

Package ‘ctsem’

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Type Package

Title Continuous Time Structural Equation Modelling

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Description A hierarchical, multivariate, continuous (and discrete) time dynamic modelling package for panel and time series data, using stochastic differential equations. Contains a faster frequentist set of functions using OpenMx for single subject and mixed-effects (random intercepts only) structural equation models, or a hierarchical Bayesian implementation using Stan that allows for random effects and non-linearity over all model parameters. Allows for modelling of multiple noisy measurements of multiple stochastic processes, time varying input / event covariates, and time invariant covariates used to predict the parameters. Bayesian formulation not available on 32 bit Windows systems.

License GPL-3

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URL <https://github.com/cdriveraus/ctsem>

Imports rstan (>= 2.17.1), rstantools (>= 1.5.0), plyr, tools, data.table, Matrix, datasets, stats, graphics, grDevices, parallel, shiny, MASS, methods, utils, corplot, mvtnorm, DEoptim, KernSmooth, ucminf

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AnomAuth

*AnomAuth***Description**

A dataset containing panel data assessments of individuals Anomia and Authoritarianism.

Format

data frame with 2722 rows, 14 columns. Column Y1 represents anomia, Y2 Authoritarianism, dTx the time interval for measurement occasion x.

Source

See <http://psycnet.apa.org/journals/met/17/2/176/> for details.

 ctCheckFit

Check absolute fit of ctFit or ctStanFit object.

Description

Check absolute fit of ctFit or ctStanFit object.

Usage

```
ctCheckFit(fit, niter = 500, probs = c(0.025, 0.5, 0.975))
```

Arguments

fit	ctFit or ctStanFit object.
niter	number of data generation iterations to use to calculate quantiles.
probs	3 digit vector of quantiles to return and to test significance.

Value

numeric matrix showing Z score difference for each lower triangular index of the covariance matrix of data – observed covariance minus mean of generated, weighted by sd of generated covariance.

Examples

```
## Not run:
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(dat=ctExample1, ctmodelobj=traitmodel)

check <- ctCheckFit(traitfit,niter=5)
plot(check)

## End(Not run)
```

ctCI	<i>ctCI Computes confidence intervals on specified parameters / matrices for already fitted ctsem fit object.</i>
------	---

Description

ctCI Computes confidence intervals on specified parameters / matrices for already fitted ctsem fit object.

Usage

```
ctCI(ctfitobj, confidenceintervals, optimizer = "NPSOL", verbose = 0)
```

Arguments

ctfitobj	Already fit ctsem fit object (class: ctsemFit) to estimate confidence intervals for.
confidenceintervals	character vector of matrices and or parameters for which to estimate 95% confidence intervals for.
optimizer	character vector. Defaults to NPSOL (recommended), but other optimizers available within OpenMx (e.g. 'CSOLNP') may be specified.
verbose	Integer between 0 and 3 reflecting amount of output while calculating.

Details

Confidence intervals typically estimate more reliably using the proprietary NPSOL optimizer available within OpenMx only when installing directly from OpenMx website. Use command `source('http://openmx.psyc.virginia.edu/install/OpenMx/NPSOL')` to install OpenMx with NPSOL. If estimating for a multigroup model, specify confidence intervals as normal, e.g. `confidenceintervals = c('DRIFT', 'diffusion_Y1_Y1')`. The necessary group prefixes are added internally.

Value

ctfitobj, with confidence intervals included.

Examples

```
## Examples set to 'dontrun' because they take longer than 5s.
## Not run:
data("ctExample3")
model <- ctModel(n.latent = 1, n.manifest = 3, Tpoints = 100,
  LAMBDA = matrix(c(1, "lambda2", "lambda3"), nrow = 3, ncol = 1),
  MANIFESTMEANS = matrix(c(0, "manifestmean2", "manifestmean3"), nrow = 3,
    ncol = 1))
fit <- ctFit(dat = ctExample3, ctmodelobj = model, objective = "Kalman",
  stationary = c("T0VAR"))

fit <- ctCI(fit, confidenceintervals = 'DRIFT')
```

```
summary(fit)$omxsummary$CI
## End(Not run)
```

ctCollapse *ctCollapse Easily collapse an array margin using a specified function.*

Description

ctCollapse Easily collapse an array margin using a specified function.

Usage

```
ctCollapse(inarray, collapsemargin, collapsefunc, ...)
```

Arguments

inarray Input array of more than one dimension.
collapsemargin Integers denoting which margins to collapse.
collapsefunc function to use over the collapsing margin.
... additional parameters to pass to collapsefunc.

Examples

```
testarray <- array(rnorm(900,2,1),dim=c(100,3,3))
ctCollapse(testarray,1,mean)
```

ctCompareExpected *ctCompareExpected Compares model implied to observed means and covariances for panel data fit with ctsem.*

Description

ctCompareExpected Compares model implied to observed means and covariances for panel data fit with ctsem.

