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Description Counting election votes and determining election results by different methods, including the single transferable vote or ranked choice (Newland and F.S. Britton, 1997; ISBN: 0903291185), approval, score, plurality, condorcet and two-round runoff methods.

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vote-package *Election Vote Counting*

Description

Counting election votes and determining election results by different methods, including the single transferable vote (ranked choice), approval, score, plurality, condorcet and two-round runoff methods.

Details

The main function of the package is called `count.votes`. If no specific method is passed, it decides on the basis of the available data which method is the most appropriate. Specific methods can also be invoked explicitly. The following voting methods are available:

- stv: Single transferable vote (STV) where voters rank candidates in order. It is also known as ranked choice voting or instant runoff.
- score: Range voting where each voter gives each candidate a score within a specific range.
- approval: Voters give each candidate one (approve) or zero (not approve).
- plurality: Each voter chooses one candidate.
- condorcet: Voters rank candidates in order. The winner is determined in pairwise comparisons.
- tworound.runoff: Two-round majority system with ranked ballots. If no candidate gets the majority, there is a run-off between the top two candidates.

Output of these functions can be viewed using `summary` methods, or in a browser using `view` methods. The `summary` methods return a data frame which can be stored in a file, see Example below. Outputs of the `stv` method can be plotted in a graph. The joint and marginal distributions of ranked votes (for `stv`, `condorcet` and `tworound.runoff`) can be visualized in an image plot.

Functions `invalid.votes` and `valid.votes` can be used to check the validity of ballots for the various methods. Function `correct.ranking` can be used to make ballot corrections to ranked data, including ballots with equal preferences.

Example datasets are included. The `ims_election` dataset contains anonymized ballots from a past Council election of the Institute of Mathematical Statistics (IMS) which uses the STV method. Modifications of this dataset are available (`ims_approval`, `ims_score`, `ims_plurality`) as examples of data required by the various methods. The `food_election` dataset taken from Wikipedia can be used to test the STV method. Similarly, methods for ranked voting can be applied to the `dublin_west` dataset which contains election ballots from the 2002 election to the Dublin West constituency in Ireland.

Author(s)

Hana Sevcikova, Bernard Silverman, Adrian Raftery

Maintainer: Hana Sevcikova

Examples

```
data(ims_election)
res <- count.votes(ims_election, method = "stv", mcan = 5)
summary(res)

# View invalid votes
invalid.votes(res)

## Not run:
# View results in a browser
view(res)

# Write election results into a csv file
s <- summary(res)
write.csv(s, "IMSstvresults.csv")
## End(Not run)
```

---

approval *Approval and Plurality Vote Count*

Description

Count votes using the approval and plurality methods. Each voter can select candidates using 1 for a selection and 0 otherwise. In the approval method, any number of candidates can be selected by a voter, while in the plurality method only one candidate can be chosen by a voter. Thus, plurality voting is a special case of approval voting. The winner(s) in either method is/are the most-approved candidate(s).

Usage

```
approval(votes, mcan = 1, fsep = "\t", quiet = FALSE, ...)

## S3 method for class 'vote.approval'
summary(object, ...)

## S3 method for class 'vote.approval'
view(object, ...)

plurality(votes, mcan = 1, fsep = "\t", quiet = FALSE, ...)

## S3 method for class 'vote.plurality'
summary(object, ...)

## S3 method for class 'vote.plurality'
view(object, ...)
```

Arguments

votes	Matrix or data frame of zeros and ones containing the votes. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read. Missing values (NA) are interpreted as zeros.
mcan	Number of candidates to be elected.
fsep	If votes is a file name, this argument gives the column separator in the file.
quiet	If TRUE no output is printed.
...	Not used.
object	Object of class vote.approval or vote.plurality.

Value

Functions approval and plurality return an object of class vote.approval and vote.plurality, respectively, both of which are lists with the following objects:

elected	Vector of names of the elected candidates in the order in which they were elected.
totals	Vector of total votes in the same order as candidates (columns) in the input data.
data	Input data with invalid votes removed.
invalid.votes	Matrix of invalid votes that were removed from the original dataset.

