Package 'PCAN'

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Title Phenotype Consensus ANalysis (PCAN)

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Description Phenotypes comparison based on a pathway consensus approach. Assess the relationship between candidate genes and a set of phenotypes based on additional genes related to the candidate (e.g. Pathways or network neighbors).

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`calcHpSim` *Compare HP terms based on semantic similarity*

Description

This function compares 2 HP terms based on provided Information Content and ancestors

Usage

```
calcHpSim(term1, term2, method = c("Resnik"), IC, ancestors)
```

Arguments

`term1`	one of the HP term to compare
`term2`	the other HP term to compare
`method`	the method for computing semantic simalirity (default: "Resnik" returns the IC of the MICA: Most Informative common ancestor)
`IC`	a named vector of Information Content by HP term
`ancestors`	a named list of ancestors by HP term

Value

A numeric value

Author(s)

Patrice Godard

See Also

compareHPSets

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

## Compute similarity between different couples of HP terms
data(hp_ancestors, hpDef, package="PCAN")
hp1 <- "HP:0000518"
hp2 <- "HP:0030084"
hp3 <- "HP:0002119"
hp4 <- "HP:0001305"
hpDef[which(hpDef$id %in% c(hp1, hp2)), 1:2]
calcHpSim(hp1, hp2, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp3)), 1:2]
calcHpSim(hp2, hp3, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp4)), 1:2]
calcHpSim(hp2, hp4, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp3, hp4)), 1:2]
calcHpSim(hp3, hp4, IC=ic, ancestors=hp_ancestors)
```

---

compareHPSets *Compare 2 sets of HP terms based on semantic similarity*

Description

This function compares each couple of HP terms from each of the 2 provided sets based on Information Content (IC)

Usage

```
compareHPSets(hpSet1, hpSet2, IC, ancestors, method = "Resnik",
  BPPARAM = bpparam())
```

Arguments

hpSet1	a set of HP terms
hpSet2	another set of HP terms
IC	a named vector of Information Content by HP term
ancestors	a named list of ancestors by HP term

method	the method for computing semantic simalirity among those available in calcHpSim (default: "Resnik" returns the IC of the MICA: Most Informative common ancestor)
BPPARAM	An optional BiocParallelParam instance defining the parallel back-end to be used during evaluation (used internally by the bpmapply function).

Value

A matrix of semantic similarity

Author(s)

Patrice Godard

See Also

calcHpSim

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
## Assessing the significance of this score by comparing to all other genes
```

```
hpGeneResnik <- compareHPSets(
    hpSet1=names(ic), hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
hpMatByGene <- lapply(
    hpByGene,
    function(x){
        hpGeneResnik[x, , drop=FALSE]
    }
)
resnSss <- unlist(lapply(
    hpMatByGene,
    hpSetCompSummary,
    method="bma", direction="symSim"
))
candScore <- resnSss[entrez]
hist(
    resnSss,
    breaks=100, col="grey",
    ylim=c(0,300),
    xlab=expression(Sim[sym]),
    ylab="Number of genes",
    main=paste(
        "Distribution of symmetric semantic similarity scores\nfor all the",
        length(resnSss), "genes"
    )
)
polygon(
    x=c(candScore, 10, 10, candScore),
    y=c(-10, -10, 1000, 1000),
    border="#BE0000",
    col="#BE000080",
    lwd=3
)
withHigher <- sum(resnSss >= candScore)
text(
    x=candScore, y=mean(par()$usr[3:4]),
    paste0(
        withHigher, " genes (",
        signif(withHigher*100/length(resnSss), 2), "%)\n",
        "show a symmetric semantic\n",
        "similarity score greater than\n",
        "the gene candidate for\n",
        "for the HPs under focus."
    ),
    pos=4,
    cex=0.6
)
```

computeHpIC *Compute Information Content (IC) for each HP based on genes by HP*

Description

Compute Information Content (IC) for each HP based on genes by HP

Usage

```
computeHpIC(content, hp.descendants)
```

Arguments

content	a list providing the content associated to each HP
hp.descendants	a list providing for each HP all its descendant HP terms

Details

This function assumes that all the HP terms taken into account belong to the same family of terms(i.e they are all descendants of the same term).

