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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**borderPoint**

**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

```r
# 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)
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)
text(287693.3, 8664215, "Vegetation", cex=1.5)
points(plt, cex=0.2, col=colors()[51], pch=20)
par(op)
```

---

**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/UVWVL A>, International Potato Center, V1

See Also

cropTime, EUisPoint, imageField, borderPoint

Examples

library(rPAex)
# Generation of cassava data
# download the TTC_0559_georeferenced.tif image from CIP DATVERSE 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**

---

**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("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 OKiokoter platform and a multiespectral camera (MicroADC-Tetracam). The multiespectral 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 multiespectral images", doi: 10.21223/P3/UVWVLA, International Potato Center, V1

See Also
cassava, EUsPoint, imageField, borderPoint

Examples

```r
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)
#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("fligth:", 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**

```r
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


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))

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
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)
#-----
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
start = 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)
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

dfourPoint(P)

Arguments

P  the three points list

Value

P  matrix, four points
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,1ty=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],1),cex=1.5)
text(90,52,round(d[3,1],1),cex=1.5)
text(29,53,round(d[4,1],1),cex=1.5)
text(58,15,round(d[6,1],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],1),cex=1.5)
text(90,52,round(d[3,1],1),cex=1.5)
text(29,53,round(d[4,1],1),cex=1.5)
text(58,15,round(d[6,1],1),cex=1.5)
x<-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 (\( n, m = 1, 2, \ldots \)). 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
- **coordinates.EU**: The limits of each experimental unit

See Also

EUSPoint, fixedPoint, fourPoint, designRaster, cassava

Examples

```r
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),
```
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

```r
library(rPAex)
ops<-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)
```

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: 1.0.5
Date: 2023-11-01
License: GPL

Author(s)

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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/UVWVLX, International Potato Center, V1.


See Also

EUsPoint, 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$book
prg1 <- system.file("examples/Ex-01.R", package="rPAex")
source(prg1)
r<-data1()
# x11()
# 3 points are set in the image, to generate the experimental area
# P<-locator(3)
P<-list(x=c(20,90,80),y=c(80,90,20))
# and complete the fourth point to close the polygon.
Q<-fourPoint(P)
polygon(Q,lwd=3)
R<-imageField(r, Q, ny=4, nx=4, dy=12, dx=12,col=colors()[18])
q<-designRaster(R$Qbase,book)$design
# An irregular area, use 4 points with p<-locator(4) and apply q<-fourPoint(p) to form the matrix
# x11()
op<-par(mar=c(2,2,2,2),cex=0.9)
terra::image(r,xlim=c(20,100),ylim=c(10,100),axes=FALSE,xlim=c(0,101))
axis(1);axis(2)
# p<-locator(4)
p<-list(x=c(40, 88, 80, 29) , y=c(83, 82, 19, 20))
q<-fourPoint(p)
dist(q)
dx=10;dy=12
nx<-4; ny<-5
S<-imageField(r,q,ny,nx,dy,dx,col=colors()[20])
points(q,ce=4,pch=20,col="white")
text(q,cex=1.5)
M<-agricolae::tapply.stat(S$Qbase[,2:3],S$Qbase$EU)
# identifying EU
text(M[,2],M[,3],M[,1],cex=1)
par(op)
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