Author(s)

Hana Sevcikova, Adrian Raftery

References

https://en.wikipedia.org/wiki/Approval_voting

https://en.wikipedia.org/wiki/Plurality_voting_method

See Also

count.votes

Examples

```
# Example using the IMS Council dataset modified for approval voting
data(ims_approval)
approval(ims_approval)

# Example using the IMS Council dataset modified for plurality voting
data(ims_plurality)
pl.ims <- plurality(ims_plurality)
invalid.votes(pl.ims)
```

condorcet *Condorcet Vote Count*

Description

Count votes using the Condorcet voting method.

Usage

```
condorcet(votes, runoff = FALSE, fsep = '\t', quiet = FALSE, ...)

## S3 method for class 'vote.condorcet'
summary(object, ...)

## S3 method for class 'vote.condorcet'
view(object, ...)

## S3 method for class 'vote.condorcet'
image(x, ...)
```

Arguments

votes	Matrix or data frame containing the votes. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read. See below for more details.
runoff	Logical. If TRUE and no condorcet winner exists, the election goes into a run-off, see below for details.
fsep	If votes is a file name, this argument gives the column separator in the file.
quiet	If TRUE no output is printed.
object, x	Object of class vote.condorcet.
...	Additional arguments passed to the underlying functions. For the image function, see arguments for image.vote.stv, especially xpref, ypref, all.pref and proportion.

Details

The Condorcet method elects the candidate that wins a majority of the ranked vote in every head-to-head election against each of the other candidates. I.e., the Condorcet winner is a candidate that beats all other candidates in pairwise comparisons. Analogously, a Condorcet loser is a candidate that loses against all other candidates. Neither Condorcet winner nor loser might exist.

If the runoff argument is set to TRUE and no Condorcet winner exists, two or more candidates with the most pairwise wins are selected and the method is applied to such subset. If more than two candidates are in such run-off, the selection is performed repeatedly, until either a winner is selected or no more selection is possible.

The input data votes is structured the same way as for the stv method: Row i contains the preferences of voter i numbered $1, 2, \ldots, r, 0, 0, 0, 0$, in some order, while equal preferences are allowed. The columns correspond to the candidates. The dimnames of the columns are the names of the candidates; if these are not supplied then the candidates are lettered A, B, C, ... If the dataset contains missing values (NA), they are replaced by zeros.

Note that if equal preferences are used, they are automatically converted into a format where for each preference i that does not have any duplicate, there must be exactly $i - 1$ preferences j with $0 < j < i$. It is the same ranking as one would obtain with rank(x,ties.method = "min"). If a conversion of a vote occurs, a warning is issued. That is done internally by calling the correct.ranking function.

The image function visualizes the joint distribution of two preferences (if all.pref=FALSE) given by xpref and ypref, as well as the marginal distribution of all preferences (if all.pref=TRUE). The joint distribution can be shown as proportions (if proportion=TRUE) or raw vote counts (if proportion=FALSE).

Value

Function condorcet returns an object of class vote.condorcet which is a list with the following objects:

elected	The Condorcet winner if exists, otherwise NULL.
loser	The Condorcet loser if exists, otherwise NULL.
totals	nc x nc matrix where nc is the number of candidates. Element ij = 1 if i won against j, otherwise 0.
runoff.winner	The run-off winner if exists and if the runoff argument was set to TRUE, otherwise NULL.
runoff.participants	List of run-off participants if the runoff argument was set to TRUE, otherwise NULL.
data	Input data (possibly corrected) with invalid votes removed.
invalid.votes	Matrix of invalid votes that were removed from the original dataset.

Author(s)

Hana Sevcikova, Salvatore Barbaro

References

Condorcet, Marquis de (1785). Essai sur l'application de l'analyse a la probabilite des decisions rendues a la probabilite des voix. Paris: De l'imprimerie royale.

https://en.wikipedia.org/wiki/Condorcet_method

Sen A. (2017). Collective Choice and Social Welfare. Harvard University Press, Cambridge, Massachusetts (Chapter A4*).

