# Package 'Ternary'

August 27, 2024

**Version** 2.3.3

**Title** Create Ternary and Holdridge Plots

**Description** Plots ternary diagrams (simplex plots / Gibbs triangles) and Holdridge life zone plots <doi:10.1126/science.105.2727.367> using the standard graphics functions.
Allows custom annotation, interpolating, contouring and scaling of plotting region.
Includes a 'Shiny' user interface for point-and-click ternary plotting.
An alternative to 'ggtern', which uses the 'ggplot2' family of plotting functions.

**URL** https://ms609.github.io/Ternary/,
https://github.com/ms609/Ternary/

**BugReports** https://github.com/ms609/Ternary/issues/

**License** GPL (>= 2)

**Language** en-GB

**Depends** R (>= 3.6.0)

**Imports** PlotTools (>= 0.2.0), RcppHungarian, shiny, sp,

**Suggests** colourpicker, knitr, readxl, rmarkdown, shinyjs, spelling, testthat (>= 3.0), vdiffr,

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**LazyData** true

**VignetteBuilder** knitr

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**NeedsCompilation** no

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**Repository** CRAN

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# Contents



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`AddToHoldridge` *Add elements to ternary or Holdridge plot*

---

## Description

Plot shapes onto a ternary diagram created with `TernaryPlot()`, or a Holdridge plot created with `HoldridgePlot()`.

## Usage

```
AddToHoldridge(PlottingFunction, pet, prec, ...)

HoldridgeArrows(fromCoordinates, toCoordinates = fromCoordinates, ...)

HoldridgeLines(pet, prec, ...)

HoldridgePoints(pet, prec, ...)

HoldridgePolygon(pet, prec, ...)

HoldridgeText(pet, prec, ...)

AddToTernary(PlottingFunction, coordinates, ...)

TernarySegments(fromCoordinates, toCoordinates = fromCoordinates, ...)

TernaryArrows(fromCoordinates, toCoordinates = fromCoordinates, ...)

TernaryLines(coordinates, ...)

TernaryPoints(coordinates, ...)

TernaryPolygon(coordinates, ...)

TernaryText(coordinates, ...)

JoinTheDots(coordinates, ...)
```

## Arguments

| | |
|---|---|
| `PlottingFunction` | Function to add data to a plot; perhaps one of `points`, `lines` or `text`. |
| `pet`, `prec` | Numeric vectors giving *p*otential *e*vapo*t*ranspiration ratio and annual *prec*ipitation (in mm). |
| `...` | Additional parameters to pass to `PlottingFunction()`. If using `TernaryText()`, this will likely include the parameter `labels`, to specify the text to plot. Other useful graphical parameters include `srt` to rotate text. |
| `fromCoordinates`, `toCoordinates` | For `TernaryArrows()`, coordinates at which arrows should begin and end; *cf.* `x0`, `y0`, `x1` and `y1` in arrows. Recycled as necessary. |
| `coordinates` | A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space. |

## Functions

- `HoldridgeArrows()`: Add arrows to Holdridge plot

- `HoldridgeLines()`: Add lines to Holdridge plot
- `HoldridgePoints()`: Add points to Holdridge plot
- `HoldridgePolygon()`: Add polygons to Holdridge plot
- `HoldridgeText()`: Add text to Holdridge plot
- `TernarySegments()`: Add segments
- `TernaryArrows()`: Add arrows
- `TernaryLines()`: Add lines
- `TernaryPoints()`: Add points
- `TernaryPolygon()`: Add polygons
- `TernaryText()`: Add text
- `JoinTheDots()`: Add points, joined by lines

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other Holdridge plotting functions: `HoldridgeHypsometricCol()`, `HoldridgePlot()`, `holdridge`, `holdridgeClasses`

## Examples

```
# Data to plot
coords <- list(
  A = c(1, 0, 2),
  B = c(1, 1, 1),
  C = c(1.5, 1.5, 0),
  D = c(0.5, 1.5, 1)
)

# Set up plot
oPar <- par(mar = rep(0, 4), xpd = NA) # reduce margins and write in them
TernaryPlot()

# Add elements to ternary diagram
AddToTernary(lines, coords, col = "darkgreen", lty = "dotted", lwd = 3)
TernaryLines(coords, col = "darkgreen")
TernaryArrows(coords[1], coords[2:4], col = "orange", length = 0.2, lwd = 1)
TernaryText(coords, cex = 0.8, col = "red", font = 2)
TernaryPoints(coords, pch = 1, cex = 2, col = "blue")
AddToTernary(graphics::points, coords, pch = 1, cex = 3)

# An equivalent syntax applies to Holdridge plots:
HoldridgePlot()
pet <- c(0.8, 2, 0.42)
prec <- c(250, 400, 1337)
HoldridgeText(pet, prec, c("A", "B", "C"))
```

```
AddToHoldridge(graphics::points, pet, prec, cex = 3)

# Restore original plotting parameters
par(oPar)
```

---

`Annotate` *Annotate points on a ternary plot*

---

## Description

`Annotate()` identifies and label individual points on a ternary diagram in the plot margins.

## Usage

```
Annotate(
  coordinates,
  labels,
  side,
  outset = 0.16,
  line.col = col,
  lty = par("lty"),
  lwd = par("lwd"),
  col = par("col"),
  font = par("font"),
  offset = 0.5,
  ...
)
```

## Arguments

| | |
|---|---|
| `coordinates` | A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space. |
| `labels` | Character vector specifying text with which to annotate each entry in `coordinates`. |
| `side` | Optional vector specifying which side of the ternary plot each point should be labelled on, using the notation `"a"`, `"b"`, `"c"` or `1`, `2`, `3`. Entries of `"n"` or `0` will not be annotated (but still require an entry in `labels`). Entries of `NA` will be allocated a side automatically, based on the midpoint of `coordinates`. |
| `outset` | Numeric specifying distance from plot margins to labels. |
| `line.col`, `lty`, `lwd` | parameters to `segments()`. |
| `col`, `font`, `offset` | parameters to `text()`. |
| `...` | Further parameters to `text()` and `segments()`. |

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Annotation vignette gives further suggestions for manual annotation.

## Examples

```
# Load some data
data("Seatbelts")
seats <- c("drivers", "front", "rear")
seat <- Seatbelts[month.abb %in% "Oct", seats]
law <- Seatbelts[month.abb %in% "Oct", "law"]

# Set up plot
oPar <- par(mar = c(2, 0, 0, 0))
TernaryPlot(alab = seats[1], blab = seats[2], clab = seats[3])
TernaryPoints(seat, cex = 0.8, col = 2 + law)

# Annotate points by year
Annotate(seat, labels = 1969:1984, col = 2 + law)

# Restore original graphical parameters
par(oPar)
```

---

# cbPalettes *Palettes compatible with colour blindness*

---

## Description

Colour palettes recommended for use with colour blind audiences.

