

Package ‘migest’

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Type Package

Title Methods for the Indirect Estimation of Bilateral Migration

Version 1.8.2

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Description Indirect methods for estimating bilateral migration flows in the presence of partial or missing data, including the estimation of bilateral migration flows from changes in bilateral migrant stock tables (e.g. Abel (2013) <doi:10.4054/DemRes.2013.28.18>).

URL <https://github.com/guyabel/migest/>

BugReports <https://github.com/guyabel/migest/issues>

License GPL-3

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Imports dplyr, purrr, tidyr, stringr, magrittr, stats, tibble, utils

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migest-package	<i>Methods for the Indirect Estimation of Bilateral Migration</i>
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Description

The migest package contains a collection of R functions for indirect methods to estimate bilateral migration flows in the presence of partial or missing data. Methods might be relevant to other categorical data situations on non-migration data, where for example, marginal totals are known and only auxiliary bilateral data is available.

Details

Package: migest
 Type: Package
 License: GPL-2

The estimation methods in this package can be grouped as 1) functions for origin-destination matrices (`cm2` and `ipf2`) and 2) functions for origin-destination matrices categorized by a further set of characteristics, such as ethnicity, employment or health status (`cm3`, `ipf3` and `ipf3_qi`). Each of these routines are based on indirect estimation methods where marginal totals are known, and a Poisson regression (log-linear) model is assumed.

The `ffs_diff`, `ffs_rates` and `ffs_demo` functions provide different methods to estimate migration bilateral flows from changes in stocks, see Abel and Cohen (2019) for a review of different methods. The demo files, `demo(cfplot_reg2)`, `demo(cfplot_reg)` and `demo(cfplot_nat)`, produce circular migration flow plots for migration estimates from Abel(2018) and Abel and Sander (2014), which were derived using the `ffs_demo` function.

Github repo: <http://github.com/guyabel/migest>

Author(s)

Guy J. Abel

References

- Abel and Cohen (2019) Bilateral international migration flow estimates for 200 countries *Scientific Data* 6 (1), 1-13
- Abel, G. J. (2018). Estimates of Global Bilateral Migration Flows by Gender between 1960 and 2015. *International Migration Review* 52 (3), 809–852.
- Abel, G. J. (2013). Estimating Global Migration Flow Tables Using Place of Birth. *Demographic Research* 28, (18) 505-546
- Abel, G. J. (2005) *The Indirect Estimation of Elderly Migrant Flows in England and Wales* (MS.c. Thesis). University of Southampton
- Abel, G. J. and Sander, N. (2014). Quantifying Global International Migration Flows. *Science*, 343 (6178) 1520-1522
- Raymer, J., G. J. Abel, and P. W. F. Smith (2007). Combining census and registration data to estimate detailed elderly migration flows in England and Wales. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 170 (4), 891–908.
- Willekens, F. (1999). Modelling Approaches to the Indirect Estimation of Migration Flows: From Entropy to EM. *Mathematical Population Studies* 7 (3), 239–78.

birth_mat

Calculate Births for Each Element of Place of Birth - Place of Residence Stock Matrix

Description

This function is predominantly intended to be used within the `ffs` routines in the `migest` package.

Usage

```
birth_mat(b_por = NULL, m2 = NULL, non_negative = TRUE)
```

Arguments

b_por	Vector of numeric values for births in each place of residence
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
non_negative	Adjust birth matrix calculation to ensure all deductions from m2 will result in positive population counts. On rare occasions when working with international stock data the number of births can exceed the increase in the number of native born population.

Value

Matrix of place of birth by place of residence for new-born's

Author(s)

Guy J. Abel

See Also

[ipf3_qi](#), [ffs_diff](#)

block_matrix

Create a Block Matrix with Non-Uniform Block Sizes.

Description

Creates a matrix with differing size blocks

Usage

```
block_matrix(x = NULL, b = NULL, byrow = FALSE, dimnames = NULL)
```

Arguments

x	Vector of numbers to identify each block.
b	Numeric value for the size of the blocks within the matrix ordered depending on byrow
byrow	Logical value. If FALSE (the default) the blocks are filled by columns, otherwise the blocks in the matrix are filled by rows.
dimnames	Character string of name attribute for the basis of the block matrix. If NULL a vector of the same length of b provides the basis of row and column names.#'

Value

Returns a matrix with block sizes determined by the b argument. Each block is filled with the same value taken from x.

Author(s)

Guy J. Abel

See Also[stripe_matrix](#), [block_sum](#), [ipf2_block](#)**Examples**

```
block_matrix(x = 1:16, b = c(2,3,4,2))
block_matrix(x = 1:25, b = c(2,3,4,2,1))
```

block_sum	<i>Sum of Selected Block in a Block Matrix</i>
-----------	--

Description

Returns of a sum of a block within a matrix. This function is predominantly intended to be used within the [ipf2_block](#) routine.

Usage

```
block_sum(block = NULL, m = NULL, block_id = NULL)
```

Arguments

block	Numeric value of block to summed. To be matched against the matrix in block_id.
m	Matrix of all blocks combined.
block_id	Matrix of the same dimensions of m used to identify blocks.

Value

Returns a numeric value of the sum of a single block.

Author(s)

Guy J. Abel

See Also[block_matrix](#), [stripe_matrix](#), [ipf2_block](#)**Examples**

```
m <- matrix(data = 100:220, nrow = 11, ncol = 11)
b <- block_matrix(x = 1:16, b = c(2, 3, 4, 2))
block_sum(block = 1, m = m, block_id = b)
block_sum(block = 4, m = m, block_id = b)
block_sum(block = 16, m = m, block_id = b)
```

cm2

Conditional Maximization Routine for the Indirect Estimation of Origin-Destination Migration Flow Table with Known Margins.

Description

The `cm2` function finds the maximum likelihood estimates for parameters in the log-linear model:

$$\log y_{ij} = \log \alpha_i + \log \beta_j + \log m_{ij}$$

as introduced by Willekens (1999). The α_i and β_j represent background information related to the characteristics of the origin and destinations respectively. The m_{ij} factor represents auxiliary information on migration flows, which imposes its interaction structure onto the estimated flow matrix.

Usage

```
cm2(
  row_tot = NULL,
  col_tot = NULL,
  m = matrix(data = 1, nrow = length(row_tot), ncol = length(col_tot)),
  tol = 1e-06,
  maxit = 500,
  verbose = TRUE,
  rtot = row_tot,
  ctot = col_tot
)
```

Arguments

<code>row_tot</code>	Vector of origin totals to constrain the sum of the imputed cell rows.
<code>col_tot</code>	Vector of destination totals to constrain the sum of the imputed cell columns.
<code>m</code>	Matrix of auxiliary data. By default set to 1 for all origin-destination combinations.
<code>tol</code>	Numeric value for the tolerance level used in the parameter estimation.
<code>maxit</code>	Numeric value for the maximum number of iterations used in the parameter estimation.
<code>verbose</code>	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.
<code>rtot</code>	Deprecated. Use <code>row_tot</code>
<code>ctot</code>	Deprecated. Use <code>col_tot</code>

Value

Parameter estimates are obtained using the EM algorithm outlined in Willekens (1999). This is equivalent to a conditional maximization of the likelihood, as discussed by Raymer et. al. (2007). It also provides identical indirect estimates to those obtained from the [ipf2](#) routine.

The user must ensure that the row and column totals are equal in sum. Care must also be taken to allow the dimension of the auxiliary matrix (*m*) to equal those provided in the row (*row_tot*) and column (*col_tot*) arguments.

