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Description Functions for determining and evaluating high-risk zones and simulating and thinning point process data, as described in 'Determining high risk zones using point process methodology - Realization by building an R package' Seibold (2012) <http://highriskzone.r-forge.r-project.org/Bachelorarbeit.pdf> and 'Determining high-risk zones for unexploded World War II bombs by using point process methodology', Mahling et al. (2013) <doi:10.1111/j.1467-9876.2012.01055.x>.

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highriskzone-package *Determining high-risk zones by using spatial point process methodology*

Description

The package highriskzone provides tools to determine and evaluate high-risk zones of unobserved events by using point process methodology.

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References

Monia Mahling, Michael Hoehle & Helmut Kuechenhoff (2013), *Determining high-risk zones for unexploded World War II bombs by using point process methodology.* Journal of the Royal Statistical Society, Series C 62(2), 181-199.

Monia Mahling (2013), *Determining high-risk zones by using spatial point process methodology.* Ph.D. thesis, Cuvillier Verlag Goettingen, available online: http://edoc.ub.uni-muenchen.de/15886/

Heidi Seibold (2012), *Determining high risk zones using point process methodology - Realization by building an R package.* Bachelor Thesis, Ludwig Maximilian University of Munich.

See Also

spatstat-package

bootcor *Bootstrap correction to obtain desired failure probability*

Description

Simulation-based iterative procedure to correct for possible bias with respect to the failure probability alpha

Usage

```
bootcor(
  ppdata,
  cutoff,
  numit = 1000,
  tol = 0.02,
  nxprob = 0.1,
  intens = NULL,
  covmatrix = NULL,
  simulate = "intens",
  radiusClust = NULL,
  clustering = 5,
  verbose = TRUE
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
cutoff	Desired failure probability alpha, which is the probability of having unobserved events outside the high-risk zone.
numit	Number of iterations to perform (per tested value for cutoff). Default value is 1000.
tol	Tolerance: acceptable difference between the desired failure probability and the fraction of high-risk zones not covering all events. Default value is 0.02.
nxprob	Probability of having unobserved events. Default value is 0.1.
intens	(optional) estimated intensity of the observed process (object of class "im", see density.ppp). If not given, it will be estimated.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only meaningful if no intensity is given. If not given, it will be estimated.
simulate	The type of simulation, can be one of "thinning", "intens" or "clintens"
radiusClust	(optional) radius of the circles around the parent points in which the cluster points are located. Only used for simulate = "clintens".
clustering	a value >= 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it also is the parameter of the Poisson distribution for the number of points per cluster. Only used for simulate = "clintens".
verbose	logical. Should information on tested values/progress be printed?

Details

For a desired failure probability alpha, the corresponding parameter which is to use when determining a high-risk zone is found in an iterative procedure. The simulation procedure is the same as in eval_method. In every iteration, the number of high-risk zones with at least one unobserved event located outside is compared with the desired failure probability. If necessary, the value of cutoff is increased or decreased. The final value alphastar can than be used in det_hrz.

If there are restriction areas in the observation window, use bootcor_restr instead.

Value

An object of class bootcorr, which consists of a list of the final value for alpha (`alphastar`) and a data.frame `course` containing information on the simulation course, e.g. the tested values.

References

Monia Mahling, Michael H?hle & Helmut K?chenhoff (2013), *Determining high-risk zones for unexploded World War II bombs by using point process methodology.* Journal of the Royal Statistical Society, Series C 62(2), 181-199.

Monia Mahling (2013), *Determining high-risk zones by using spatial point process methodology.* Ph.D. thesis, Cuvillier Verlag G?ttingen, available online: http://edoc.ub.uni-muenchen.de/15886/ Chapter 6

See Also

`det_hrz`, `eval_method`, `bootcor_restr`

Examples

```
## Not run:
data(craterB)
set.seed(4321)

bc <- bootcor(ppdata=craterB, cutoff=0.2, numit=100, tol=0.02, nxprob=0.1)
bc
summary(bc)
plot(bc)


hrzbc <- det_hrz(craterB, type = "intens", criterion = "indirect",
cutoff = bc$alphastar, nxprob = 0.1)

## End(Not run)
```

---

bootcorr *Bootstrap correction to obtain desired failure probability*

Description

Simulation-based iterative procedure to correct for possible bias with respect to the failure probability alpha

Usage

```
bootcorr(
  ppdata,
  cutoff,
  numit = 1000,
```

```
  tol = 0.02,
  nxprob = 0.1,
  intens = NULL,
  covmatrix = NULL,
  simulate = "intens",
  radiusClust = NULL,
  clustering = 5,
  verbose = TRUE
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
cutoff	Desired failure probability alpha, which is the probability of having unobserved events outside the high-risk zone.
numit	Number of iterations to perform (per tested value for cutoff). Default value is 1000.
tol	Tolerance: acceptable difference between the desired failure probability and the fraction of high-risk zones not covering all events. Default value is 0.02.
nxprob	Probability of having unobserved events. Default value is 0.1.
intens	(optional) estimated intensity of the observed process (object of class "im", see density.ppp). If not given, it will be estimated.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only meaningful if no intensity is given. If not given, it will be estimated.
simulate	The type of simulation, can be one of "thinning", "intens" or "clintens"
radiusClust	(optional) radius of the circles around the parent points in which the cluster points are located. Only used for simulate = "clintens".
clustering	a value >= 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it also is the parameter of the Poisson distribution for the number of points per cluster. Only used for simulate = "clintens".
verbose	logical. Should information on tested values/progress be printed?

Details

For a desired failure probability alpha, the corresponding parameter which is to use when determining a high-risk zone is found in an iterative procedure. The simulation procedure is the same as in eval_method. In every iteration, the number of high-risk zones with at least one unobserved event located outside is compared with the desired failure probability. If necessary, the value of cutoff is increased or decreased. The final value alphastar can than be used in det_hrz.

If there are restriction areas in the observation window, use bootcor_restr instead.

Value

An object of class bootcorr, which consists of a list of the final value for alpha (alphastar) and a data.frame course containing information on the simulation course, e.g. the tested values.

References

Monia Mahling, Michael H?hle & Helmut K?chenhoff (2013), *Determining high-risk zones for unexploded World War II bombs by using point process methodology.* Journal of the Royal Statistical Society, Series C 62(2), 181-199.

Monia Mahling (2013), *Determining high-risk zones by using spatial point process methodology.* Ph.D. thesis, Cuvillier Verlag G?ttingen, available online: http://edoc.ub.uni-muenchen.de/15886/ Chapter 6

See Also

det_hrz, eval_method, bootcor_restr

Examples

```
## Not run:
data(craterB)
set.seed(4321)

bc <- bootcor(ppdata=craterB, cutoff=0.2, numit=100, tol=0.02, nxprob=0.1)
bc
summary(bc)
plot(bc)


hrzbc <- det_hrz(craterB, type = "intens", criterion = "indirect",
cutoff = bc$alphastar, nxprob = 0.1)

## End(Not run)
```

---

bootcor_restr *Bootstrap correction to obtain desired failure probability*

Description

Simulation-based iterative procedure to correct for possible bias with respect to the failure probability alpha

