Package ‘mxsem’

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Type Package

Title Specify 'OpenMx' Models with a 'lavaan'-Style Syntax

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Description Provides a 'lavaan'-like syntax for 'OpenMx' models. The syntax supports definition variables, bounds, and parameter transformations. This allows for latent growth curve models with person-specific measurement occasions, moderated nonlinear factor analysis and much more.

License GPL (>= 3)

Depends OpenMx

Imports Rcpp (>= 1.0.10), stats, methods, dplyr, utils

LinkingTo Rcpp

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URL https://jhorzek.github.io/mxsem/,
https://github.com/jhorzek/mxsem/

BugReports https://github.com/jhorzek/mxsem/issues

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`clean_syntax` *clean_syntax*

Description

takes in a lavaan style syntax and removes comments, white space, etc.

Usage

```
clean_syntax(syntax)
```

Arguments

`syntax`	lavaan style syntax

Value

vector of strings with cleaned syntax

get_groups   *get_groups*

Description

returns a list of groups for a multi group model

Usage

```
get_groups(multi_group_model)
```

Arguments

`multi_group_model`	multi group model created with mxsem_group_by

Value

list with data for each group

Examples

```
# THE FOLLOWING EXAMPLE IS ADAPTED FROM
# https://openmx.ssri.psu.edu/docs/OpenMx/latest/_static/Rdoc/mxModel.html
library(mxsem)

model <- 'spatial =~ visual + cubes + paper
          verbal  =~ general + paragrap + sentence
          math    =~ numeric + series + arithmet'

mg_model <- mxsem(model = model,
                  data  = OpenMx::HS.ability.data) |>
  # we want separate models for all combinations of grades and schools:
  mxsem_group_by(grouping_variables = "school") |>
  mxTryHard()

# let's summarize the results:
summarize_multi_group_model(mg_model)

# let's get the groups:
get_groups(mg_model)
```

get_individual_algebra_results *get_individual_algebra_results*

Description

evaluates algebras for each subject in the data set. This function is useful if you have algebras with definition variables (e.g., in mnlfa).

Usage

```
get_individual_algebra_results(
  mxModel,
  algebra_names = NULL,
  progress_bar = TRUE
)
```

Arguments

`mxModel`	mxModel with algebras
`algebra_names`	optional: Only compute individual algebras for a subset of the parameters
`progress_bar`	should a progress bar be shown?

Value

a list of data frames. The list contains data frames for each of the algebras. The data frames contain the individual specific algebra results as well as all definition variables used to predict said algebra

Examples

```
library(mxsem)

set.seed(123)
dataset <- simulate_moderated_nonlinear_factor_analysis(N = 50)

model <- "
  xi  =~ x1 + x2 + x3
  eta =~ y1 + y2 + y3
  eta ~  {a := a0 + data.k*a1}*xi
  "
fit <- mxsem(model = model,
             data = dataset) |>
  mxTryHard()

algebra_results <- get_individual_algebra_results(mxModel = fit,
                                                  progress_bar = FALSE)

# the following plot will only show two data points because there is only
# two values for the definition variable k (0 or 1).

plot(x = algebra_results[["a"]]$k,
     y = algebra_results[["a"]]$algebra_result)
```

---

mxsem *mxsem*

Description

Create an extended SEM with **OpenMx** (Boker et al., 2011) using a **lavaan**-style (Rosseel, 2012) syntax.

Usage

```
mxsem(
  model,
  data,
  scale_loadings = TRUE,
  scale_latent_variances = FALSE,
  add_intercepts = TRUE,
  add_variances = TRUE,
  add_exogenous_latent_covariances = TRUE,
  add_exogenous_manifest_covariances = TRUE,
  lbound_variances = TRUE,
  directed = unicode_directed(),
  undirected = unicode_undirected(),
  return_parameter_table = FALSE
)
```

Arguments

`model`	model syntax similar to **lavaan**'s syntax
`data`	raw data used to fit the model. Alternatively, an object created with `OpenMx::mxData` can be used (e.g., `OpenMx::mxData(observed = cov(OpenMx::Bollen), means = colMeans(OpenMx::Bollen), numObs = nrow(OpenMx::Bollen), type = "cov")`).
`scale_loadings`	should the first loading of each latent variable be used for scaling?
`scale_latent_variances`	should the latent variances be used for scaling?
`add_intercepts`	should intercepts for manifest variables be added automatically? If set to false, intercepts must be added manually. If no intercepts are added, **mxsem** will automatically use just the observed covariances and not the observed means.
`add_variances`	should variances for manifest and latent variables be added automatically?
`add_exogenous_latent_covariances`	should covariances between exogenous latent variables be added automatically?

