Package: recmap (via r-universe)

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Type Package

Title Compute the Rectangular Statistical Cartogram

Version 1.0.21

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Description Implements the RecMap MP2 construction heuristic (<doi:10.1109/INFVIS.2004.57>). 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., a country) is represented by a rectangle whose area reflects the provided statistical value, thereby maintaining zero cartographic error. Computationally intensive tasks are implemented in C++. The included vignette documents usage of the recmap algorithm.

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Depends R (>= 4.1), GA (>= 3.1), Rcpp (>= 1.0), sp (>= 1.3)

Suggests doParallel, knitr, rmarkdown, shiny, testthat, tufte

LinkingTo Rcpp (>= 1.0)

VignetteBuilder knitr

NeedsCompilation yes BugReports: https://github.com/cpanse/recmap/issues Encoding: UTF-8

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`.draw_recmap_us_state_ev` *this function reproduces the original election cartogram from 2004 using the cartogram output from the 2003 implementation.*

Description

this function reproduces the original election cartogram from 2004 using the cartogram output from the 2003 implementation.

Usage

```
.draw_recmap_us_state_ev(plot = TRUE)
```

Arguments

`plot`	default is TRUE

Value

the plot

`.get_7triangles` *construct polygon mesh displayed in Figure 4a in*

Description

construct polygon mesh displayed in Figure 4a in

Usage

```
.get_7triangles(A = 1)
```

Arguments

`A`	defines the area of a region in the center

Value

a SpatialPolygons object

References

doi:10.1109/TVCG.2004.1260761

Examples

```
triangle.map <- recmap:::.get_7triangles()
z <- c(rep(4, 4), rep(1, 3))
cols <- c(rep('white', 4), rep('grey',3))

op <- par(mfrow=c(1,2), mar=c(0, 0, 0, 0))
plot(triangle.map, col=cols)

## Not run:
 # requires libfft.so installed in linux
if (require(getcartr) & require(Rcartogram)){
  cartogram <- quick.carto(triangle.map, z, res=64)
  plot(cartogram, col=cols)
}

## End(Not run)
```

`.getUS_map` *return a overlapping minimal bounding boxes (MBB) of the U.S. using datasets.*

Description

return a overlapping minimal bounding boxes (MBB) of the U.S. using datasets.

Usage

```
.getUS_map()
```

Author(s)

Christian Panse, 2016

References

- doi:10.18637/jss.v086.c01
- doi:10.1109/INFVIS.2004.57

`as.recmap.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.recmap(X)
```

Arguments

`X`	`SpatialPolygonsDataFrame` object.

Value

returns a `recmap` object.

References

Roger S. Bivand, Edzer Pebesma, Virgilio Gomez-Rubio, 2013. Applied spatial data analysis with R, Second edition. Springer, NY.

Examples

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

---

as.SpatialPolygonsDataFrame.recmap *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.
`...`	...

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

n	defines the size of the map. default is 8 which will generate a map having 64 regions.
ratio	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])
```

---

is.recmap *Is an Object from a Class recmap?*

Description

Is an Object from a Class recmap?

Usage

```
is.recmap(object)
```

Arguments

object	any R object.

jss2711 *jss2711 data*

Description

jss2711 contains the replication materials (input and output) for the doi:10.18637/jss.v086.c01 manuscript's Figures 4, 5, 6, 7, 11, 12, and 13.

Format

A set of nested `list` of `data.frames`.

Author(s)

Christian Panse, 2018

Source

- Figure 4 – `mbb_check` contains a `data.frame` with some `recmap` implemention benchmarks. Generated on
  - MacBook Pro (15-inch, 2017).
  - Processor: 2.9 GHz Intel Core i7
  - Memory: 16 GB 2133 MHz LPDDR3
- Figure 5 – `cmp_GA_GRASP` contains a `list` of results using a `GRASP` and `GA` metaheuristic. Generated on a MacBook Pro (Retina, 13-inch, Mid 2014).
- Figure 11 – `Switzerland`:
  - input map rectangles derived from: Swiss Federal Office of Topography `https://www.swisstopo.admin.ch` using Landscape Models / Boundaries GG25, downloaded 2016-05-01; Perfomed on a Intel(R) Xeon(R) CPU E5-2698 v3 @ 2.30GHz/ Debian8
  - statistical data: Bundesamt fur Statistik (BFS) `https://www.bfs.admin.ch`, Website Statistik Schweiz, downloaded file `je-d-21.03.01.xls` on 2016-05-26.,
  - Perfomed on a Intel(R) Xeon(R) CPU E5-2698 v3 @ 2.30GHz/ Debian8.
- Figure 12 – `SBB`:
  - Source: https://data.sbb.ch/explore 2016-05-12.
  - Perfomed on a Intel(R) Xeon(R) CPU E5-2698 v3 @ 2.30GHz/ Debian 8.
- Figure 13 – `UK`:
  - input map rectangles derived from: `https://census.edina.ac.uk/ukborders`; Contains OS data Crown copyright [and database right] (2016);
  - Source of election data: NISRA
  - copyright - Contains National Statistics data Crown copyright and database right 2016 Contains NRS data Crown copyright and database right 2016
  - Perfomed on a Intel(R) Xeon(R) CPU E5-2698 v3 @ 2.30GHz/ Debian8