Returns a list object with

N	Origin-Destination matrix of indirect estimates
theta	Collection of parameter estimates

Author(s)

Guy J. Abel

References

Raymer, J., G. J. Abel, and P. W. F. Smith (2007). Combining census and registration data to estimate detailed elderly migration flows in England and Wales. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 170 (4), 891–908.

Willekens, F. (1999). Modelling Approaches to the Indirect Estimation of Migration Flows: From Entropy to EM. *Mathematical Population Studies* 7 (3), 239–78.

See Also

[ipf2](#)

Examples

```
## with Willekens (1999) data
dn <- LETTERS[1:2]
y <- cm2(row_tot = c(18, 20), col_tot = c(16, 22),
        m = matrix(c(5, 1, 2, 7), ncol = 2, dimnames = list(orig = dn, dest = dn)))
y

## with all elements of offset equal (independence fit)
y <- cm2(row_tot = c(18, 20), col_tot = c(16, 22))
y

## with bigger matrix
dn <- LETTERS[1:4]
y <- cm2(row_tot = c(250, 100, 140, 110), col_tot = c(150, 150, 180, 120),
        m = matrix(data = c(0, 100, 30, 70, 50, 0, 45, 5, 60, 35, 0, 40, 20, 25, 20, 0),
                  nrow = 4, ncol = 4, dimnames = list(orig = dn, dest = dn), byrow = TRUE))

# display with row and col totals
round(addmargins(y$n))
```

cm3	<i>Conditional Maximization Routine for the Indirect Estimation of Origin-Destination-Migrant Type Migration Flow Tables with Known Origin and Destination Margins.</i>
-----	---

Description

The cm3 function finds the maximum likelihood estimates for parameters in the log-linear model:

$$\log y_{ijk} = \log \alpha_i + \log \beta_j + \log m_{ijk}$$

as introduced by Abel (2005). The α_i and β_j represent background information related to the characteristics of the origin and destinations respectively. The m_{ijk} factor represents auxiliary information on origin-destination migration flows by a migrant characteristic (such as age, sex, disability, household type, economic status, etc.). This method is useful for combining data from detailed data collection processes (such as a Census) with more up-to-date information on migration inflows and outflows (where details on movements by migrant characteristics are not known).

Usage

```
cm3(
  row_tot = NULL,
  col_tot = NULL,
  m = NULL,
  tol = 1e-06,
  maxit = 500,
  verbose = TRUE
)
```

Arguments

row_tot	Vector of origin totals to constrain the sum of the imputed cell rows.
col_tot	Vector of destination totals to constrain the sum of the imputed cell columns.
m	Array of auxiliary data. By default set to 1 for all origin-destination-migrant typology combinations.
tol	Numeric value for the tolerance level used in the parameter estimation.
maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Value

Parameter estimates were obtained using the conditional maximization of the likelihood, as discussed by Abel (2005) and Raymer et. al. (2007).

The user must ensure that the row and column totals are equal in sum. Care must also be taken to allow the row and column dimension of the auxiliary matrix (m) to equal those provided in the row and column totals.

Returns a list object with

N	Origin-Destination matrix of indirect estimates
theta	Collection of parameter estimates

Author(s)

Guy J. Abel

References

Abel, G. J. (2005) *The Indirect Estimation of Elderly Migrant Flows in England and Wales* (MS.c. Thesis). University of Southampton

Raymer, J., G. J. Abel, and P. W. F. Smith (2007). Combining census and registration data to estimate detailed elderly migration flows in England and Wales. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 170 (4), 891–908.

See Also

[cm2](#), [ipf3](#)

Examples

```
## over two tables
dn <- LETTERS[1:2]
y <- cm3(row_tot = c(18, 20) * 2, col_tot = c(16, 22) * 2,
         m = array(c(5, 1, 2, 7, 4, 2, 5, 9), dim = c(2, 2, 2),
                  dimnames = list(orig = dn, dest = dn, type = c("ILL", "HEALTHY"))))
# display with row, col and table totals
y

## over three tables
y <- cm3(row_tot = c(170, 120, 410), col_tot = c(500, 140, 60),
         m = array(c(5, 1, 2, 7, 4, 2, 5, 9, 5, 4, 3, 1), dim = c(2, 2, 3),
                  dimnames = list(orig = dn, dest = dn, type = c("--15", "15-60", ">60"))),
         verbose = FALSE)
# display with row, col and table totals
y
```

cm_net	<i>Conditional Maximisation Routine for the Indirect Estimation of Origin-Destination-Type Migration Flow Tables with Known Net Migration Totals.</i>
--------	---

Description

The `cm_net` function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{ij} = \log \alpha_i + \log \alpha_i^{-1} + \log m_{ij}$$

Usage

```
cm_net(net_tot = NULL, m = NULL, tol = 1e-06, maxit = 500, verbose = TRUE)
```

Arguments

net_tot	Vector of net migration totals to constrain the sum of the imputed cell columns. Elements must sum to zero.
m	Array of auxiliary data. By default set to 1 for all origin-destination-migrant typologies combinations.
tol	Numeric value for the tolerance level used in the parameter estimation.
maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Value

Conditional maximisation routine set up using the partial likelihood derivatives. The argument `net_tot` takes the known net migration totals. The user must ensure that the net migration totals sum globally to zero.

Returns a list object with

mu	Array of indirect estimates of origin-destination matrices by migrant characteristic
it	Iteration count
tol	Tolerance level at final iteration

Author(s)

Guy J. Abel

Examples

```

m <- matrix(data = 1:16, nrow = 4)
# m[lower.tri(m)] <- t(m)[lower.tri(m)]
addmargins(m)
sum_net(m)

y <- cm_net(net_tot = c(30, 40, -15, -55), m = m)
addmargins(y$n)
sum_net(y$n)

dn <- LETTERS[1:4]
m <- matrix(data = c(0, 100, 30, 70, 50, 0, 45, 5, 60, 35, 0, 40, 20, 25, 20, 0),
            nrow = 4, ncol = 4,
            dimnames = list(orig = dn, dest = dn), byrow = TRUE)
addmargins(m)
sum_net(m)

y <- cm_net(net_tot = c(-100, 125, -75, 50), m = m)
addmargins(y$n)
sum_net(y$n)

```

death_mat	<i>Calculate Deaths for Each Element of Place of Birth - Place of Residence Stock Matrix</i>
-----------	--

Description

This function is predominantly intended to be used within the ffs routines in the migest package.

Usage

```

death_mat(
  d_por = NULL,
  m1 = NULL,
  method = "proportion",
  m2 = NULL,
  b_por = NULL
)

```

Arguments

d_por	Vector of numeric values for deaths in each place of residence.
m1	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$. Used to distribute deaths proportionally to each migrant stock population. For use when method = "accounting"

method	Character string of either "proportion" or "accounting" to choose method to distribute deaths. The "proportion" method assumes the mortality rate in each place of birth sub-group (native born and all foreign born stocks) is the same. The "accounting" method ensures that the deaths by place of birth matches that implied by demographic accounting. Still needs to be explored fully.
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$. Used to distribute deaths proportionally to each migrant stock population.
b_por	Vector of numeric values for births in each place of residence. For use when method = "accounting".

Value

Matrix of place of death by place of residence

Author(s)

Guy J. Abel

See Also

[ipf3_qi](#), [ffs_diff](#)

ffs_demo

Estimation of Bilateral Migrant Flows from Bilateral Migrant Stocks Using Demographic Accounting Approaches

Description

Estimates migrant transitions flows between two sequential migrant stock tables. Replaces old ffs.