## Usage

```
cbPalette8

cbPalette13

cbPalette15
```

## Format

Character vectors of lengths 8, 13 and 15.

An object of class `character` of length 8.

An object of class `character` of length 13.

An object of class `character` of length 15.

### Details

Since R 4.0, `cbPalette8` is available in base R as `palette.colors(8)`.

`cbPalette15` is a Brewer palette. Because colours 4 and 7 are difficult to distinguish from colours 13 and 3, respectively, in individuals with tritanopia, `cbPalette13` omits these colours (i.e. `cbPalette13 <- cbPalette15[-c(4, 7)]`).

### Source

- `cbPalette8`: *Wong B. 2011. Color blindness. Nat. Methods. 8:441. doi:10.1038/nmeth.1618*
- `cbPalette15`: http://mkweb.bcgsc.ca/biovis2012/color-blindness-palette.png

### Examples

```
data("cbPalette8")
plot.new()
plot.window(xlim = c(1, 16), ylim = c(0, 3))
text(1:8 * 2, 3, 1:8, col = cbPalette8)
points(1:8 * 2, rep(2, 8), col = cbPalette8, pch = 15)

data("cbPalette15")
text(1:15, 1, col = cbPalette15)
text(c(4, 7), 1, "[   ]")
points(1:15, rep(0, 15), col = cbPalette15, pch = 15)
```

---

## ColourTernary *Colour a ternary plot according to the output of a function*

---

### Description

Colour a ternary plot according to the output of a function

### Usage

```
ColourTernary(
  values,
  spectrum = hcl.colors(256L, palette = "viridis", alpha = 0.6),
  resolution = sqrt(ncol(values)),
  direction = getOption("ternDirection", 1L),
  legend,
  ...
)

ColorTernary(
  values,
  spectrum = hcl.colors(256L, palette = "viridis", alpha = 0.6),
  resolution = sqrt(ncol(values)),
  direction = getOption("ternDirection", 1L),
```

```
  legend,
  ...
)
```

## Arguments

| | |
|---|---|
| values | Numeric matrix, possibly created using TernaryPointValues(), with four named rows: x, y, cartesian coordinates of each triangle centre; z, value associated with that coordinate; down, triangle direction: 0 = point upwards; 1 = point downwards. |
| spectrum | Vector of colours to use as a spectrum, or NULL to use values["z", ]. |
| resolution | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |
| legend | Character vector specifying annotations for colour scale. If not provided, no colour legend is displayed. Specify TRUE to generate automatically, or a single integer to generate legend annotations. |
| ... | Further arguments to SpectrumLegend(). |

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Fine control over continuous legends: PlotTools::SpectrumLegend()

Other contour plotting functions: TernaryContour(), TernaryDensityContour(), TernaryPointValues()

Other functions for colouring and shading: TernaryTiles()

## Examples

```
TernaryPlot(alab = "a", blab = "b", clab = "c")

FunctionToContour <- function (a, b, c) {
  a - c + (4 * a * b) + (27 * a * b * c)
}

values <- TernaryPointValues(FunctionToContour, resolution = 24L)
ColourTernary(
  values,
  x = "topleft",
  bty = "n", # No box
  legend = signif(seq(max(values), min(values), length.out = 4), 3)
)
TernaryContour(FunctionToContour, resolution = 36L)
```

```
TernaryPlot()
values <- TernaryPointValues(rgb, resolution = 20)
ColourTernary(values, spectrum = NULL)

# Create a helper function to place white centrally:
rgbWhite <- function (r, g, b) {
  highest <- apply(rbind(r, g, b), 2L, max)
  rgb(r/highest, g/highest, b/highest)
}

TernaryPlot()
values <- TernaryPointValues(rgbWhite, resolution = 20)
ColourTernary(values, spectrum = NULL)
```

---

`holdridge` *Random sample of points for Holdridge plotting*

---

## Description

A stratified random sampling (average of 100 points) using a global mapping of Holdridge's scheme.

## Usage

```
holdridge
```

## Format

An object of class `data.frame` with 39 rows and 4 columns.

## Author(s)

James Lee Tsakalos

## See Also

Other Holdridge plotting functions: `AddToHoldridge()`, `HoldridgeHypsometricCol()`, `HoldridgePlot()`, `holdridgeClasses`

## Examples

```
data("holdridge", package = "Ternary")
head(holdridge)
```

`holdridgeClasses` *Names of the 38 classes defined with the Holdridge system*

## Description

`holdridgeClasses` is a character vector naming, from left to right, top to bottom, the 38 classes defined by the International Institute for Applied Systems Analysis (IIASA).

## Usage

```
holdridgeClasses

holdridgeLifeZones

holdridgeLifeZonesUp

holdridgeClassesUp
```

## Format

An object of class `character` of length 38.

An object of class `character` of length 33.

An object of class `character` of length 33.

An object of class `character` of length 38.

## Details

`holdridgeLifeZones` is a character vector naming, from left to right, top to bottom, the 38 cells of the Holdridge classification plot.

`holdridgeClassesUp` and `holdridgeLifeZonesUp` replace spaces with new lines, for more legible plotting with `HoldridgeHexagons()`.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## Source

Holdridge (1947), "Determination of world plant formations from simple climatic data", *Science* 105:367–368. doi:10.1126/science.105.2727.367

Holdridge (1967), *Life zone ecology*. Tropical Science Center, San José.

Leemans, R. (1990), "Possible change in natural vegetation patterns due to a global warming", *International Institute for Applied Systems Analysis* Working paper WP-90-08. https://pure.iiasa.ac.at/id/eprint/3443/1/WP-90-008.pdf

## See Also

Other Holdridge plotting functions: `AddToHoldridge()`, `HoldridgeHypsometricCol()`, `HoldridgePlot()`, `holdridge`

---

`HoldridgeHypsometricCol` *Convert a point in evapotranspiration-precipitation space to an appropriate cross-blended hypsometric colour*

---

## Description

Used to colour `HoldridgeHexagons()`, and may also be used to aid the interpretation of PET + precipitation data in any graphical context.

## Usage

```
HoldridgeHypsometricCol(pet, prec, opacity = NA)
```

## Arguments

| | |
|---|---|
| `pet`, `prec` | Numeric vectors giving *p*otential *e*vapo*t*ranspiration ratio and annual *prec*ipitation (in mm). |
| `opacity` | Opacity level to be converted to the final two characters of an RGBA hexadecimal colour definition, e.g. `#000000FF`. Specify a character string, which will be interpreted as a hexadecimal alpha value and appended to the six RGB hexadecimal digits; a numeric in the range 0 (transparent) to 1 (opaque); or `NA`, to return only the six RGB digits. |

## Value

Character vector listing RGB or (if `opacity != NA`) RGBA values corresponding to each PET-precipitation value pair.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## References

Palette derived from the hypsometric colour scheme presented at Shaded Relief.