Examples

```
data(food_election)
cdc.food <- condorcet(food_election)
summary(cdc.food)
# show the marginal distribution of the preferences
par(mai=c(1, 1.2, 0.8, 0.4)) # expand the left margin
image(cdc.food, all.pref = TRUE)

# Example with a runoff
votes <- matrix(c(2, 1, 3, 4,
                  2, 1, 3, 4,
                  4, 3, 2, 1,
                  4, 3, 2, 1,
                  1, 4, 3, 2), byrow = TRUE, nrow = 5)
colnames(votes) <- LETTERS[1:4]
cdc.v <- condorcet(votes, runoff = TRUE)
```

`count.votes` *Count Votes*

Description

Count votes using one of five methods. View valid and invalid ballots.

Usage

```
count.votes(votes, method = c("auto", "plurality", "approval", "stv",
    "score", "condorcet", "tworound.runoff"), fsep = "\t", ...)

invalid.votes(object)
valid.votes(object)
```

Arguments

`votes`	Matrix or data frame containing the votes. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read.
`method`	Voting method to use. If "auto", the input data is passed through a checker for each of the methods and the one with the largest number of valid votes is used. In case of the same number of valid votes, it goes by their ordering in the function definition.
`fsep`	If `votes` is a file name, this argument gives the column separator in the file.
`...`	Additional arguments passed to the underlying functions, e.g. `mcan`, `max.score` etc.
`object`	Object returned by one of the functions `plurality`, `approval`, `stv`, `score`, `condorcet`, `tworound.runoff`.

Value

Depending which method is used, `count.votes` returns an object of class `vote.plurality`, `vote.approval`, `vote.stv`, `vote.score`, `vote.condorcet`, or `vote.tworound.runoff`.

Functions `valid.votes` and `invalid.votes` return a subset of the input data with valid records and invalid records, respectively.

Author(s)

Hana Sevcikova, Bernard Silverman

See Also

`stv`, `approval`, `score`, `condorcet`

Examples

```
# Example using the IMS Council dataset modified for score voting
data(ims_score)
# should recognize that it is a dataset with score voting data
count.votes(ims_score, max.score = 9, larger.wins = FALSE)

# All records with score larger than 8 are excluded
res <- count.votes(ims_score, method = "score", max.score = 8)
head(invalid.votes(res))

summary(res)
```

---

dublin_west *Election Dataset to Dublin West Constituency*

Description

Dataset containing ranked votes for the Dublin West constituency in 2002, Ireland. Results of that STV elections can be viewed at https://en.wikipedia.org/wiki/Dublin_West#2002_general_election. They can be reproduced via the `stv` function, see Example below.

Usage

```
data("dublin_west")
```

Format

A data frame with 29988 observations and 9 candidates. Each record corresponds to one ballot with candidates being ranked between 1 and 9 with zeros allowed.

References

https://en.wikipedia.org/wiki/Dublin_West#2002_general_election

Examples

```
data(dublin_west)
head(dublin_west)

## Not run:
# reproduce results from the Wikipedia link above
dwstv <- stv(dublin_west, mcan = 3, eps = 1)

# plot results
plot(dwstv)
image(dwstv)
image(dwstv, all.pref = TRUE)
## End(Not run)
```

---

food_election *Example Dataset*

Description

Dataset on food election which serves as a simple example for the STV method taken from Wikipedia.

Usage

```
data("food_election")
```

Format

A data frame with 20 observations and 5 candidates (Oranges, Pears, Chocolate, Strawberries, Sweets). Each record corresponds to one ballot with ranking for each of the candidates.

Source

https://en.wikipedia.org/wiki/Single_transferable_vote#Example

Examples

```
data(food_election)
head(food_election)
```

`ims_election` *Datasets on IMS Election*

Description

Datasets containing anonymized votes for a past Council election of the Institute of Mathematical Statistics (IMS). The dataset `ims_election` (named also `ims_stv`) is the original dataset used with single transferable vote, where candidate names have been changed. Each of the other datasets is a modified version of the original data to be used as an example for each of the other voting methods.

