Package ‘infercnv’

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Type Package

Title Infer Copy Number Variation from Single-Cell RNA-Seq Data

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BugReports https://github.com/broadinstitute/inferCNV/issues

Description Using single-cell RNA-Seq expression to visualize CNV in cells.

biocViews Software, CopyNumberVariation, VariantDetection, StructuralVariation, GenomicVariation, Genetics, Transcriptomics, StatisticalMethod, Bayesian, HiddenMarkovModel, SingleCell

Depends R(>= 4.0)

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LazyData TRUE

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Suggests BiocStyle, knitr, rmarkdown, testthat

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NeedsCompilation no

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Imports graphics, grDevices, RColorBrewer, gplots, futile.logger, stats, utils, methods, ape, phyclust, Matrix, fastcluster, parallelDist, dplyr, HiddenMarkov, ggplot2, edgeR, coin, caTools, digest, RANN, igraph, reshape2, rjags, fitdistrplus, future, foreach, doParallel, Seurat, BiocGenerics, SummarizedExperiment, SingleCellExperiment, tidyr, parallel, coda, gridExtra, argparse

URL https://github.com/broadinstitute/inferCNV/wiki

Collate 'SplatterScrape.R' 'data.R' 'inferCNV.R' 'inferCNV_BayesNet.R' 'inferCNV_HMM.R' 'inferCNV_constants.R' 'inferCNV_heatmap.R' 'inferCNV_hidden_spike.R' 'inferCNV_i3HMM.R' 'inferCNV_mask_non_DE.R' 'inferCNV_meanVarSim.R'
R topics documented:

'inferCNV_ops.R' 'inferCNV_simple_sim.R'
'inferCNV_tumor_subclusters.R'
'inferCNV_tumor_subclusters.random_smoothed_trees.R'
'infercnv_sampling.R' 'noise_reduction.R'
'seurat_interaction.R'

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Description

Using single-cell RNA-Seq expression to visualize CNV in cells.

Details

The main functions you will need to use are CreateInfercnvObject() and run(infercnv_object). For additional details on running the analysis step by step, please refer to the example vignette.

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See Also

Useful links:

• https://github.com/broadinstitute/inferCNV/wiki
• Report bugs at https://github.com/broadinstitute/inferCNV/issues

Description

Add meta.data about CNAs to a Seurat object from an infercnv_obj

Usage

add_to_seurat(
  seurat_obj = NULL,
  assay_name = "RNA",
  infercnv_output_path,
  top_n = 10,
  bp_tolerance = 2e+06,
  column_prefix = NULL
)
Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>seurat_obj</td>
<td>Seurat object to add meta.data to (default: NULL)</td>
</tr>
<tr>
<td>assay_name</td>
<td>Name of the assay in the Seurat object if provided. (default: &quot;RNA&quot;)</td>
</tr>
<tr>
<td>infercnv_output_path</td>
<td>Path to the output folder of the infercnv run to use</td>
</tr>
<tr>
<td>top_n</td>
<td>How many of the largest CNA (in number of genes) to get.</td>
</tr>
<tr>
<td>bp_tolerance</td>
<td>How many bp of tolerance to have around feature start/end positions for top_n</td>
</tr>
<tr>
<td>column_prefix</td>
<td>String to add as a prefix to the Seurat metadata columns. Only applied to the</td>
</tr>
<tr>
<td></td>
<td>seurat_obj, if supplied. Default is NULL</td>
</tr>
</tbody>
</table>

Value

seurat_obj

Description

Apply a median filtering to the expression matrix within each tumor bounds

Usage

```r
apply_median_filtering(
  infercnv_obj,
  window_size = 7,
  on_observations = TRUE,
  on_references = TRUE
)
```

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>infercnv_obj</td>
<td>infercnv_object</td>
</tr>
<tr>
<td>window_size</td>
<td>Size of the window side centered on the data point to filter (default = 7).</td>
</tr>
<tr>
<td>on_observations</td>
<td>boolean (default=TRUE), run on observations data (tumor cells).</td>
</tr>
<tr>
<td>on_references</td>
<td>boolean (default=TRUE), run on references (normal cells).</td>
</tr>
</tbody>
</table>

Value

infercnv_obj with median filtering applied to observations
Examples

```r
# infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
# gene_order_file=infercnv_genes_example,
# annotations_file=infercnv_annots_example,
# ref_group_names=c("normal"))

# infercnv_object_example <- infercnv::run(infercnv_object_example,
#   cutoff=1,
#   out_dir=tempfile(),
#   cluster_by_groups=TRUE,
#   denoise=TRUE,
#   HMM=FALSE,
#   num_threads=2,
#   no_plot=TRUE)

data(infercnv_object_example)

infercnv_object_example <- infercnv::apply_median_filtering(infercnv_object_example)
# plot result object
```

---

color.palette

*Helper function allowing greater control over the steps in a color palette.*

Description

Helper function allowing greater control over the steps in a color palette. Source: http://menugget.blogspot.com/2011/11/define-color-steps-for-colorramppalette.html#more

Usage

```r
color.palette(steps, between = NULL, ...)
```

Arguments

- `steps`: Vector of colors to change use in the palette
- `between`: Steps where gradients change
- `...`: Additional arguments of colorRampPalette