`add_exogenous_manifest_covariances`	should covariances between exogenous manifest variables be added automatically?
`lbound_variances`	should the lower bound for variances be set to 0.000001?
`directed`	symbol used to indicate directed effects (regressions and loadings)
`undirected`	symbol used to indicate undirected effects (variances and covariances)
`return_parameter_table`	if set to TRUE, the internal parameter table is returend together with the mxModel

Details

Setting up SEM can be tedious. The **lavaan** (Rosseel, 2012) package provides a great syntax to make the process easier. The objective of **mxsem** is to provide a similar syntax for **OpenMx**. **OpenMx** is a flexible R package for extended SEM. However, note that **mxsem** only covers a small part of the **OpenMx** framework by focusing on "standard" SEM. Similar to **lavaan**'s `sem()`-function, `mxsem` tries to set up parts of the model automatically (e.g., adding variances automatically or scaling the latent variables automatically). If you want to unlock the full potential of **OpenMx**, **mxsem** may not be the best option.

Warning: The syntax and settings of **mxsem** may differ from **lavaan** in some cases. See `vignette("Syntax", package = "mxsem")` for more details on the syntax and the default arguments.

Alternatives:

You will find similar functions in the following packages:

- **metaSEM** (Cheung, 2015) provides a `lavaan2RAM` function that can be combined with the `create.mxModel` function. This combination offers more features than **mxsem**. For instance, constraints of the form `a < b` are supported. In **mxsem** such constraints require algebras (e.g., `!diff; a := b - exp(diff)`).
- **umx** (Bates et al., 2019) provides the `umxRAM` and `umxLav2RAM` functions that can parse single **lavaan**-style statements (e.g., `eta =~ y1 + y2 + y3`) or an entire **lavaan** models to **OpenMx** models.
- **tidySEM** (van Lissa, 2023) provides the `as_ram` function to translate **lavaan** syntax to **OpenMx** and also implements a unified syntax to specify both, **lavaan** and **OpenMx** models. Additionally, it works well with the **tidyverse**.
- **ezMx** (Bates, et al. 2014) simplifies fitting SEM with **OpenMx** and also provides a translation of **lavaan** models to **OpenMx** with the `lavaan.to.OpenMx` function.

Because **mxsem** implements the syntax parser from scratch, it can extend the **lavaan** syntax to account for specific **OpenMx** features. This enables implicit transformations with curly braces.

Citation:

Cite **OpenMx** (Boker et al., 2011) for the modeling and **lavaan** for the syntax (Rosseel, 2012). **mxsem** itself is just a very small package and lets **OpenMx** do all the heavy lifting.

Defaults:

By default, **mxsem** scales latent variables by setting the loadings on the first item to 1. This can be changed by setting `scale_loadings = FALSE` in the function call. Setting `scale_latent_variances = TRUE` sets latent variances to 1 for scaling.

mxsem will add intercepts for all manifest variables as well as variances for all manifest and latent variables. A lower bound of 1e-6 will be added to all variances. Finally, covariances for all exogenous variables will be added. All of these options can be changed when calling **mxsem**.

Syntax:

The syntax is, for the most part, identical to that of **lavaan**. The following specifies loadings of a latent variable `eta` on manifest variables `y1`-`y4`:

```
eta =~ y1 + y2 + y3
```

Regressions are specified with ~:

```
xi  =~ x1 + x2 + x3
eta =~ y1 + y2 + y3
# predict eta with xi:
eta ~  xi
```

Add covariances with ~~

```
xi  =~ x1 + x2 + x3
eta =~ y1 + y2 + y3
# predict eta with xi:
eta ~  xi
x1 ~~ x2
```

Intercepts are specified with `~1`

```
xi  =~ x1 + x2 + x3
eta =~ y1 + y2 + y3
# predict eta with xi:
eta ~  xi
x1 ~~ x2

eta ~ 1
```

Parameter labels and constraints:

Add labels to parameters as follows:

```
xi  =~ l1*x1 + l2*x2 + l3*x3
eta =~ l4*y1 + l5*y2 + l6*y3
# predict eta with xi:
eta ~  b*xi
```

