

OpenMx Reference Manual

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Title The OpenMx Statistical Modeling Package

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URL <http://openmx.psyc.virginia.edu>

Description The OpenMx Project intends to rewrite and extend the popular statistical package Mx to address the challenges facing a large range of modern statistical problems such as: the difficulty of measuring behavioral traits; the availability of technologies - such as such as magnetic resonance imaging, continuous physiological monitoring and microarrays - which generate extremely large amounts of data often with complex time-dependent patterning; and increased sophistication in the statistical models used to analyze the data.

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Depends methods

Suggests snowfall

LazyLoad yes

LazyData yes

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 mxAlgebra

Function To Create MxAlgebra Object

Description

This function creates a new [MxAlgebra](#) object.

Usage

```
mxAlgebra(expression, name = NA, dimnames = NA)
```

Arguments

expression	An R expression of matrix operators and matrix functions.
name	An optional character string indicating the name of the object.
dimnames	list. The dimnames attribute for the algebra: a list of length 2 giving the row and column names respectively. An empty list is treated as NULL, and a list of length one as row names. The list can be named, and the list names will be used as names for the dimensions.

Details

The mxAlgebra function is used to create algebraic expressions that operate on one or more [MxMatrix](#) objects. To evaluate an [MxAlgebra](#) object, it must be placed in an [MxModel](#) object, along with all referenced [MxMatrix](#) objects and the `mxAlgebraObjective` function. The `mxAlgebraObjective` function must reference the [MxAlgebra](#) object to be evaluated by name.

The following operations are supported in mxAlgebra:

```

solve() Inversion
t() Transposition
+ Addition
- Subtraction
%*% Matrix Multiplication
* Element or dot product
/ Element division
%x% Kronecker product
%&% Quadratic product
cbind() Horizontal adhesion
rbind() Vertical adhesion

```

The following functions are supported in mxAlgebra:

```

sum(diag()) Trace
det() Determinant
sum() Sum
max() Maximum
min() Min
abs() Absolute value
sin() Sine
sinh() Hyperbolic sine
cos() Cosine
cosh() Hyperbolic cosine
tan() Tangent
tanh() Hyperbolic tangent

```

`exp()` Exponent
`log()` Natural Logarithm
`sqrt()` Square root
`diag()` Diagonal to vector or vector to diagonal, depending on input
`c(t())` Matrix to vector (by row; returns vector)
`c()` Matrix to vector (by column)
`vech()` Lower triangular matrix to vector (requires MCMCpack package)
`cov2cor()` Standardize matrix
`ly.values=TRUE)$values` Real eigenvalues (for matrix A)
`Re(eigen(A,)$values)` Real eigenvectors (for matrix A)
`ly.values=TRUE)$values` Imaginary eigenvalues (for matrix A)
`Im(eigen(A,)$values)` Imaginary eigenvectors (for matrix A)
`colMeans()` Mean of columns
`var()` Covariance of columns

Value

Returns a new [MxAlgebra](#) object.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[MxAlgebra](#) for the S4 class created by `mxAlgebra`. [MxMatrix](#) and `mxMatrix` for objects which may be entered in the 'expression' argument and the function that creates them. More information about the OpenMx package may be found [here](#).

Examples

```

A <- mxMatrix("Full", nrow = 3, ncol = 3, values=2, name = "A")

# Simple example: algebra B simply evaluates to the matrix A
B <- mxAlgebra(A, name = "B")

# Compute A + B
C <- mxAlgebra(A + B, name = "C")

# Compute sin(C)
D <- mxAlgebra(sin(C), name = "D")

# Make a model and evaluate the mxAlgebra object 'D'
A <- mxMatrix("Full", nrow = 3, ncol = 3, values=2, name = "A")
model <- mxModel("AlgebraExample", A, B, C, D )
fit <- mxRun(model)
  
```

```
mxEval(D, fit)
```

MxAlgebra-class *MxAlgebra Class*

Description

MxAlgebra is an S4 class. An MxAlgebra object is a [named entity](#). New instances of this class can be created using the function [mxAlgebra](#).

Details

The MxAlgebra class has the following slots:

- name - The name of the object
- formula - The R expression to be evaluated
- result - Either NULL or a 1x1 matrix with the computation result

The 'name' slot is the name of the MxAlgebra object. Use of MxAlgebra objects in the [mxConstraint](#) function or an [OpenMx](#) objective function requires reference by name.

The 'formula' slot is an expression containing one or more [MxMatrix](#) objects. These objects are operated on or related to one another using one or more operations detailed in the [mxAlgebra](#) help file.

The 'result' slot is used to hold the results of an optimization on the expression in the 'formula' slot. If this MxAlgebra has not been used as an argument in an objective function and subsequently included in an [MxModel](#) object and executed using the [mxRun](#) function, this slot will have a value of NULL. If this MxAlgebra has been used as an argument in an objective function and subsequently included in an [MxModel](#) object and executed using the [mxRun](#) function, then this slot will have a 1x1 matrix with the results of that optimization as its only value.

Slots may be referenced with the @ symbol. See the documentation for [Classes](#) and the examples in the [mxAlgebra](#) document for more information.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxAlgebra](#) for creating MxAlgebra objects. [MxMatrix](#) and [mxMatrix](#) for objects which may be entered in the 'formula' slot and the function that creates them. More information about the OpenMx package may be found [here](#).

mxAlgebraObjective *Function to Create MxAlgebraObjective Object*

Description

This function creates a new MxAlgebraObjective object.

Usage

```
mxAlgebraObjective(algebra)
```

Arguments

`algebra` A character string indicating the name of an [MxAlgebra](#) or [MxMatrix](#) object to use for optimization.

Details

Objective functions are functions for which free parameter values are chosen such that the value of the objective function is minimized. While the other objective functions in OpenMx are packaged with a function to be optimized (i.e., maximum likelihood), the mxAlgebraObjective function uses the referenced [MxAlgebra](#) or [MxMatrix](#) object as the function to be minimized.

If no free parameters are included in any part of the 'algebra' argument, the mxAlgebraObjective works as an algebra evaluator. If the 'algebra' argument is given an [MxMatrix](#) object with no free parameters, the original object is returned. If the 'algebra' argument is given an [MxAlgebra](#) object whose referenced matrices and algebras have no free parameters, the mxAlgebraObjective function carries out the operations defined in the 'expression' argument of that [MxAlgebra](#) object.

If free parameters are included in the objects references in the 'algebra' argument, the mxAlgebraObjective minimizes the algebra defined in the 'algebra' argument. More than one free parameter may be included in the algebra, but the mxAlgebraObjective should be specified such that the objective function evaluates to a 1x1 matrix or scalar value. If the contents of the 'algebra' argument evaluates to a non-scalar matrix, only the first entry of that matrix is minimized.

To evaluate, place MxAlgebraObjective objects, referenced [MxAlgebra](#) and [MxMatrix](#) objects, and optional [MxBounds](#) and [MxConstraint](#) objects in an [MxModel](#) object. This model may then be evaluated using the [mxRun](#) function. The results of the optimization can be found in the 'output' slot of the resulting model, and may be obtained using the [mxEval](#) function.

