Package ‘GameTheory’

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Description Implementation of a common set of punctual solutions for Cooperative Game Theory.

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`GameTheory-package` *Cooperative Game Theory*

Description

Implementation of a common set of punctual solutions for Cooperative Game Theory.

Details

Package:	GameTheory
Type:	Package
Version:	1.0
Date:	2015-02-04
License:	GPL (>= 2)

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Aumann, R.J. and Maschler, M., (1985) "Game Theoretic Analysis of a bankruptcy from the Talmud." *Journal of Economic Theory* **36**, pp.195–213.

O'Neill B. (1982). "A problem of rights arbitration from the Talmud." *Mathematical Social Sciences*, **2**(4), pp.345–371.

Shapley L, Shubik M (1954). "A Method for Evaluating the Distribution of Power in a Committee System." *The American Political Science Review*, **48**(3), 787–792.

Shapley L (1953). *A value for n-person games. In Tucker A, Kuhn H (Eds.), Contributions to the theory of games II (pp. 307–317). Princeton University Press: Princeton NJ.*

Schmeidler D (1969). "The Nucleolus of a characteristic function game." *SIAM Journal of Applied Mathematics*, **17**, 1163–1170.

Examples

```
### TRANSFERABLE UTILITY

## 3 PLAYER SHAPLEY VALUE

# Begin defining the game

COALITIONS <- c(46125,17437.5,5812.5,69187.5,53812.5,30750,90000)
LEMAIRE<-DefineGame(3,COALITIONS)
summary(LEMAIRE)

# End defining the game

NAMES <- c("Investor 1","Investor 2","Investor 3")
LEMAIRESHAPLEY <- ShapleyValue(LEMAIRE,NAMES)
summary(LEMAIRESHAPLEY)

# 3 PLAYER NUCLEOLUS OF A GAINS GAME

LEMAIRENUCLEOLUS<-Nucleolus(LEMAIRE)
summary(LEMAIRENUCLEOLUS)


# 4 PLAYER SHAPLEY VALUE

COALITIONS <- c(26,27,55,57,53,81,83,82,84,110,108,110,110,110,110)
AIR<-DefineGame(4,COALITIONS)

NAMES <- c("Airline 1","Airline 2","Airline 3","Airline 4")
AIRSHAPLEY<-ShapleyValue(AIR,NAMES)
summary(AIRSHAPLEY)

# 4 PLAYER NUCLEOLUS OF A COST GAME

AIRNUCLEOLUS<-Nucleolus(AIR,type="Cost")
summary(AIRNUCLEOLUS)

## SHAPLEY - SHUBIK POWER INDEX

# 2003 Elections
SEATS<-c(46,42,23,15,9)
PARTIES<-c("CiU","PSC","ERC","PP","ICV")
E2003<-ShapleyShubik(68,SEATS,PARTIES)
summary(E2003)

# 2006 Elections
SEATS<-c(48,37,21,14,12,3)
PARTIES<-c("CiU","PSC","ERC","PP","ICV","C's")
E2006<-ShapleyShubik(68,SEATS,PARTIES)
summary(E2006)
```

```
# 2012 Elections
SEATS<-c(50,20,21,19,13,9,3)
PARTIES<-c("CiU","PSC","ERC","PP","ICV","C's","CUP")
E2012<-ShapleyShubik(68,SEATS,PARTIES)
summary(E2012)

## CONFLICTING CLAIMS PROBLEM

## replication of Gallastegui et al. (2003), Table 7.

CLAIMS <- c(158,299,927,2196,4348,6256,13952)
COUNTRIES <- c("Germany","Netherlands","Belgium","Ireland","UK","Spain","France")
INARRA <- AllRules(13500,CLAIMS,COUNTRIES)
summary(INARRA)

plot(INARRA,5) ## Display allocations for UK
LorenzRules(INARRA) ## Inequality graph
```

`AdjustedProportional` *Adjusted Proportional Rule*

Description

This function calculates how to distribute a given endowment by the Adjusted Proportional rule.

Usage

```
AdjustedProportional(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Curiel, I. J., Maschler, M., & Tijs, S. H. (1987). "Bankruptcy games." *Zeitschrift fur Operations Research*, **31**(5), A143-A159.

AllRules *All conflicting claims rules simultaneously*

Description

This function runs simultaneously all conflicting claims rules available in the package. It also calculates the Gini Index to check inequality among them.

Usage

```
AllRules(E, C, Names = NULL, pct = 0, r = 2)
```

Arguments

E	Endowment
C	Claims
Names	Labels of the agents
pct	Format of the results. If pct=1, the output is given in percentage
r	Decimals of the table

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Gallastegui M, Inarra E, Prellezo R (2003). "Bankruptcy of Fishing Resources: The Northern European Anglerfish Fishery." *Marine Resource Economics*, **17**, 291–307.

Examples

```
## replication of Gallastegui et al. (2003), Table 7.