Usage

```
bootcor_restr(
  ppdata,
  cutoff,
  numit = 100,
  tol = 0.001,
  nxprob = 0.1,
  hole = NULL,
  obsprobimage = NULL,
  intens = NULL,
```

```
  covmatrix = NULL,
  simulate = "intens",
  radiusClust = NULL,
  clustering = 5,
  verbose = TRUE
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
cutoff	Desired failure probability alpha, which is the probability of having unobserved events outside the high-risk zone.
numit	Number of iterations to perform (per tested value for cutoff). Default value is 1000.
tol	Tolerance: acceptable difference between the desired failure probability and the fraction of high-risk zones not covering all events. Default value is 0.02.
nxprob	Probability of having unobserved events. Default value is 0.1.
hole	(optional) an object of class owin representing a region inside the observation window of the ppdata where no observations were possible.
obsprobimage	(optional) an object of class im giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of ppdata. Only used if obsprobs is not given.
intens	(optional) estimated intensity of the observed process (object of class "im", see density.ppp). If not given, it will be estimated.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only meaningful if no intensity is given. If not given, it will be estimated.
simulate	The type of simulation, can be one of "thinning", "intens" or "clintens"
radiusClust	(optional) radius of the circles around the parent points in which the cluster points are located. Only used for simulate = "clintens".
clustering	a value >= 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it also is the parameter of the Poisson distribution for the number of points per cluster. Only used for simulate = "clintens".
verbose	logical. Should information on tested values/progress be printed?

Details

For a desired failure probability alpha, the corresponding parameter which is to use when determining a high-risk zone is found in an iterative procedure. The simulation procedure is the same as in eval_method. In every iteration, the number of high-risk zones with at least one unobserved event located outside is compared with the desired failure probability. If necessary, the value of cutoff is increased or decreased. The final value alphastar can than be used in det_hrz.

The function offers the possibility to take into account so-called restriction areas. This is relevant in situations where the observed point pattern ppdata is incomplete. If it is known that no observations can be made in a certain area (for example because of water expanses), this can be accounted for by

integrating a hole in the observation window. The shape and location of the hole is given by `hole`. Holes are part of the resulting high-risk zone. Another approach consists in weighting the observed events with their reciprocal observation probability when estimating the intensity. To do so, the observation probability can be specified by using `obsprobsimage` (an image of the observation probability). Note that the observation probability may vary in space.

For further information, see Mahling (2013), Appendix A (References).

If there are no restriction areas in the observation window, `bootcor` can be used instead.

Value

An object of class bootcorr, which consists of a list of the final value for alpha (`alphastar`) and a data.frame `course` containing information on the simulation course, e.g. the tested values.

References

Monia Mahling, Michael H?hle & Helmut K?chenhoff (2013), *Determining high-risk zones for unexploded World War II bombs by using point process methodology.* Journal of the Royal Statistical Society, Series C 62(2), 181-199.

Monia Mahling (2013), *Determining high-risk zones by using spatial point process methodology.* Ph.D. thesis, Cuvillier Verlag G?ttingen, available online: http://edoc.ub.uni-muenchen.de/15886/ Chapter 6 and Appendix A

See Also

`det_hrz`, `eval_method`, `bootcor`

Examples

```
data(craterA)
set.seed(4321)
# define restriction area
restrwin <- spatstat.geom::owin(xrange = craterA$window$xrange,
                          yrange = craterA$window$yrange,
                          poly = list(x = c(1500, 1500, 2000, 2000),
                                      y = c(2000, 1500, 1500, 2000)))

# create image of observation probability (30% inside restriction area)
wim <- spatstat.geom::as.im(craterA$window, value = 1)
rim <- spatstat.geom::as.im(restrwin, xy = list(x = wim$xcol, y = wim$yrow))
rim$v[is.na(rim$v)] <- 0
oim1 <- spatstat.geom::eval.im(wim - 0.7 * rim)

## Not run:
# perform bootstrap correction
bc1 <- bootcor_restr(ppdata=craterA, cutoff=0.4, numit=100, tol=0.02, obsprobimage=oim1, nxprob=0.1)
bc1
summary(bc1)
plot(bc1)

# determine high-risk zone by weighting the observations
```

```
hrzi1 <- det_hrz_restr(ppdata=craterA, type = "intens", criterion = "indirect",
 cutoff = bc1$alphastar, hole=NULL, obsprobs=NULL, obsprobimage=oim1, nxprob = 0.1)

# perform bootstrap correction
set.seed(4321)
bc2 <- bootcor_restr(ppdata=craterA, cutoff=0.4, numit=100, tol=0.02, hole=restrwin, nxprob=0.1)
bc2
summary(bc2)
plot(bc2)

# determine high-risk zone by accounting for a hole
hrzi2 <- det_hrz_restr(ppdata=craterA, type = "intens", criterion = "indirect",
 cutoff = bc2$alphastar, hole=restrwin, obsprobs=NULL, obsprobimage=NULL, nxprob = 0.1)

## End(Not run)
```

`check_det_hrz_input` *Checks the arguments of det_hrz*

Description

For each argument it is checked if it is of a correct value or class.

Usage

```
check_det_hrz_input(
  ppdata,
  type,
  criterion,
  cutoff,
  distancemap,
  intens,
  nxprob,
  covmatrix
)
```

Arguments

`ppdata`	Observed spatial point process of class ppp.
`type`	Method to use, can be one of `"dist"` (method of fixed radius or quantile-based method), or `"intens"` (intensity-based method)
`criterion`	criterion to limit the high-risk zone, can be one of `"area"` (giving size of hrz), `"indirect"` (giving quantile/alpha depending on type), or `"direct"` (giving radius/threshold c depending on type)
`cutoff`	Value of criterion (area, radius, quantile, alpha or threshold). Depending on criterion and type: If criterion = "direct" and type = "intens", cutoff is the maximum intensity of unexploded bombs outside the risk zone. If type = "dist" instead, cutoff is the radius of the circle around each exploded bomb. "If criterion

= "indirect", cutoff is the quantile for the quantile-based method and the failure probability alpha for the intensity-base method. If criterion = "area", cutoff is the area the high-risk zone should have.

`distancemap` (optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for `type="dist"`. If not given, it will be computed by `distmap`.

`intens` (optional) estimated intensity of the observed process (object of class "im"), only needed for type="intens". If not given, it will be estimated using `density.ppp`.

`nxprob` Probability of having unobserved events. Default value is 0.1.

`covmatrix` (optional) Covariance matrix of the kernel of a normal distribution, only needed for `type="intens"` if no intensity is given. If not given, it will be estimated using `Hscv`.

See Also

`det_hrz`

`check_det_hrz_restr_input` *Checks the arguments of det_hrz_restr*

Description

For each argument it is checked if it is of a correct value or class.

Usage

```
check_det_hrz_restr_input(
  ppdata,
  type,
  criterion,
  cutoff,
  hole,
  integratehole,
  obsprobs,
  obsprobimage,
  distancemap,
  intens,
  nxprob,
  covmatrix,
  returnintens
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
type	Method to use, can be one of "dist"(method of fixed radius or quantile-based method), or "intens"(intensity based method)
criterion	criterion to limit the high-risk zone, can be one of "area" (giving size of hrz), "indirect" (giving quantile/alpha depending on type), or "direct" (giving radius/threshold c depending on type)
cutoff	Value of criterion (area, radius, quantile, alpha or threshold). Depending on criterion and type.
hole	(optional) an object of class owin representing a region inside the observation window of the ppdata where no observations were possible.
integratehole	Should the hole be part of the resulting high-risk zone? Defaults to TRUE.
obsprobs	(optional) Vector of observation probabilities associated with the observations contained in ppdata. Must be given in the same order as the coordinates of the observations. Only meaningful for the intensity-based method if some observations are located in areas where not all events can actually be observed. For example, if only one third of the events in a specific region could be observed, the observation probability of the corresponding observations is 1/3.
obsprobimage	(optional) an object of class im giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of ppdata. Only used if obsprobs is not given.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for type="dist". If not given, it will be computed by distmap.
intens	(optional) estimated intensity of the observed process (object of class "im", see density.ppp), only needed for type="intens". If not given, it will be estimated.
nxprob	Probability of having unobserved events. Default value is 0.1.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only needed for type="intens" if no intensity is given. If not given, it will be estimated.
returnintens	Should the image of the estimated intensity be returned? Defaults to TRUE.

---

craterA *Bomb crater Point Pattern*

Description

Bomb crater Point Pattern

Usage

```
data(craterA)
```

Format

An object of class "ppp" representing a point pattern of bomb craters. The Cartesian coordinates are in meters. See ppp.object for details of the format of a point pattern object.

---

craterB *Bomb crater Point Pattern*

Description

Bomb crater Point Pattern

Usage

```
data(craterB)
```

Format

An object of class "ppp" representing a point pattern of bomb craters. The Cartesian coordinates are in meters. See ppp.object for details of the format of a point pattern object.