Usage

```
data("ims_election")
data("ims_stv")

data("ims_approval")
data("ims_score")
data("ims_plurality")
```

Format

A data frame with 620 observations and 10 candidates (names were made up). Each record corresponds to one ballot. Values depend on the voting method. The IMS Council voting is done using the STV method, and thus the `ims_election` dataset contains ballots with candidates being ranked between 1 and 10 with zeros allowed.

Source

The original dataset (which was randomized and anonymized, with write-in votes removed) was obtained from the the Institute of Mathematical Statistics.

References

https://imstat.org/elections/single-transferable-voting-system/

Examples

```
data(ims_election)
head(ims_election)
```

score *Score Vote Count*

Description

Count votes using the score (or range) method. Voters give each candidate a score, the scores are added and the candidate(s) with the highest (or lowest) totals is/are elected.

Usage

```
score(votes, mcan = 1, max.score = NULL, larger.wins = TRUE,
  fsep = "\t", quiet = FALSE, ...)

## S3 method for class 'vote.score'
summary(object, ...)

## S3 method for class 'vote.score'
view(object, ...)
```

Arguments

votes	Matrix or data frame containing the votes which should be numbers between 0 and max.score. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read. Missing values (NA) are interpreted as zeros.
mcan	Number of candidates to be elected.
max.score	Maximum score allowed. It is used to remove invalid votes. If not given, the maximum value contained in the data is taken and thus, all non-negative votes are valid.
larger.wins	Logical argument indicating whether the winners are the candidates with the highest scores (default) or the lowest scores.
fsep	If votes is a file name, this argument gives the column separator in the file.
quiet	If TRUE no output is printed.
...	Not used.
object	Object of class vote.score.

Value

Function score returns an object of class vote.score which is a list with the following objects:

elected	Vector of names of the elected candidates in the order in which they were elected.
totals	Vector of total votes in the same order as candidates (columns) in the input data.
larger.wins	Input argument of the same name.
data	Input data with invalid votes removed.
invalid.votes	Number of invalid votes that were removed from the original dataset.

Author(s)

Hana Sevcikova, Adrian Raftery

References

https://en.wikipedia.org/wiki/Range_voting

See Also

count.votes

Examples

```
# Example using the IMS Council dataset modified for score voting
data(ims_score)
score.ims <- score(ims_score, max.score = 9)
summary(score.ims)
```

---

stv *Single Transferable Vote*

Description

Count votes using the single transferable voting method, also known as ranked choice voting or instant runoff.

Usage

```
stv(votes, mcan = NULL, eps = 0.001, equal.ranking = FALSE,
  fsep = '\t', verbose = FALSE, seed = 1234, quiet = FALSE, ...)

## S3 method for class 'vote.stv'
summary(object, ..., digits = 3)

## S3 method for class 'vote.stv'
view(object, ...)

## S3 method for class 'vote.stv'
plot(x, xlab = "Count", ylab = "Preferences", point.size = 2, ...)

## S3 method for class 'vote.stv'
image(x, xpref = 2, ypref = 1, all.pref = FALSE, proportion = TRUE, ...)

correct.ranking(votes, quiet = FALSE)
```

Arguments

votes	Matrix or data frame containing the votes. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read. See below for more details.
mcan	Number of candidates to be elected. By default it is half the number of candidates standing.
eps	Value added to the quota. I.e. the STV quota is computed as number_of_first_preferences/(number_of_seats + 1) + eps.
equal.ranking	If TRUE equal preferences are allowed, see below.
fsep	If votes is a file name, this argument gives the column separator in the file.
verbose	Logical. If TRUE the progress of the count will be printed.
seed	Integer. Seed of the random number generator. Only used if there are ties that cannot be resolved by the tie-breaking method. If set to NULL, the RNG is not initialized.
quiet	If TRUE no output is printed.
object, x	Object of class vote.stv.
digits	How many significant digits to be used in the output table.
xlab, ylab	Labels of the x- and y-axis.
point.size	Size of the points in the plot.
xpref, ypref	Preference for the x- and y-axis, respectively, for showing the joined distribution of the votes. It is not used if all.pref is TRUE.
all.pref	Logical. If TRUE the marginal distribution of all preferences is shown in the image. Otherwise, the joint distribution of xpref and ypref is shown.
proportion	If TRUE the preferences are shown as proportions across the x-axis, otherwise raw vote counts are shown. Only available when all.pref is FALSE.
...	Additional arguments passed to the underlying functions.