References

Panse C (2018). "Rectangular Statistical Cartograms in R: The recmap Package." Journal of Statistical Software, Code Snippets, 86(1), pp. 1-27. doi:10.18637/jss.v086.c01.

Examples

```
options(warn = -1)

## Figure 4
jss2711_figure4 <- function(nrep = 1, size = 2:10){
  recmap_debug_code <- '
  // [[Rcpp::plugins(cpp11)]]

  #include <Rcpp.h>
  #include <string>
  #include <recmap.h>

  using namespace Rcpp;

  // [[Rcpp::depends(recmap)]]
  // [[Rcpp::export]]
  int recmap_debug(DataFrame df,
    bool map_region_intersect_multiset = true) {
    // access the columns
    NumericVector x = df["x"];
    NumericVector y = df["y"];
    NumericVector dx = df["dx"];
    NumericVector dy = df["dy"];


    NumericVector z = df["z"];
    CharacterVector name = df["name"];

    NumericVector cartogram_x(x.size());
    NumericVector cartogram_y(x.size());
    NumericVector cartogram_dx(x.size());
    NumericVector cartogram_dy(x.size());

    NumericVector dfs_num(x.size());
    NumericVector topology_error(x.size());
    NumericVector relpos_error(x.size());
    NumericVector relpos_nh_error(x.size());

    crecmap::RecMap X;
    X.set_map_region_intersect_multiset(map_region_intersect_multiset);

    for (int i = 0; i < x.size(); i++) {
      std::string sname = Rcpp::as<std::string>(name[i]);
      X.push_region(x[i], y[i], dx[i], dy[i], z[i],  sname);
    }

    X.run(true);
```

```
  return(X.get_intersect_count());
}
'

sourceCpp(code = recmap_debug_code, rebuild = TRUE, verbose = TRUE)

do.call('rbind', lapply(size, function(size){
  set.seed(1);
  CB <- checkerboard(size);

  do.call('rbind',lapply(rep(size, nrep), function(n){

    CB.smp <- CB[sample(nrow(CB), nrow(CB)), ]
    start_time <- Sys.time()
    ncall.multiset <- recmap_debug(CB.smp,
       map_region_intersect_multiset = TRUE)

    end_time <- Sys.time()

    diff_time.multiset <- as.numeric(difftime(end_time,
      start_time, units = "secs"))


    start_time <- Sys.time()
    ncall.list <- recmap_debug(CB.smp,
      map_region_intersect_multiset = FALSE)
    end_time <- Sys.time()
    diff_time.list <- as.numeric(difftime(end_time,
      start_time, units = "secs"))

    rv <- rbind(data.frame(number = ncall.multiset,
      algorithm="multiset", size = nrow(CB),
 time_in_secs = diff_time.multiset),
      data.frame(number = ncall.list,
 algorithm="list", size = nrow(CB),
   time_in_secs =  diff_time.list))

    rv$machine <- Sys.info()['machine']
    rv$sysname <- Sys.info()['sysname']
    rv
    }))
  }))
}

## Not run:
 mbb_check <- jss2711_figure4()

## End(Not run)

data(jss2711)
boxplot(number  ~ sqrt(size),
  axes=FALSE,
```

```
  data = mbb_check,
  log='y',
  cex = 0.75,
  subset = algorithm == "list",
  col = "red", boxwex = 0.25);
abline(v = sqrt(50), col = 'lightgray', lwd = 3)

boxplot(number  ~ sqrt(size),
  data = mbb_check,log='y',
  subset = algorithm == "multiset",
  cex = 0.75,
  ylab = 'number of MBB intersection calls',
  xlab = 'number of map regions',
  boxwex = 0.25, add = TRUE, axes=FALSE);
axis(2)
axis(1, c(5, sqrt(50), 10, 15, 20), c("5x5", "US", "10x10", "15x15", "20x20"))
box()

legend("bottomright", c("C++ STL list", "C++ STL multiset"),
      col=c('red', 'black'), pch = 16, cex = 1.0)



## Figure 5

op <- par(mar=c(0, 0, 0, 0), mfrow=c(1, 3), bg = 'azure')

plot(cmp_GA_GRASP$GRASP$Map,
     border='black',
     col=c('white', 'white', 'white', 'black')[cmp_GA_GRASP$GRASP$Map$z])

plot(cmp_GA_GRASP$GRASP$Cartogram,
     border='black',