Value

Returns a new MxAlgebraObjective object. MxAlgebraObjective objects should be included with models with referenced [MxAlgebra](#) and [MxMatrix](#) objects.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```

#Create a matrix 'A' with no free parameters
A <- mxMatrix('Full', nrow = 1, ncol = 1, values = c(0), name = 'A')

#Create an algebra 'B', which defines the expression A + A
B <- mxAlgebra(A + A, name = 'B')

#Define the objective function for algebra 'B'
objective <- mxAlgebraObjective('B')

#Place the algebra, its associated matrix and its objective function in a model
model <- mxModel(A, B, objective)

#Evaluate the algebra
modelRun <- mxRun(model)

#View the results
modelRun@output

```

mxBounds

Function To Create an mxBounds Object

Description

This function creates a new [MxBounds](#) object.

Usage

```
mxBounds(parameters, min = NA, max = NA)
```

Arguments

parameters	A character vector indicating the names of the parameters on which to apply bounds.
min	A numeric value for the lower bound. NA means use default value.
max	A numeric value for the upper bound. NA means use default value.

Details

Creates a set of boundaries or limits for a parameter or set of parameters. Parameters may be any free parameter or parameters from an [MxMatrix](#) object. Parameters may be referenced either by name or by referring to their position in the 'spec' matrix of an [MxMatrix](#) object.

Minima and maxima may be specified as scalar numeric values.

Value

Returns a new [MxBounds](#) object. If used as an argument in an [MxModel](#) object, the parameters referenced in the 'parameters' argument must also be included prior to optimization.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[MxBounds](#) for the S4 class created by `mxBounds`. [MxMatrix](#) and `mxMatrix` for free parameter specification. More information about the OpenMx package may be found [here](#).

Examples

```
#Create lower and upper bounds for parameters 'A' and 'B'
bounds <- mxBounds(c('A', 'B'), 3, 5)

#Create a lower bound of zero for a set of variance parameters
varianceBounds <- mxBounds(c('Var1', 'Var2', 'Var3'), 0)
```

MxBounds-class *MxBounds Class*

Description

MxBounds is an S4 class. New instances of this class can be created using the function `mxBounds`.

Details

The MxBounds class has the following slots:

min	-	The lower bound
max	-	The upper bound
parameters	-	The vector of parameter names

The 'min' and 'max' slots hold scalar numeric values for the lower and upper bounds on the list of parameters, respectively.

Parameters may be any free parameter or parameters from an `MxMatrix` object. Parameters may be referenced either by name or by referring to their position in the 'spec' matrix of an `MxMatrix` object. To affect an estimation or optimization, an MxBounds object must be included in an `MxModel` object with all referenced `MxAlgebra` and `MxMatrix` objects.

Slots may be referenced with the @ symbol. See the documentation for [Classes](#) and the examples in the `mxBounds` document for more information.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxBounds](#) for the function that creates MxBounds objects. [MxMatrix](#) and [mxMatrix](#) for free parameter specification. More information about the OpenMx package may be found [here](#).

 mxConstraint

Function To Create an MxConstraint Object

Description

This function creates a new [MxConstraint](#) object.

Usage

```
mxConstraint(alg1, relation, alg2, name = NA)
```

Arguments

alg1	A character string indicating the name of an MxAlgebra or MxMatrix object, whose relationship to the object specified in the 'alg2' argument is constrained.
relation	A character string indicating the relation between 'alg1' and 'alg2'. Must be either "<", "=", or ">".
alg2	A character string indicating the name of an MxAlgebra or MxMatrix object, whose relationship to the object specified in the 'alg1' argument is constrained.
name	An optional character string indicating the name of this object.

Details

The mxConstraint function defines relationships between two [MxAlgebra](#) or [MxMatrix](#) objects. They are used to affect the estimation of free parameters in the referenced objects. The relationships "<", "=", and ">" are supported. To affect an estimation or optimization, an [MxConstraint](#) object must be included in an [MxModel](#) object with all referenced [MxAlgebra](#) and [MxMatrix](#) objects.

The mxConstraint function may not be used to constrain free parameters, either by name or by their position in an [MxMatrix](#) or [MxAlgebra](#) object. Free parameters in the same [MxModel](#) may be constrained to equality by giving them the same name in their respective 'spec' matrices.

Value

Returns an [MxConstraint](#) object. If used as an argument in an [MxModel](#) object, the objects referenced in the 'alg1' and 'alg2' arguments must also be included prior to optimization.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[MxConstraint](#) for the S4 class created by `mxConstraint`. [MxAlgebra](#) and [MxMatrix](#) for objects which may be entered as arguments in the `'alg'` and `'alg2'` arguments, and [mxAlgebra](#) and [mxMatrix](#) for the functions that create them. More information about the OpenMx package may be found [here](#).

Examples

```
#Create a constraint between MxMatrices 'A' and 'B'
constraint <- mxConstraint('A', '=', 'B', name = 'constraint')

# Constrain a matrix of free parameters 'K' to be equal to matrix 'limit'
K <- mxMatrix(type="Full", nrow=2, ncol=2, free=TRUE, name="K")
limit <- mxMatrix(type="Full", nrow=2, ncol=2, free=FALSE, name="limit", values=1:4)

model<- mxModel("con_test", K, limit,
  mxConstraint("K", "=", "limit"),
  mxAlgebra(min(K), name="minK"),
  mxAlgebraObjective("minK")
)
## Not run:
fit <- mxRun(model)
fit@matrices$K@values
## End(Not run)
#      [,1] [,2]
# [1,]    1    3
# [2,]    2    4
```

MxConstraint-class *MxConstraint Class*

Description

`MxConstraint` is an S4 class. An `MxConstraint` object is a [named entity](#). New instances of this class can be created using the function `mxConstraint`.

Details

The `MxConstraint` class has the following slots:

- name - The name of the object
- alg1 - The name of an [MxAlgebra](#) or [MxMatrix](#) object
- relation - A character string, either `'<'`, `'='`, or `'>'`
- alg2 - The name of an [MxAlgebra](#) or [MxMatrix](#) object

The `'name'` slot is the name of the `MxConstraint` object.

The `'alg1'` and `'alg2'` slots hold [MxAlgebra](#) or [MxMatrix](#) objects whose relationship is constrained

or defined by the contents of the 'relation' slot. To affect an estimation or optimization, an MxConstraint object must be included in an MxModel object with all referenced MxAlgebra and MxMatrix objects.

Slots may be referenced with the @ symbol. See the documentation for [Classes](#) and the examples in the [mxConstraint](#) document for more information.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxConstraint](#) for the function that creates MxConstraint objects. [MxAlgebra](#) and [MxMatrix](#) for objects which may be entered as arguments in the 'alg' and 'alg2' arguments, and [mxAlgebra](#) and [mxMatrix](#) for the functions that create them. More information about the OpenMx package may be found [here](#).

 mxData

Function To Create MxData Object

Description

This function creates a new [MxData](#) object.

Usage

```
mxData(observed, type, means = NA, numObs = NA)
```

Arguments

observed	A matrix or data.frame which provides data to the MxData object.
type	A character string defining the type of data in the 'observed' argument. Must be one of "raw", "cov", "cor", or "sscp".
means	An optional vector of means for use when 'type' is "cov", or "cor".
numObs	The number of observations in the data supplied in the 'observed' argument. Required unless 'type' equals "raw".

Details

The mxData function creates [MxData](#) objects, which can be used as arguments in [MxModel](#) objects. The 'observed' argument may take either a data frame or a matrix, which is then described with the 'type' argument. Data types describe compatibility and usage with objective functions in MxModel objects. Four different data types are supported:

- raw The contents of the ‘observed’ argument are treated as raw data. Missing values are permitted and must be designated as the system missing value. The ‘means’ and ‘numObs’ arguments cannot be specified, as the ‘means’ argument is not relevant and the ‘numObs’ argument is automatically populated with the number of rows in the data. Data of this type must use the [mxFIMLObjective](#) function as its objective function in MxModel objects, which deals with covariance estimation under full-information maximum likelihood.
- cov The contents of the ‘observed’ argument are treated as a covariance matrix. The ‘means’ argument is not required, but may be included for estimations involving means. The ‘numObs’ argument is required, which should reflect the number of observations or rows in the data described by the covariance matrix. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.
- cor The contents of the ‘observed’ argument are treated as a correlation matrix. The ‘means’ argument is not required, but may be included for estimations involving means. The ‘numObs’ argument is required, which should reflect the number of observations or rows in the data described by the covariance matrix. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.
- sscp The contents of the ‘observed’ argument are treated as a sums-of-squares and cross-products matrix. The ‘means’ argument is not used. The ‘numObs’ argument is required, which should reflect the number of observations or rows in the data described by the covariance matrix. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.

MxData objects may not be included in [MxAlgebra](#) objects or use the [mxAlgebraObjective](#) function. If these capabilities are desired, data should be appropriately input or transformed using the [mxMatrix](#) and [mxAlgebra](#) functions.

While column names are stored in the ‘observed’ slot of MxData objects, these names are not recognized as variable names in [MxPath](#) objects. Variable names must be specified using the ‘manifestVars’ argument of the [mxModel](#) function prior to use in MxPath objects.

The mxData function does not currently place restrictions on the size, shape, or symmetry of matrices input into the ‘observed’ argument. While it is possible to specify MxData objects as covariance, correlation or sscp matrices that do not have the properties commonly associated with these matrices, failure to correctly specify these matrices will likely lead to problems in model estimation.

OpenMx uses the names of variables to map them onto the objective functions and other elements associated with your model. For data.frames, ensure you have set the names(). For matrices set names using, for instance, row.names=c("your", "columns"). Covariance cor and sscp matrices need to have both the row and column names set and these must be identical, for instance by using dimnames=list(varNames, varNames).

Value

Returns a new [MxData](#) object.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[MxData](#) for the S4 class created by `mxData`. [matrix](#) and [data.frame](#) for objects which may be entered as arguments in the 'observed' slot. More information about the OpenMx package may be found [here](#).

Examples

