

# Package ‘alphashape3d’

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**Title** Implementation of the 3D Alpha-Shape for the Reconstruction of  
3D Sets from a Point Cloud

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**Suggests** alphahull

**Description** Implementation in R of the alpha-shape of a finite set of points in the three-dimensional space. The alpha-shape generalizes the convex hull and allows to recover the shape of non-convex and even non-connected sets in 3D, given a random sample of points taken into it. Besides the computation of the alpha-shape, this package provides users with functions to compute the volume of the alpha-shape, identify the connected components and facilitate the three-dimensional graphical visualization of the estimated set.

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alphashape3d-package    *Computation of the 3D  $\alpha$ -shape*

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### Description

Implementation in R of the  $\alpha$ -shape of a finite set of points in the three-dimensional space. The  $\alpha$ -shape generalizes the convex hull and allows to recover the shape of non-convex and even non-connected sets in 3D, given a random sample of points taken into it. Besides the computation of the  $\alpha$ -shape, this package provides users with functions to compute the volume of the  $\alpha$ -shape, identify the connected components and facilitate the three-dimensional graphical visualization of the estimated set.

### Details

Package:    alphashape3d  
Version:    1.3  
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License:    GPL-2  
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### Author(s)

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### References

Edelsbrunner, H., Mucke, E. P. (1994). Three-Dimensional Alpha Shapes. *ACM Transactions on Graphics*, 13(1), pp.43-72.

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ashape3d                    *3D  $\alpha$ -shape computation*

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### Description

This function calculates the 3D  $\alpha$ -shape of a given sample of points in the three-dimensional space for  $\alpha > 0$ .

### Usage

```
ashape3d(x, alpha, pert = FALSE, eps = 1e-09)
```

**Arguments**

<code>x</code>	A 3-column matrix with the coordinates of the input points. Alternatively, an object of class "ashape3d" can be provided, see Details.
<code>alpha</code>	A single value or vector of values for $\alpha$ .
<code>pert</code>	Logical. If the input points are not in general position and <code>pert</code> is set to TRUE the observations are perturbed by adding random noise, see Details.
<code>eps</code>	Scaling factor used for data perturbation when the input points are not in general position, see Details.

**Details**

If `x` is an object of class "ashape3d", then `ashape3d` does not recompute the 3D Delaunay triangulation (it reduces the computational cost).

If the input points `x` are not in general position and `pert` is set to TRUE, the function adds random noise to the data. The noise is generated from a normal distribution with mean zero and standard deviation  $\text{eps} \times \text{sd}(x)$ .

**Value**

An object of class "ashape3d" with the following components (see Edelsbrunner and Mücke (1994) for notation):

<code>tetra</code>	For each tetrahedron of the 3D Delaunay triangulation, the matrix <code>tetra</code> stores the indices of the sample points defining the tetrahedron (columns 1 to 4), a value that defines the intervals for which the tetrahedron belongs to the $\alpha$ -complex (column 5) and for each $\alpha$ a value (1 or 0) indicating whether the tetrahedron belongs to the $\alpha$ -shape (columns 6 to last).
<code>triang</code>	For each triangle of the 3D Delaunay triangulation, the matrix <code>triang</code> stores the indices of the sample points defining the triangle (columns 1 to 3), a value (1 or 0) indicating whether the triangle is on the convex hull (column 4), a value (1 or 0) indicating whether the triangle is attached or unattached (column 5), values that define the intervals for which the triangle belongs to the $\alpha$ -complex (columns 6 to 8) and for each $\alpha$ a value (0, 1, 2 or 3) indicating, respectively, that the triangle is not in the $\alpha$ -shape or it is interior, regular or singular (columns 9 to last). As defined in Edelsbrunner and Mücke (1994), a simplex in the $\alpha$ -complex is interior if it does not belong to the boundary of the $\alpha$ -shape. A simplex in the $\alpha$ -complex is regular if it is part of the boundary of the $\alpha$ -shape and bounds some higher-dimensional simplex in the $\alpha$ -complex. A simplex in the $\alpha$ -complex is singular if it is part of the boundary of the $\alpha$ -shape but does not bound any higher-dimensional simplex in the $\alpha$ -complex.
<code>edge</code>	For each edge of the 3D Delaunay triangulation, the matrix <code>edge</code> stores the indices of the sample points defining the edge (columns 1 and 2), a value (1 or 0) indicating whether the edge is on the convex hull (column 3), a value (1 or 0) indicating whether the edge is attached or unattached (column 4), values that define the intervals for which the edge belongs to the $\alpha$ -complex (columns 5 to 7) and for each $\alpha$ a value (0, 1, 2 or 3) indicating, respectively, that the edge is not in the $\alpha$ -shape or it is interior, regular or singular (columns 8 to last).