Value

a vector of IC named with HP terms

Examples

```
##########################################
## Compute information content of each HP according to associated genes
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)
hist(
    ic,
    breaks=100, col="grey",
    main="Distribution of Information Content",
    xlab="IC base on genes associated to HP"
)
```

geneByHp *Entrez gene IDs associated to HP terms (Example data)*

Description

Each entrez gene IDs is associated to one or several HP terms

Format

A data frame with 67989 rows and 2 columns:

entrez entrez gene IDs

hp HP terms

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

Two ressources were used in May 27 2015:

- ftp://ftp.ncbi.nlm.nih.gov/pub/clinvar/xml/ClinVarFullRelease_2015-05.xml.gz was used to find genes associated to each OMIM disease with a "Pathogenic" clinical status and one of the follwing origins: "germline", "de novo", "inherited", "maternal", "paternal", "biparental", "uniparental".
- http://compbio.charite.de/hudson/job/hpo.annotations/1039/artifact/misc/phenotype_annotation.tab was used to find HP associated to each OMIM disease.

Examples

```
##########################################
## Compute information content of each HP according to associated genes
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)
hist(
    ic,
    breaks=100, col="grey",
    main="Distribution of Information Content",
    xlab="IC base on genes associated to HP"
)
```

geneByTrait *Gene associated to trait (Example data)*

Description

Each trait is associated to one or several genes. Only genes associated to OMIM disease with a "Pathogenic" clinical status and one of the follwing origins: "germline", "de novo", "inherited", "maternal", "paternal", "biparental", "uniparental".

Format

A data frame with 4569 rows and 3 columns:

entrez Entrez gene IDs.

db Trait database: always "OMIM" here.

id Trait ID: OMI IDs here

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

ftp://ftp.ncbi.nlm.nih.gov/pub/clinvar/xml/ClinVarFullRelease_2015-05.xml.gz

Examples

```
data(geneByTrait, traitDef, geneDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
# Gene associated to this disease
entrez <- geneByTrait[which(geneByTrait$id==omim), "entrez"]
geneDef[which(geneDef$entrez %in% entrez),]
# All diseases associated to this gene
traitDef[
     which(
         traitDef$id %in%
         geneByTrait[which(geneByTrait$entrez==entrez), "id"]
     ),
]
```

geneDef *Description of genes (Example data)*

Description

Basic information about genes Only genes associated to at least one OMIM disease are taken into account.

Format

A data frame with 3265 rows and 3 columns:

entrez Entrez gene ID.

name Gene name.

symbol Gene symbol.

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

ftp://ftp.ncbi.nlm.nih.gov/pub/clinvar/xml/ClinVarFullRelease_2015-05.xml.gz

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

##########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
```

```
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
```

---

hpByTrait *HP IDs associated to trait (Example data)*

Description

Each trait is associated to one or several HP terms.

Format

A data frame with 55311 rows and 3 columns:

hp HP terms.

db Trait database: always "OMIM" here.

id Trait ID: OMI IDs here

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

http://compbio.charite.de/hudson/job/hpo.annotations/1039/artifact/misc/phenotype_annotation.tab

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
```

```
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
```

---

hpDef *Description of HP terms (Example data)*

Description

HP terms basic information. Only descendants of 'Phenotypic abnormality' were taken into account.

Format

A data frame with 10962 rows and 2 columns:

id HP term IDs

name HP term names

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

http://compbio.charite.de/hudson/job/hpo/1529/artifact/hp/hp.obo

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

## Compute similarity between different couples of HP terms
data(hp_ancestors, hpDef, package="PCAN")
hp1 <- "HP:0000518"
hp2 <- "HP:0030084"
hp3 <- "HP:0002119"
hp4 <- "HP:0001305"
hpDef[which(hpDef$id %in% c(hp1, hp2)), 1:2]
calcHpSim(hp1, hp2, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp3)), 1:2]
calcHpSim(hp2, hp3, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp4)), 1:2]
calcHpSim(hp2, hp4, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp3, hp4)), 1:2]
calcHpSim(hp3, hp4, IC=ic, ancestors=hp_ancestors)
```

---

hpGeneHeatmap *HP to Gene heatmap*

Description

This function draw a heatmap corresponding to the result of the pathway consensus method. For each gene of the pathway under focus and each HP of interest it shows the best score.

Usage

