = gaMonitor,
  min = 1, max = nrow(M) ,
  popSize = 4 * nrow(M),
  maxiter = 10,
  run = 100,
  parallel=TRUE,
  pmutation = 0.25)

plot(reemap(M[reemapGA@solution[1,],]))

plot(reemapGA)

## End(Not run)

## Not run:
# install.packages('rbenchmark')

library(rbenchmark)
benchmark(reemap(US.Map[sample(50,50),]), replications=100)
##           test replications elapsed relative user.self
##1 reemap(US.Map[sample(50, 50), ])          100  1.255         1    1.124
## sys.self user.child sys.child
##1    0.038         0         0
## End(Not run)

## Have Fun!

```

Description

high-level function for [recmap](#) using a Genetic Algorithm as metaheuristic.

Usage

```
recmapGA(Map,
  fitness = .recmap.fitness,
  pmutation = 0.25,
  popSize = 10 * nrow(Map),
  maxiter = 10,
  run = maxiter,
  monitor = if (interactive()) { gaMonitor } else FALSE,
  parallel = FALSE,
  ...)
```

Arguments

The following arguments are passed through [ga](#).

defines the input map regions formatted as [data.frame](#) having the column names c('x', 'y', 'dx', 'dy', 'z', 'name') as described above.

Map	a fitness function function(idxOrder, Map, ...) returning a number which as to be maximized.
fitness	
pmutation	see docu of ga .
popSize	see docu of ga .
maxiter	see docu of ga .
run	see docu of ga .
monitor	see docu of ga .
parallel	see docu of ga .
...	passed through the ga method.

Value

returns a list of the input Map, the solution of the [ga](#) function, and a [recmap](#) object containing the cartogram.

Author(s)

Christian Panse

References

Luca Scrucca (2013). GA: A Package for Genetic Algorithms in R. Journal of Statistical Software, 53(4), 1-37. <http://dx.doi.org/10.18637/jss.v053.i04>.

See Also

- [recmap](#) - Compute a Rectangular Statistical Cartogram
- [ga](#) - Genetic Algorithms

Examples

```
## The default fitness function is currently defined as
function(idxOrder, Map, ...){

  Cartogram <- recmap(Map[idxOrder, ])
  # a map region could not be placed;
  # accept only feasible solutions!

  if (sum(Cartogram$topology.error == 100) > 0){return (0)}

  1 / sum(Cartogram$relpos.error)
}

## use Genetic Algorithms (GA >=3.0.0) as metaheuristic
set.seed(1)
res <- recmapGA(Map = checkerboard(4), pmutation = 0.25)

op <- par(mfrow = c(1, 3))
plot(res$Map, main = "Input Map")
plot(res$GA, main="Genetic Algorithm")
plot(res$Cartogram, main = "Output Cartogram")

## US example
getUS_map <- function(){
  usa <- data.frame(x = state.center$x,
    y = state.center$y,
    # make the rectangles overlapping by correcting
    # lines of longitude distance.
    dx = sqrt(state.area) / 2
      / (0.8 * 60 * cos(state.center$y * pi / 180)),
    dy = sqrt(state.area) / 2 / (0.8 * 60),
    z = sqrt(state.area),
    name = state.name)

  usa$z <- state.x77[, 'Population']
  US.Map <- usa[match(usa$name,
    c('Hawaii', 'Alaska'), nomatch = 0) == 0, ]

  class(US.Map) <- c('recmap', 'data.frame')
  US.Map
}

## Not run:
# takes 34.268 seconds on CRAN
```

```

res <- reemapGA(getUS_map(), maxiter = 5)
op <- par(ask = TRUE)
plot(res)
par(op)
summary(res)

## End(Not run)

```

reemapGRASP

Greedy Randomized Adaptive Search Procedure Wrapper Function for reemap

Description

Implements a metaheuristic for [reemap](#) based on GRASP.

Usage

```

reemapGRASP(Map, fitness = .reemap.fitness, n.samples = nrow(Map) * 2,
  fitness.cutoff = 1.7, iteration.max = 10)

```

Arguments

Map	defines the input map regions formatted as data.frame having the column names c('x', 'y', 'dx', 'dy', 'z', 'name') as described above.
fitness	a fitness function function(idxOrder, Map, ...) returning a number which as to be maximized.
n.samples	number of samples.
fitness.cutoff	cut-off value.
iteration.max	maximal number of iteration.

Value

returns a list of the input Map, the best solution of GRASP, and a [reemap](#) object containing the cartogram.

Author(s)

Christian Panse

References

Feo TA, Resende MGC (1995). "Greedy Randomized Adaptive Search Procedures." *Journal of Global Optimization*, 6(2), 109-133. ISSN 1573-2916. doi: [10.1007/BF01096763](https://doi.org/10.1007/BF01096763).

See Also

[reemapGA](#) and [reemap](#)

Examples

```
## US example
getUS_map <- function(){
  usa <- data.frame(x = state.center$x,
    y = state.center$y,
    # make the rectangles overlapping by correcting
    # lines of longitude distance.
    dx = sqrt(state.area) / 2
      / (0.8 * 60 * cos(state.center$y * pi / 180)),
    dy = sqrt(state.area) / 2 / (0.8 * 60),
    z = sqrt(state.area),
    name = state.name)

  usa$z <- state.x77[, 'Population']
  US.Map <- usa[match(usa$name,
    c('Hawaii', 'Alaska'), nomatch = 0) == 0, ]

  class(US.Map) <- c('recmap', 'data.frame')
  US.Map
}

## Not run:
res <- recmapGRASP(getUS_map())
plot(res$Map, main = "Input Map")
plot(res$Cartogram, main = "Output Cartogram")

## End(Not run)
```

summary.recmmap

Summary for recmap

Description

Summary method for S3 class [recmap](#). The area error is computed as described in the CartoDraw paper.

Usage

```
## S3 method for class 'recmap'
summary(object, ...)
```

Arguments

object S3 class recmap.
... whatsoever.

Value

returns a `data.frame` containing summary information, e.g., objective functions or number of map regions.

Author(s)

Christian Panse 2016

References

D. A. Keim, S. C. North, and C. Panse, "CartoDraw: A Fast Algorithm for Generating Contiguous Cartograms," *IEEE Trans. Vis. Comput. Graph.*, vol. 10, no. 1, pp. 95-110, 2004. doi: [10.1109/TVCG.2004.1260761](https://doi.org/10.1109/TVCG.2004.1260761).

Examples

```
summary(checkerboard(4))  
summary(recmap(checkerboard(4)))
```

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