Usage

```
ctCompareExpected(fitobj, cov = TRUE, outputmatrices = FALSE,
  pause = TRUE, varlist = "all", ylim = c(-1, 1), ...)
```

Arguments

fitobj	Fitted model object from OpenMx or ctsem.
cov	Logical. If TRUE, show covariance plots, if FALSE show correlations.
outputmatrices	if TRUE, output expected, observed, and residual correlation matrices as well as plots.
pause	if TRUE (default) output plots interactively, one at a time. If FALSE, output without stopping.
varlist	if "all" include all variables in dataset. Otherwise, specify numeric vector of variables to include.
ylim	vector of min and max Y axis limits for plot.
...	additional arguments passed to plot.

 ctDeintervalise

ctDeintervalise

Description

Converts intervals in ctsem long format data to absolute time

Usage

```
ctDeintervalise(datalong, id = "id", dT = "dT", startoffset = 0)
```

Arguments

datalong	data to use, in ctsem long format (attained via function ctWideToLong)
id	character string denoting column of data containing numeric identifier for each subject.
dT	character string denoting column of data containing time interval preceding observations in that row.
startoffset	Number of units of time to offset by when converting.

 ctDensity

ctDensity

Description

Wrapper for base R density function that removes outliers and computes 'reasonable' bandwidth and x and y limits. Used for ctsem density plots.

Usage

```
ctDensity(x, bw = "auto", plot = FALSE, ...)
```

Arguments

x	numeric vector on which to compute density.
bw	either 'auto' or a numeric indicating bandwidth.
plot	logical to indicate whether or not to plot the output.
...	Further args to density.

Examples

```
y <- ctDensity(exp(rnorm(80)))
plot(y$density, xlim=y$xlim, ylim=y$ylim)

#### Compare to base defaults:
par(mfrow=c(1,2))
y=exp(rnorm(10000))
ctdens<-ctDensity(y)
plot(ctdens$density, ylim=ctdens$ylim, xlim=ctdens$xlim)
plot(density(y))
```

 ctDiscretePars

ctDiscretePars

Description

Generate discrete time parameters for a sequence of times based on a list containing continuous time parameter matrices as used in ctsem.

Usage

```
ctDiscretePars(ctpars, times = seq(0, 10, 0.1), type = "all")
```


Arguments

ctpars	List of continuous time parameter matrices.
times	Numeric vector of positive values, discrete time parameters will be calculated for each.
type	String. 'all' returns all possible outputs in a list. 'discreteDRIFT' returns only discrete time auto and cross regression effects. 'latentMeans' returns only the expected latent means, given initial (T0MEANS) level, latent intercept (CINT) and temporal effects (DRIFT).

Examples

```
pars <- ctStanContinuousPars(ctstantestfit)
ctDiscretePars(pars, times=c(.5,1))
```

ctDiscretiseData	<i>Discretise long format continuous time (ctsem) data to specific timestep.</i>
------------------	--

Description

Extends and rounds timing information so equal intervals, according to specified timestep, are achieved. NA's are inserted in other columns as necessary, any columns specified by TDpredNames or TIpredNames have zeroes rather than NA's inserted (because some estimation routines do not tolerate NA's in covariates).

Usage

```
ctDiscretiseData(dlong, timestep, timecol = "time", idcol = "id",
  TDpredNames = NULL, TIpredNames = NULL)
```

Arguments

dlong	Long format data
timestep	Positive real value to discretise
timecol	Name of column containing absolute (not intervals) time information.
idcol	Name of column containing subject id variable.
TDpredNames	Vector of column names of any time dependent predictors
TIpredNames	Vector of column names of any time independent predictors

Value

long format ctsem data.

Examples

```

long <- ctWideToLong(datawide=ctExample2,Tpoints=8,n.manifest=2,n.TDpred=1,
  manifestNames=c('LeisureTime','Happiness'),
  TDpredNames=c('MoneyInt'))

long <- ctDeintervalise(long)

long <- ctDiscretiseData(dlong=long, timestep = 1.1,TDpredNames=c('MoneyInt'))

```

`ctExample1`*ctExample1*

Description

Simulated example dataset for the ctsem package

Format

100 by 17 matrix containing containing ctsem wide format data. 6 measurement occasions of leisure time and happiness and 5 measurement intervals for each of 100 individuals.

`ctExample1TIpred`*ctExample1TIpred*

Description

Simulated example dataset for the ctsem package

Format

100 by 18 matrix containing containing ctsem wide format data. 6 measurement occasions of leisure time and happiness, 1 measurement of number of friends, and 5 measurement intervals for each of 100 individuals.

 ctExample2

 ctExample2

Description

Simulated example dataset for the ctsem package

Format

100 by 18 matrix containing containing ctsem wide format data. 8 measurement occasions of leisure time and happiness, 7 measurement occasions of a money intervention dummy, and 7 measurement intervals for each of 50 individuals.