```
hpGeneHeatmap(hpGeneListRes, genesOfInterest = NULL, geneLabels = NULL,
  hpLabels = NULL, clustByGene = TRUE, clustByHp = TRUE,
  palFun = colorRampPalette(c("white", "red")), goiCol = "blue", ...)
```

Arguments

hpGeneListRes	the result of the hpGeneListComp function.
genesOfInterest	a list of gene to highlight.
geneLabels	a named vector of gene labels (all the genes id found in hpGeneListRes should be in names(geneLabels)).
hpLabels	a named vector of HP labels (all the HP id found in hpGeneListRes should be in names(hpLabels)).
clustByGene	should the heatmap be clustered according to genes (default: TRUE).
clustByHp	should the heatmap be clustered according to HP (default: TRUE).

palFun	the palette function for the heatmap.
goiCol	the color used to highlight genes of interest.
...	parameters for the codeheatmap function

Value

A list of 2 matrix (invisible return):

bmValues For each gene and each HP of interest the best match value.

bestMatches The gene associated HP best matching the HP of interest.

See Also

hpGeneListComp, hpSetCompBestMatch

Examples

```
data(geneByHp, hp_descendants, package="PCAN")
data(hp_ancestors, hpDef, package="PCAN")
data(traitDef, geneDef, package="PCAN")
data(hpByTrait, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)

########################################
## Compute information content of each HP according to associated genes
ic <- computeHpIC(geneByHp, hp_descendants)

########################################
## Use case: comparing a gene and a disease
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]
## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## HP Comparison
hpGeneResnik <- compareHPSets(
    hpSet1=names(ic), hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
hpMatByGene <- lapply(
    hpByGene,
    function(x){
        hpGeneResnik[x, , drop=FALSE]
    }
```

```
)
resnSss <- unlist(lapply(
    hpMatByGene,
    hpSetCompSummary,
    method="bma", direction="symSim"
))
candScore <- resnSss[entrez]

########################################
## The pathway consensus approach
## What about genes belonging to the same pathways as the candidate
data(rPath, hsEntrezByRPath, package="PCAN")
candPath <- names(hsEntrezByRPath)[which(unlist(lapply(
    hsEntrezByRPath,
    function(x) entrez %in% x
)))]
rPath[which(rPath$Pathway %in% candPath),]
rPathRes <- hpGeneListComp(
    geneList=hsEntrezByRPath[[candPath]],
    ssMatByGene = hpMatByGene,
    geneSSScore = resnSss
)
hist(
    resnSss,
    breaks=100, col="grey",
    ylim=c(0,5),
    xlab=expression(Sim[sym]),
    ylab="Density",
    main=paste(
        "Distribution of symmetric semantic similarity scores for all the",
        length(resnSss), "genes"
    ),
    probability=TRUE
)
toAdd <- hist(
    rPathRes$scores,
    breaks=100,
    plot=FALSE
)
for(i in 1:length(toAdd$density)){
    polygon(
        x=toAdd$breaks[c(i, i+1, i+1, i)],
        y=c(0, 0, rep(toAdd$density[i], 2)),
        col="#BE000040",
        border="#800000FF"
    )
}
legend(
    "topright",
    paste0(
        "Genes belonging to the ", candPath," pathway:\n'",
        rPath[which(rPath$Pathway %in% candPath),"Pathway_name"],
        "'\nand with a symmetric semantic similarity score (",
```

```
        sum(!is.na(rPathRes$scores)),
        "/",
        length(rPathRes$scores),
        ")\n",
        "p-value: ", signif(rPathRes$p.value, 2)
    ),
    pch=15,
    col="#BE000040",
    bty="n",
    cex=0.6
)
## Assessing the symmetric semantic similarity for each gene in the pathway
pathSss <- rPathRes$scores[which(!is.na(rPathRes$scores))]
names(pathSss) <- geneDef[match(names(pathSss), geneDef$entrez), "symbol"]
opar <- par(mar=c(7.1, 4.1, 4.1, 2.1))
barplot(
    sort(pathSss),
    las=2,
    ylab=expression(Sim[sym]),
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)
p <- c(0.25, 0.5, 0.75, 0.95)
abline(
    h=quantile(resnSss, probs=p),
    col="#BE0000",
    lty=c(2, 1, 2, 2),
    lwd=c(2, 2, 2, 1)
)
text(
    rep(0,4),
    quantile(resnSss, probs=p),
    p,
    pos=3,
    offset=0,
    col="#BE0000",
    cex=0.6
)
legend(
    "topleft",
    paste0(
        "Quantiles of the distribution of symmetric semantic similarity\n",
        "scores for all the genes."
    ),
    lty=1,
    col="#BE0000",
    cex=0.6
)
par(opar)