     col = c('white', 'white', 'white', 'black')[cmp_GA_GRASP$GRASP$Cartogram$z])

plot(cmp_GA_GRASP$GA$Cartogram,
     border='black',
     col = c('white', 'white', 'white', 'black')[cmp_GA_GRASP$GA$Cartogram$z])
par(op)

## Figure 6 - right

op <- par(mar = c(0, 0, 0, 0), mfrow=c(1, 1), bg = 'azure')
# found by the GA
smp <- cmp_GA_GRASP$GA$GA@solution[1,]

Cartogram.Checkerboard <- recmap(cmp_GA_GRASP$GA$Map[smp, ])
idx <- order(Cartogram.Checkerboard$dfs.num)

plot(Cartogram.Checkerboard,
     border='black',
     col=c('white', 'white', 'white', 'black')[Cartogram.Checkerboard$z])
```

```
# draw placement order
lines(Cartogram.Checkerboard$x[idx],
  Cartogram.Checkerboard$y[idx],
  col = rgb(1,0,0, alpha=0.3), lwd = 4, cex=0.5)

text(Cartogram.Checkerboard$x[idx],
  Cartogram.Checkerboard$y[idx],
  1:length(idx), pos=1, col=rgb(1,0,0, alpha=0.7))

points(Cartogram.Checkerboard$x[idx[1]],
  Cartogram.Checkerboard$y[idx[1]], lwd = 5, col = 'red')
text(Cartogram.Checkerboard$x[idx[1]],
  Cartogram.Checkerboard$y[idx[1]], "start", col = 'red', pos=3)
points(Cartogram.Checkerboard$x[idx[length(idx)]],
  Cartogram.Checkerboard$y[idx[length(idx)]],
       cex = 1.25, lwd = 2, col = 'red', pch = 5)
par(op)
op <- par(mar = c(4, 4, 1.5, 0.5), mfrow = c(1, 1), bg = 'white')
plot(best ~ elapsedtime, data = cmp_GA_GRASP$cmp,
     type = 'n',
     ylab = 'best fitness value',
     xlab = 'elapsed time [in seconds]')
abline(v=60, col='lightgrey',lwd=2)
lines(cmp_GA_GRASP$cmp[cmp_GA_GRASP$cmp$algorithm == "GRASP",
  c('elapsedtime', 'best')], type = 'b', col='red', pch=16)
lines(cmp_GA_GRASP$cmp[cmp_GA_GRASP$cmp$algorithm == "GA",
  c('elapsedtime', 'best')], type = 'b', pch=16)
legend("bottomright",
  c("Evolutionary based Genetic Algorithm (GA)",
    "Greedy Randomized Adaptive Search Procedures (GRASP)"),
    col = c('black', 'red'),
       pch=16, cex=1.0)

par(op)

## Figure 7
## Not run:

res <- lapply(c(1, 1, 2, 2, 3, 3), function(seed){
  set.seed(seed);
  res <- recmapGA(V = 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.recmap(res[[1]]$Cartogram, res[[2]]$Cartogram, TRUE)
identical.recmap(res[[3]]$Cartogram, res[[4]]$Cartogram, TRUE)
identical.recmap(res[[5]]$Cartogram, res[[6]]$Cartogram, TRUE)
identical.recmap(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
```

```
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])))

## Figure 12

fitness.SBB <- function(idxOrder, Map, ...){
  Cartogram <- recmap(Map[idxOrder, ])
  if (sum(Cartogram$topology.error == 100) > 1){return (0)}
  1 / sum(Cartogram$z / (sqrt(sum(Cartogram$z^2))) * Cartogram$relpos.error)
}

## Not run:
SBB <- recmapGA(V=SBB$Map,
  parallel=TRUE,
  maxiter=1000,
  run=1000,
  seed = 1,
  keepBest = TRUE,
  fitness=fitness.SBB)

## End(Not run)

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)
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 plattform
op <- par(mfrow = c(2, 2), mar = c(5, 5, 5, 5))
identical.recmap(Cartogram.recomp, SBB$Cartogram, TRUE)
```

```
## Figure 13

## Not run:
DF <- data.frame(Pct_Leave = UK$Map$Pct_Leave, row.names = UK$Map$name)
spplot(as.SpatialPolygonsDataFrame(UK$Map, DF),
  main="Input England/Wales/Scottland")

UK.recmap <- recmap(UK$Map)
spplot(as.SpatialPolygonsDataFrame(UK.recmap , DF))

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

## End(Not run)
```

`plot.recmap` *Plot a recmap object.*

Description

plots input and output of the `recmap` function. The function requires column names (x, y, dx, dy).