Fix parameters by using numeric values instead of labels:

```
xi  =~ 1*x1 + l2*x2 + l3*x3
eta =~ 1*y1 + l5*y2 + l6*y3
# predict eta with xi:
eta ~  b*xi
```

Bounds:

Lower and upper bounds allow for constraints on parameters. For instance, a lower bound can prevent negative variances.

```
xi  =~ 1*x1 + l2*x2 + l3*x3
eta =~ 1*y1 + l5*y2 + l6*y3
# predict eta with xi:
eta ~  b*xi
# residual variance for x1
x1 ~~ v*x1
# bound:
v > 0
```

Upper bounds are specified with v < 10. Note that the parameter label must always come first. The following is not allowed: `0` < v or `10` > v.

(Non-)linear constraints:

Assume that latent construct `eta` was observed twice, where `eta1` is the first observation and `eta2` the second. We want to define the loadings of `eta2` on its observations as `l_1` + `delta_l1`. If `delta_l1` is zero, we have measurement invariance.

```
eta1 =~ l1*y1 + l2*y2 + l3*y3
eta2 =~ l4*y4 + l5*y5 + l6*y6
# define new delta-parameter
!delta_1; !delta_2; !delta_3
# redefine l4-l6
l4 := l1 + delta_1
l5 := l2 + delta_2
l6 := l3 + delta_3
```

Alternatively, implicit transformations can be used as follows:

```
eta1 =~ l1*y1 + l2*y2 + l3*y3
eta2 =~ {l1 + delta_1} * y4 + {l2 + delta_2} * y5 + {l3 + delta_3} * y6
```

Specific labels for the transformation results can also be provided:

```
eta1 =~ l1*y1 + l2*y2 + l3*y3
eta2 =~ {l4 := l1 + delta_1} * y4 + {l5 := l2 + delta_2} * y5 + {l6 := l3 + delta_3} * y6
```

This is inspired by the approach in **metaSEM** (Cheung, 2015).

Definition variables:

Definition variables allow for person-specific parameter constraints. Use the `data.`-prefix to specify definition variables.

```
I =~ 1*y1 + 1*y2 + 1*y3 + 1*y4 + 1*y5
S =~ data.t_1 * y1 + data.t_2 * y2 + data.t_3 * y3 + data.t_4 * y4 + data.t_5 * y5

I ~ int*1
S ~ slp*1
```

Starting Values:

mxsem differs from **lavaan** in the specification of starting values. Instead of providing starting values in the model syntax, the `set_starting_values` function is used.

References:

- Bates, T. C., Maes, H., & Neale, M. C. (2019). umx: Twin and Path-Based Structural Equation Modeling in R. Twin Research and Human Genetics, 22(1), 27–41. https://doi.org/10.1017/thg.2019.2
- Bates, T. C., Prindle, J. J. (2014). ezMx. https://github.com/OpenMx/ezMx
- Boker, S. M., Neale, M., Maes, H., Wilde, M., Spiegel, M., Brick, T., Spies, J., Estabrook, R., Kenny, S., Bates, T., Mehta, P., & Fox, J. (2011). OpenMx: An Open Source Extended Structural Equation Modeling Framework. Psychometrika, 76(2), 306–317. https://doi.org/10.1007/s11336-010-9200-6
- Cheung, M. W.-L. (2015). metaSEM: An R package for meta-analysis using structural equation modeling. Frontiers in Psychology, 5. https://doi.org/10.3389/fpsyg.2014.01521
- Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. Journal of Statistical Software, 48(2), 1–36. https://doi.org/10.18637/jss.v048.i02
- van Lissa, C. J. (2023). tidySEM: Tidy Structural Equation Modeling. R package version 0.2.4, https://cjvanlissa.github.io/tidySEM/.

Value

mxModel object that can be fitted with mxRun or mxTryHard. If return_parameter_table is TRUE, a list with the mxModel and the parameter table is returned.