## See Also

Other Holdridge plotting functions: `AddToHoldridge()`, `HoldridgePlot()`, `holdridge`, `holdridgeClasses`

## Examples

```
HoldridgePlot(hex.col = HoldridgeHypsometricCol)
VeryTransparent <- function(...) HoldridgeHypsometricCol(..., opacity = 0.3)
HoldridgePlot(hex.col = VeryTransparent)
pet <- holdridge$PET
prec <- holdridge$Precipitation
ptCol <- HoldridgeHypsometricCol(pet, prec)
HoldridgePoints(pet, prec, pch = 21, bg = ptCol)
```

---

`HoldridgePlot` *Plot life zones on a Holdridge plot*

---

## Description

`HoldridgePlot()` creates a blank triangular plot, as proposed by Holdridge (1947, 1967), onto which potential evapotranspiration (PET) ratio and annual precipitation data can be plotted (using the `AddToHoldridge()` family of functions) in order to interpret climatic life zones.

## Usage

```
HoldridgePlot(
  atip = NULL,
  btip = NULL,
  ctip = NULL,
  alab = "Potential evapotranspiration ratio",
  blab = "Annual precipitation / mm",
  clab = "Humidity province",
  lab.offset = 0.22,
  lab.col = c("#D81B60", "#1E88E5", "#111111"),
  xlim = NULL,
  ylim = NULL,
  region = NULL,
  lab.cex = 1,
  lab.font = 0,
  tip.cex = lab.cex,
  tip.font = 2,
  tip.col = "black",
  isometric = TRUE,
  atip.rotate = NULL,
  btip.rotate = NULL,
  ctip.rotate = NULL,
  atip.pos = NULL,
  btip.pos = NULL,
  ctip.pos = NULL,
  padding = 0.16,
  col = NA,
  panel.first = NULL,
```

```
  panel.last = NULL,
  grid.lines = 8,
  grid.col = c(NA, "#1E88E5", "#D81B60"),
  grid.lty = "solid",
  grid.lwd = par("lwd"),
  grid.minor.lines = 0,
  grid.minor.col = "lightgrey",
  grid.minor.lty = "solid",
  grid.minor.lwd = par("lwd"),
  hex.border = "#888888",
  hex.col = HoldridgeHypsometricCol,
  hex.lty = "solid",
  hex.lwd = par("lwd"),
  hex.cex = 0.5,
  hex.labels = NULL,
  hex.font = NULL,
  hex.text.col = "black",
  axis.cex = 0.8,
  axis.col = c(grid.col[2], grid.col[3], NA),
  axis.font = par("font"),
  axis.labels = TRUE,
  axis.lty = "solid",
  axis.lwd = 1,
  axis.rotate = TRUE,
  axis.pos = NULL,
  axis.tick = TRUE,
  ticks.lwd = axis.lwd,
  ticks.length = 0.025,
  ticks.col = grid.col,
  ...
)

HoldridgeBelts(
  grid.col = "#004D40",
  grid.lty = "dotted",
  grid.lwd = par("lwd")
)

HoldridgeHexagons(
  border = "#004D40",
  hex.col = HoldridgeHypsometricCol,
  lty = "dotted",
  lwd = par("lwd"),
  labels = NULL,
  cex = 1,
  text.col = NULL,
  font = NULL
)
```

## Arguments

| | |
|---|---|
| atip, btip, ctip | Character string specifying text to title corners, proceeding clockwise from the corner specified in point (default: top). |
| alab, blab, clab | Character string specifying text with which to label the corresponding sides of the triangle. Left or right-pointing arrows are produced by typing \\U2190 or \\U2192, or using expression('value' %->% ''). |
| lab.offset | Numeric specifying distance between midpoint of axis label and the axis. The default value is given in the 'Usage' section; a value of 0 will position the axis label directly on the axis. Increase padding if labels are being clipped. Use a vector of length three to specify a different offset for each label. |
| lab.col | Character vector specifying colours for axis labels. Use a vector of length three to specify a different colour for each label. |
| xlim, ylim | Numeric vectors of length two specifying the minimum and maximum *x* and *y* limits of the plotted area, to which padding will be added. The default is to display the complete height or width of the plot. Allows cropping to magnified region of the plot. (See vignette for diagram.) May be overridden if isometric = TRUE; see documentation of isometric parameter. |
| region | (optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. list(min = c(40, 0, 0), max = c(100, 60, 60)); or a set of coordinates in a format accepted by TernaryPoints(). The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates. |
| lab.cex, tip.cex | Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to specify a different value for each direction. |
| lab.font, tip.font | Numeric specifying font style (Roman, bold, italic, bold-italic) for axis titles. Use a vector of length three to set a different font for each direction. |
| isometric | Logical specifying whether to enforce an equilateral shape for the ternary plot. If only one of xlim and ylim is set, the other will be calculated to maintain an equilateral plot. If both xlim and ylim are set, but have different ranges, then the limit with the smaller range will be scaled until its range matches that of the other limit. |
| atip.rotate, btip.rotate, ctip.rotate | Integer specifying number of degrees to rotate label of rightmost apex. |
| atip.pos, btip.pos, ctip.pos | Integer specifying positioning of labels, iff the corresponding xtip.rotate parameter is set. |
| padding | Numeric specifying size of internal margin of the plot; increase if axis labels are being clipped. |
| col | The colour for filling the plot; see polygon. |
| panel.first | An expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be useful for drawing backgrounds, e.g. with ColourTernary() or HorizontalGrid(). Note that this works by lazy evaluation: passing this argument from other plot methods may well not work since it may be evaluated too early. |

`panel.last` An expression to be evaluated after plotting has taken place but before the axes and box are added. See the comments about `panel.first`.

`grid.lines` Integer specifying the number of grid lines to plot. If `axis.labels = TRUE`, this will be used as a hint to `pretty()`.

`grid.col, grid.minor.col`
Colours to draw the grid lines. Use a vector of length three to set different values for each direction.

`grid.lty, grid.minor.lty`
Character or integer vector; line type of the grid lines. Use a vector of length three to set different values for each direction.

`grid.lwd, grid.minor.lwd`
Non-negative numeric giving line width of the grid lines. Use a vector of length three to set different values for each direction.

`grid.minor.lines`
Integer specifying the number of minor (unlabelled) grid lines to plot between each major pair.

`hex.border, hex.lty, hex.lwd`
Parameters to pass to `HoldridgeHexagons()`. Set to `NA` to suppress hexagons.

`hex.col` Fill colour for hexagons. Provide a vector specifying a colour for each hexagon in turn, reading from left to right and top to bottom, or a function that accepts two arguments, numerics `pet` and `prec`, and returns a colour in a format accepted by `polygon()`.

`hex.cex, hex.font, hex.text.col`
Parameters passed to `text()` to plot `hex.labels`.