Value

Color palette
CreateInfercnvObject

Examples

color.palette(c("darkblue", "white", "darkred"),
c(2, 2))

CreateInfercnvObject

Description

Creation of an infercnv object. This requires the following inputs: A more detailed description of
each input is provided below:

The raw_counts_matrix:

MGH54_P16_F12 MGH53_P5_C12 MGH54_P12_C10 MGH54_P16_F02 MGH54_P11_C11 ...
DDX11L1 0.0000000 0.000000 0.000000 0.000000 0.0000000 W ASH7P 0.0000000 2.231939 7.186235
5.284944 0.9650009 FAM138A 0.1709991 0.000000 0.000000 0.0000000 OR4F5 0.0000000
0.000000 0.000000 0.0000000 0.00000000 OR4F29 0.00000000 0.00000000 0.0000000
...

The gene_order_file, contains chromosome, start, and stop position for each gene, tab-delimited:

chr start stop DDX11L1 chr1 11869 14412 W ASH7P chr1 14363 29806 FAM138A chr1 34554
36081 OR4F5 chr1 69091 70008 OR4F29 chr1 367640 368634 OR4F16 chr1 621059 622053 ...

The annotations_file, containing the cell name and the cell type classification, tab-delimited.

V1 V2 1 MGH54_P2_C12 Microglia/Macrophage 2 MGH36_P6_F03 Microglia/Macrophage 3
MGH53_P4_H08 Microglia/Macrophage 4 MGH53_P2_E09 Microglia/Macrophage 5 MGH36_P5_E12
Oligodendrocytes (non-malignant) 6 MGH54_P2_H07 Oligodendrocytes (non-malignant) ...
179
93_P9_H03 malignant 180 93_P10_D04 malignant 181 93_P8_G09 malignant 182 93_P10_B10
malignant 183 93_P9_C07 malignant 184 93_P8_A12 malignant ...

and the ref_group_names vector might look like so: c("Microglia/Macrophage","Oligodendrocytes
(non-malignant)")

Usage

CreateInfercnvObject(
  raw_counts_matrix,
  gene_order_file,
  annotations_file,
  ref_group_names,
  delims = ",\t",
  max_cells_per_group = NULL,
  min_max_counts_per_cell = c(100, +Inf),
  chr_exclusion = c("chrX", "chrY", "chrM")
)
CreateInfercnvObject

Arguments

raw_counts_matrix
the matrix of genes (rows) vs. cells (columns) containing the raw counts. If a filename is given, it'll be read via read.table() otherwise, if matrix or Matrix, will use the data directly.

gene_order_file
data file containing the positions of each gene along each chromosome in the genome.

annotations_file
a description of the cells, indicating the cell type classifications

ref_group_names
a vector containing the classifications of the reference (normal) cells to use for inferring cnv

delim
delimiter used in the input files

max_cells_per_group
maximum number of cells to use per group. Default=NULL, using all cells defined in the annotations_file. This option is useful for randomly subsetting the existing data for a quicker preview run, such as using 50 cells per group instead of hundreds.

min_max_counts_per_cell
minimum and maximum counts allowed per cell. Any cells outside this range will be removed from the counts matrix. default=(100, +Inf) and uses all cells. If used, should be set as c(min_counts, max_counts)

chr_exclude
list of chromosomes in the reference genome annotations that should be excluded from analysis. Default = c('chrX', 'chrY', 'chrM')

Value

infercnv

Examples

data(infercnv_data_example)
data(infercnv_annots_example)
data(infercnv_genes_example)

infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
gene_order_file=infercnv_genes_example,
annotations_file=infercnv_annots_example,
ref_group_names=c("normal"))
filterHighPNormals: Filter the HMM identified CNV’s by the CNV’s posterior probability of belonging to a normal state.

**Description**

The following function will filter the HMM identified CNV’s by the CNV’s posterior probability of belonging to a normal state identified by the function inferCNVBayesNet(). Will filter CNV’s based on a user desired threshold probability. Any CNV with a probability of being normal above the threshold will be removed.

**Usage**

```r
filterHighPNormals(MCMC_inferCNV_obj, HMM_states, BayesMaxPNormal, useRaster)
```

**Arguments**

- `MCMC_inferCNV_obj`: MCMC inferCNV object.
- `HMM_states`: InferCNV object with HMM states in expression data.
- `BayesMaxPNormal`: Option to filter CNV or cell lines by some probability threshold.
- `useRaster`: Option to use rasterization when plotting.

**Value**

Returns a list of (MCMC_inferCNV_obj, HMM_states) With removed CNV’s.

**Examples**

```r
data(mcmc_obj)
mcmc_obj_hmm_states_list <- infercnv::filterHighPNormals(MCMC_inferCNV_obj = mcmc_obj, HMM_states = HMM_states, BayesMaxPNormal = 0.5)
```

**HMM_states**

infercnv object result of the processing of run() in the HMM example, to be used for other examples.

**Description**

infercnv object result of the processing of run() in the HMM example, to be used for other examples.
Usage

HMM_states

Format

An infercnv object containing HMM predictions

Description

An infercnv object encapsulates the expression data and gene chromosome ordering information that is leveraged by infercnv for data exploration. The infercnv object is passed among the infercnv data processing and plotting routines.

