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LazyData yes
ByteCompile yes
Description This package contains functions for fitting general linear structural
equation models (with observed and unobserved variables) using the RAM approach,
and for fitting structural equations in observed-variable models by two-stage least squares.
License GPL (>= 2)
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Bollen  Bollen's Data on Industrialization and Political Democracy

Description

This data set includes four measures of democracy at two points in time, 1960 and 1965, and three measures of industrialization in 1960, for 75 developing countries.

Usage

Bollen

Format

A data frame with 75 observations on the following 11 variables.

y1 freedom of the press, 1960
y2 freedom of political opposition, 1960
y3 fairness of elections, 1960
Variables y1 through y4 are intended to be indicators of the latent variable political democracy in 1960; y5 through y8 indicators of political democracy in 1965; and x1 through x3 indicators of industrialization in 1960.

Source

personal communication from Ken Bollen.

References


---

**bootSem**

*Bootstrap a Structural Equation Model*

**Description**

Bootstraps a structural equation model in an `sem` object (as returned by the `sem` function).

**Usage**

```r
bootSem(model, ...) 
```

- `## S3 method for class 'sem'`
  ```r
  bootSem(model, R=100, Cov= cov, data=model$data, max.failures=10, ...)
  ```

- `## S3 method for class 'msem'`
  ```r
  bootSem(model, R=100, Cov= cov, data=model$data, max.failures=10, ...)
  ```

- `## S3 method for class 'bootsem'`
  ```r
  print(x, digits=getOption("digits"), ...)
  ```

- `## S3 method for class 'bootsem'`
  ```r
  summary(object, 
    type=c("perc", "bca", "norm", "basic", "none"), level=0.95, ...)
  ```
Arguments

model
   an sem or msem object, produced by the sem function.
R
   the number of bootstrap replications; the default is 100, which should be enough for computing standard errors, but not confidence intervals (except for the normal-theory intervals).
Cov
   a function to compute the input covariance or moment matrix; the default is cov. Use cor if the model is fit to the correlation matrix. The function hetcor in the polycor package will compute product-moment, polychoric, and polyserial correlations among mixed continuous and ordinal variables (see the first example below for an illustration).
data
   in the case of a sem (i.e., single-group) model, a data set in a form suitable for Cov; for example, for the default Cov=cov, data may be a numeric data frame or a numeric matrix. In the case of an msem (i.e., multi-group) model, a list of data sets (again in the appropriate form), one for each group; in this case, bootstrapping is done within each group, treating the groups as strata. Note that the original observations are required, not just the covariance matrix of the observed variables in the model. The default is the data set stored in the sem object, which will be present only if the model was fit to a data set rather than to a covariance or moment matrix, and may not be in a form suitable for Cov.
max.failures
   maximum number of consecutive convergence failures before bootSem gives up.
x, object
   an object of class bootsem.
digits
   controls the number of digits to print.
type
   type of bootstrapped confidence intervals to compute; the default is "perc" (percentile); see boot.ci for details.
level
   level for confidence intervals; default is 0.95.
...  
   in bootSem, arguments to be passed to sem; otherwise ignored.

Details

bootSem implements the nonparametric bootstrap, assuming an independent random sample. Convergence failures in the bootstrap resamples are discarded (and a warning printed); more than max.failures consecutive convergence failures (default, 10) result in an error. You can use the boot function in the boot package for more complex sampling schemes and additional options.

Bootstrapping is implemented by resampling the observations in data, recalculating the input covariance matrix with Cov, and refitting the model with sem, using the parameter estimates from the original sample as start-values.

Warning: the bootstrapping process can be very time-consuming.

Value

bootSem returns an object of class bootsem, which inherits from class boot, supported by the boot package. The returned object contains the following components:
t0
   the estimated parameters in the model fit to the original data set.
a matrix containing the bootstrapped estimates, one bootstrap replication per row.

data the data to which the model was fit.

seed the value of .Random.seed when bootSem was called.

statistic the function used to produce the bootstrap replications; this is always the local function `refit` from `bootSem`.

sim always set to "ordinary"; see the documentation for the `boot` function.

stype always set to "i"; see the documentation for the `boot` function.

call the call of the `bootSem` function.

weights a vector of length equal to the number of observations $N$, with entries $1/N$. For a multi-group model, the weights in group $j$ are $1/N_j$, the inverse of the number of observations in the group.

strata a vector of length $N$ containing the number of the stratum to which each observation belongs; for a single-group model, all entries are 1.

Author(s)

John Fox <jfox@mcmaster.ca>

References


See Also

boot, sem

Examples

```r
## Not run:

# A simple confirmatory factor-analysis model using polychoric correlations.
# The polycor package is required for the hetcor function.

library(polycor)

# The following function returns correlations computed by hetcor,
# and is used for the bootstrapping.

hcor <- function(data) hetcor(data, std.err=FALSE)$correlations

model.cnes <- specifyModel()
F -> MBSA2, lam1
F -> MBSA7, lam2
F -> MBSA8, lam3
F -> MBSA9, lam4
F <-> F, NA, 1
```
```
MBSA2 <- MBSA2, the1
MBSA7 <- MBSA7, the2
MBSA8 <- MBSA8, the3
MBSA9 <- MBSA9, the4

R.cnnes <- hcor(CNES)

sem.cnnes <- sem(model.cnnes, R.cnnes, N=1529)
summary(sem.cnnes)

# Note: this can take a minute:
set.seed(12345) # for reproducibility

system.time(boot.cnnes <- bootSem(sem.cnnes, R=100, Cov=hcor, data=CNES))
summary(boot.cnnes, type="norm")
# cf., standard errors to those computed by summary(sem.cnnes)

# An example bootstrapping a multi-group model

library(MBEES) # for data
data(HS.data)

mod.hs <- cfa()
spatial: visual, cubes, paper, flags
verbal: general, paragraph, sentence, wordc, wordm
memory: wordr, numberf, figurer, object, numberb, figurew
math: deduct, numeric, problemr, series, arithmet

mod.mg <- multigroupModel(mod.hs, groups=c("Female", "Male"))

sem.mg <- sem(mod.mg, data=HS.data, group="Gender",
formula = ~ visual + cubes + paper + flags +
general + paragraph + sentence + wordc + wordm +
wordr + numberf + figurer + object + numberb + figurew +
deduct + numeric + problemr + series + arithmet
)

# Note: this example can take several minutes or more;
# you can decrease R if you just want to see how it works:
set.seed(12345) # for reproducibility

system.time(boot.mg <- bootSem(sem.mg, R=100))
summary(boot.mg, type="norm")
# cf., standard errors to those computed by summary(sem.mg)

## End(Not run)
```
Description

These variables are from the mailback questionnaire to the 1997 Canadian National Election Study, and are intended to tap attitude towards “traditional values.”

Usage

CNES

Format

A data frame with 1529 observations on the following 4 variables.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MBSC</td>
<td>an ordered factor with levels StronglyDisagree, Disagree, Agree, and StronglyAgree, in response to the statement, “We should be more tolerant of people who choose to live according to their own standards, even if they are very different from our own.”</td>
</tr>
<tr>
<td>MBSD</td>
<td>an ordered factor with levels StronglyDisagree, Disagree, Agree, and StronglyAgree, in response to the statement, “Newer lifestyles are contributing to the breakdown of our society.”</td>
</tr>
<tr>
<td>MBSX</td>
<td>an ordered factor with levels StronglyDisagree, Disagree, Agree, and StronglyAgree, in response to the statement, “The world is always changing and we should adapt our view of moral behaviour to these changes.”</td>
</tr>
<tr>
<td>MBSY</td>
<td>an ordered factor with levels StronglyDisagree, Disagree, Agree, and StronglyAgree, in response to the statement, “This country would have many fewer problems if there were more emphasis on traditional family values.”</td>
</tr>
</tbody>
</table>

Source

York University Institute for Social Research.

effects.sem  Total, Direct, and Indirect Effects for Structural Equation Models

Description

The sem method for the standard generic function effects computes total, direct, and indirect effects for a fitted structural equation model according to the method described in Fox (1980).

Usage

```r
# S3 method for class 'sem'
effects(object, ...)
# S3 method for class 'msem'
effects(object, ...)

# S3 method for class 'semeffects'
print(x, digits = getOption("digits"), ...)
# S3 method for class 'semeffectsList'
print(x, digits = getOption("digits"), ...)```
Arguments

object a fitted structural-equation model object produced by the \texttt{sem} function.

\texttt{x} an object of class \texttt{semeffects} or \texttt{semeffectsList}, produced by \texttt{effects}.

digits digits to print.

\texttt{...} not used.

Value

effect.sem returns an object of class \texttt{semeffects} with Total, Direct, and Indirect elements.

Author(s)

John Fox \texttt{<jfox@mcmaster.ca>}

References


See Also

\texttt{sem}

Examples

```r
## Not run:

# These examples are from Fox (1980)

# In the first pair of examples, readMoments() and specifyModel() read from the
# input stream. These examples cannot be executed via example() but can be entered
# at the command prompt. The Blau and Duncan example is repeated using file input;
# this example can be executed via example().

# The recursive Blau and Duncan basic stratification model:
# x1 is father’s education, x2 father’s SES, y3 respondent’s education,
# y4 SES of respondent’s first job, y5 respondent’s SES in 1962

R_bd <- readMoments(names=c("x1", "x2", "y3", "y4", "y5"))
  1
  .516 1
  .453 .438 1
  .332 .417 .538 1
  .322 .405 .596 .541 1

mod_bd <- specifyModel()
y3 <- x1, gam31
y3 <- x2, gam32
y4 <- x2, gam42
y4 <- y3, beta43
```
effects.sem

y5 <- x2, gam52
y5 <- y3, beta53
y5 <- y4, beta54

sem.bd <- sem(mod.bd, R.bd, N=20700, fixed.x=c("x1", "x2"))
summary(sem.bd)
effects(sem.bd)

# The nonrecursive Duncan, Haller, and Portes peer-influences model for observed variables:
R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp", "FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp"))
model.dhp <- specifyModel()
RIQ -> ROccAsp, gam51, NA
RSES -> ROccAsp, gam52, NA
FSES -> FOccAsp, gam63, NA
FIQ -> FOccAsp, gam64, NA
FOccAsp -> ROccAsp, beta56, NA
ROccAsp -> FOccAsp, beta65, NA
ROccAsp <-> ROccAsp, ps55, NA
FOccAsp <-> FOccAsp, ps66, NA
ROccAsp <-> FOccAsp, ps56, NA

# Note: The following generates a warning because not all of the variables
# in the correlation matrix are used
sem.dhp <- sem(model.dhp, R.DHP, 329,
               fixed.x=c('RIQ', 'RSES', 'FSES', 'FIQ'))
summary(sem.dhp)
effects(sem.dhp)

## End(Not run)

## the following example may be executed via example()

e tc <- system.file(package="sem", "etc") # path to data and model files

# The recursive Blau and Duncan basic stratification model:
# x1 is father's education, x2 father's SES, y3 respondent's education,
# y4 SES of respondent's first job, y5 respondent's SES in 1962
(R.bd <- readMoments(file=file.path(tc, "R-Blau-Duncan.txt"),
## fscores

### Factor Scores for Latent Variables

#### Description

Calculate factor scores or factor-score coefficients for the latent variables in a structural-equation model.

#### Usage

```r
## S3 method for class 'sem'
fscores(model, data=model$data, center=TRUE, scale=FALSE, ...)
## S3 method for class 'msem'
fscores(model, data=model$data, center=TRUE, scale=FALSE, ...)
```

#### Arguments

- **model**: an object of class "sem" or "msem", produced by the `sem` function.
- **data**: an optional numeric data frame or matrix containing the observed variables in the model; if not NULL, the estimated factor scores are returned; if NULL, the factor-score coefficients are returned. The default is the data element of `model`, which is non-NULL if the model was fit to a data set rather than a covariance or moment matrix.
- **center**: if TRUE, the default, the means of the observed variables are subtracted prior to computing factor scores. One would normally use this option if the model is estimated from a covariance or correlation matrix among the observed variables.
- **scale**: if TRUE, the possibly centered variables are divided by their root-mean-squares; the default is FALSE. One would normally use this option if the model is estimated from a correlation matrix among the observed variables. Centering and scaling are performed by the `scale` function.
- **...**: arguments to pass down.

#### Details

Factor-score coefficients are computed by the “regression” method as $B = C^{-1}C^*$, where $C$ is the model-implied covariance or moment matrix among the observed variables and $C^*$ is the matrix of model-implied covariances or moments between the observed and latent variables.

#### Value

Either a matrix of estimated factor scores (if the `data` argument is supplied) or a matrix of factor-score coefficients (otherwise). In the case of an "msem" argument, a list of matrices is returned.
Author(s)

John Fox <jfox@mcmaster.ca>

References


See Also

sem, scale

Examples

# In the first example, readMoments() and specifyModel() read from the
# input stream. This example cannot be executed via example() but can be entered
# at the command prompt. The example is repeated using file input;
# this example can be executed via example().
## Not run:

S.wh <- readMoments(names=c('Anomia67','Powerless67','Anomia71',
                           'Powerless71','Education','SEI'))

11.834
  6.947  9.364
  6.819  5.091 12.532
  4.783  5.028  7.495  9.986

# This model in the SAS manual for PROC CALIS

model.wh.1 <- specifyModel()

Alienation67  -> Anomia67,    NA,  1
Alienation67  -> Powerless67, NA,  0.833
Alienation71  -> Anomia71,    NA,  1
Alienation71  -> Powerless71, NA,  0.833
SES           -> Education,   NA,  1
SES           -> SEI,         lamb, NA
SES           -> Alienation67, gam1, NA
Alienation67  -> Alienation71, beta, NA
SES           -> Alienation71, gam2, NA
Anomia67      <- Alienation67, the1, NA
Anomia71      <- Alienation67, the1, NA
Powerless67   <- Powerless67, the2, NA
Powerless71   <- Powerless71, the2, NA
Education     <- Education,   the3, NA
SEI           <- SEI,         the4, NA
Anomia67      <- Anomia71,    the5, NA
Powerless67   <- Anomia71,    the5, NA
Alienation67  <- Alienation67, ps1, NA
Alienation71  <- Alienation71, ps1, NA
SES           <- SES,         phi,  NA
information.criteria

Additional Information Criteria

Description

These are generic functions for computing, respectively, the AICc (second-order corrected Akaike Information Criterion) and CAIC (consistent Akaike Information Criterion).

Usage

AICc(object, ...)

CAIC(object, ...)

Arguments

object an object for which an appropriate AICc or CAIC method exists.

... possible additional arguments for methods.

Author(s)

Jarrett Byrnes and John Fox <jfox@mcmaster.ca>

References


Klein’s Data on the U. S. Economy

Description

Data for Klein’s (1950) simple econometric model of the U. S. economy.

The Klein data frame has 22 rows and 10 columns.

Usage

Klein

Format

This data frame contains the following columns:

Year 1921–1941
C consumption.
P private profits.
Wp private wages.
I investment.
K.lag capital stock, lagged one year.
X equilibrium demand.
Wg government wages.
G government non-wage spending.
T indirect business taxes and net exports.

Source


References

Examples