---

det_alpha *calculation of alpha (failure probability), when having the threshold c*

Description

This function is used for the intensity-based method. It determines the probability to have at least one unobserved event outside the high-risk zone. A Poisson distribution is used for the number of unobserved events in a certain area or field. Used in functions det_threshold, det_thresholdfromarea.

Usage

```
det_alpha(intens, threshold, nxprob = 0.1)
```

Arguments

intens	estimated intensity of the observed process (object of class "im", see density.ppp)
threshold	threshold c: The high-risk zone is the field in which the estimated intensity exceeds this value.
nxprob	probability of having unobserved events

Value

value of alpha

det_alpha_eval_ar *Determination of failure probability within evaluation area*

Description

Determination of failure probability within evaluation area

Usage

```
det_alpha_eval_ar(intens, eval_ar, threshold, nxprob = 0.1)
```

Arguments

intens	estimated intensity
eval_ar	evaluation area
threshold	given threshold
nxprob	constant probability of non-explosion

det_area *Calculation of the area of the high-risk zone.*

Description

This function is used for the intensity-based method. Calculation of the area of the high-risk zone given the observation window, the intensity matrix and the threshold c. Used in function det_thresholdfromarea.

Usage

```
det_area(win, intensmatrix, threshold)
```

Arguments

win	observation window
intensmatrix	matrix of the estimated intensity of the observed process (as.matrix(intens))
threshold	threshold c: The high-risk zone is the field in which the estimated intensity exceeds this value

Value

A numerical value giving the area of the high-risk zone.

See Also

owin, area.owin

det_area_hole *Calculation of the area of the high-risk zone.*

Description

This function is used for the intensity-based method with a hole restriction area. Calculation of the area of the high-risk zone given the observation window, the intensity matrix, the threshold c and a hole. Used in function det_thresholdfromarea_hole.

Usage

```
det_area_hole(win, intensmatrix, threshold, hole, integratehole = TRUE)
```

Arguments

win	observation window
intensmatrix	matrix of the estimated intensity of the observed process (as.matrix(intens))
threshold	threshold c: The high-risk zone is the field in which the estimated intensity exceeds this value
hole	specified hole
integratehole	Should the hole be part of the resulting high-risk zone? Defaults to TRUE

Value

A numerical value giving the area of the high-risk zone.

See Also

owin, area.owin

det_guard_width *Estimation of width of a guard region given an estimated highriskzone*

Description

det_guard_width determines the necessary width of a guard region in which the existence of additional observed bomb craters could change a intensity based estimated highriskzone within the evaluation area of interest. Within the evaluation area, the high risk zone consists of all points at which the estimated intensity of unexploded bombs exceeds a certain, specified or estimated threshold c. At a given point s, the intensity of unexploded bombs is given by the sum of all evaluated bivariate normal kernels centered at the observed bomb craters multiplied by a constant nxprob/1-nxprob. If the estimated intensity of unexploaded bombs is zero at a point at the boarder of the evaluation area an additional observation outside the area could lift the intensity only above the determined threshold if the distance to the boarder is small enough so that the density of the

normal kernel (which is centered at the additional observation) is bigger than the threshold at the boarder (assuming that the estimated kernel doesn't change due to the additional observation). The function returns the biggest distance in which it is possible that the density of the bivariate normal kernel of the intensity of the supplied highriskzone exceeds thresh_const times the threshold of the highriskzone. If thresh_const is set to 1, the guard region is the smallest region with constant width around the evaluation area in which a single additional observation could (but not necessarily does) increase the highriskzone within the evaluation area at a point at the boarder if the intensity of unexploaded bombs was zero at this point before. If the intensity was >0 at a point at the boarder of the evaluation area, or more than 1 additional observations are found nearby outside of the evaluation area, the highriskzone within the evaluation area could already expand by addditional observations with a bigger distance from the boarder. This can be considered by setting thresh_const < 1, which intuitively means that 1/thresh_const crater observation at the same point could expand the highriskzone within the evaluation area in the direction of the additional observations, or that a point the boarder becomes part of the highriskzone by the observation of a single additional crater if the intensity at this point was thresh_cont times the highriskzone threshold based on all crater observations within the evaluation area.

Usage

```
det_guard_width(highriskzone, thresh_const = 0.5)
```

Arguments

highriskzone	the estimated highriskzone for the evaluation area
thresh_const	the constant multiplied with the determined threshold, 0 < thresh_const < 1.

Details

For more infos on the construction of guard zones see Mahling (2013, Appendix B, Approach 2)

Value

The constant width of the guard region.

Examples

```
## change npixel to 1000 to obtain nicer plots
spatstat.geom::spatstat.options(npixel=100)
data(craterA)
# reduce number of observations for faster computation
thin.craterA <- craterA[1:50]
hrzi1 <- det_hrz(thin.craterA, type = "intens", criterion = "area", cutoff = 100000, nxprob = 0.1)
det_guard_width(hrzi1, thresh_const = .25)
```

det_hrz *Determination of the high-risk zone.*

Description

det_hrz determines the high-risk zone through the method of fixed radius (type = "dist" and criterion = "direct"), the quantile-based method (type = "dist" and criterion = "area"/"indirect") and the intensity-based method (type = "intens").

Usage

```
det_hrz(
  ppdata,
  type,
  criterion,
  cutoff,
  distancemap = NULL,
  intens = NULL,
  nxprob = 0.1,
  covmatrix = NULL
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
type	Method to use, can be one of "dist" (method of fixed radius or quantile-based method), or "intens" (intensity-based method)
criterion	criterion to limit the high-risk zone, can be one of "area" (giving size of hrz), "indirect" (giving quantile/alpha depending on type), or "direct" (giving radius/threshold c depending on type)
cutoff	Value of criterion (area, radius, quantile, alpha or threshold). Depending on criterion and type: If criterion = "direct" and type = "intens", cutoff is the maximum intensity of unexploded bombs outside the risk zone. If type = "dist" instead, cutoff is the radius of the circle around each exploded bomb. "If criterion = "indirect", cutoff is the quantile for the quantile-based method and the failure probability alpha for the intensity-base method. If criterion = "area", cutoff is the area the high-risk zone should have.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for type="dist". If not given, it will be computed by distmap.
intens	(optional) estimated intensity of the observed process (object of class "im"), only needed for type="intens". If not given, it will be estimated using density.ppp.
nxprob	Probability of having unobserved events. Default value is 0.1.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only needed for type="intens" if no intensity is given. If not given, it will be estimated using Hscv.

Details

There are different methods implemented to determine a high-risk zone.

Method of fixed radius In this method, the high-risk zone is determined by drawing a circle around each observed event with a fixed radius. This method will be used when `type = "dist"` and `criterion = "direct"`. `cutoff` then is the radius.

Quantile-based method This method is a development of the above. Here the radius is not fixed. It uses the distance of every observed event to the nearest other event, which is calculated by the nearest-neighbour distance. The radius is assessed by the p-quantile of the empirical distribution function of the nearest-neighbour distance. This method will be used when `type = "dist"` and `criterion = "indirect"` or `"area"`. If `criterion = "indirect"`, then `cutoff` is the quantile that should be used. If `criterion = "area"` then `cutoff` is the area that the high-risk zone has to have at the end and from that the quantile/the radii are determined. When the calculation is done via the area, it can not really be classified to the quantile-based method. It is rather a third "distance-based" method.

Intensity-based method The first step of this method is to estimate the intensity of the observed events. Based on the estimated intensity and the specified probability of unobserved bombs `nxprob` it is possible to estimate the intensity of unobserved/unexploded bombs. The high-risk zone is then the area in which the estimated intensity of unexploded bombs exceeds a certain value. This value is called threshold c. The method will be used when `type = "intens"`. There are three different ways to construct a high-risk zone:

1. Fixing the threshold c: `criterion = "direct"`
2. Fixing the area of the high-risk zone: `criterion = "area"`
3. Fixing the failure probability alpha, which is the probability of having unobserved events outside the high-risk zone: `criterion = "indirect"` Here, the point process is assumed to be an inhomogeneous Poisson process.

For further information see Mahling et al. (2013) (References).

If there are restriction areas in the observation window, use `det_hrz_restr` instead. For estimation of intensity based highrikszones with a bigger observation area than area of interest (evaluation area) use `det_hrz_eval_ar`.

Value

An object of class `"highriskzone"`, which is a list of

`typehrz, criterion, cutoff, nxprob`
: see arguments

`zone`
: Determined high-risk zone: Object of class "owin" based on a binary mask. See `owin`.

`threshold`
: determined threshold. If type = "dist" and criterion = "direct" it is the specified radius. If criterion = "indirect" or "area" the determined radius used to construct a risk zone fulfilling the specified criterion and cutoff. If type = "dist" it is the specified or calculated threshold c, the maximum intensitiy of unexploded bombs outside the risk zone.

`calccutoff`
: determined cutoff-value. For type="dist" and criterion="area", this is the quantile of the nearest-neighbour distance. For type="intens" and criterion="area" or "direct", it is the failure probability alpha. For all other criterions it is NA.

covmatrix If not given (and type="intens"), it is estimated. See Hscv.

References

Monia Mahling, Michael Hoehle & Helmut Kuechenhoff (2013), *Determining high-risk zones for unexploded World War II bombs by using point process methodology.* Journal of the Royal Statistical Society, Series C 62(2), 181-199.

Monia Mahling (2013), *Determining high-risk zones by using spatial point process methodology.* Ph.D. thesis, Cuvillier Verlag Goettingen, available online: http://edoc.ub.uni-muenchen.de/15886/

See Also

distmap, eval.im, owin, eval_method, det_hrz_restr

Examples

