Package ‘rPAex’

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Type Package

Title Automatic Detection of Experimental Unit in Precision Agriculture

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Imports raster, 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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R topics documented:

`borderPoint` *Border in the experimental units*

Description

Generates the spectral information of the edge of the UEs for analysis of the border effect, it requires the spectral image, the distance of the border and the segmentation of the UEs 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 UEs
`...`	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 <- raster::rasterFromXYZ(cassava)
# cassava area
P<-list(x=c(287689.4, 287702.8, 287706.2),y=c(8664210, 8664214, 8664179))
Q<-fourPoint(P)
op<-par(mfrow=c(1,2))
raster::image(r,useRaster=FALSE)
Rbook<-imageField(r,Q,3,2,11,6,plotting=TRUE)
out<-borderPoint(r,Rbook,distance=1, main="Image crop")
par(op)
# NDVI in border
ndvi<-with(out$Border, (L1-L2)/(L1+L2))
plt<-out$Border[ndvi>0.5,1:2]
op<-par(mfrow=c(1,1))
w<-raster::rasterFromXYZ(out$Border)
raster::image(w,useRaster=FALSE,main="Border plants")
points(plt,cex=0.8,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 raster package (Hijmans, 2022). The R code instructions that were used for the cassava dataframe were:
library(raster); img = "TTC_0559_georeferenced.tif"
layer1 = raster(img,band=1); layer2 = raster(img,band=2); layer3 = raster(img,band=3)
r = addLayer(layer1,layer2,layer3); e = extent(287688, 287709, 8664174, 8664217)
rc = crop(r, e); bands = values(rc); xy = coordinates(rc); cassava = data.frame(xy,bands)

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, Robert J. 2022. Raster: Geographic Data Analysis and Modeling. https://CRAN.R-project.org/package=raster.

See Also

`evolution`, `EUsPoint`, `imageField`, `borderPoint`

Examples

```
library(rPAex)
data(cassava)
head(cassava)
```

---

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

```
library(rPAex)
oldpar<-par(mar=c(2,2,3,2),cex=0.8)
# 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)
#--------
raster::image(r,main="alpha design in the image
with the distribution of treatments",col=col2rgb(10))
#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(oldpar)
```

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)
library(raster)
data(cassava)
e <- extent(287697.8, 287705.8,8664189, 8664203)
s <- rasterFromXYZ(cassava)
r <- crop(s,e)
#-----
# P<-locator(3)
```

```
P<-list(x=c(287698.21, 287700.99, 287702.39), y=c(8664200.68, 8664201.57,8664190.63))
Q<-fourPoint(P)
#-----
ny<-11; nx<-3; dy=1; dx=0.9
image(r,useRaster=FALSE,main="Cassava crop\nnear infrared image")
Rbook<-imageField(r, Q, ny, nx, dy, dx, plotting = TRUE, border="blue",lwd=1)
# See experimental unit number 11
Q<-EUsPoint(Rbook,EU=11)
polygon(Q,lty=2,density=20)
```

`evolution` *Spectral evolution of cassava cultivation*

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("evolution")
```

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 raster function (Hijmans, 2022), 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 multiespectral camera (MicroADC-Tetracam). The multiespectral images are composed of information in the NIR, Red and Green bands. The images were acquired at 95 meteres average flight altitude. drone flight date, began on December 18, 2014, and ended on November 4, 2015 (Loayza, 2018). The evolution data table was built from the "tif" images and the raster package (Himans, 2015). 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, Robert J. 2022. Raster: Geographic Data Analysis and Modeling. https://CRAN.R-project.org/package=raster.

See Also

cassava, EUsPoint, imageField, borderPoint

Examples

```
library(rPAex)
data(evolution)
icolor<-c(19,19,20,20,21,21,22,49,50,51,51,81,81,85,85,85)
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")
op<-par(mar=c(0,0,3,0),mfrow=c(3,3))
for(i in fly) {
  P<-subset(evolution,Flight==i)
  ndvi<-with(P,(L1-L2)/(L1+L2))
  nd<-round((ndvi+1)*10,0) # ndvi encoding
  nd<-nd+1-min(nd)
  colorxy<-icolor[nd]
    with(P,plot(x,y,col=colors()[colorxy],axes=FALSE,
    main=paste("Fly:",fly[i],"\n",dates[i])))
}
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()
oldpar<-par(mar=c(2,2,4,2),cex=0.8)
raster::image(r,col=col2rgb(10),main="Orientation, position and length of the experimental unit")
# P<-locator(2)
P<-list(x=c(20,80),y=c(40,80))
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)
text(Q,cex=1.5)
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(oldpar)
```