## A heatmap showing the best HP match for each gene in the pathway
geneLabels <- geneDef$symbol[which(!duplicated(geneDef$entrez))]
names(geneLabels) <- geneDef$entrez[which(!duplicated(geneDef$entrez))]
hpLabels <- hpDef$name
```

```
names(hpLabels) <- hpDef$id
hpGeneHeatmap(
    rPathRes,
    genesOfInterest=entrez,
    geneLabels=geneLabels,
    hpLabels=hpLabels,
    clustByGene=TRUE,
    clustByHp=TRUE,
    palFun=colorRampPalette(c("white", "red")),
    goiCol="blue",
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)

########################################
## What about genes interacting with the candidate (including itself)
data(hqStrNw, package="PCAN")
neighbors <- unique(c(
    hqStrNw$gene1[which(hqStrNw$gene2==entrez)],
    hqStrNw$gene2[which(hqStrNw$gene1==entrez)],
    entrez
))
neighRes <- hpGeneListComp(
    geneList=neighbors,
    ssMatByGene = hpMatByGene,
    geneSSScore = resnSss
)
hist(
    resnSss,
    breaks=100, col="grey",
    ylim=c(0,10),
    xlab=expression(Sim[sym]),
    ylab="Density",
    main=paste(
        "Distribution of symmetric semantic similarity scores for all the",
        length(resnSss), "genes"
    ),
    probability=TRUE
)
toAdd <- hist(
    neighRes$scores,
    breaks=100,
    plot=FALSE
)
for(i in 1:length(toAdd$density)){
    polygon(
        x=toAdd$breaks[c(i, i+1, i+1, i)],
        y=c(0, 0, rep(toAdd$density[i], 2)),
        col="#BE000040",
        border="#800000FF"
    )
}
legend(
    "topright",
```

```
    paste0(
        "Genes interacting with ",
        geneDef[which(geneDef$entrez==entrez),"symbol"],
        " (", entrez, ")",
        "\nand with a symmetric semantic similarity score (",
        sum(!is.na(neighRes$scores)),
        "/",
        length(neighRes$scores),
        ")\n",
        "p-value: ", signif(neighRes$p.value, 2)
    ),
    pch=15,
    col="#BE000040",
    bty="n",
    cex=0.6
)

## Assessing the symmetric semantic similarity score for each interacting gene
neighSss <- neighRes$scores[which(!is.na(neighRes$scores))]
names(neighSss) <- geneDef[match(names(neighSss), geneDef$entrez), "symbol"]
opar <- par(mar=c(7.1, 4.1, 4.1, 2.1))
barplot(
    sort(neighSss),
    las=2,
    ylab=expression(Sim[sym]),
    main=paste0(
        "Genes interacting with ",
        geneDef[which(geneDef$entrez==entrez),"symbol"],
        " (", entrez, ")"
    )
)
p <- c(0.25, 0.5, 0.75, 0.95)
abline(
    h=quantile(resnSss, probs=p),
    col="#BE0000",
    lty=c(2, 1, 2, 2),
    lwd=c(2, 2, 2, 1)
)
text(
    rep(0,4),
    quantile(resnSss, probs=p),
    p,
    pos=3,
    offset=0,
    col="#BE0000",
    cex=0.6
)
legend(
    "topleft",
    paste0(
        "Quantiles of the distribution of symmetric semantic similarity\n",
        "scores for all the genes."
    ),
```

```
    lty=1,
    col="#BE0000",
    cex=0.6
)
par(opar)