```r
Klein$P.lag <- c(NA, Klein$P[-22])
Klein$X.lag <- c(NA, Klein$X[-22])

summary tsls(C ~ P + P.lag + I(Wp + Wg),
    instruments=1 + G + T + Wg + I(Year - 1931) + K.lag + P.lag + X.lag,
    data=Klein))

summary tsls(I ~ P + P.lag + K.lag,
    instruments=1 + G + T + Wg + I(Year - 1931) + K.lag + P.lag + X.lag,
    data=Klein))

summary tsls(Wp ~ X + X.lag + I(Year - 1931),
    instruments=1 + G + T + Wg + I(Year - 1931) + K.lag + P.lag + X.lag,
    data=Klein))
```

Kmenta Partly Artificial Data on the U. S. Economy

Description

These are partly contrived data from Kmenta (1986), constructed to illustrate estimation of a simultaneous-equation model.

The Kmenta data frame has 20 rows and 5 columns.

Usage

Kmenta

Format

This data frame contains the following columns:

- **Q**  food consumption per capita.
- **P**  ratio of food prices to general consumer prices.
- **D**  disposable income in constant dollars.
- **F**  ratio of preceding year’s prices received by farmers to general consumer prices.
- **A**  time in years.

Details

The exogenous variables D, F, and A are based on real data; the endogenous variables P and Q were generated by simulation.

Source

miSem uses the mi function in the mi package to generate multiple imputations of missing data, fitting the specified model to each completed data set.

Usage

miSem(model, ...)

## S3 method for class 'semmod'
miSem(model, ..., data, formula = ~., raw = FALSE,
      fixed.x=NULLL, objective=objectiveML, n.imp=5, n.iter=30,
      seed=sample(1e+06, 1), mi.args=list())

## S3 method for class 'semmodList'
miSem(model, ..., data, formula = ~., group, raw=FALSE,
      fixed.x=NULLL, objective=msemObjectiveML,
      n.imp=5, n.iter=30, seed=sample(1e6, 1), mi.args=list())

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

## S3 method for class 'miSem'
summary(object, digits=max(3,getOption("digits") - 2), ...)

Arguments

model an SEM model-description object of class semmod or semmodList, created by
      specifyEquations cfa, or specifyModel, in the case of a multi-group model
      in combination with multigroupModel.
..., formula, raw, fixed.x, objective, group
      arguments to be passed to sem.
data an R data frame, presumably with some missing data (encoded as NA), containing
      the data for fitting the SEM, possibly along with other variables to use to obtain
      multiple imputations of missing values. In the case of a multi-group model, this
      must be a single data frame.
n.imp number of imputations (default 5).
n.iter number of iterations for the multiple-imputation process (default 30).
seed seed for the random-number generator (default is an integer sampled from 1 to
      1E6); stored in the resulting object.mi.args other arguments to be passed to mi.
x, object an object of class "miSem".digits for printing numbers.
miSem returns an object of class "miSem" with the following components:

- **initial.fit**: an sem model object produced using `objectiveFIML` if `raw=TRUE`, or the objective function given by the objective argument otherwise.
- **mi.fits**: a list of sem model objects, one for each imputed data set.
- **imputation**: the object produced by `mi`, containing the imputed data sets.
- **seed**: the seed used for the random number generator.

**Author(s)**

John Fox <jfox@mcmaster.ca>

**References**


**See Also**

- `sem`, `mi`

**Examples**

```r
## Not run:
mod.cfa.tests <- cfa(raw=TRUE)
verbal: x1, x2, x3
math: y1, y2, y3

imps <- miSem(mod.cfa.tests, data=Tests, fixed.x="Intercept", raw=TRUE, seed=12345, 
mi.args=list(add.noise=noise.control(post.run.iter=30)))
summary(imps, digits=3)

library(MBESS) # for data
data(HS.data)

# introduce some missing data:
HS <- HS.data[, c(2,7:10,11:15,20:25,26:30)]
set.seed(12345)
r <- sample(301, 100, replace=TRUE)
c <- sample(2:21, 100, replace=TRUE)
for (i in 1:100) HS[r[i], c[i]] <- NA

mod.hs <- cfa()
spatial: visual, cubes, paper, flags
verbal: general, paragrap, sentence, wordc, wordm
memory: wordr, numberr, figurer, object, numberf, figurew
math: deduct, numeric, problemr, series, arithmet

mod.mg <- multigroupModel(mod.hs, groups=c("Female", "Male"))
```
Methods for sem Objects Fit Using the \texttt{objectiveML}, \texttt{objectiveGLS}, \texttt{objectiveFIML}, \texttt{msemObjectiveML}, and \texttt{msemObjectiveGLS} Objective Functions

Description

These functions are for objects fit by \texttt{sem} using the \texttt{objectiveML} (multivariate-normal full-information maximum-likelihood), \texttt{link\{objectiveFIML\}} (multivariate-normal full-information maximum-likelihood in the presence of missing data), \texttt{objectiveGLS} (generalized least squares), and \texttt{msemObjectiveML} (multigroup multivariate-normal FIML) objective functions.

Usage

\begin{verbatim}
## S3 method for class 'objectiveML'
anova(object, model.2, robust=FALSE, ...)
## S3 method for class 'objectiveFIML'
anova(object, model.2, ...)

## S3 method for class 'objectiveML'
logLik(object, ...)
## S3 method for class 'objectiveFIML'
logLik(object, saturated=FALSE,
       intercept="Intercept", iterlim=1000, ...)

## S3 method for class 'objectiveML'
deviance(object, ...)
## S3 method for class 'objectiveFIML'
deviance(object, saturated.logLik, ...)

## S3 method for class 'msemObjectiveML'
deviance(object, ...)

## S3 method for class 'objectiveML'
AIC(object, ..., k)
## S3 method for class 'objectiveFIML'
AIC(object, saturated.logLik, ..., k)

## S3 method for class 'msemObjectiveML'
AIC(object, ..., k)

## S3 method for class 'objectiveML'
AICC(object, ...)
## S3 method for class 'objectiveFIML'
AICC(object, saturated.logLik, ...)

## S3 method for class 'msemObjectiveML'

\end{verbatim}
AICc(object, ...)  
## S3 method for class 'objectiveML'
BIC(object, ...)  
## S3 method for class 'objectiveFIML'
BIC(object, saturated.logLik, ...)  
## S3 method for class 'msesObjectiveML'
BIC(object, ...)  
## S3 method for class 'objectiveML'
CAIC(object, ...)  
## S3 method for class 'objectiveFIML'
CAIC(object, saturated.logLik, ...)

## S3 method for class 'objectiveML'
print(x, ...)  
## S3 method for class 'objectiveGLS'
print(x, ...)  
## S3 method for class 'objectiveFIML'
print(x, saturated=FALSE, ...)  
## S3 method for class 'msesObjectiveML'
print(x, ...)  
## S3 method for class 'msesObjectiveGLS'
print(x, ...)

## S3 method for class 'objectiveML'
summary(object, digits=getOption("digits"),
  conf.level=.90, robust=FALSE, analytic.se=object$t <= 500,
  fit.indices=c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI",
    "IFI", "SRMR", "AIC", "AICc", "BIC", "CAIC"), ...)
## S3 method for class 'objectiveFIML'
summary(object, digits=getOption("digits"), conf.level=.90,
  fit.indices=c("AIC", "AICc", "BIC", "CAIC"),
  saturated=FALSE, intercept="Intercept", saturated.logLik, ...)
## S3 method for class 'objectiveGLS'
summary(object, digits=getOption("digits"), conf.level=.90,
  fit.indices=c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI", "IFI", "SRMR"),
  ...)  
## S3 method for class 'msesObjectiveML'
summary(object, digits=getOption("digits"),
  conf.level=.90, robust=FALSE,
  analytic.se=object$t <= 500,
  fit.indices=c("GFI", "AGFI", "RMSEA", "NFI", "NNFI", "CFI", "RNI",
    "IFI", "SRMR", "AIC", "AICc", "BIC"), ...)
## S3 method for class 'msesObjectiveGLS'
summary(object, digits=getOption("digits"),
  conf.level=.90,
  fit.indices=c("GFI", "AGFI", "RMSEA", "NFI", "NNFI",
    "CFI", "RNI", "IFI", "SRMR"), ...)
Arguments

- `object, model, x`
  - an object inheriting from class `objectiveml, objectiveGls, objectiveFIML, msemObjectiveML, or msemObjectiveGls`.
- `robust` if TRUE, compute robust standard errors or test.
- `fit.indices` a character vector of “fit indices” to report; the allowable values are those given in `Usage` above, and vary by the objective function. If the argument isn’t given then the fit indices reported are taken from the R `fit.indices` option; if this option isn’t set, then only the AIC and BIC are reported for models fit with `objectiveml, objectiveFIML, or msemObjectiveML, and no fit indices are reported for models fit with `objectiveGls or msemObjectiveGls`.
- `k, ...` ignored.
- `digits` digits to be printed.
- `conf.level` level for confidence interval for the RMSEA index (default is .9).
- `analytic.se` use analytic (as opposed to numeric) coefficient standard errors; default is TRUE where analytic standard errors are available if there are no more than 100 parameters in the model and FALSE otherwise.
- `saturated` if TRUE (the default is FALSE); compute the log-likelihood (and statistics that depend on it) for the saturated model when the objective function is FIML in the presence of missing data. This can be computationally costly.
- `intercept` the name of the intercept regressor in the raw data, to be used in calculating the saturated log-likelihood for the FIML estimator; the default is "Intercept".
- `saturated.logLik` the log-likelihood for the saturated model, as returned by `logLik` with `saturated=TRUE`; if absent, this will be computed and the computation can be time-consuming.
- `iterlim` iteration limit used by the `nlm` optimizer to compute the saturated log-likelihood for the FIML estimator with missing data; defaults to 1000.

Author(s)

John Fox <jfox@mcmaster.ca> and Jarrett Byrnes

References

See `sem`.

See Also

`sem.objective.functions, modIndices.objectiveML`
modIndices

Modification Indices for Structural Equation Models

Description

mod.indices calculates modification indices (score tests) and estimated parameter changes for the fixed and constrained parameters in a structural equation model fit by multinormal maximum likelihood.

Usage

## S3 method for class 'objectiveML'
modIndices(model, duplicated, deviance=NULL, ...)
## S3 method for class 'msemObjectiveML'
modIndices(model, ...)

## S3 method for class 'modIndices'
print(x, n.largest=5, ...)
## S3 method for class 'msemModIndices'
print(x, ...)

## S3 method for class 'modIndices'
summary(object, round=2,
    print.matrices=c("both", "par.change", "mod.indices"), ...)
## S3 method for class 'msemModIndices'
summary(object, ...)

Arguments

model
  an object of class objectiveML or msemObjectiveML, produced by the sem function.

object, x
  an object of class modIndices or msemModIndices, produced by the modIndices function.

n.largest
  number of modification indices to print in each of the A and P matrices of the RAM model.

round
  number of places to the right of the decimal point in printing modification indices.

print.matrices
  which matrices to print: estimated changes in the fixed parameters, modification indices, or both (the default).

 duplicated, deviance
  for internal use.

... arguments to be passed down.
Details

Modification indices are one-df chi-square score ("Lagrange-multiplier") test statistics for the fixed and constrained parameters in a structural equation model. They may be regarded as an estimate of the improvement in the likelihood-ratio chi-square statistic for the model if the corresponding parameter is respecified as a free parameter. The `modIndices` function also estimates the change in the value of a fixed or constrained parameter if the parameter is respecified as free. When several parameters are set equal, modification indices and estimated changes are given for all but the first. Modification indices and estimated parameter changes for currently free parameters are given as NA.

The method employed is described in Saris, Satorra, and Sorbom (1987) and Sorbom (1989).

Value

`modIndices` returns an object of class `modIndices` with the following elements:

- `mod.A`: modification indices for the elements of the \( A \) matrix.
- `mod.P`: modification indices for the elements of the \( P \) matrix.
- `par.A`: estimated parameter changes for the elements of the \( A \) matrix.
- `par.P`: estimated parameter changes for the elements of the \( P \) matrix.

Author(s)

John Fox <jfox@mcmaster.ca> and Michael Culbertson

References


See Also

`sem`

Examples

```r
# In the first example, readMoments() and specifyModel() read from the
# input stream. This example cannot be executed via example() but can be entered
# at the command prompt. The example is repeated using file input;
# this example can be executed via example().
## Not run:
# This example is adapted from the SAS manual

S.wh <- readMoments(names=c('Anomia67','Powerless67','Anomia71',
                           'Powerless71','Education','SEI'))