```
#Create a covariance matrix
covMatrix <- matrix( c(0.77642931, 0.39590663,
  0.39590663, 0.49115615),
  nrow = 2, ncol = 2, byrow = TRUE)

#Create an MxData object including that covariance matrix
data <- mxData(covMatrix, 'cov', numObs = 100)

model <- mxModel(data)
```

MxData-class

MxData Class

Description

`MxData` is an S4 class. An `MxData` object is a [named entity](#). New instances of this class can be created using the function `mxData`. `MxData` is an S4 class union. An `MxData` object is either `NULL` or a `MxNonNullData` object.

Details

The `MxNonNullData` class has the following slots:

name	-	The name of the object
observed	-	Either a matrix or a data frame
vector	-	A vector for means, or NA if missing
type	-	Either 'raw', 'cov', 'cor', or 'sscp'
numObs	-	The number of observations

The 'name' slot is the name of the `MxData` object.

The 'observed' slot is used to contain data, either as a matrix or as a data frame. Use of the data in this slot by other functions depends on the value of the 'type' slot. When 'type' is equal to 'cov', 'cor', or 'sscp', the data input into the 'matrix' slot should be a symmetric matrix or data frame.

The 'vector' slot is used to contain a vector of numeric values, which is used as a vector of means for `MxData` objects with 'type' equal to 'cov', 'cor', or 'sscp'. This slot may be used in estimation using the [mxMLObjective](#) function.

The 'type' slot may take one of four supported values:

- raw The contents of the 'observed' slot are treated as raw data. Missing values are permitted and must be designated as the system missing value. The 'vector' and 'numObs' slots cannot be specified, as the 'vector' argument is not relevant and the 'numObs' argument is automatically populated with the number of rows in the data. Data of this type must use the [mxFIMLObjective](#) function as its objective function in MxModel objects, which deals with covariance estimation under full-information maximum likelihood.
- cov The contents of the 'observed' slot are treated as a covariance matrix. The 'vector' argument is not required, but may be included for estimations involving means. The 'numObs' slot is required. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.
- cor The contents of the 'observed' slot are treated as a correlation matrix. The 'vector' argument is not required, but may be included for estimations involving means. The 'numObs' slot is required. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.
- sscp The contents of the 'observed' slot are treated as a sums-of-squares and cross-products matrix. The 'vector' argument is not required, but may be included for estimations involving means. The 'numObs' slot is required. Data of this type may use the [mxMLObjective](#), or [mxRAMObjective](#) functions, depending on the specified model.

The 'numObs' slot describes the number of observations in the data. If 'type' equals 'raw', then 'numObs' is automatically populated as the number of rows in the matrix or data frame in the 'observed' slot. If 'type' equals 'cov', 'cor', or 'sscp', then this slot must be input using the 'numObs' argument in the [mxData](#) function when the MxData argument is created.

MxData objects may not be included in [MxAlgebra](#) objects or use the [mxAlgebraObjective](#) function. If these capabilities are desired, data should be appropriately input or transformed using the [mxMatrix](#) and [mxAlgebra](#) functions.

While column names are stored in the 'observed' slot of MxData objects, these names are not recognized as variable names in [MxPath](#) objects. Variable names must be specified using the 'manifestVars' argument of the [mxModel](#) function prior to use in MxPath objects.

The [mxData](#) function does not currently place restrictions on the size, shape, or symmetry of matrices input into the 'observed' argument. While it is possible to specify MxData objects as covariance, correlation or sscp matrices that do not have the properties commonly associated with these matrices, failure to correctly specify these matrices will likely lead to problems in model estimation.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxData](#) for creating MxData objects, [matrix](#) and [data.frame](#) for objects which may be entered as arguments in the 'matrix' slot. More information about the OpenMx package may be found [here](#).

`mxEval`*Function To Evaluate MxModel Values*

Description

This function can be used to evaluate an arbitrary R expression that includes named entities from a [MxModel](#) object, or labels from a [MxMatrix](#) object.

Usage

```
mxEval(expression, model, compute = FALSE, show = FALSE)
```

Arguments

<code>expression</code>	An arbitrary R expression.
<code>model</code>	The model in which to evaluate the expression.
<code>compute</code>	If TRUE then compute the value of algebra expressions.
<code>show</code>	If TRUE then print the translated expression.

Details

The argument ‘expression’ is an arbitrary R expression. Any named entities that are used within the R expression are translated into their current value from the model. Any labels from the matrices within the model are translated into their current value from the model. Finally the expression is evaluated and the result is returned. To enable debugging, the ‘show’ argument has been provided. The most common mistake when using this function is to include named entities in the model that are identical to R function names. For example, if a model contains a named entity named ‘c’, then the following `mxEval` call will return an error: `mxEval(c(A, B, C), model)`.

If ‘compute’ is FALSE, then `MxAlgebra` expressions returns their current value as they have been computed by the optimization call (using `mxRun`). If the ‘compute’ argument is TRUE, then `MxAlgebra` expressions will be calculated in R. Any references to an objective function that has not yet been calculated will return a 1 x 1 matrix with a value of NA.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
matrixA <- mxMatrix("Full", nrow = 1, ncol = 1,
  values = 1, name = "A")
algebraB <- mxAlgebra(A + A, name = "B")

model <- mxModel(matrixA, algebraB)
model <- mxRun(model)
start <- mxEval(-pi * A, model)
```

```
## Not run:
mxEval(plot(sin, start, B * pi), model)
# The statement above is equivalent to:
plot(sin, -pi, 2 * pi)
## End(Not run)
```

mxFIMLObjective *Function To Create MxFIMLObjective Object*

Description

This function creates a new MxFIMLObjective object.

Usage

```
mxFIMLObjective(covariance, means, dimnames = NA, thresholds = NA, vector = FALSE)
```

Arguments

covariance	A character string indicating the name of the expected covariance algebra.
means	A character string indicating the name of the expected means algebra.
dimnames	An optional character vector to be assigned to the dimnames of the covariance and means algebras.
thresholds	An optional character string indicating the name of the thresholds matrix.
vector	A logical value indicating whether the objective function result is the likelihood vector.

Details

Objective functions are functions for which free parameter values are chosen such that the value of the objective function is minimized. The mxFIMLObjective function uses full-information maximum likelihood to provide maximum likelihood estimates of free parameters in the algebra defined by the 'covariance' and 'means' arguments. The 'covariance' argument takes an [MxAlgebra](#) object, which defines the expected covariance of an associated [MxData](#) object. The 'means' argument takes an [MxAlgebra](#) object, which defines the expected means of an associated [MxData](#) object. The 'dimnames' arguments takes an optional character vector. If this argument is not a single NA, then this vector be assigned to be the dimnames of the means vector, and the row and columns dimnames of the covariance matrix. The 'vector' argument is either TRUE or FALSE, and determines whether the objective function returns a column vector of the likelihoods, or a single $-2*(\log \text{likelihood})$ value.

mxFIMLObjective evaluates with respect to an [MxData](#) object. The [MxData](#) object need not be referenced in the mxFIMLObjective function, but must be included in the [MxModel](#) object. mxFIMLObjective requires that the 'type' argument in the associated [MxData](#) object be equal to 'raw'. Missing values are permitted in the associated [MxData](#) object.

dimnames must be supplied where the matrices referenced by the covariance and means algebras are not themselves labeled. Failure to do so leads to an error noting that the covariance or means matrix associated with the FIML objective does not contain dimnames.

To evaluate, place MxFIMLObjective objects, the [mxData](#) object for which the expected covariance approximates, referenced [MxAlgebra](#) and [MxMatrix](#) objects, and optional [MxBounds](#) and [MxConstraint](#) objects in an [MxModel](#) object. This model may then be evaluated using the [mxRun](#) function. The results of the optimization can be found in the 'output' slot of the resulting model, and may be referenced using the [Extract](#) functionality.