`hex.labels` 38-element character vector specifying label for each hexagonal class, from top left to bottom right.

`axis.cex` Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to set a different value for each direction.

`axis.col, ticks.col, tip.col`
Colours for the axis line, tick marks and tip labels respectively. Use a vector of length three to set a different value for each direction. `axis.col = NULL` means to use `par('fg')`, possibly specified inline, and `ticks.col = NULL` means to use whatever colour `axis.col` resolved to.

`axis.font` Font for text. Defaults to `par('font')`.

`axis.labels` This can either be a logical value specifying whether (numerical) annotations are to be made at the tickmarks, or a character or expression vector of labels to be placed at the tick points, or a list of length three, with each entry specifying labels to be placed on each axis in turn.

`axis.lty` Line type for both the axis line and tick marks. Use a vector of length three to set a different value for each direction.

`axis.lwd, ticks.lwd`
Line width for the axis line and tick marks. Zero or negative values will suppress the line or ticks. Use a vector of length three to set different values for each axis.

`axis.rotate` Logical specifying whether to rotate axis labels to parallel grid lines, or numeric specifying custom rotation for each axis, to be passed as `srt` parameter to `text()`. Expand margins or set `par(xpd = NA)` if labels are clipped.

| | |
|---|---|
| axis.pos | Vector of length one or three specifying position of axis labels, to be passed as pos parameter to text(); populated automatically if NULL (the default). |
| axis.tick | Logical specifying whether to mark the axes with tick marks. |
| ticks.length | Numeric specifying distance that ticks should extend beyond the plot margin. Also affects position of axis labels, which are plotted at the end of each tick. Use a vector of length three to set a different length for each direction. |
| ... | Additional parameters to plot. |
| border | Colour to use for hexagon borders. |
| lty, lwd, cex, font | Graphical parameters specifying properties of hexagons to be plotted. |
| labels | Vector specifying labels for life zone hexagons to be plotted. Suggested values: holdridgeClassesUp, holdridgeLifeZonesUp. |
| text.col | Colour of text to be printed in hexagons. |

## Details

HoldridgePoints(), HoldridgeText() and related functions allow data points to be added to an existing plot; AddToHoldridge() allows plotting using any of the standard plotting functions.

HoldridgeBelts() and HoldridgeHexagons() plot interpretative lines and hexagons allowing plotted data to be linked to interpreted climate settings.

Please cite Tsakalos *et al.* (2023) when using this function.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## References

Holdridge (1947), "Determination of world plant formations from simple climatic data", *Science* 105:367–368. doi:10.1126/science.105.2727.367

Holdridge (1967), *Life zone ecology*. Tropical Science Center, San José

Tsakalos, Smith, Luebert & Mucina (2023). "climenv: Download, extract and visualise climatic and elevation data.", *Journal of Vegetation Science* 6:e13215. doi:10.1111/jvs.13215

## See Also

Other Holdridge plotting functions: AddToHoldridge(), HoldridgeHypsometricCol(), holdridge, holdridgeClasses

## Examples

```
data(holdridgeLifeZonesUp, package = "Ternary")
HoldridgePlot(hex.labels = holdridgeLifeZonesUp)
HoldridgeBelts()
```

`OutsidePlot` *Is a point in the plotting area?*

## Description

Evaluate whether a given set of coordinates lie outwith the boundaries of a plotted ternary diagram.

## Usage

```
OutsidePlot(x, y, tolerance = 0)
```

## Arguments

| | |
|---|---|
| `x, y` | Vectors of *x* and *y* coordinates of points. |
| `tolerance` | Consider points this close to the edge of the plot to be inside. Set to negative values to count points that are just outside the plot as inside, and to positive values to count points that are just inside the margins as outside. Maximum positive value: 1/3. |

## Value

`OutsidePlot()` returns a logical vector specifying whether each pair of *x* and *y* coordinates corresponds to a point outside the plotted ternary diagram.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other plot limits: `TernaryXRange()`

## Examples

```
TernaryPlot()
points(0.5, 0.5, col = "darkgreen")
OutsidePlot(0.5, 0.5)

points(0.1, 0.5, col = "red")
OutsidePlot(0.1, 0.5)

OutsidePlot(c(0.5, 0.1), 0.5)
```

Polygon-Geometry *Polygon geometry*

## Description

Geometry functions for irregular polygons.

## Usage

```
PolygonArea(x, y = NULL, positive = TRUE)

PolygonCentre(x, y = NULL)

PolygonCenter(x, y = NULL)

GrowPolygon(x, y = NULL, buffer = 0)
```

## Arguments

| | |
|---|---|
| x, y | Vectors containing the coordinates of the vertices of the polygon. |
| positive | If vertices are specified in an anticlockwise direction, the polygon will be treated as a hole, with a negative area, unless positive is set to TRUE. Vertices specified in a clockwise sequence always yield a positive area. |
| buffer | Numeric specifying distance by which to grow polygon. |

## Value

PolygonArea() returns the area of the specified polygon.

PolygonCentre() returns a single-row matrix containing the *x* and *y* coordinates of the geometric centre of the polygon.

GrowPolygon() returns coordinates of the vertices of polygon after moving each vertex buffer away from the polygon's centre.

## Functions

- PolygonArea(): Calculate the area of an irregular polygon
- PolygonCentre(): Locate the centre of a polygon
- GrowPolygon(): Enlarge a polygon in all directions

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other tiling functions: TriangleCentres(), TriangleInHull()

## Examples

```
x <- c(-3, -1, 6, 3, -4)
y <- c(-2, 4, 1, 10, 9)
plot(x, y, frame.plot = FALSE)
polygon(x, y)
PolygonArea(x, y)
points(PolygonCentre(x, y), pch = 3, cex = 2)
polygon(GrowPolygon(x, y, 1), border = "darkgreen",
        xpd = NA # Allow drawing beyond plot border
       )

# Negative values shrink the polygon
polygon(GrowPolygon(x, y, -1), border = "red")
```

---

# ReflectedEquivalents *Reflected equivalents of points outside the ternary plot*

---

## Description

To avoid edge effects, it may be desirable to add the value of a point within a ternary plot with the value of its 'reflection' across the nearest axis or corner.

## Usage

```
ReflectedEquivalents(x, y, direction = getOption("ternDirection", 1L))
```

## Arguments

| | |
|---|---|
| x, y | Vectors of *x* and *y* coordinates of points. |
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |

## Value

`ReflectedEquivalents()` returns a list of the *x*, *y* coordinates of the points produced if the given point is reflected across each of the edges or corners.