Details

For a description of the single transferable vote system see https://imstat.org/elections/single-transferable-voting-system/.

The input data votes is structured as follows: Row i contains the preferences of voter i numbered $1, 2, \ldots, r, 0, 0, 0, 0$, in some order. The columns correspond to the candidates. The dimnames of the columns are the names of the candidates; if these are not supplied then the candidates are lettered A, B, C, ... If the dataset contains missing values (NA), they are replaced by zeros.

By default the preferences are not allowed to contain duplicates per vote. However, if the argument equal.ranking is set to TRUE, votes are allowed to have the same ranking for multiple candidates. The desired format is such that for each preference i that does not have any duplicate, there must be exactly $i - 1$ preferences j with $0 < j < i$. For example, valid ordered preferences are $1, 1, 3, 4, \ldots$, or $1, 2, 3, 3, 3, 6, \ldots$, but NOT $1, 1, 2, 3, \ldots$, or NOT $1, 2, 3, 3, 3, 5, 6, \ldots$. If the data contain such invalid votes, they are automatically corrected and a warning is issued by calling the correct.ranking function.

The correct.ranking function does the above correction for all records, regardless if they contain duplicates or not. It can either be used by calling it explicitely, otherwise it is called by stv if equal.ranking = TRUE. The function is also called from within the condorcet function.

Ties in the STV algorithm are resolved using the forwards tie-breaking method, see Newland and Briton (Section 5.2.5).

The plot function shows the evolution of the total score for each candidate as well as the quota. The image function visualizes the joint distribution of two preferences (if all.pref=FALSE) as well as the marginal distribution of all preferences (if all.pref=TRUE). The joint distribution can be shown either as proportions (if proportion=TRUE) or raw vote counts (if proportion=FALSE).

Value

Function stv returns an object of class vote.stv which is a list with the following objects:

elected	Vector of names of the elected candidates in the order in which they were elected.
preferences	Matrix of preferences. Columns correspond to the candidates and rows to the counts (i.e. voting rounds).
quotas	Vector of quotas, one for each count.
elect.elim	Matrix of the same shape as preferences. Value 1 means that the corresponding candidate was elected in that round; value -1 means an elimination.
equal.pref.allowed	Input argument equal.ranking.
data	Input data (possibly corrected) with invalid votes removed.
invalid.votes	Matrix of invalid votes that were removed from the original dataset.

Author(s)

Bernard Silverman, Hana Sevcikova, Adrian Raftery

References

R.A. Newland and F.S. Britton (1997). How to conduct an election by the Single Transferable Vote. ERS 3rd Edition. http://www.rosenstiel.co.uk/stvrules/index.html

