BigSEM Developer Manual

This is the developer manual of BigSEM for those who want to contribute to the development of BigSEM program. If you only intend to use BigSEM, please check out the user's manual here.

We have developed two R packages - networksem for SEM analysis with network data, and TextSEM for SEM analysis with text data. The source codes of both packages can be found on Githhub now.

- networksem: https://github.com/iasnobmatsu/networksem
- TextSEM: https://github.com/Stan7s/TextSEM

We welcome anyone to contribute to the development of the packages. One can push the changes to the packages directly.

- The development of the networksem Package
- The development of the TextSEM Package
- The development of the online app

The development of the networksem Package

The package networksem includes various functions to analyze network data in the SEM framework. networksem has two major components.

- Functions started with sem.net: These are functions used to convert network data into SEM compatible formats and then embed those data in lavaan-based SEM analyses.
- Other functions: functions such as summary() and path.networksem() calculates values of interest such as mediation effect post-hoc.

List of functions

The following functions are available in the packages. The exported functions are:

- path.networksem
- sem.net
- sem.net.edge
- sem.net.edge.lsm
- sem.net.lsm
- summary.networksem

The following functions are not imported and are used by other functions.

- sem.net.addvar.stat
- sem.net.addvar.influential
- sem.net.addvar

sem.net

This function uses a two-stage method to obtain network statistics from networks and then fit the SEM model with them.

```
#' Fit a sem model with network data using node statistics as variables. User-specified network statistics will be calculated and used as variables instead of the networks themselves in the SEM.
#' @param model a model specified in lavaan model syntax.
#' @param data a list containing the observed non-network nodal variables and the network data
#' @param netstats a user-specified list of network statistics to be calculated and used in the SEM, e.g., c("degree", "betweenness"), available options include "degree", "betweenness", "closeness", "evcent",
```

"stresscent", and "infocent" from the "sna" package and "ivi", "hubness.score", "spreading.score" and "clusterRank" from the "influential" package

#' @param netstats.options a user-specified named list with element names corresponding to the network statistics names and element values corresponding to other lists. The list corresponding to each network statistics name has element names being the argument names for calculating the network statistics, and values being the argument values, as used in the corresponding functions in the "sna" or "influential" packages. e.g., netstats.options=list("degree"=list("cmode"="freeman"), "closeness"=list("cmode"="undirected"), "clusterRank"=list("directed"=FALSE))

#' @param netstats.rescale a list of logical value indicating whether to rescale network statistics to have mean 0 and sd 1.

#' @param data.rescale whether to rescale the whole dataset (with restructured network and nonnetwork data) to have mean 0 and standard deviation 1 when fitting it to SEM, default to FALSE

#' @param ordered parameter same as "ordered" in the lavaan sem() function; whether to treat data as ordinal

#' @param sampling.weights parameter same as "sampling.weights" in the lavaan sem() function; whether to apply weights to data

#' @param group parameter same as "group" in the lavaan sem() function; whether to fit a multigroup model

#' @param cluster parameter same as "cluster" in the lavaan sem() function; whether to fit a cluster model

#' @param constraints parameter same as "constraints" in the lavaan sem() function; whether to apply constraints to the model

#' @param WLS.V parameter same as "WLS.V" in the lavaan sem() function; whether to use WLS.V estimator

#' @param NACOV parameter same as "NACOV" in the lavaan sem() function; whether to use NACOV estimator

#' @param ... optional arguments for the sem() function

#' @return the updated model specification with the network statistics as variables and a lavaan object which is the SEM results

#' @import lavaan

#' @import sna

#' @import igraph

#' @import influential

#' @import latentnet

#' @import ergm

#' @import network

#' @export

#' @examples

#' \donttest{

#' set.seed(100)

#' nsamp = 20

#' net <- ifelse(matrix(rnorm(nsamp^2), nsamp, nsamp) > 1, 1, 0)

#' mean(net) # density of simulated network

#' lv1 <- rnorm(nsamp)

#' lv2 <- rnorm(nsamp)

```
#' nonnet <- data.frame(x1 = lv1*0.5 + rnorm(nsamp),
#'                      x2 = lv1*0.8 + rnorm(nsamp),
#'                      x3 = lv2*0.5 + rnorm(nsamp),
#'                      x4 = lv2*0.8 + rnorm(nsamp))
#'
#' model <-'
#'   lv1 =~ x1 + x2
#'   lv2 =~ x3 + x4
#'  net ~ lv2
#'   lv1 ~ net + lv2
#' '
#' data = list(network = list(net = net), nonnetwork = nonnet)
#' set.seed(100)
#' res <- sem.net(model = model, data = data, netstats = c('degree'))
#' summary(res)
#' }
sem.net <- function(model=NULL, data=NULL, netstats=NULL,
                    ordered = NULL, sampling.weights = NULL, data.rescale = FALSE,
                    netstats.rescale = FALSE, group = NULL, cluster = NULL,
                    constraints = "", WLS.V = NULL, NACOV = NULL,
                    netstats.options=NULL, ...){
  ## checking proper input
  if(is.null(model)){
    stop("required argument model is not specified.")
  }
  if(is.null(data)){
    stop("required argument data is not specified.")
  }



  params <- c(as.list(environment()), list(...))



  ## get the variable names in the model
  model.info <- lavaan::lavParseModelString(model)
  model.var <- unique(c(model.info$lhs, model.info$rhs))

  ## non-network data variable names
  data.nonnetwork.var <- names(data$nonnetwork)
```

```
  ## network data variable names
  if (!is.null(data$network)){
    data.network.var <- names(data$network)
  }

  ## find the network variables in the model
  model.network.var <- data.network.var[data.network.var %in% model.var]

  ## create variables for network data and model
  ## add network data variables to the non-network data
  model.network.stat.var.list <- list()
  if (length(model.network.var) > 0){
    if (is.null(netstats)){
      ## loop through the statistics
      for (i in 1:length(model.network.var)){
        ## call helper function, which loops over all target statistics to be used
        res.tmp <- sem.net.addvar(model.network.stat.var.list, data, c("degree"), model.network.var[i])
        model.network.stat.var.list <-res.tmp[[1]]
        data$nonnetwork <- res.tmp[[2]]
      }
    }else{
      ## loop through the variables and statistics
      for (i in 1:length(model.network.var)){
        res.tmp <- sem.net.addvar(model.network.stat.var.list, data, netstats, model.network.var[i],
netstats.rescale, netstats.options)
        model.network.stat.var.list <- res.tmp[[1]]
        data$nonnetwork <- res.tmp[[2]]
      }
    }
  }



  ## reconstruct the path model with the network variables
  ## replace the network variable name with the network variable stats name

  ## lavaanify the model
  model.lavaanify <- lavaan::lavaanify(model)

  ## get the use specified model information
  model.user <- model.lavaanify[model.lavaanify$user==1, ]
```

```
## now process each part of the user specified model
model.to.remove.index <- NULL # row index of the model items to remove
model.to.add <- ""
for (i in 1:nrow(model.user)){
  ## check if the variable on the lhs is a network variable
  if (model.user$lhs[i] %in% model.network.var && (!(model.user$rhs[i] %in% model.network.var))){
    ## if it is, record the index i and create new model items for te network
    model.to.remove.index <- c(model.to.remove.index, i)
    model.stat.var.to.add <- model.network.stat.var.list[[model.user$lhs[i]]]
    for (j in 1:length(model.stat.var.to.add)){
      model.temp <- paste0("\n", model.stat.var.to.add[j], model.user$op[i], model.user$rhs[i])
      model.to.add <- paste0(model.to.add, model.temp)
    }
  }

  ## check if the variable on the rhs is a network variable and the lhs is not
  if (model.user$rhs[i] %in% model.network.var  && (!(model.user$lhs[i] %in% model.network.var))){
    ## record the index i and create new model items
    model.to.remove.index <- c(model.to.remove.index, i)
    model.stat.var.to.add <- model.network.stat.var.list[[model.user$rhs[i]]]
    for (j in 1:length(model.stat.var.to.add)){
      model.temp <- paste0("\n", model.user$lhs[i], model.user$op[i], model.stat.var.to.add[j])
      model.to.add <- paste0(model.to.add, model.temp)
    }
  }
  ## check if both lhs and rhs are network variables
  if (model.user$rhs[i] %in% model.network.var  && model.user$lhs[i] %in% model.network.var){
    ## if it is, record the index i and create new model items
    model.to.remove.index <- c(model.to.remove.index, i)
    model.stat.var.to.add.rhs <- model.network.stat.var.list[[model.user$rhs[i]]]
    model.stat.var.to.add.lhs <- model.network.stat.var.list[[model.user$lhs[i]]]
    for (j in 1:length(model.stat.var.to.add.rhs)){
      for (k in 1:length(model.stat.var.to.add.lhs)){
        model.temp <- paste0("\n", model.stat.var.to.add.lhs[j], model.user$op[i], model.stat.var.to.add.rhs[k])
        model.to.add <- paste0(model.to.add, model.temp)
      }
    }
  }
}
```

```
  model.remove.network.var <- model.user[-model.to.remove.index, ] # remove initial model specification
  # add altered model specification
  model.non.network.var <- ""
  if (nrow(model.remove.network.var) > 0 ){
    for (i in 1:nrow(model.remove.network.var)){
      model.non.network.var.temp <- paste0(paste0(model.remove.network.var[i, c('lhs', 'op', 'rhs')], collapse = '
'))
      model.non.network.var <- paste0(model.non.network.var.temp, "\n", model.non.network.var)
    }
  }


  model.full <- paste0(model.non.network.var, "\n", model.to.add)

  # if(!is.null(community)){
  #   communities_clust <- cutree(sna::equiv.clust(network)$cluster, k=community)
  #   data["communities_clust"]<-communities_clust
  # }
  #

  # if(!is.null(community) || !is.null(group)){
  #   group <- ifelse(!is.null(community), "communities_clust", group)
  # }
  #


  lavparams <- list()
  for (i in 1:length(params)){
    if (names(params)[i] %in% names(lavaan::lavOptions())){
      lavparams[[names(params[i])]] <- params[[i]]
    }
  }


  if (data.rescale){
    for (i in 1:ncol(data$nonnetwork)){
      if (is.numeric(data$nonnetwork[,i])){
        data$nonnetwork[,i] <- scale(data$nonnetwork[,i], center = TRUE, scale = TRUE)
      }
```

```
  }
 }

 lavparams[["data"]] <- data$nonnetwork
 lavparams[["model"]] <- model.full
 lavparams[["ordered"]] <- ordered
 lavparams[["sampling.weights"]] <- sampling.weights
 lavparams[["group"]] <- group
 lavparams[["cluster"]] <- cluster
 lavparams[["constraints"]] <- constraints
 lavparams[["WLS.V"]] <- WLS.V
 lavparams[["NACOV"]] <- NACOV

 model.res <- do.call(what="sem", args=c(lavparams))



 obj <- list(model=model.full, estimates=model.res, data=data)
 class(obj) <- "networksem"
 return(obj)
}
```