## See Also

Other coordinate translation functions: `TernaryCoords()`, `TriangleCentres()`, `XYToTernary()`

## Examples

```
TernaryPlot(axis.labels = FALSE, point = 4)

xy <- cbind(
  TernaryCoords(0.9, 0.08, 0.02),
  TernaryCoords(0.15, 0.8, 0.05),
```

```
  TernaryCoords(0.05, 0.1, 0.85)
)
x <- xy[1, ]
y <- xy[2, ]

points(x, y, col = "red", pch = 1:3)
ref <- ReflectedEquivalents(x, y)
points(ref[[1]][, 1], ref[[1]][, 2], col = "blue", pch = 1)
points(ref[[2]][, 1], ref[[2]][, 2], col = "green", pch = 2)
points(ref[[3]][, 1], ref[[3]][, 2], col = "orange", pch = 3)
```

---

`TernaryApp` *Graphical user interface for creating ternary plots*

---

## Description

`TernaryApp()` launches a 'Shiny' application for the construction of ternary plots. The 'app' allows data to be loaded and plotted, and provides code to reproduce the plot in R should more sophisticated plotting functions be desired.

## Usage

```
TernaryApp()
```

## Details

### Load data:

The 'Load data' input tab allows for the upload of datasets. Data can be read from csv files, `.txt` files created with `write.table()`, or (if the 'readxl' package is installed) Excel spreadsheets.

Data should be provided as three columns, corresponding to the three axes of the ternary plot. Colours or point styles may be specified in columns four to six to allow different categories of point to be plotted distinctly. Example datasets are installed at `system.file("TernaryApp", package = "Ternary")`.

Axes are automatically labelled using column names, if present; these can be edited manually on this tab.

### Plot display:

Allows the orientation, colour and configuration of the plot and its axes to be adjusted,

### Grids:

Adjust the number, spacing and styling of major and minor grid lines.

### Labels:

Configure the colour, position and size of tip and axis labels.

### Points:

Choose whether to plot points, lines, connected points, or text. Set the style of points and lines.

### Exporting plots

A plot can be saved to PDF or as a PNG bitmap at a specified size. Alternatively, R script that will generate the displayed plot can be viewed (using the 'R code' output tab) or downloaded to file.

### Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

### References

If you use figures produced with this package in a publication, please cite

Smith, Martin R. (2017). *Ternary: An R Package for Creating Ternary Plots.* Zenodo, doi: doi:10.5281/zenodo.1068996.

### See Also

Full detail of plotting with 'Ternary', including features not (yet) implemented in the application, is provided in the accompanying vignette.

---

`TernaryContour` *Add contours to a ternary plot*

---

### Description

Draws contour lines to depict the value of a function in ternary space.

### Usage

```
TernaryContour(
  Func,
  resolution = 96L,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault),
  within = NULL,
  filled = FALSE,
  legend,
  legend... = list(),
  nlevels = 10,
  levels = pretty(zlim, nlevels),
  zlim,
  color.palette = function(n) hcl.colors(n, palette = "viridis", alpha = 0.6),
  fill.col = color.palette(length(levels) - 1),
  func... = list(),
  ...
)
```

## Arguments

| | |
|---|---|
| Func | Function taking vectors of coordinates a, b and c, which returns a numeric vector whose value at each coordinate will be depicted. |
| resolution | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |
| region | (optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. `list(min = c(40, 0, 0), max = c(100, 60, 60))`; or a set of coordinates in a format accepted by `TernaryPoints()`. The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates. |
| within | List or matrix of *x, y* coordinates within which contours should be evaluated, in any format supported by `xy.coords(x = within)`. If NULL, defaults to a region slightly smaller than the ternary plot. The $hull entry generated by `TriangleInHull()` may also be used. |
| filled | Logical; if TRUE, contours will be filled (using `.filled.contour()`.). |
| legend | Character vector specifying annotations for colour scale. If not provided, no colour legend is displayed. Specify TRUE to generate automatically, or a single integer to generate legend annotations. |
| legend... | List of additional parameters to send to `SpectrumLegend()`. |
| nlevels, levels, zlim, ... | parameters to pass to `contour()`. |
| color.palette | parameters to pass to `.filled.contour()`. |
| fill.col | Sent as col parameter to `.filled.contour()`. Computed from color.palette if not specified. |
| func... | List of additional parameters to send to Func(). |

## Value

`TernaryContour()` invisibly returns a list containing:

- x,y: the Cartesian coordinates of each evaluated point;
- z: The value of `Func()` at each coordinate.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other contour plotting functions: `ColourTernary()`, `TernaryDensityContour()`, `TernaryPointValues()`

## Examples

```
FunctionToContour <- function (a, b, c) {
  a - c + (4 * a * b) + (27 * a * b * c)
}

# Set up plot
originalPar <- par(mar = rep(0, 4))
TernaryPlot(alab = "a", blab = "b", clab = "c")
values <- TernaryPointValues(FunctionToContour, resolution = 24L)
ColourTernary(
  values,
  legend = signif(seq(max(values), min(values), length.out = 4), 2),
  bty = "n"
)
TernaryContour(FunctionToContour, resolution = 36L)

# Note that FunctionToContour is sent a vector.
# Instead of
BadMax <- function (a, b, c) {
  max(a, b, c)
}

# Use
GoodMax <- function (a, b, c) {
  pmax(a, b, c)
}
TernaryPlot(alab = "a", blab = "b", clab = "c")
ColourTernary(TernaryPointValues(GoodMax))
TernaryContour(GoodMax)

# Or, for a generalizable example,
GeneralMax <- function (a, b, c) {
  apply(rbind(a, b, c), 2, max)
}
TernaryPlot(alab = "a", blab = "b", clab = "c")
# Fill the contour areas, rather than using tiles
TernaryContour(GeneralMax, filled = TRUE,
               legend = c("Max", "...", "Min"), legend... = list(bty = "n"),
               fill.col =  hcl.colors(14, palette = "viridis", alpha = 0.6))
# Re-draw edges of plot triangle over fill
TernaryPolygon(diag(3))

# Restore plotting parameters
par(originalPar)
```

---

TernaryCoords *Convert ternary coordinates to Cartesian space*

---

## Description

Convert coordinates of a point in ternary space, in the format (*a*, *b*, *c*), to *x* and *y* coordinates of Cartesian space, which can be sent to standard functions in the 'graphics' package.

## Usage

```
TernaryCoords(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

## S3 method for class 'matrix'
TernaryToXY(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

## S3 method for class 'numeric'
TernaryToXY(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

TernaryToXY(
  abc,
  b_coord = NULL,
  c_coord = NULL,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)
```

## Arguments

| | |
|---|---|
| abc | A vector of length three giving the position on a ternary plot that points in the direction specified by `direction` (1 = up, 2 = right, 3 = down, 4 = left). `c(100, 0, 0)` will plot in the `direction`-most corner; `c(0, 100, 0)` will plot in the corner clockwise of `direction`; `c(0, 0, 100)` will plot in the corner anti-clockwise of `direction`. Alternatively, the a coordinate can be specified as the first parameter, in which case the b and c coordinates must be specified via `b_coord` |

and c_coord. Or, a matrix with three rows, representing in turn the a, b and c coordinates of points.

b_coord — The b coordinate, if abc is a single number.

c_coord — The c coordinate, if abc is a single number.

direction — (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

region — (optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. `list(min = c(40, 0, 0), max = c(100, 60, 60))`; or a set of coordinates in a format accepted by TernaryPoints(). The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.