## A heatmap showing the best HP match for each neighbor gene
hpGeneHeatmap(
    neighRes,
    genesOfInterest=entrez,
    geneLabels=geneLabels,
    hpLabels=hpLabels,
    clustByGene=TRUE,
    clustByHp=TRUE,
    palFun=colorRampPalette(c("white", "red")),
    goiCol="blue",
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)
```

---

hpGeneListComp *HP semantic similarity for a whole gene list.*

Description

This function compare a whole gene list to a set of HP terms using a matrix of semantic similarity.

Usage

```
hpGeneListComp(geneList, ssMatByGene, geneSSScore = NULL, ...)
```

Arguments

geneList	a vector providing the genes of interest.
ssMatByGene	a list (one element per gene) of matrix of semantic similarity between HP terms as returned by compareHPSets. This list has to be unbiased in order to compute p-values.
geneSSScore	a vector of semantic similarity scores for all the genes in ssMatByGene list. If not provided these scores are computed from ssMatByGene.
...	parameters for hpSetCompSummary if geneSSScore is not provided.

Value

A list with the following elements:

hpoi The original HP of interest.

allScoreDist The distribution of scores for all genes for the HP of interest.

scores The semantic similarity by gene.

best.matches For each gene which related HP terms best fits with the HP of interest (colnames of the elements of ssMatByGene).

median The median of scores.

p.value According to a `wilcox.test` comparing genes of interest to all the other genes.

best.gene Gene with the highest score among the genes of interest.

max Maximum score.

score.quantiles Quantile of the scores compared to the whole list of gene.

adj.quant Adjusted quantiles according Benjamini Hochberg (`link{p.adjust}`).

Author(s)

Patrice Godard

See Also

`hpGeneHeatmap`, `compareHPSets`, `hpSetCompSummary` and `hpSetCompBestMatch`

Examples

```
data(geneByHp, hp_descendants, package="PCAN")
data(hp_ancestors, hpDef, package="PCAN")
data(traitDef, geneDef, package="PCAN")
data(hpByTrait, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)

##########################################
## Compute information content of each HP according to associated genes
ic <- computeHpIC(geneByHp, hp_descendants)

##########################################
## Use case: comparing a gene and a disease
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]
## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## HP Comparison
hpGeneResnik <- compareHPSets(
    hpSet1=names(ic), hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
hpMatByGene <- lapply(
    hpByGene,
```

```
    function(x){
        hpGeneResnik[x, , drop=FALSE]
    }
)
resnSss <- unlist(lapply(
    hpMatByGene,
    hpSetCompSummary,
    method="bma", direction="symSim"
))
candScore <- resnSss[entrez]

########################################
## The pathway consensus approach
## What about genes belonging to the same pathways as the candidate
data(rPath, hsEntrezByRPath, package="PCAN")
candPath <- names(hsEntrezByRPath)[which(unlist(lapply(
    hsEntrezByRPath,
    function(x) entrez %in% x
)))]
rPath[which(rPath$Pathway %in% candPath),]
rPathRes <- hpGeneListComp(
    geneList=hsEntrezByRPath[[candPath]],
    ssMatByGene = hpMatByGene,
    geneSSScore = resnSss
)
hist(
    resnSss,
    breaks=100, col="grey",
    ylim=c(0,5),
    xlab=expression(Sim[sym]),
    ylab="Density",
    main=paste(
        "Distribution of symmetric semantic similarity scores for all the",
        length(resnSss), "genes"
    ),
    probability=TRUE
)
toAdd <- hist(
    rPathRes$scores,
    breaks=100,
    plot=FALSE
)
for(i in 1:length(toAdd$density)){
    polygon(
        x=toAdd$breaks[c(i, i+1, i+1, i)],
        y=c(0, 0, rep(toAdd$density[i], 2)),
        col="#BE000040",
        border="#800000FF"
    )
}
legend(
    "topright",
    paste0(
```