11.834
6.947  9.364
6.819  5.091 12.532
4.783  5.028  7.495  9.986
```

model.wh <- specifyModel()
  Alienation67  --> Anomia67, NA, 1
  Alienation67  --> Powerless67, NA, 0.833
  Alienation71  --> Anomia71, NA, 1
  Alienation71  --> Powerless71, NA, 0.833
  SES           --> Education, NA, 1
  SES           --> SEI, lamb, NA
  SES           --> Alienation67, gam1, NA
  Alienation67  --> Alienation71, beta, NA
  SES           --> Alienation71, gam2, NA
  Anomia67      --> Anomia67, the1, NA
  Anomia71      --> Anomia71, the1, NA
  Powerless67   --> Powerless67, the2, NA
  Powerless71   --> Powerless71, the2, NA
  Education     --> Education, the3, NA
  SEI           --> SEI, the4, NA
  Anomia67      --> Anomia71, the5, NA
  Powerless67   --> Powerless71, the5, NA
  Alienation67  --> Alienation67, psi1, NA
  Alienation71  --> Alienation71, psi2, NA
  SES           --> SES, phi, NA

sem.wh <- sem(model.wh, S.wh, 932)
modIndices(sem.wh)

## End(Not run)

# The following example can be executed via example():

e tc <-  system.file(package="sem", "etc") # path to data and model files

(S.wh <-  readMoments(file=file.path(etc, "S-Wheaton.txt"),
  names=c('Anomia67','Powerless67','Anomia71',
    'Powerless71','Education','SEI')))  
(model.wh <-  specifyModel(file=file.path(etc, "model-Wheaton-I.txt")))

(sem.wh <-  sem(model.wh, S.wh, 932))
modIndices(sem.wh)

---

**objective.functions**  

**sem Objective-Function Builders**

**Description**

These functions return objective functions suitable for use with optimizers called by sem. The user would not normally call these functions directly, but rather supply one of them in the objective argument to sem. Users may also write their own objective functions. objectiveML and objectiveML2 are for multinormal maximum-likelihood estimation; objectiveGLS and objectiveGLS2 are for
generalized least squares; and objectiveFIML is for so-called “full-information maximum-likelihood” estimation in the presence of missing data. The FIML estimator provides the same estimates as the ML estimator when there is no missing data; it can be slow because it iterates over the unique patterns of missing data that occur in the data set. objectiveML and objectiveGLS use compiled code and are therefore substantially faster. objectiveML2 and objectiveGLS2 are provided primarily to illustrate how to write sem objective functions in R. msemObjectiveML uses compiled code is for fitting multi-group models by multinormal maximum likelihood; msemObjectiveML2 is similar but doesn’t use compiled code. msemObjectiveGLS uses compiled code and is for fitting multi-group models by generalized least squares.

Usage

objectiveML(gradient=TRUE, hessian=FALSE)
ojectiveML2(gradient=TRUE)

objectiveGLS(gradient=FALSE)
ojectiveGLS2(gradient=FALSE)

objectiveFIML(gradient=TRUE, hessian=FALSE)
ojectiveFIML2(gradient=TRUE, hessian=FALSE)

msemObjectiveML(gradient=TRUE)
msemObjectiveML2(gradient=TRUE)

msemObjectiveGLS(gradient=FALSE)

Arguments

gradient    If TRUE, the object that's returned includes a function for computing an analytic gradient; there is at present no analytic gradient available for objectiveFIML, objectiveGLS, objectiveGLS2, or msemObjectiveGL.

hessian     If TRUE, the object returned includes a function to compute an analytic Hessian; only available for objectiveML and not generally recommended.

Value

These functions return an object of class "semObjective", with up to two elements:

objective    an objective function.
gradient      a gradient function.

Author(s)

John Fox <jfox@mcmaster.ca>

References

See sem.
optimizers

See Also

sem, optimizers

optimizers sem Optimizers

Description

The default optimizer used by sem is optimizerSem, which employs compiled code and is integrated with the objectiveML and objectiveGLS objective functions; optimizerSem, written by Zhenghua Nie, is a modified version of the standard R nlm optimizer, which was written by Saikat DebRoy, R-core, and Richard H. Jones. The other functions call optimizers (nlm, optim, or nlminb), to fit structural equation models, and are called by the sem function. The user would not normally call these functions directly, but rather supply one of them in the optimizer argument to sem. Users may also write their own optimizer functions. msemOptimizerNlm is for fitting multigroup models, and also adapts the nlm code.

Usage

optimizerSem(start, objective=objectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn, ...)

optimizerMsem(start, objective=msemObjectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn=FALSE, ...)

optimizerNlm(start, objective=objectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn, ...)

optimizerOptim(start, objective=objectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn, method="CG", ...)

optimizerNlminb(start, objective=objectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn, ...)

msemOptimizerNlm(start, objective=msemObjectiveML, gradient=TRUE, maxiter, debug, par.size, model.description, warn=FALSE, ...)

Arguments

start a vector of start values for the parameters.
objective the objective function to be optimized; see objective.functions.
gradient TRUE if an analytic gradient is to be used (if one is available).
maxiter the maximum number of iterations allowed.
debug TRUE to show the iteration history and other available information about the optimization.
par.size "startvalues" to have the optimizer scale the problem according to the magnitudes of the start values (ignored by optimizer nlminb).

model.description
a list with elements describing the structural-equation model (see the code for details).

warn
if FALSE, suppress warnings during the optimization.

method
the method to be employed by the optim optimizer; the default is "CG" (conjugate-gradient).

... additional arguments for the nlm, optim, or nlminb optimizer.

Value
An object of class "semResult", with elements:

convergence TRUE if the optimization apparently converged.

iterations the number of iterations required.

par the vector of parameter estimates.

vcov the estimated covariance matrix of the parameter estimates, based on a numeric Hessian; not supplied by optimizer nlminb.

criterion the optimized value of the objective function.

C the model-implied covariance or moment matrix at the parameter estimates.

A the estimated A matrix.

P the estimated P matrix.

Author(s)
John Fox <jfox@mcmaster.ca>, and Zhenghua Nie, in part adapting work by Saikat DebRoy, R-core, and Richard H. Jones.

See Also
sem, objective.functions, nlm, optim, nlminb

Description
pathDiagram creates a description of the path diagram for a structural-equation-model or SEM-specification object to be processed by the graph-drawing program dot, which can be called automatically; see Koutsofios and North (2002) and http://www.graphviz.org/. To obtain graphics output directly, the dot program must be on the system search path. The semmod method sets up a call to the sem method.
Usage

## S3 method for class 'sem'

```r
pathDiagram(model, file, min.rank=NULL, max.rank=NULL,
            same.rank=NULL, variables=model$var.names, parameters,
            ignore.double=TRUE, edge.labels=c("names", "values", "both"),
            size=c(8, 8), node.font=c("Helvetica", 14),
            edge.font=c("Helvetica", 10), rank.direction=c("LR", "TB"),
            digits=2, standardize=FALSE, output.type=c("graphics", "dot"),
            graphics.fmt="pdf", dot.options=NULL, ...)
```

## S3 method for class 'semmod'

```r
pathDiagram(model, obs.variables, ...)```

Arguments

- **model**: a structural-equation-model or SEM-specification object produced by `sem`, or, respectively, `specifyEquations`, `specifyModel`, or `cfa`. 

- **...**: arguments passed down, e.g., from the `semmod` method to the `sem` method.

- **file**: a file name, given without an extension, to which to write the dot description of the path diagram and, by default, to use that to draw a graph of the model; if not specified, the dot description is written to standard output (normally the R Console). Note that by default (see the `output.type` argument below), two files are written: a "dot" file and a graphics file of type specified by the `graphics.fmt` argument (below); file may include a path specification.

- **min.rank**: a character string listing names of variables to be assigned minimum rank (order) in the graph; the names should be separated by commas.

- **max.rank**: a character string listing names of variables to be assigned maximum rank in the graph; the names should be separated by commas.

- **same.rank**: a character string or vector of character strings of variables to be assigned equivalent rank in the graph; names in each string should be separated by commas.

- **variables**: variable names; defaults to the variable names in `model`. If specified, the variable names should be in the same order as in `model`.

- **parameters**: parameter names; defaults to the parameter names in `model`. If specified, the parameter names should be in the same order as in `model`.

- **ignore.double**: if TRUE, the default, double-headed arrows, representing variances and covariances, are not graphed.

- **edge.labels**: "names" to label arrows with parameter names; "values" to label arrows with parameter estimates, or "both".

- **size**: the size of the graph, in inches.

- **node.font**: font name and point-size for printing variable names.

- **edge.font**: font name and point-size for printing arrow names or values.

- **rank.direction**: draw graph left-to-right, "LR", the default, or top-to-bottom, "TB".

- **digits**: number of digits after the decimal point (default, 2) to which to round parameter estimates.
pathDiagram

standardize if TRUE, display standardized coefficients; default is FALSE.
output.type if "graphics", the default, both a ".dot" file and a graphics file will be created.
graphics.fmt a graphics format recognized by the dot program; the default is "pdf"; graphics.fmt is also used for the extension of the graphics file that is created.
dot.options options to be passed to the dot program, given as a character string.
obs.variables a character vector with the names of the observed variables in the model.

Value
null: pathDiagram is used for its side-effect, producing a graph description of the model.

Author(s)
John Fox <jfox@mcmaster.ca>, Adam Kramer, and Michael Friendly

References

See Also
sem, specifyEquations, specifyModel, cfa

Examples
## Not run:
# The Duncan, Haller, and Portes Peer-Influences Model

R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp",
"FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp"))
  .6247
  .3269 .3669
  .4216 .3275 .6404
  .2137 .2742 .1124 .0839
  .4105 .4043 .2903 .2598 .1839
  .3240 .4047 .3054 .2786 .0489 .2220
  .2938 .2407 .4105 .3607 .0186 .1861 .2707
  .2995 .2863 .5191 .5007 .0782 .3355 .2302 .2950
  .0760 .0702 .2784 .1988 .1147 .1021 .0931 -.0438 .2087

model.dhp <- specifyModel()
  RParAsp -> RGenAsp, gam11, NA
  RIQ -> RGenAsp, gam12, NA
  RSES -> RGenAsp, gam13, NA
  FSES -> RGenAsp, gam14, NA
  RSES -> FGenAsp, gam23, NA
  FSES -> FGenAsp, gam24, NA
  FIQ -> FGenAsp, gam25, NA
  FParAsp -> FGenAsp, gam26, NA
Description

Print the labelled RAM definition matrix for a structural-equation model fit by `sem`.

Usage

```r
ram(object, digits=getOption("digits"), startvalues=FALSE)
```

Arguments

- `object` an object of class `sem` returned by the `sem` function.
- `digits` number of digits for printed output.
- `startvalues` if TRUE, start values for parameters are printed; otherwise, the parameter estimates are printed; the default is FALSE.
**Value**

A data frame containing the labelled RAM definition matrix, which is normally just printed.

**Author(s)**

John Fox <jfox@mcmaster.ca>

**See Also**

sem

**Examples**

```r
#-------------------- assumes that Duncan, Haller and Portes peer-influences model
#-------------------- has been fit and is in sem.dhp

## Not run:
ram(sem.dhp)

## End(Not run)
```

---

**rawMoments**

**Compute Raw Moments Matrix**

**Description**

Computes the “uncorrected” sum-of-squares-and-products matrix divided by the number of observations.

**Usage**

```r
## S3 method for class 'formula'
rawMoments(formula, data, subset, na.action, contrasts=NULL, ...)

## Default S3 method:
rawMoments(object, na.rm=FALSE, ...)

cov2raw(cov, mean, N, sd)

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

object       a one-sided model formula or an object coercible to a numeric matrix.
formula      a one-sided model formula specifying the model matrix for which raw moments
             are to be computed; note that a constant is included if it is not explicitly sup-
             pressed by putting ~1 in the formula.
data         an optional data frame containing the variables in the formula. By default the
             variables are taken from the environment from which rawMoments is called.
subset       an optional vector specifying a subset of observations to be used in computing
             moments.
na.action    a function that indicates what should happen when the data contain NAs. The
             default is set by the na.action option.
contrasts    an optional list. See the contrasts.arg argument of model.matrix.default.
na.rm        if TRUE, any data rows with missing data will be removed.
cov          a covariance or correlation matrix.
mean         a vector of means.
N            the number of observations on which the covariances or correlations are based.
sd           an optional vector of standard deviations, to be given if cov is a correlation
             matrix.
x            an object of class rawmoments to print.
...          arguments passed down.

Value

rawMoments and cov2raw return an object of class rawmoments, which is simply a matrix with an
attribute "N" that contains the number of observations on which the moments are based.

Author(s)

John Fox <jfox@mcmaster.ca>

See Also

sem

Examples

# the following are all equivalent (with the exception of the name of the intercept):
rawMoments(cbind(1, Kmenta))
rawMoments(~ Q + P + D + F + A, data=Kmenta)
Cov <- with(Kmenta, cov(cbind(Q, P, D, F, A)))
cov2raw(Cov, colMeans(Kmenta), nrow(Kmenta))
readMoments

Input a Covariance, Correlation, or Raw Moment Matrix

Description

This function makes it simpler to input covariance, correlation, and raw-moment matrices to be analyzed by the \texttt{sem} function. The matrix is input in lower-triangular form on as many lines as is convenient, omitting the above-diagonal elements. The elements on the diagonal may also optionally be omitted, in which case they are taken to be 1.

Usage

\begin{verbatim}
readMoments(file="", diag=TRUE, 
             names=as.character(paste("X", 1:n, sep = "")))
\end{verbatim}

Arguments

- \texttt{file} The (quoted) file from which to read the model specification, including the path to the file if it is not in the current directory. If "" (the default), then the specification is read from the standard input stream, and is terminated by a blank line.
- \texttt{diag} If \texttt{TRUE} (the default), then the input matrix includes diagonal elements.
- \texttt{names} a character vector containing the names of the variables, to label the rows and columns of the moment matrix.

Value

Returns a lower-triangular matrix (i.e., with zeroes above the main diagonal) suitable for input to \texttt{sem}.

Author(s)

John Fox <jfox@mcmaster.ca>

See Also

\texttt{sem}

Examples

\begin{verbatim}
## Not run:
R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp", 
                                         "FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp"))
  .6247  .3269  .3669
  .4216  .3275  .6404
  .2137  .2742  .1124  .0839
  .4105  .4043  .2903  .2598  .1839
\end{verbatim}
### Description

These functions compute residual covariances, variance-standardized residual covariances, and normalized residual covariances for the observed variables in a structural-equation model fit by `sem`.

### Usage

```r
## S3 method for class 'sem'
residuals(object, ...)
## S3 method for class 'msem'
residuals(object, ...)