Usage

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

Arguments

`x`	`recmap` object - can be input or output of `recmap`.
`col`	a vector of colors.
`col.text`	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'`.
`...`	whatsoever

Value

graphical output

Author(s)

Christian Panse, 2016

References

- doi:10.18637/jss.v086.c01
- doi:10.1109/INFVIS.2004.57

Examples

```
checkerboard(2) |> recmap() |> plot()
```

`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) also defines 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 = NULL)
```

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*.

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.

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, the 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.

Author(s)

Christian Panse, 2016

References

- doi:10.18637/jss.v086.c01
- doi:10.1109/INFVIS.2004.57

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)
US.Map |> recmap() |> plot()
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)
}
```

---

recmapGA *Genetic Algorithm Wrapper Function for recmap*

Description

higher-level function for recmap using a Genetic Algorithm as metaheuristic.

Usage

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

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.
fitness	the fitness function, any allowable R function which takes as input an individual `string` representing a potential solution, and returns a numerical value describing its "fitness".
pmutation	the probability of mutation in a parent chromosome. Usually mutation occurs with a small probability, and by default is set to 0.1.
popSize	the population size.
maxiter	the maximum number of iterations to run before the GA search is halted.
run	the number of consecutive generations without any improvement in the best fitness value before the GA is stopped.
monitor	a logical or an R function which takes as input the current state of the `ga-class` object and show the evolution of the search. By default, for interactive sessions the function `gaMonitor` prints the average and best fitness values at each iteration. If set to `plot` these information are plotted on a graphical device. Other functions can be written by the user and supplied as argument. In non interactive sessions, by default `monitor = FALSE` so any output is suppressed.
parallel	An optional argument which allows to specify if the Genetic Algorithm should be run sequentially or in parallel. For a single machine with multiple cores, possible values are: • a logical value specifying if parallel computing should be used (`TRUE`) or not (`FALSE`, default) for evaluating the fitness function; • a numerical value which gives the number of cores to employ. By default, this is obtained from the function `detectCores`; • a character string specifying the type of parallelisation to use. This depends on system OS: on Windows OS only `"snow"` type functionality is available, while on Unix/Linux/Mac OSX both `"snow"` and `"multicore"` (default) functionalities are available.

In all the cases described above, at the end of the search the cluster is automatically stopped by shutting down the workers.

If a cluster of multiple machines is available, evaluation of the fitness function can be executed in parallel using all, or a subset of, the cores available to the machines belonging to the cluster. However, this option requires more work from the user, who needs to set up and register a parallel back end. In this case the cluster must be explicitly stopped with `stopCluster`.

`...` additional arguments to be passed to the fitness function. This allows to write fitness functions that keep some variables fixed during the search.

Value

returns a list of the input `Map`, the solution of the `ga` function, and a `recmap` object containing the cartogram.

References

doi:10.18637/jss.v053.i04.

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)

## https://github.com/luca-scr/GA/issues/52
if (Sys.info()['machine'] == "arm64") GA::gaControl(useRcpp = FALSE)
res <- recmapGA(V = 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")


## Not run:
# takes 34.268 seconds on CRAN
res <- recmapGA(V = recmap:::.getUS_map(), maxiter = 5)
op <- par(ask = TRUE)
```

```
plot(res)
par(op)
summary(res)

## End(Not run)
```

---

recmapGRASP *Greedy Randomized Adaptive Search Procedure Wrapper Function for recmap*

Description

Implements a metaheuristic for recmap based on GRASP.

Usage

```
recmapGRASP(
  Map,
  fitness = .recmap.fitness,
  n.samples = nrow(Map) * 2,
  fitness.cutoff = 1.7,
  iteration.max = 10
)
```

Arguments

Map	input map, see recmap.
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	defines the maximal number of iterations.

Value

returns a list of the input Map, the best solution of GRASP, and a recmap object containing the cartogram.

Author(s)

Christian Panse, 2016

References

doi:10.1007/BF01096763

See Also

recmapGA and recmap

Examples

```
## Not run:
  recmap::.getUS_map() |> recmapGRASP() -> res;
  plot(res$Map, main = "Input Map");
  plot(res$Cartogram, main = "Output Cartogram")

## End(Not run)
```

---

summary.recmap *Summary for recmap object*

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	an object for which a summary is desired.
...	additional arguments affecting the summary produced.

Value

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

Author(s)

Christian Panse, 2016

References

- doi:10.18637/jss.v086.c01
- doi:10.1109/INFVIS.2004.57

Examples

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

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