Details

Slots in the infercnv object include:

Slots

expr.data <matrix> the count or expression data matrix, manipulated throughout infercnv ops

count.data <matrix> retains the original count data, but shrinks along with expr.data when genes are removed.

gene_order <data.frame> chromosomal gene order

reference_grouped_cell_indices <list> mapping ['group_name'] to c(cell column indices) for reference (normal) cells

observation_grouped_cell_indices <list> mapping ['group_name'] to c(cell column indices) for observation (tumor) cells

tumor_subclusters <list> stores subclustering of tumors if requested

options <list> stores the options relevant to the analysis in itself (in contrast with options relevant to plotting or paths)

.hspike a hidden infercnv object populated with simulated spiked-in data
inferCNVBayesNet

inferCNVBayesNet: Run Bayesian Network Mixture Model To Obtain Posterior Probabilities For HMM Predicted States

Description

Uses Markov Chain Monte Carlo (MCMC) and Gibbs sampling to estimate the posterior probability of being in one of six Copy Number Variation states (states: 0, 0.5, 1, 1.5, 2, 3) for CNV’s identified by inferCNV’s HMM. Posterior probabilities are found for the entire CNV cluster and each individual cell line in the CNV.

Usage

inferCNVBayesNet(
  file_dir,
  infercnv_obj,
  HMM_states,
  out_dir,
  resume_file_token,
  model_file = NULL,
  CORES = 1,
  postMcmcMethod = NULL,
  plotingProbs = TRUE,
  quietly = TRUE,
  diagnostics = FALSE,
  HMM_type = HMM_type,
  k_obs_groups = k_obs_groups,
  cluster_by_groups = cluster_by_groups,
  reassignCNVs = TRUE,
  no_plot = no_plot,
  useRaster
)

Arguments

file_dir: Location of the directory of the inferCNV outputs.
infercnv_obj: InferCNV object.
HMM_states: InferCNV object with HMM states in expression data.
out_dir: (string) Path to where the output file should be saved to.
resume_file_token: (string) String token that contains some info on settings used to name files.
model_file: Path to the BUGS Model file.
CORES: Option to run parallel by specifying the number of cores to be used. (Default: 1)
postMcmcMethod: What actions to take after finishing the MCMC.
plotingProbs: Option for adding plots of Cell and CNV probabilities. (Default: TRUE)
**inferCNVBayesNet**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>quietly</td>
<td>Option to print descriptions along each step. (Default: TRUE)</td>
</tr>
<tr>
<td>diagnostics</td>
<td>Option to plot Diagnostic plots and tables. (Default: FALSE)</td>
</tr>
<tr>
<td>HMM_type</td>
<td>The type of HMM that was ran, either ‘i3’ or ‘i6’. Determines how many state</td>
</tr>
<tr>
<td></td>
<td>were predicted by the HMM.</td>
</tr>
<tr>
<td>k_obs_groups</td>
<td>Number of groups in which to break the observations. (default: 1)</td>
</tr>
<tr>
<td>cluster_by_groups</td>
<td>If observations are defined according to groups (ie. patients), each group</td>
</tr>
<tr>
<td></td>
<td>of cells will be clustered separately. (default=FALSE, instead will use k_</td>
</tr>
<tr>
<td></td>
<td>obs_groups setting)</td>
</tr>
<tr>
<td>reassignCNVs</td>
<td>(boolean) Given the CNV associated probability of belonging to each possible</td>
</tr>
<tr>
<td></td>
<td>state, reassign the state assignments made by the HMM to the state that has</td>
</tr>
<tr>
<td></td>
<td>the highest probability. (default: TRUE)</td>
</tr>
<tr>
<td>no_plot</td>
<td>(boolean) Option set by infercnv::run() for producing visualizations.</td>
</tr>
<tr>
<td>useRaster</td>
<td>Option to use rasterization when plotting</td>
</tr>
</tbody>
</table>

**Value**

Returns a MCMC_inferCNV_obj and posterior probability of being in one of six Copy Number Variation states (states: 0, 0.5, 1, 1.5, 2, 3) for CNV’s identified by inferCVN’s HMM.

**Examples**

```r
data(infercnv_data_example)
data(infercnv_annots_example)
data(infercnv_genes_example)
data(HMM_states)

infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
  gene_order_file=infercnv_genes_example,
  annotations_file=infercnv_annots_example,
  ref_group_names=c("normal"))

out_dir = tempfile()
infercnv_object_example <- infercnv::run(infercnv_object_example,
  cutoff=1,
  out_dir=out_dir,
  cluster_by_groups=TRUE,
  analysis_mode="samples",
  denoise=TRUE,
  HMM=TRUE,
  num_threads=2,
  no_plot=TRUE)

mcmc_obj <- infercnv::inferCNVBayesNet(infercnv_obj = infercnv_object_example,
  HMM_states = HMM_states,
  file_dir = out_dir,
  postMcmcMethod = "removeCNV",
  out_dir = out_dir,
  resume_file_token = "HMMi6.hmm_mode-samples",
  quietly = TRUE,
  )
```
infercnv_data_example

```
CORES = 2,
plotingProbs = FALSE,
diagnostics = FALSE,
HMM_type = 'i6',
k_obs_groups = 1,
cluster_by_groups = FALSE,
reassignCNVs = FALSE,
no_plot = TRUE)
```

infercnv_annots_example

*Generated classification for 10 normal cells and 10 tumor cells.*

**Description**

Generated classification for 10 normal cells and 10 tumor cells.