CLAIMS <- c(158,299,927,2196,4348,6256,13952)
COUNTRIES <- c("Germany","Netherlands","Belgium","Ireland","UK","Spain","France")
INARRA <- AllRules(13500,CLAIMS,COUNTRIES)
summary(INARRA)

plot(INARRA,5) ## Display allocations for UK
LorenzRules(INARRA) ## Inequality graph
```

`AlphaMin` *AlphaMin Rule*

Description

This function calculates how to distribute a given endowment by the Alphamin rule.

Usage

```
AlphaMin(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Details

For each endowment and each claim, the $\alpha - min$ rule ensures an equal division of the endowment among the claimants as far as the smallest claim is totally honoured; then, the remainig endowment is distributed proportionally among the revised claims.

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Maria Jose Solis-Baltodano <mary2014sep@gmail.com>

References

Gimenez-Gomez J.M., & Peris J.E. (2014). "A proportional approach to claims problems with a guaranteed minimun." *European Journal of Operational Research*, **232**(1), pp.109–116.

Examples

```
CLAIMS<-c(10,20,30,40)
AGENTS<-c("Paul","John","George","Ringo")
AlphaMin(67,CLAIMS,AGENTS)->ALPHA
summary(ALPHA)

# Assignment according to the Alpha-min Rule rule for an Endowment of 67

#        Claims Amin
```

```
# Paul      10 10.0
# John      20 14.5
# George    30 19.0
# Ringo     40 23.5
```

CEA *Constrained Equal Awards Rule*

Description

This function calculates how to distribute a given endowment by the CEA rule.

Usage

```
CEA(E, C, Names = NULL)
```

Arguments

E	Endowment
C	Claims of the agents
Names	Labels of the agents

Details

The **constrained equal awards (CEA)** rule (Maimonides, 12th century), proposes equal awards to all agents subject to no one receiving more than his claim.

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Aumann, R.J. and Maschler, M., (1985) "Game Theoretic Analysis of a bankruptcy from the Talmud." *Journal of Economic Theory* **36**, pp.195–213.

`CEL` *Constrained Equal Losses Rule*

Description

This function calculates how to distribute a given endowment by the CEL rule.

Usage

```
CEL(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Details

The **constrained equal losses (CEL)** rule (Maimonides, 12th century and Aumann, 1985), chooses the awards vector at which all agents incur equal losses, subject to no one receiving a negative amount

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Aumann, R.J. and Maschler, M., (1985) "Game Theoretic Analysis of a bankruptcy from the Talmud." *Journal of Economic Theory* **36**, pp.195–213.

DefineGame *Transferable Utility Game*

Description

Definition of a Transferable-Utility Game

Usage

```
DefineGame(n, V)
```

Arguments

n	Number of agents
V	Coalition values in lexicographic order

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

Examples

```
Lemaire<-DefineGame(3,c(46125,17437.5,5812.5,69187.5,53812.5,30750,90000))
summary(Lemaire)

# Characteristic form of the game
# Number of agents: 3
# Coaliton Value(s)

#        v(i)
# 1   46125.0
# 2   17437.5
# 3    5812.5
# 12  69187.5
# 13  53812.5
# 23  30750.0
# 123 90000.0
```

LorenzRules *Inequality plot among rules*

Description

Displays a graph with a Lorenz curve for each confliciting claims rule.

Usage

```
LorenzRules(x)
```

Arguments

x	Output object from `AllRules`

Examples

```
## replication of Gallastegui et al. (2003), Table 7.

CLAIMS <- c(158,299,927,2196,4348,6256,13952)
COUNTRIES <- c("Germany","Netherlands","Belgium","Ireland","UK","Spain","France")
INARRA <- AllRules(13500,CLAIMS,COUNTRIES)
summary(INARRA)

plot(INARRA,5) ## Display allocations for UK
LorenzRules(INARRA) ## Inequality graph
```

Nucleolus *Nucleolus solution*

Description

This function computes the nucleolus solution of a game with a maximum of 4 agents.

Usage

```
Nucleolus(x, type = "Gains")
```

Arguments

x	Object of class Game
type	Specify if the game refers to Gains or Cost

Details

The nucleolus looks for an individually rational distribution of the worth of the grand coalition in which the maximum dissatisfaction is minimized. The nucleolus selects the element in the core, if this is nonempty, that lexicographically minimizes the vector of non-increasing ordered excesses of coalitions. In order to compute this solution we consider a sequence of linear programs, which looks for an imputation that minimizes the maximum excess among all coalitions.

Value

The command returns a table with the following elements:

`v(S)`	Individual value of player *i*
`x(S)`	Nucleolus solution of the player *i*
`Ei`	Excess of the player *i*

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Lemaire J (1991). "Cooperative game theory and its insurance applications." Astin Bulletin, **21**(01), 17–40.

Schmeidler D (1969). "The Nucleolus of a characteristic function game." *SIAM Journal of Applied Mathematics*, **17**, pp.1163–1170.

Examples