```
 data(craterA)
## change npixel to 1000 to obtain nicer plots
spatstat.geom::spatstat.options(npixel=100)
## type: dist
hrzd1 <- det_hrz(craterA, type = "dist", criterion = "area", cutoff = 1000000, nxprob = 0.1)
hrzd2 <- det_hrz(craterA, type = "dist", criterion = "indirect", cutoff = 0.9, nxprob = 0.1)
hrzd3 <- det_hrz(craterA, type = "dist", criterion = "direct", cutoff = 100, nxprob = 0.1)

op <- par(mfrow = c(2, 2))
plot(craterA)
plot(hrzd1, zonecol = 2, win = craterA$window, plotwindow = TRUE)
plot(hrzd2, zonecol = 3,  win = craterA$window, plotwindow = TRUE)
plot(hrzd3, zonecol = 4,  win = craterA$window, plotwindow = TRUE)
par(op)

## Not run:
# or first calculate the distancemap and use it:
distm <- distmap(craterA)
hrzd <- det_hrz(craterA, type = "dist", criterion = "direct", cutoff = 100,
                distancemap = distm, nxprob = 0.1)

## End(Not run)
## type: intens
# reduce number of observations for faster computation
thin.craterA <- craterA[1:10]
hrzi1 <- det_hrz(thin.craterA, type = "intens", criterion = "area", cutoff = 100000, nxprob = 0.1)
plot(hrzi1)
plot(thin.craterA, add = TRUE)
plot(thin.craterA$window, add = TRUE)
## Not run:
hrzi2 <- det_hrz(craterA, type = "intens", criterion = "indirect", cutoff = 0.1, nxprob = 0.1)
hrzi3 <- det_hrz(craterA, type = "intens", criterion = "direct", cutoff = 0.0001, nxprob = 0.1)
plot(hrzi2)
plot(hrzi3)

## End(Not run)
```

```
## More detailed examples on http://highriskzone.r-forge.r-project.org/
```

`det_hrz_eval_ar` *Determination of high-risk zone on smaller area of interest (evaluation area) than observation area.*

Description

`det_hrz_eval_ar` determines intensity based highriskzones if bomb crater observations are available for a bigger area than the area of main interest (evaluation area). All observations are used for intensity estimation, the highriskzone is however constructed only in the evaluation area. Either based on specifying a failure probability alpha that indicates the probability of unobserved bombs outside the highriskzone but inside the evaluation area of interest (and not in the overall observation area) (criterion = "indirect"), or by specifying the threshold (maximum intensity of non- exploded bombs outside the) highriskzone directly and intersecting the resulting hrz with the evaluation area (criterion = "direct").

Usage

```
det_hrz_eval_ar(
  ppdata,
  eval_ar,
  criterion = c("indirect", "direct"),
  cutoff,
  intens = NULL,
  nxprob = 0.1,
  covmatrix = NULL
)
```

Arguments

`ppdata`	Observed spatial point process of class ppp in the observation area.
`eval_ar`	area of interest specified via an object of class owin
`criterion`	criterion to limit the high-risk zone, can be `"indirect"` (failure probability alpha) or `"direct"` (threshold, i.e. maximum intensity of unexploded bombs outside hrz)
`cutoff`	Value of criterion (alpha or threshold)
`intens`	(optional) estimated intensity of the observed process (object of class "im") in (bigger) observation area, if not given, it will be estimated using `density.ppp`.
`nxprob`	Probability of having unobserved events. Default value is 0.1.
`covmatrix`	(optional) Covariance matrix of the kernel of a normal distribution, only needed for `type="intens"` if no intensity is given. If not given, it will be estimated using `Hscv`.

Value

An object of class "highriskzone"

Examples

```
set.seed(12412)
spatstat.geom::spatstat.options(npixel=300)
data(craterB)
# reduce number of observations for faster computation
thin.craterB <- craterB[sample(1:craterB$n, 40)]
# define evaluation area of interest
eval.ar <- spatstat.geom::owin(xrange = c(0, 1900), yrange = c(0, 3400),
               poly = matrix(c(250,250, 1200,1000,250,1000), byrow = TRUE, ncol = 2))

hrzi1 <- det_hrz_eval_ar(thin.craterB, eval_ar = eval.ar, criterion = "direct",
                         cutoff = 3e-6, nxprob = .2)

plot(hrzi1)
plot(thin.craterB, add = TRUE)
plot(eval.ar, add = TRUE)
plot(craterB$window, add = TRUE)
```

---

det_hrz_restr *Determination of the high-risk zone.*

Description

det_hrz_restr determines the high-risk zone through the method of fixed radius (type = "dist" and criterion = "direct"), the quantile-based method (type = "dist" and criterion = "area"/"indirect") and the intensity-based method (type = "intens"). Restriction areas can be taken into account.

Usage

```
det_hrz_restr(
  ppdata,
  type,
  criterion,
  cutoff,
  hole = NULL,
  integratehole = TRUE,
  obsprobs = NULL,
  obsprobimage = NULL,
  distancemap = NULL,
  intens = NULL,
  nxprob = 0.1,
  covmatrix = NULL,
  returnintens = TRUE
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
type	Method to use, can be one of "dist"(method of fixed radius or quantile-based method), or "intens"(intensity based method)
criterion	criterion to limit the high-risk zone, can be one of "area" (giving size of hrz), "indirect" (giving quantile/alpha depending on type), or "direct" (giving radius/threshold c depending on type)
cutoff	Value of criterion (area, radius, quantile, alpha or threshold). Depending on criterion and type.
hole	(optional) an object of class owin representing a region inside the observation window of the ppdata where no observations were possible.
integratehole	Should the hole be part of the resulting high-risk zone? Defaults to TRUE.
obsprobs	(optional) Vector of observation probabilities associated with the observations contained in ppdata. Must be given in the same order as the coordinates of the observations. Only meaningful for the intensity-based method if some observations are located in areas where not all events can actually be observed. For example, if only one third of the events in a specific region could be observed, the observation probability of the corresponding observations is 1/3.
obsprobimage	(optional) an object of class im giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of ppdata. Only used if obsprobs is not given.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for type="dist". If not given, it will be computed by distmap.
intens	(optional) estimated intensity of the observed process (object of class "im", see density.ppp), only needed for type="intens". If not given, it will be estimated.
nxprob	Probability of having unobserved events. Default value is 0.1.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only needed for type="intens" if no intensity is given. If not given, it will be estimated.
returnintens	Should the image of the estimated intensity be returned? Defaults to TRUE.