vertex	For each sample point, the matrix vertex stores the index of the point (column 1), a value (1 or 0) indicating whether the point is on the convex hull (column 2), values that define the intervals for which the point belongs to the $\alpha$ -complex (columns 3 and 4) and for each $\alpha$ a value (1, 2 or 3) indicating, respectively, if the point is interior, regular or singular (columns 5 to last).
x	A 3-column matrix with the coordinates of the original sample points.
alpha	A single value or vector of values of $\alpha$ .
xpert	A 3-column matrix with the coordinates of the perturbed sample points (only when the input points are not in general position and pert is set to TRUE).

## References

Edelsbrunner, H., Mucke, E. P. (1994). Three-Dimensional Alpha Shapes. *ACM Transactions on Graphics*, 13(1), pp.43-72.

## Examples

```
T1 <- rtorus(1000, 0.5, 2)
T2 <- rtorus(1000, 0.5, 2, ct = c(2, 0, 0), rotx = pi/2)
x <- rbind(T1, T2)
# Value of alpha
alpha <- 0.25
# 3D alpha-shape
ashape3d.obj <- ashape3d(x, alpha = alpha)
plot(ashape3d.obj)

# For new values of alpha, we can use ashape3d.obj as input (faster)
alpha <- c(0.15, 1)
ashape3d.obj <- ashape3d(ashape3d.obj, alpha = alpha)
plot(ashape3d.obj, indexAlpha = 2:3)
```

---

components\_ashape3d    *Connected subsets computation*

---

## Description

This function calculates and clusters the different connected components of the  $\alpha$ -shape of a given sample of points in the three-dimensional space.

## Usage

```
components_ashape3d(as3d, indexAlpha = 1)
```

**Arguments**

as3d	An object of class "ashape3d" that represents the $\alpha$ -shape of a given sample of points in the three-dimensional space, see <a href="#">ashape3d</a> .
indexAlpha	A single value or vector with the indexes of as3d\$alpha that should be used for the computation, see Details.

**Details**

The function components\_ashape3d computes the connected components of the  $\alpha$ -shape for each value of  $\alpha$  in as3d\$alpha[indexAlpha] when indexAlpha is numeric.

If indexAlpha="all" or indexAlpha="ALL" then the function computes the connected components of the  $\alpha$ -shape for all values of  $\alpha$  in as3d\$alpha.

**Value**

If indexAlpha is a single value then the function returns a vector  $v$  of length equal to the sample size. For each sample point  $i$ ,  $v[i]$  represents the label of the connected component to which the point belongs (for isolated points,  $v[i]=-1$ ). The labels of the connected components are ordered by size where the largest one (in number of vertices) gets the smallest label which is one.

Otherwise components\_ashape3d returns a list of vectors describing the connected components of the  $\alpha$ -shape for each selected value of  $\alpha$ .

**See Also**

[ashape3d](#), [plot.ashape3d](#)

**Examples**

```
T1 <- rtorus(1000, 0.5, 2)
T2 <- rtorus(1000, 0.5, 2, ct = c(2, 0, 0), rotx = pi/2)
x <- rbind(T1, T2)
alpha <- c(0.25, 2)
ashape3d.obj <- ashape3d(x, alpha = alpha)
plot(ashape3d.obj, indexAlpha = "all")

# Connected components of the alpha-shape for both values of alpha
comp <- components_ashape3d(ashape3d.obj, indexAlpha = "all")
class(comp)
# Number of components and points in each component for alpha=0.25
table(comp[[1]])
# Number of components and points in each component for alpha=2
table(comp[[2]])

# Plot the connected components for alpha=0.25
plot(ashape3d.obj, byComponents = TRUE, indexAlpha = 1)
```

---

inashape3d

*Test of the inside of an  $\alpha$ -shape*


---

## Description

This function checks whether points are inside an  $\alpha$ -shape.

## Usage

```
inashape3d(as3d, indexAlpha = 1, points)
```

## Arguments

as3d	An object of class "ashape3d" that represents the $\alpha$ -shape of a given sample of points in the three-dimensional space, see <a href="#">ashape3d</a> .
indexAlpha	A single value or vector with the indexes of as3d\$alpha that should be used for the computation, see Details.
points	A 3-column matrix with the coordinates of the input points.