```
## EXAMPLE FROM LEMAIRE (1991)

# Begin defining the game

COALITIONS <- c(46125,17437.5,5812.5,69187.5,53812.5,30750,90000)
LEMAIRE<-DefineGame(3,COALITIONS)

# End defining the game

LEMAIRENUCLEOLUS<-Nucleolus(LEMAIRE)
summary(LEMAIRENUCLEOLUS) # Gains Game, the excess should be negative
```

`NucleolusCapita` *Per Capita Nucleolus*

Description

This function computes the per capita nucleolus solution of a gains game with a maximum of 4 agents.

Usage

```
NucleolusCapita(x, type = "Gains")
```

Arguments

`x`	Object of class Game
`type`	Specify if the game refers to Gains or Cost

Details

The per capita nucleolus represents a measure of dissatisfaction per capita of such a coalition. It is also an individually rational distribution of the worth of the grand coalition in which the maximum per capita dissatisfaction is minimized. Formally, is defined like the nucleolus but taking into the account the per capita excess.

Value

The command returns a table with the following elements:

`v(S)`	Individual value of player *i*
`x(S)`	Nucleolus solution of the player *i*
`Ei`	Excess of the player *i*

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Lemaire J (1991). "Cooperative game theory and its insurance applications." Astin Bulletin, **21**(01), 17–40.

Schmeidler D (1969). "The Nucleolus of a characteristic function game." *SIAM Journal of Applied Mathematics*, **17**, pp.1163–1170.

Examples

```
## DATA FROM LEMAIRE (1991)

# Begin defining the game

COALITIONS <- c(46125,17437.5,5812.5,69187.5,53812.5,30750,90000)
LEMAIRE<-DefineGame(3,COALITIONS)

# End defining the game

LEMAIRENUCLEOLUS<-NucleolusCapita(LEMAIRE)
summary(LEMAIRENUCLEOLUS)
```

`plot.ClaimsRules` *Plot all conficting claims rules*

Description

Plot results of every rule for a given player.

Usage

```
## S3 method for class 'ClaimsRules'
plot(x, y, ...)
```

Arguments

`x`	Object of class ClaimsRules
`y`	Agent
`...`	Other graphical parameters

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

Examples

```
## replication of Gallastegui et al. (2003), Table 7.

CLAIMS <- c(158,299,927,2196,4348,6256,13952)
COUNTRIES <- c("Germany","Netherlands","Belgium","Ireland","UK","Spain","France")
INARRA <- AllRules(13500,CLAIMS,COUNTRIES)
summary(INARRA)

plot(INARRA,5) ## Display allocations for UK
LorenzRules(INARRA) ## Inequality graph
```

`Proportional` *Proportional Rule*

Description

This function calculates how to distribute a given endowment by the Proportional rule.

Usage

```
Proportional(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

`RandomArrival` *Random Arrival Rule*

Description

This function calculates how to distribute a given endowment by the Random Arrival rule.

Usage

```
RandomArrival(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Details

The **random arrival** rule (O'Neill, 1982) works in the following fashion: suppose that each claim is fully honored until the endowment runs out following the order of the claimants arrival. In order to remove the unfairness of the first-come first-serve scheme associated with any particular order of arrival, the rule proposes to take the average of the awards vectors calculated in this way when all orders are equally probable.

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

O'Neill B. (1982). "A problem of rights arbitration from the Talmud." *Mathematical Social Sciences*, **2**(4), pp.345–371.

`ShapleyShubik` *Shapley Shubik Power Index*

Description

This function computes Shapley - Shubik Power Index of a coalition.

Usage

```
ShapleyShubik(quota, y, Names = NULL)
```

Arguments

`quota`	Minimum amount of votes to pass a vote
`y`	Seats of every party
`Names`	Labels of the parties

Details

The *Shapley and Shubik index* works as follows. There is a group of individuals all willing to vote on a proposal. They vote in order and as soon as a majority has voted for the proposal, it is declared passed and the member who voted last is given credit for having passed it. Let us consider that the members are voting randomly. Then we compute the frequency with which an individual is the one that gets the credit for passing the proposal. That measures the number of times that the action of that individual joining the coalition of their predecessors makes it a winning coalition. Note that if this index reaches the value of 0, then it means that this player is a dummy. When the index reaches the value of 1, the player is a dictator.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Shapley L, Shubik M (1954). "A Method for Evaluating the Distribution of Power in a Committee System." *The American Political Science Review*, **48**(3), 787–792.

Examples