Details

Used in functions eval_method, sim_clintens, sim_intens.
This function contains the same functionalities as det_hrz. In addition, it offers the possibility to take into account so-called restriction areas. This is relevant in situations where the observed point pattern ppdata is incomplete. If it is known that no observations can be made in a certain area (for example because of water expanses), this can be accounted for by integrating a hole in the observation window. The shape and location of the hole is given by hole, whereas integratehole is used to state whether the hole is to become part of the resulting high-risk zone. This may also be a reasonable approach if only few observations could be made in a certain area. Another approach consists in weighting the observed events with their reciprocal observation probability when estimating the intensity. To do so, the observation probability can be specified by using obsprobs (value of the observation probability for each event) or obsprobsimage (image of the observation probability). Note that the observation probability may vary in space.

If there are no restriction areas in the observation window, det_hrz can be used instead.
Note that for criterion = "area", cutoff specifies the area of the high-risk zone outside the hole.
If integratehole = TRUE, the area of the resulting high-risk zone will exceed cutoff.

For further information, Mahling et al. (2013) and Mahling (2013), Chapters 4 and 8 and Appendix A (References).

Value

An object of class "highriskzone", which is a list of

typehrz, criterion, cutoff, nxprob	see arguments
zone	Determined high-risk zone: Object of class "owin" based on a binary mask. See owin.
threshold	determined threshold. If type = "dist" and criterion = "direct" it is the specified radius. If criterion = "indirect" or "area" the determined radius used to construct a risk zone fulfilling the specified criterion and cutoff. If type = "dist" it is the specified or calculated threshold c, the maximum intensitiy of unexploded bombs outside the risk zone.
calccutoff	determined cutoff-value. For type="dist" and criterion="area", this is the quantile of the nearest-neighbour distance. For type="intens" and criterion="area" or "direct", it is the failure probability alpha. For all other criterions it is NA.
covmatrix	If not given (and type="intens"), it is estimated. See Hscv.
estint	Estimated intensity. See density.ppp.

See Also

distmap, eval.im, owin

Examples

```
set.seed(1211515)
data(craterA)
#change npixel = 100 to 1000 to get a nicer picture
spatstat.geom::spatstat.options(npixel=100)
# reduce number of observations for faster computation
craterA <- craterA[sample(1:craterA$n, 150)]
# define restriction area
restrwin <- spatstat.geom::owin(xrange=craterA$window$xrange, yrange=craterA$window$yrange,
                    poly=list(x=c(1500, 1500, 2000, 2000), y=c(2000, 1500, 1500, 2000)))

# create image of observation probability (30% inside restriction area)
wim <- spatstat.geom::as.im(craterA$window, value=1)
rim <- spatstat.geom::as.im(restrwin, xy=list(x=wim$xcol, y=wim$yrow))
rim$v[is.na(rim$v)] <- 0
oim1 <- spatstat.geom::eval.im(wim - 0.7 * rim)
# determine high-risk zone by weighting the observations
hrzi1 <- det_hrz_restr(ppdata=craterA, type = "intens", criterion = "indirect",
                 cutoff = 0.4, hole=NULL, obsprobs=NULL, obsprobimage=oim1, nxprob = 0.1)
```

```
# determine high-risk zone by accounting for a hole
hrzi2 <- det_hrz_restr(ppdata=craterA, type = "intens", criterion = "indirect",
               cutoff = 0.4, hole=restrwin, obsprobs=NULL, obsprobimage=NULL, nxprob = 0.1)
```

`det_nnarea` *Determination of the area of a high-risk zone using the nearest-neighbour distance.*

Description

Used in function det_radius.

Usage

```
det_nnarea(cutoffval, distancemap, win)
```

Arguments

`cutoffval`	distance used as radius of the discs
`distancemap`	distance map (object of class "im", see `distmap`): distance of every location in the observation window to the nearest event
`win`	observation window of class owin

Value

A numerical value giving the area of the window.

See Also

`eval.im`, `owin`, `area.owin`

`det_nsintens` *Determination of the intensity for the Neyman Scott simulation.*

Description

Used in function sim_nsppp.

Usage

```
det_nsintens(ppdata, radius)
```

Arguments

ppdata	observed point pattern whose estimated intensity (adjusted for thinning and divided by "clustering") is used for simulating the parent process
radius	radius of the circles around the parent points in which the cluster points are located

Value

A pixel image (object of class "im"). See density.ppp.

See Also

density.ppp, boundingbox, owin, Hscv

---

det_nsintens_restr *Determination of the intensity for the Neyman-Scott simulation.*

Description

Used in function bootcor_restr.

Usage

```
det_nsintens_restr(ppdata, radius, weights)
```

Arguments

ppdata	observed point pattern whose estimated intensity (adjusted for thinning and divided by "clustering") is used for simulating the parent process
radius	radius of the circles around the parent points in which the cluster points are located
weights	Vector of observation probabilities associated with the observations contained in ppdata.

Value

A pixel image (object of class "im"). See density.ppp.

See Also

density.ppp, boundingbox, owin, Hscv

det_radius — *Determination of the nearest-neighbour distance which results in a high-risk zone with desired area*

Description

Used in function det_hrz.

Usage

```
det_radius(ppdata, distancemap, areahrz, win)
```

Arguments

ppdata	observed spatial point pattern of class ppp.
distancemap	distance map (object of class "im", see distmap): distance of every location in the observation window to the nearest event
areahrz	given area of the high-risk zone
win	observation window of class owin

Value

A list of

cutoffdist	quantile of the nearest-neighbour distance
thresh	distance

See Also

det_nnarea, quantile, uniroot

det_threshold — *Calculation of the threshold c, when having failure probability alpha.*

Description

The high-risk zone is the field in which the estimated intensity exceeds the threshold c, which is determined here, having the failure probability alpha. This function is for the intensity-based method. Used in function det_hrz.

Usage

```
det_threshold(intens, alpha = 1e-05, nxprob = 0.1)
```

Arguments

intens	estimated intensity of the observed process (object of class "im", see density.ppp)
alpha	failure probability: probability to have at least one unobserved event outside the high-risk zone
nxprob	probability of having unobserved events

Value

value of the threshold c

See Also

det_alpha, uniroot

---

det_thresholdfromarea *Determination of alpha and the threshold c which results in a high-risk zone with desired area.*

Description

This function is used for the intensity-based method. Used in function det_hrz.

Usage

```
det_thresholdfromarea(intens, areahrz, win, nxprob = 0.1)
```

Arguments

intens	estimated intensity of the observed process (object of class "im", see density.ppp)
areahrz	area of the high-risk zone
win	observation window
nxprob	probability of having unbserved events

Value

A list of

threshold	Value of the threshold c. The high-risk zone is the field in which the estimated intensity exceeds this value
calccutoff	failure probability alpha for given area; probability to have at least unobserved event outside the high-risk zone

See Also

det_area, det_alpha

`det_thresholdfromarea_rest` *Determination of alpha and the threshold c which results in a high-risk zone with desired area if a hole is present.*

Description

This function is used for the intensity-based method. Used in function det_hrz_restr.

Usage

```
det_thresholdfromarea_rest(
  intens,
  areahrz,
  win,
  nxprob = 0.1,
  hole = hole,
  integratehole = TRUE
)
```

Arguments

`intens`	estimated intensity of the observed process (object of class "im", see `density.ppp`)
`areahrz`	area of the high-risk zone
`win`	observation window
`nxprob`	probability of having unbserved events
`hole`	an object of class `owin` representing a region inside the observation window of the `ppdata` where no observations were possible.
`integratehole`	Should the `hole` be part of the resulting high-risk zone? Defaults to `TRUE`.