https://imstat.org/elections/single-transferable-voting-system/

https://en.wikipedia.org/wiki/Single_transferable_vote

Examples

```
# Reproducing example from Wikipedia
# https://en.wikipedia.org/wiki/Single_transferable_vote#Example
# Uses eps=1
data(food_election)
stv.food <- stv(food_election, mcan = 3, eps = 1)
summary(stv.food)
## Not run:
view(stv.food)
```

```
## End(Not run)

# Example of the IMS Council voting
data(ims_election)
stv.ims <- stv(ims_election, mcan = 5)
## Not run:
view(stv.ims)
plot(stv.ims)
image(stv.ims)

# write election results into a csv file
s <- summary(stv.ims)
write.csv(s, "myfile.csv")
## End(Not run)

## Not run:
# Example of Dublin West 2002 elections
# https://en.wikipedia.org/wiki/Dublin_West#2002_general_election
data(dublin_west)
stv(dublin_west, mcan = 3, eps = 1)
## End(Not run)

# Example of a small committee dataset
# with four candidates (C) and four
# voting committee members (uses tie-breaking)
votes <- data.frame(C1=c(3,2,1,3), C2=c(2,1,2,4),
                    C3=c(4,3,3,1), C4=c(1,4,4,2))
stv(votes, mcan = 2, verbose = TRUE)

# Example with equal ranking and correction
votes <- data.frame(C1=c(3,2,1,3), C2=c(1,1,2,0),
                    C3=c(4,3,3,1), C4=c(1,4,2,2))
stv(votes, mcan = 2, equal.ranking = TRUE)
# vote #3 was corrected by stv which used this data:
correct.ranking(votes, quiet = TRUE)
```

`tworound.runoff` *Two-Round Runoff Vote Count*

Description

Count votes using the two-round voting method with ranked ballots. If no candidate reaches the majority, the top two candidates go into a run-off.

Usage

```
tworound.runoff(votes, fsep = '\t', seed = NULL, quiet = FALSE, ...)

## S3 method for class 'vote.tworound.runoff'
summary(object, ...)
```

```
## S3 method for class 'vote.tworound.runoff'
view(object, ...)

## S3 method for class 'vote.tworound.runoff'
image(x, ...)
```

Arguments

votes	Matrix or data frame containing the votes. Rows correspond to the votes, columns correspond to the candidates. If it is a character string it is interpreted as a file name from which the votes are to be read. See below for more details.
fsep	If votes is a file name, this argument gives the column separator in the file.
seed	Integer. Seed of the random number generator (RNG). Only used if there are ties either between candidates to enter the run-off, or between the two run-off contenders. If set to NULL, the RNG is not initialized.
quiet	If TRUE no output is printed.
object, x	Object of class vote.tworound.runoff.
...	Additional arguments passed to the underlying functions. For the image function, see arguments for image.vote.stv, especially xpref, ypref, all.pref and proportion.

Details

First, the number of first preferences is counted. If there is a candidate with more than 50%, that candidate gets elected. Otherwise, there is a runoff between the top two candidates.

The input data votes is structured the same way as for the stv method: Row i contains the preferences of voter i numbered $1, 2, \ldots, r, 0, 0, 0, 0$, in some order. Equal preferences are not allowed. The columns correspond to the candidates. The dimnames of the columns are the names of the candidates; if these are not supplied then the candidates are lettered A, B, C, ... If the dataset contains missing values (NA), they are replaced by zeros.

The image function visualizes the joint distribution of two preferences (if all.pref=FALSE) given by xpref and ypref, as well as the marginal distribution of all preferences (if all.pref=TRUE). The joint distribution can be shown as proportions (if proportion=TRUE) or raw vote counts (if proportion=FALSE).

Value

Function tworound.runoff returns an object of class vote.tworound.runoff which is a list with the following objects:

elected	The elected candidate.
totals	Vector of total votes in the same order as candidates (columns) in the input data.
totals2r	Vector of total votes from the run-off (second round).
coin.toss.winner	TRUE if the winner was sampled between candidates with the same score, otherwise FALSE.

`coin.toss.runoff`
: `TRUE` if the run-off contenders were sampled from candidates with the same score. Otherwise it is `FALSE`.

`data`
: Input data (possibly corrected) with invalid votes removed.

`invalid.votes`
: Matrix of invalid votes that were removed from the original dataset.

Author(s)

Hana Sevcikova, Salvatore Barbaro

References

Sen A. (2017). Collective Choice and Social Welfare. Harvard University Press, Cambridge, Massachusetts, Chapter 10*3 (p. 243ff).

https://en.wikipedia.org/wiki/Two-round_system

Examples

```
data(ims_election)
trr <- tworound.runoff(ims_election)
summary(trr)
```

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