## S3 method for class 'sem'
standardizedResiduals(object, ...)
## S3 method for class 'msem'
standardizedResiduals(object, ...)

## S3 method for class 'objectiveML'
normalizedResiduals(object, ...)
## S3 method for class 'objectiveGLS'
normalizedResiduals(object, ...)
## S3 method for class 'msemObjectiveML'
normalizedResiduals(object, ...)
```

### Arguments

- `object`: an object inheriting from class `sem` or `msem` returned by the `sem` function.
- `...`: not for the user.

### Details

Residuals are defined as \( S - C \), where \( S \) is the sample covariance matrix of the observed variables and \( C \) is the model-reproduced covariance matrix. The standardized residual covariance for a pair
of variables divides the residual covariance by the product of the sample standard deviations of the two variables, \((s_{ij} - c_{ij})/(s_{ii}s_{jj})^{1/2}\). The normalized residual is given by

\[
\frac{s_{ij} - c_{ij}}{[(c_{ii}c_{jj} - c_{ij}^2)/N^*]^{1/2}}
\]

where \(N^*\) is the number of observations minus one if the model is fit to a covariance matrix, or the number of observations if it is fit to a raw moment matrix.

**Value**

Each function returns a matrix of residuals.

**Author(s)**

John Fox <jfox@mcmaster.ca>

**References**


**See Also**

`sem`

**Examples**

```r
R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp", "FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp"))
R.DHP

model.dhp <- specifyModel()
RParAsp -> RGenAsp, gam11, NA
RIQ -> RGenAsp, gam12, NA
RSES -> RGenAsp, gam13, NA
FSES -> RGenAsp, gam14, NA
RSES -> FGenAsp, gam23, NA
```
sem fits general structural equation models (with both observed and unobserved variables). Observed variables are also called indicators or manifest variables; unobserved variables are also called factors or latent variables. Normally, the generic function (sem) is called directly with a semmod first argument produced by specifyModel, specifyEquations, or cfa, invoking the
sem. semmod method, which in turn sets up a call to the sem.default method; thus, the user may wish to specify arguments accepted by the semmod and default methods. Similarly, for a multi-group model, sem would normally be called with a semmodList object produced by multigroupModel as its first argument, and would then generate a call to the code msemmod method.

Usage

## S3 method for class 'semmod'
sem(model, S, N, data,
    raw=identical(NULL, na.action), obs.variables=rownames(S),
    fixed.x=NULL, formula= ~ .., na.action=na.omit,
    robust=!missing(data), debug=FALSE,
    optimizer=optimizerSem, objective=objectiveML, ...)

## Default S3 method:
sem(model, S, N, data=FALSE, start.fn=start.values,
    pattern.number=NULL, valid.data.patterns=NULL,
    use.means=TRUE, param.names,
    var.names, fixed.x=NULL, robust=!is.null(data), semmod=NULL, debug=FALSE,
    analytic.gradient=!identical(objective, objectiveFIML),
    warn=FALSE, maxiter=1000, par.size=c("ones", "startvalues"),
    start.tol=1E-6, optimizer=optimizerSem, objective=objectiveML, cls, ...)

## S3 method for class 'semmodList'
sem(model, S, N, data, raw=FALSE, fixed.x=FALSE,
    robust=!missing(data), formula, group="Group", debug=FALSE, ...)

## S3 method for class 'msemmod'
sem(model, S, N, start.fn=start.values,
    group="Group", groups=names(model), raw=FALSE, fixed.x,
    param.names, var.names, debug=FALSE, analytic.gradient=TRUE, warn=FALSE,
    maxiter=5000, par.size = c("ones", "startvalues"), start.tol = 1e-06,
    start=c("initial.fit", "startvalues"), initial.maxiter=1000,
    optimizer = optimizerMsem, objective = msemObjectiveML, ...)

startvalues(S, ram, debug=FALSE, tol=1E-6)
startvalues2(S, ram, debug=FALSE, tol=1E-6)

## S3 method for class 'sem'
coef(object, standardized=FALSE, ...)
## S3 method for class 'msem'
coef(object, ...)
## S3 method for class 'sem'
vcov(object, robust=FALSE,
    analytic=inherits(object, "objectiveML") && object$t <= 500, ...)
## S3 method for class 'msem'
vcov(object, robust=FALSE,
    analytic=inherits(object, "msemObjectiveML") && object$t <= 500, ...)
## S3 method for class 'sem'
Arguments

model
RAM specification, which is a simple encoding of the path diagram for the
model. The model may be given either in symbolic form (as a semmod object,
as returned by the specifyModel, specifyEquations, or cfa function, or as a
character matrix), invoking sem.semmod, which calls sem.default after setting
up the model, or (less conveniently) in numeric form, invoking sem.default
directly, which is not recommended (see Details below). The model argument
may also be a multigroup-model specification, as produced by multigroupModel.

S
covariance matrix among observed variables; may be input as a symmetric ma-
trix, or as a lower- or upper-triangular matrix. S may also be a raw (i.e., “un-
corrected”) moment matrix — that is, a sum-of-squares-and-products matrix
divided by N. This form of input is useful for fitting models with intercepts,
in which case the moment matrix should include the mean square and cross-
products for a unit variable all of whose entries are 1; of course, the raw mean
square for the unit variable is 1. Raw-moment matrices may be computed by
rawMoments. If the ram argument is given in symbolic form, then the observed-
variable covariance or raw-moment matrix may contain variables that do not
appear in the model, in which case a warning is printed. S may also be a list
of covariance or moment matrices for each group in a multigroup model. As an
alternative to specifying S the user may supply a data frame containing the data
for the model (see the argument data).

N
number of observations on which the covariance matrix is based; for a multi-
group model, a vector of group Ns.

data
As a generally preferable alternative to specifying S and N, the user may supply
a data frame containing the data to which the model is to be fit. In a multigroup
model, the data argument may be a list of data frames or a single data frame; in
the later event, the factor given as the group argument is used to split the data
into groups.

start.fn
a function to compute startvalues for the free parameters of the model; two func-
tions are supplied, startvalues and a older version, startvalues2, the first of
which is the default.

na.action
a function to process missing data, if raw data are supplied in the data argu-
ment. The default is na.omit, which returns only complete cases; specify
na.action=na.pass to get FIML estimates in the presence of missing data from
the objectiveFIML and objectiveFIML2 objective functions.

raw
TRUE if S is a raw moment matrix or if a raw moment matrix — as opposed to a
covariance matrix — is to be computed from data; the default is FALSE unless
the na.action argument is set to na.pass.

pattern.number, valid.data.patterns
these arguments pass information about valid (i.e., non-missing) data patterns
and normally would not be specified directly by the user.
use.means
When raw data are supplied and intercepts are included in the model, use the observed-variable means as start values for the intercepts; the default is TRUE.

obs.variables
names of observed variables, by default taken from the row names of the covariance or moment matrix S, which may be given directly or generated according to the data and formula arguments.

fixed.x
names (if the ram matrix is given in symbolic form) or indices (if it is in numeric form) of fixed exogenous variables. Specifying these obviates the necessity of having to fix the variances and covariances among these variables (and produces correct degrees of freedom for the model chisquare).

formula
a one-sided formula, to be applied to data to generate the variables for which covariances or raw moments are computed. The default formula is $\sim \ldots$, i.e., all of the variables in the data, including an implied intercept; if a covariance matrix is to be computed, the constant is suppressed. In a multigroup model, alternatively a list one one-sided formulas as be given, to be applied individually to the groups.

robust
In sem: if TRUE, then quantities are calculated that can be used to compute robust estimates of coefficient standard errors and robust tests when the model is fit by multinormal maximum likelihood; the default is TRUE when the data argument is TRUE, and this option is only available when the data argument is given. In vcov: if TRUE, return a robust coefficient covariance matrix (if object contains the requisite information).

semmod
a semmod object containing the description of the model; optional, and normally supplied not directly by the user but via the semmod method for sem.

debug
if TRUE, some information is printed to help you debug the symbolic model specification; for example, if a variable name is misspelled, sem will assume that the variable is a (new) latent variable. Information about the optimization will also be printed, but details will vary with the optimizer employed. The default is FALSE.

... arguments to be passed down, including from sem.default to the optimizer.

param.names
names of the $t$ free parameters, given in their numerical order; default names are Param1, ..., Param. Note: Should not be specified when the model is given in symbolic form.

var.names
names of the $m$ entries of the $v$ vector (typically the observed and latent variables — see below), given in their numerical order; default names are Var1, ..., Var.m. Note: Should not be specified when the model is given in symbolic form.

analytic.gradient
if TRUE (the default, except for the objectiveFIML objective function, where, at present, an analytic gradient slows down the computation), then analytic first derivatives are used in the maximization of the likelihood if the optimizer employed will accept them; otherwise numeric derivatives are used, again if the optimizer will compute them.

warn
if TRUE, warnings produced by the optimization function will be printed. This should generally not be necessary, since sem prints its own warning, and saves information about convergence. The default is FALSE.

maxiter
the maximum number of iterations for the optimization of the objective function, to be passed to the optimizer.
par.size  
the anticipated size of the free parameters; if "ones", a vector of ones is used; if "startvalues", taken from the start values. You can try changing this argument if you encounter convergence problems. The default is "startvalues" if the largest input variance is at least 100 times the smallest, and "ones" otherwise. Whether this argument is actually used depends upon the optimizer employed.

start.tol, tol  
if the magnitude of an automatic start value is less than start.tol, then it is set to start.tol; defaults to 1E-6.

optimizer  
a function to be used to minimize the objective function; the default for single-group models is optimizerSem. Alternatives are nlm, which employs the standard R optimizer nlm; optimizerOptim, which employs optim; and optimizerNlminb, which uses nlminb — or the user can supply an optimizer. For multigroup model, the default is optimizerMsem, and msemOptimizerNlm, based on nlm, is provided as an alternative.

objective  
An objective function to be minimized, sometimes called a “fit” function in the SEM literature. The default for single-group models is objectiveML, which produces maximum-likelihood estimates assuming multinormality. An alternative is objectiveGLS, which produced generalized least squares estimates — or the user can supply an objective function to be minimized. For multigroup models, the default is available is msemObjectiveML for ML estimates and an alternative is msemObjectiveGLS for GLS estimates.

cls  
primary class to be assigned to the result; normally this is not specified directly, but rather is inferred from the objective function.

ram  
numeric RAM matrix.

object  
an object of class "sem" or "msem", returned by sem.

standardized  
if TRUE, return standardized coefficients.

analytic  
return an analytic (as opposed to numeric) estimate of the coefficient covariance matrix; at present only available for the objectiveML objective function. The default is FALSE for this objective function if there are no more than 100 parameters and FALSE otherwise.

group  
for a multigroup model, the quoted name of the group variable; if the data argument is given, sld is a single data frame, then this should be a factor in the data set or a variable coercible to a factor, to be used to split the data into groups; otherwise, the name is arbitrary.

groups  
a character vector giving the names of the groups; will be ignored if group is a factor in data.

start  
if "initial.fit" (the default), start values for a multi-group model are computed by first fitting the intra-group models separately by group; if "startvalues", then start values are computed as for a single-group model. In some cases, the intra-group models may not be identified even if the multi-group model is, and then start="initial.fit" should not be used.

initial.maxiter  
if start="initial.fit" for a multi-group model, then initial.maxiter gives the maximum number of iterations for each initial intra-group fit.
Details

The model is set up using either RAM ("reticular action model" – don’t ask!) notation – a simple format for specifying general structural equation models by coding the “arrows” in the path diagram for the model (see, e.g., McArdle and McDonald, 1984) – typically using the `specifyModel` function; in equation format using the `specifyEquations` function; or, for a simple confirmatory factor analysis model, via the `cfa` function. In any case, the model is represented internally in RAM format.

The variables in the \( v \) vector in the model (typically, the observed and unobserved variables, but not error variables) are numbered from 1 to \( m \). the RAM matrix contains one row for each (free or constrained) parameter of the model, and may be specified either in symbolic format or in numeric format.

A symbolic `ram` matrix consists of three columns, as follows:

1. Arrow specification: This is a simple formula, of the form "A -> B" or, equivalently, "B <-> A" for a regression coefficient (i.e., a single-headed or directional arrow); "A <-> A" for a variance or "A <-> B" for a covariance (i.e., a double-headed or bidirectional arrow). Here, A and B are variable names in the model. If a name does not correspond to an observed variable, then it is assumed to be a latent variable. Spaces can appear freely in an arrow specification, and there can be any number of hyphens in the arrows, including zero: Thus, e.g., "A->B", "A -- B", and "A>B" are all legitimate and equivalent.

2. Parameter name: The name of the regression coefficient, variance, or covariance specified by the arrow. Assigning the same name to two or more arrows results in an equality constraint. Specifying the parameter name as `NA` produces a fixed parameter.

3. Value: start value for a free parameter or value of a fixed parameter. If given as `NA`, `sem` will compute the start value.

It is simplest to construct the RAM matrix with the `specifyModel`, `specifyEquations`, or `cfa` function, all of which return an object of class `semmod`, and also incorporate some model-specification convenience shortcuts. This process is illustrated in the examples below.

A numeric `ram` matrix consists of five columns, as follows:

1. Number of arrow heads: 1 (directed arrow) or 2 (covariance).

2. Arrow to: index of the variable at the head of a directional arrow, or at one end of a bidirectional arrow. Observed variables should be assigned the numbers 1 to \( n \), where \( n \) is the number of rows/columns in the covariance matrix \( S \), with the indices corresponding to the variables’ positions in \( S \). Variable indices above \( n \) represent latent variables.

3. Arrow from: the index of the variable at the tail of a directional arrow, or at the other end of a bidirectional arrow.

4. Parameter number: free parameters are numbered from 1 to \( t \), but do not necessarily appear in consecutive order. Fixed parameters are given the number 0. Equality contraints are specified by assigning two or more parameters the same number.

5. Value: start value for a free parameter, or value of a fixed parameter. If given as `NA`, the program will compute a start value, by a slight modification of the method described by McDonald and Hartmann (1992). **Note:** In some circumstances, some start values are selected randomly; this might produce small differences in the parameter estimates when the program is rerun.
The numeric `ram` matrix is normally generated automatically, not specified directly by the user.

For `specifyEquations`, each input line is either a regression equation or the specification of a variance or covariance. Regression equations are of the form

\[ y = \text{par1}x1 + \text{par2}x2 + \ldots + \text{parK}xk \]

where \( y \) and the \( x \)s are variables in the model (either observed or latent), and the \( \text{pars} \) are parameters.

If a parameter is given as a numeric value (e.g., 1) then it is treated as fixed. Note that no “error” variable is included in the equation; “error variances” are specified via either the `covs` argument, via \( V(y) = \text{par} \) (see immediately below), or are added automatically to the model when, as by default, `endog.variances=TRUE`.

Variances are specified in the form \( V(\text{var}) = \text{par} \) and covariances in the form \( C(\text{var1}, \text{var2}) = \text{par} \),

where the \( \text{vars} \) are variables (observed or unobserved) in the model. The symbols \( V \) and \( C \) may be in either lower- or upper-case. If \( \text{par} \) is a numeric value (e.g., 1) then it is treated as fixed. In conformity with the RAM model, a variance or covariance for an endogenous variable in the model is an “error” variance or covariance.

To set a start value for a free parameter, enclose the numeric start value in parentheses after the parameter name, as `parameter(value)`.

`sem` fits the model by calling the optimizer specified in the `optimizer` argument to minimize the objective function specified in the `objective` argument. If the optimization fails to converge, a warning message is printed.

The RAM formulation of the general structural equation model is given by the basic equation

\[ v = Av + u \]

where \( v \) and \( u \) are vectors of random variables (observed or unobserved), and the parameter matrix \( A \) contains regression coefficients, symbolized by single-headed arrows in a path diagram. Another parameter matrix,

\[ P = E(uu') \]

contains covariances among the elements of \( u \) (assuming that the elements of \( u \) have zero means). Usually \( v \) contains endogenous and exogenous observed and unobserved variables, but not error variables (see the examples below).

The `startvalues` function may be called directly, but is usually called by `sem.default; startvalues2` is an older version of this function that may be used alternatively; see the `startvalues` argument to `sem`.

**Value**

`sem` returns an object of class `c(objective, "sem")`, where `objective` is the name of the objective function that was optimized (e.g., "objectiveML"), with the following elements:

- `var.names` vector of variable names.
- `ram` RAM matrix, including any rows generated for covariances among fixed exogenous variables; column 5 includes computed start values.
- `S` observed covariance matrix.
- `J` RAM selection matrix, \( J \), which picks out observed variables.
- `n.fix` number of fixed exogenous variables.
n number of observed variables.
N number of observations.
m number of variables (observed plus unobserved).
t number of free parameters.
raw TRUE if the model is fit to a raw moment matrix, FALSE otherwise.
data the observed-variable data matrix, or NULL if data are not supplied.
semmod the semmod specification object for the model, if one was supplied; otherwise NULL.
optimizer the optimizer function.
objective the objective function.
coeff estimates of free parameters.
v cov estimated asymptotic covariance matrix of parameter estimates, based on a numeric Hessian, if supplied by the optimizer; otherwise NULL.
par. posn indices of free parameters.
convergence TRUE or FALSE, depending upon whether the optimization apparently converged.
iterations number of iterations performed.
criterion value of the objective function at the minimum.
C model-reproduced covariance matrix.
A RAM A matrix.
P RAM P matrix.
adj. obj robust adjusted value of the objective function; NULL if robust is FALSE.
robust. vcov robust estimated coefficient covariance matrix; NULL if robust is FALSE.

For multigroup models, sem returns an object of class c("msemObjectiveML", "msem").

Warning
A common error is to fail to specify variance or covariance terms in the model, which are denoted by double-headed arrows, <->.

In general, every observed or latent variable in the model should be associated with a variance or error variance. This may be a free parameter to estimate or a fixed constant (as in the case of a latent exogenous variable for which you wish to fix the variance, e.g., to 1). Again in general, there will be an error variance associated with each endogenous variable in the model (i.e., each variable to which at least one single-headed arrow points — including observed indicators of latent variables), and a variance associated with each exogenous variable (i.e., each variable that appears only at the tail of single-headed arrows, never at the head).

To my knowledge, the only apparent exception to this rule is for observed variables that are declared to be fixed exogenous variables. In this case, the program generates the necessary (fixed-constant) variances and covariances automatically.

If there are missing variances, a warning message will be printed, and estimation will almost surely fail in some manner. Missing variances might well indicate that there are missing covariances too, but it is not possible to deduce this in a mechanical manner. The specifyModel function will by default supply error-variance parameters if these are missing.
Author(s)

John Fox <jfox@mcmaster.ca>, Zhenghua Nie, and Jarrett Byrnes

References


See Also

rawMoments, startvalues, objectiveML, objectiveGls, optimizerNlm, optimizerOptim, optimizerNlminb, nlm, optim, nlminb, specifyModel, specifyEquations, cfa

Examples

# Note: The first set of examples can't be run via example() because the default file
# argument of specifyModel() and readMoments() requires that the model
# specification and covariances, correlations, or raw moments be entered
# at the command prompt. The examples can be copied and run in the R console,
# however. See ?specifyModel and ?readMoments for further information.
# These examples are repeated below using file input to specifyModel() and
# readMoments(). The second version of the examples may be executed through example().

## Not run:

# --------------- Duncan, Haller and Portes peer-influences model ---------------
# A nonrecursive SEM with unobserved endogenous variables and fixed exogenous variables

R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp",
                                          "FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp"))

.6247
# Fit the model using a symbolic ram specification