Value

A list of

`threshold`	Value of the threshold c. The high-risk zone is the field in which the estimated intensity exceeds this value
`calccutoff`	failure probability alpha for given area; probability to have at least unobserved event outside the high-risk zone

See Also

`det_area`, `det_alpha`

det_threshold_eval_ar *Determination of necessary threshold to keep alpha in evaluation area*

Description

Determination of necessary threshold to keep alpha in evaluation area

Usage

```
det_threshold_eval_ar(intens, eval_ar, alpha = 1e-05, nxprob = 0.1)
```

Arguments

intens	estimated intensity
eval_ar	evaluation area
alpha	desired failure probability in eval area
nxprob	constant probability of non-explosion

est_intens *Estimates the intensity of the point pattern.*

Description

Estimates the intensity of the point pattern by a kernel method (See density.ppp).

Usage

```
est_intens(ppdata, covmatrix = NULL, weights = NULL)
```

Arguments

ppdata	data of class ppp
covmatrix	(Optional) Covariance matrix of the kernel of a normal distribution
weights	(Optional) vector of weights attached to each observation

Value

A list of

intensest	Estimated intensity (object of class "im", see density.ppp).
covmatrix	Covariance matrix. If covmatrix = NULL, the matrix is estimated by Hscv.

See Also

density.ppp, Hscv, eval.im

Examples

```
data(craterA)
#change npixel = 50 to 1000 to get a nicer picture
spatstat.geom::spatstat.options(npixel=50)
# use only ten observations for fast computation
thin.craterA <- craterA[1:10]
int <- est_intens(thin.craterA)
# Plot estimated intensity
plot(int$intensest, main = "pixel image of intensity")
plot(craterA$window, main = "contour plot of intensity")
contour(int$intensest, add =TRUE)
```

`est_intens_spde` *Estimates the intensity of the point pattern by using the SPDE method from r-INLA.*

Description

Estimates the intensity of the point pattern by using the SPDE method from r-INLA.

Usage

```
est_intens_spde(
  coords,
  win = NULL,
  npixel = 50,
  fine_mesh = FALSE,
  mesh = NULL,
  weights = NULL,
  alpha = 2,
  ...
)
```

Arguments

`coords`	ppp object or matrix with x and y coordinates of the observed bombs
`win`	observation window, either of class owin or a matrix with the x and y coordinates of the boundary, not neccessary if coords is a ppp object
`npixel`	number of pixel per dimension (see `spatstat.options`)
`fine_mesh`	logical, if FALSE a coarse mesh will be created, if TRUE a fine mesh will be created, only used if argument mesh is NULL
`mesh`	(optional) a predefined mesh for the spde model
`weights`	(optional) integration weights for the spde model, only used if argument mesh is NULL
`alpha`	(optional) alpha value for the spde model, only used if argument spde is NULL
`...`	additional arguments for the construction of the spde model (see INLA/inla.spde2.matern documentation)

Value

A list of

intensest	Pixel image with the estimated intensities of the random field.
mesh	The mesh.

Examples

```
## Not run:
data(craterA)
est_spde <- est_intens_spde(coords=craterA)
image.plot(list(x=est_spde$intensest$xcol, y=est_spde$intensest$yrow,
                z=log(t(est_spde$intensest$v))), main="estimated logarithmic intensity")
points(craterA)

## End(Not run)
```

---

est_intens_weight *Estimates the intensity of the point pattern.*

Description

Estimates the intensity of the point pattern by a kernel method (See density.ppp).

Usage

```
est_intens_weight(ppdata, covmatrix = NULL, weights = NULL)
```

Arguments

ppdata	data of class ppp
covmatrix	(Optional) Covariance matrix of the kernel of a normal distribution
weights	(Optional) vector of weights attached to each observation

Value

A list of

intensest	Estimated intensity (object of class "im", see density.ppp).
covmatrix	Covariance matrix. If covmatrix = NULL the matrix is estimated by Hscv.

See Also

density.ppp, Hscv, eval.im

Examples

```
data(craterA)
#change npixel = 50 to 1000 to get a nicer picture
spatstat.geom::spatstat.options(npixel=50)
# use only ten observations for fast computation
thin.craterA <- craterA[1:10]
# weight first 5 observations twice
weights <- c(rep(2, 5), rep(1, 5))
int <- est_intens_weight(thin.craterA, weights = weights)
plot(int$intensest, main = "pixel image of intensity")
plot(craterA$window, main = "contour plot of intensity")
contour(int$intensest, add =TRUE)
```

---

eval_hrz *Evaluation of the high-risk zone.*

Description

Evaluation of the high-risk zone, which is only possible with simulated or thinned data or if the locations of the unobserved events have been revealed..

Usage

```
eval_hrz(hrz, unobspp, obspp = NULL)
```

Arguments

hrz	High-risk zone of class owin based on a binary mask (see area.owin)
unobspp	Unobserved spatial point process
obspp	Observed spatial point process

Value

An object of class "hrzeval", which is a list of

numbermiss	number of unobserved events outside the high-risk zone
numberunobserved	number of events in the unobserved point pattern
missingfrac	fraction of unobserved events outside the high-risk zone (numbermiss/numberunobserved)
arearegion	area of the high-risk zone
numberobs	number of events in the observed point pattern
out	subset of the unobserved events, which are outside the high-risk zone
insd	subset of the unobserved events, which are inside the high-risk zone

See Also

inside.owin, area.owin

Examples

```
data(craterB)
# thin data
set.seed(100)
thdata <- thin(craterB, nxprob=0.1)

# determine hrz for the "observed events"
hrz <- det_hrz(thdata$observed, type = "dist", criterion = "area", cutoff = 1500000, nxprob = 0.1)

# evaluate the hrz
evaluation <- eval_hrz(hrz = hrz$zone, unobspp = thdata$unobserved, obspp = thdata$observed)
evaluation$missingfrac

op <- par(mar=c(1, 4, 1, 6) , xpd=TRUE)
plot(evaluation, hrz = hrz, obspp = thdata$observed, plothrz = TRUE, plotobs = TRUE,
insidecol = "magenta", outsidecol = "magenta", obscol = "blue", insidepch = 1,
outsidepch = 19, main = "Evaluation visualized")
legend(2400, 2456.4061, c("observed", "unobs inside", "unobs outside"),
col = c("blue", "magenta", "magenta"), yjust=1, pch=c(1, 1, 19), cex=0.8)
par(op)
```

`eval_method` *Evaluation of the procedures determining the high-risk zone.*

Description

Evaluates the performance of the three methods:

- Method of fixed radius
- Quantile-based method
- Intensity-based method

For further details on the methods, see `det_hrz` or the paper of Mahling et al. (2013)(References). There are three ways to simulate data for the evaluation.

Usage

```
eval_method(
  ppdata,
  type,
  criterion,
  cutoff,
  numit = 100,
  nxprob = 0.1,
  distancemap = NULL,
  intens = NULL,
  covmatrix = NULL,
  simulate,
```

```
  radiusClust = NULL,
  clustering = 5,
  pbar = TRUE
)
```

Arguments

ppdata	Observed spatial point process of class ppp.
type	Method to use, can be one of "dist" (method of fixed radius or quantile-based method), or "intens" (intensity-based method)
criterion	criterion to limit the high-risk zone, can be one of "area" (giving size of hrz), "indirect" (giving quantile/alpha depending on type), or "direct" (giving radius/threshold c depending on type)
cutoff	Value of criterion (area, radius, quantile, alpha or threshold). Depending on criterion and type: If criterion = "direct" and type = "intens", cutoff is the maximum intensity of unexploded bombs outside the risk zone. If type = "dist" instead, cutoff is the radius of the circle around each exploded bomb. "If criterion = "indirect", cutoff is the quantile for the quantile-based method and the failure probability alpha for the intensity-base method. If criterion = "area", cutoff is the area the high-risk zone should have.
numit	Number of iterations
nxprob	Probability of having unobserved events. Default value is 0.1.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for type="dist". If not given, it will be computed by distmap.
intens	(optional) estimated intensity of the observed process (object of class "im"), only needed for type="intens". If not given, it will be estimated using density.ppp.
covmatrix	(optional) Covariance matrix of the kernel of a normal distribution, only needed for type="intens" if no intensity is given. If not given, it will be estimated using Hscv.
simulate	The type of simulation, can be one of "thinning", "intens" or "clintens"
radiusClust	(Optional) radius of the circles around the parent points in which the cluster points are located. Only used for simulate = "clintens".
clustering	a value >= 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it is also the parameter of the Poisson distribution for the number of points per cluster. Only used for simulate = "clintens".
pbar	logical. Should progress bar be printed?