sem.net.edge

This function uses a two-stage method to get latent positions and/or network statistics as variables and then fit the SEM model with them.

```
#' Fit a sem model with network data using node latent positions and/or network statistics as variables. User-specified network statistics will be calculated and used as variables instead of the networks themselves in the SEM.
#' @param model a model specified in lavaan model syntax.
#' @param data a list containing both the non-network and network data
#' @param netstats.rescale a logical value indicating whether to rescale network statistics or variables to have mean 0 and sd 1
#' @param data.rescale whether to rescale the whole dataset (with restructured network and nonnetwork data) to have mean 0 and standard deviation 1 when fitting it to SEM, default to FALSE
#' @param ordered parameter same as "ordered" in the lavaan sem() function; whether to treat data as ordinal
#' @param sampling.weights parameter same as "sampling.weights" in the lavaan sem() function; whether to apply weights to data
```

```
#' @param group parameter same as "group" in the lavaan sem() function; whether to fit a multigroup model
#' @param cluster parameter same as "cluster" in the lavaan sem() function; whether to fit a cluster model
#' @param constraints parameter same as "constraints" in the lavaan sem() function; whether to apply
constraints to the model
#' @param WLS.V parameter same as "WLS.V" in the lavaan sem() function; whether to use WLS.V estimator
#' @param NACOV parameter same as "NACOV" in the lavaan sem() function; whether to use NACOV estimator
#' @param latent.dim number of network latent dimensions to use
#' @param ... optional arguments for the sem() function
#' @return the updated model specification with the network statistics as variables and a lavaan object which is
the SEM results
#' @export
#' @examples
#' \dontrun{
#' \donttest{
#' set.seed(10)
#' nsamp = 20
#' net <- ifelse(matrix(rnorm(nsamp^2), nsamp, nsamp) > 1, 1, 0)
#' mean(net) # density of simulated network
#' lv1 <- rnorm(nsamp)
#' lv2 <- rnorm(nsamp)
#' nonnet <- data.frame(x1 = lv1*0.5 + rnorm(nsamp),
#'                      x2 = lv1*0.8 + rnorm(nsamp),
#'                      x3 = lv2*0.5 + rnorm(nsamp),
#'                      x4 = lv2*0.8 + rnorm(nsamp))
#'
#' model <-'
#'   lv1 =~ x1 + x2
#'   lv2 =~ x3 + x4
#'   net ~ lv2
#'   lv1 ~ net + lv2
#' '
#' data = list(network = list(net = net), nonnetwork = nonnet)
#' set.seed(100)
#' res <- sem.net.lsm(model = model, data = data, latent.dim = 2)
#' summary(res)
#' }}
sem.net.lsm <- function(model=NULL, data=NULL, latent.dim = 2,
                        ordered = NULL, sampling.weights = NULL, data.rescale=FALSE,
                        netstats.rescale=FALSE, group = NULL, cluster = NULL,
                        constraints = "", WLS.V = NULL, NACOV = NULL, ...){
```

```
 ## checking proper input
 if(is.null(model)){
   stop("required argument model is not specified.")
 }
 if(is.null(data)){
   stop("required argument data is not specified.")
 }

params <- c(as.list(environment()), list(...))



 ## get the variable names in the model
 model.info <- lavaan::lavParseModelString(model)
 model.var <- unique(c(model.info$lhs, model.info$rhs))

 ## non-network data variable names
 data.nonnetwork.var <- names(data$nonnetwork)

 ## network data variable names
 if (!is.null(data$network)){
   data.network.var <- names(data$network)
 }
 latent.network = data.network.var

 ## find the network variables in the model
 model.network.var <- data.network.var[data.network.var %in% model.var]

 ## create variables for network data and model
 ## add network data variables to the non-network data

 latent.vars <- list()
 model.lavaanify <- lavaan::lavaanify(model)

 ## get the use specified model information
 model.user <- model.lavaanify[model.lavaanify$user==1, ]



 ## estimate network latent positions
 lsm.fits <- list()
 for (i in 1:length(latent.network)){
```

```
    fit <- latentnet::ergmm(network::network(data$network[[latent.network[i]]]) ~ euclidean(d = latent.dim))
    lsm.fits[[i]] <-fit
    latent.vars[[latent.network[i]]] <- c()
    for (dimind in 1:latent.dim){
      data$nonnetwork[paste0(latent.network[i], ".Z", dimind)] <- fit$mcmc.mle$Z[,dimind]
      if (netstats.rescale){
        data$nonnetwork[paste0(latent.network[i], ".Z", dimind)] <- scale(fit$mcmc.mle$Z[,dimind], center =
TRUE, scale = TRUE)
      }
      latent.vars[[latent.network[i]]] <- c(latent.vars[[latent.network[i]]], paste0(latent.network[i], ".Z", dimind))
    }
  }

  # print(lsm.fits)




  ## reconstruct the path model with the network variables
  ## replace the network variable name with the network variable stats name

  ## lavaanify the model
  model.lavaanify <- lavaan::lavaanify(model)

  ## get the use specified model information
  model.user <- model.lavaanify[model.lavaanify$user==1, ]


  ## now process each part of the user specified model
  model.to.remove.index <- NULL
  model.to.add <- ""
  for (i in 1:nrow(model.user)){
    ## check if left is network with LSM, remake
    if (model.user$lhs[i] %in% latent.network){
      model.to.remove.index <- c(model.to.remove.index, i)
      model.stat.var.to.add <- latent.vars[[model.user$lhs[i]]]
      for (j in 1:length(model.stat.var.to.add)){
        model.temp <- paste0("\n ", model.stat.var.to.add[j], model.user$op[i], model.user$rhs[i])
        model.to.add <- paste0(model.to.add, model.temp)
      }
```

```
  }
  ## check if right is network with LSM and left is other variables
  if (model.user$rhs[i] %in% latent.network){
    model.to.remove.index <- c(model.to.remove.index, i)
    model.stat.var.to.add <- latent.vars[[model.user$rhs[i]]]
    for (j in 1:length(model.stat.var.to.add)){
      model.temp <- paste0("\n ",  model.user$lhs[i], model.user$op[i],  model.stat.var.to.add[j])
      model.to.add <- paste0(model.to.add, model.temp)
    }
  }
}

if (!is.null(model.to.remove.index)){
  model.remove.network.var <- model.user[-model.to.remove.index, ]
}

model.non.network.var <- ""
if(nrow(model.remove.network.var) > 0){
  for (i in 1:nrow(model.remove.network.var)){
    model.non.network.var.temp <- paste0(paste0(model.remove.network.var[i, c('lhs', 'op', 'rhs')], collapse = '
'))
    model.non.network.var <- paste0(model.non.network.var.temp, "\n", model.non.network.var)
  }
}



model.full <- paste0(model.non.network.var, "\n", model.to.add)




lavparams <- list()
for (i in 1:length(params)){
  if (names(params)[i] %in% names(lavOptions())){
    lavparams[[names(params[i])]] <- params[[i]]
  }
}

if (data.rescale){
  for (i in 1:ncol(data$nonnetwork)){
    if (is.numeric(data$nonnetwork[,i])){
```

```
      data$nonnetwork[,i] <- scale(data$nonnetwork[,i], center = TRUE, scale = TRUE)
    }
   }
  }

  lavparams[["data"]] <- data$nonnetwork
  lavparams[["model"]] <- model.full
  lavparams[["ordered"]] <- ordered
  lavparams[["sampling.weights"]] <- sampling.weights
  lavparams[["group"]] <- group
  lavparams[["cluster"]] <- cluster
  lavparams[["constraints"]] <- constraints
  lavparams[["WLS.V"]] <- WLS.V
  lavparams[["NACOV"]] <- NACOV

  model.res <- do.call(what="sem", args=c(lavparams))



  obj <- list(model=model.full, estimates=list(sem.es=model.res,lsm.es=lsm.fits), data=data)
  class(obj) <- "networksem"
  return(obj)
}
```