Examples

```
# THE FOLLOWING EXAMPLE IS ADAPTED FROM LAVAAN
library(mxsem)

model <- '
  # latent variable definitions
     ind60 =~ x1 + x2 + x3
     dem60 =~ y1 + a1*y2 + b*y3 + c1*y4
     dem65 =~ y5 + a2*y6 + b*y7 + c2*y8

  # regressions
    dem60 ~ ind60
    dem65 ~ ind60 + dem60

  # residual correlations
    y1 ~~ y5
    y2 ~~ y4 + y6
    y3 ~~ y7
    y4 ~~ y8
    y6 ~~ y8
'

fit <- mxsem(model = model,
             data  = OpenMx::Bollen) |>
  mxTryHard()
omxGetParameters(fit)


model_transformations <- '
```

```
  # latent variable definitions
     ind60 =~ x1 + x2 + x3
     dem60 =~ y1 + a1*y2 + b1*y3 + c1*y4
     dem65 =~ y5 + {a2 := a1 + delta_a}*y6 + {b2 := b1 + delta_b}*y7 + c2*y8

  # regressions
    dem60 ~ ind60
    dem65 ~ ind60 + dem60

  # residual correlations
    y1 ~~ y5
    y2 ~~ y4 + y6
    y3 ~~ y7
    y4 ~~ y8
    y6 ~~ y8
'

fit <- mxsem(model = model_transformations,
            data  = OpenMx::Bollen) |>
  mxTryHard()
omxGetParameters(fit)
```

`mxsem_group_by` *mxsem_group_by*

Description

creates a multi-group model from an OpenMx model.

Usage

```
mxsem_group_by(
  mxModel,
  grouping_variables,
  parameters = c(".*"),
  use_grepl = TRUE
)
```

Arguments

`mxModel`	mxModel with the entire data
`grouping_variables`	Variables used to split the data in groups
`parameters`	the parameters that should be group specific. By default all parameters are group specific.
`use_grepl`	if set to TRUE, grepl is used to check which parameters are group specific. For instance, if parameters = "a" and use_grepl = TRUE, all parameters whose label contains the letter "a" will be group specific. If use_grep = FALSE only the parameter that has the label "a" is group specific.

Details

mxsem_group_by creates a multi-group model by splitting the data found in an mxModel object using dplyr's group_by function. The general idea is as follows:

1. The function extracts the data from mxModel 2. The data is split using the group_by function of dplyr with the variables in grouping_variables 3. a separate model is set up for each group. All parameters that match those specified in the parameters argument are group specific

Warning: The multi-group model may differ from **lavaan**! For instance, **lavaan** will automatically set the latent variances for all but the first group free if the loadings are fixed to equality. Such automatic procedures are not yet implemented in **mxsem**.

Value

mxModel with multiple groups. Use get_groups to extract the groups

Examples

```
# THE FOLLOWING EXAMPLE IS ADAPTED FROM
# https://openmx.ssri.psu.edu/docs/OpenMx/latest/_static/Rdoc/mxModel.html
library(mxsem)

model <- 'spatial =~ visual + cubes + paper
          verbal  =~ general + paragrap + sentence
          math    =~ numeric + series + arithmet'

mg_model <- mxsem(model = model,
                  data  = OpenMx::HS.ability.data) |>
  # we want separate models for all combinations of grades and schools:
  mxsem_group_by(grouping_variables = "school") |>
  mxTryHard()

# let's summarize the results:
summarize_multi_group_model(mg_model)
```

`parameters` *parameters*

Description

Returns the parameter estimates of an mxModel. Wrapper for omxGetParameters

Usage

```
parameters(mxMod)
```

Arguments

`mxMod`	mxModel object

Value

vector with parameter estimates

`parameter_table_rcpp` *parameter_table_rcpp*

Description

creates a parameter table from a lavaan like syntax

Usage

```
parameter_table_rcpp(
  syntax,
  add_intercept,
  add_variance,
  add_exogenous_latent_covariances,
  add_exogenous_manifest_covariances,
  scale_latent_variance,
  scale_loading
)
```

Arguments

`syntax`	lavaan like syntax
`add_intercept`	should intercepts for manifest variables be automatically added?
`add_variance`	should variances for all variables be automatically added?
`add_exogenous_latent_covariances`	should covariances between exogenous latent variables be added automatically?
`add_exogenous_manifest_covariances`	should covariances between exogenous manifest variables be added automatically?
`scale_latent_variance`	should variances of latent variables be set to 1?
`scale_loading`	should the first loading of each latent variable be set to 1?

Value

parameter table

`print.multi_group_parameters` *print the multi_group_parameters*

Description

print the multi_group_parameters

Usage

```
## S3 method for class 'multi_group_parameters'
print(x, ...)
```

Arguments

`x`	object from summarize_multi_group_model
`...`	not used

Value

nothing

`set_starting_values` *set_starting_values*

Description

set the starting values of an OpenMx model. This is just an interface to omxSetParameters.