**Usage**

`infercnv_annots_example`

**Format**

A data frame with 20 rows (cells) and 1 columns (classification)

infercnv_data_example

*Generated SmartSeq2 expression data with 10 normal cells and 10 tumor cells. This is only to demonstrate how to use methods, not actual data to be used in an analysis.*

**Description**

Generated SmartSeq2 expression data with 10 normal cells and 10 tumor cells. This is only to demonstrate how to use methods, not actual data to be used in an analysis.

**Usage**

`infercnv_data_example`

**Format**

A data frame with 8252 rows (genes) and 20 columns (cells)
infercnv_genes_example

Description

Downsampled gene coordinates file from GrCh37

Usage

infercnv_genes_example

Format

A data frame with 10338 rows (genes) and 3 columns (chr, start, end)

infercnv_object_example

Description

infercnv object result of the processing of run() in the example, to be used for other examples.

Usage

infercnv_object_example

Format

An infercnv object
**MCMC_inferCNV-class  MCMC_inferCNV class**

**Description**

Uses Markov Chain Monte Carlo (MCMC) and Gibbs sampling to estimate the posterior probability of being in one of six Copy Number Variation states (states: 0, 0.5, 1, 1.5, 2, 3) for CNV's identified by inferCNV's HMM. Posterior probabilities are found for the entire CNV cluster and each individual cell line in the CNV.

**Slots**

- `bugs_model`  BUGS model.
- `sig`  fitted values for cell lines, 1/standard deviation to be used for determining the distribution of each cell line.
- `mu`  Mean values to be used for determining the distribution of each cell line.
- `group_id`  ID's given to the cell clusters.
- `cell_gene`  List containing the Cells and Genes that make up each CNV.
- `cnv_probabilities`  Probabilities of each CNV belonging to a particular state from 0 (least likely) to 1 (most likely).
- `cell_probabilities`  Probabilities of each cell being in a particular state, from 0 (least likely) to 1 (most likely).
- `args`  Input arguments given by the user.
- `cnv_regions`  ID for each CNV found by the HMM.

**mcmc_obj**

infercnv object result of the processing of inferCNVBayesNet in the example, to be used for other examples.

**Description**

infercnv object result of the processing of inferCNVBayesNet in the example, to be used for other examples.

**Usage**

mcmc_obj

**Format**

An infercnv object containing posterior probability of CNV states.
plot_cnv

Plot the matrix as a heatmap, with cells as rows and genes as columns, ordered according to chromosome

Description

Formats the data and sends it for plotting.

Usage

plot_cnv(
  infercnv_obj,
  out_dir = ".",
  title = "inferCNV",
  obs_title = "Observations (Cells)",
  ref_title = "References (Cells)",
  cluster_by_groups = TRUE,
  cluster_references = TRUE,
  plot_chr_scale = FALSE,
  chr_lengths = NULL,
  k_obs_groups = 1,
  contig_cex = 1,
  x.center = mean(infercnv_obj@expr.data),
  x.range = "auto",
  hclust_method = "ward.D",
  custom_color_pal = NULL,
  color_safe_pal = FALSE,
  output_filename = "infercnv",
  output_format = "png",
  png_res = 300,
  dynamic_resize = 0,
  ref_contig = NULL,
  write_expr_matrix = FALSE,
  write_phylo = FALSE,
  useRaster = TRUE
)

Arguments

infercnv_obj infercnv object
out_dir Directory in which to save pdf and other output.
title Plot title.
obs_title Title for the observations matrix.
ref_title Title for the reference matrix.
cluster_by_groups
   Whether to cluster observations by their annotations or not. Using this ignores k_obs_groups.

cluster_references
   Whether to cluster references within their annotations or not. (dendrogram not displayed)

plot_chr_scale
   Whether to scale the chromosome width on the heatmap based on their actual size rather than just the number of expressed genes.

chr_lengths
   A named list of chromosomes lengths to use when plot_chr_scale=TRUE, or else chromosome size is assumed to be the last chromosome’s stop position + 10k bp

k_obs_groups
   Number of groups to break observation into.

contig_cex
   Contig text size.

x.center
   Value on which to center expression.

x.range
   vector containing the extreme values in the heatmap (ie. c(-3,4) )

hclust_method
   Clustering method to use for hclust.

custom_color_pal
   Specify a custom set of colors for the heatmap. Has to be in the shape color.palette(c("darkblue", "white", "darkred"), c(2, 2))

color_safe_pal
   Logical indication of using a color blindness safe palette.

output_filename
   Filename to save the figure to.

output_format
   format for heatmap image file (default: ‘png’), options(‘png’, ’pdf’, NA) If set to NA, will print graphics natively

png_res
   Resolution for png output.

dynamic_resize
   Factor (>= 0) by which to scale the dynamic resize of the observation heatmap and the overall plot based on how many cells there are. Default is 0, which disables the scaling. Try 1 first if you want to enable.

ref_contig
   If given, will focus cluster on only genes in this contig.

write_expr_matrix
   Includes writing a matrix file containing the expression data that is plotted in the heatmap.

write_phylo
   Write newick strings of the dendrograms displayed on the left side of the heatmap to file.

useRaster
   Whether to use rasterization for drawing heatmap. Only disable if it produces an error as it is much faster than not using it.

