

# Package ‘highriskzone’

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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*

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### 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 <a href="#">density.ppp</a> ). 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 $\geq 1$ 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 <a href="#">density.ppp</a> ). 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 $\geq 1$ 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 then 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 <code>ppp</code> .
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 <code>owin</code> representing a region inside the observation window of the <code>ppdata</code> where no observations were possible.
obsprobimage	(optional) an object of class <code>im</code> giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of <code>ppdata</code> . Only used if <code>obsprobs</code> is not given.
intens	(optional) estimated intensity of the observed process (object of class <code>"im"</code> , see <a href="#">density.ppp</a> ). 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 <code>"thinning"</code> , <code>"intens"</code> or <code>"clintens"</code>
radiusClust	(optional) radius of the circles around the parent points in which the cluster points are located. Only used for <code>simulate = "clintens"</code> .

clustering	a value $\geq 1$ 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 <code>simulate = "clintens"</code> .
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 then 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::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::as.im(craterA$window, value = 1)
rim <- spatstat::as.im(restrwin, xy = list(x = wim$xcol, y = wim$yrow))
rim$v[is.na(rim$v)] <- 0
oim1 <- spatstat::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 <a href="#">distmap</a> .
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 <a href="#">density.ppp</a> .
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 <a href="#">Hscv</a> .

**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 <code>owin</code> representing a region inside the observation window of the <code>ppdata</code> 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 <code>ppdata</code> . 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 <code>im</code> giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of <code>ppdata</code> . Only used if <code>obsprobs</code> is not given.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for <code>type="dist"</code> . If not given, it will be computed by <code>distmap</code> .
intens	(optional) estimated intensity of the observed process (object of class "im", see <code>density.ppp</code> ), only needed for <code>type="intens"</code> . 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 <code>type="intens"</code> 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	<i>Bomb crater Point Pattern</i>
---------	----------------------------------

---

**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	<i>calculation of alpha (failure probability), when having the threshold c</i>
-----------	--

---

**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 <a href="#">density.ppp</a> )
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 ( <code>as.matrix(intens)</code> )
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	<i>Calculation of the area of the high-risk zone.</i>
---------------	---

---

### 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

<code>win</code>	observation window
<code>intensmatrix</code>	matrix of the estimated intensity of the observed process ( <code>as.matrix(intens)</code> )
<code>threshold</code>	threshold $c$ : The high-risk zone is the field in which the estimated intensity exceeds this value
<code>hole</code>	specified hole
<code>integratehole</code>	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	<i>Estimation of width of a guard region given an estimated highriskzone</i>
-----------------	--

---

### 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 unexploded 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 unexploded 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 additional 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\_const 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,  $0 < \text{thresh\_const} < 1$ .

### 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::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 <a href="#">distmap</a> .
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 <a href="#">density.ppp</a> .
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 <a href="#">Hscv</a> .

### 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 highriskzones 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

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

## 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::spatstat.options(npixel=1000)
## 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:
dism <- distmap(craterA)
hrzd <- det_hrz(craterA, type = "dist", criterion = "direct", cutoff = 100,
               distancemap = dism, 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	<i>Determination of high-risk zone on smaller area of interest (evaluation area) than observation area.</i>
-----------------	---

---

### 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 <a href="#">density.ppp</a> .
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 <a href="#">Hscv</a> .

### Value

An object of class "highriskzone"

### Examples

```
set.seed(12412)
spatstat::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::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 <code>im</code> giving the observation probabilities inside the observation window. Ranges of the coordinates must equal those of <code>ppdata</code> . Only used if <code>obsprobs</code> is not given.
distancemap	(optional) distance map: distance of every pixel to the nearest observation of the point pattern; only needed for <code>type="dist"</code> . If not given, it will be computed by <code>distmap</code> .
intens	(optional) estimated intensity of the observed process (object of class <code>"im"</code> , see <code>density.ppp</code> ), only needed for <code>type="intens"</code> . 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 <code>type="intens"</code> if no intensity is given. If not given, it will be estimated.
returnintens	Should the image of the estimated intensity be returned? Defaults to <code>TRUE</code> .

## 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 `obsprobimage` (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

<code>typehrz</code> , <code>criterion</code> , <code>cutoff</code> , <code>nxprob</code>	see arguments
<code>zone</code>	Determined high-risk zone: Object of class <code>"owin"</code> based on a binary mask. See <code>owin</code> .
<code>threshold</code>	determined threshold. If <code>type = "dist"</code> and <code>criterion = "direct"</code> it is the specified radius. If <code>criterion = "indirect"</code> or <code>"area"</code> the determined radius used to construct a risk zone fulfilling the specified criterion and cutoff. If <code>type = "dist"</code> it is the specified or calculated threshold <code>c</code> , the maximum intensity 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 <a href="#">Hscv</a> .
estint	Estimated intensity. See <a href="#">density.ppp</a> .

### See Also

[distmap](#), [eval.im](#), [owin](#)

### Examples