## Details

The function `inashape3d` checks whether each point in `points` is inside the  $\alpha$ -shape for each value of  $\alpha$  in `as3d$alpha[indexAlpha]`.

If `indexAlpha="all"` or `indexAlpha="ALL"` then the function checks whether each point in `points` is inside the  $\alpha$ -shape for all values of  $\alpha$  in `as3d$alpha`.

## Value

If `indexAlpha` is a single value then the function returns a vector of boolean of length the number of input points. The element at position `i` is TRUE if the point in `points[i, ]` is inside the  $\alpha$ -shape.

Otherwise `inashape3d` returns a list of vectors of boolean values (each object in the list as described above).

## See Also

[ashape3d](#)

## Examples

```
T1 <- rtorus(2000, 0.5, 2)
T2 <- rtorus(2000, 0.5, 2, ct = c(2, 0, 0), rotx = pi/2)
x <- rbind(T1, T2)
ashape3d.obj <- ashape3d(x, alpha = 0.4)
# Random sample of points in a plane
points <- matrix(c(5*runif(10000) - 2.5, rep(0.01, 5000)), nc = 3)
in3d <- inashape3d(ashape3d.obj, points = points)
```

```
plot(ashape3d.obj, transparency = 0.2)
colors <- ifelse(in3d, "blue", "green")
rgl.points(points, col = colors)
```

---

plot.ashape3d *Plot the  $\alpha$ -shape in 3D*

---

## Description

This function plots the  $\alpha$ -shape in 3D using the package [rgl](#).

## Usage

```
## S3 method for class 'ashape3d'
plot(x, clear = TRUE, col = c(2, 2, 2),
     byComponents = FALSE, indexAlpha = 1, transparency = 1,
     walpha = FALSE, triangles = TRUE, edges = TRUE, vertices = TRUE, ...)
```

## Arguments

x	An object of class "ashape3d" that represents the $\alpha$ -shape of a given sample of points in the three-dimensional space, see <a href="#">ashape3d</a> .
clear	Logical, specifying whether the current rgl device should be cleared.
col	A vector of length three specifying the colors of the triangles, edges and vertices composing the $\alpha$ -shape, respectively.
byComponents	Logical, if TRUE the connected components of the $\alpha$ -shape are represented in different colors, see <a href="#">components_ashape3d</a> .
indexAlpha	A single value or vector with the indexes of x\$alpha that should be used for the computation, see Details.
transparency	The coefficient of transparency, from 0 (transparent) to 1 (opaque), used to plot the $\alpha$ -shape.
walpha	Logical, if TRUE the value of $\alpha$ is displayed in the rgl device.
triangles	Logical, if TRUE triangles are plotted.
edges	Logical, if TRUE edges are plotted.
vertices	Logical, if TRUE vertices are plotted.
...	Material properties. See <a href="#">rgl.material</a> for details.

## Details

The function plot.ashape3d opens a rgl device for each value of  $\alpha$  in x\$alpha[indexAlpha]. Device information is displayed in the console.

If indexAlpha="all" or indexAlpha="ALL" then the function represents the  $\alpha$ -shape for all values of  $\alpha$  in as3d\$alpha.

**See Also**

[ashape3d](#), [components\\_ashape3d](#)

**Examples**

```
T1 <- rtorus(1000, 0.5, 2)
T2 <- rtorus(1000, 0.5, 2, ct = c(2, 0, 0), rotx = pi/2)
x <- rbind(T1, T2)
alpha <- c(0.15, 0.25, 1)
ashape3d.obj <- ashape3d(x, alpha = alpha)

# Plot the alpha-shape for all values of alpha
plot(ashape3d.obj, indexAlpha = "all")

# Plot the connected components of the alpha-shape for alpha=0.25
plot(ashape3d.obj, byComponents = TRUE, indexAlpha = 2)
```

---

rtorus

*Generate points in the torus*

---

**Description**

This function generates  $n$  random points within the torus whose minor radius is  $r$ , major radius is  $R$  and center is  $ct$ .

**Usage**

```
rtorus(n, r, R, ct = c(0, 0, 0), rotx = NULL)
```

**Arguments**

<code>n</code>	Number of observations.
<code>r</code>	Minor radius (radius of the tube).
<code>R</code>	Major radius (distance from the center of the tube to the center of the torus).
<code>ct</code>	A vector with the coordinates of the center of the torus.
<code>rotx</code>	If not NULL, a rotation through an angle <code>rotx</code> (in radians) about the $x$ -axis is performed.

