

Package ‘rPAex’

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Type Package

Title Automatic Detection of Experimental Unit in Precision
Agriculture

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Imports terra, agricolae

Depends R (>= 3.5.0)

Description A part of precision agriculture is linked to the spectral image obtained from the cameras. With the image information of the agricultural experiment, the included functions facilitate the collection of spectral data associated with the experimental units. Some designs generated in R are linked to the images, which allows the use of the information of each pixel of the image in the experimental unit and the treatment. Tables and images are generated for the analysis of the precision agriculture experiment during the entire vegetative period of the crop.

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NeedsCompilation no

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borderPoint	<i>Border in the experimental units</i>
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Description

Generates the spectral information of the edge of the EUs for analysis of the border effect, it requires the spectral image, the distance of the border and the segmentation of the EUs generated by imageField.

Usage

```
borderPoint(r, Rbook, distance, plotting=TRUE, ...)
```

Arguments

r	spectral image
Rbook	Object generated by imageField
distance	distance defining the border of the exterior to the experimental plot
plotting	Logic value to display the image of the border effect around the EUs
...	plot parameter to document the image as main, axis, etc

Details

Set the border in terms of distance in units measured in the field

Value

Qborder	Border bounds matrix
border	dataframe spectral border and that is expressed in the image.

Author(s)

Felipe de Mendiburu

See Also

[cassava](#), [fourPoint](#), [imageField](#)

Examples

```

# use cassava crop information
library(rPAex)
data(cassava)
r <- terra::rast(cassava,type="xyz")
# cassava area
# Apply: x11()
terra::image(r,axes=FALSE)
# p <- locator(3) to generate 3 points in the area
p<-list(x=c(287689.4, 287702.8, 287706.2),y=c(8664210, 8664214, 8664179))
# Generate the fourth points of the area
q<-fourPoint(p)
op<-par(mfrow=c(1,3),mar=c(0,0,0,0))
terra::image(r,axes=FALSE)
text(287693.3,8664215,"Image crop",cex=1.5)
r <- terra::rast(cassava,type="xyz")
# cassava area
# Apply: p <- locator(3) to generate 3 points in the area

p<-list(x=c(287689.4, 287702.8, 287706.2),y=c(8664210, 8664214, 8664179))
# Generate the fourth points of the area
q<-fourPoint(p)
op<-par(mfrow=c(1,3),mar=c(0,0,0,0))
terra::image(r,axes=FALSE)
text(287693.3,8664215,"Image crop",cex=1.5)
# The area is divided into 3x2 plots of 11x6 meters per experimental unit
Rbook<-imageField(r,q,3,2,11,6,plotting=TRUE)
out<-borderPoint(r,Rbook,distance=1,axes=FALSE)
text(287693.4, 8664214, "Border",cex=1.5)
# NDVI in border
ndvi<-with(out$Border, (L1-L2)/(L1+L2))
# NDVI > 0.5 more probability of vegetation
plt<-out$Border[ndvi>0.5,1:2]
w<-terra::rast(out$Border)
text(287693.3,8664215,"Border",cex=1,5)
terra::image(w,axes=FALSE)
text(287693.3,8664215,"Vegetation",cex=1.5)
points(plt,cex=0.2,col=colors()[51],pch=20)
par(op)

```

cassava

Cassava crop

Description

The image of the cassava crop corresponds to flight 11 recorded by the drone on February 26, 2015 at the International Potato Center, with a multispectral camera. The cultivation area includes 6 plots of 11 x 6 meters. Due to the size of the images, only image 11 was used in rPAex.

Usage

```
data("cassava")
```

Format

A data frame with 262056 observations on the following 5 variables.

x coordinate X, a numeric vector
y coordinate Y, a numeric vector
L1 Near-Infrared Light (NIR), a numeric vector
L2 Red band, a numeric vector
L3 Green band, a numeric vector

Details

The cassava crop data was built with the TTC_0559_georeferenced.tif image (Loayza, 2018) and the terra package (Hijmans, 2023).

Source

International Potato Center. CIP - Lima Peru. Dataverse CIP.