Value

Returns a new MxFIMLObjective object. MxFIMLObjective objects should be included with models with referenced [MxAlgebra](#), [MxData](#) and [MxMatrix](#) objects.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
A <- mxMatrix(values = 0.5, nrow = 2, ncol = 1,
              free = TRUE, name = "A")

D <- mxMatrix(type = "Diag", values = c(0, 0.5),
              free = c(FALSE, TRUE), nrow = 2, name = "D")

M <- mxMatrix(type = "Zero", nrow = 1, ncol = 2, name = "M")

expectedCov <- mxAlgebra(A %*% t(A) + D, "expectedCov")

objective <- mxFIMLObjective("expectedCov", "M")

model <- mxModel(A, D, expectedCov, objective)
```

mxMatrix

Function To Create MxMatrix Object

Description

This functions creates a new [MxMatrix](#) object.

Usage

```
mxMatrix(type = "Full", nrow = NA, ncol = NA,
         free = FALSE, values = NA, labels = NA, lbound = NA,
         ubound = NA, byrow = getOption('mxByrow'), dimnames = NA, name = NA)
```

Arguments

type	a character string indicating the matrix type, where type indicates the range of values and equalities in the matrix. Must be one of: 'Diag', 'Full', 'Iden', 'Lower', 'Sdiag', 'Stand', 'Symm', 'Unit', or 'Zero'.
nrow	the desired number of rows. One or both of 'nrow' and 'ncol' is required when 'values', 'free', 'labels', 'lbound', and 'ubound' arguments are not matrices, depending on the matrix type.
ncol	the desired number of columns. One or both of 'nrow' and 'ncol' is required when 'values', 'free', 'labels', 'lbound', and 'ubound' arguments are not matrices, depending on the matrix type.
free	a vector or matrix of logicals for free parameter specification. A single 'TRUE' or 'FALSE' will set all allowable variables to free or fixed, respectively.
values	a vector or matrix of numeric starting values. By default, all values are set to zero.
labels	a vector or matrix of characters for variable label specification.
lbound	a vector or matrix of numeric lower bounds. Default bounds are specified with an NA.
ubound	a vector or matrix of numeric upper bounds. Default bounds are specified with an NA.
byrow	logical. If 'FALSE' (default), the 'values', 'free', 'labels', 'lbound', and 'ubound' matrices are populated by column rather than by row.
dimnames	list. The dimnames attribute for the matrix: a list of length 2 giving the row and column names respectively. An empty list is treated as NULL, and a list of length one as row names. The list can be named, and the list names will be used as names for the dimensions.
name	an optional character string indicating the name of the MxMatrix object created by the mxModel function.

Details

The `mxMatrix` function creates `MxMatrix` objects, which consist of a pair of matrices and a 'type' argument. The 'values' matrix is made up of numeric elements whose usage and capabilities in other functions are defined by the 'free' matrix. If an element is specified as a fixed parameter in the 'free' matrix, then the element in the 'values' matrix is treated as a constant value and cannot be altered or updated by an objective function when included in an `mxRun` function. If an element is specified as a free parameter in the 'free' matrix, the element in the 'value' matrix is considered a starting value and can be changed by an objective function when included in an `mxRun` function. Free parameters are specified with a character string, non-zero numeric value, or 'NA'; fixed parameters are specified with a numeric zero.

Objects created by the `mxMatrix` function are of a specific ‘type’, which specifies the number and location of parameters in the ‘labels’ matrix and the starting values in the ‘values’ matrix. Input ‘values’, ‘free’, and ‘labels’ matrices must be of appropriate shape and have appropriate values for the matrix type requested. Nine types of matrices are supported:

‘Diag’	matrices must be square, and only elements on the principle diagonal may be specified as free parameters or take no
‘Full’	matrices may be either rectangular or square, and all elements in the matrix may be freely estimated. This type is th
‘Iden’	matrices must be square, and consist of no free parameters. Matrices of this type have a value of 1 for all entries on
‘Lower’	matrices must be square, with a value of 0 for all entries in the upper triangle and no free parameters in the upper tri
‘Sdiag’	matrices must be square, with a value of 0 for all entries in the upper triangle and along the diagonal. No free param
‘Symm’	matrices must be square, and elements in the principle diagonal and lower triangular portion of the matrix may be fr
‘Stand’	matrices are symmetric matrices (see ‘Symm’) with 1’s along the main diagonal.
‘Unit’	matrices may be either rectangular or square, and contain no free parameters. All elements in matrices of this type h
‘Zero’	matrices may be either rectangular or square, and contain no free parameters. All elements in matrices of this type h

When ‘type’ is either ‘Lower’, ‘Sdiag’, ‘Symm’, or ‘Stand’, and the arguments to ‘free’, ‘values’, ‘labels’, ‘lbound’, or ‘ubound’ are vectors with enough elements to populate exactly one half of the matrix, then `mxMatrix()` populates the lower triangle of the matrix (and transposes the lower triangle if the matrix is symmetric).

Value

Returns a new `MxMatrix` object, which consists of a ‘values’ matrix of numeric starting values, a ‘free’ matrix describing free parameter specification, a ‘labels’ matrix of labels for the variable names, and ‘lbound’ and ‘ubound’ matrices of the lower and upper parameter bounds. This `MxMatrix` object can be used as an argument in the `mxAlgebra`, `mxBounds`, `mxConstraint` and `mxModel` functions.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

`MxMatrix` for the S4 class created by `mxMatrix`. More information about the OpenMx package may be found [here](#).

Examples

```
# Create a 3 x 3 identity matrix

idenMatrix <- mxMatrix(type = "Iden", nrow = 3,
  ncol = 3, name = "I")

# Create a full 4 x 2 matrix from existing
# value matrix with all free parameters

vals <- matrix(1:8, nrow = 4)
fullMatrix <- mxMatrix(type = "Full", values = vals,
  free = TRUE, name = "foo")
```

```
# Create a 3 x 3 symmetric matrix with free off-
# diagonal parameters and starting values

symmMatrix <- mxMatrix(type = "Symm", nrow = 3, ncol = 3,
  free = c(FALSE, TRUE, TRUE, FALSE, TRUE, FALSE),
  values = c(1, .8, .8, 1, .8, 1),
  labels = c(NA, "free1", "free2", NA, "free3", NA),
  name = "bar")
```

MxMatrix-class *MxMatrix Class*

Description

MxMatrix is an S4 class. An MxMatrix object is a [named entity](#). New instances of this class can be created using the function [mxMatrix](#). MxMatrix objects may be used as arguments in other functions from the OpenMx library, including [mxAlgebra](#), [mxConstraint](#), and [mxModel](#).

Details

The MxMatrix class has the following slots:

name	-	the name of the object
free	-	the free matrix
values	-	the values matrix
labels	-	the labels matrix

The 'name' slot is the name of the MxMatrix object. Use of MxMatrix objects in an [mxAlgebra](#) or [mxConstraint](#) function requires reference by name.

The 'free' slot takes a matrix which describes the location of free and fixed parameters. A variable is a free parameter if-and-only-if the corresponding value in the 'free' matrix is 'TRUE'. Free parameters are elements of an MxMatrix object whose values may be changed by an objective function when that MxMatrix object is included in an [MxModel](#) object and evaluated using the [mxRun](#) function.

The 'values' slot takes a matrix of numeric values. If an element is specified as a fixed parameter in the 'free' matrix, then the element in the 'values' matrix is treated as a constant value and cannot be altered or updated by an objective function when included in an [mxRun](#) function. If an element is specified as a free parameter in the 'free' matrix, the element in the 'value' matrix is considered a starting value and can be changed by an objective function when included in an [mxRun](#) function.

The 'labels' slot takes a matrix which describes the labels of free and fixed parameters. Fixed parameters with identical labels must have identical values. Free parameters with identical labels impose an equality constraint. The same label cannot be applied to a free parameter and a fixed parameter. A free parameter with the label 'NA' implies a unique free parameter, that cannot be constrained to equal any other free parameter.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxMatrix](#) for creating MxMatrix objects. More information about the OpenMx package may be found [here](#).

mxMLOjective *Function To Create MxMLOjective Object*

Description

This function creates a new MxMLOjective object.

Usage