sem.net.lsm

This function will first get the edge information and the fit a sem model.

```
#' Fit a sem model with network data using edges as variables. User-specified network statistics will be calculated and used as variables instead of the networks themselves in the SEM.
#' @param model a model specified in lavaan model syntax.
#' @param data a list containing both the non-network and network data
#' @param type "difference" for using the difference between the network statistics of the two actors as the edge covariate; "average" for using the average of the network statistics of the two actors as the edge covariate
#' @param ordered parameter same as "ordered" in the lavaan sem() function; whether to treat data as ordinal
#' @param data.rescale whether to rescale the whole dataset (with restructured network and nonnetwork data) to have mean 0 and standard deviation 1 when fitting it to SEM, default to FALSE
#' @param netstats.rescale a logical value indicating whether to rescale network statistics or variables to have mean 0 and sd 1
```

```
#' @param sampling.weights parameter same as "sampling.weights" in the lavaan sem() function; whether to apply weights to data
#' @param group parameter same as "group" in the lavaan sem() function; whether to fit a multigroup model
#' @param cluster parameter same as "cluster" in the lavaan sem() function; whether to fit a cluster model
#' @param constraints parameter same as "constraints" in the lavaan sem() function; whether to apply constraints to the model
#' @param WLS.V parameter same as "WLS.V" in the lavaan sem() function; whether to use WLS.V estimator
#' @param NACOV parameter same as "NACOV" in the lavaan sem() function; whether to use NACOV estimator
#' @param ... optional arguments for the sem() function
#' @return the updated model specification and a lavaan object which is the SEM results, and the data generated
#' @export
#' @examples
#' \dontrun{
#' \donttest{
#' set.seed(100)
#' nsamp = 20
#' net <- data.frame(ifelse(matrix(rnorm(nsamp^2), nsamp, nsamp) > 1, 1, 0))
#' mean(net) # density of simulated network
#' lv1 <- rnorm(nsamp)
#' lv2 <- rnorm(nsamp)
#' nonnet <- data.frame(x1 = lv1*0.5 + rnorm(nsamp),
#'                      x2 = lv1*0.8 + rnorm(nsamp),
#'                      x3 = lv2*0.5 + rnorm(nsamp),
#'                      x4 = lv2*0.8 + rnorm(nsamp))
#'
#' model <-'
#'   lv1 =~ x1 + x2
#'   lv2 =~ x3 + x4
#'   lv1 ~ net
#'   lv2 ~ lv1
#' '
#' data = list(network = list(net = net), nonnetwork = nonnet)
#' set.seed(100)
#' res <- sem.net.edge(model = model, data = data, type = 'difference')
#' summary(res)
#' }}
sem.net.edge <- function(model = NULL, data = NULL, type = "difference",
                         ordered = NULL, sampling.weights = NULL, data.rescale = FALSE,
                         group = NULL, cluster = NULL, netstats.rescale = FALSE,
```

```
                constraints = "", WLS.V = NULL, NACOV = NULL,
                ...){
  ## checking proper input
  if(is.null(model)){
    stop("required argument model is not specified.")
  }
  if(is.null(data)){
    stop("required argument data is not specified.")
  }


 params <- c(as.list(environment()), list(...))



  ## get the variable names in the model
  model.info <- lavParseModelString(model)
  model.var <- unique(c(model.info$lhs, model.info$rhs))

  ## non-network data variable names
  data.nonnetwork.var <- names(data$nonnetwork)

  ## network data variable names
  if (!is.null(data$network)){
    data.network.var <- names(data$network)
  }

  ## find the network variables in the model
  model.network.var <- data.network.var[data.network.var %in% model.var]

  ## create variables for network data and model
  ## add network data variables to the non-network data
  model.network.stat.var.list <- list()
  data_edge = data.frame(row_actor=rep(NA, nrow(data$nonnetwork)^2), col_actor=rep(NA,
nrow(data$nonnetwork)^2))
  for (i in 1:length(model.network.var)){
    data_edge[model.network.var[i]]=NA
  }
  if (length(model.network.var)>0){
      for (i in 1:nrow(data$nonnetwork)){
        for (j in 1:nrow(data$nonnetwork)){
```

```
        data_edge[j+(i-1)*nrow(data$nonnetwork), "row_actor"]=i
        data_edge[j+(i-1)*nrow(data$nonnetwork), "col_actor"]=j
        for (netind in 1:length(model.network.var)){
          data_edge[j+(i-1)*nrow(data$nonnetwork), model.network.var[netind]]=data$network[[netind]][i,j]

        }
       }
     }
  }

  if(netstats.rescale){
    for (netind in 1:length(model.network.var)){
      data_edge[model.network.var[netind]]=scale(data_edge[model.network.var[netind]], center=TRUE,
scale=TRUE)
    }
  }



  #print(model.network.stat.var.list)
  ## reconstruct the path model with the network variables
  ## replace the network variable name with the network variable stats name

  ## lavaanify the model
  model.lavaanify <- lavaanify(model)

  ## get the use specified model information
  model.user <- model.lavaanify[model.lavaanify$user==1, ]

  ## now process each part of the user specified model
  model.to.remove.index <- NULL
  model.to.add <- ""

  variables.to.change=c()
  for (i in 1:nrow(model.user)){
    ## check if the variable on the lhs is a nonnetwork variable
    if (model.user$lhs[i] %in% colnames(data$nonnetwork) && !model.user$lhs[i] %in% model.network.var){
      variables.to.change <- c(variables.to.change, model.user$lhs[i])
    }
    if (model.user$rhs[i] %in% colnames(data$nonnetwork) && !model.user$rhs[i] %in% model.network.var){
```

```
    variables.to.change <- c(variables.to.change, model.user$rhs[i])
  }
}



for (i in 1:length(variables.to.change)){
  data_edge[variables.to.change[i]]=NA
}

if (length(variables.to.change)>0){
  for (vind in 1:length(variables.to.change)){
    v_row <- rep(data$nonnetwork[variables.to.change[vind]][[1]], each=nrow(data$nonnetwork))
    v_col <- rep(data$nonnetwork[variables.to.change[vind]][[1]], nrow(data$nonnetwork))
    if (type=="difference"){
      data_edge[variables.to.change[vind]] <- v_row - v_col
    }else if (type=="average"){
      data_edge[variables.to.change[vind]] <- (v_row + v_col)/2
    }

  }
}




lavparams <- list()
for (i in 1:length(params)){
  if (names(params)[i] %in% names(lavOptions())){
    lavparams[[names(params[i])]] <- params[[i]]
  }
}

if (data.rescale){
  for (i in 1:ncol(data_edge)){
    if (is.numeric(data_edge[,i])){
      data_edge[,i] <- scale(data_edge[,i], center = TRUE, scale = TRUE)
    }
  }
}
```

```
  lavparams[["data"]] <- data_edge
  lavparams[["model"]] <- model
  lavparams[["ordered"]] <- ordered
  lavparams[["sampling.weights"]] <- sampling.weights
  lavparams[["group"]] <- group
  lavparams[["cluster"]] <- cluster
  lavparams[["constraints"]] <- constraints
  lavparams[["WLS.V"]] <- WLS.V
  lavparams[["NACOV"]] <- NACOV

  model.res <- do.call(what="sem", args=c(lavparams))



  obj <- list(model=model, estimates=model.res, data=data_edge)
  class(obj) <- "networksem"
  return(obj)
}
```