```
        "Genes belonging to the ", candPath," pathway:\n'",
        rPath[which(rPath$Pathway %in% candPath),"Pathway_name"],
        "'\nand with a symmetric semantic similarity score (",
        sum(!is.na(rPathRes$scores)),
        "/",
        length(rPathRes$scores),
        ")\n",
        "p-value: ", signif(rPathRes$p.value, 2)
    ),
    pch=15,
    col="#BE000040",
    bty="n",
    cex=0.6
)
## Assessing the symmetric semantic similarity for each gene in the pathway
pathSss <- rPathRes$scores[which(!is.na(rPathRes$scores))]
names(pathSss) <- geneDef[match(names(pathSss), geneDef$entrez), "symbol"]
opar <- par(mar=c(7.1, 4.1, 4.1, 2.1))
barplot(
    sort(pathSss),
    las=2,
    ylab=expression(Sim[sym]),
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)
p <- c(0.25, 0.5, 0.75, 0.95)
abline(
    h=quantile(resnSss, probs=p),
    col="#BE0000",
    lty=c(2, 1, 2, 2),
    lwd=c(2, 2, 2, 1)
)
text(
    rep(0,4),
    quantile(resnSss, probs=p),
    p,
    pos=3,
    offset=0,
    col="#BE0000",
    cex=0.6
)
legend(
    "topleft",
    paste0(
        "Quantiles of the distribution of symmetric semantic similarity\n",
        "scores for all the genes."
    ),
    lty=1,
    col="#BE0000",
    cex=0.6
)
par(opar)

## A heatmap showing the best HP match for each gene in the pathway
```

```
geneLabels <- geneDef$symbol[which(!duplicated(geneDef$entrez))]
names(geneLabels) <- geneDef$entrez[which(!duplicated(geneDef$entrez))]
hpLabels <- hpDef$name
names(hpLabels) <- hpDef$id
hpGeneHeatmap(
    rPathRes,
    genesOfInterest=entrez,
    geneLabels=geneLabels,
    hpLabels=hpLabels,
    clustByGene=TRUE,
    clustByHp=TRUE,
    palFun=colorRampPalette(c("white", "red")),
    goiCol="blue",
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)

########################################
## What about genes interacting with the candidate (including itself)
data(hqStrNw, package="PCAN")
neighbors <- unique(c(
    hqStrNw$gene1[which(hqStrNw$gene2==entrez)],
    hqStrNw$gene2[which(hqStrNw$gene1==entrez)],
    entrez
))
neighRes <- hpGeneListComp(
    geneList=neighbors,
    ssMatByGene = hpMatByGene,
    geneSSScore = resnSss
)
hist(
    resnSss,
    breaks=100, col="grey",
    ylim=c(0,10),
    xlab=expression(Sim[sym]),
    ylab="Density",
    main=paste(
        "Distribution of symmetric semantic similarity scores for all the",
        length(resnSss), "genes"
    ),
    probability=TRUE
)
toAdd <- hist(
    neighRes$scores,
    breaks=100,
    plot=FALSE
)
for(i in 1:length(toAdd$density)){
    polygon(
        x=toAdd$breaks[c(i, i+1, i+1, i)],
        y=c(0, 0, rep(toAdd$density[i], 2)),
        col="#BE000040",
        border="#800000FF"
    )
```

```
}
legend(
    "topright",
    paste0(
        "Genes interacting with ",
        geneDef[which(geneDef$entrez==entrez),"symbol"],
        " (", entrez, ")",
        "\nand with a symmetric semantic similarity score (",
        sum(!is.na(neighRes$scores)),
        "/",
        length(neighRes$scores),
        ")\n",
        "p-value: ", signif(neighRes$p.value, 2)
    ),
    pch=15,
    col="#BE000040",
    bty="n",
    cex=0.6
)

## Assessing the symmetric semantic similarity score for each interacting gene
neighSss <- neighRes$scores[which(!is.na(neighRes$scores))]
names(neighSss) <- geneDef[match(names(neighSss), geneDef$entrez), "symbol"]
opar <- par(mar=c(7.1, 4.1, 4.1, 2.1))
barplot(
    sort(neighSss),
    las=2,
    ylab=expression(Sim[sym]),
    main=paste0(
        "Genes interacting with ",
        geneDef[which(geneDef$entrez==entrez),"symbol"],
        " (", entrez, ")"
    )
)
p <- c(0.25, 0.5, 0.75, 0.95)
abline(
    h=quantile(resnSss, probs=p),
    col="#BE0000",
    lty=c(2, 1, 2, 2),
    lwd=c(2, 2, 2, 1)
)
text(
    rep(0,4),
    quantile(resnSss, probs=p),
    p,
    pos=3,
    offset=0,
    col="#BE0000",
    cex=0.6
)
legend(
    "topleft",
    paste0(
```