```
## SHAPLEY - SHUBIK POWER INDEX APPLIED TO THE CATALAN PARLIAMENT

# 2012 Elections
SEATS<-c(50,20,21,19,13,9,3)
PARTIES<-c("CiU","PSC","ERC","PP","ICV","C's","CUP")
E2012<-ShapleyShubik(68,SEATS,PARTIES)
summary(E2012)

# Results for 2012 elections

#                    CiU    PSC    ERC     PP     ICV    C's    CUP
# Votes           50.000 20.000 21.000 19.000 13.0000 9.0000 3.0000
# Votes (R)        0.370  0.148  0.156  0.141  0.0963 0.0667 0.0222
# Shapley-Shubik   0.533  0.133  0.133  0.133  0.0333 0.0333 0.0000
```

ShapleyValue *Shapley Value Solution*

Description

Calculates the Shapley value for a N-agent cooperative game.

Usage

```
ShapleyValue(x, Names = NULL)
```

Arguments

`x`	object of class Game
`Names`	Labels of the agents

Details

Please check `ShapleyShubik` for an extension to voting power index.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Shapley L (1953). *A value for n-person games. In Tucker A, Kuhn H (Eds.), Contributions to the theory of games II (pp. 307-317). Princeton University Press: Princeton NJ.*

Examples

```
# Begin defining the game

COALITIONS <- c(46125,17437.5,5812.5,69187.5,53812.5,30750,90000)
LEMAIRE<-DefineGame(3,COALITIONS)

# End defining the game

NAMES <- c("Investor 1","Investor 2","Investor 3")
LEMAIRESHAPLEY <- ShapleyValue(LEMAIRE,NAMES)
summary(LEMAIRESHAPLEY)
```

`summary.ClaimsRule` *Summary Method for ClaimsRule Objects*

Description

`summary` method for class `"ClaimsRule"`.

Usage

```
## S3 method for class 'ClaimsRule'
summary(object, ...)
```

Arguments

`object`	an object of class `"ClaimsRule"`
`...`	Other parameters passed down to `print()` and `summary()`

`summary.ClaimsRules` *Summary methods for a ClaimsRules Object*

Description

Summary methods for a ClaimsRules Object

Usage

```
## S3 method for class 'ClaimsRules'
summary(object, ...)
```

Arguments

`object`	A `ClaimsRules` object
`...`	Other parameters passed down to `print()` and `summary()`

`summary.Game` *Summary methods for a Game Object*

Description

Summary methods for a Game Object

Usage

```
## S3 method for class 'Game'
summary(object, ...)
```

Arguments

`object`	A `Game` object
`...`	Other parameters passed down to `print()` and `summary()`

`summary.Nucleolus` *Summary methods for a Nucleolus Object*

Description

Summary methods for a Nucleolus Object

Usage

```
## S3 method for class 'Nucleolus'
summary(object, ...)
```

Arguments

`object`	A `Nucleolus` object
`...`	Other parameters passed down to `print()` and `summary()`

`summary.ShapleyShubik` *Summary methods for a ShapleyShubik Object*

Description

Summary methods for a ShapleyShubik Object

Usage

```
## S3 method for class 'ShapleyShubik'
summary(object, ...)
```

Arguments

`object`	A `ShapleyShubik` object
`...`	Other parameters passed down to `print()` and `summary()`

`summary.ShapleyValue` *Summary methods for a ShapleyValue Object*

Description

Prints the summary of the Shapley values solution for a given game.

Usage

```
## S3 method for class 'ShapleyValue'
summary(object, ...)
```

Arguments

`object`	A `ShapleyValue` object
`...`	Other parameters passed down to `print()` and `summary()`

`Talmud` *Talmud Rule*

Description

This function calculates how to distribute a given endowment by the Talmud rule.

Usage

```
Talmud(E, C, Names = NULL)
```

Arguments

`E`	Endowment
`C`	Claims of the agents
`Names`	Labels of the agents

Details

The **Talmud** rule (Aumann 1985) proposes to apply the constrained equal awards rule, if the endowment is not enough to satisfy the half-sum of the claims. Otherwise, each agent receives the half of her claim and the constrained equal losses rule is applied to distribute the remaining endowment.

Note

In order to calculate the rule properly, input the claims of the agents in ascending order.

Author(s)

Sebastian Cano-Berlanga <cano.berlanga@gmail.com>

References

Aumann, R.J. and Maschler, M., (1985) Game Theoretic Analysis of a bankruptcy from the Talmud. *Journal of Economic Theory* **36**, pp.195–213.

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