sem.net.edge.lsm

This function fits fits a sem model with network data using latent distances between actors as variables.

```
#' Fit a sem model with network data using latent distances between actors as variables
#' @param model a model specified in lavaan model syntax.
#' @param data a list containing both the non-network and network data
#' @param type "difference" for using the difference between the network statistics of the two actors as the edge covariate; "average" for using the average of the network statistics of the two actors as the edge covariate
#' @param ordered parameter same as "ordered" in the lavaan sem() function; whether to treat data as ordinal
#' @param sampling.weights parameter same as "sampling.weights" in the lavaan sem() function; whether to apply weights to data
#' @param data.rescale whether to rescale the whole dataset (with restructured network and nonnetwork data) to have mean 0 and standard deviation 1 when fitting it to SEM, default to FALSE
#' @param netstats.rescale a logical value indicating whether to rescale network statistics or variables to have mean 0 and sd 1
#' @param group parameter same as "group" in the lavaan sem() function; whether to fit a multigroup model
#' @param cluster parameter same as "cluster" in the lavaan sem() function; whether to fit a cluster model
#' @param constraints parameter same as "constraints" in the lavaan sem() function; whether to apply constraints to the model
```

```
#' @param WLS.V parameter same as "WLS.V" in the lavaan sem() function; whether to use WLS.V estimator
#' @param NACOV parameter same as "NACOV" in the lavaan sem() function; whether to use NACOV estimator
#' @param latent.dim number of network latent dimensions to use
#' @param ... optional arguments for the sem() function
#' @return the updated model specification with the network statistics as variables and a lavaan object which is the SEM results, also the data generated
#' @export
#' @examples
#' \dontrun{
#' \donttest{
#' set.seed(10)
#' nsamp = 20
#' lv1 <- rnorm(nsamp)
#' net <- ifelse(matrix(rnorm(nsamp^2) , nsamp, nsamp) > 1, 1, 0)
#' lv2 <- rnorm(nsamp)
#' nonnet <- data.frame(x1 = lv1*0.5 + rnorm(nsamp),
#'                      x2 = lv1*0.8 + rnorm(nsamp),
#'                      x3 = lv2*0.5 + rnorm(nsamp),
#'                      x4 = lv2*0.8 + rnorm(nsamp))
#'
#' model <-'
#'   lv1 =~ x1 + x2
#'   lv2 =~ x3 + x4
#'   net ~ lv1
#'   lv2 ~ net
#' '
#' data = list(network = list(net = net), nonnetwork = nonnet)
#' set.seed(100)
#' res <- sem.net.edge.lsm(model = model, data = data, latent.dim = 1)
#' summary(res)
#' }}
sem.net.edge.lsm <- function(model=NULL, data=NULL, type="difference",
                             latent.dim = 2, data.rescale = FALSE,
                    ordered = NULL, sampling.weights = NULL,
                    group = NULL, cluster = NULL, netstats.rescale = FALSE,
                    constraints = "", WLS.V = NULL, NACOV = NULL,
                    ...){
  ## checking proper input
  if(is.null(model)){
    stop("required argument model is not specified.")
```

```
  }
  if(is.null(data)){
    stop("required argument data is not specified.")
  }


 params <- c(as.list(environment()), list(...))


  ## get the variable names in the model
  model.info <- lavParseModelString(model)
  model.var <- unique(c(model.info$lhs, model.info$rhs))


  ## non-network data variable names
  data.nonnetwork.var <- names(data$nonnetwork)


  ## network data variable names
  if (!is.null(data$network)){
    data.network.var <- names(data$network)
  }


  ## find the network variables in the model
  model.network.var <- data.network.var[data.network.var %in% model.var]
  latent.network <- model.network.var


  data_edge = data.frame(row_actor=rep(NA, nrow(data$nonnetwork)^2), col_actor=rep(NA,
nrow(data$nonnetwork)^2))

  for (i in 1:length(model.network.var)){
    data_edge[model.network.var[i]]=NA
  }
  if (length(model.network.var)>0){
    for (i in 1:nrow(data$nonnetwork)){
      for (j in 1:nrow(data$nonnetwork)){
        data_edge[j+(i-1)*nrow(data$nonnetwork), "row_actor"]=i
        data_edge[j+(i-1)*nrow(data$nonnetwork), "col_actor"]=j
```

```
      for (netind in 1:length(model.network.var)){
        data_edge[j+(i-1)*nrow(data$nonnetwork),model.network.var[netind]]=data$network[[netind]][i,j]
      }
    }
  }
}



latent.vars <- list()
lsm.fits <- list()
fit.prev <- NULL
cov.mani <- list()
edgeatt <- list()

model.lavaanify <- lavaan::lavaanify(model)

## get the use specified model information
model.user <- model.lavaanify[model.lavaanify$user==1, ]



## change nonnetwork variable to be pairwise
variables.to.change=c()
for (i in 1:nrow(model.user)){
  ## check if the variable on the lhs is a nonnetwork variable
  if (model.user$lhs[i] %in% colnames(data$nonnetwork) && !model.user$lhs[i] %in% model.network.var){
    variables.to.change <- c(variables.to.change, model.user$lhs[i])
  }
  if (model.user$rhs[i] %in% colnames(data$nonnetwork) && !model.user$rhs[i] %in% model.network.var){
    variables.to.change <- c(variables.to.change, model.user$rhs[i])
  }
}



for (i in 1:length(variables.to.change)){
  data_edge[variables.to.change[i]]=NA
}

if (length(variables.to.change)>0){
  for (vind in 1:length(variables.to.change)){
```

```
    v_row <- rep(data$nonnetwork[variables.to.change[vind]][[1]], each = nrow(data$nonnetwork))
    v_col <- rep(data$nonnetwork[variables.to.change[vind]][[1]], nrow(data$nonnetwork))
    if (type=="difference"){
      data_edge[variables.to.change[vind]] <- v_row - v_col
    }else if (type=="average"){
      data_edge[variables.to.change[vind]] <- (v_row + v_col)/2
    }

  }
}



## estimate network latent positions
lsm.fits <- list()
for (i in 1:length(latent.network)){
  fit <- latentnet::ergmm(network::network(data$network[[latent.network[i]]]) ~ euclidean(d = latent.dim))
  lsm.fits[[i]] <-fit
  latent.vars[[latent.network[i]]] <- c()
  for (dimind in 1:latent.dim){
    distsum <- 0
    for (dimind in 1:latent.dim){
      distsum = distsum + outer(fit$mcmc.mle$Z[,dimind], fit$mcmc.mle$Z[,dimind], "-")^2
    }
    dists <- array(t(sqrt(distsum)))

    data_edge[paste0(model.network.var[i], ".dists")] <- dists
    if (netstats.rescale){
      data_edge[paste0(model.network.var[i], ".dists")] <- scale(dists, center = TRUE, scale = TRUE)
    }
    latent.vars[[model.network.var[i]]] <- c(paste0(model.network.var[i], ".dists"))
  }
}

# print(lsm.fits)



#print(model.network.stat.var.list)
## reconstruct the path model with the network variables
## replace the network variable name with the network variable stats name
```

```
  ## lavaanify the model
  model.lavaanify <- lavaan::lavaanify(model)

  ## get the use specified model information
  model.user <- model.lavaanify[model.lavaanify$user==1, ]



  ## now process each part of the user specified model
  model.to.remove.index <- NULL
  model.to.add <- ""
  model.to.remove.index <- NULL
  model.to.add <- ""
  for (i in 1:nrow(model.user)){
    ## check if left is network with LSM, remake
    if (model.user$lhs[i] %in% latent.network){
      model.to.remove.index <- c(model.to.remove.index, i)
      model.stat.var.to.add <- latent.vars[[model.user$lhs[i]]]
      for (j in 1:length(model.stat.var.to.add)){
        model.temp <- paste0("\n ", model.stat.var.to.add[j], model.user$op[i], model.user$rhs[i])
        model.to.add <- paste0(model.to.add, model.temp)
      }
    }
    ## check if right is network with LSM and left is other variables
    if (model.user$rhs[i] %in% latent.network){
      model.to.remove.index <- c(model.to.remove.index, i)
      model.stat.var.to.add <- latent.vars[[model.user$rhs[i]]]
      for (j in 1:length(model.stat.var.to.add)){
        model.temp <- paste0("\n ",  model.user$lhs[i], model.user$op[i],  model.stat.var.to.add[j])
        model.to.add <- paste0(model.to.add, model.temp)
      }
    }
  }



  model.remove.network.var <- model.user[-model.to.remove.index, ]
  model.non.network.var <- ""
  if (nrow(model.remove.network.var)>0){
    for (i in 1:nrow(model.remove.network.var)){
      model.non.network.var.temp <- paste0(paste0(model.remove.network.var[i, c('lhs', 'op', 'rhs')], collapse = '
'))
```

```
    model.non.network.var <- paste0(model.non.network.var.temp, "\n", model.non.network.var)
  }
}



model.full <- paste0(model.non.network.var, "\n", model.to.add)




lavparams <- list()
for (i in 1:length(params)){
  if (names(params)[i] %in% names(lavOptions())){
    lavparams[[names(params[i])]] <- params[[i]]
  }
}

if (data.rescale){
  for (i in 1:ncol(data_edge)){
    if (is.numeric(data_edge[,i])){
      data_edge[,i] <- scale(data_edge[,i], center = TRUE, scale = TRUE)
    }
  }
}

lavparams[["data"]] <- data_edge
lavparams[["model"]] <- model.full
lavparams[["ordered"]] <- ordered
lavparams[["sampling.weights"]] <- sampling.weights
lavparams[["group"]] <- group
lavparams[["cluster"]] <- cluster
lavparams[["constraints"]] <- constraints
lavparams[["WLS.V"]] <- WLS.V
lavparams[["NACOV"]] <- NACOV

model.res <- do.call(what="sem", args=c(lavparams))
```

```
  obj <- list(model=model.full, estimates=list(sem.es=model.res,lsm.es=lsm.fits), data = data_edge)
  class(obj) <- "networksem"
  return(obj)
}
```