```r
model.dhp <- specifyModel()
  RParAsp -> RGenAsp, gam11, NA
  RIQ  -> RGenAsp, gam12, NA
  RSES -> RGenAsp, gam13, NA
  FSES -> RGenAsp, gam14, NA
  RSES -> FGenAsp, gam23, NA
  FSES -> FGenAsp, gam24, NA
  FIQ  -> FGenAsp, gam25, NA
  FParAsp -> FGenAsp, gam26, NA
  FGenAsp -> RGenAsp, beta12, NA
  RGenAsp -> FGenAsp, beta21, NA
  RGenAsp -> ROccAsp, NA, 1
  RGenAsp -> REdAsp, lam21, NA
  FGenAsp -> FOccAsp, NA, 1
  FGenAsp -> FEdAsp, lam42, NA
  RGenAsp <-> RGenAsp, ps11, NA
  FGenAsp <-> FGenAsp, ps22, NA
  RGenAsp <-> FGenAsp, ps12, NA
  ROccAsp <-> ROccAsp, theta1, NA
  REdAsp <-> REdAsp, theta2, NA
  FOccAsp <-> FOccAsp, theta3, NA
  FEdAsp <-> FEdAsp, theta4, NA

# an equivalent specification, allowing specifyModel() to generate
# variance parameters for endogenous variables (and suppressing the
# unnecessary NAs):

model.dhp <- specifyModel()
  RParAsp -> RGenAsp, gam11
  RIQ  -> RGenAsp, gam12
  RSES -> RGenAsp, gam13
  FSES -> RGenAsp, gam14
  RSES -> FGenAsp, gam23
  FSES -> FGenAsp, gam24
  FIQ  -> FGenAsp, gam25
  FParAsp -> FGenAsp, gam26
  FGenAsp -> RGenAsp, beta12
  RGenAsp -> FGenAsp, beta21
  RGenAsp -> ROccAsp, NA, 1
  RGenAsp -> REdAsp, lam21
  FGenAsp -> FOccAsp, NA, 1
  FGenAsp -> FEdAsp, lam42
```
RGenAsp <-> FGenAsp, ps12

# Another equivalent specification, telling specifyModel to add paths for
# variances and covariance of RGenAsp and FGenAsp:

model.dhp <- specifyModel(covs="RGenAsp, FGenAsp")
RPParasp -> RGenAsp, gam1
RIQ -> RGenAsp, gam12
RSES -> RGenAsp, gam13
FSES -> RGenAsp, gam14
RSES -> FGenAsp, gam23
FSES -> FGenAsp, gam24
FIQ -> FGenAsp, gam25
FParasp -> FGenAsp, gam26
FGenAsp -> RGenAsp, beta12
RGenAsp -> FGenAsp, beta21
RGenAsp -> ROccasp, NA, 1
RGenAsp -> REDasp, lam21
FGenAsp -> FOCCasp, NA, 1
FGenAsp -> FECCasp, lam42

# Yet another equivalent specification using specifyEquations():

model.dhp.1 <- specifyEquations(covs="RGenAsp, FGenAsp")
RGenAsp = gam11*RPParasp + gam12*RIQ + gam13*RSES + gam14*FSES + beta12*FGenAsp
FGenAsp = gam23*RSES + gam24*FSES + FIQ + gam25*FParasp + beta21*RGenAsp
ROCCasp = 1*RGenAsp
REDasp = lam21(1)*RGenAsp # to illustrate setting start values
FOCCasp = 1*FGenAsp
FECCasp = lam42(1)*FGenAsp

sem.dhp.1 <- sem(model.dhp.1, R.DHP, 329,
  fixed.x=c("'RPParasp', 'RIQ', 'RSES', 'FSES', 'FIQ', 'FParasp'"))
summary(sem.dhp.1)

# Fit the model using a numerical ram specification (not recommended!)

ram.dhp <- matrix(c(
  # heads to from param start
  1, 1, 11, 0, 1,
  1, 2, 11, 1, NA, # lam21
  1, 3, 12, 0, 1,
  1, 4, 12, 2, NA, # lam42
  1, 11, 5, 3, NA, # gam11
  1, 11, 6, 4, NA, # gam12
  1, 11, 7, 5, NA, # gam13
  1, 11, 8, 6, NA, # gam14
  1, 12, 7, 7, NA, # gam23
  1, 12, 8, 8, NA, # gam24
  1, 12, 9, 9, NA, # gam25
  1, 12, 10, 10, NA, # gam26
  1, 11, 12, 11, NA, # beta12
  1, 12, 11, 12, NA, # beta21

sem

params.dhp <- c('lam21', 'lam42', 'gam11', 'gam12', 'gam13', 'gam14',
                 'gam23', 'gam24', 'gam25', 'gam26',
                 'beta21', 'beta22', 'theta1', 'theta2', 'theta3', 'theta4',
                 'psi11', 'psi12', 'psi22')

vars.dhp <- c('R0ccAsp', 'REdAsp', 'F0ccAsp', 'FEdAsp', 'RParAsp', 'RIQ',
              'RSES', 'FSES', 'FIQ', 'FParAsp', 'RGenAsp', 'FGenAsp')

sem.dhp.2 <- sem(ram.dhp, R.DHP, 329, param.names=params.dhp, var.names=vars.dhp,
                 fixed.x=5:10)
summary(sem.dhp.2)

# -------------------------- Wheaton et al. alienation data --------------------------

S.wh <- readMoments(names=c('Anomia67','Powerless67','Anomia71',
                              'Powerless71','Education','SEI'))

11.834  6.947  9.364
 6.819  5.891 12.532
 4.783  5.028  7.495  9.986

# This is the model in the SAS manual for PROC CALIS: A Recursive SEM with
# latent endogenous and exogenous variables.
# Curiously, both factor loadings for two of the latent variables are fixed.

model.wh.1 <- specifyModel()
  Alienation67  -> Anomia67, NA, 1
  Alienation67  -> Powerless67, NA, 0.833
  Alienation71  -> Anomia71, NA, 1
  Alienation71  -> Powerless71, NA, 0.833
  SES  -> Education, NA, 1
  SES  -> SEI, lamb, NA
  SES  -> Alienation67, gam1, NA
  Alienation67  -> Alienation71, beta, NA
  SES  -> Alienation71, gam2, NA
  Anomia67  <-> Anomia67, the1, NA
  Anomia71  <-> Anomia71, the1, NA
  Powerless67  <-> Powerless67, the2, NA
  Powerless71  <-> Powerless71, the2, NA
  Education  <-> Education, the3, NA
SEI  <-> SEI, the4, NA
Anomia67  <-> Anomia71, the5, NA
Powerless67  <-> Powerless71, the5, NA
Alienation67  <-> Alienation67, psi1, NA
Alienation71  <-> Alienation71, psi2, NA
SES  <-> SES, phi1, NA

sem.wh.1 <- sem(model.wh.1, S.wh, 932)
summary(sem.wh.1)

# The same model in equation format:

model.wh.1 <- specifyEquations()
Anomia67 = 1*Alienation67
Powerless67 = 0.833*Alienation67
Anomia71 = 1*Alienation71
Powerless71 = 0.833*Alienation71
Education = 1*SES
SEI = lamb1*SES
Alienation67 = gam1*SES
Alienation71 = gam2*SES + beta*Alienation67
V(Anomia67) = the1
V(Anomia71) = the1
V(Powerless67) = the2
V(Powerless71) = the2
V(SES) = phi
C(Anomia67, Anomia71) = the5
C(Powerless67, Powerless71) = the5

# The same model, but treating one loading for each latent variable as free
# (and equal to each other).

model.wh.2 <- specifyModel()
Alienation67  -> Anomia67, NA, 1
Alienation67  -> Powerless67, lamby, NA
Alienation71  -> Anomia71, NA, 1
Alienation71  -> Powerless71, lamby, NA
SES  -> Education, NA, 1
SES  -> SEI, lambx, NA
SES  -> Alienation67, gam1, NA
Alienation67  -> Alienation71, beta, NA
SES  -> Alienation71, gam2, NA
Anomia67  <-> Anomia67, the1, NA
Anomia71  <-> Anomia71, the1, NA
Powerless67  <-> Powerless67, the2, NA
Powerless71  <-> Powerless71, the2, NA
Education  <-> Education, the3, NA
SEI  <-> SEI, the4, NA
Anomia67  <-> Anomia71, the5, NA
Powerless67  <-> Powerless71, the5, NA
Alienation67  <-> Alienation67, psi1, NA
Alienation71  <-> Alienation71, psi2, NA
SES  <-> SES, phi1, NA
sem

sem.wh.2 <- sem(model.wh.2, S.wh, 932)
summary(sem.wh.2)

# And again, in equation format:

model.wh <- specifyEquations()

Anomia67 = 1*Alienation67
Powerless67 = lamby*Alienation67
Anomia71 = 1*Alienation71
Powerless71 = lamby*Alienation71
Education = 1*SES
SEI = lambx*SES
Alienation67 = gam1*SES
Alienation71 = gam2*SES + beta*Alienation67
V(Anomia67) = the1
V(Anomia71) = the1
V(Powerless67) = the2
V(Powerless71) = the2
V(SES) = phi
C(Anomia67, Anomia71) = the5
C(Powerless67, Powerless71) = the5

# Compare the two models by a likelihood-ratio test:

anova(sem.wh.1, sem.wh.2)

# ------------------------ Thurstone data -------------------------------

# Second-order confirmatory factor analysis, from the SAS manual for PROC CALIS

R.thur <- readMoments(diag=FALSE, names=c('Sentences','Vocabulary',
                                          'Letter.Series','Pedigrees','Letter.Group'))

   .828
  .776 .779
  .439 .493 .46
  .432 .464 .425 .674
  .447 .489 .443 .59 .541
  .447 .432 .401 .381 .402 .288
  .541 .537 .534 .35 .367 .32 .555
  .38 .358 .359 .424 .446 .325 .598 .452

model.thur <- specifyModel()

F1 -> Sentences, lam11
F1 -> Vocabulary, lam21
F1 -> Sent.Completion, lam31
F2 -> First.Letters, lam42
F2 -> 4.Letter.Words, lam52
F2 -> Suffixes, lam62
F3 -> Letter.Series, lam73
F3 -> Pedigrees, lam83
F3 -> Letter.Group, lam93
F4 -> F1, gam1
F4 -> F2, gam2
F4 -> F3, gam3
F1 <- F1, NA, 1
F2 <- F2, NA, 1
F3 <- F3, NA, 1
F4 <- F4, NA, 1

sem.thur <- sem(model.thur, R.thur, 213)
summary(sem.thur)

# The model in equation format:

model.thur <- specifyEquations()
Sentences = lam11*F1
Vocabulary = lam21*F1
Sent.Completion = lam31*F1
First.Letters = lam42*F2
4.Letter.Words = lam52*F2
Suffixes = lam62*F2
Letter.Series = lam73*F3
Pedigrees = lam83*F3
Letter.Group = lam93*F3
F1 = gam1*F4
F2 = gam2*F4
F3 = gam3*F4
V(F1) = 1
V(F2) = 1
V(F3) = 1
V(F4) = 1

#----------------------------- Kerchoff/Kenney path analysis -----------------------------
# An observed-variable recursive SEM from the LISREL manual

R.kerch <- readMoments(diag=FALSE, names=c('Intelligence','Siblings',
                                          'FatherEd','FatherOcc','Grades','EducExp','OccupAsp'))
  .100
  .277 -.152
  .250 -.108 .611
  .572 -.105 .294 .248
  .489 -.213 .446 .410 .597
  .335 -.153 .303 .331 .478 .651

model.kerch <- specifyModel()
Intelligence -> Grades, gam51
Siblings -> Grades, gam52
FatherEd -> Grades, gam53
FatherOcc -> Grades, gam54
Intelligence -> EducExp, gam61
Siblings -> EducExp, gam62
sem.kerch <- sem(model.kerch, R.kerch, 737,
  fixed.x=c('Intelligence', 'Siblings', 'FatherEd', 'FatherOcc'))
summary(sem.kerch)

# The model in equation format:
model.kerch <- specifyEquations()
Grades = gam51*Intelligence + gam52*Siblings + gam53*FatherEd + gam54*FatherOcc
EducExp = gam61*Intelligence + gam62*Siblings + gam63*FatherEd + gam64*FatherOcc + beta65*Grades
OccupAsp = gam71*Intelligence + gam72*Siblings + gam73*FatherEd + gam74*FatherOcc + beta75*Grades + beta76*EducExp

# This model, from McArdle and Epstein (1987, p.118), illustrates the use of a raw moment matrix to fit a model with an intercept. (The example was suggested by Mike Stoolmiller.)
M.McArdle <- readMoments(
  names=c('WISC1', 'WISC2', 'WISC3', 'WISC4', 'UNIT'))
  365.661  503.175  675.656  890.680  18.034
 719.905  958.479 1265.846 1712.475 25.819
1303.392 2278.257 35.255  46.593
2278.257 46.593  1.000

mod.McArdle <- specifyModel()
C -> WISC1, NA, 6.07
C -> WISC2, B2, NA
C -> WISC3, B3, NA
C -> WISC4, B4, NA
UNIT -> C, Mc, NA
C <-> C, Vc, NA,
WISC1 <-> WISC1, Vd, NA
WISC2 <-> WISC2, Vd, NA
WISC3 <-> WISC3, Vd, NA
WISC4 <-> WISC4, Vd, NA

sem.McArdle <- sem(mod.McArdle, M.McArdle, 204, fixed.x="UNIT", raw=TRUE)
summary(sem.McArdle)
# The model in equation format:

```r
mod.McArdle <- specifyEquations()
WISC1 = 6.87*C
WISC2 = B2*C
WISC3 = B3*C
WISC4 = b4*C
C = Mc*UNIT
v(C) = Vc
v(WISC1) = Vd
v(WISC2) = Vd
v(WISC3) = Vd
v(WISC4) = Vd
```

#---------- Bollen industrialization and democracy example ---------------
# This model, from Bollen (1989, Ch. 8), illustrates the use in sem() of a
# case-by-variable data (see ?Bollen) set rather than a covariance or moment matrix

```r
model.bollen <- specifyModel()
Demo60 -> y1, NA, 1
Demo60 -> y2, lam2,
Demo60 -> y3, lam3,
Demo60 -> y4, lam4,
Demo65 -> y5, NA, 1
Demo65 -> y6, lam2,
Demo65 -> y7, lam3,
Demo65 -> y8, lam4,
Indust -> x1, NA, 1
Indust -> x2, lam6,
Indust -> x3, lam7,
y1 <-> y5, theta15
y2 <-> y4, theta24
y2 <-> y6, theta26
y3 <-> y7, theta37
y4 <-> y8, theta48
y6 <-> y8, theta68
Indust -> Demo60, gamma11,
Indust -> Demo65, gamma21,
Demo60 -> Demo65, beta21,
Indust <-> Indust, phi

sem.bollen <- sem(model.bollen, data=Bollen)
summary(sem.bollen)
summary(sem.bollen, robust=TRUE) # robust SEs and tests
summary(sem.bollen, analytic.se=FALSE) # uses numeric rather than analytic Hessian

    # GLS rather than ML estimator:
sem.bollen.gls <- sem(model.bollen, data=Bollen, objective=objectiveGLS)
summary(sem.bollen.gls)
```

# The model in equation format:
sem

model.bollen <- specifyEquations()
y1 = 1*Demo60
y2 = lam2*Demo60
y3 = lam3*Demo60
y4 = lam4*Demo60
y5 = 1*Demo65
y6 = lam2*Demo65
y7 = lam3*Demo65
y8 = lam4*Demo65
x1 = 1*Indust
x2 = lam6*Indust
x3 = lam7*Indust
c(y1, y5) = theta15
c(y2, y4) = theta24
c(y2, y6) = theta26
c(y3, y7) = theta37
c(y4, y8) = theta48
c(y6, y8) = theta68
Demo60 = gamma11*Indust
Demo65 = gamma21*Indust + beta21*Demo60
v(Indust) = phi

# -------------- A simple CFA model for the Thurstone mental tests data ---------------

R.thur <- readMoments(diag=FALSE,

.828
.776 .779
.439 .493 .46
.432 .464 .425 .674
.447 .489 .443 .59 .541
.447 .432 .401 .381 .402 .288
.541 .537 .534 .35 .367 .32 .555
.38 .358 .359 .424 .446 .325 .598 .452

# (1) in CFA format:

mod.cfa.thur.c <- cfa(reference.indicators=FALSE)
FA: Sentences, Vocabulary, Sent.Completion
FC: Letter.Series, Pedigrees, Letter.Group

cfa.thur.c <- sem(mod.cfa.thur.c, R.thur, 213)
summary(cfa.thur.c)

# (2) in equation format:

mod.cfa.thur.e <- specifyEquations(covs="F1, F2, F3")
Sentences = lam11*F1
Vocabulary = lam21*F1
Sent.Completion = lam31*F1
First.Letters = lam42*F2
4.Letter.Words = lam52*F2
Suffixes = lam62*F2
Letter.Series = lam73*F3
Pedigrees = lam83*F3
Letter.Group = lam93*F3
V(F1) = 1
V(F2) = 1
V(F3) = 1

cfa.thur.e <- sem(mod.cfa.thur.e, R.thur, 213)
summary(cfa.thur.e)

# (3) in path format:

mod.cfa.thur.p <- specifyModel(covs="F1, F2, F3")
F1 -> Sentences,     lam11
F1 -> Vocabulary,    lam21
F1 -> Sent.Completion, lam31
F2 -> First.Letters, lam41
F2 -> 4.Letter.Words, lam52
F2 -> Suffixes,      lam62
F2 -> Letter.Series, lam73
F3 -> Pedigrees,     lam83
F3 -> Letter.Group,  lam93
F1 <-> F1,           NA,  1
F2 <-> F2,           NA,  1
F3 <-> F3,           NA,  1

cfa.thur.p <- sem(mod.cfa.thur.p, R.thur, 213)
summary(cfa.thur.p)

# ------ a CFA model fit by FIML to the mental-tests dataset with missing data ------

mod.cfa.tests <- cfa(raw=TRUE)
verbal: x1, x2, x3
math: y1, y2, y3
cfa.tests <- sem(mod.cfa.tests, data=Tests, na.action=na.pass,
                 objective=objectiveFIML, fixed.x="Intercept")
summary(cfa.tests)
summary(cfa.tests, saturated=TRUE) # takes time to fit saturated model for comparison

# ---- a multigroup CFA model fit to the Holzinger-Swineford mental-tests data -----

library(MBESS) # for data
data(HS.data)

mod.hs <- cfa()
spatial: visual, cubes, paper, flags
verbal: general, paragraph, sentence, wordc, wordm
memory: wordr, numberr, figurer, object, numberf, figurew
math: deduct, numeric, problemr, series, arithmet

mod.mg <- multigroupModel(mod.hs, groups=c("Female", "Male"))

sem.mg <- sem(mod.mg, data=HS.data, group="Gender",
             formula = ~ visual + cubes + paper + flags +
              general + paragrap + sentence + wordc + wordm +
              wordr + numberr + figurer + object + numberf + figurew +
              deduct + numeric + problemr + series + arithmet
)
summary(sem.mg)

# with cross-group equality constraints:

mod.mg.eq <- multigroupModel(mod.hs, groups=c("Female", "Male"), allEqual=TRUE)

sem.mg.eq <- sem(mod.mg.eq, data=HS.data, group="Gender",
                formula = ~ visual + cubes + paper + flags +
                 general + paragrap + sentence + wordc + wordm +
                 wordr + numberr + figurer + object + numberf + figurew +
                 deduct + numeric + problemr + series + arithmet
)
summary(sem.mg.eq)

anova(sem.mg, sem.mg.eq) # test equality constraints

## End(Not run)

## ################################################################################

# The following examples use file input and may be executed via example():

etc <- system.file(package="sem", "etc") # path to data and model files

# to get all fit indices (not recommended, but for illustration):

opt <- options(fit.indices = c("GFI", "AGFI", "RMSEA", "NFI", "NNFI",
                             "CFI", "RNI", "IFI", "SRMR", "AIC", "AICc", "BIC", "CAIC"))

# -------------- Duncan, Haller and Portes peer-influences model ---------------
# A nonrecursive SEM with unobserved endogenous variables and fixed exogenous variables

(R.DHP <- readMoments(file=file.path(etc, "R-DHP.txt"),
                      diag=FALSE, names=c("ROccAsp", "REDAsp", "FOccAsp",
                                "FEDAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp")))

(model.dhp <- specifyModel(file=file.path(etc, "model-DHP.txt")))

sem.dhp.1 <- sem(model.dhp, R.DHP, 329,
                 fixed.x=c("RParAsp", "RIQ", "RSES", 'FSES', 'FIQ', 'FParAsp'))

summary(sem.dhp.1)

# -------------------------- Wheaton et al. alienation data ------------------
(S.wh <- readMoments(file=file.path(etc, "S-Wheaton.txt"),
names=c('Anomia67','Powerless67','Anomia71',
        'Powerless71','Education','SEI')))

# This is the model in the SAS manual for PROC CALIS: A Recursive SEM with
# latent endogenous and exogenous variables.
# Curiously, both factor loadings for two of the latent variables are fixed.

(model.wh.1 <- specifyModel(file=file.path(etc, "model-Wheaton-1.txt")))
sem.wh.1 <- sem(model.wh.1, S.wh, 932)
summary(sem.wh.1)

# The same model, but treating one loading for each latent variable as free
# (and equal to each other).

(model.wh.2 <- specifyModel(file=file.path(etc, "model-Wheaton-2.txt")))
sem.wh.2 <- sem(model.wh.2, S.wh, 932)
summary(sem.wh.2)

# Compare the two models by a likelihood-ratio test:
anova(sem.wh.1, sem.wh.2)

# -------------------------------- Thurstone data --------------------------------
# Second-order confirmatory factor analysis, from the SAS manual for PROC CALIS

(R.thur <- readMoments(file=file.path(etc, "R-Thurstone.txt"),
diag=FALSE, names=c('Sentences','Vocabulary',
                  'Letter.Series','Pedigrees', 'Letter.Group')))
(model.thur <- specifyModel(file=file.path(etc, "model-Thurstone.txt")))
sem.thur <- sem(model.thur, R.thur, 213)
summary(sem.thur)

#----------------------------------- Kerchoff/Kenney path analysis ---------------
# An observed-variable recursive SEM from the LISREL manual

(R.kerch <- readMoments(file=file.path(etc, "R-Kerchoff.txt"),
diag=FALSE, names=c('Intelligence','Siblings',
           'FatherEd','FatherOcc','Grades','EducExp','OccupAsp'))) 
(model.kerch <- specifyModel(file=file.path(etc, "model-Kerchoff.txt")))
sem.kerch <- sem(model.kerch, R.kerch, 737,
     fixed.x=c('Intelligence','Siblings','FatherEd','FatherOcc'))
summary(sem.kerch)

#--------------------------- McArdle/Epstein latent-growth-curve model ------------
# This model, from McArule and Epstein (1987, p.118), illustrates the use of a
# raw moment matrix to fit a model with an intercept. (The example was suggested
# by Mike Stoolmiller.)

(M.McArule <- readMoments(file=file.path(etc, "M-McArule.txt"),
                         names=c('WISC1', 'WISC2', 'WISC3', 'WISC4', 'UNIT')))
(mod.McArule <- specifyModel(file=file.path(etc, "model-McArule.txt")))
sem.McArule <- sem(mod.McArule, M.McArule, 204, fixed.x="UNIT", raw=TRUE)
summary(sem.McArule)

# -------------- Bollen industrialization and democracy example --------------

# This model, from Bollen (1989, Ch. 8), illustrates the use in sem() of a
# case-by-variable data set (see ?Bollen) rather than a covariance or moment matrix

(model.bollen <- specifyModel(file=file.path(etc, "model-Bollen.txt")))
sem.bollen <- sem(model.bollen, data=Bollen)
summary(sem.bollen)
summary(sem.bollen, robust=TRUE)  # robust SEs and tests
summary(sem.bollen, analytic.se=FALSE)  # uses numeric rather than analytic Hessian

# GLS rather than ML estimator:
sem.bollen.gls <- sem(model.bollen, data=Bollen, objective=objectiveGLS)
summary(sem.bollen.gls)

# ---- a CFA model fit by FIML to the mental-tests dataset with missing data -----

(mod.cfa.tests <- cfa(file=file.path(etc, "model-Tests.txt"), raw=TRUE))
cfa.tests <- sem(mod.cfa.tests, data=Tests, na.action=na.pass,
                 optimizer=optimizerNlm, objective=objectiveFIML, fixed.x="Intercept")
summary(cfa.tests)

# -------------- Holzinger and Swineford multigroup CFA example --------------

if (require(MBESS)){  # for data
data(HS.data)

mod.hs <- cfa(file=file.path(etc, "model-HS.txt"))

mod.mg <- multigroupModel(mod.hs, groups=c("Female", "Male"))

sem.mg <- sem(mod.mg, data=HS.data, group="Gender",
              formula = ~ visual + cubes + paper + flags +
                        general + paragrap + sentence + wordc + wordm +
                        wordr + numberr + figurer + object + numberf + figurew +
                        deduct + numeric + problemr + series + arithmet)
summary(sem.mg)

# with cross-group equality constraints:

mod.mg.eq <- multigroupModel(mod.hs, groups=c("Female", "Male"), allEqual=TRUE)
sem.deprecated

sem.deprecated

Deprecated Functions in the sem Package

Description
These functions are provided for compatibility with older versions of the sem package only, and may be removed eventually. Although an effort has been made to insure backwards-compatibility, commands that worked in versions of the sem package prior to version 2.0-0 will not necessarily work in version 2.0-0 and beyond, or may not work in the same manner.

Usage
boot.sem(...)
mod.indices(...)
normalized.residuals(...)
path.diagram(...)
raw.moments(...)
read.moments(...)
specify.model(...)
standardized.coefficients(...)
standardized.residuals(...)
std.coef(...)

Arguments
...           pass arguments down to replacements for deprecated functions.

Details
boot.sem is now a synonym for the bootSem function.
mod.indices is now a synonym for modIndices.
normalized.residuals is now a synonym for normalizedResiduals.
path.diagram is now a synonym for pathDiagram.
raw.moments is now a synonym for `rawMoments`.
read.moments is now a synonym for `readMoments`.
specify.model is now a synonym for `specifyModel`.
standardized.coefficients and std.coef are now synonyms for the `standardizedCoefficients`
and `stdCoef` functions.
standardized.residuals is now a synonym for `standardizedResiduals`.

---

**specifyModel**

*Specify a Structural Equation Model*

**Description**

Create the RAM specification of a structural equation model.

**Usage**