```
        "Quantiles of the distribution of symmetric semantic similarity\n",
        "scores for all the genes."
    ),
    lty=1,
    col="#BE0000",
    cex=0.6
)
par(opar)

## A heatmap showing the best HP match for each neighbor gene
hpGeneHeatmap(
    neighRes,
    genesOfInterest=entrez,
    geneLabels=geneLabels,
    hpLabels=hpLabels,
    clustByGene=TRUE,
    clustByHp=TRUE,
    palFun=colorRampPalette(c("white", "red")),
    goiCol="blue",
    main=rPath[which(rPath$Pathway %in% candPath),"Pathway_name"]
)
```

`hpSetCompBestMatch` *Best matches between two sets of HP terms*

Description

This function returns the best matches from a semantic similarity matrix.

Usage

```
hpSetCompBestMatch(hpSetComp, direction = c("b", "r", "c"))
```

Arguments

`hpSetComp`	a matrix of semantic similarities between couples of HP terms
`direction`	taken into account. "r": best match per row. "c": best match per column. "b" (symetric): best match for the whole matrix

Value

A data frame with the compared term, the best match and the value of the match.

Author(s)

Patrice Godard

See Also

`compareHPSets` and `hpSetCompSummary`

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

##########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
```

`hpSetCompSummary` *Global semantic similarity between 2 HP sets*

Description

This function summarize the comparison of 2 sets of HP terms

Usage

```
hpSetCompSummary(hpSetComp, method = c("bma", "bm", "average"),
  direction = c("symSim", "r", "c"))
```

Arguments

`hpSetComp`	a matrix of semantic similarities between couples of HP terms

method	"bma" (Best Match Average): the average of the best matches on rows or columns (see direction param). "bm": the maximum value. "average": the average of the whole matrix.
direction	taken into account only if method="bma". "r": best match per row. "c": best match per column. "symSim" (symmetric semantic similarity): average of calls with "r" and "c"

Value

A numeric value corresponding to the semantic similarity of the 2 HP sets

Author(s)

Patrice Godard

See Also

compareHPSets

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

##########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
```

hp_ancestors *HP ancestors (Example data)*

Description

HP terms which are ancestors of each HP term (including itself) in the Human Phenotype Ontology (http://www.human-phenotype-ontology.org/). Only descendants of 'Phenotypic abnormality' were taken into account.

Format

A named list of 10962 character vectors.

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

http://compbio.charite.de/hudson/job/hpo/1529/artifact/hp/hp.obo

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

## Compute similarity between different couples of HP terms
data(hp_ancestors, hpDef, package="PCAN")
hp1 <- "HP:0000518"
hp2 <- "HP:0030084"
hp3 <- "HP:0002119"
hp4 <- "HP:0001305"
hpDef[which(hpDef$id %in% c(hp1, hp2)), 1:2]
calcHpSim(hp1, hp2, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp3)), 1:2]
calcHpSim(hp2, hp3, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp2, hp4)), 1:2]
calcHpSim(hp2, hp4, IC=ic, ancestors=hp_ancestors)
hpDef[which(hpDef$id %in% c(hp3, hp4)), 1:2]
calcHpSim(hp3, hp4, IC=ic, ancestors=hp_ancestors)
```

hp_class *HP class (Example data)*

Description

Each HP term can be of one or several classes. Classes are HP terms direct descendants of the 'Phenotypic abnormality' term.

Format

A named list of 10962 character vectors.

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

http://compbio.charite.de/hudson/job/hpo/1529/artifact/hp/hp.obo

Examples

```
data(hpDef, hp_class, package="PCAN")
hp <- "HP:0100089"
hpDef[which(hpDef$id==hp),]
# This term has 2 classes:
hpDef[which(hpDef$id %in% hp_class[[hp]]),]
```

hp_descendants *HP descendants (Example data)*

Description

HP terms which are descendants of each HP term (including itself) in the Human Phenotype Ontology (http://www.human-phenotype-ontology.org/). Only descendants of 'Phenotypic abnormality' were taken into account.

Format

A named list of 10962 character vectors.