## Value

TernaryCoords() returns a vector of length two that converts the coordinates given in abc into Cartesian (*x*, *y*) coordinates corresponding to the plot created by the last call of TernaryPlot().

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

- TernaryPlot()

Other coordinate translation functions: ReflectedEquivalents(), TriangleCentres(), XYToTernary()

## Examples

```
TernaryCoords(100, 0, 0)
TernaryCoords(c(0, 100, 0))

coords <- matrix(1:12, nrow = 3)
TernaryToXY(coords)
```

---

# TernaryDensityContour *Add contours of estimated point density to a ternary plot*

---

## Description

Use two-dimensional kernel density estimation to plot contours of point density.

## Usage

```
TernaryDensityContour(
  coordinates,
  bandwidth,
  resolution = 25L,
  tolerance = -0.2/resolution,
  edgeCorrection = TRUE,
  direction = getOption("ternDirection", 1L),
  filled = FALSE,
  nlevels = 10,
  levels = pretty(zlim, nlevels),
  zlim,
  color.palette = function(n) hcl.colors(n, palette = "viridis", alpha = 0.6),
  fill.col = color.palette(length(levels) - 1),
  ...
)
```

## Arguments

| | |
|---|---|
| coordinates | A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space. |
| bandwidth | Vector of bandwidths for x and y directions. Defaults to normal reference bandwidth (see MASS::bandwidth.nrd). A scalar value will be taken to apply to both directions. |
| resolution | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |
| tolerance | Numeric specifying how close to the margins the contours should be plotted, as a fraction of the size of the triangle. Negative values will cause contour lines to extend beyond the margins of the plot. |
| edgeCorrection | Logical specifying whether to correct for edge effects (see details). |
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |
| filled | Logical; if TRUE, contours will be filled (using .filled.contour().). |
| nlevels, levels, zlim, ... | parameters to pass to contour(). |
| color.palette | parameters to pass to .filled.contour(). |
| fill.col | Sent as col parameter to .filled.contour(). Computed from color.palette if not specified. |

## Details

This function is modelled on MASS::kde2d(), which uses "an axis-aligned bivariate normal kernel, evaluated on a square grid".

This is to say, values are calculated on a square grid, and contours fitted between these points. This produces a couple of artefacts. Firstly, contours may not extend beyond the outermost point within

the diagram, which may fall some distance from the margin of the plot if a low `resolution` is used. Setting a negative `tolerance` parameter allows these contours to extend closer to (or beyond) the margin of the plot.

Individual points cannot fall outside the margins of the ternary diagram, but their associated kernels can. In order to sample regions of the kernels that have "bled" outside the ternary diagram, each point's value is calculated by summing the point density at that point and at equivalent points outside the ternary diagram, "reflected" across the margin of the plot (see function `ReflectedEquivalents`). This correction can be disabled by setting the `edgeCorrection` parameter to `FALSE`.

A model based on a triangular grid may be more appropriate in certain situations, but is non-trivial to implement; if this distinction is important to you, please let the maintainers known by opening a Github issue.

## Value

`TernaryDensityContour()` invisibly returns a list containing:

- x,y: the Cartesian coordinates of each grid coordinate;
- z: The density at each grid coordinate.

## Author(s)

Adapted from `MASS::kde2d()` by Martin R. Smith

## See Also

Other contour plotting functions: `ColourTernary()`, `TernaryContour()`, `TernaryPointValues()`

## Examples

```
# Generate some example data
nPoints <- 400L
coordinates <- cbind(abs(rnorm(nPoints, 2, 3)),
                     abs(rnorm(nPoints, 1, 1.5)),
                     abs(rnorm(nPoints, 1, 0.5)))
# Set up plot
oPar <- par(mar = rep(0, 4))
TernaryPlot(axis.labels = seq(0, 10, by = 1))

# Colour background by density
ColourTernary(TernaryDensity(coordinates, resolution = 10L),
              legend = TRUE, bty = "n", title = "Density")

# Plot points
TernaryPoints(coordinates, col = "red", pch = ".")

# Contour by density
TernaryDensityContour(coordinates, resolution = 30L)

# Reset plotting parameters
par(oPar)
```

`TernaryPlot` *Create a ternary plot*

## Description

Create and style a blank ternary plot.

## Usage

```
TernaryPlot(
  atip = NULL,
  btip = NULL,
  ctip = NULL,
  alab = NULL,
  blab = NULL,
  clab = NULL,
  lab.offset = 0.16,
  lab.col = NULL,
  point = "up",
  clockwise = TRUE,
  xlim = NULL,
  ylim = NULL,
  region = ternRegionDefault,
  lab.cex = 1,
  lab.font = 0,
  tip.cex = lab.cex,
  tip.font = 2,
  tip.col = "black",
  isometric = TRUE,
  atip.rotate = NULL,
  btip.rotate = NULL,
  ctip.rotate = NULL,
  atip.pos = NULL,
  btip.pos = NULL,
  ctip.pos = NULL,
  padding = 0.08,
  col = NA,
  panel.first = NULL,
  panel.last = NULL,
  grid.lines = 10,
  grid.col = "darkgrey",
  grid.lty = "solid",
  grid.lwd = par("lwd"),
  grid.minor.lines = 4,
  grid.minor.col = "lightgrey",
  grid.minor.lty = "solid",
  grid.minor.lwd = par("lwd"),
```

```
  axis.lty = "solid",
  axis.labels = TRUE,
  axis.cex = 0.8,
  axis.font = par("font"),
  axis.rotate = TRUE,
  axis.pos = NULL,
  axis.tick = TRUE,
  axis.lwd = 1,
  ticks.lwd = axis.lwd,
  ticks.length = 0.025,
  axis.col = "black",
  ticks.col = grid.col,
  ...
)

HorizontalGrid(
  grid.lines = 10,
  grid.col = "grey",
  grid.lty = "dotted",
  grid.lwd = par("lwd"),
  direction = getOption("ternDirection", 1L)
)
```