Usage

```
ffs_demo(
  m1 = NULL,
  m2 = NULL,
  b_por = NULL,
  d_por = NULL,
  m = NULL,
  stayer_assumption = TRUE,
  match_global = "before-demo-adjust",
  match_pob_tot_method = "rescale",
  birth_non_negative = TRUE,
  death_method = "proportion",
  verbose = FALSE,
  ...
)
```

Arguments

m1	Matrix of migrant stock totals at time t . Rows in the matrix correspond to place of birth and columns to place of residence at time t
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
b_por	Vector of the number of births between time t and $t+1$ in each region.
d_por	Vector of the number of deaths between time t and $t+1$ in each region.
m	Matrix of auxiliary data. By default set to 1 for all origin-destination combinations.
stayer_assumption	Logical value to indicate whether to use <code>ipf3</code> or <code>ipf3_qi</code> to estimate flows. By default uses <code>ipf3_qi</code> , i.e. is set to TRUE. The <code>ipf</code> function is useful for replicating method of Azoze and Raferty.
match_global	Character string used to indicate whether to balance the change in stocks totals with the changes in births and deaths. Only applied when <code>match_pob_tot_method</code> is either <code>rescale</code> or <code>rescale-adjust-zero-fb</code> . By default uses <code>after-demo-adjust</code> rather than <code>before-demo-adjust</code> which I think minimises risk of negative values.
match_pob_tot_method	Character string passed to method argument in <code>match_pob_tot</code> to ensure place of birth margins in stock tables match.
birth_non_negative	Logical value passed to <code>non_negative</code> argument in <code>birth_mat</code> .
death_method	Character string passed to method argument in <code>death_mat</code> .
verbose	Logical value to indicate the print the parameter estimates at each iteration of the various IPF routines. By default FALSE.
...	Additional arguments passes to <code>ipf3_qi</code> or <code>ipf3</code> .

Value

Estimates migrant transitions flows between two sequential migrant stock tables using various methods. See the example section for possible variations on estimation methods.

Returns a list object with:

mu	Array of indirect estimates of origin-destination matrices by place of birth.
it	Iteration count.
tol	Tolerance level at final iteration.
y	Array of indirect estimates of origin-destination matrices by place of birth with additional rows and columns for births, deaths and moves to other regions.
...	Slots to record which estimation method was used (as set by arguments above)
od_flow	Matrix of estimated origin-destination flows

Author(s)

Guy J. Abel

References

- Abel and Cohen (2019) Bilateral international migration flow estimates for 200 countries *Scientific Data* 6 (1), 1-13
- Azose & Raftery (2019) Estimation of emigration, return migration, and transit migration between all pairs of countries *Proceedings of the National Academy of Sciences* 116 (1) 116-122
- Abel, G. J. (2018). Estimates of Global Bilateral Migration Flows by Gender between 1960 and 2015. *International Migration Review* 52 (3), 809–852.
- Abel, G. J. and Sander, N. (2014). Quantifying Global International Migration Flows. *Science*, 343 (6178) 1520-1522
- Abel, G. J. (2013). Estimating Global Migration Flow Tables Using Place of Birth. *Demographic Research* 28, (18) 505-546

See Also

[ipf3_qi](#), [ffs_diff](#), [ffs_rates](#)

Examples

```
##
## without births and deaths over period
##
# data as in papers
s1 <- matrix(data = c(1000, 100, 10, 0, 55, 555, 50, 5, 80, 40, 800, 40, 20, 25, 20, 200),
             nrow = 4, ncol = 4, byrow = TRUE)
s2 <- matrix(data = c(950, 100, 60, 0, 80, 505, 75, 5, 90, 30, 800, 40, 40, 45, 0, 180),
             nrow = 4, ncol = 4, byrow = TRUE)
b <- d <- rep(0, 4)
reg <- LETTERS[1:4]
dimnames(s1) <- dimnames(s2) <- list(pob = reg, por = reg)
names(b) <- names(d) <- reg
s1; s2; b; d

# demographic research and science paper example
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d)

# international migration review paper example
s1[,] <- c(100, 20, 10, 20, 10, 55, 40, 25, 10, 25, 140, 20, 0, 10, 65, 200)
s2[,] <- c(70, 25, 10, 40, 30, 60, 55, 45, 10, 10, 140, 0, 10, 15, 50, 180)
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d)

# international migration review supp. material example
dm <- matrix(data = c(0, 5, 50, 500, 5, 0, 45, 495, 50, 45, 0, 450, 500, 495, 450, 0),
             nrow = 4, ncol = 4, byrow = TRUE)
dimnames(dm) <- list(orig = reg, dest = reg)
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d, m = dm)

##
## with births and deaths over period
##
# demographic research paper example
```

```

s1[,] <- c(1000, 55, 80, 20, 100, 555, 40, 25, 10, 50, 800, 20, 0, 5, 40, 200)
s2[,] <- c(1060, 45, 70, 30, 60, 540, 75, 30, 10, 40, 770, 20, 10, 0, 70, 230)
b[] <- c(80, 20, 40, 60)
d[] <- c(70, 30, 50, 10)
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d, match_pob_tot_method = "open-dr")
# makes more sense to use this method
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d, match_pob_tot_method = "open")

# science paper supp. material example
b[] <- c(80, 20, 60, 60)
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d)

# international migration review supp. material example
s1[,] <- c(100, 20, 10, 20, 10, 55, 40, 25, 10, 25, 140, 20, 0, 10, 65, 200)
s2[,] <- c(75, 20, 30, 30, 25, 45, 40, 30, 5, 30, 150, 20, 0, 15, 60, 230)
b[] <- c(10, 50, 25, 60)
d[] <- c(30, 10, 40, 10)
ffs_demo(m1 = s1, m2 = s2, b_por = b, d_por = d)

```

ffs_diff

*Estimation of Bilateral Migrant Flows from Bilateral Migrant Stocks
Using Stock Differencing Approaches*

Description

Estimates migrant transitions flows between two sequential migrant stock tables using differencing approaches commonly used by economists.

Usage

```
ffs_diff(m1, m2, decrease = "return", include_native_born = FALSE)
```

Arguments

m1	Matrix of migrant stock totals at time t . Rows in the matrix correspond to place of birth and columns to place of residence at time t
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
decrease	How to treat decreases in bilateral stocks over the t to $t+1$ period (so as to avoid a negative bilateral flow estimates). See details for possible options. Default is return
include_native_born	Logical value to indicate wheather to include diagonal elements of m1 and m2. Default of FALSE - not include.

Value

Estimates migrant transitions flows between two sequential migrant stock tables.

When decrease = "zero" all decreases in migrant stocks over there period are set to zero, following the approach of Bertoli and Fernandez-Huertas Moraga (2015)

When decrease = "return" all decreases in migrant stocks are assumed to correspond to return flows back to their place of birth, following the approach of Beine and Parsons (2015) #' @refer-ences Beine, Michel, Simone Bertoli, and Jesús Fernández-Huertas Moraga. (2016). A Practition-ers' Guide to Gravity Models of International Migration. *The World Economy* 39(4):496–512.