summary.networksem

This method function works for the networksem object to print nice information from the analysis.

```
#' Summarize output from networksem
#' @param object a networksem output
#' @param ... optional arguments
#' @return a summary of the output
#' @export
summary.networksem <- function(object,...){

  res = object
  otype = "obs"
  if (class(res$estimates)=="list"){
    otype = "lsm"
  }

#   cat("The reconstructed model:\n")
#   cat(res$model)
#   cat("\n\n")

  if (otype == "obs"){
    lvsummary <- getMethod("summary",signature(object="lavaan"))
    cat("The SEM output:\n")
    print(lvsummary(res$estimates, fit = T))
  }else{
    lvsummary <- getMethod("summary",signature(object="lavaan"))

    # just fit info
    semsum <- lvsummary(res$estimates$sem.es)
    teststats <- semsum$test$standard$stat
    df <- semsum$test$standard$df
    pval <- semsum$test$standard$pval
    cat("Model Fit Information")
    cat("SEM Test statistics: ", teststats, "on", df, "df with p-value: ", pval, "\n")
```

```
    for (i in 1:length(res$estimates$lsm.es)){
      lsmsum <- summary(res$estimates$lsm.es[[i]])
      bic <- lsmsum$bic$overall
      cat("network", i, "LSM BIC: ", bic, "\n")
    }
    cat("========================================= \n")
    cat("=========================================\n\n")

    # full output
    cat("The SEM output:\n")
    print(lvsummary(res$estimates$sem.es, fit = T))
    cat("The LSM output:\n")
    for (lsmout in res$estimates$lsm.es){
      print(summary(lsmout))
    }
  }
}
.S3method("summary", "networksem", "summary.networksem")
```

path.networksem

This function can be used to calculate a mediation effect.

```
#' Calculate a mediation effect from a networksem model
#' @param res a networksem output file
#' @param predictor a character string of the predictor variable
#' @param mediator a character string of the mediator variable
#' @param outcome a character string of the outcome variable
#' @return a target path, associated estimates, and z-score
#' @export
path.networksem <- function(res, predictor, mediator, outcome){
  # only allow 1 predictor and 1 outcome
  if (length(predictor) > 1 | length(outcome) > 1){
    stop("Only 1 predictor and 1 outcome are allowed")
  }
```

```
  otype = "obs"
  if (class(res$estimates)=="list"){
    otype = "lsm"
  }

  if (otype == "obs"){
    pars <- parameterEstimates(res$estimates)
    covm <- vcov(res$estimates)
  }else{
    pars <- parameterEstimates(res$estimates$sem.es)
    covm <- vcov(res$estimates$sem.es)
  }



  effect_table <- expand.grid("predictor" = predictor,
                              "mediator" = mediator,
                              "outcome" = outcome)
  effect_table$apath = NA; effect_table$bpath = NA; effect_table$indirect = NA;
  effect_table$indirect_se = NA; effect_table$indirect_z = NA;



  for (i in 1:nrow(effect_table)){

    # estimates of a and b paths
    effect_table$apath[i] <- pars[pars$rhs == effect_table$predictor[i] & pars$lhs == effect_table$mediator[i],
"est"]
    effect_table$bpath[i] <- pars[pars$rhs == effect_table$mediator[i] & pars$lhs == effect_table$outcome[i],
"est"]
    effect_table$indirect[i] <- effect_table$apath[i]*effect_table$bpath[i]



    # indirect effect se usinh sobel
    headera = paste0(effect_table$mediator[i], "~", effect_table$predictor[i])
    headerb = paste0(effect_table$outcome[i], "~", effect_table$mediator[i])
    abcov = covm[c(headera, headerb), c(headera, headerb)]
    a <- effect_table$apath[i]
    b <- effect_table$bpath[i]
    ab_vector <- c(a, b)
    var_ab <- t(ab_vector) %*% abcov %*% ab_vector
    effect_table$indirect_se[i] <- sqrt(var_ab)
```

```
    effect_table$indirect_z[i] <- effect_table$indirect[i]/effect_table$indirect_se[i]

  }

  return(effect_table)
}
```

sem.net.addvar.stat

```
#' Compute a list of user-specified network statistics values using the "sna" package and add them to the non-network data.
#' @param data a list containing both the non-network and network data
#' @param model.network.stat.var.list a list of elements with names corresponding to the network names and values corresponding to lists of network statistics that will be calculated for the corresponding network
#' @param model.network.var.i an index indicating a specific network within all networks
#' @param stats a network statistics that can be calculated using package "sna"
#' @param statsname name of the network statistics
#' @param netstats.rescale a logical value indicating whether to rescale network statistics to have mean 0 and sd 1
#' @param netstats.options a list with names being the argument names for calculating the network statistics, and values being the argument values
#' @return a list with the first value being the list of network statistics names and the second value being the data frame with added network statistics
sem.net.addvar.stat <- function(model.network.stat.var.list, data, model.network.var.i, stats, statsname, netstats.rescale, netstats.options=NULL){
  degree <- sna::degree
  betweenness <- sna::betweenness
  closeness <- sna::closeness
  ## create the network stats variable name
  model.network.stat.var <- paste0(model.network.var.i, ".", statsname)

  ## add network statistics to the variable list
  model.network.stat.var.list[[model.network.var.i]] <- c(model.network.stat.var.list[[model.network.var.i]], model.network.stat.var)



  ## using do.call to calculate the network statistics in variable list, add statistics to nonnetwork data
  args <- list("dat"=data$network[[model.network.var.i]])
```

```
  args <- c(args, netstats.options)
  data$nonnetwork[[model.network.stat.var]] <- do.call(what=stats, args=args)



  # scale
  if(netstats.rescale){
    data$nonnetwork[model.network.stat.var] <- scale(data$nonnetwork[model.network.stat.var])
  }

  return(list(model.network.stat.var.list, data$nonnetwork))
}
```

sem.net.addvar.influential

```
#' Compute a list of user-specified network statistics using the "influential" package and add it to the existing data.
#' @param model.network.stat.var.list a list of elements with names corresponding to the network names and values corresponding to lists of network statistics that will be calculated for the corresponding network
#' @param data a list containing both the non-network and network data
#' @param model.network.var.i an index indicating a specific network within all networks
#' @param stats a network statistics that can be calculated using package "influential"
#' @param statsname name of the network statistics
#' @param netstats.rescale a logical value indicating whether to rescale network statistics to have mean 0 and sd 1
#' @param netstats.options a list with names being the argument names for calculating the network statistics, and values being the argument values
#' @return a list with the first value being the list of network statistics names and the second value being the data frame with added network statistics
sem.net.addvar.influential <- function(model.network.stat.var.list, data, model.network.var.i, stats, statsname, netstats.rescale, netstats.options=NULL){
  ## create the network stats variable name
  model.network.stat.var <- paste0(model.network.var.i, ".", statsname)

  ## add network statistics to the variable list
  model.network.stat.var.list[[model.network.var.i]] <- c(model.network.stat.var.list[[model.network.var.i]], model.network.stat.var)
```

```
  ## using do.call to calculate the network statistics in variable list, add statistics to nonnetwork data
  args <- list("graph"=graph_from_adjacency_matrix(data$network[[model.network.var.i]]))
  args <- c(args, netstats.options)
  data$nonnetwork[[model.network.stat.var]] <- do.call(what=stats, args=args)

  # scale
  if(netstats.rescale){
    data$nonnetwork[model.network.stat.var] <- scale(data$nonnetwork[model.network.stat.var])
  }

  return(list(model.network.stat.var.list, data$nonnetwork))
}
```

