

## Functional Boxplots

### Description

Produces functional boxplots or enhanced functional boxplots of the given functional data. It can also be used to carry out functional data ordering based on band depth.

### Usage

```
fbplot(fit, x = NULL, method = "MBD", depth = NULL, plot = TRUE,
       prob = 0.5, color = 6, outliercol = 2, barcol = 4,
       fullout=FALSE, factor=1.5,xlim=c(1,nrow(fit)),
       ylim=c(min(fit)-.5*diff(range(fit)),max(fit)+.5*diff(range(fit))),...)
## S3 method for class 'fd'
boxplot(x, z=NULL, ...)
## S3 method for class 'fdPar'
boxplot(x, z=NULL, ...)
## S3 method for class 'fdSmooth'
boxplot(x, z=NULL, ...)
```

### Arguments

#### fit

a p-by-n functional data matrix where n is the number of curves, and p is defined below.

#### x

For `fbplot`, x is the x coordinates of curves. Defaults to 1:p where p is the number of x coordinates.

For `boxplot.fd`, `boxplot.fdPar` and `boxplot.fdSmooth`, x is an object of class `fd`, `fdPar` or `fdSmooth`, respectively.

#### z

The coordinate of the curves, labeled x for `fdplot`. For `boxplot.fd`, `boxplot.fdPar` and `boxplot.fdSmooth`, this cannot be x, because that would clash with the generic `boxplot(x, ...)` standard.

#### method

the method to be used to compute band depth. Can be one of "BD2", "MBD" or "Both" with a default of "MBD". See also details.

#### depth

a vector giving band depths of curves. If missing, band depth computation is conducted.

#### plot

logical. If TRUE (the default) then a functional boxplot is produced. If not, band depth and outliers are returned.

<b>prob</b>	a vector giving the probabilities of central regions in a decreasing order, then an enhanced functional boxplot is produced. Defaults to be 0.5 and a functional boxplot is plotted.
<b>color</b>	a vector giving the colors of central regions from light to dark for an enhanced functional boxplot. Defaults to be magenta for a functional boxplot.
<b>outliercol</b>	color of outlying curves. Defaults to be red.
<b>barcol</b>	color of bars in a functional boxplot. Defaults to be blue.
<b>fullout</b>	logical for plotting outlying curves. If FALSE (the default) then only the part outside the box is plotted. If TRUE, complete outlying curves are plotted.
<b>factor</b>	the constant factor to inflate the middle box and determine fences for outliers. Defaults to be 1.5 as in a classical boxplot.
<b>xlim</b>	x-axis limits
<b>ylim</b>	y-axis limits
<b>...</b>	For <code>fbplot</code> , optional arguments for <code>plot</code> . For <code>boxplot.fd</code> , <code>boxplot.fdPar</code> , or <code>boxplot.fdsSmooth</code> , optional arguments for <code>fbplot</code> .

## Details

For functional data, the band depth (BD) or modified band depth (MBD) allows for ordering a sample of curves from the center outwards and, thus, introduces a measure to define functional quantiles and the centrality or outlyingness of an observation. A smaller rank is associated with a more central position with respect to the sample curves. BD usually provides many ties (curves have the same depth values), but MBD does not. "BD2" uses two curves to determine a band. The method "Both" uses "BD2" first and then uses "MBD" to break ties. The method "Both" uses BD2 first and then uses MBD to break ties. The computation is carried out by the fast algorithm proposed by Sun et. al. (2012).

## Value

<b>depth</b>	band depths of given curves.
<b>outpoint</b>	

column indices of detected outliers.

## Author(s)

Ying Sun [sunwards@stat.osu.edu](mailto:sunwards@stat.osu.edu)

Marc G. Genton [marc.genton@kaust.edu.sa](mailto:marc.genton@kaust.edu.sa)

## References

Sun, Y., Genton, M. G. and Nychka, D. (2012), "Exact fast computation of band depth for large functional datasets: How quickly can one million curves be ranked?" *Stat*, 1, 68-74.

Sun, Y. and Genton, M. G. (2011), "Functional Boxplots," *Journal of Computational and Graphical Statistics*, 20, 316-334.

Lopez-Pintado, S. and Romo, J. (2009), "On the concept of depth for functional data," *Journal of the American Statistical Association*, 104, 718-734.

Ramsay, James O., Hooker, Giles, and Graves, Spencer (2009), *Functional data analysis with R and Matlab*, Springer, New York.

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## Examples

```
##  
## 1. generate 50 random curves with some covariance structure  
##      model 1 without outliers  
##  
cov.fun=function(d,k,c,mu){  
  k*exp(-c*d^mu)  
}  
n=50  
p=30  
t=seq(0,1,len=p)  
d=dist(t,upper=TRUE,diag=TRUE)  
d.matrix=as.matrix(d)  
#covariance function in time  
t.cov=cov.fun(d.matrix,1,1,1)  
# Cholesky Decomposition  
L=chol(t.cov)  
mu=4*t  
e=matrix(rnorm(n*p),p,n)  
ydata = mu+t(L)%%e
```

```

#functional boxplot
oldpar <- par(no.readonly=TRUE)
fbplot(ydata,method='MBD',ylim=c(-11,15))

# The same using boxplot.fd
boxplot.fd(ydata, method='MBD', ylim=c(-11, 15))

# same with default ylim
boxplot.fd(ydata)

## 
## 2. as an fd object
##
T      = dim(ydata)[1]
time   = seq(0,T,len=T)
ybasis = create.bspline.basis(c(0,T), 23)
Yfd    = smooth.basis(time, ydata, ybasis)$fd
boxplot(Yfd)

## 
## 3. as an fdPar object
##
Ypar <- fdPar(Yfd)
boxplot(Ypar)

## 
## 4. Smoothed version
##
Ysmooth <- smooth.fdPar(Yfd)
boxplot(Ysmooth)

## 
## 5. model 2 with outliers
##
#magnitude
k=6
#randomly introduce outliers
C=rbinom(n,1,0.1)
s=2*rbinom(n,1,0.5)-1
cs.m=matrix(C*s,p,n,byrow=TRUE)

e=matrix(rnorm(n*p),p,n)
y=mu+t(L) %*% e+k*cs.m

#functional boxplot
fbplot(y,method='MBD',ylim=c(-11,15))
par(oldpar)

```