Value

A list of all relevent settings used for the plotting to be able to reuse them in another plot call while keeping consistant plotting settings, most importantly x.range.
Examples

```r
# data(infercnv_data_example)
# data(infercnv_annots_example)
# data(infercnv_genes_example)

# infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
# gene_order_file=infercnv_genes_example,
# annotations_file=infercnv_annots_example,
# ref_group_names=c("normal"))

# infercnv_object_example <- infercnv::run(infercnv_object_example,
# cutoff=1,
# out_dir=tempfile(),
# cluster_by_groups=TRUE,
# denoise=TRUE,
# HMM=FALSE,
# num_threads=2,
# no_plot=TRUE)

data(infercnv_object_example)

plot_cnv(infercnv_object_example,
  out_dir=tempfile(),
  obs_title="Observations (Cells)",
  ref_title="References (Cells)",
  cluster_by_groups=TRUE,
  x.center=1,
  x.range="auto",
  hclust_method='ward.D',
  color_safe_pal=FALSE,
  output_filename="infercnv",
  output_format="png",
  png_res=300,
  dynamic_resize=0)
```

Description

Takes an infercnv object and subdivides it into one object per group of cells to allow plotting of each group on a separate plot. If references are selected, they will appear on the observation heatmap area as it is larger.

Usage

```r
plot_per_group()
```
infercnv_obj,  
on_references = TRUE,  
on_observations = TRUE,  
sample = FALSE,  
n_cells = 1000,  
every_n = NULL,  
above_m = 1000,  
k_obs_groups = 1,  
base_filename = "infercnv_per_group",  
output_format = "png",  
write_expr_matrix = TRUE,  
save_objects = FALSE,  
png_res = 300,  
dynamic_resize = 0,  
useRaster = TRUE,  
out_dir
)

Arguments

infercnv_obj infercnv_object
on_references boolean (default=TRUE), plot references (normal cells).
on_observations boolean (default=TRUE), plot observations data (tumor cells).
sample Whether unique groups of cells should be sampled from or not. (see other parameters for how sampling is done) (Default: FALSE)
n_cells Number of cells that should be sampled per group if sampling is enabled (default = 1000).
every_n Sample 1 cell every_n cells for each group that has above_m cells, if sampling is enabled. If subclusters are defined, this will make sure that at least one cell per subcluster is sampled. Requires above_m to be set to work, overriding n_cells parameter. (Default: NULL)
above_m Sample only groups that have at least above_m cells if sampling is enabled. (default: 1000) Does not require every_n to be set.
k_obs_groups Number of groups to break each group in with cutree (in the color bars on the left side of the plot only). (Default: 1)
base_filename Base prefix for the output files names. Will be followed by OBS/REF to indidate the type of the group, and the group name. (Default: “infercnv_per_group”)
output_format Output format for the figure. Choose between "png", "pdf" and NA. NA means to only write the text outputs without generating the figure itself. (default: "png")
write_expr_matrix Includes writing a matrix file containing the expression data that is plotted in the heatmap. (default: FALSE)
save_objects Whether to save the infercnv objects generated for each group as RDS. (default: FALSE)
plot_subclusters

- **png_res**: Resolution for png output. (Default: 300)
- **dynamic_resize**: Factor (>= 0) by which to scale the dynamic resize of the observation heatmap and the overall plot based on how many cells there are. Default is 0, which disables the scaling. Try 1 first if you want to enable. (Default: 0)
- **useRaster**: Whether to use rasterization for drawing heatmap. Only disable if it produces an error as it is much faster than not using it.
- **out_dir**: Directory in which to save plots and other outputs.

**Value**

void

**Examples**

```r
# data(infercnv_data_example)
# data(infercnv_annots_example)
# data(infercnv_genes_example)

# infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
#                                                          gene_order_file=infercnv_genes_example,
#                                                          annotations_file=infercnv_annots_example,
#                                                          ref_group_names=c("normal"))

# infercnv_object_example <- infercnv::run(infercnv_object_example,
#                                          cutoff=1,
#                                          out_dir=tempfile(),
#                                          cluster_by_groups=TRUE,
#                                          denoise=TRUE,
#                                          HMM=FALSE,
#                                          num_threads=2,
#                                          no_plot=TRUE)

data(infercnv_object_example)

infercnv::plot_per_group(infercnv_object_example, out_dir=tempfile())
```

---

**plot_subclusters**

Plot a heatmap of the data in the infercnv object with the subclusters being displayed as annotations.

**Description**

Formats the data and sends it for plotting.
plot_subclusters

Usage

plot_subclusters(
  infercnv_obj,
  out_dir,
  output_filename = "subcluster_as_annotations"
)

Arguments

infercnv_obj infercnv object
out_dir Directory in which to output.
output_filename Filename to save the figure to.