sem.net.addvar

```
#' Compute user-specified network statistics for a specific network.
#' @param model.network.stat.var.list  a list of elements with names corresponding to the network names and values corresponding to lists of network statistics that will be calculated for the corresponding network
#' @param data a list containing both the non-network and network data
#' @param netstats a list of user-specified network statistics
#' @param model.network.var.i the index of a network within all networks
#' @param netstats.rescale a logical value indicating whether to rescale network statistics to have mean 0 and sd 1
#' @param netstats.options a list with element names corresponding to the network statistics and element values corresponding to another list. The list corresponding to each network statistics has element names being the argument names for calculating the network statistics, and values being the argument values
#' @return a list with the first value being the list of network statistics names and the second value being the data frame with added network statistics variables
sem.net.addvar <- function(model.network.stat.var.list=NULL, data=NULL, netstats=NULL, model.network.var.i=NULL, netstats.rescale=TRUE, netstats.options=NULL){
  res.list<-list()
  for (stat in netstats){

    if( stat %in% c("degree", "closeness", "betweenness", "evcent", "stresscent", "infocent")){
      # sna
      res.list<-sem.net.addvar.stat(model.network.stat.var.list, data, model.network.var.i, stats=stat, statsname=stat,  netstats.rescale, netstats.options[[stat]])
    }else{
```

```
      # influential
      res.list<-sem.net.addvar.influential(model.network.stat.var.list, data, model.network.var.i, stats=stat,
statsname=stat,  netstats.rescale, netstats.options[[stat]])
    }
    model.network.stat.var.list <- res.list[[1]]
    data$nonnetwork <- res.list[[2]]
  }
  return(res.list)
}
```

The development of the TextSEM Package

The package TextSEM includes various functions to analyze text data in the SEM framework.

List of functions

The following functions are available in the packages. The exported functions are:

- sem.sentiment for dictionary based sentiment analysis
- sem.encode and sem.emb for sentence embedding based analysis
- sem.topic for analysis based on topic modeling

sem.sentiment

```
#' Structural Equation Modeling with Sentiment Analysis
#'
#' This function integrates sentiment analysis into a structural equation model (SEM) by calculating sentiment scores for specified text variables and incorporating them as additional variables in the SEM.
#'
#' @param model The structural equation model specified as a character string.
#' @param df A data frame containing the input data.
#' @param text_vars A character vector of text variable names in the data frame for which sentiment analysis should be performed.
#' @param text_stats A character vector of text sentiment statistics to be added to the SEM. Currently supports only 'OverallSenti' (overall sentiment).
#' @param polarity_dt A data table for polarity lexicon to be used for sentiment analysis. Defaults to `lexicon::hash_sentiment_jockers_rinker`.
#' @param valence_shifters_dt A data table for valence shifters to be used for sentiment analysis. Defaults to `lexicon::hash_valence_shifters`.
#' @param missing The method for handling missing data in the SEM. Defaults to 'ML' (maximum likelihood).
#' @param fixed.x Logical. If `TRUE`, the exogenous variables are treated as fixed. Defaults to `FALSE`.
#' @param ... Additional arguments passed to the `sentiment_by` function from the `sentimentr` package and to the `sem` function from the `lavaan` package.
#'
```

```
#' @return A list containing three items:
#' \item{model}{A character string representing the modified SEM with added sentiment variables.}
#' \item{data}{A data frame with added text sentiment statistics.}
#' \item{estimates}{The fitted SEM model object.}
#' @importFrom lavaan lavParseModelString lavaanify sem
#' @importFrom sentimentr sentiment_by
#' @importFrom data.table rbindlist
#' @importFrom sentiment.ai sentiment_score
#' @export
#'
sem.sentiment <- function(model,
                  df,
                  text_vars,
                  method="sentimentr",
                  text_stats=c('sentiment'),
                  polarity_dt = lexicon::hash_sentiment_jockers_rinker,
                  valence_shifters_dt = lexicon::hash_valence_shifters,
                  missing = 'ML',
                  fixed.x = FALSE,
                  ...){

 ## parse the model
 model_info <- lavParseModelString(model)
 model_var <- unique(c(model_info$lhs, model_info$rhs))

 ## get the list of text variables in the model
 text_vars <- text_vars[text_vars %in% model_var]
 # print("text_vars")
 # print(text_vars)

 N <- length(text_vars) # Number of text variables
 if (N > 0){
  ## now get the sentiment score of the text
  text_scores <- list()

  batch_sentiment <- function(text, batch_size = 200, ...) {
   if(method == "sentimentr"){
    text_batches <- split(text, ceiling(seq_along(text) / batch_size))
    scores <- data.table::rbindlist(lapply(text_batches, sentiment_by))$ave_sentiment
   }else if(method == "sentiment.ai"){
```

```
    scores <- unname(sentiment_score(text))
  }
  return(scores)
}

for(i in 1:N){
  sentiment_result <- batch_sentiment(df[, text_vars[i]]) # Compute sentiment scores
  text_scores[[i]] <- sentiment_result
}
names(text_scores) <- text_vars
# print("text_score")
# print(as.data.frame(text_score))

print("456")
data_new <- cbind(df, as.data.frame(text_scores))
names(data_new) <- c(names(df), paste0(rep(text_vars, each = length(text_stats)), '.', text_stats))
print("data_new")
print(names(data_new))

model_lavaanify <- lavaanify(model)
model_user <- model_lavaanify[model_lavaanify$user==1, ]
# print("model_user")
# print(model_user)

model_new <- c()
for(i in 1:nrow(model_user)){
  row <- model_user[i,]
  # print(row)
  if((row['lhs'] %in% text_vars) && (row['rhs'] %in% text_vars)){
    model_new <- c(model_new, paste0(rep(paste0(row['lhs'], '.', text_stats), each = length(text_stats)),
                                     ' ', row['op'], ' ', rep(paste0(row['rhs'], '.', text_stats), length(text_stats))))
  } else if(row['lhs'] %in% text_vars){
    model_new <- c(model_new, paste0(row['lhs'], '.', text_stats, ' ', row['op'], ' ', row['rhs']))
  } else if(row['rhs'] %in% text_vars){
    model_new <- c(model_new, paste0(row['lhs'], ' ', row['op'], ' ', row['rhs'], '.', text_stats))
  } else{
    model_new <- c(model_new, paste0(row['lhs'],  ' ', row['op'], ' ', row['rhs']))
  }
}
# print(model_new)
```

```
    # model_new <- paste0(model_new, collapse = '\n')
  }
  model_res <- sem(model=model_new, data=data_new,
                   missing = missing, fixed.x = fixed.x)

  return(list(model=model_new, data=data_new, estimates=model_res))
}
```