Details

The three simulation types are:

Data-based simulation Here a given data set is used. The data set is thinned as explained below. Note that this method is very different from the others, since it is using the real data.

Simulation of an inhomogeneous Poisson process Here, an inhomogeneous Poisson process is simulated and then that data is thinned.

Simulation of a Neyman-Scott process Here a Neyman-Scott process is simulated (see `sim_nsppp`, `rNeymanScott`) and this data is then also thinned.

Thinning:
Let X be the spatial point process, which is the location of all events and let Y be a subset of X describing the observed process. The process of unobserved events then is $Z = X \setminus Y$, meaning that Z and Y are disjoint and together forming X.
Since Z is not known, in this function an observed or simulated spatial point pattern `ppdata` is taken as the full pattern (which we denote by $\tilde{X}$) comprising the observed events $\tilde{Y}$ as well as the unobserved $\tilde{Z}$. Each event in $\tilde{X}$ is assigned to one of the two processes $\tilde{Y}$ or $\tilde{Z}$ by drawing independent Bernoulli random numbers.
The resulting process of observed events $\tilde{Y}$ is used to determine the high-risk zone. Knowing now the unobserved process, it can be seen how many events are outside and inside the high-risk zone.

`type` and `criterion` may be vectors in this function.

Value

A `data.frame` with variables

`Iteration`	Iterationstep of the result
`Type, Criterion, Cutoff, nxprob`	see arguments
`threshold`	determined threshold. If criterion="area", it is either the distance (if type="dist") or the threshold c (for type="intens"). If criterion="indirect", it is either the quantile of the nearest-neighbour distance which is used as radius (if type="dist") or the threshold c (for type="intens"). If criterion="direct", it equals the cutoff for both types.
`calccutoff`	determined cutoff-value. For type="dist" and criterion="area", this is the quantile of the nearest-neighbour distance. For type="intens" and criterion="area", it is the failure probability alpha. For all other criterions it is NA.
`covmatrix11, covmatrix12, covmatrix21, covmatrix22`	values in the covariance matrix. covmatrix11 and covmatrix22 are the diagonal elements (variances).
`numbermiss`	number of unobserved points outside the high-risk zone
`numberunobserved`	number of observations in the unobserved point pattern $\tilde{Z}$
`missingfrac`	fraction of unobserved events outside the high-risk zone (numbermiss/numberunobserved)
`arearegion`	area of the high-risk zone
`numberobs`	number of observations in the observed point pattern $\tilde{Y}$

See Also

`det_hrz`, `rNeymanScott`, `thin`, `sim_nsppp`, `sim_intens`

Examples

```
## Not run:
 data(craterB)

 # the input values are mainly the same as in det_hrz, so for more example ideas,
 # see the documentation of det_hrz.
 evalm <- eval_method(craterB, type = c("dist", "intens"), criterion = c("area", "area"),
                      cutoff = c(1500000, 1500000), nxprob = 0.1, numit = 10,
                      simulate = "clintens", radiusClust = 300,
                      clustering = 15, pbar = FALSE)
 evalm_d <- subset(evalm, evalm$Type == "dist")
 evalm_i <- subset(evalm, evalm$Type == "intens")

 # pout:  fraction of high-risk zones that leave at least one unobserved event uncovered
 # pmiss:  Mean fraction of unobserved events outside the high-risk zone
 data.frame(pmiss_d = mean(evalm_d$missingfrac),
            pmiss_i = mean(evalm_i$missingfrac),
            pout_d = ( sum(evalm_d$numbermiss > 0) / nrow(evalm_d) ),
            pout_i = ( sum(evalm_i$numbermiss > 0) / nrow(evalm_i) ))

## End(Not run)
```

`plot.bootcorr` *Visualize the bootstrap correction for a high-risk zone.*

Description

Plot a visualization of the bootstrap correction for a high-risk zone. The different values tested for alpha are plotted.

Usage

```
## S3 method for class 'bootcorr'
plot(x, ...)
```

Arguments

`x`	bootstrap correction for a high-risk zone (object of class "`bootcorr`")
`...`	extra arguments passed to the generic `plot` function.

Details

This is the plot method for the class `bootcorr`.

See Also

`plot`, `print.bootcorr`, `summary.bootcorr`

`plot.highriskzone` *Plot a high-risk zone*

Description

Plot a high-risk zone.

Usage

```
## S3 method for class 'highriskzone'
plot(
  x,
  ...,
  pattern = NULL,
  win = NULL,
  plotpattern = FALSE,
  plotwindow = FALSE,
  windowcol = "white",
  usegpclib = FALSE,
  zonecol = "grey"
)
```

Arguments

`x`	high-risk zone (object of class "`highriskzone`")
`...`	extra arguments passed to the generic `plot` function
`pattern`	spatial point pattern for which the highriskzone was determined.
`win`	observation winodw
`plotpattern`	logical flag; if `TRUE`, the point pattern is plotted.
`plotwindow`	logical flag; if `TRUE`, the observation window is plotted.
`windowcol`	the color used to plot the observation window
`usegpclib`	logical flag; if `TRUE`, the observation window is transformed in a polygonal window (object of class "`owin`" and of type "`polygonal`"). See `as.polygonal`
`zonecol`	the colour used to plot the high-risk zone.

Details

This is the plot method for the class `highriskzone`.

See Also

`plot`, for examples see `det_hrz`

`plot.hrzeval` *Visualize the evaluation of a high-risk zone.*

Description

Plot a visualization of the evaluation of a high-risk zone. At least the observation window and the unobserved events inside and outside the high-risk zone are plotted.

Usage

```
## S3 method for class 'hrzeval'
plot(
  x,
  ...,
  hrz = NULL,
  obspp = NULL,
  plothrz = FALSE,
  plotobs = FALSE,
  windowcol = "white",
  insidecol = "blue",
  outsidecol = "red",
  insidepch = 20,
  outsidepch = 19,
  zonecol = "grey",
  obscol = "black",
  obspch = 1
)
```

Arguments

`x`	evaluation of a high-risk zone (object of class "`hrzeval`")
`...`	extra arguments passed to the generic `plot` function.
`hrz`	(optional) high-risk zone (object of class "`highriskzone`")
`obspp`	(optional) observed point pattern
`plothrz`	logical flag; should the high-risk zone be plotted?
`plotobs`	logical flag; should the observed point pattern be plotted?
`windowcol`	the color used to plot the observation window
`insidecol`	the color used to plot the unobserved events inside the high-risk zone
`outsidecol`	the color used to plot the unobserved events outside the high-risk zone
`insidepch`	plotting 'character' of the unobserved events inside the high-risk zone, i.e., symbol to use. This can either be a single character or an integer code for one of a set of graphics symbols. The full set of S symbols is available with pch=0:18, see `points`.
`outsidepch`	plotting 'character' of the unobserved events outside the high-risk zone

zonecol	the color used to plot the high-risk zone
obscol	the color used to plot the observed events
obspch	plotting 'character' of the observed events

Details

This is the plot method for the class hrzeval.

See Also

plot, eval_hrz, plot.highriskzone

---

print.bootcorr *Print Brief Details of a bootstrap correction for a high-risk zone*

Description

Prints a very brief description of the bootstrap correction for a high-risk zone.