Value

infercnv_obj the modified infercnv object that was plotted where subclusters are assigned as annotation groups

Examples

# data(infercnv_data_example)
# data(infercnv_annots_example)
# data(infercnv_genes_example)

# infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
# gene_order_file=infercnv_genes_example,
# annotations_file=infercnv_annots_example,
# ref_group_names=c("normal"))

# infercnv_object_example <- infercnv::run(infercnv_object_example,
# cutoff=1,
# out_dir=tempfile(),
# cluster_by_groups=TRUE,
# denoise=TRUE,
# HMM=FALSE,
# num_threads=2,
# no_plot=TRUE)

data(infercnv_object_example)

plot_subclusters(infercnv_object_example,
  out_dir=tempfile(),
  output_filename="subclusters_as_annotations"
)
run

**run()** : Invokes a routine inferCNV analysis to Infer CNV changes given a matrix of RNASeq counts.

### Description

Function doing the actual analysis before calling the plotting functions.

### Usage

```r
run(
  infercnv_obj,
  cutoff = 1,
  min_cells_per_gene = 3,
  out_dir = NULL,
  window_length = 101,
  smooth_method = c("pyramidinal", "runmeans", "coordinates"),
  num_ref_groups = NULL,
  ref_subtract_use_mean_bounds = TRUE,
  cluster_by_groups = TRUE,
  cluster_references = TRUE,
  k_obs_groups = 1,
  hclust_method = "ward.D2",
  max_centered_threshold = 3,
  scale_data = FALSE,
  HMM = FALSE,
  HMM_transition_prob = 1e-06,
  HMM_report_by = c("subcluster", "consensus", "cell"),
  HMM_type = c("i6", "i3"),
  HMM_i3_pval = 0.05,
  HMM_i3_use_KS = FALSE,
  BayesMaxPNormal = 0.5,
  sim_method = "meanvar",
  sim_foreground = FALSE,
  reassignCNVs = TRUE,
  analysis_mode = c("subclusters", "samples", "cells"),
  tumor_subcluster_partition_method = c("leiden", "random_trees", "qnorm", "pheight",
                                      "qgamma", "shc"),
  tumor_subcluster_pval = 0.1,
  k_nn = 20,
  leiden_method = c("PCA", "simple"),
  leiden_function = c("CPM", "modularity"),
  leiden_resolution = "auto",
  leiden_method_per_chr = c("simple", "PCA"),
  leiden_function_per_chr = c("modularity", "CPM"),
  leiden_resolution_per_chr = 1,
  per_chr_hmm_subclusters = FALSE,
)```
per_chr_hmm_subclusters_references = FALSE,
z_score_filter = 0.8,
denoise = FALSE,
noise_filter = NA,
sd_amplifier = 1.5,
noise_logistic = FALSE,
outlier_method_bound = "average_bound",
outlier_lower_bound = NA,
outlier_upper_bound = NA,
final_scale_limits = NULL,
final_center_val = NULL,
debug = FALSE,
num_threads = 4,
plot_steps = FALSE,
inspect_subclusters = TRUE,
resume_mode = TRUE,
png_res = 300,
plot_probabilities = TRUE,
save_rds = TRUE,
save_final_rds = TRUE,
diagnostics = FALSE,
remove_genes_at_chr_ends = FALSE,
prune_outliers = FALSE,
mask_nonDE_genes = FALSE,
mask_nonDE_pval = 0.05,
test.use = "wilcoxon",
require_DE_all_normals = "any",
hspike_aggregate_normals = FALSE,
no_plot = FALSE,
no_prelim_plot = FALSE,
write_expr_matrix = FALSE,
write_phylo = FALSE,
output_format = "png",
plot_chr_scale = FALSE,
chr_lengths = NULL,
useRaster = TRUE,
up_to_step = 100
)

Arguments

infercnv_obj  An infercnv object populated with raw count data

cutoff  Cut-off for the min average read counts per gene among reference cells. (default: 1)

min_cells_per_gene  minimum number of reference cells requiring expression measurements to include the corresponding gene. default: 3

out_dir  path to directory to deposit outputs (default: NULL, required to provide non
run

## Smoothing params

**window_length**  
Length of the window for the moving average (smoothing). Should be an odd integer. (default: 101)

**smooth_method**  
Method to use for smoothing: c(runmeans,pyramidinal,coordinates) default: pyramidinal

### num_ref_groups  
The number of reference groups or a list of indices for each group of reference indices in relation to reference_obs. (default: NULL)

### ref_subtract_use_mean_bounds  
Determine means separately for each ref group, then remove intensities within bounds of means (default: TRUE) Otherwise, uses mean of the means across groups.

### cluster_by_groups  
If observations are defined according to groups (ie. patients), each group of cells will be clustered separately. (default=FALSE, instead will use k_obs_groups setting)

### cluster_references  
Whether to cluster references within their annotations or not. (dendrogram not displayed) (default: TRUE)

**k_obs_groups**  
Number of groups in which to break the observations. (default: 1)

**hclust_method**  
Method used for hierarchical clustering of cells. Valid choices are: "ward.D", "ward.D2", "single", "complete", "average", "mcquitty", "median", "centroid". default("ward.D2")

**max_centered_threshold**  
The maximum value a value can have after centering. Also sets a lower bound of -1 * this value. (default: 3), can set to a numeric value or "auto" to bound by the mean bounds across cells. Set to NA to turn off.

**scale_data**  
perform Z-scaling of logtransformed data (default: FALSE). This may be turned on if you have very different kinds of data for your normal and tumor samples. For example, you need to use GTEx representative normal expression profiles rather than being able to leverage normal single cell data that goes with your experiment.

### HMM  
when set to True, runs HMM to predict CNV level (default: FALSE)

**HMM_transition_prob**  
transition probability in HMM (default: 1e-6)

**HMM_report_by**  
cell, consensus, subcluster (default: subcluster) Note, reporting is performed entirely separately from the HMM prediction. So, you can predict on subclusters, but get per-cell level reporting (more voluminous output).
HMM_type  
HMM model type. Options: (i6 or i3): i6: infercnv 6-state model (0, 0.5, 1, 1.5, 2, >2) where state emissions are calibrated based on simulated CNV levels. i3: infercnv 3-state model (del, neutral, amp) configured based on normal cells and HMM_i3_pval 

HMM_i3_pval  p-value for HMM i3 state overlap (default: 0.05) 

HMM_i3_use_KS  boolean: use the KS test statistic to estimate mean of amp/del distributions (ala HoneyBadger). (default=TRUE) 

BayesMaxPNormal  maximum P(Normal) allowed for a CNV prediction according to BayesNet. (default=0.5, note zero turns it off) 

sim_method  method for calibrating CNV levels in the i6 HMM (default: 'meanvar') 

sim_foreground  don't use... for debugging, developer option. 

reassignCNVs  (boolean) Given the CNV associated probability of belonging to each possible state, reassign the state assignments made by the HMM to the state that has the highest probability. (default: TRUE) 