sem.encode

```
#' Generate Sentence Embeddings using Sentence Transformers
#'
#' This function generates sentence embeddings for a given vector of text using a specified pre-trained model from the `sentence_transformers` Python package.
#'
#' @param text_vector A character vector containing the text data to be embedded.
#' @param encoder A character string specifying the name of the pre-trained model to be used for generating embeddings.
#' @param reduce_method Dimension reduction method for embeddings. Can be either "SVD" or "PCA".
#' @param reduce_dim An integer denoting the size of embedding after reduction.
#'
#' @return A matrix of sentence embeddings with each row corresponding to a sentence from `text_vector` and each column representing a dimension of the embedding space.
#' @import reticulate
#' @export
#'
#' @examples
#' \dontrun{
#' # Example usage
#' text_vector <- c("This is a sentence.", "This is another sentence.")
#' model_name <- "paraphrase-MiniLM-L6-v2"
#' embeddings <- sem.emb(text_vector, model_name)
#' print(embeddings)
#' }
sem.encode <- function(text_vector, encoder = "all-mpnet-base-v2", reduce_method = "SVD", reduce_dim = 5){
  models.sbert = c("all-mpnet-base-v2", "paraphrase-MiniLM-L6-v2")
  models.gpt = c("text-embedding-3-small", "text-embedding-3-large", "text-embedding-ada-002")

  normalize_l2 <- function(vector) {
    norm <- norm(vector, type = "2")
```

```
  if (norm == 0) norm <- 1  # Avoid division by zero
  return(vector / norm)
}

generate_emb <- function(text){
  response = openai$embeddings$create(input=text, model=encoder, encoding_format="float")
  emb = response$data[[1]]$embedding
  normalized_emb = normalize_l2(emb)
  return(normalized_emb)
}

if(encoder %in% models.sbert){
  sbert <- import("sentence_transformers")
  model <- sbert$SentenceTransformer(encoder)
  embeddings <- model$encode(text_vector)
} else if(encoder %in% models.gpt){
  openai <- import("openai")
  openai$api_key <- Sys.getenv("OPENAI_API_KEY")
  embs <- lapply(text_vector, generate_emb)
  embeddings <- do.call(rbind, embs)
} else {
  stop("Encoder not supported.")
}

if(reduce_method == "SVD"){
  svd_result <- svd(embeddings)
  U <- svd_result$u
  D <- diag(svd_result$d[1:reduce_dim])
  reduced_emb <- U[, 1:reduce_dim] %*% D
  print(dim(reduced_emb))  # Should be n x reduce_dim
  print(reduced_emb)
} else if(reduce_method == 'PCA'){
  pca_result <- prcomp(embeddings, scale. = TRUE, center = TRUE)
  reduced_emb <- pca_result$x[, 1:reduce_dim]
  # print(dim(reduced_emb))  # Should be n x reduce_dim
  # print(reduced_emb)
}

# Rename the columns
colnames(reduced_emb) <- paste0('v', 1:ncol(reduced_emb))
```

```
  rownames(reduced_emb) <- 1:nrow(reduced_emb)
  return(as.matrix(reduced_emb))
}

#' Structural Equation Modeling with Embeddings
#'
#' This function performs Structural Equation Modeling (SEM) using text embeddings. It checks if the specified `.rda` file with embeddings exists. If the file exists, it loads the embeddings; otherwise, it generates the embeddings using the `sem.encode` function. The embeddings are then incorporated into the SEM model.
#'
#' @param sem_model A character string specifying the SEM model.
#' @param data A data frame containing the input data.
#' @param text_var A character string specifying the name of the text variable in the data frame.
#' @param pca_dim A integer specifying reduced dimension through PCA.
#' @param encoder A character string specifying the encoder model to be used for generating embeddings. Defaults to "all-mpnet-base-v2".
#' @param reduce_dim An integer denoting the size of embedding after reduction.
#' @param emb_filepath A character string specifying the path to the `.rda` file containing the embeddings. If `NULL`, embeddings are generated using `sem.encode`.
#'
#' @return The result of the `lavaan::sem` function, which is an object of class `lavaan`.
#' @importFrom lavaan sem
#' @importFrom stats prcomp
#' @export
#'
#' @examples
#' \dontrun{
#' sem_model <- 'rating ~ book + difficulty + comments'
#' res <- sem.emb(sem_model = sem_model, data = prof.nest, text_var = "comments",
#'                pca_dim = 10, emb_model = "all-mpnet-base-v2")
#' summary(res, fit=TRUE)
#' }
#'
sem.emb <- function(sem_model, data, text_var, encoder = "all-mpnet-base-v2", emb_filepath = NULL, reduce_method = "SVD", reduce_dim = 5){

  df <- data

  # Check if the file path ends with .rda
  load_flag = FALSE
```

```
  if (!is.null(emb_filepath)) {
    if (grepl("\\.rda$", emb_filepath)) {
      if (file.exists(emb_filepath)) {
        # Load the file
        print("Loading embeddings from file...")
        embeddings <- get(load(emb_filepath))
        if (is.matrix(embeddings)) {
          if (nrow(embeddings) == nrow(df)) {
            print("Success.")
            load_flag = TRUE
          } else {
            print("Incorrect dimension.")
          }
        } else {
          print("Loaded object is not a matrix.")
        }
      } else {
        print("File doesn't exist.")
      }
    } else {
      stop("The specified file is not an `.rda` file.")
    }
  }

  if (!load_flag){
    print("Generating embeddings, this might take a while...")
    embeddings <- TextSEM::sem.encode(df[[text_var]], reduce_method = reduce_method, reduce_dim =
reduce_dim)
    print("Success.")
  }
  replace_vars_in_model <- function(model, var_old, var_new) {
    replacement <- paste(var_new, collapse = " + ")
    updated_model <- gsub(paste0("\\b", var_old, "\\b"), replacement, model)
    return(updated_model)
  }

  colnames(embeddings) <- paste0(text_var, '.', colnames(embeddings))
  model_new <- replace_vars_in_model(sem_model, text_var, colnames(embeddings))

  df <- cbind(df, embeddings)
```

```
  df <- as.data.frame(df)
  estimates <- lavaan::sem(model = model_new, data = df)

  list(model = model_new, data = df, estimates = estimates)
}
```