## Arguments

| | |
|---|---|
| atip, btip, ctip | Character string specifying text to title corners, proceeding clockwise from the corner specified in point (default: top). |
| alab, blab, clab | Character string specifying text with which to label the corresponding sides of the triangle. Left or right-pointing arrows are produced by typing \\U2190 or \\U2192, or using expression('value' %->% ''). |
| lab.offset | Numeric specifying distance between midpoint of axis label and the axis. The default value is given in the 'Usage' section; a value of 0 will position the axis label directly on the axis. Increase padding if labels are being clipped. Use a vector of length three to specify a different offset for each label. |
| lab.col | Character vector specifying colours for axis labels. Use a vector of length three to specify a different colour for each label. |
| point | Character string specifying the orientation of the ternary plot: should the triangle point "up", "right", "down" or "left"? The integers 1 to 4 can be used in place of the character strings. |
| clockwise | Logical specifying the direction of axes. If TRUE (the default), each axis runs from zero to its maximum value in a clockwise direction around the plot. |
| xlim, ylim | Numeric vectors of length two specifying the minimum and maximum *x* and *y* limits of the plotted area, to which padding will be added. The default is to display the complete height or width of the plot. Allows cropping to magnified region of the plot. (See vignette for diagram.) May be overridden if isometric = TRUE; see documentation of isometric parameter. |

region (optional) Named list of length two specifying the the minimum and maximum values of each ternary axis to be drawn (e.g. list(min = c(40, 0, 0), max = c(100, 60, 60)); or a set of coordinates in a format accepted by TernaryPoints(). The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates.

lab.cex, tip.cex
Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to specify a different value for each direction.

lab.font, tip.font
Numeric specifying font style (Roman, bold, italic, bold-italic) for axis titles. Use a vector of length three to set a different font for each direction.

isometric Logical specifying whether to enforce an equilateral shape for the ternary plot. If only one of xlim and ylim is set, the other will be calculated to maintain an equilateral plot. If both xlim and ylim are set, but have different ranges, then the limit with the smaller range will be scaled until its range matches that of the other limit.

atip.rotate, btip.rotate, ctip.rotate
Integer specifying number of degrees to rotate label of rightmost apex.

atip.pos, btip.pos, ctip.pos
Integer specifying positioning of labels, iff the corresponding xtip.rotate parameter is set.

padding Numeric specifying size of internal margin of the plot; increase if axis labels are being clipped.

col The colour for filling the plot; see polygon.

panel.first An expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be useful for drawing backgrounds, e.g. with ColourTernary() or HorizontalGrid(). Note that this works by lazy evaluation: passing this argument from other plot methods may well not work since it may be evaluated too early.

panel.last An expression to be evaluated after plotting has taken place but before the axes and box are added. See the comments about panel.first.

grid.lines Integer specifying the number of grid lines to plot. If axis.labels = TRUE, this will be used as a hint to pretty().

grid.col, grid.minor.col
Colours to draw the grid lines. Use a vector of length three to set different values for each direction.

grid.lty, grid.minor.lty
Character or integer vector; line type of the grid lines. Use a vector of length three to set different values for each direction.

grid.lwd, grid.minor.lwd
Non-negative numeric giving line width of the grid lines. Use a vector of length three to set different values for each direction.

grid.minor.lines
Integer specifying the number of minor (unlabelled) grid lines to plot between each major pair.

`axis.lty` Line type for both the axis line and tick marks. Use a vector of length three to set a different value for each direction.

`axis.labels` This can either be a logical value specifying whether (numerical) annotations are to be made at the tickmarks, or a character or expression vector of labels to be placed at the tick points, or a list of length three, with each entry specifying labels to be placed on each axis in turn.

`axis.cex` Numeric specifying character expansion (font size) for axis labels. Use a vector of length three to set a different value for each direction.

`axis.font` Font for text. Defaults to `par('font')`.

`axis.rotate` Logical specifying whether to rotate axis labels to parallel grid lines, or numeric specifying custom rotation for each axis, to be passed as `srt` parameter to `text()`. Expand margins or set `par(xpd = NA)` if labels are clipped.

`axis.pos` Vector of length one or three specifying position of axis labels, to be passed as `pos` parameter to `text()`; populated automatically if `NULL` (the default).

`axis.tick` Logical specifying whether to mark the axes with tick marks.

`axis.lwd`, `ticks.lwd`
Line width for the axis line and tick marks. Zero or negative values will suppress the line or ticks. Use a vector of length three to set different values for each axis.

`ticks.length` Numeric specifying distance that ticks should extend beyond the plot margin. Also affects position of axis labels, which are plotted at the end of each tick. Use a vector of length three to set a different length for each direction.

`axis.col`, `ticks.col`, `tip.col`
Colours for the axis line, tick marks and tip labels respectively. Use a vector of length three to set a different value for each direction. `axis.col = NULL` means to use `par('fg')`, possibly specified inline, and `ticks.col = NULL` means to use whatever colour `axis.col` resolved to.

`...` Additional parameters to `plot`.

`direction` (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left.

## Details

The plot will be generated using the standard 'graphics' plot functions, on which additional elements can be added using cartesian coordinates, perhaps using functions such as `arrows`, `legend` or `text`.

## Functions

- `HorizontalGrid()`: Add `grid.lines` horizontal lines to the ternary plot

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

- AddToTernary(): Add elements to a ternary plot
- TernaryCoords(): Convert ternary coordinates to Cartesian (*x* and *y*) coordinates
- TernaryXRange(), TernaryYRange(): What are the *x* and *y* limits of the plotted region?

## Examples

```
TernaryPlot(
  atip = "Top", btip = "Bottom", ctip = "Right", axis.col = "red",
  col = rgb(0.8, 0.8, 0.8)
)
HorizontalGrid(grid.lines = 2, grid.col = "blue", grid.lty = 1)
# the second line corresponds to the base of the triangle, and is not drawn
```

---

# TernaryPointValues *Value of a function at regularly spaced points*

---

## Description

Intended to facilitate coloured contour plots with ColourTernary(), TernaryPointValue() evaluates a function at points on a triangular grid; TernaryDensity() calculates the density of points in each grid cell.

## Usage

```
TernaryPointValues(
  Func,
  resolution = 48L,
  direction = getOption("ternDirection", 1L),
  ...
)

TernaryDensity(
  coordinates,
  resolution = 48L,
  direction = getOption("ternDirection", 1L)
)
```

## Arguments

| | |
|---|---|
| Func | Function taking vectors of coordinates a, b and c, which returns a numeric vector whose value at each coordinate will be depicted. |
| resolution | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |

| | |
|---|---|
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |
| ... | Additional parameters to Func(). |
| coordinates | A list, matrix, data.frame or vector in which each element (or row) specifies the three coordinates of a point in ternary space. |

## Value

TernaryPointValues() returns a matrix whose rows correspond to:

- **x**, **y**: co-ordinates of the centres of smaller triangles
- **z**: The value of Func(a, b, c, ...), where a, b and c are the ternary coordinates of x and y.
- **down**: 0 if the triangle concerned points upwards (or right), 1 otherwise

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other contour plotting functions: ColourTernary(), TernaryContour(), TernaryDensityContour()

## Examples

```
TernaryPointValues(function (a, b, c) a * b * c, resolution = 2)

TernaryPlot(grid.lines = 4)
cols <- TernaryPointValues(rgb, resolution = 4)
text(as.numeric(cols["x", ]), as.numeric(cols["y", ]),
     labels =  ifelse(cols["down", ] == "1", "v", "^"),
     col = cols["z", ])

TernaryPlot(axis.labels = seq(0, 10, by = 1))

nPoints <- 4000L
coordinates <- cbind(abs(rnorm(nPoints, 2, 3)),
                     abs(rnorm(nPoints, 1, 1.5)),
                     abs(rnorm(nPoints, 1, 0.5)))

density <- TernaryDensity(coordinates, resolution = 10L)
ColourTernary(density, legend = TRUE, bty = "n", title = "Density")
TernaryPoints(coordinates, col = "red", pch = ".")
```

TernaryTiles *Paint tiles on ternary plot*

## Description

Function to fill a ternary plot with coloured tiles. Useful in combination with TernaryPointValues and TernaryContour.