```
mxMLOjective(covariance, means = NA, dimnames = NA, thresholds = NA)
```

Arguments

<code>covariance</code>	A character string indicating the name of the expected covariance algebra.
<code>means</code>	An optional character string indicating the name of the expected means algebra.
<code>dimnames</code>	An optional character vector to be assigned to the dimnames of the covariance and means algebras.
<code>thresholds</code>	An optional character string indicating the name of the thresholds matrix.

Details

Objective functions are functions for which free parameter values are chosen such that the value of the objective function is minimized. The mxMLOjective function uses full-information maximum likelihood to provide maximum likelihood estimates of free parameters in the algebra defined by the 'covariance' argument given the covariance of an [MxData](#) object. The 'covariance' argument takes an [MxAlgebra](#) object, which defines the expected covariance of an associated [MxData](#) object. The 'dimnames' arguments takes an optional character vector. If this argument is not a single NA, then this vector be assigned to be the dimnames of the means vector, and the row and columns dimnames of the covariance matrix.

mxMLOjective evaluates with respect to an [MxData](#) object. The [MxData](#) object need not be referenced in the mxMLOjective function, but must be included in the [MxModel](#) object. mxMLOjective requires that the 'type' argument in the associated [MxData](#) object be equal to 'cov', 'cov', or 'sscp'. The 'covariance' argument of this function evaluates with respect to the 'matrix' argument of the associated [MxData](#) object, while the 'means' argument of this function evaluates with respect to the 'vector' argument of the associated [MxData](#) object. The 'means' and 'vector' arguments are optional in both functions. If the 'means' argument is not specified (NA), the optional 'vector' argument of the [MxData](#) object is ignored. If the 'means' argument is specified, the associated [MxData](#) object should specify a 'means' argument of equivalent dimension as the 'means' algebra.

dimnames must be supplied where the matrices referenced by the covariance and means algebras are not themselves labeled. Failure to do so leads to an error noting that the covariance or means matrix associated with the ML objective does not contain dimnames.

To evaluate, place MxMLObjective objects, the `mxData` object for which the expected covariance approximates, referenced `MxAlgebra` and `MxMatrix` objects, and optional `MxBounds` and `MxConstraint` objects in an `MxModel` object. This model may then be evaluated using the `mxRun` function. The results of the optimization can be found in the 'output' slot of the resulting model, or using the `mxEval` function.

Value

Returns a new MxMLObjective object. MxMLObjective objects should be included with models with referenced `MxAlgebra`, `MxData` and `MxMatrix` objects.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
vars <- c('x', 'y')

A <- mxMatrix(values = 0.5, nrow = 2, ncol = 1,
  free = TRUE, name = "A")
D <- mxMatrix(type = "Diag", values = c(0, 0.5),
  free = c(FALSE, TRUE), nrow = 2, name = "D")

expectedCov <- mxAlgebra(A %**% t(A) + D, "expectedCov")
observedCov <- mxData(matrix(c(1.2, 0.8, 0.8, 1.3),
  nrow = 2, ncol = 2, dimnames = list(vars, vars)), 'cov', numObs = 150)

objective <- mxMLObjective(covariance = "expectedCov", dimnames = vars)

model <- mxModel("mxMLObjective example", A, D, expectedCov, objective, observedCov)

## Not run: summary(mxRun(model))
```

mxModel

Function To Create MxModel Object

Description

This function creates a new `MxModel` object.

Usage

```
mxModel(model = NA, ..., manifestVars = NA, latentVars = NA,
  remove = FALSE, independent = NA, type = NA, name = NA)
```

Arguments

model	This argument is either an MxModel object or a string. If 'model' is an Mx-Model object, then all elements of that model are placed in the resulting Mx-Model object. If 'model' is a string, then a new model is created with the string as its name. If 'model' is either unspecified or 'model' is a named entity, data source, or MxPath object, then a new model is created.
...	An arbitrary number of named entities, data sources, or MxPath objects. These will all be added or removed from the model as specified in the 'model' argument, based on the 'remove' argument.
manifestVars	A list of manifest variables to be included in the model.
latentVars	A list of latent variables to be included in the model.
remove	logical. If TRUE, elements listed in this statement are removed from the original model. If FALSE, elements listed in this statement are added to the original model.
independent	logical. If TRUE then the model is independent.
type	character vector. The name of the model type to assign to this model.
name	An optional character vector indicating the name of the object.

Details

The mxModel function is used to create [MxModel](#) objects. Objects created by this function may be new, or may be modified versions of existing [MxModel](#) objects. To create a new [MxModel](#) object, omit or specify a character string in the 'model' argument. To create a modified version of an existing [MxModel](#) object, include this model in the 'model' argument.

Other [named-entities](#) may be added as arguments to the mxModel function, which are then added to or removed from the model specified in the 'model' argument. [MxAlgebra](#) objects, [MxBounds](#) objects, [MxConstraint](#) objects, [MxData](#) objects, [MxMatrix](#) objects, [MxModel](#) objects and objective functions may all be added in this way. [MxModel](#) objects that are included as arguments will be considered sub-models of the output model, and may be estimated separately or jointly depending on shared parameters and the 'independent' flag discussed below. Only one [MxData](#) object and one objective function may be included per model, but there are no restrictions on the number of other [named-entities](#) included in an mxModel statement.

All other arguments must be named (i.e. 'latentVars = names'), or they will be interpreted as elements of the ellipsis list. The 'manifestVars' and 'latentVars' arguments specify the names of the manifest and latent variables, respectively, for use with the [mxPath](#) function. The 'remove' argument may be used when mxModel is used to create a modified version of an existing [MxMatrix](#) object. When 'remove' is set to TRUE, the listed objects are removed from the model specified in the 'model' argument. When 'remove' is set to FALSE, the listed objects are added to the model specified in the 'model' argument.

Model independence may be specified with the 'independent' argument. If a model is independent ('independent = TRUE'), then the parameters of this model are not shared with any other model. An independent model may be estimated with no dependency on any other model. If a model is not independent ('independent = FALSE'), then this model shares parameters with one or more other models such that these models must be jointly estimated. These dependent models must be entered as arguments in another model, so that they are simultaneously optimized.

The model type is determined by a character vector supplied to the ‘type’ argument. The type of a model is a dynamic property, ie. it is allowed to change during the lifetime of the model. To see a list of available types, use the `mxTypes` command. When a new model is created and no type is specified, the type specified by `options("mxDefaultType")` is used.

To be estimated, `MxModel` objects must include objective functions as arguments (`mxAlgebraObjective`, `mxFIMLObjective`, `mxMLObjective` or `mxRAMObjective`) and executed using the `mxRun` function. When `MxData` objects are included in models, the ‘type’ argument of these objects may require or exclude certain objective functions, or set an objective function as default.

Named entities in `MxModel` objects may be viewed and referenced by name using double brackets (`model[["matrixname"]]`). Slots may be referenced with the `@` symbol (`model@data`). See the documentation for `Classes` and the examples in this document for more information.

Value

Returns a new `MxModel` object. `MxModel` objects must include an objective function to be used as arguments in `mxRun` functions.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

`MxModel` for the S4 class created by `mxMatrix`. More information about the OpenMx package may be found [here](#).

Examples

```
# Create an empty model, and place it in an object.
model <- mxModel()

# Create a model named 'firstdraft' with one matrix
model <- mxModel('firstdraft',
                 mxMatrix('Full', nrow = 3, ncol = 3, name = "A"))

# Add other matrices to model 'firstdraft', and rename that model 'finaldraft'
model <- mxModel(model,
                 mxMatrix('Symm', nrow = 3, ncol = 3, name = "S"),
                 mxMatrix('Iden', nrow = 3, name = "F"),
                 name = "finaldraft")

# Add data to the model from an existing data frame in object 'data'
data <- data.frame()
model <- mxModel(model, mxData(data, type='raw'))

#View the matrix named "A" in MxModel object 'model'
model[["A"]]

#View the data associated with MxModel object 'model'
model@data
```

MxModel-class *MxModel Class*

Description

MxModel is an S4 class. An MxModel object is a [named entity](#). New instances of this class can be created using the function [mxModel](#).