Examples

```
## Not run:
#two process, one time dependent predictor example
Tpoints=20
manifestNames<-c('LeisureTime','Happiness')
TDpredNames<- 'MoneyInt'
testm<-ctModel(Tpoints=Tpoints,n.latent=3,n.TDpred=1,n.TIpred=0,n.manifest=2,
  LAMBDA=cbind(diag(1,2),0),
  MANIFESTVAR=diag(.1,2),
  DRIFT=matrix(c(-.3,.12,0, -.02,-.3,0, 1,-.3,-.0001 ),nrow=3,ncol=3),
  TRAITVAR=t(chol(matrix(c(.2,-.1,0, -.1,.21,0, 0,0,0.00001),ncol=3,nrow=3))),
  DIFFUSION=t(chol(diag(c(1.2,.6,0.0001),3))),
  CINT=matrix(c(1,.3,0),nrow=3),
  T0MEANS=matrix(0,ncol=1,nrow=3),
  T0VAR=diag(c(1,1,0),3),
  TDPREDEFFECT=matrix(c(.6,.4,1),nrow=3),
  TDPREDVAR=diag(c(rep(0,Tpoints)),Tpoints),
  TDPREDMEANS=matrix(c(0,0,0,0,0,1,rep(0,Tpoints-6)),ncol=1,nrow=(Tpoints)))
testd<-ctGenerate(testm,n.subjects=10,burnin=10) #generate data

ctIndplot(testd,Tpoints=Tpoints,n.manifest=2,n.subjects=10,colourby="variable")

timestokeep=c(0,1,4,5,7,8,16,19)
deltaT<-timestokeep[-1] - timestokeep[-8]
testd<-testd[,c(paste0('Y',1:2,'_T',rep(timestokeep,each=2)),paste0('TD1_T',timestokeep))]
testd<-cbind(testd,matrix(deltaT,nrow=nrow(testd),ncol=length(deltaT),byrow=TRUE))

colnames(testd)<-ctWideNames(n.manifest=2,Tpoints=8,n.TDpred=1,
  manifestNames=manifestNames,TDpredNames=TDpredNames)
ctExample2<-testd
save(ctExample2,file=".\data\ctExample2.rda")

## End(Not run)
```

ctExample2level *ctExample2level*

Description

Simulated example dataset for the ctsem package

Format

100 by 18 matrix containing ctsem wide format data. 8 measurement occasions of leisure time and happiness, 7 measurement occasions of a money intervention dummy, and 7 measurement intervals for each of 50 individuals.

ctExample3 *ctExample3*

Description

Simulated example dataset for the ctsem package

Format

1 by 399 matrix containing containing ctsem wide format data. 100 observations of variables Y1 and Y2 and 199 measurement intervals, for 1 subject.

ctExample4 *ctExample4*

Description

Simulated example dataset for the ctsem package

Format

20 by 79 matrix containing 20 observations of variables Y1, Y2, Y3, and 19 measurement intervals dTx, for each of 20 individuals.

Examples

```
## Not run:
Tpoints=20
subjects=20
full<-c()
for(i in 1:20){
  LAMBDA<-matrix(c(1,.7,ifelse(i >(subjects/2),.2,1.4)))
  print(LAMBDA)
  testm<-ctModel(Tpoints=Tpoints,n.latent=1,n.TDpred=0,n.TIpred=0,n.manifest=3,
    MANIFESTVAR=diag(.2,3),
    # TRAITVAR=diag(.2,1),
    LAMBDA=LAMBDA,
    DRIFT=matrix(c(-.1),nrow=1,ncol=1),
    DIFFUSION=diag(c(.12),1),
    MANIFESTMEANS=matrix(c(0,.42,1.3),ncol=1),
    CINT=matrix(c(.2),ncol=1))

  testd<-ctGenerate(testm,n.subjects=1,burnin=300)
  full<-rbind(full,testd)
}

ctExample4<-full
save(ctExample4,file=".\data\ctExample4.rda") #save wide format example

## End(Not run)
```

 ctFit

Fit a ctsem object

Description

This function fits continuous time SEM models specified via [ctModel](#) to a dataset containing one or more subjects.