References

Loayza, Hildo; Silva, Luis; Palacios, Susan; Balcazar, Mario; Quiroz, Roberto, 2018, "Dataset for: Modelling crops using high resolution multispectral images", <doi: 10.21223/P3/UVWVLA>, International Potato Center, V1
Hijmans R (2023). _terra: Spatial Data Analysis. <https://CRAN.R-project.org/package=terra>

See Also

[cropTime](#), [EUsPoint](#), [imageField](#), [borderPoint](#)

Examples

```
library(rPAex)
# Generation of cassava data
# download the TTC_0559_georeferenced.tif image from CIP DATAVERSE repository
# library(terra)
# img = "TTC_0559_georeferenced.tif"
# r<-rast(img)
# e = ext(287688, 287709, 8664174, 8664217)
# rc = crop(r, e)
# terra::image(rc) # Image cassava
# to use locator(), fourPoint() and imageField() to generate the cassava data
data(cassava)
# Contains 262056 pixels of 5 centimeters each with multispectral data
r<-terra::rast(cassava,type="xyz")
terra::image(r) # Image cassava
```

cropTime	<i>Spectral evolution of cassava cultivation</i>
----------	--

Description

Spectral data of the cassava crop during its development, of the 38 spectral images of the data repository of the International Potato Center, plot number 3 of 6 cultivated, is described in 9 moments of its development, obtaining near-infrared, red responses and green

Usage

```
data("cropTime")
```

Format

A data frame with 172263 observations on the following 6 variables.

Flight a numeric vector

x coordinate X, a numeric vector

y coordinate Y, a numeric vector

L1 Near-Infrared Light (NIR), a numeric vector

L2 Red band, a numeric vector

L3 Green band, a numeric vector

Details

The images were read with the `rast` function (Hijmans, 2023), plot 3 was located and the information of the 38 images was obtained with the `rPAex imageField` function. Due to the size of the images, only 9 images were used as part of the `rPAex` data. The images were captured with a Remotely Piloted Aircraft System (RPAS), the system included an OKtokoter platform and an multispectral camera (MicroADC-Tetracam). The multispectral images are composed of information in the NIR, Red and Green bands. The images were acquired at 95 meters average flight altitude. drone flight date, began on December 18, 2014, and ended on November 4, 2015 (Loayza, 2018). The `cropTime` data table was built from the "tif" images and the `terra` package (Himans, 2023). The R code instructions for reading the images were similar to the "cassava data" construction, in which the `rPAex` function `imageField()` was added, to then select plot-3 of 9 images separated in time.

Source

International Potato Center. CIP - Lima Peru. Dataverse CIP.

References

Loayza, Hildo; Silva, Luis; Palacios, Susan; Balcazar, Mario; Quiroz, Roberto, 2018, "Dataset for: Modelling crops using high resolution multispectral images", doi: 10.21223/P3/UVWVLA, International Potato Center, V1

Hijmans R (2023). `_terra: Spatial Data Analysis_`. <https://CRAN.R-project.org/package=terra>.

See Also

[cassava](#), [EUsPoint](#), [imageField](#), [borderPoint](#)

Examples

```
library(rPAex)
data(cropTime)
ndvi<-with(cropTime,(L1-L2)/(L1+L2))
ndviTime<-data.frame(cropTime,ndvi)
fly<-c(1, 2, 6, 11, 20, 23, 30, 36, 38)
dates<-c("2014-12-18","2015-01-06","2015-01-29","2015-02-26","2015-04-22",
         "2015-05-15", "2015-07-03","2015-08-13","2015-08-28")
#x11()
op<-par(mfrow=c(3,3),mar=c(0,0,1,0),cex=0.8)
for(i in 1:9){
  P<-ndviTime[ndviTime$Flight==fly[i],]
  P$ndvi<-(P$L1-P$L2)/(P$L1+P$L2)
  I<-terra::rast(P[,c(2,3,7)],type="xyz")
  terra::image(I,col= hcl.colors(12, "Greens 3", rev = TRUE),axes=FALSE,
              main=paste("flighth:", fly[i]))
}
par(op)
```

designRaster

Experimental Design on a Raster Image

Description

It uses a design generated by the agricolae package in a raster image.