## Usage

```
TernaryTiles(
  x,
  y,
  down,
  resolution,
  col,
  direction = getOption("ternDirection", 1L)
)
```

## Arguments

| | |
|---|---|
| x, y | Numeric vectors specifying *x* and *y* coordinates of centres of each triangle. |
| down | Logical vector specifying TRUE if each triangle should point down (or right), FALSE otherwise. |
| resolution | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |
| col | Vector specifying the colour with which to fill each triangle. |
| direction | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other functions for colouring and shading: ColourTernary()

## Examples

```
TernaryPlot()
TernaryXRange()
TernaryYRange()

TernaryTiles(0, 0.5, TRUE, 10, "red")
xy <- TernaryCoords(c(4, 3, 3))
TernaryTiles(xy[1], xy[2], FALSE, 5, "darkblue")
```

`TernaryXRange` *X and Y coordinates of ternary plotting area*

## Description

X and Y coordinates of ternary plotting area

## Usage

```
TernaryXRange(direction = getOption("ternDirection", 1L))

TernaryYRange(direction = getOption("ternDirection", 1L))
```

## Arguments

| | |
|---|---|
| `direction` | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |

## Value

`TernaryXRange()` and `TernaryYRange()` return the minimum and maximum X or Y coordinate of the area in which a ternary plot is drawn, oriented in the specified direction. Because the plotting area is a square, the triangle of the ternary plot will not occupy the full range in one direction. Assumes that the defaults have not been overwritten by specifying `xlim` or `ylim`.

## Functions

- `TernaryYRange()`: Returns the minimum and maximum Y coordinate for a ternary plot in the specified direction.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other plot limits: `OutsidePlot()`

`TriangleCentres` *Coordinates of triangle mid-points*

## Description

Calculate *x* and *y* coordinates of the midpoints of triangles tiled to cover a ternary plot.

## Usage

```
TriangleCentres(resolution = 48L, direction = getOption("ternDirection", 1L))
```

## Arguments

| | |
|---|---|
| `resolution` | The number of triangles whose base should lie on the longest axis of the triangle. Higher numbers will result in smaller subdivisions and smoother colour gradients, but at a computational cost. |
| `direction` | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |

## Value

`TriangleCentres()` returns a matrix with three named rows:

- `x` *x* coordinates of triangle midpoints;
- `y` *y* coordinates of triangle midpoints;
- `triDown` `0` for upwards-pointing triangles, `1` for downwards-pointing.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Add triangles to a plot: `TernaryTiles()`

Other coordinate translation functions: `ReflectedEquivalents()`, `TernaryCoords()`, `XYToTernary()`

Other tiling functions: `Polygon-Geometry`, `TriangleInHull()`

## Examples

```
TernaryPlot(grid.lines = 4)
centres <- TriangleCentres(4)
text(centres["x", ], centres["y", ], ifelse(centres["triDown", ], "v", "^"))
```

`TriangleInHull` *Does triangle overlap convex hull of points?*

## Description

Does triangle overlap convex hull of points?

## Usage

```
TriangleInHull(triangles, coordinates, buffer)
```

## Arguments

| | |
|---|---|
| `triangles` | Three-row matrix as produced by `TriangleCentres()`. |
| `coordinates` | A matrix with two or three rows specifying the coordinates of points in *x, y* or *a, b, c* format. |
| `buffer` | Include triangles whose centres lie within `buffer` triangles widths (i.e. edge lengths) of the convex hull. |

## Value

`TriangleInHull()` returns a list with the elements:

- `$inside`: vector specifying whether each of a set of triangles produced by `TriangleCentres()` overlaps the convex hull of points specified by `coordinates`.
- `$hull`: Coordinates of convex hull of `coordinates`, after expansion to cover overlapping triangles.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other tiling functions: `Polygon-Geometry`, `TriangleCentres()`

## Examples

```
set.seed(0)
nPts <- 50
a <- runif(nPts, 0.3, 0.7)
b <- 0.15 + runif(nPts, 0, 0.7 - a)
c <- 1 - a - b
coordinates <- rbind(a, b, c)

TernaryPlot(grid.lines = 5)
TernaryPoints(coordinates, pch = 3, col = 4)
triangles <- TriangleCentres(resolution = 5)
```

```
inHull <- TriangleInHull(triangles, coordinates)
polygon(inHull$hull, border = 4)
values <- rbind(triangles,
                z = ifelse(inHull$inside, "#33cc3333", "#cc333333"))
points(triangles["x", ], triangles["y", ],
       pch = ifelse(triangles["triDown", ], 6, 2),
       col = ifelse(inHull$inside, "#33cc33", "#cc3333"))
ColourTernary(values)
```

---

`XYToTernary` *Cartesian coordinates to ternary point*

---

## Description

Convert cartesian (*x*, *y*) coordinates to a point in ternary space.

## Usage

```
XYToTernary(
  x,
  y,
  direction = getOption("ternDirection", 1L),
  region = getOption("ternRegion", ternRegionDefault)
)

XYToHoldridge(x, y)

XYToPetPrec(x, y)
```

## Arguments

| | |
|---|---|
| `x, y` | Numeric values giving the *x* and *y* coordinates of a point or points. |
| `direction` | (optional) Integer specifying the direction that the current ternary plot should point: 1, up; 2, right; 3, down; 4, left. |
| `region` | (optional) Named list of length two specifying the the `minimum` and `maximum` values of each ternary axis to be drawn (e.g. `list(min = c(40, 0, 0), max = c(100, 60, 60))`; or a set of coordinates in a format accepted by `TernaryPoints()`. The plotted region will correspond to the smallest equilateral triangle that encompasses the specified ranges or coordinates. |

## Value

`XYToTernary()` Returns the ternary point(s) corresponding to the specified *x* and *y* coordinates, where a + b + c = 1.

## Author(s)

Martin R. Smith (martin.smith@durham.ac.uk)

## See Also

Other coordinate translation functions: `ReflectedEquivalents()`, `TernaryCoords()`, `TriangleCentres()`

## Examples

```
XYToTernary(c(0.1, 0.2), 0.5)
```

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