```r
specifyModel(file = "", exog.variances = FALSE, endog.variances = TRUE, covs,
 suffix = "", quiet = FALSE)

specifyEquations(file = "", ...)

cfa(file = "", covs = paste(factors, collapse = ","), reference.indicators = TRUE,
 raw = FALSE, ...)

multigroupModel(..., groups = names(models), allEqual = FALSE)

classifyVariables(model)

removeRedundantPaths(model, warn = TRUE)
## S3 method for class 'semmod'
combineModels(..., warn = TRUE)
## S3 method for class 'semmod'
update(object, file = "", ...)
## S3 method for class 'semmod'
edit(name, ...)

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

**Arguments**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>file</strong></td>
<td>The (quoted) file from which to read the model specification, including the path to the file if it is not in the current directory. If &quot;&quot; (the default), then the specification is read from the standard input stream, and is terminated by a blank line.</td>
</tr>
</tbody>
</table>
exog.variances  If TRUE (the default is FALSE), free variance parameters are added for the exogenous variables that lack them.

endog.variances  If TRUE (the default), free error-variance parameters are added for the endogenous variables that lack them.

covs  optional: a character vector of one or more elements, with each element giving a string of variable names, separated by commas. Variances and covariances among all variables in each such string are added to the model. For confirmatory factor analysis models specified via cfa, covs defaults to all of the factors in the model, thus specifying all covariances among these factors.

suffix  a character string (defaulting to an empty string) to be appended to each parameter name; this can be convenient for specifying multiple-group models.

reference.indicators  if FALSE, the default, variances of factors are set to 1 by cfa; if TRUE, variances of factors are free parameters to estimate from the data, and instead the first factor loading for each factor is set to 1 to identify the model.

raw  if TRUE (the default is FALSE), a path from Intercept to each observed variable is added to the model, and the raw second moment for Intercept is fixed to 1. The sem function should then be called with raw=TRUE, and either supplied with a data set (via the data argument) or a raw-moment matrix (via the S argument).

quiet  if FALSE, the default, then the number of input lines is reported and a message is printed suggesting that specifyEquations or cfa be used.

x, model, object, name  An object of class semmod or semmodList, as produced by specifyModel or multigroupModel.

warn  print a warning if redundant paths are detected.

...  For multigroupModel, one or more optionally named arguments each of which is a semmod object produced, e.g., by specifyModel, specifyEquations, or cfa; if only one such model is given, then it will be used for all groups defined by the groups argument. If parameters have the same name in different groups, then they will be constrained to be equal. For specifyEquations and cfa, arguments (such as covs, in the case of specifyEquations) to be passed to specifyModel; for combineModels, sem objects; ignored in the update and print methods.

groups  a character vector of names for the groups in a multigroup model; taken by default from the names of the ... arguments.

allEqual  if FALSE (the default), then if only one model object is given for a multigroup model, all corresponding parameters in the groups will be distinct; if TRUE, all corresponding parameters will be constrained to be equal.

Details

The principal functions for model specification are specifyModel, to specify a model in RAM (path) format via single- and double-headed arrows; specifyEquations, to specify a model in equation format, which is then translated by the function into RAM format; and cfa, for compact specification of simple confirmatory factor analysis models.
specifyModel:

Each line of the RAM specification for specifyModel consists of three (unquoted) entries, separated by commas:

1. **Arrow specification:** This is a simple formula, of the form $A \rightarrow B$ or, equivalently, $B \leftarrow A$ for a regression coefficient (i.e., a single-headed or directional arrow); $A \leftrightarrow A$ for a variance or $A \leftrightarrow B$ for a covariance (i.e., a double-headed or bidirectional arrow). Here, $A$ and $B$ are variable names in the model. If a name does not correspond to an observed variable, then it is assumed to be a latent variable. Spaces can appear freely in an arrow specification, and there can be any number of hyphens in the arrows, including zero: Thus, e.g., $A \rightarrow B$, $A \leftarrow B$, and $A \leftrightarrow B$ are all legitimate and equivalent.

2. **Parameter name:** The name of the regression coefficient, variance, or covariance specified by the arrow. Assigning the same name to two or more arrows results in an equality constraint. Specifying the parameter name as `NA` produces a fixed parameter.

3. **Value:** start value for a free parameter or value of a fixed parameter. If given as `NA` (or simply omitted), `sem` will compute the start value.

Lines may end in a comment following `#`.

specifyEquations:

For specifyEquations, each input line is either a regression equation or the specification of a variance or covariance. Regression equations are of the form

$$y = \text{par}1 \times x1 + \text{par}2 \times x2 + \ldots + \text{par}k \times xk$$

where $y$ and the $x$s are variables in the model (either observed or latent), and the $\text{pars}$ are parameters. If a parameter is given as a numeric value (e.g., 1) then it is treated as fixed. Note that no “error” variable is included in the equation; “error variances” are specified via either the covs argument, via $V(y) = \text{par}$ (see immediately below), or are added automatically to the model when, as by default, `endog.variances=TRUE`. A regression equation may be split over more than one input by breaking at a $K$, so that $K$ is either the last non-blank character on a line or the first non-blank character on the subsequent line.

Variances are specified in the form $V(\text{var}) = \text{par}$ and covariances in the form $C(\text{var}1, \text{var}2) = \text{par}$, where the $\text{vars}$ are variables (observed or unobserved) in the model. The symbols $V$ and $C$ may be in either lower- or upper-case. If $\text{par}$ is a numeric value (e.g., 1) then it is treated as fixed. In conformity with the RAM model, a variance or covariance for an endogenous variable in the model is an “error” variance or covariance.

To set a start value for a free parameter, enclose the numeric start value in parentheses after the parameter name, as `parameter(value)`.

cfa:

For cfa, each input line includes the names of the variables, separated by commas, that load on the corresponding factor; the name of the factor is given optionally at the beginning of the line, followed by a colon. If necessary, the variables that load on a factor may be continued across two or more input lines; in this case, each such line but the last must end in a comma. A variable may load on more than one factor (as long as the resulting model is identified, of course), but each factor may appear in only one input line (or set of input lines, if the variable list is continued onto the next line). If the argument `reference.indicators=FALSE`, the default, cfa will fix the variance of each factor to 1, and by default include covariances (i.e., correlations) among all pairs of factors.
Alternatively, if `reference.indicators=TRUE`, then the factor variances are free parameters to be estimated from the data, and the first loading for each factor is set to 1 to identify the model. These two approaches produce equivalent models, with the same fit to the data, but alternative parametrizations. Specifying the argument `covs=TRUE` implicitly fixes the factor intercorrelations to 0.

See `sem` and the examples for further details on model specification.

Other Functions:

- `classifyVariables` classifies the variables in a model as endogenous or exogenous.
- `combineModels` and `removeRedundantPaths` take `semmod` objects as arguments and do what their names imply.
- The `file` input argument to the `update` method for `semmod` objects, which by default comes from standard input, is a set of update directives, one per line. There are five kinds of directives. In each case the directive begins with the directive name, followed by one or more fields separated by commas.

1. **delete**: Remove a path from the model. Example: `delete`, RSES -> FGenAsp
2. **add**: Add a path to the model. Example (the NA for the start value is optional): `add`, RSES -> FGenAsp, gam14, NA
3. **replace**: Replace every occurrence of the first string with the second in the variables and parameters of the model. This directive may be used, for example, to change one variable to another or to rename a parameter. Example: `replace`, gam, gamma, substitutes the string “gamma” for “gam” wherever the latter appears, presumably in parameter names.
4. **fix**: Fix a parameter that was formerly free. Example: `fix`, RGenAsp -> REdAsp, 1
5. **free**: Free a parameter that was formerly fixed. Example (the NA for the start value is optional): `free`, RGenAsp -> ROccAsp, lam11, NA

The `edit` method for `semmod` objects opens the model in the R editor.

Value

- `specifyModel`, `specifyEquations`, `cfa`, `removeRedundantPaths`, `combineModels`, `update`, and `edit` return an object of class `semmod`, suitable as input for `sem`.
- `multigroupModel` returns an object of class `semmodList`, also suitable as input for `sem`.
- `classifyVariables` returns a list with two character vectors: `endogenous`, containing the names of endogenous variables in the model; and `exogenous`, containing the names of exogenous variables.

Author(s)

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See Also

- `sem`
Examples

# Note: These examples can't be run via example() because the default file
# argument of specifyModel() requires that the model specification be entered
# at the command prompt. The examples can be copied and run in the R console,
# however.