Usage

```
designRaster(R,book)
```

Arguments

R	output object imageField
book	function output field book design.* agricolae

Details

The R object contains the following information: pixel coordinates and image layer information.

The outDesign object is generated by the design functions of the agricolae package

Value

design	The matrix R of the image with the experimental design information
rasterField	the R matrix of the image with the information of the bands and the characteristics of the experimental design

Author(s)

Felipe de Mendiburu

References

Felipe de Mendiburu (2019). agricolae: Statistical Procedures for Agricultural Research. R package version 1.3-1. <http://tarwi.lamolina.edu.pe/~fmendiburu/>

Kwanchai A. Gomez, Arturo A. Gomez (1984). Statistical Procedures for Agricultural Research. John Wiley & Sons, new York.

See Also

[imageField](#)

Examples

```
# alpha design with 12 treatments
library(rPAex)
# r = simulated raster image data
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()

# Alpha design, r-raster image
trt<-1:12
t <- length(trt)
# size block k
k<-3
# Blocks s
s<-t/k
# replications r =2
outdesign<- agricolae::design.alpha(trt,k=3,r=2,serie=1)
r1<-subset(outdesign$book, replication==1)
r2<-subset(outdesign$book, replication==2)
#-----
#x11()
op<-par(mar=c(2,2,3,2),cex=0.8)
terra::image(r,main="alpha design in the image
with the distribution of treatments",col=col2rgb(10),axes=FALSE)
axis(1); axis(2,seq(0,100,20))
#P<-locator(3)
p1<-list(x=c(4.27, 35.42, 47.49),y=c(68.12, 70.82, 23.63))
q1<-fourPoint(p1)
p2<-list(x=c(50.27, 81.42, 93.49),y=c(68.12, 70.82, 23.63))
q2<-fourPoint(p2)
polygon(q1,lwd=3,lty=2,border=colors()[51])
polygon(q2,lwd=3,lty=2,border=colors()[51])
R1<-imageField(r, Q=q1, ny=4, nx=3, dy=10, dx=9,col=colors()[18])
R2<-imageField(r, Q=q2, ny=4, nx=3, dy=10, dx=9,col=colors()[18])
q1<-designRaster(R=R1$Qbase,book=r1)$design
q2<-designRaster(R=R2$Qbase,book=r2)$design
```

```
text(q1[,6],q1[,7],q1[,4])
text(q2[,6],q2[,7],q2[,4])
par(op)
```

EUsPoint

Generates the matrix Q of a particular experimental unit

Description

The Q matrix is formed by 4 points that limits the Experimental unit, this matrix is used by the imageField function to generate the units, by obtaining the Q matrix of an unit, it is possible to generate subplots of the units.

Usage

```
EUsPoint(Rbook,EU)
```

Arguments

Rbook	object imagenField
EU	constant. number of experimental unit

Value

Q	matrix, four points
---	---------------------

See Also

[imageField](#), [cassava](#)

Examples

```
library(rPAex)
data(cassava)
s <- terra::rast(cassava,type="xyz")
# Use image and locator(2)
#x11()
op<-par(mar=c(2,2,3,2),cex=0.8)
# terra::image(s)
# p<-locator(2)
# e<-terra::ext(unlist(p))
e <- terra::ext(287691.9, 287708.6, 8664188, 8664203)
r <- terra::crop(s,e)
#-----
# Define the border of the plot
# p<-locator(3)
p<-list(x=c(287698.21, 287700.99, 287702.39), y=c(8664200.68, 8664201.57,8664190.63))
q<-fourPoint(p)
#-----
```

```

# Define a subarea of 11x3 units by 1x0.9 meters
ny<-11; nx<-3; dy=1; dx=0.9
terra::image(r,main="Cassava crop\nnear infrared image",bty="l")
Rbook<-imageField(r, q, ny, nx, dy, dx, plotting = TRUE, border="blue",lwd=1)
# identify unit 11 with the spectral information
Q<-EUsPoint(Rbook,EU=11)
polygon(Q,col="black")
pol <- terra::vect(Q, "polygons")
R <- terra::extract(r, pol, xy = TRUE)
head(R)
par(op)

```

fixedPoint

Orientation, Position and Length of the Experimental Unit

Description

Generates a number of equidistant spatial points in an area. Fixed a couple of points in the image and the number of segments included, the function determines the position of the segments according to the length of the segment. The function relates the real dimension of the segment measurement to the image dimension. The function is useful for sizing plot sizes in the field, it also facilitates the generation of experimental units in the field.