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()
oldpar<-par(mar=c(2,2,4,2),cex=0.8)
raster::image(r,main="Generating the fourth point of the study plot",col=col2rgb(10))
#P<-locator(3)
P<-list(x=c(20,80,80),y=c(70,80,30))
Q<-fourPoint(P)
polygon(Q,lty=2,density=8)
text(Q,cex=2)
points(Q[4,1],Q[4,2],cex=6,col=2,lwd=2)
par(oldpar)
```

`imageField` *Matching Pixels With Field Book*

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 x m units (n, m = 1,2, ...). 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)
library(raster)
data(cassava)
r <- rasterFromXYZ(cassava)
e <- extent(287697.8, 287705.8,8664189, 8664203)  # cutout of study area
rc <- crop(r, e)
#-----
```

```
# P<-locator(3)
P1<-list(x=c(287698.21, 287700.99, 287702.39),
         y=c(8664200.68, 8664201.57,8664190.63))
P2<-list(x=c(287701.59, 287704.3, 287705.25),y=c(8664198.5, 8664199.3, 8664191.6))
Q1<-fourPoint(P1)
Q2<-fourPoint(P2)
#-----
dy=1; dx=0.9
raster::image(rc,useRaster=FALSE,main="Cassava crop\nnear infrared image")
img1<-imageField(rc, Q1, ny=11, nx=3, dy, dx, plotting = TRUE, border="blue",lwd=1)
img2<-imageField(rc, Q2, ny=6, nx=3, dy, dx, start=34,plotting = TRUE, border="blue",lwd=1)
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)
```

---

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 fourPoint 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 fourPoint function

Author(s)

Felipe de Mendiburu

See Also

imageField

Examples

```
library(rPAex)
#
op<-par(mfrow=c(1,3),mar=c(0,0,0,0))
plot(0,0,xlim=c(0.08,0.9),ylim=c(0.1,0.9),axes=FALSE)
p0<-list(x=c(0.20, 0.64, 0.81),y=c(0.71, 0.83, 0.40)) # locator(3)
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)
areaUE<-round(dp[1]*dp[2],4)
text(centro[1],centro[2],paste("Area=",areaUE),col="blue")
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=2)
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=2)
text(centro[1],centro[2]+0.05,paste("Area=",areaUE),col="red")
text(centro[1],0.9,"Change position\n of the new images",cex=2)
#--------
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=2)
q<-list(x=c(0.3,0.6),y=c(0.6,0.6))
Qq<-movePlot(Q0,q)
polygon(Qq,border="red",lty=2,lwd=1.5)
text(Qq,cex=2)
centro<-apply(Qq,2,mean)
text(centro[1],centro[2]+0.1,paste("Area=",areaUE),col="red")
par(op)
```

---

rPAex *Automatic Detection of Experimental Unit in Precision Agriculture*

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

Package:	rPAex
Type:	Package
Version:	1.0.3
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Note

The fileRaster() function converts a TIFF image to raster. You need to install rgdal first then activite. see example.

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References

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See Also

EUsPoint, fixedPoint, fourPoint, imageField, borderPoint, designRaster, movePlot,cassava,evolution

Examples

```
# activate fileRaster() function.
# fraster <- system.file("script/fileRaster.R", package="rPAex")
# source(fraster)
# r<- fileRaster(tiff)
#
# 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$book
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()
oldpar<-par(mar=c(2,2,4,2),cex=0.9)
raster::image(r,main="Graeco - latin square design\n
Treatments T1 (a, b, c, d) and T2 (v, w, x, y)",col=col2rgb(2))
#P<-locator(3)
P<-list(x=c(20,90,80),y=c(80,90,20))
Q<-fourPoint(P)
polygon(Q,lwd=3)
R<-imageField(r, Q, ny=4, nx=4, dy=12, dx=12,col=colors()[18])
q<-designRaster(R$Qbase,book)$design
text(q[,6],q[,7]+2,q[,1])
text(q[,6],q[,7]-2,paste(q[,4],q[,5],sep=" - "))
par(oldpar)
```

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