Details

The MxModel class has the following slots:

name	-	The name of the object
matrices	-	A list of MxMatrix objects
algebras	-	A list of MxAlgebra objects
submodels	-	A list of MxModel objects
constraints	-	A list of MxConstraint objects
bounds	-	A list of MxBounds objects
latentVars	-	A list of latent variables
manifestVars	-	A list of manifest variables
data	-	A MxData object
objective	-	Either NULL or a MxObjective object
independent	-	TRUE if-and-only-if the model is independent
options	-	A list of optimizer options
output	-	A list with optimization results

The ‘name’ slot is the name of the MxModel object.

The ‘matrices’ slot contains a list of the [MxMatrix](#) objects included in the model. These objects are listed by name. Two objects may not share the same name. If a new [MxMatrix](#) is added to an MxModel object with the same name as an [MxMatrix](#) object in that model, the added version replaces the previous version. There is no imposed limit on the number of [MxMatrix](#) objects that may be added here.

The ‘algebras’ slot contains a list of the [MxAlgebra](#) objects included in the model. These objects are listed by name. Two objects may not share the same name. If a new [MxAlgebra](#) is added to an MxModel object with the same name as an [MxAlgebra](#) object in that model, the added version replaces the previous version. All [MxMatrix](#) objects referenced in the included [MxAlgebra](#) objects must be included in the ‘matrices’ slot prior to estimation. There is no imposed limit on the number of [MxAlgebra](#) objects that may be added here.

The ‘submodels’ slot contains references to all of the MxModel objects included as submodels of this MxModel object. Models held as arguments in other models are considered to be submodels. These objects are listed by name. Two objects may not share the same name. If a new submodel is added to an MxModel object with the same name as an existing submodel, the added version replaces the previous version. When a model containing other models is executed using [mxRun](#), all included submodels are executed as well. If the submodels are dependent on one another, they are treated as one larger model for purposes of estimation.

The ‘constraints’ slot contains a list of the [MxConstraint](#) objects included in the model. These objects are listed by name. Two objects may not share the same name. If a new [MxConstraint](#) is added to an [MxModel](#) object with the same name as an [MxConstraint](#) object in that model, the added version replaces the previous version. All [MxMatrix](#) objects referenced in the included [MxConstraint](#) objects must be included in the ‘matrices’ slot prior to estimation. There is no imposed limit on the number of [MxAlgebra](#) objects that may be added here.

The ‘bounds’ slot contains a list of the [MxBounds](#) objects included in the model. These objects are listed by name. Two objects may not share the same name. If a new [MxBounds](#) is added to an [MxModel](#) object with the same name as an [MxBounds](#) object in that model, the added version replaces the previous version. All [MxMatrix](#) objects referenced in the included [MxBounds](#) objects must be included in the ‘matrices’ slot prior to estimation. There is no imposed limit on the number of [MxAlgebra](#) objects that may be added here.

The ‘latentVars’ slot contains a list of latent variable names, which may be referenced by [MxPath](#) objects. This slot defaults to ‘NA’, and is only used when the [mxPath](#) function is used.

The ‘manifestVars’ slot contains a list of latent variable names, which may be referenced by [MxPath](#) objects. This slot defaults to ‘NA’, and is only used when the [mxPath](#) function is used.

The ‘data’ slot contains an [MxData](#) object. This slot must be filled prior to execution when an objective function referencing data is used. Only one [MxData](#) object may be included per model, but submodels may have their own data in their own ‘data’ slots. If an [MxData](#) object is added to an [MxModel](#) which already contains an [MxData](#) object, the new object replaces the existing one.

The ‘objective’ slot contains an objective function. This slot must be filled prior to using the [mxRun](#) function for model execution and optimization. [MxAlgebra](#), [MxData](#), and [MxMatrix](#) objects required by the included objective function must be included in the appropriate slot of the [MxModel](#) prior to using [mxRun](#).

The ‘independent’ slot contains a logical value indicating whether or not the model is independent. If a model is independent (independent=TRUE), then the parameters of this model are not shared with any other model. An independent model may be estimated with no dependency on any other model. If a model is not independent (independent=FALSE), then this model shares parameters with one or more other models such that these models must be jointly estimated. These dependent models must be entered as submodels of another [MxModel](#) objects, so that they are simultaneously optimized.

The ‘options’ slot contains a list of options for the optimizer. The name of each entry in the list is the option name to be passed to the optimizer. The values in this list are the values of the optimizer options. The standard interface for updating options is through the [mxOption](#) function.

The ‘output’ slot contains a list of output added to the model by the [mxRun](#) function. Output includes parameter estimates, optimization information, model fit, and other information as dictated by the objective function. If a model has not been optimized using the [mxRun](#) function, the ‘output’ slot will be ‘NULL’.

[Named entities](#) in [MxModel](#) objects may be viewed and referenced by name using double brackets (model[["matrixname"]]). Slots may be referenced with the @ symbol (model@data). See the documentation for [Classes](#) and the examples in [mxModel](#) for more information.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[mxModel](#) for creating MxModel objects. More information about the OpenMx package may be found [here](#).

`mxOption`*Set or Clear an Optimizer Option*

Description

The function sets or clears an option that is specific to the optimizer in the back-end.

Usage

```
mxOption(model, key, value, reset = FALSE)
```

Arguments

<code>model</code>	An MxModel object
<code>key</code>	The name of the option.
<code>value</code>	The value of the option.
<code>reset</code>	If TRUE then reset all options to their defaults.

Details

Sets an option that is specific to the particular optimizer used in the back-end. The name of the option is the 'key' argument. Use `value = NULL` to remove an existing option. Before the model is submitted to the back-end, all keys and values are converted into strings using the [as.character](#) function. To reset all options to their default values, use `reset = TRUE`. If `reset = TRUE`, then 'key' and 'value' are ignored. Use `getOption('mxOptimizerOptions')` to see the default optimizer options.

Value

Returns the model with the optimizer option either set or cleared.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
model <- mxModel()

model <- mxOption(model, "Function Precision", 1e-5)
model <- mxOption(model, "Hessian", "No")
model <- mxOption(model, "Function Precision", NULL)
```

mxPath

*Function To Create List of Paths***Description**

This function creates a list of paths.

Usage

```
mxPath(from, to = NA, all = FALSE, arrows = 1,
       free = TRUE, values = NA, labels = NA,
       lbound = NA, ubound = NA)
```

Arguments

from	character vector. these are the sources of the new paths.
to	character vector. these are the sinks of the new paths.
all	boolean value. If TRUE, then connect all sources to all sinks.
arrows	numeric value. Must be either 1 for single-headed or 2 for double-headed arrows.
free	boolean vector. Indicates whether paths are free or fixed.
values	numeric vector. The starting values of the parameters.
labels	character vector. The names of the paths.
lbound	numeric vector. The lower bounds of free parameters.
ubound	numeric vector. The upper bounds of free parameters.

Details

The mxPath function creates [MxPath](#) objects, which are lists of paths describing the relationships between variables in a model using the RAM modeling approach (McArdle and MacDonald, 1984). Variables are referenced by name, which are included in the 'manifestVar' and 'latentVar' arguments of the [mxModel](#) function.

Paths are specified as going from one variable or set of variables to another variable or set of variables using the 'from' and 'to' arguments, respectively. Sets of variables may be input as a vector of variable names. If the 'all' argument is set to FALSE, then paths are created going from each entry in the 'from' vector to the corresponding position in the 'to' vector. If the 'to' and 'from' vectors are of different lengths when the 'all' argument is set to FALSE, the shorter vector is repeated to make the vectors of equal length. If the 'all' argument is set to TRUE, all possible paths from the vector of 'from' variables to the vector of 'to' variables are created.

The 'free' argument specifies whether the paths created by the mxPath function are free or fixed parameters. This argument may take either TRUE for free parameters, FALSE for fixed parameters, or a vector of TRUEs and FALSEs to be applied in order to the created paths.

The 'arrows' argument specifies the type of paths created. A value of 1 indicates a one-headed arrow representing regression. This path represents a regression of the 'to' variable on the 'from'

variable, such that the arrow points to the 'to' variable in a path diagram. A value of 2 indicates a two-headed arrow, representing a covariance or variance. If multiple paths are created in the same mxPath function, then the 'arrows' argument may take a vector of 1s and 2s to be applied to the set of created paths.

The 'values' is a numeric vectors containing the starting values of the created paths. 'values' gives a starting value for estimation. The 'labels' argument specifies the names of the resulting MxPath object. The 'lbound' and 'ubound' arguments specify lower and upper bounds for the created paths.

Value

Returns a list of paths.

References

McArdle, J. J. and MacDonald, R. P. (1984). Some algebraic properties of the Reticular Action Model for moment structures. *British Journal of Mathematical and Statistical Psychology*, 37, 234-251.

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
myManifest <- sprintf("%02d", c(1:100))
myLatent <- c("G1", "G2", "G3", "G4", "G5")
model <- mxModel(type = "RAM", manifestVars = myManifest, latentVars = myLatent)

singles <- list()
for (i in 1:5) {
  j <- i*20
  singles <- c(singles, mxPath(from = myLatent[i],
                              to = myManifest[(j - 19) : j],
                              arrows = 1,
                              free = c(FALSE, rep(TRUE, 19)),
                              values = c(1, rep(0.75, 19))))
}
model <- mxModel(model, singles)

doubles <- mxPath(from = myLatent, all = TRUE, arrows = 2,
                 free = TRUE, values = 1)

model <- mxModel(model, doubles)
```

mxRAMObjective

Function To Create MxRAMObjective Object

Description

This function creates a new MxRAMObjective object.