Usage

```
fixedPoint(start, end, segments, length)
```

Arguments

start	Starting point
end	Point at the end
segments	Number of segments
length	Segment length

Details

This function is used by imageField.

Value

xy	Data vector with the coordinate of the points
----	---

See Also

[imageField](#)

Examples

```

library(rPAex)
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()
#x11()
op<-par(mar=c(2,2,4,2),cex=0.8)
terra::image(r,col=col2rgb(10),main="Orientation, position and length of the experimental
  unit\nstart = P1, end = P2, segments=4 and segment length = 10",bty="l")
P<-list(x=c(20,80),y=c(40,80)) # or P<-locator(2)
P<-cbind(x=P$x,y=P$y)
Q<-fixedPoint(start = P[1,],end = P[2,],4,length = 10)
x <- Q[,1]; y <- Q[,2]
s <- seq(length(x)-1) # one shorter than data
segments(x[s], y[s], x[s+1], y[s+1], col= c(1,0),lwd=2)
# Description:
text(Q,cex=2,col="red")
text(20,80,"Total length = 72.11 units")
text(20,70,"total segments = 4")
text(60,40," Free space = 10.7037 units")
text(60,30,"Segment length = 10 units")
text(50,10,"fixedPoint(start ,end ,segments = 4,length = 10)")
text(20,35,"start",cex=1.5)
text(80,75,"end",cex=1.5)
par(op)

```

fourPoint

*Generating the Fourth Point of the Study Plot***Description**

Generate the fourth reference point of the plot according to three defined geo-referential points. This function is important for the correct use of all the functions of the rPAex package. In the image the plot is a parallelogram, the first assigned point must be located in the upper left and continue the second point in the upper right side and the third point in the lower right, always in a clockwise direction.

Usage

```
fourPoint(P)
```

Arguments

P the three points list

Value

P matrix, four points

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

```

library(rPAex)
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()
# x11()
op<-par(mar=c(2,2,4,2),cex=0.8)
terra::image(r,main="Generating the fourth point of the study plot",col=col2rgb(10),
xlim=c(20,101), ylim=c(0,101),axes=FALSE)
# p<-locator(3)
p<-list(x=c(40, 88, 80) , y=c(83, 82, 19))
q<-fourPoint(p)
polygon(q,lty=2,lwd=2)
text(q,cex=2)
points(q[4,1],q[4,2],cex=6,col=2,lwd=2)
d<-dist(q)
text(64,86,round(d[1],1),cex=1.5)
text(90,52,round(d[3],1),cex=1.5)
text(29,53,round(d[4],1),cex=1.5)
text(58,15,round(d[6],1),cex=1.5)
par(op)
# x11()
op <-par(mar=c(2,2,4,2),cex=0.8)
# An irregular area, use 4 points with p<-locator(4) and apply q<-fourPoint(p) to form the matrix
terra::image(r,bty="l",main="An irregular area")
#p<-locator(4)
p<-list(x=c(40, 88, 80, 29) , y=c(83, 82, 19, 20))
q<-fourPoint(p)
d<-dist(q)
polygon(q)
text(64,86,round(d[1],1),cex=1.5)
text(90,52,round(d[3],1),cex=1.5)
text(29,53,round(d[4],1),cex=1.5)
text(56,15,round(d[6],1),cex=1.5)
nx<-2;ny<-3
dy=d[3]/ny;dx=d[1]/nx
# EU area= dx*dy
out<-imageField(r,q,ny,nx,dy,dx)
par(op)
# number of pixels per EU
table(out$Qbase$EU)

```

Description

The function uses the raster image of all bands. It generates the limits of the unit and extracts the values of each pixel of the plot $n \times m$ units ($n, m = 1, 2, \dots$). The function requires the dimensions of the unit observed and the number of units per row (width) and column (length). The result is a table with image information and the characteristics of the experimental unit.