**Examples**

```
T1 <- rtorus(2000, 0.5, 2.5)
rgl.bbox()
rgl.points(T1, col = 4)
```



```
T2 <- rtorus(2000, 0.5, 2.5, ct = c(2, 0, 0.5), rotx = pi/2)
rgl.points(T2, col = 2)
```

---

surfaceNormals      *Normal vectors computation*

---

## Description

This function calculates the normal vectors of all the triangles which belong to the boundary of the  $\alpha$ -shape.

## Usage

```
surfaceNormals(x, indexAlpha = 1, display = FALSE, col = 3, scale = 1,
  ...)
```

## Arguments

x	An object of class "ashape3d" that represents the $\alpha$ -shape of a given sample of points in the three-dimensional space, see <a href="#">ashape3d</a> .
indexAlpha	A single value or vector with the indexes of <code>as3d\$alpha</code> that should be used for the computation, see Details.
display	Logical, if TRUE, <code>surfaceNormals</code> open a new rgl device and display the related $\alpha$ -shape and its normals vectors.
col	Color of the normal vectors.
scale	Scale parameter to control the length of the surface normals, only affect display.
...	Material properties. See <a href="#">rgl.material</a> for details.

## Details

The function `surfaceNormals` computes the normal vectors of all the triangles which belong to the boundary of the  $\alpha$ -shape for each value of  $\alpha$  in `x$alpha[indexAlpha]`. The magnitude of each vector is equal to the area of its associated triangle.

If `indexAlpha="all"` or `indexAlpha="ALL"` then the function computes the normal vectors for all values of  $\alpha$  in `as3d$alpha`.

## Value

If `indexAlpha` is a single value then the function returns an object of class "normals" with the following components:

normals	Three-column matrix with the euclidean coordinates of the normal vectors.
centers	Three-column matrix with the euclidean coordinates of the centers of the triangles that form the $\alpha$ -shape.

Otherwise `surfaceNormals` returns a list of class "normals-List" (each object in the list as described above).

**See Also**[ashape3d](#)**Examples**

```
x <- rtorus(1000, 0.5, 1)
alpha <- 0.25
ashape3d.obj <- ashape3d(x, alpha = alpha)
surfaceNormals(ashape3d.obj, display = TRUE)
```

---

 volume\_ashape3d

*Volume computation*


---

**Description**

This function calculates the volume of the  $\alpha$ -shape of a given sample of points in the three-dimensional space.

**Usage**

```
volume_ashape3d(as3d, byComponents = FALSE, indexAlpha = 1)
```

**Arguments**

as3d	An object of class "ashape3d" that represents the $\alpha$ -shape of a given sample of points in the three-dimensional space, see <a href="#">ashape3d</a> .
byComponents	Logical, if FALSE (default) volume_ashape3d computes the volume of the whole $\alpha$ -shape. If TRUE, volume_ashape3d computes the volume of each connected component of the $\alpha$ -shape separately.
indexAlpha	A single value or vector with the indexes of as3d\$alpha that should be used for the computation, see Details.

**Details**

The function volume\_ashape3d computes the volume of the  $\alpha$ -shape for each value of  $\alpha$  in as3d\$alpha[indexAlpha] when indexAlpha is numeric.

If indexAlpha="all" or indexAlpha="ALL" then the function computes the volume of the  $\alpha$ -shape for all values of  $\alpha$  in as3d\$alpha.

**Value**

If indexAlpha is a single value then the function returns the volume of the  $\alpha$ -shape (if the argument byComponents is set to FALSE) or a vector with the volumes of each connected component of the  $\alpha$ -shape (if the argument byComponents is set to TRUE).

Otherwise volume\_ashape3d returns a list (each object in the list as described above).

**See Also**

[ashape3d](#), [components\\_ashape3d](#)

**Examples**

```
C1 <- matrix(runif(6000), nc = 3)
C2 <- matrix(runif(6000), nc = 3) + 2
x <- rbind(C1, C2)
ashape3d.obj <- ashape3d(x, alpha = 0.75)
plot(ashape3d.obj, byComponents = TRUE)

# Compute the volume of the alpha-shape
volume_ashape3d(ashape3d.obj)
# Compute the volumes of the connected components of the alpha-shape
volume_ashape3d(ashape3d.obj, byComponents = TRUE)
```

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