Usage

```
set_starting_values(mx_model, values)
```

Arguments

`mx_model`	model of class mxModel
`values`	vector with labeled parameter values

Value

mxModel with changed parameter values

Examples

```
library(mxsem)

model <- '
  # latent variable definitions
     ind60 =~ x1 + x2 + x3
     dem60 =~ y1 + a1*y2 + b*y3 + c1*y4
     dem65 =~ y5 + a2*y6 + b*y7 + c2*y8

  # regressions
    dem60 ~ ind60
    dem65 ~ ind60 + dem60

  # residual correlations
    y1 ~~ y5
    y2 ~~ y4 + y6
    y3 ~~ y7
    y4 ~~ y8
    y6 ~~ y8
'

fit <- mxsem(model = model,
            data  = OpenMx::Bollen) |>
  set_starting_values(values = c("a1" = .4, "c1" = .6)) |>
  mxTryHard()
```

simulate_latent_growth_curve
simulate_latent_growth_curve

Description

simulate data for a latent growth curve model with five measurement occasions. The time-distance between these occasions differs between subjects.

Usage

```
simulate_latent_growth_curve(N = 100)
```

Arguments

N	sample size

Value

data set with columns y1-y5 (observations) and t_1-t_5 (time of observation)

Examples

```
set.seed(123)
dataset <- simulate_latent_growth_curve(N = 100)

model <- "
  I =~ 1*y1 + 1*y2 + 1*y3 + 1*y4 + 1*y5
  S =~ data.t_1 * y1 + data.t_2 * y2 + data.t_3 * y3 + data.t_4 * y4 + data.t_5 * y5

  I ~ int*1
  S ~ slp*1

  # set intercepts of manifest variables to zero
  y1 ~ 0*1; y2 ~ 0*1; y3 ~ 0*1; y4 ~ 0*1; y5 ~ 0*1;
  "

mod <- mxsem(model = model,
             data = dataset) |>
  mxTryHard()
```

`simulate_moderated_nonlinear_factor_analysis` *simulate_moderated_nonlinear_factor_analysis*

Description

simulate data for a moderated nonlinear factor analysis.

Usage

```
simulate_moderated_nonlinear_factor_analysis(N)
```

Arguments

`N`	sample size

Value

data set with variables x1-x3 and y1-y3 representing repeated measurements of an affect measure. It is assumed that the autoregressive effect is different depending on covariate k

Examples

```
library(mxsem)
set.seed(123)
dataset <- simulate_moderated_nonlinear_factor_analysis(N = 2000)

model <- "
xi =~ x1 + x2 + x3
eta =~ y1 + y2 + y3
eta ~ a*xi

# we need two new parameters: a0 and a1. These are created as follows:
!a0
!a1
# Now, we redefine a to be a0 + k*a1, where k is found in the data
a := a0 + data.k*a1
"

mod <- mxsem(model = model,
             data = dataset) |>
  mxTryHard()

omxGetParameters(mod)
```

---

summarize_multi_group_model

summarize_multi_group_model

Description

summarize the results of a multi group model created with mxsem_group_by

Usage

```
summarize_multi_group_model(multi_group_model)
```

Arguments

`multi_group_model`	multi group model created with mxsem_group_by

Value

list with goup specific parameters and common parameters

Examples

```
# THE FOLLOWING EXAMPLE IS ADAPTED FROM
# https://openmx.ssri.psu.edu/docs/OpenMx/latest/_static/Rdoc/mxModel.html
library(mxsem)

model <- 'spatial =~ visual + cubes + paper
          verbal  =~ general + paragrap + sentence
          math    =~ numeric + series + arithmet'

mg_model <- mxsem(model = model,
                  data  = OpenMx::HS.ability.data) |>
  # we want separate models for all combinations of grades and schools:
  mxsem_group_by(grouping_variables = "school") |>
  mxTryHard()

# let's summarize the results:
summarize_multi_group_model(mg_model)
```

`unicode_directed` *unicode_directed*

Description

this function returns the unicode for directed arrows

Usage

```
unicode_directed()
```

Value

returns unicode for directed arrows

`unicode_undirected` *unicode_undirected*

Description

this function returns the unicode for undirected arrows

Usage

```
unicode_undirected()
```

Value

returns unicode for undirected arrows

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