Author(s)

Guy J. Abel

See Also

[ffs_demo](#), [ffs_rates](#)

Examples

```
s1 <- matrix(data = c(100, 10, 10, 0, 20, 55, 25, 10, 10, 40, 140, 65, 20, 25, 20, 200),
             nrow = 4, ncol = 4, byrow = TRUE)
s2 <- matrix(data = c(75, 25, 5, 15, 20, 45, 30, 15, 30, 40, 150, 35, 10, 50, 5, 200),
             nrow = 4, ncol = 4, byrow = TRUE)
reg <- LETTERS[1:4]
dimnames(s1) <- dimnames(s2) <- list(pob = reg, por = reg)
s1; s2

ffs_diff(m1 = s1, m2 = s2, decrease = "zero")
ffs_diff(m1 = s1, m2 = s2, decrease = "return")
```

ffs_rates

*Estimation of Bilateral Migrant Flows from Bilateral Migrant Stocks
Using Rates Approaches*

Description

Estimates migrant transitions flows between two sequential migrant stock tables using approached based on rates.

Usage

```
ffs_rates(m1 = NULL, m2 = NULL, M = NULL, method = "dennett")
```


Arguments

m1	Matrix of migrant stock totals at time t . Rows in the matrix correspond to place of birth and columns to place of residence at time t
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
M	Numeric value for the global sum of migration flows, used for dennett approach.
method	Method to estimate flows. Can take values dennett or rogers-von-rabenau. See details section for more information. Uses dennett as default.

Value

Estimates migrant transitions flows based on migration rates.

When method = "dennett" migration are derived from the matrix supplied to m1. Dennett uses bilateral migrant stocks at beginning of period. Rates then multiplied by global migration flows supplied in M.

When method = "rogers-von-rabenau" a matrix of growth rates are derived from the changes in initial populations stock m1 to obtain m2;

$$P^{t+1} = gP^t$$

and then multiplied by the corresponding populations at risk in m1. Can result in negative flows.

@references Dennett, A. (2015). Estimating an Annual Time Series of Global Migration Flows - An Alternative Methodology for Using Migrant Stock Data. *Global Dynamics: Approaches from Complexity Science*, 125–142. <https://doi.org/10.1002/9781118937464.ch7>

Rogers, A., & Von Rabenau, B. (1971). Estimation of interregional migration streams from place-of-birth-by-residence data. *Demography*, 8(2), 185–194.

Author(s)

Guy J. Abel

See Also

[ffs_demo](#), [ffs_rates](#)

Examples

```
s1 <- matrix(data = c(100, 10, 10, 0, 20, 55, 25, 10, 10, 40, 140, 65, 20, 25, 20, 200),
             nrow = 4, ncol = 4, byrow = TRUE)
s2 <- matrix(data = c(75, 25, 5, 15, 20, 45, 30, 15, 30, 40, 150, 35, 10, 50, 5, 200),
             nrow = 4, ncol = 4, byrow = TRUE)
reg <- LETTERS[1:4]
dimnames(s1) <- dimnames(s2) <- list(pob = reg, por = reg)
s1; s2

# calculate total migration flows for dennett approach
n <- colSums(s2) - colSums(s1)
```

```
ffs_rates(m1 = s1, M = sum(abs(n)), method = "dennett" )
ffs_rates(m1 = s1, m2 = s2, method = "rogers-von-rabenau" )
```

ipf2 *Iterative Proportional Fitting Routine for the Indirect Estimation of Origin-Destination Migration Flow Table with Known Margins.*

Description

The ipf2 function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{ij} = \log \alpha_i + \log \beta_j + \log m_{ij}$$

where m_{ij} is a set of prior estimates for y_{ij} and itself is no more complex than the one being fitted.

Usage

```
ipf2(
  row_tot = NULL,
  col_tot = NULL,
  m = matrix(1, length(row_tot), length(col_tot)),
  tol = 1e-05,
  maxit = 500,
  verbose = FALSE
)
```

Arguments

row_tot	Vector of origin totals to constrain the sum of the imputed cell rows.
col_tot	Vector of destination totals to constrain the sum of the imputed cell columns.
m	Matrix of auxiliary data. By default set to 1 for all origin-destination combinations.
tol	Numeric value for the tolerance level used in the parameter estimation.
maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Value

Iterative Proportional Fitting routine set up in a similar manner to Agresti (2002, p.343). This is equivalent to a conditional maximization of the likelihood, as discussed by Willekens (1999), and hence provides identical indirect estimates to those obtained from the [cm2](#) routine.

The user must ensure that the row and column totals are equal in sum. Care must also be taken to allow the dimension of the auxiliary matrix (m) to equal those provided in the row and column totals.

If only one of the margins is known, the function can still be run. The indirect estimates will correspond to the log-linear model without the α_i term if (`row_tot = NULL`) or without the β_j term if (`col_tot = NULL`)

Returns a list object with

<code>mu</code>	Origin-Destination matrix of indirect estimates
<code>it</code>	Iteration count
<code>tol</code>	Tolerance level at final iteration

Author(s)

Guy J. Abel

References

Agresti, A. (2002). *Categorical Data Analysis* 2nd edition. Wiley.

Willekens, F. (1999). Modelling Approaches to the Indirect Estimation of Migration Flows: From Entropy to EM. *Mathematical Population Studies* 7 (3), 239–78.

See Also

[cm2](#), [ipf3](#)

Examples

```
## with Willekens (1999) data
dn <- LETTERS[1:2]
y <- ipf2(row_tot = c(18, 20), col_tot = c(16, 22),
          m = matrix(c(5, 1, 2, 7), ncol = 2,
                    dimnames = list(orig = dn, dest = dn)))
round(addmargins(y$mu),2)

## with all elements of offset equal
y <- ipf2(row_tot = c(18, 20), col_tot = c(16, 22))
round(addmargins(y$mu),2)

## with bigger matrix
dn <- LETTERS[1:3]
y <- ipf2(row_tot = c(170, 120, 410), col_tot = c(500, 140, 60),
          m = matrix(c(50, 10, 220, 120, 120, 30, 545, 0, 10), ncol = 3,
                    dimnames = list(orig = dn, dest = dn)))
# display with row and col totals
round(addmargins(y$mu))

## only one margin known
dn <- LETTERS[1:2]
y <- ipf2(row_tot = c(18, 20), col_tot = NULL,
          m = matrix(c(5, 1, 2, 7), ncol = 2,
                    dimnames = list(orig = dn, dest = dn)))
round(addmargins(y$mu))
```

ipf2_block	<i>Iterative Proportional Fitting Routine for the Indirect Estimation of Origin-Destination-Type Migration Flow Tables with Known Origin and Destination Margins and Block Diagonal Elements.</i>
------------	---

Description

The ipf2.b function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{pq} = \log \alpha_p + \log \beta_q + \log \lambda_{ij} I(p \in i, q \in j) + \log m_{pq}$$

where m_{pq} is a prior estimate for y_{pq} and is no more complex than the matrices being fitted. The $\lambda_{ij} I(p \in i, q \in j)$ term ensures a saturated fit on the block the (i, j) block.

Usage

```
ipf2_block(
  row_tot = NULL,
  col_tot = NULL,
  block_tot = NULL,
  block = NULL,
  m = NULL,
  tol = 1e-05,
  maxit = 500,
  verbose = TRUE,
  ...
)
```

Arguments

row_tot	Vector of origin totals to constrain the sum of the imputed cell rows.
col_tot	Vector of destination totals to constrain the sum of the imputed cell columns.
block_tot	Matrix of block totals to constrain the sum of the imputed cell blocks.
block	Matrix of block structure corresponding to block_tot.
m	Matrix of auxiliary data. By default set to 1 for all origin-destination combinations.
tol	Numeric value for the tolerance level used in the parameter estimation.
maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.
...	Additional arguments passes to block_matrix .