Usage

```
imageField(r, Q, ny, nx, dy, dx, start=1, plotting = TRUE, ...)
```

Arguments

r	raster image
Q	References points of de area
ny	Number of experimental units along the plot (y axis)
nx	Number of experimental units across the plot (x axis)
dy	Wide of unit plots
dx	Length of unit plots
start	Number of the first experimental unit
plotting	Overlap the units in the area, TRUE or FALSE
...	Other parameters the plot

Value

parameters	Parameters of experimental design in precision agriculture
Qbase	Image data frame with location in field
coordinates.EU	The limits of each experimental unit

See Also

[EUsPoint](#), [fixedPoint](#), [fourPoint](#), [designRaster](#), [cassava](#)

Examples

```
library(rPAex)
data(cassava)
r <- terra::rast(cassava, type="xyz")
# x11()
# terra::image(r)
# p<-locator(2)
# e<-terra::ext(unlist(p))
e <- terra::ext(287691.9, 287708.6, 8664188, 8664203)
rc <- terra::crop(r,e)
# Selection of experimental units, p1 and p2 in terra::image(r)
p1<-list(x=c(287698.34, 287701.14, 287702.33),
         y=c(8664200.89, 8664201.65, 8664190.67))
p2<-list(x=c(287701.56, 287704.37, 287705.24),
```

```

y=c(8664198.68, 8664199.44, 8664191.46))
q1<-fourPoint(p1)
q2<-fourPoint(p2)
# dimension of the experimental unit
dy=1; dx=0.9
op<-par(mar=c(0,0,3,0))
terra::image(rc,main="Selection of experimental units\nCassava crop",axes=FALSE)
img1<-imageField(rc, q1, ny=11, nx=3, dy, dx, plotting = TRUE, border="blue",lwd=1)
img2<-imageField(rc, q2, ny=8, nx=3, dy, dx, start=34,plotting = TRUE, border="blue",lwd=1)
# Spectral data of selected units
R<-rbind(img1$Qbase,img2$Qbase)
head(R)
Q<-agricolae::tapply.stat(R[,2:3],R[,1],mean)
text(Q[,2],Q[,3],Q[,1],cex=1)
par(op)

```

movePlot

Rotation and Translation of the Plot Position

Description

The coordinates of the plot generated with the `locate()` and `fourPoint()` functions define the experimental units with the field dimensions, In the successive images in time, these may have some difference in position and it is necessary to adapt the experimental units to obtain exactly the information within the unit.

Usage

```
movePlot(Q, q)
```

Arguments

Q	matrix. Four points of the plot as described by the <code>fourPoint</code> function
q	matrix or list. Two points, the first one sets the position and the second the orientation

Details

The matrix Q has the points organized according to the `fourPoint` function. To know the numbering in the plane, execute `text(Q)`. The first must be the upper left and numbered clockwise.

Value

q	matrix. Four points of the new plot as described by the <code>fourPoint</code> function
---	---

Author(s)