Usage

```
## S3 method for class 'bootcorr'
print(x, ...)
```

Arguments

x	bootstrap correction for of a high-risk zone (object of class "bootcorr")
...	ignored

Details

A very brief description of the bootstrap correction x for a high-risk zone is printed. This is a method for the generic function print.

See Also

print, summary.bootcorr

print.highriskzone *Print Brief Details of a high-risk zone*

Description

Prints a very brief description of a high-risk zone.

Usage

```
## S3 method for class 'highriskzone'
print(x, ...)
```

Arguments

x	high-risk zone (object of class "highriskzone")
...	ignored

Details

A very brief description of the highriskzone x is printed. This is a method for the generic function print.

See Also

print, summary.highriskzone

print.hrzeval *Print Brief Details of an evaluation of a high-risk zone*

Description

Prints a very brief description of the evaluation of a high-risk zone.

Usage

```
## S3 method for class 'hrzeval'
print(x, ...)
```

Arguments

x	evaluation of a high-risk zone (object of class "hrzeval")
...	ignored

Details

A very brief description of the evaluation x of a high-risk zone is printed. This is a method for the generic function print.

See Also

print, summary.hrzeval

`read_pppdata` *Read data, so it can be used for high-risk zone methodology.*

Description

If xwin or ywin is NULL, the observation window will be a rectangular bounding box. Vertices must be listed anticlockwise; no vertex should be repeated. Only needed for data that is not already of class ppp.

Usage

```
read_pppdata(xppp, yppp, xwin = NULL, ywin = NULL, unitname = NULL)
```

Arguments

xppp	Vector of x coordinates of data points
yppp	Vector of y coordinates of data points
xwin	Vector of x coordinates of the vertices of a polygon circumscribing the observation window
ywin	Vector of y coordinates of the vertices of a polygon circumscribing the observation window
unitname	Optional. Name of unit of length. Either a single character string, or a vector of two character strings giving the singular and plural forms, respectively.

Value

An object of class "ppp" describing a point pattern in the two-dimensional plane.

See Also

ppp, bounding.box.xy, owin

Examples

```
data(craterA)
windowA <- data.frame(x = craterA$window$bdry[[1]]$x, y = craterA$window$bdry[[1]]$y)
patternA <- data.frame(x = craterA$x, y = craterA$y)
str(patternA)
str(windowA)
crater <- read_pppdata(xppp = patternA$x, yppp = patternA$y,
                       xwin = windowA$x, ywin = windowA$y)
crater
```

---

sim_intens *Simulation on given intensity*

Description

Generation of a random point pattern using the inhomogeneous Poisson process (if lambda is not constant) and thinning of this data, to obtain "observed" and "unobserved" events.

Usage

```
sim_intens(ppdata, intensSim, nxprob)
```

Arguments

ppdata	Observed spatial point process of class ppp
intensSim	Intensity to use for the simulation
nxprob	Probability of having unobserved events

Value

A list of of observed and unobserved point patterns (see thin)

See Also

thin, rpoispp

sim_nsppp *Generation of a realisation of a Neyman-Scott process*

Description

This algorithm generates a realisation of a Neyman-Scott process whose expected number of points equals the number of observations in a given pattern.

Usage

```
sim_nsppp(ppdata, radius, clustering = 5, thinning = 0)
```

Arguments

ppdata	observed point pattern, whose estimated intensity (adjusted for thinning and divided by "clustering") is used for simulating the parent process
radius	radius of the circles around the parent points in which the cluster points are located (Maximum radius of a random cluster)
clustering	a value larger or equal 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it is also the parameter of the Poisson distribution for the number of points per cluster
thinning	constant thinning probability (in case the observed pattern is a thinned version of a full pattern); usually equal to the probability of having unobserved events

Details

First, the algorithm generates a Poisson point process (see rpoispp for details) of parent points with intensity kappa, which is a pixel image object of class "im" (see im.object).
This pixel image is derived from the observed pattern using density.ppp. The bandwidth is not chosen in advance.
If only a thinned version of the original pattern has been observed, this can be taken into account using the parameter thinning. Usually, not the estimated intensity itself is used for simulating the parent process, but its values are divided by a constant named "clustering".
Second, each parent point is replaced by a random cluster of points, created by calling the function runifdisc. Each cluster consists of a Poisson distributed number of points (with clustering being the expected number of points in each cluster) which are located in a disc of a given radius. These clusters are combined to yield a single point pattern which is then returned as the result.
The estimation of the intensity (on an adequate window) and the simulation of the Neyman-Scott process are performed seperately, so the intensity does not need to be reestimated in every iteration.
The resulting process is a Mat?rn process whose parent process is an inhomogeneous Poisson point process.

Value

The simulated point pattern (an object of class "ppp"). Additionally, some intermediate results of the simulation are returned as attributes of this point pattern: see rNeymanScott.

See Also

rNeymanScott, rThomas, rMatClust

Examples

```
## Not run:
 data(craterA)
 data(craterB)
 set.seed(100)
 sim_pp1 <- sim_nsppp(craterA, radius=300, clustering=15, thinning=0.1)
 sim_pp2 <- sim_nsppp(craterB, radius=300, clustering=15, thinning=0.1)
 op <- par(mfrow = c(1, 2))
 plot(sim_pp1, main = "simulated cluster process 1")
 plot(sim_pp2, main = "simulated cluster process 2")
 par(op)

## End(Not run)
```

---

sim_nsprocess *Simulation of the Neyman-Scott process.*

Description

Simulation of the Neyman-Scott process. Only applicable if the intensity was estimated for an appropriately enlarged window. More details in sim_nsppp.

Usage

```
sim_nsprocess(ppdata, intens, radius, clustering = 5, thinning = 0)
```

Arguments

ppdata	observed point pattern whose estimated intensity (adjusted for thinning and divided by "clustering") is used for simulating the parent process
intens	estimated intensity
radius	radius of the circles around the parent points in which the cluster points are located (Maximum radius of a random cluster)
clustering	a value larger or equal 1 which describes the amount of clustering; the adjusted estimated intensity of the observed pattern is divided by this value; it is also the parameter of the Poisson distribution for the number of points per cluster
thinning	constant thinning probability (in case the observed pattern is a thinned version of a full pattern); usually equal to the probability of having unobserved events

Value

The simulated point pattern (an object of class "ppp"). Additionally, some intermediate results of the simulation are returned as attributes of this point pattern: see rNeymanScott.

summary.bootcorr *Summary of a the bootstrap correction for a high-risk zone*

Description

Prints a useful summary of the bootstrap correction for a high-risk zone.

Usage

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

Arguments

object	bootstrap correction for a high-risk zone (object of class "bootcorr")
...	ignored

Details

A useful summary of the bootstrap correction x for a high-risk zone is printed. This is a method for the generic function summary.

See Also

summary, print.bootcorr, plot.bootcorr

summary.highriskzone *Summary of a high-risk zone*

Description

Prints a useful summary of a high-risk zone.

Usage

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

Arguments

object	high-risk zone (object of class "highriskzone")
...	ignored

Details

A useful description of the highriskzone object is printed. This is a method for the generic function summary.

See Also

summary, print.highriskzone

---

summary.hrzeval *Summary of a the evaluation of a high-risk zone*

Description

Prints a useful summary of the evaluation of a high-risk zone.

Usage

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

Arguments

object	evaluation of a high-risk zone (object of class "hrzeval")
...	ignored

Details

A useful description of the hrzeval object is printed. This is a method for the generic function summary.

See Also

summary, print.hrzeval

thin *Thinning of the observations (for evaluating the method)*

Description

The thinning is done by drawing independently from a Bernoulli distribution. This function is needed for functions eval_method, sim_clintens, sim_intens

Usage

```
thin(full, nxprob)
```

Arguments

full	all observations of the point pattern
nxprob	probability of having unobserved events

Value

A list of observed and unobserved point patterns. Both of class ppp.

See Also

rbinom, ppp

Examples

```
data(craterB)
thdata <- thin(craterB, nxprob=0.1)
thdata
plot(thdata$observed); points(thdata$unobserved, col=4)
```

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