Value

Iterative Proportional Fitting routine set up using the partial likelihood derivatives. The arguments `row_tot` and `col_tot` take the row-table and column-table specific known margins. The `block_tot` take the totals over the blocks in the matrix defined with `b`. Diagonal values can be added by the user, but care must be taken to ensure resulting diagonals are feasible given the set of margins.

The user must ensure that the row and column totals in each table sum to the same value. Care must also be taken to allow the dimension of the auxiliary matrix (`m`) equal those provided in the row and column totals.

Returns a list object with

<code>mu</code>	Array of indirect estimates of origin-destination matrices by migrant characteristic
<code>it</code>	Iteration count
<code>tol</code>	Tolerance level at final iteration

Author(s)

Guy J. Abel

See Also

[block_matrix](#), [stripe_matrix](#), [block_sum](#)

Examples

```
y <- ipf2_block(row_tot= c(30,20,30,10,20,5,0,10,5,5,5,10),
               col_tot = c(45,10,10,5,5,10,50,5,10,0,0,0),
               block_tot = matrix(data = c(0,0 ,50,0, 35,0,25,0, 10,10,0,0, 10,10,0,0),
                                   nrow = 4, byrow = TRUE),
               block = block_matrix(x = 1:16, b = c(2,3,4,3)))
addmargins(y$mu)
```

ipf2_stripe

Iterative Proportional Fitting Routine for the Indirect Estimation of Origin-Destination-Type Migration Flow Tables with Known Origin and Destination Margins and Stripe Elements.

Description

The `ipf2.b` function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{pq} = \log \alpha_p + \log \beta_q + \log \lambda_{ij} I(p \in i, q \in j) + \log m_{pq}$$

where m_{pq} is a prior estimate for y_{pq} and is no more complex than the matrices being fitted. The $\lambda_{ij} I(p \in i, q \in j)$ term ensures a saturated fit on the block the (i, j) block.

Usage

```
ipf2_stripe(
  row_tot = NULL,
  col_tot = NULL,
  stripe_tot = NULL,
  stripe = NULL,
  m = NULL,
  tol = 1e-05,
  maxit = 500,
  verbose = TRUE,
  ...
)
```

Arguments

<code>row_tot</code>	Vector of origin totals to constrain the sum of the imputed cell rows.
<code>col_tot</code>	Vector of destination totals to constrain the sum of the imputed cell columns.
<code>stripe_tot</code>	Matrix of stripe totals to constrain the sum of the imputed cell blocks.
<code>stripe</code>	Matrix of stripe structure corresponding to <code>stripe_tot</code> .
<code>m</code>	Matrix of auxiliary data. By default set to 1 for all origin-destination combinations.
<code>tol</code>	Numeric value for the tolerance level used in the parameter estimation.
<code>maxit</code>	Numeric value for the maximum number of iterations used in the parameter estimation.
<code>verbose</code>	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.
<code>...</code>	Additional arguments passes to stripe_matrix .

Value

Iterative Proportional Fitting routine set up using the partial likelihood derivatives. The arguments `row_tot` and `col_tot` take the row-table and column-table specific known margins. The `stripe_tot` take the totals over the stripes in the matrix defined with `b`. Diagonal values can be added by the user, but care must be taken to ensure resulting diagonals are feasible given the set of margins. The user must ensure that the row and column totals in each table sum to the same value. Care must also be taken to allow the dimension of the auxiliary matrix (`m`) equal those provided in the row and column totals. Returns a `list` object with

<code>mu</code>	Array of indirect estimates of origin-destination matrices by migrant characteristic
<code>it</code>	Iteration count
<code>tol</code>	Tolerance level at final iteration

Author(s)

Guy J. Abel

See Also

[stripe_matrix](#), [block_matrix](#), [block_sum](#)

Examples

```
y <- ipf2_stripe(row_tot = c(85, 70, 35, 30, 60, 55, 65),
  stripe_tot = matrix(c(15,20,50,
    35,10,25,
    5 ,0 ,30,
    10,10,10,
    30,30,0,
    15,30,10,
    35,25,5 ), ncol = 3, byrow = TRUE),
  stripe = stripe_matrix(x = 1:21, s = c(2,2,3), byrow = TRUE))
addmargins(y$mu)
```

ipf3	<i>Iterative Proportional Fitting Routine for the Indirect Estimation of Origin-Destination-Migrant Type Migration Flow Tables with Known Origin and Destination Margins.</i>
------	---

Description

The ipf3 function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{ijk} = \log \alpha_i + \log \beta_j + \log \lambda_k + \log \gamma_{ik} + \log \kappa_{jk} + \log m_{ijk}$$

where m_{ijk} is a set of prior estimates for y_{ijk} and is no more complex than the matrices being fitted.

Usage

```
ipf3(
  row_tot = NULL,
  col_tot = NULL,
  m = NULL,
  tol = 1e-05,
  maxit = 500,
  verbose = TRUE
)
```

Arguments

row_tot	Vector of origin totals to constrain the sum of the imputed cell rows.
col_tot	Vector of destination totals to constrain the sum of the imputed cell columns.
m	Array of auxiliary data. By default set to 1 for all origin-destination-migrant typologies combinations.
tol	Numeric value for the tolerance level used in the parameter estimation.

maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Value

Iterative Proportional Fitting routine set up in a similar manner to Agresti (2002, p.343). The arguments row_tot and col_tot take the row-table and column-table specific known margins.

The user must ensure that the row and column totals in each table sum to the same value. Care must also be taken to allow the dimension of the auxiliary matrix (m) to equal those provided in the row and column totals.

Returns a list object with

mu	Array of indirect estimates of origin-destination matrices by migrant characteristic
it	Iteration count
tol	Tolerance level at final iteration

Author(s)

Guy J. Abel

References

Abel and Cohen (2019) Bilateral international migration flow estimates for 200 countries *Scientific Data* 6 (1), 1-13

Azose & Raftery (2019) Estimation of emigration, return migration, and transit migration between all pairs of countries *Proceedings of the National Academy of Sciences* 116 (1) 116-122

Abel, G. J. (2013). Estimating Global Migration Flow Tables Using Place of Birth. *Demographic Research* 28, (18) 505-546

Agresti, A. (2002). *Categorical Data Analysis* 2nd edition. Wiley.

See Also

[ipf3_qi](#), [ipf2](#)

Examples

```
## create row-table and column-table specific known margins.
dn <- LETTERS[1:4]
P1 <- matrix(c(1000, 100, 10, 0,
              55, 555, 50, 5,
              80, 40, 800, 40,
              20, 25, 20, 200),
            nrow = 4, ncol = 4, byrow = TRUE,
            dimnames = list(pob = dn, por = dn))
P2 <- matrix(c(950, 100, 60, 0,
```



```

      80, 505, 75, 5,
      90, 30, 800, 40,
      40, 45, 0, 180),
      nrow = 4, ncol = 4, byrow = TRUE,
      dimnames = list(pob = dn, por = dn))
# display with row and col totals
addmargins(P1)
addmargins(P2)

# run ipf
y <- ipf3(row_tot = t(P1), col_tot = P2)
# display with row, col and table totals
round(addmargins(y$mu), 1)
# origin-destination flow table
round(sum_od(y$mu), 1)

## with alternative offset term
dis <- array(c(1, 2, 3, 4, 2, 1, 5, 6, 3, 4, 1, 7, 4, 6, 7, 1), c(4, 4, 4))
y <- ipf3(row_tot = t(P1), col_tot = P2, m = dis)
# display with row, col and table totals
round(addmargins(y$mu), 1)
# origin-destination flow table
round(sum_od(y$mu), 1)

```

ipf3_qi

Iterative Proportional Fitting Routine for the Indirect Estimation of Origin-Destination-Migrant Type Migration Flow Tables with Known Origin and Destination Margins and Diagonal Elements.