```
set.seed(1211515)
data(craterA)
#change npixel = 100 to 1000 to get a nicer picture
spatstat::spatstat.options(npixel=100)
# reduce number of observations for faster computation
craterA <- craterA[sample(1:craterA$n, 150)]
# define restriction area
restrwin <- spatstat::owin(xrange=craterA$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::as.im(craterA$window, value=1)
rim <- spatstat::as.im(restrwin, xy=list(x=wim$xcol, y=wim$yrow))
rim$v[is.na(rim$v)] <- 0
oim1 <- spatstat::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	<i>Determination of the area of a high-risk zone using the nearest-neighbour distance.</i>
------------	--

---

### 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 <a href="#">distmap</a> ): 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	<i>Determination of the intensity for the Neyman Scott simulation.</i>
--------------	--

---

**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 <a href="#">distmap</a> ): 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	<i>Calculation of the threshold <math>c</math>, when having failure probability <math>\alpha</math>.</i>
---------------	--

---

**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 <a href="#">density.ppp</a> )
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 <a href="#">density.ppp</a> )
areahrz	area of the high-risk zone
win	observation window
nxprob	probability of having unobserved 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 <a href="#">density.ppp</a> )
areahrz	area of the high-risk zone
win	observation window
nxprob	probability of having unobserved 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	<i>Estimates the intensity of the point pattern.</i>
------------	--

---

### 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 <a href="#">density.ppp</a> ).
covmatrix	Covariance matrix. If covmatrix = NULL, the matrix is estimated by <a href="#">Hscv</a> .

### See Also

[density.ppp](#), [Hscv](#), [eval.im](#)

### Examples

```
data(craterA)
#change npixel = 50 to 1000 to get a nicer picture
spatstat::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	<i>Estimates the intensity of the point pattern by using the SPDE method from r-INLA.</i>
-----------------	---

---

### 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 necessary if coords is a ppp object
npixel	number of pixel per dimension (see <a href="#">spatstat.options</a> )
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 <a href="#">density.ppp</a> ).
covmatrix	Covariance matrix. If covmatrix = NULL the matrix is estimated by <a href="#">Hscv</a> .

### See Also

[density.ppp](#), [Hscv](#), [eval.im](#)

### Examples

```
data(craterA)
#change npixel = 50 to 1000 to get a nicer picture
spatstat::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	<i>Evaluation of the high-risk zone.</i>
----------	--

---

### 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 <a href="#">area.owin</a> )
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 <a href="#">distmap</a> .
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 <a href="#">density.ppp</a> .
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 <a href="#">Hscv</a> .
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 $\geq 1$ 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	<i>Visualize the bootstrap correction for a high-risk zone.</i>
---------------	---

---

### 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 <a href="#">plot</a> function.

### Details

This is the plot method for the class bootcorr.

### See Also

[plot](#), [print.bootcorr](#), [summary.bootcorr](#)

---

plot.highriskzone	<i>Plot a high-risk zone</i>
-------------------	------------------------------

---

### Description

Plot a high-risk zone.

### Usage

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

**Arguments**

x	high-risk zone (object of class "highriskzone")
...	extra arguments passed to the generic <code>plot</code> function
pattern	spatial point pattern for which the highriskzone was determined.
win	observation window
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
usegpclip	logical flag; if TRUE, the observation window is transformed in a polygonal window (object of class "owin" and of type "polygonal"). See <a href="#">as.polygonal</a>
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 <code>plot</code> 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 <a href="#">points</a> .
outsidepch	plotting 'character' of the unobserved events outside the high-risk zone
zonocol	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	<i>Read data, so it can be used for high-risk zone methodology.</i>
--------------	---

---

**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**

<code>xppp</code>	Vector of x coordinates of data points
<code>yppp</code>	Vector of y coordinates of data points
<code>xwin</code>	Vector of x coordinates of the vertices of a polygon circumscribing the observation window
<code>ywin</code>	Vector of y coordinates of the vertices of a polygon circumscribing the observation window
<code>unitname</code>	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	<i>Generation of a realisation of a Neyman-Scott process</i>
-----------	--

---

### 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 separately, 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	<i>Summary of a the bootstrap correction for a high-risk zone</i>
------------------	---

---

**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	<i>Summary of a high-risk zone</i>
----------------------	------------------------------------

---

**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	<i>Thinning of the observations (for evaluating the method)</i>
------	---

---

**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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