Felipe de Mendiburu

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

```

library(rPAex)
op<-par(mfrow=c(1,3),mar=c(0,0,0,0))
# Coordinates during initial flight
plot(0,0,xlim=c(0.08,0.9),ylim=c(0.1,0.9),axes=FALSE)
# x11(); p0<-locator(3)
p0<-list(x=c(0.20, 0.64, 0.81),y=c(0.71, 0.83, 0.40))
Q0<-fourPoint(p0)
dp<-dist(Q0)
text(Q0[1],Q0[2],paste("(",Q0[1],",",Q0[2],")",sep=""),cex=1.2)
polygon(Q0,border="blue",lwd=1.5)
centro<-apply(Q0,2,mean)
areaEU<-round(dp[1]*dp[2],4)
text(centro[1],centro[2],paste("Area=",areaEU),col="blue")
text(0.50,0.2,"old plot",cex=1.5)
#-----
# Change of coordinates effect of flight, correction to initial flight
plot(0,0,xlim=c(0.08,0.9),ylim=c(0.1,0.9),axes=FALSE)
polygon(Q0,border="blue",lwd=1.5)
text(Q0,cex=1.5)
# x11(); s <-locator(3)
s<-list(x=c(0.2,0.62),y=c(0.71,0.73))
Qs<-movePlot(Q0,s)
centro<-apply(Qs,2,mean)
polygon(Qs,border="red",lty=2,lwd=1.5)
text(Qs,cex=1.5)
text(centro[1],centro[2]+0.05,paste("Area=",areaEU),col="red")
text(centro[1],0.9,"Change position\n of the new images",cex=1.5)
text(0.50,0.2,"change position",cex=1.5)
#-----
# correction result
plot(0,0,xlim=c(0.08,0.9),ylim=c(0.1,0.9),axes=FALSE)
polygon(Qs,border="red",lwd=1.5)
text(Qs,cex=1.5)
text(centro[1],centro[2],paste("Area=",areaEU),col="red")
text(0.50,0.2,"new plot",cex=1.5)
par(op)

```

Description

The package contains functions to manage images obtained by remote sensing of the experimental fields. In the field the characteristics of the plot are defined (number of units per row and column and

dimensions in meters or other dimension measures). The program uses the information to generate the limits and record the content of the different layers, as well as the coordinates of the pixels and the identification of the observation units in the field. It also allows to extract the experimental designs generated in agricolae package and distribute the treatments in the image according to the distribution of the generated plan. The images used in the examples were obtained from the repository of (Loayza et al. 2018) International Potato Center, V1.

Details

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References

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Richards, J. A. Remote sensing digital image analysis: An introduction. 2012

See Also

[EUPoint](#), [fixedPoint](#), [fourPoint](#), [imageField](#), [borderPoint](#), [designRaster](#), [movePlot](#), [cassava](#), [cropTime](#)

Examples

```
# Simple examples of the most important functions
library(rPAex)
# Graeco - latin square design
T1<-c("a","b","c","d")
T2<-c("v","w","x","y")
outdesign <- agricolae::design.graeco(T1,T2,serie=1)
book<-outdesign$book
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()
# x11()
op<-par(mar=c(2,2,4,2),cex=0.9)
terra::image(r,main="Graeco - latin square design\n
Treatments T1 (a, b, c, d) and T2 (v, w, x, y)",col=col2rgb(2),axes=FALSE,xlim=c(0,101))
axis(1);axis(2)
# 3 points are set in the image, to generate the experimental area
# P<-locator(3)
P<-list(x=c(20,90,80),y=c(80,90,20))
# and complete the fourth point to close the polygon.
Q<-fourPoint(P)
polygon(Q,lwd=3)
R<-imageField(r, Q, ny=4, nx=4, dy=12, dx=12,col=colors()[18])
q<-designRaster(R$Qbase,book)$design
text(q[,6],q[,7]+2,q[,1])
text(q[,6],q[,7]-2,paste(q[,4],q[,5],sep=" - "))
par(op)
# An irregular area, use 4 points with p<-locator(4) and apply q<-fourPoint(p) to form the matrix
# x11()
op<-par(mar=c(2,2,2,2),cex=0.9)
terra::image(r,xlim=c(20,100),ylim=c(10,100),axes=FALSE,main="An irregular area",col=col2rgb(3))
axis(1);axis(2)
# p<-locator(4)
p<-list(x=c(40, 88, 80, 29) , y=c(83, 82, 19, 20))
q<-fourPoint(p)
dist(q)
dx=10;dy=12
nx<-4; ny<-5
S<-imageField(r,q,ny,nx,dy,dx,col=colors()[20])
points(q,cex=4,pch=20,col="white")
```

```
text(q,cex=1.5)
M<-agricolae::tapply.stat(S$Qbase[,2:3],S$Qbase$EU)
# identifying EU
text(M[,2],M[,3],M[,1],cex=1)
par(op)
```

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