Description

This function is predominantly intended to be used within the [ffs](#) routine.

Usage

```

ipf3_qi(
  row_tot = NULL,
  col_tot = NULL,
  diag_count = NULL,
  m = NULL,
  speed = TRUE,
  tol = 1e-05,
  maxit = 500,
  verbose = TRUE
)

```

Arguments

row_tot	Vector of origin totals to constrain the sum of the imputed cell rows.
col_tot	Vector of destination totals to constrain the sum of the imputed cell columns.
diag_count	Array with counts on diagonal to constrain diagonal elements of the indirect estimates too. By default these are taken as their maximum possible values given the relevant margins totals in each table. If user specifies their own array of diagonal totals, values on the non-diagonals in the array can take any positive number (they are ultimately ignored).
m	Array of auxiliary data. By default set to 1 for all origin-destination-migrant typologies combinations.
speed	Speeds up the IPF algorithm by minimizing sufficient statistics.
tol	Numeric value for the tolerance level used in the parameter estimation.
maxit	Numeric value for the maximum number of iterations used in the parameter estimation.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Details

The ipf3 function finds the maximum likelihood estimates for fitted values in the log-linear model:

$$\log y_{ijk} = \log \alpha_i + \log \beta_j + \log \lambda_k + \log \gamma_{ik} + \log \kappa_{jk} + \log \delta_{ijk} I(i = j) + \log m_{ijk}$$

where m_{ijk} is a set of prior estimates for y_{ijk} and is no more complex than the matrices being fitted. The $\delta_{ijk} I(i = j)$ term ensures a saturated fit on the diagonal elements of each (i, j) matrix.

Value

Iterative Proportional Fitting routine set up using the partial likelihood derivatives illustrated in Abel (2013). The arguments row_tot and col_tot take the row-table and column-table specific known margins. By default the diagonal values are taken as their maximum possible values given the relevant margins totals in each table. Diagonal values can be added by the user, but care must be taken to ensure resulting diagonals are feasible given the set of margins.

The user must ensure that the row and column totals in each table sum to the same value. Care must also be taken to allow the dimension of the auxiliary matrix (m) equal those provided in the row and column totals.

Returns a list object with

mu	Array of indirect estimates of origin-destination matrices by migrant characteristic
it	Iteration count
tol	Tolerance level at final iteration

Author(s)

Guy J. Abel

References

Abel, G. J. (2013). Estimating Global Migration Flow Tables Using Place of Birth. *Demographic Research* 28, (18) 505-546

See Also

[ipf3](#), [ffs_demo](#)

Examples

```
## create row-table and column-table specific known margins.
dn <- LETTERS[1:4]
P1 <- matrix(c(1000, 100, 10, 0,
              55, 555, 50, 5,
              80, 40, 800, 40,
              20, 25, 20, 200),
            nrow = 4, ncol = 4, byrow = TRUE,
            dimnames = list(pob = dn, por = dn))
P2 <- matrix(c(950, 100, 60, 0,
              80, 505, 75, 5,
              90, 30, 800, 40,
              40, 45, 0, 180),
            nrow = 4, ncol = 4, byrow = TRUE,
            dimnames = list(pob = dn, por = dn))
# display with row and col totals
addmargins(P1)
addmargins(P2)

# run ipf
y <- ipf3_qi(row_tot = t(P1), col_tot = P2)
# display with row, col and table totals
round(addmargins(y$mu), 1)
# origin-destination flow table
round(sum_od(y$mu), 1)

## with alternative offset term
dis <- array(c(1, 2, 3, 4, 2, 1, 5, 6, 3, 4, 1, 7, 4, 6, 7, 1), c(4, 4, 4))
y <- ipf3_qi(row_tot = t(P1), col_tot = P2, m = dis)
# display with row, col and table totals
round(addmargins(y$mu), 1)
# origin-destination flow table
round(sum_od(y$mu), 1)
```

ipf_seed

Quickly Create IPF Seed

Description

This function is predominantly intended to be used within the ipf routines in the migest package.

Usage

```
ipf_seed(m = NULL, R = NULL, n_dim = NULL, dn = NULL)
```

Arguments

m	Matrix, Array or NULL to build seed. If NULL seed will be 1 for all elements.
R	Number of rows, columns and possibly n_dimensions for seed matrix or array.
n_dim	Numeric integer for the number of n_dimensions - 2 for matrix, 3 or more for an array
dn	Vector of character strings for n_dimension names

Value

An array or matrix

Author(s)

Guy J. Abel

See Also

[ipf3_qi](#), [ffs_diff](#)

Examples

```
ipf_seed(m = NULL, R = 4, n_dim = 2)
ipf_seed(m = NULL, R = 5, n_dim = 3, dn = LETTERS[1:5])
ipf_seed(m = matrix(1:4, nrow = 2), n_dim = 3, dn = LETTERS[1:2])
```

match_pob_tot

Adjust Migrant Stock Tables to Have Matching Place of Birth Totals

Description

This function is predominantly intended to be used within the ffs routines in the migest package.

Usage

```
match_pob_tot(m1, m2, method = "rescale", verbose = FALSE)
```

Arguments

m1	Matrix of migrant stock totals at time t . Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
method	Character string matching either rescale, rescale-adjust-zero-fb, open or open-dr. See details.
verbose	Logical value to indicate the print the parameter estimates at each iteration of the rescale, as used in ipf2. By default FALSE.

Details

The rescale and rescale-adjust-zero-fb method ensure flow estimates closely match the net migration totals implied by the changes in population totals, births and deaths - as introduced in the Science paper. The rescale-adjust-zero-fb can adjust for rare cases when row total margins that are smaller than native born totals in countries where there are no foreign born populations (e.g. South Sudan 1990-1995). The open-dr method allows for moves in and out of the global system - as introduced in the Demographic Research paper. The open method is a slight improvement over open-dr - the calculation of the moves and in and out using more sensible weights.

Value

Returns a list object with:

m1_adj	Matrix of adjusted m1 where rows (place of births) match m2_adj.
m2_adj	Matrix of adjusted m2 where rows (place of births) match m1_adj.
in_mat	Matrix of estimated inflows into the system.
out_mat	Matrix of estimated outflows from the system.

Author(s)

Guy J. Abel

References

- Abel and Cohen (2019) Bilateral international migration flow estimates for 200 countries *Scientific Data* 6 (1), 1-13
- Azose & Raftery (2019) Estimation of emigration, return migration, and transit migration between all pairs of countries *Proceedings of the National Academy of Sciences* 116 (1) 116-122
- Abel, G. J. (2018). Estimates of Global Bilateral Migration Flows by Gender between 1960 and 2015. *International Migration Review* 52 (3), 809–852.
- Abel, G. J. and Sander, N. (2014). Quantifying Global International Migration Flows. *Science*, 343 (6178) 1520-1522

See Also

[ipf3_qi](#), [ffs_diff](#)

multi_comp	<i>Multiplicative Component Description of Origin-Destination Migration Flow Tables</i>
------------	---

Description

Multiplicative component descriptions of *n*-dimension flow tables based on total reference coding system.

Usage

```
multi_comp(m)
```

Arguments

`m` matrix or array of migration flows

Value

matrix or array of multiplicative components of 'm'. When output is an array the total for each table of origin-destination flows is used.