sem.topic

```
#' Perform Latent Dirichlet Allocation on a Data Frame
#'
#' This function takes a data frame and performs text preprocessing followed by Latent Dirichlet Allocation (LDA) for topic modeling.
#'
#' @param data A data frame containing the data.
#' @param text_var A variable in the data frame containing the text data to be analyzed.
#' @param n_topic Number of topics to be extracted.
#' @param method The method to be used for LDA fitting; currently method = "VEM" or method= "Gibbs" are supported.
#' @param sparse A numeric for the maximal allowed sparsity in the range from bigger zero to smaller one.
#' @param seed Random seed for LDA estimation
#'
#' @return A topic model object of class "LDA" from the `topicmodels` package.
#' @import dplyr
#' @importFrom tidytext unnest_tokens cast_dtm
#' @importFrom tm removeSparseTerms
#' @importFrom topicmodels LDA
#' @importFrom SnowballC wordStem
#' @importFrom utils data
#' @export
#'
#' @examples
#' \dontrun{
#' data(prof.nest)
#' lda.model <- sem.lda(df, text_var = c("comments"), n_topic = c(6))
#' lda.model
#' }
sem.lda <- function(df, text_var, n_topic, method = "VEM", sparse = .995, seed = 42){

  df["row_index"] <- 1:nrow(df)
```

```
  # Split text into terms (words)
  df.tm <- unnest_tokens(df, word, {{text_var}})

  ## Remove stopwords
  data(stopwords, envir = environment())
  df.tm <- df.tm %>% anti_join(filter(stopwords, lexicon == "evaluation"), by = join_by(word))

  ## Stem words
  df.tm$word <- SnowballC::wordStem(df.tm$word)
  df.tm <- df.tm %>%
    filter(!grepl("[[:digit:]]", word))

  ## Build Document-term matrix: https://en.wikipedia.org/wiki/Document-term_matrix
  df.dtm <- df.tm %>%
    count(.data[["row_index"]], word) %>%    ## word frequency
    tidytext::cast_dtm(.data[["row_index"]], word, n)  ## convert to dtm matrix
  df.dtm <- tm::removeSparseTerms(df.dtm, sparse)

  ## Latent Dirichlet Allocation (LDA): https://en.wikipedia.org/wiki/Latent_Dirichlet_allocation
  topicmodels::LDA(df.dtm, k = n_topic, control=list(seed = seed))
}



#' Perform Structural Equation Modeling with Latent Dirichlet Allocation
#'
#' This function performs structural equation modeling (SEM) combined with Latent Dirichlet Allocation (LDA) to analyze text data.
#'
#' @param model A description of the user-specified model. Typically, the model is described using the lavaan model syntax. See model.syntax for more information. Alternatively, a parameter table (eg. the output of the lavaanify() function) is also accepted.
#' @param data A data frame containing the data.
#' @param text_vars A character vector of text variable names in the data frame containing the text data to be analyzed.
#' @param n_topics A numeric vector containing number of topics to be extracted for each text variable.
#' @param method The method to be used for LDA fitting; currently method = "VEM" or method= "Gibbs" are supported.
#' @param sparse A numeric for the maximal allowed sparsity in the range from bigger zero to smaller one.
#' @param seed Random seed for LDA estimation
#'
```

```
#' @return A list containing four elements:
#' \item{model}{A character string representing the modified SEM with added topic variables.}
#' \item{data}{A data frame with added topic statistics.}
#' \item{estimates}{The fitted SEM model object.}
#' \item{lda}{A vector of LDA model objects.}
#' @import dplyr
#' @importFrom tidytext tidy
#' @importFrom lavaan sem
#' @importFrom tidyr spread
#' @importFrom stats setNames
#' @export
#'
#' @examples
#' \dontrun{
#' data(prof.nest)
#' model <- 'rating ~ book + difficulty + comments + tags'
#' res <- sem.topic(model = model,
#'                  data = prof.nest,
#'                  text_vars = c('comments', 'tags'),
#'                  n_topics = c(6, 3))
#' summary(res$model, fit=TRUE)
#' }
sem.topic <- function(model, data, text_vars, n_topics, method = "VEM", sparse = .995, seed = 42){

  df <- data
  df["row_index"] <- 1:nrow(df)

  lda_objects = c()
  for(i in 1:length(text_vars)){
    # print(i)

    # Get LDA matrix
    df.lda <- sem.lda(df, text_vars[i], n_topics[i], method = method)
    lda_objects <- c(lda_objects, df.lda)

    ## Gamma (per-document-per-topic probability): the proportion of the document that is made up of words from the assigned topic
    document.prob <- tidytext::tidy(df.lda, matrix = "gamma")
    document.prob <- document.prob %>%
      tidyr::spread(key=topic, value=gamma, sep='')
```

```
    ## Combine the data with gamma
    # Rename the columns: topic_i -> text_var.topic_i
    names(document.prob)[2:(n_topics[i] + 1)] <- paste(rep(text_vars[i], n_topics[i]),
names(document.prob)[2:(n_topics[i] + 1)], sep = ".")
    document.prob$document <- as.numeric(document.prob$document)
    df <- left_join(df, document.prob, by=join_by(row_index==document))
  }

  lda_objects <- setNames(lda_objects, text_vars)

  ## Rewrite the lavaan model by replacing text_var with text_var.topic_i
  model_lavaanify <- lavaanify(model)
  model_user <- model_lavaanify[model_lavaanify$user==1, ]
  model_new <- c()

  # Remove the last topic component
  df_topic <- setNames(n_topics - 1, text_vars)

  for(i in 1:nrow(model_user)){
    row <- model_user[i,]
    # print(row)
    if((row['lhs'] %in% text_vars) && (row['rhs'] %in% text_vars)){
      left <- paste0(rep(paste0(row['lhs'], '.topic'), df_topic[as.character(row$lhs)]),
1:df_topic[as.character(row$lhs)])
      right <- paste0(rep(paste0(row['rhs'], '.topic'), df_topic[as.character(row$rhs)]),
1:df_topic[as.character(row$rhs)])
    } else if(row['lhs'] %in% text_vars){
      left <- paste0(rep(paste0(row['lhs'], '.topic'), df_topic[as.character(row$lhs)]),
1:df_topic[as.character(row$lhs)])
      right <- as.character(row$rhs)
      model_new <- c(model_new, paste0(row['lhs'], '.topic', text_stats, ' ', row['op'], ' ', row['rhs']))
    } else if(row['rhs'] %in% text_vars){
      left <- as.character(row$lhs)
      right <- paste0(rep(paste0(row['rhs'], '.topic'), df_topic[as.character(row$rhs)]),
1:df_topic[as.character(row$rhs)])
    } else{
      left <- as.character(row$lhs)
      right <- as.character(row$rhs)
    }
```

```
    combinations <- expand.grid(left, right)
    model_new <- c(model_new, paste(combinations$Var1, row['op'], combinations$Var2))
  }

  # print(model_new)
  # model_new <- paste0(model_new, collapse = '\n')

  estimates <- lavaan::sem(model = model_new, data = df)

  list(model = model_new, data = df, estimates = estimates, lda = lda_objects)
}

#' Plot Top Terms in LDA Topics
#'
#' This function plots the top terms in each topic from a Latent Dirichlet Allocation (LDA) model.
#'
#' @param df.lda A fitted LDA model object.
#'
#' @return A ggplot object showing the top terms in each topic.
#' @import dplyr
#' @import ggplot2
#' @importFrom tidytext tidy scale_x_reordered
#' @importFrom stats reorder
#' @export
#'
#' @examples
#' \dontrun{
#' # Assuming 'lda_model' is a fitted LDA model object
#' sem.topic.plot(lda_model)
#' }
sem.topic.plot <- function(df.lda){

  df.topics <- tidy(df.lda, matrix = "beta")

  ## terms & topics
  df.terms <- df.topics %>%
    group_by(topic) %>%
    top_n(10, beta) %>%
    ungroup() %>%
    arrange(topic, -beta)
```

```
  # df.terms %>% print(n=60)

  reorder_within <- function (x, by, within, fun = mean, sep = "___", ...)
  {
    new_x <- paste(x, within, sep = sep)
    stats::reorder(new_x, by, FUN = fun)
  }

  ## plot the topics and terms
  df.terms %>%
    mutate(topic=as.factor(topic), term = reorder_within(term, beta, topic, sep="")) %>%
    ggplot(aes(term, beta, fill = topic)) +
    geom_col(show.legend = FALSE) + facet_wrap(~topic, scales = "free", labeller = "label_both") +
    xlab("Terms") + ylab("Topics") + coord_flip() + tidytext::scale_x_reordered() + scale_fill_grey()+
    theme(axis.text=element_text(size=10),
          axis.title=element_text(size=12))
}
```

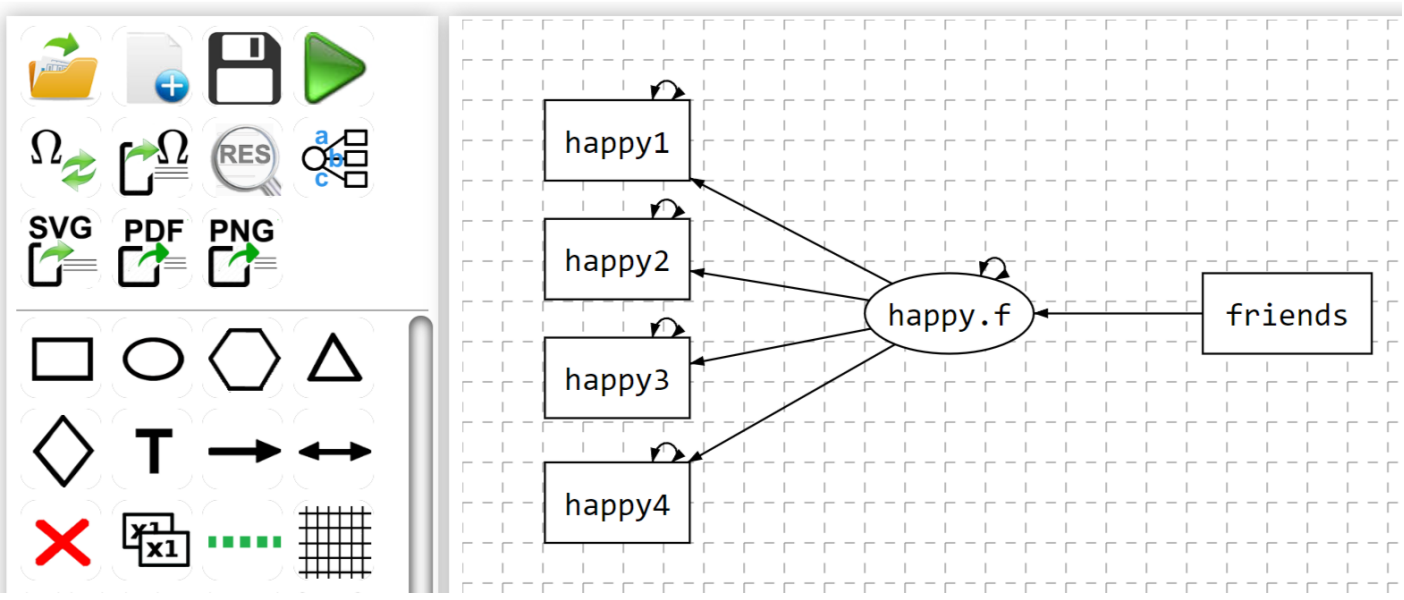
The development of the online app

The online app BigSEM uses R in the backend to run analyses on a web server. The current server setup for the working BigSEM app is below:

- Ubuntu 24.04.1 LTS
- Apache/2.4.58
- PHP 8.3.6
- MySQL 8.0.40
- R 4.4.2

However, any server that supports PHP and MySQL should work. The app can also be easily set up on a local or remote server using xampp. If you plan to use the app offline, xampp is highly recommended.

Graphical Interface



The graphical interface is developed using JavaScript. The core code is available at https://github.com/johnnyzhz/semdiag.

R Setup

One needs to install R and the networksem and TextSEM on the server first. R can be a security risk. If used on a remote server, some security measures should be taken. On our server, we use AppArmor and R package RAppArmor.

PHP for Bridging the Interface and R

We use PHP to connect to R to conduct the analysis.