Usage

```
mxRAMObjective(A, S, F, M = NA, dimnames = NA, thresholds = NA)
```

Arguments

A	A character string indicating the name of the 'A' matrix.
S	A character string indicating the name of the 'S' matrix.
F	A character string indicating the name of the 'F' matrix.
M	An optional character string indicating the name of the 'M' matrix.
dimnames	An optional character vector to be assigned to the column names of the 'F' and 'M' matrices.
thresholds	An optional character string indicating the name of the thresholds matrix.

Details

Objective functions are functions for which free parameter values are chosen such that the value of the objective function is minimized. The `mxRAMObjective` provides maximum likelihood estimates of free parameters in a model of the covariance of a given `MxData` object. This model is defined by reticular action modeling (McArdle and McDonald, 1984). The 'A', 'S', and 'F' arguments must refer to `MxMatrix` objects with the associated properties of the A, S, and F matrices in the RAM modeling approach.

The 'dimnames' argument takes an optional character vector. If this argument is not a single NA, then this vector is assigned to be the column names of the 'F' matrix and optionally to the 'M' matrix, if the 'M' matrix exists.

The 'A' argument refers to the A or asymmetric matrix in the RAM approach. This matrix consists of all of the asymmetric paths (one-headed arrows) in the model. A free parameter in any row and column describes a regression of the variable represented by that row regressed on the variable represented in that column.

The 'S' argument refers to the S or symmetric matrix in the RAM approach, and as such must be square. This matrix consists of all of the symmetric paths (two-headed arrows) in the model. A free parameter in any row and column describes a covariance between the variable represented by that row and the variable represented by that column. Variances are covariances between any variable at itself, which occur on the diagonal of the specified matrix.

The 'F' argument refers to the F or filter matrix in the RAM approach. If no latent variables are included in the model (i.e., the A and S matrices are of both of the same dimension as the data matrix), then the 'F' should refer to an identity matrix. If latent variables are included (i.e., the A and S matrices are not of the same dimension as the data matrix), then the 'F' argument should consist of a horizontal adhesion of an identity matrix and a matrix of zeros.

The 'M' argument refers to the M or means matrix in the RAM approach. It is a 1 x n matrix, where n is the number of manifest variables + the number of latent variables. The M matrix must be specified if either the `mxData` type is "cov" or "cor" and a means vector is provided, or if the `mxData` type is "raw". Otherwise the M matrix is ignored.

The `MxMatrix` objects included as arguments may be of any type, but should have the properties described above. The `mxRAMObjective` will not return an error for incorrect specification, but incorrect specification will likely lead to estimation problems or errors in the `mxRun` function.

mxRAMObjective evaluates with respect to an `MxData` object. The `MxData` object need not be referenced in the `mxRAMObjective` function, but must be included in the `MxModel` object. `mxRAMObjective` requires that the 'type' argument in the associated `MxData` object be equal to 'cov', 'cor' or 'sscp'.

To evaluate, place `MxRAMObjective` objects, the `mxData` object for which the expected covariance approximates, referenced `MxAlgebra` and `MxMatrix` objects, and optional `MxBounds` and `MxConstraint` objects in an `MxModel` object. This model may then be evaluated using the `mxRun` function. The results of the optimization can be found in the 'output' slot of the resulting model, and may be obtained using the `mxEval` function..

Value

Returns a new `MxRAMObjective` object. `MxRAMObjective` objects should be included with models with referenced `MxAlgebra`, `MxData` and `MxMatrix` objects.

References

McArdle, J. J. and MacDonald, R. P. (1984). Some algebraic properties of the Reticular Action Model for moment structures. *British Journal of Mathematical and Statistical Psychology*, 37, 234-251.

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
matrixA <- mxMatrix("Full", values=c(0,0.2,0,0), name="A", nrow=2, ncol=2)
matrixS <- mxMatrix("Full", values=c(0.8,0,0,0.8), name="S", nrow=2, ncol=2, free=TRUE)
matrixF <- mxMatrix("Full", values=c(1,0,0,1), name="F", nrow=2, ncol=2)

# Create a RAM objective with default A, S, F matrix names
objective <- mxRAMObjective("A", "S", "F")

model <- mxModel(matrixA, matrixS, matrixF, objective)
```

mxRObjective

Function to Create MxRObjective Object

Description

This function creates a new `MxRObjective` object.

Usage

```
mxRObjective(objfun)
```

Arguments

`objfun` A function that accepts two arguments.

Details

The `objfun` argument must be a function that accepts two arguments. The first argument is the `mxModel` that should be evaluated, and the second argument is some persistent state information that can be stored between one iteration of optimization to the next iteration. It is valid for the function to simply ignore the second argument.

The function must return either a single numeric value, or a list of exactly two elements. If the function returns a list, the first argument must be a single numeric value and the second element will be the new persistent state information to be passed into this function at the next iteration. The single numeric value will be used by the optimizer to perform optimization.

The initial default value for the persistent state information is NA.

Value

Returns a new `MxROjective` object.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
A <- mxMatrix(nrow = 2, ncol = 2, values = c(1:4), free = TRUE, name = 'A')

squared <- function(x) { x ^ 2 }

objFunction <- function(model, state) {
  values <- model[['A']]@values
  return(squared(values[1,1] - 4) + squared(values[1,2] - 3) +
         squared(values[2,1] - 2) + squared(values[2,2] - 1))
}
objective <- mxROjective(objFunction)

model <- mxModel('model', A, objective)
```

 mxRun

Send a Model to the Optimizer

Description

This function begins optimization on the top-level model.

Usage

```
mxRun(model)
```


Arguments

model An [MxModel](#) object to be optimized.

Details

The mxRun function is used to optimize free parameters in [MxModel](#) objects based on an objective function. MxModel objects included in the mxRun function must include an appropriate objective function.

Free parameters are estimated or updated based on the objective function. These estimated values, along with estimation information and model fit, can be found in the 'output' slot of MxModel objects after mxRun has been used.

If a model is dependent on or shares parameters with another model, both models must be included as arguments in another MxModel object. This top-level MxModel object must include objective functions in both submodels, as well as an additional objective function describing how the results of the first two should be combined.