Examples

```
n <- LETTERS[1:4]
m0 <- matrix(data = c(0, 100, 30, 70, 50, 0, 45, 5, 60, 35, 0, 40, 20, 25, 20, 0),
             nrow = 4, ncol = 4, dimnames = list(orig = n, dest = n), byrow = TRUE)
addmargins(m0)
multi_comp(m = m0)
```

multi_comp2	<i>Multiplicative component descriptions of origin-destination flow tables based on total reference coding system.</i>
-------------	--

Description

Multiplicative component descriptions of origin-destination flow tables based on total reference coding system.

Usage

```
multi_comp2(m)
```

Arguments

`m` matrix of migration flows

Value

matrix of multiplicative components of ‘m’. When output is an array the total for each table of origin-destination flows is used.

Examples

```
n <- LETTERS[1:2]
m0 <- array(c(5, 1, 2, 7, 4, 2, 5, 9), dim = c(2, 2, 2),
            dimnames = list(orig = n, dest = n, type = c("ILL", "HEALTHY")))
addmargins(m0)
multi_comp(m = m0)
multi_comp2(m = m0)
```

net_from_lifetime	<i>Estimate Net Migration from Lifetime Migration Data</i>
-------------------	--

Description

Estimate Net Migration from Lifetime Migration Data

Usage

```
net_from_lifetime(
  .data,
  in_migrant = "in_migrants",
  out_migrant = "out_migrants",
  year = "year",
  in_survival,
  out_survival
)
```

Arguments

.data	A data frame with two rows with the total number of lifetime in- and out-migrants in separate columns. The first row contains totals at the first time point and second row at the second time point.
in_migrant	Character string name of column containing in-migrant counts. Default ‘code"in_migrants"‘.
out_migrant	Character string name of column containing out-migrant counts. Default ‘code"out_migrants"‘.
year	Character string name of column containing time points. Default ‘code"year"‘.
in_survival	Survival probability for foreign migrants in region
out_survival	Survival probability for native migrants outside of region

Value

Data frame with estimates of net migration

net_param	<i>Estimate Parameters for Net Migration Scaling.</i>
-----------	---

Description

This function is predominantly intended to be used within the `cm_net` routine.

Usage

```
net_param(m, region, net_tot)
```

Arguments

m	Matrix of origin-destination flows, where the first and second dimensions correspond to origin and destination respectively.
region	Integer value corresponding to the region that the net migration sum is desired. Will return sums for all regions by default.
net_tot	Vector of net migration totals to constrain the sum of the imputed cell columns. Elements must sum to zero.

Value

Vector of two values corresponding to the roots for the quadratic equation.

Author(s)

Guy J. Abel

net_scale	<i>Scale Migration Flows in Origin-Destination</i>
-----------	--

Description

This function is predominantly intended to be used within the `cm_net` routine.

Usage

```
net_scale(m, region = NULL, alpha)
```

Arguments

m	Matrix of origin-destination flows, where the first and second dimensions correspond to origin and destination respectively.
region	Integer corresponding to row (column) in a square matrix for the region where scaling is to be applied
alpha	Numeric value of the scaling factor

Value

Matrix scaled in region(s) by value of alpha, where alpha applied to destination flows and inverse of alpha applied to origin flows

Author(s)

Guy J. Abel

net_stream	<i>Calculate Counterstream and Stream Net Migration</i>
------------	---

Description

Calculate Counterstream and Stream Net Migration

Usage

net_stream(m)

Arguments

m A matrix or data frame of origin-destination flows. For matrix the first and second dimensions correspond to origin and destination respectively. For a data frame the first and second columns correspond to origin and destination respectively. The third column contains the number of migrants or migrants.

Value

A tibble with columns for orig, destination, corridor, stream, counterstream and net stream in each pair (corridor)

quadratic_eqn	<i>Solve Quadratic Equation</i>
---------------	---------------------------------

Description

General function to solve classic quadratic equation:

$$ax^2 + bx + c = 0$$

Usage

quadratic_eqn(a, b, c)

Arguments

a	Numeric value for quadratic term of x.
b	Numeric value for multiplicative term of x.
c	Numeric value for constant term.

Value

Vector of two values corresponding to the roots for the quadratic equation.

Author(s)

Guy J. Abel

Source

Adapted from <https://rpubs.com/kikihatizstavrou/80124>

Examples

```
quadratic_eqn(a = 2, b = 4, c = -6)
```

rc9

Rogers-Castro Migration Schedule

Description

Provides the Rogers-Castro schedule,

$$M(x) = a_1 \exp[-\alpha_1 x] + a_2 \exp[\alpha_2(x - \mu_2) - \exp[\lambda_2(x - \mu_2)]] + c$$

for a given set of parameters and ages.

Usage

```
rc9(x, param = NULL, scaled = TRUE)
```

Arguments

x	Vector of numbers
param	List with names matching the parameters in the age schedule
scaled	Scale estimates to sum to one across all ages, x.

Value

Returns the $M(x)$ values from the Rogers-Castro schedule of age specific migration rate. The age range for the calculation can take any sequence of positive numbers, such as ages in single or 5-year intervals. The `param` argument must be a list with correct names for each parameter. See for example the [rc9.fund](#) object for an example of the naming convention.

Author(s)

Guy J. Abel

References

Rogers, A., and L. J. Castro. (1981). Model Migration Schedules. *IIASA Research Report 81 RR-81-30*

See Also[rc9.fund](#)**Examples**

```
# single age groups
x <- 1:100
m <- rc9(x, param = rc9.fund)
plot(x, m, type="l")

# 5 year age groups
m <- rc9(x, param = rc9.fund)
plot(x, m, type="l")
```

`rc9.fund`*Fundamental Parameters for Rogers-Castro Migration Schedule*

Description

Set of fundamental parameters for the Rogers-Castro migration age schedule, as suggested in Rogers and Castro (1981).

Usage`rc9.fund`**Format**

A list of the parameters required by the `rc9` function:

$$a_1 = 0.02$$

$$\alpha_1 = 0.1$$

$$a_2 = 0.06$$

$$\alpha_2 = 0.1$$

$$\mu_2 = 20$$

$$\lambda_2 = 0.4$$

$$c = 0.003$$

Source

Rogers, A., and L. J. Castro. (1981). Model Migration Schedules. *IIASA Research Report 81 RR-81-30*

Examples

```
# check format
str(rc9.fund)

# single age groups
x <- 1:100
m <- rc9(x, param = rc9.fund)
plot(x, m, type="l")

# alter to see the effect of mu2
p1 <- rc9.fund
p1$mu2 <- 30
m1 <- rc9(x, param = p1)
plot(x, m, type="l")
lines(x, m1, lty=2)
```

rescale_integer_sum *Rescale Integer Vector to a Set sum*

Description

For when you want to rescale a set of numbers to sum to a given value and do not want all rescaled values to be integers.

Usage

```
rescale_integer_sum(x, tot)
```

Arguments

x	Vector of numeric values
tot	Numeric integer value to rescale sum to.

Value

Vector or integer values that sum to tot

Author(s)

Guy J. Abel

See Also

[ipf3_qi](#), [ffs_diff](#)

Examples

```
x <- rnorm(n = 10, mean = 5, sd = 20)
y <- rescale_integer_sum(x, tot = 10)
y
sum(y)

for(i in 1:10){
  y <- rescale_integer_sum(x = rpois(n = 10, lambda = 10), tot = 1000)
  print(sum(y))
}
```

rescale_nb	<i>Rescale Native Born Populations to Match Global Differences in Births and Deaths over Period</i>
------------	---

Description

This function is predominantly intended to be used within the ffs routines in the migest package. Adjustment to ensure that global differences in stocks match the global demographic changes from births and deaths.