analysis_mode  options(samples|subclusters|cells), Grouping level for image filtering or HMM predictions. default: samples (fastest, but subclusters is ideal) 

tumor_subcluster_partition_method  method for defining tumor subclusters. Options('leiden', 'random_trees', 'qnorm') 

leiden: Runs a nearest neighbor search, where communities are then partitionned with the Leiden algorithm. random_trees: Slow, uses permutation statistics w/ tree construction. qnorm: defines tree height based on the quantile defined by the tumor_subcluster_pval 

tumor_subcluster_pval  max p-value for defining a significant tumor subcluster (default: 0.1) 

k_nn  number k of nearest neighbors to search for when using the Leiden partition method for subclustering (default: 20) 

leiden_method  Method used to generate the graph on which the Leiden algorithm is applied, one of "PCA" or "simple". (default: "PCA") 

leiden_function  Whether to use the Constant Potts Model (CPM) or modularity in igraph. Must be either "CPM" or "modularity". (default: "CPM") 

leiden_resolution  resolution parameter for the Leiden algorithm using the CPM quality score (default: auto) 

leiden_method_per_chr  Method used to generate the graph on which the Leiden algorithm is applied for the per chromosome subclustering, one of "PCA" or "simple". (default: "simple") 

leiden_function_per_chr  Whether to use the Constant Potts Model (CPM) or modularity in igraph for the per chromosome subclustering. Must be either "CPM" or "modularity". (default: "modularity")
leiden_resolution_per_chr

resolution parameter for the Leiden algorithm for the per chromosome subclustering (default: 1)

per_chr_hmm_subclusters

Run subclustering per chromosome over all cells combined to run the HMM on those subclusters instead. Only applicable when using Leiden subclustering. This should provide enough definition in the predictions while avoiding subclusters that are too small thus providing less evidence to work with. (default: FALSE)

per_chr_hmm_subclusters_references

Whether the per chromosome subclustering should also be done on references, which should not have as much variation as observations. (default = FALSE)

z_score_filter

Z-score used as a threshold to filter genes used for subclustering. Applied based on reference genes to automatically ignore genes with high expression variability such as MHC genes. (default: 0.8)

# de-noising parameters#

denoise

If True, turns on denoising according to options below

noise_filter

Values +/- from the reference cell mean will be set to zero (whitening effect) default(NA, instead will use sd_amplifier below).

sd_amplifier

Noise is defined as mean(reference_cells) +/- sdev(reference_cells) * sd_amplifier default: 1.5

noise_logistic

use the noise_filter or sd_amplifier based threshold (whichever is invoked) as the midpoint in a logistic model for downscaling values close to the mean. (default: FALSE)

# Outlier pruning

outlier_method_bound

Method to use for bounding outlier values. (default: "average_bound") Will preferentially use outlier_lower_bound and outlier_upper_bound if set.

outlier_lower_bound

Outliers below this lower bound will be set to this value.

outlier_upper_bound

Outliers above this upper bound will be set to this value.

# Misc options

final_scale_limits

The scale limits for the final heatmap output by the run() method. Default "auto". Alt, c(low,high)

final_center_val

Center value for final heatmap output by the run() method.

debug

If true, output debug level logging.

num_threads

(int) number of threads for parallel steps (default: 4)

plot_steps

If true, saves infercnv objects and plots data at the intermediate steps.

inspect_subclusters

If true, plot subclusters as annotations after the subclustering step to easily see if the subclustering options are good. (default = TRUE)
resume_mode leverage pre-computed and stored infercnv objects where possible. (default=TRUE)
png_res Resolution for png output.
plot_probabilities option to plot posterior probabilities (default: TRUE)
save_rds Whether to save the current step object results as an .rds file (default: TRUE)
save_final_rds Whether to save the final object results as an .rds file (default: TRUE)
diagnostics option to create diagnostic plots after running the Bayesian model (default: FALSE)

# Experimental options
remove_genes_at_chr_ends experimental option: If true, removes the window_length/2 genes at both ends of the chromosome.
prune_outliers Define outliers loosely as those that exceed the mean boundaries among all cells. These are set to the bounds.
mask_nonDE_genes If true, sets genes not significantly differentially expressed between tumor/normal to the mean value for the complete data set (default: 0.05)
mask_nonDE_pval p-value threshold for defining statistically significant DE genes between tumor/normal

test.use statistical test to use. (default: "wilcoxon") alternatives include 'perm' or 't'.
require_DE_all_normals If mask_nonDE_genes is set, those genes will be masked only if they are are found as DE according to test.use and mask_nonDE_pval in each of the comparisons to normal cells options: "any", "most", "all" (default: "any")

hspike_aggregate_normals instead of trying to model the different normal groupings individually, just merge them in the hspike.

no_plot don’t make any of the images. Instead, generate all non-image outputs as part of the run. (default: FALSE)

no_prelim_plot don’t make the preliminary infercnv image (default: FALSE)
write_expr_matrix Whether to write text files with the content of matrices when generating plots (default: FALSE)
write_phylo Whether to write newick strings of the dendrograms displayed on the left side of the heatmap to file (default: FALSE)

output_format Output format for the figure. Choose between "png", "pdf" and NA. NA means to only write the text outputs without generating the figure itself. (default: "png")

plot_chr_scale Whether to scale the chromosome width on the heatmap based on their actual size rather than just the number of expressed genes.
sample_object

| chr_lengths | A named list of chromosomes lengths to use when plot_chr_scale=TRUE, or else chromosome size is assumed to be the last chromosome’s stop position + 10k bp |
| useRaster    | Whether to use rasterization for drawing heatmap. Only disable if it produces an error as it is much faster than not using it. (default: TRUE) |
| up_to_step   | run() only up to this exact step number (default: 100 » 23 steps currently in the process) |

**Value**

infercnv_obj containing filtered and transformed data

**Examples**