Value

Returns an MxModel object with free parameters updated to their final values. The return value contains an "output" slot with the results of optimization.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
#Create a model that includes data, matrices A, S and F, and an objective function
## Not run:
data <- mxData(mydata, type="cov", numObs = 100)
objective <- mxRAMObjective('A', 'S', 'F')
model <- mxModel("mymodel", A, S, F, data, objective)

#Use mxRun to optimize the free parameters in the matrices A and S
model <- mxRun(model)

#print the output
model@output
## End(Not run)
```

mxTypes

List Currently Available Model Types

Description

This function returns a vector of the currently available type names.

Usage

```
mxTypes()
```

Value

Returns a character vector of type names.

Examples

```
mxTypes()
```

```
mxVersion
```

Returns Current Version String

Description

This function returns a string with the current version number of OpenMx.

Usage

```
mxVersion()
```

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

Examples

```
mxVersion()
```

```
Named-entity
```

Named Entities

Description

A named entity is an S4 object that can be referenced by name.

Details

Every named entity is guaranteed to have a slot 'name'. Within a model, the named entities of that model can be accessed using the `model[['name']]` notation. Access is limited to one nesting depth, such that if 'B' is a submodel of 'A', and 'C' is a matrix of 'B', then 'C' must be accessed using `A[['B']][['C']]`. See the documentation for [Extract](#) for more information.

The following S4 classes are named entities in the OpenMx library: [MxAlgebra](#), [MxConstraint](#), [MxMatrix](#), [MxModel](#), [MxData](#), and [MxObjective](#).

`omxCheckCloseEnough`*Approximate Equality Testing Function*

Description

This function tests whether two numeric vectors or matrixes are approximately equal to one another, within a specified threshold.

Usage

```
omxCheckCloseEnough(a, b, epsilon = 10^(-15))
```

Arguments

<code>a</code>	A numeric vector or matrix.
<code>b</code>	A numeric vector or matrix.
<code>epsilon</code>	A non-negative tolerance threshold.

Details

Arguments ‘a’ and ‘b’ must be of the same type, ie. they must be either vectors of equal dimension or matrices of equal dimension. The two arguments are compared element-wise for approximate equality. If the absolute value of the difference of any two values is greater than the threshold, then an error will be thrown. If ‘a’ and ‘b’ are approximately equal to each other, by default the function will print a statement informing the user the test has passed. To turn off these print statements use `options("mxPrintUnitTests" = FALSE)`.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[CheckWithinPercentError](#) for approximate equality testing within a percentage.

[omxCheckIdentical](#) for exact equality testing.

[omxCheckSetEquals](#) for set equality testing.

[omxCheckTrue](#) for boolean equality testing.

Examples

```
omxCheckCloseEnough(c(1, 2, 3), c(1.1, 1.9, 3.0), epsilon = 0.5)

omxCheckCloseEnough(matrix(3, 3, 3), matrix(4, 3, 3), epsilon = 2)

# Throws an error
```

```
try(omxCheckCloseEnough(c(1, 2, 3), c(1.1, 1.9, 3.0), epsilon = 0.01))
```

omxCheckIdentical *Exact Equality Testing Function*

Description

This function tests whether two objects are equal.

Usage

```
omxCheckIdentical(a, b)
```

Arguments

a	The first value to compare.
b	The second value to compare.

Details

Performs the ‘identical’ comparison on the two arguments. If the two arguments are not equal, then an error will be thrown. If ‘a’ and ‘b’ are equal to each other, by default the function will print a statement informing the user the test has passed. To turn off these print statements use `options("mxPrintUnitTests" = FALSE)`.

References

The OpenMx User’s guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[omxCheckCloseEnough](#) for approximate equality testing within an epsilon.
[CheckWithinPercentError](#) for approximate equality testing within a percentage.
[omxCheckSetEquals](#) for set equality testing.
[omxCheckTrue](#) for boolean equality testing.

Examples

```
omxCheckIdentical(c(1, 2, 3), c(1, 2, 3))  
  
omxCheckIdentical(FALSE, FALSE)  
  
# Throws an error  
try(omxCheckIdentical(c(1, 2, 3), c(2, 1, 3)))
```

omxCheckSetEquals Set Equality Testing Function

Description

This function tests whether two vectors contain the same elements.

Usage

```
omxCheckSetEquals(a, b)
```

Arguments

a	The first vector to compare.
b	The second vector to compare.

Details

Performs the 'setequal' function on the two arguments. If the two arguments do not contain the same elements, then an error will be thrown. If 'a' and 'b' contain the same elements, by default the function will print a statement informing the user the test has passed. To turn off these print statements use `options("mxPrintUnitTests" = FALSE)`.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

`omxCheckCloseEnough` for approximate equality testing within an epsilon.
`CheckWithinPercentError` for approximate equality testing within a percentage.
`omxCheckIdentical` for exact equality testing.
`omxCheckTrue` for boolean equality testing.

Examples

```
omxCheckSetEquals(c(1, 1, 2, 2, 3), c(3, 2, 1))

omxCheckSetEquals(matrix(1, 1, 1), matrix(1, 3, 3))

# Throws an error
try(omxCheckSetEquals(c(1, 2, 3, 4), c(2, 1, 3)))
```

omxCheckTrue *Boolean Equality Testing Function*

Description

This function tests whether an object is equal to TRUE.

Usage

```
omxCheckTrue(a)
```

Arguments

a The value to test.

Details

Checks element-wise whether an object is equal to TRUE. If any of the elements are false, then an error will be thrown. If 'a' is TRUE, by default the function will print a statement informing the user the test has passed. To turn off these print statements use `options("mxPrintUnitTests" = FALSE)`.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[omxCheckCloseEnough](#) for approximate equality testing within an epsilon.

[CheckWithinPercentError](#) for approximate equality testing within a percentage.

[omxCheckIdentical](#) for exact equality testing.

[omxCheckSetEquals](#) for set equality testing.

Examples

```
omxCheckTrue(1 + 1 == 2)

omxCheckTrue(matrix(TRUE, 3, 3))

# Throws an error
try(omxCheckTrue(FALSE))
```

omxCheckWithinPercentError
Approximate Percent Equality Testing Function

Description

This function tests whether two numeric vectors or matrixes are approximately equal to one another, within a specified percentage.

Usage

```
omxCheckWithinPercentError(a, b, percent = 0.1)
```

Arguments

a	A numeric vector or matrix.
b	A numeric vector or matrix.
percent	A non-negative percentage.

Details

Arguments 'a' and 'b' must be of the same type, ie. they must be either vectors of equal dimension or matrices of equal dimension. The two arguments are compared element-wise for approximate equality. If the absolute value of the difference of any two values is greater than the percentage difference of 'a', then an error will be thrown. If 'a' and 'b' are approximately equal to each other, by default the function will print a statement informing the user the test has passed. To turn off these print statements use `options("mxPrintUnitTests" = FALSE)`.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

See Also

[omxCheckCloseEnough](#) for approximate equality testing within an epsilon.

[omxCheckIdentical](#) for exact equality testing.

[omxCheckSetEquals](#) for set equality testing.

[omxCheckTrue](#) for boolean equality testing.

Examples

```
omxCheckWithinPercentError(c(1, 2, 3), c(1.1, 1.9, 3.0), percent = 50)

omxCheckWithinPercentError(matrix(3, 3, 3), matrix(4, 3, 3), percent = 150)

# Throws an error
```

```
try(omxCheckWithinPercentError(c(1, 2, 3), c(1.1, 1.9, 3.0), percent = 0.01))
```

omxGraphviz	<i>Show RAM Model in Graphviz Format</i>
-------------	--

Description

The function accepts a RAM style model and outputs a visual representation of the model in Graphviz format. The function will output either to a file or to the console. The recommended file extension for an output file is ".dot".

Usage

```
omxGraphviz(model, dotFilename = "")
```

Arguments

model	An RAM-type model.
dotFilename	The name of the output file. Use "" to write to console.

Value

Invisibly returns a string containing the model description in graphviz format.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

OpenMx	<i>OpenMx: Package for Matrix Algebra Optimization</i>
--------	--

Description

OpenMx is a package for structural equation modeling, matrix algebra optimization and other statistical estimation problems.

Details

OpenMx is a package for algebra optimization and statistical estimation problems using matrix algebra. The OpenMx library defines a set of S4 classes and functions used to create them. The majority of these classes are used as arguments in models, which may include data, matrices, algebras, bounds and constraints. These models are then paired with objective functions, either existing (maximum likelihood, FIML) or user-defined with included algebra functions. These models can then be optimized, resulting in parameter estimation, algebra evaluation, and output for additional models.

Objects used or created by OpenMx may be of the following classes: [MxAlgebra](#), [MxBounds](#), [MxConstraint](#), [MxData](#), [MxMatrix](#), [MxModel](#), and [MxPath](#). Objects of these classes may be created by the following OpenMx functions: [mxAlgebra](#), [mxBounds](#), [mxConstraint](#), [mxData](#), [mxMatrix](#), [mxModel](#), and [mxPath](#). The functions [mxAlgebraObjective](#), [mxFIMLObjective](#), [mxMLObjective](#) and [mxRAMObjective](#) create objective functions for model estimation. Models which include objective functions may be estimated using the [mxRun](#) function.

References

The OpenMx User's guide can be found at <http://openmx.psyc.virginia.edu/documentation>.

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