Usage

```
rescale_nb(m1, m2, b, d, verbose = FALSE)
```

Arguments

m1	Matrix of migrant stock totals at time t . Rows in the matrix correspond to place of birth and columns to place of residence at time t
m2	Matrix of migrant stock totals at time $t+1$. Rows in the matrix correspond to place of birth and columns to place of residence at time $t+1$.
b	Vector of the number of births between time t and $t+1$ in each region.
d	Vector of the number of deaths between time t and $t+1$ in each region.
verbose	Logical value to indicate the print the parameter estimates at each iteration. By default FALSE.

Value

List with adjusted m1 and m2.

Author(s)

Guy J. Abel

See Also

[ipf3_qi](#), [ffs_diff](#)

Examples

```

dn <- LETTERS[1:4]
P1 <- matrix(data = c(1000, 100, 10, 0, 55, 555, 50, 5, 80, 40, 800, 40, 20, 25, 20, 200),
             nrow = 4, ncol = 4, dimnames = list(pob = dn, por = dn), byrow = TRUE)
P2 <- matrix(data = c(950, 100, 60, 0, 80, 505, 75, 5, 90, 30, 800, 40, 40, 45, 0, 180),
             nrow = 4, ncol = 4, dimnames = list(pob = dn, por = dn), byrow = TRUE)
# display with row and col totals
addmargins(A = P1)
addmargins(A = P2)

# births and deaths
b <- rep(x = 10, 4)
d <- rep(x = 5, 4)
# no change in stocks, but 20 more births than deaths...
sum(P2 - P1) + sum(b - d)
# rescale
y <- rescale_nb(m1 = P1, m2 = P2, b = b, d = d)
y
sum(y$m1_adj - y$m2_adj) + sum(b - d)

# check for when extra is positive and odd
d[1] <- 31
d
sum(P2 - P1) - sum(b - d)
# rescale
y <- rescale_nb(m1 = P1, m2 = P2, b = b, d = d)
sum(y$m1_adj - y$m2_adj) - sum(b - d)

```

rescale_net

Rescale Net Migration Total to a Global Zero Sum

Description

Modify a set of net migration (or any numbers) so that they sum to zero.

Usage

```

rescale_net(
  x,
  method = "no-switches",
  w = rep(1, length(x)),
  integer_result = TRUE
)

```

Arguments

x Vector of net migration values

method	Method used to adjust net migration values of x to obtain a global zero sum. By default method="no-switches". Can also take values method="switches". See details for explanation on each method.
w	Weights used in rescaling method
integer_result	Logical operator to indicate if output should be integers, default is TRUE.

Value

Rescales net migration for a number of regions in vector x to sum to zero. When method="no-switches" rescaling of values are done for the positive and negative values separately, to ensure the final global sum is zero. When method="switches" the mean of the unscaled net migration is subtracted from each value.

Author(s)

Guy J. Abel

References

Abel, G. J. (2018). Non-zero trajectories for long-run net migration assumptions in global population projection models. *Demographic Research* 38, (54) 1635–1662

Examples

```
# net migration in regions countries (does not add up to zero)
x <- c(-200, -30, -5, 0, 10, 20, 60, 80)
x
sum(x)
# rescale
y1 <- rescale_net(x)
y1
sum(y1)
# rescale without integer restriction
y2 <- rescale_net(x, integer_result = FALSE)
y2
sum(y2)
# rescale allowing switching of signs (small negative value becomes positive)
y3 <- rescale_net(x, method = "switches")
y3
sum(y3)
```

stripe_matrix

Create a Stripped Matrix with Non-Uniform Block Sizes.

Description

Create a Stripped Matrix with Non-Uniform Block Sizes.

Usage

```
stripe_matrix(x = NULL, s = NULL, byrow = FALSE, dimnames = NULL)
```

Arguments

x	Vector of numbers to identify each stripe.
s	Vector of values for the size of the stripes, order depending on byrow
byrow	Logical value. If FALSE (the default) the stripes are filled by columns, otherwise the stripes in the matrix are filled by rows.
dimnames	Character string of name attribute for the basis of the stripped matrix. If NULL a vector of the same length of s provides the basis of row and column names.

Value

Returns a matrix with stripe sizes determined by the s argument. Each stripe is filled with the same value taken from x.

Author(s)

Guy J. Abel

See Also

[block_matrix](#), [block_sum](#), [ipf2_stripe](#)

Examples

```
stripe_matrix(x = 1:44, s = c(2,3,4,2), dimnames = LETTERS[1:4], byrow = TRUE)
```

sum_net	<i>Extract Net Migration from an Origin-Destination Migration Flow Matrix.</i>
---------	--

Description

Sums each regions flows (from origin rows and destination columns) to obtain net migration sums.

Usage

```
sum_net(m, region = 1:dim(m)[1])
```

Arguments

m	Matrix of origin-destination flows, where the first and second dimensions correspond to origin and destination respectively.
region	Integer value corresponding to the region that the net migration sum is desired. Will return sums for all regions by default.

Value

Returns a numeric value of the sum of a single block.

Author(s)

Guy J. Abel

See Also

[block_sum](#), [sum_od](#)

Examples

```
m <- matrix(data = 1:16, nrow = 4, ncol = 4)
sum_net(m)
```

sum_od

Extract a Classic Origin-Destination Migration Flow Matrix.

Description

Extract a classic origin-destination migration flow matrix from a more detailed dis-aggregation of flows stored in an (array) object.

Usage

```
sum_od(y)
```

Arguments

y Array of origin-destination matrices, where the first and second dimensions correspond to origin and destination respectively. Higher dimension(s) refer to additional migrant characteristic(s).

Value

Matrix from summing over the first and second dimension. Set diagonals to zero.

Returns a `matrix` object of origin-destination flows

Author(s)

Guy J. Abel

Examples

```
dn <- LETTERS[1:2]
y <- cm3(row_tot = c(18, 20) * 2, col_tot = c(16, 22) * 2,
        m = array(c(5, 1, 2, 7, 4, 2, 5, 9), dim = c(2, 2, 2),
                 dimnames = list(orig = dn, dest = dn, type = c("ILL", "HEALTHY"))))
round(addmargins(y$n))
round(addmargins(sum_od(y$n)))
```

sum_total

Origin or Destination Sums for Origin-Destination Tidy Data

Description

Sums of inflows and out flows from tidy origin-destination data.

Usage

```
sum_total(d = NULL, type = "orig")
```

Arguments

d data frame of origin-destination data. Must contain columns with names orig, dest and flow.

type string (either orig or dest) indicating if totals should be for origins (outflows) or destinations (inflows)

Value

tibble data frame

Author(s)

Guy J. Abel

sum_turnover

Extract Total In- and Out-Migration Totals from an Origin-Destination Migration Flow Matrix.

Description

Extract Total In- and Out-Migration Totals from an Origin-Destination Migration Flow Matrix.

Usage

```
sum_turnover(m, drop_diagonal = TRUE, include_net = TRUE)
```

Arguments

m	A matrix or data frame of origin-destination flows. For matrix the first and second dimensions correspond to origin and destination respectively. For a data frame the first and second columns correspond to origin and destination respectively. The third column contains the number of migrants or migrants.
drop_diagonal	Logical to indicate dropping of diagonal terms, where the origin and destination are the same, in the calculation of totals. Default TRUE.
include_net	Logical to indicate inclusion of a net migration total column for each region, in addition to the total in- and out-flows. Default TRUE.

Value

A tibble with total in- and out-flows for each region.

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