```r
data(infercnv_data_example)
data(infercnv_annots_example)
data(infercnv_genes_example)

infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
gene_order_file=infercnv_genes_example,
annotations_file=infercnv_annots_example,
ref_group_names=c("normal"))

infercnv_object_example <- infercnv::run(infercnv_object_example,
cutoff=1,
out_dir=tempfile(),
cluster_by_groups=TRUE,
denoise=TRUE,
HMM=FALSE,
um_threads=2,
analysis_mode="samples",
no_plot=TRUE)
```

**Description**

Apply sampling on an infercnv object to reduce the number of cells in it and allow faster plotting or have all groups take up the same height on the heatmap

**Usage**

```r
sample_object(
    infercnv_obj,
    n_cells = 100,
    every_n = NULL,
)```
above_m = NULL,
on_references = TRUE,
on_observations = TRUE
)

Arguments

infercnv_obj infercnv_object
n_cells Number of cells that should be sampled per group (default = 100).
every_n Sample 1 cell every_n cells for each group. If subclusters are defined, this will make sure that at least one cell per subcluster is sampled. Requires above_m to be set to work, overriding n_cells parameter.
above_m Sample groups that have at least above_m cells. Requires every_n to be set to work, overriding n_cells parameter
on_references boolean (default=TRUE), sample references (normal cells).
on_observations boolean (default=TRUE), sample observations data (tumor cells).

Value

sampled infercnv_obj

Examples

# data(infercnv_data_example)
# data(infercnv_annots_example)
# data(infercnv_genes_example)

# infercnv_object_example <- infercnv::CreateInfercnvObject(raw_counts_matrix=infercnv_data_example,
# gene_order_file=infercnv_genes_example,
# annotations_file=infercnv_annots_example,
# ref_group_names=c("normal"))

# infercnv_object_example <- infercnv::run(infercnv_object_example,
# cutoff=1,
# out_dir=tempfile(),
# cluster_by_groups=TRUE,
# denoise=TRUE,
# HMM=FALSE,
# num_threads=2,
# no_plot=TRUE)

data(infercnv_object_example)

infercnv_object_example <- infercnv::sample_object(infercnv_object_example, n_cells=5)
# plot result object
validate_infercnv_obj

validate_infercnv_obj

Description

validate an infercnv_obj ensures that order of genes in the @gene_order slot match up perfectly
with the gene rows in the @expr.data matrix. Otherwise, throws an error and stops execution.

Usage

validate_infercnv_obj(infercnv_obj)

Arguments

infercnv_obj infercnv_object

Value

none
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