## Not run:
model.dhp <- specifyModel()
  RParAsp -> RGenAsp, gam11, NA
  RIQ  -> RGenAsp, gam12, NA
  RSES -> RGenAsp, gam13, NA
  FSES -> FGenAsp, gam14, NA
  RSES -> FGenAsp, gam23, NA
  FSES -> FGenAsp, gam24, NA
  FIQ  -> FGenAsp, gam25, NA
  FParAsp -> FGenAsp, gam26, NA
  FGenAsp -> RGenAsp, beta12, NA
  RGenAsp -> FGenAsp, beta21, NA
  RGenAsp -> ROccAsp, NA, 1
  RGenAsp -> REdAsp, lam21, NA
  FGenAsp -> FOccAsp, NA, 1
  FGenAsp -> FEdAsp, lam42, NA
  RGenAsp <-> RGenAsp, ps11, NA
  FGenAsp <-> FGenAsp, ps22, NA
  RGenAsp <-> FGenAsp, ps12, NA
  ROccAsp <-> ROccAsp, theta1, NA
  REdAsp <-> REdAsp, theta2, NA
  FOccAsp <-> FOccAsp, theta3, NA
  FEdAsp <-> FEdAsp, theta4, NA

model.dhp

# an equivalent specification, allowing specifyModel() to generate
# variance parameters for endogenous variables (and suppressing
# the unnecessary trailing NAs):

model.dhp <- specifyModel()
  RParAsp -> RGenAsp, gam11
  RIQ  -> RGenAsp, gam12
  RSES -> RGenAsp, gam13
  FSES -> RGenAsp, gam14
  RSES -> FGenAsp, gam23
  FSES -> FGenAsp, gam24
  FIQ  -> FGenAsp, gam25
  FParAsp -> FGenAsp, gam26
  FGenAsp -> RGenAsp, beta12
  RGenAsp -> FGenAsp, beta21
  RGenAsp -> ROccAsp, NA, 1
  RGenAsp -> REdAsp, lam21, NA
  FGenAsp -> FOccAsp, NA, 1
  FGenAsp -> FEdAsp, lam42
RGenAsp <- FGenAsp, ps12

model.dhp

# Another equivalent specification, telling specifyModel to add paths for
# variances and covariance of RGenAsp and FGenAsp:

model.dhp <- specifyModel(covs="RGenAsp, FGenAsp")
RParAsp -> RGenAsp, gam11
RIQ -> RGenAsp, gam12
RSES -> RGenAsp, gam13
FSES -> RGenAsp, gam14
RSES -> FGenAsp, gam23
FSES -> FGenAsp, gam24
FIQ -> FGenAsp, gam25
FParAsp -> FGenAsp, gam26
FGenAsp -> RGenAsp, beta12
RGenAsp -> FGenAsp, beta21
RGenAsp -> ROCcAsp, NA, 1
RGenAsp -> REDasp, lam21
FGenAsp -> FOccAsp, NA, 1
FGenAsp -> FEAdasp, lam42

model.dhp

# The same model in equation format:

model.dhp.1 <- specifyEquations(covs="RGenAsp, FGenAsp")
RGenAsp = gam11*RParAsp + gam12*RIQ + gam13*RSES + gam14*FSES + beta12*FGenAsp
FGenAsp = gam23*RSES + gam24*FSES + gam25*FIQ + gam26*FParAsp + beta21*RGenAsp
ROCcAsp = 1*RGenAsp
REDasp = lam21(1)*RGenAsp # to illustrate setting start values
FOccAsp = 1*FGenAsp
FEAdasp = lam42(1)*FGenAsp

model.dhp

classifyVariables(model.dhp)

# updating the model to impose equality constraints
# and to rename the latent variables and gamma parameters

model.dhp.eq <- update(model.dhp)
delete, RSES -> FGenAsp
delete, FSES -> FGenAsp
delete, FIQ -> FGenAsp
delete, FParAsp -> FGenAsp
delete, RGenAsp -> FGenAsp
add, RSES -> FGenAsp, gam14, NA
add, FSES -> FGenAsp, gam13, NA
add, FIQ -> FGenAsp, gam12, NA
add, FParAsp -> FGenAsp, gam26, NA
add, RGenAsp -> FGenAsp, beta12, NA
specifyModel

replace, gam, gamma
replace, Gen, General

model.dhp.eq

# A three-factor CFA model for the Thurstone mental-tests data,
# specified three equivalent ways:

R.thur <- readMoments(diag=FALSE,
                  names=c('Sentences','Vocabulary','
                  'Letter.Series','Pedigrees','Letter.Group'))

.828
.776 .779
.439 .493 .46
.432 .464 .425 .674
.447 .489 .443 .59 .541
.447 .432 .401 .381 .402 .288
.541 .537 .534 .35 .367 .32 .555
.38 .358 .359 .424 .446 .325 .598 .452

# (1a) in CFA format:

mod.cfa.thur.c <- cfa(reference.indicators=FALSE)
FA: Sentences, Vocabulary, Sent.Completion
FC: Letter.Series, Pedigrees, Letter.Group

cfa.thur.c <- sem(mod.cfa.thur.c, R.thur, 213)
summary(cfa.thur.c)

# (1b) in CFA format, using reference indicators:

mod.cfa.thur.r <- cfa()
FA: Sentences, Vocabulary, Sent.Completion
FC: Letter.Series, Pedigrees, Letter.Group

cfa.thur.r <- sem(mod.cfa.thur.r, R.thur, 213)
summary(cfa.thur.r)

# (2) in equation format:

mod.cfa.thur.e <- specifyEquations(covs="F1, F2, F3")
Sentences = lam11*F1
Vocabulary = lam21*F1
Sent.Completion = lam31*F1
First.Letters = lam42*F2
4.Letter.Words = lam52*F2
Suffixes = lam62*F2
Letter.Series = lam73*F3
Pedigrees = lam83*F3
Letter.Group = lam93*F3
\[
\begin{align*}
V(F1) &= 1 \\
V(F2) &= 1 \\
V(F3) &= 1 \\
\end{align*}
\]

```r
\text{cfa.thur.e} \leftarrow \text{sem(mod.cfa.thur.e, R.thur, 213)} \\
\text{summary(cfa.thur.e)}
```

# (3) in path format:

```r
\text{mod.cfa.thur.p} \leftarrow \text{specifyModel(covs="F1, F2, F3")} \\
F1 \rightarrow \text{Sentences, lam11} \\
F1 \rightarrow \text{Vocabulary, lam21} \\
F1 \rightarrow \text{Sent.Completion, lam31} \\
F2 \rightarrow \text{First.Letters, lam41} \\
F2 \rightarrow \text{4.Letter.Words, lam52} \\
F2 \rightarrow \text{Suffixes, lam62} \\
F3 \rightarrow \text{Letter.Series, lam73} \\
F3 \rightarrow \text{Pedigrees, lam83} \\
F3 \rightarrow \text{Letter.Group, lam93} \\
F1 \leftrightarrow F1, \text{NA, 1} \\
F2 \leftrightarrow F2, \text{NA, 1} \\
F3 \leftrightarrow F3, \text{NA, 1}
```

```r
\text{cfa.thur.p} \leftarrow \text{sem(mod.cfa.thur.p, R.thur, 213)} \\
\text{summary(cfa.thur.p)}
```

# a multigroup CFA model fit to the Holzinger-Swineford
# mental-tests data (from the MBESS package)

```r
\text{library(MBESS)} \\
\text{data(HS.data)}
```

```r
\text{mod.hs} \leftarrow \text{cfa(} \\
\text{spatial: visual, cubes, paper, flags} \\
\text{verbal: general, paragraph, sentence, wordc, wordm} \\
\text{memory: wordr, numberr, figurer, object, numberf, figurew} \\
\text{math: deduct, numeric, problemr, series, arithmet}\)
```

```r
\text{mod.mg} \leftarrow \text{multigroupModel(mod.hs, groups=c("Female", "Male"))}
```

```r
\text{sem.mg} \leftarrow \text{sem(mod.mg, data=HS.data, group="Gender",} \\
\text{formula = ~ visual + cubes + paper + flags +} \\
\text{general + paragraph + sentence + wordc + wordm +} \\
\text{wordr + numberr + figurer + object + numberf + figurew +} \\
\text{deduct + numeric + problemr + series + arithmet)} \\
\text{summary(sem.mg)}
```

# with cross-group equality constraints:

```r
\text{mod.mg.eq} \leftarrow \text{multigroupModel(mod.hs, groups=c("Female", "Male"), allEqual=TRUE)} \\
\text{sem.mg.eq} \leftarrow \text{sem(mod.mg.eq, data=HS.data, group="Gender",}
```
standardizedCoefficients

Standardized Coefficients for Structural Equation Models

Description

These functions calculate standardized regression coefficients for structural equation models. The function stdCoef is simply an abbreviation for standardizedCoefficients.

Usage

standardizedCoefficients(object, ...)  # S3 method for class 'sem'
stdCoef(object, ...)

Arguments

object an object of class sem or msem returned by the sem function.
digits number of digits for printed output.
oneheaded standardize path coefficients? Default is TRUE.
twoheaded standardize variances and covariances? Default is TRUE.
... arguments to pass down.

Value

Returns a data frame with the coefficients, labelled both by parameter names and by arrows in the path diagram for the model. The msem (multigroup) method computes and prints the standardized coefficients for each group; it does not return a useful result.

Author(s)

John Fox <jfox@mcmaster.ca> and Adam Kramer
References


See Also

sem

Examples

# In the first example, readMoments() and specifyModel() read from the
# input stream. This example cannot be executed via example() but can be entered
# at the command prompt. The example is repeated using file input;
# this example can be executed via example().
## Not run:
# Duncan, Haller, and Portes peer-influences model

R.DHP <- readMoments(diag=FALSE, names=c("ROccAsp", "REdAsp", "FOccAsp",
    "FEdAsp", "RParAsp", "RIQ", "RSES", "FSES", "FIQ", "FParAsp")
    .6247
  .3269 .3669
  .4216 .3275 .6404
  .2137 .2742 .1124 .0839
  .4105 .4043 .2903 .2598 .1839
  .3240 .4047 .3054 .2786 .0489 .2220
  .2930 .2407 .4105 .3607 .0186 .1861 .2707
  .2995 .2863 .5191 .5007 .0782 .3355 .2382 .2950
  .0760 .0702 .2784 .1988 .1147 .1021 .0931 -.0438 .2087

model.dhp <- specifyModel()
  RParAsp  ->  RGenAsp, gam11, NA
  RIQ     ->  RGenAsp, gam12, NA
  RSES    ->  RGenAsp, gam13, NA
  FSES    ->  FGenAsp, gam14, NA
  RSES    ->  FGenAsp, gam23, NA
  FSES    ->  FGenAsp, gam24, NA
  FIQ     ->  FGenAsp, gam25, NA
  FParAsp  ->  FGenAsp, gam26, NA
  FGenAsp  ->  RGenAsp, beta12, NA
  RGenAsp  ->  FGenAsp, beta21, NA
  RGenAsp  ->  ROccAsp, NA,  1
  RGenAsp  ->  REdAsp, lam21, NA
  FGenAsp  ->  FOccAsp, NA,  1
  FGenAsp  ->  FEdAsp, lam42, NA
  RGenAsp  ->  RGenAsp, psi11, NA
  FGenAsp  ->  FGenAsp, psi22, NA
  RGenAsp  ->  FGenAsp, psi12, NA
  ROccAsp  ->  ROccAsp, theta1, NA
  REdAsp   ->  REdAsp, theta2, NA
  FOccAsp  ->  FOccAsp, theta3, NA
  FEdAsp   ->  FEdAsp, theta4, NA

sem.dhp <- sem(model.dhp, R.DHP, 329,
### Tests

Six Mental Tests

#### Description

These data are from the SAS manual and consist of six mental tests for 32 students, with some missing data. The three \( x \) variables are intended to load on a verbal factor, and the three \( y \) variables on a math factor. The data can be used to illustrate the estimation of a confirmatory factor analysis model by multinormal full-information maximum-likelihood in the presence of missing data.

#### Usage

Tests

#### Format

A data frame with 32 observations on the following 6 variables.

- \( x_1 \) score on verbal test 1.
- \( x_2 \) score on verbal test 2.
- \( x_3 \) score on verbal test 3.
- \( y_1 \) score on math test 1.
- \( y_2 \) score on math test 2.
- \( y_3 \) score on math test 3.

#### Source

Two-Stage Least Squares

Description

Fits a regression equation, such as an equation in a structural-equation model, by two-stage least squares. This is equivalent to direct instrumental-variables estimation when the number of instruments is equal to the number of predictors.

Usage

## S3 method for class 'formula'
tsls(formula, instruments, data, subset, weights, na.action, contrasts=NULL, ...)
## Default S3 method:
tsls(y, X, Z, w, names=NULL, ...)

## S3 method for class 'tssl'
print(x, ...)
## S3 method for class 'tssl'
summary(object, digits=getOption("digits"), ...)
## S3 method for class 'summary.tsll'
print(x, ...)

## S3 method for class 'tssl'
anova(object, model=2, s2, dfe, ...)

## S3 method for class 'tssl'
fitted(object, ...)
## S3 method for class 'tssl'
residuals(object, ...)
## S3 method for class 'tssl'
coef(object, ...)
## S3 method for class 'tssl'
vcov(object, ...)

Arguments

- **formula**: model formula for structural equation to be estimated; a regression constant is implied if not explicitly omitted.
- **instruments**: one-sided model formula specifying instrumental variables.
- **data**: an optional data frame containing the variables in the model. By default the variables are taken from the environment from which tsls is called.
- **subset**: an optional vector specifying a subset of observations to be used in fitting the model.
weights, w  an optional vector of weights to be used in the fitting process; if specified should be a non-negative numeric vector with one entry for each observation, to be used to compute weighted 2SLS estimates.

na.action  a function that indicates what should happen when the data contain NAs. The default is set by the na.action option.

contrasts  an optional list. See the contrasts.arg argument of model.matrix.default.

y  Response-variable vector.

X  Matrix of predictors, including a constant (if one is in the model).

Z  Matrix of instrumental variables, including a constant (if one is in the model).

names  optional character vector of names for the columns of the X matrix.

x, object, model 2  objects of class tsls returned by tsls.formula (or of class summary.tls), for an anova containing nested models to be compared by an incremental $F$-test. One model should be nested in the other; the order of models is immaterial.

s2  an optional estimate of error variance for the denominator of the $F$-test. If missing, the error-variance estimate is taken from the larger model.

dfe  optional error degrees of freedom, to be specified when an estimate of error variance is given.

digits  number of digits for summary output.

Value  

tsls.formula returns an object of class tsls, with the following components:

n  number of observations.

p  number of parameters.

coefficients  parameter estimates.

V  estimated covariance matrix of coefficients.

s  residual standard error.

residuals  vector of residuals.

response  vector of response values.

X  model matrix.

Z  instrumental-variables matrix.

response.name  name of response variable, or expression evaluating to response.

formula  model formula.

instruments  one-sided formula for instrumental variables.

Author(s)  

John Fox <jfox@mcmaster.ca>
References


See Also

`sem`

Examples

```r
summary(tsls(Q ~ P + D, ~ D + F + A, data=Kmenta))  # demand equation

summary(tsls(Q ~ P + F + A, ~ D + F + A, data=Kmenta))  # supply equation

anova(tsls(Q ~ P + F + A, ~ D + F + A, data=Kmenta),
       tsls(Q ~ 1, ~ D + F + A, data=Kmenta))
```
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