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

http://compbio.charite.de/hudson/job/hpo/1529/artifact/hp/hp.obo

Examples

```
##########################################
## Compute information content of each HP according to associated genes
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)
hist(
    ic,
    breaks=100, col="grey",
    main="Distribution of Information Content",
    xlab="IC base on genes associated to HP"
)
```

---

hqStrNw *STRIND database network of Homo sapiens genes (Example data)*

Description

A network of human entrez gene IDs taken from the STRING database.

Format

A data frame of 643683 and 3 columns:

gene1 Entrez gene IDs.

gene2 Entrez gene IDs.

upstream TRUE if the directionality of the interaction between the 2 genes is known. In this case gene1 is upstream gene 2.

Source

Different ressources were used in June 2 2015:

- http://string-db.org/newstring_download/protein.actions.v10/9606.protein.actions.v10.txt.gz was used to get the network of Ensembl protein IDs. Only interaction with a score greater or equal to 500 were kept.
- BioMart from http://jan2013.archive.ensembl.org/index.html was used to map Ensembl protein IDs to Ensembl gene IDs. Ensembl gene IDs were mapped to Entrez gene IDs using this ressource in addition to ftp://ftp.ncbi.nih.gov/gene/DATA/gene2ensembl.gz

Examples

```
## Not run: example(hpGeneListComp)
```

hsEntrezByRPath *Homo sapiens entrez gene ID by Reactome pathway (Example data)*

Description

The human genes coding for proteins involved in the different Reactome pathways.

Format

A named list of 1345 character vectors.

Source

Two ressources were used in June 2 2015:

- http://www.reactome.org/download/current/UniProt2Reactome.txt was used to get list of Uniprot ID associated to each pathway.
- ftp://ftp.uniprot.org/pub/databases/uniprot/current_release/knowledgebase/idmapping/by_organism/HUMAN_9606_idmapping.dat.gz was used to map Uniprot ID to Entrez gene IDs

Examples

```
## Not run: example(hpGeneListComp)
```

rPath *Reactome pathways (Example data)*

Description

Pathways taken from the Reactome database.

Format

A data frame with 1345 rows and 2 columns:

Pathway Reactome ID.

Pathway_name The name of the pathway.

Source

http://www.reactome.org/download/current/UniProt2Reactome.txt

Examples

```
## Not run: example(hpGeneListComp)
```

traitDef *Description of Traits (Example data)*

Description

Basic information about traits. Only OMIM diseases associated to at least one gene are taken into account.

Format

A data frame with 3675 rows and 3 columns:

db Always "OMIM" here.

id The trait ID (OMIM IDs here).

name The name of the trait.

Details

These data are used to examplify the different functions of the package. More data are available in the MultiHumanPhenoDB package.

Source

ftp://ftp.ncbi.nlm.nih.gov/pub/clinvar/xml/ClinVarFullRelease_2015-05.xml.gz

Examples

```
## Prerequisite
data(geneByHp, hp_descendants, package="PCAN")
geneByHp <- unstack(geneByHp, entrez~hp)
ic <- computeHpIC(geneByHp, hp_descendants)

##########################################
## Use case: comparing a gene and a disease
data(traitDef, geneDef, hp_ancestors, hpDef, package="PCAN")
omim <- "612285"
traitDef[which(traitDef$id==omim),]
entrez <- "57545"
geneDef[which(geneDef$entrez==entrez),]
## Get HP terms associated to the disease
data(hpByTrait, package="PCAN")
hpOfInterest <- hpByTrait$hp[which(hpByTrait$id==omim)]

## Get HP terms associated to the gene
hpByGene <- unstack(stack(geneByHp), ind~values)
geneHps <- hpByGene[[entrez]]
## Comparison of the two sets of HP terms
compMat <- compareHPSets(
    hpSet1=geneHps, hpSet2=hpOfInterest,
```

```
    IC=ic,
    ancestors=hp_ancestors,
    method="Resnik",
    BPPARAM=SerialParam()
)
## Get the symmetric semantic similarity score
hpSetCompSummary(compMat, method="bma", direction="symSim")
bm <- hpSetCompBestMatch(compMat, "b")
hpDef[match(c(bm$compared, bm$candidate), hpDef$id),]
```

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