Usage

```
ctFit(dat, ctmodelobj, dataform = "wide", objective = "auto",
  stationary = c("T0TRAITEFFECT", "T0TIPREDEFFECT"),
  optimizer = "CSOLNP", retryattempts = 15, iterationSummary = FALSE,
  carefulFit = TRUE, carefulFitWeight = 100, showInits = FALSE,
  asymptotes = FALSE, meanIntervals = FALSE,
  plotOptimization = FALSE, crossEffectNegStarts = TRUE, fit = TRUE,
  nofit = FALSE, discreteTime = FALSE, verbose = 0,
  useOptimizer = TRUE, omxStartValues = NULL,
  transformedParams = TRUE, datawide = NA)
```

Arguments

dat	the data you wish to fit a ctsem model to, in either wide format (one individual per row), or long format (one time point of one individual per row). See details.
ctmodelobj	the ctsem model object you wish to use, specified via the <code>ctModel</code> function.
dataform	either "wide" or "long" depending on which input format you wish to use for the data. See details and or vignette.
objective	'auto' selects either 'Kalman', if fitting to single subject data, or 'mxRAM' for multiple subjects. For single subject data, 'Kalman' uses the <code>mxExpectationStateSpace</code> function from OpenMx to implement the Kalman filter. For more than one subject, 'mxRAM' specifies a wide format SEM with a row of data per subject. 'cov' may be specified, in which case the 'meanIntervals' argument is set to TRUE, and the covariance matrix of the supplied data is calculated and fit instead of the raw data. This is much faster but only a rough approximation, unless there are no individual differences in time interval and no missing data. 'Kalman' may be specified for multiple subjects, however as no trait matrices are used by the Kalman filter one must consider how average level differences between subjects are accounted for. See <code>ctMultigroupFit</code> for the possibility to apply the Kalman filter over multiple subjects)
stationary	Character vector of T0 matrix names in which to constrain any free parameters to stationarity. Defaults to <code>c('T0TRAITEFFECT', 'T0TIPREDEFFECT')</code> , constraining only between person effects to stationarity. Use NULL for no constraints, or 'all' to constrain all T0 matrices.
optimizer	character string, defaults to the open-source 'CSOLNP' optimizer that is distributed in all versions of OpenMx. However, 'NPSOL' may sometimes perform better for these problems, though requires that you have installed OpenMx via the OpenMx web site, by running: <code>source('http://openmx.psyc.virginia.edu/getOpenMx.R')</code>
retryattempts	Number of times to retry the start value randomisation and fit procedure, if non-convergence or uncertain fits occur.
iterationSummary	if TRUE, outputs limited fit details after every fit attempt.
carefulFit	if TRUE, first fits the specified model with a penalised likelihood function to force MANIFESTVAR, DRIFT, TRAITVAR, MANIFESTTRAITVAR parameters to remain close to 0, then fits the specified model normally, using these estimates as starting values. Can help to ensure optimization begins at sensible, non-extreme values, though results in any user specified start values being ignored for the final fit (though they are still used for initial fit).
carefulFitWeight	Positive numeric. Sets the weight for the penalisation (or prior) applied by the carefulFit algorithm. Generally unnecessary to adjust, may be helpful to try a selection of values (perhaps between 0 and 1000) when optimization is problematic.
showInits	if TRUE, prints the list of starting values for free parameters. These are the 'raw' values used by OpenMx, and reflect the log (var / cov matrices) or -log(DRIFT matrices) transformations used in ctsem. These are saved in the fit object under <code>fitobject\$omxStartValues</code> .

asymptotes	when TRUE, optimizes over asymptotic parameter matrices instead of continuous time parameter matrices. Can be faster for optimization and in some cases makes reliable convergence easier. Will result in equivalent models when continuous time input matrices (DRIFT, DIFFUSION, CINT) are free, but fixing the values of any such matrices will result in large differences - a value of 0 in a cell of the normal continuous time DIFFUSION matrix does not necessarily result in a value of 0 for the asymptotic DIFFUSION matrix, for instance.
meanIntervals	Use average time intervals for each column for calculation (both faster and inaccurate to the extent that intervals vary across individuals).
plotOptimization	If TRUE, uses checkpointing for OpenMx function mxRun, set to checkpoint every iteration, output checkpoint file to working directory, then creates a plot for each parameter's values over iterations.
crossEffectNegStarts	Logical. If TRUE (default) free DRIFT matrix cross effect parameters have starting values set to small negative values (e.g. -.05), if FALSE, the start values are 0. The TRUE setting is useful for easy initialisation of higher order models, while the FALSE setting is useful when one has already estimated a model without cross effects, and wishes to begin optimization from those values by using the omxStartValues switch. are re-transformed into regular continuous time parameter matrices, and may be interpreted as normal.
fit	if FALSE, output only openmx model without fitting
nofit	Deprecated. If TRUE, output only openmx model without fitting
discreteTime	Estimate a discrete time model - ignores timing information, parameter estimates will correspond to those of classical vector autoregression models, OpenMx fit object will be directly output, thus ctsem summary and plot functionality will be unavailable. Time dependent predictor type also becomes irrelevant.
verbose	Integer between 0 and 3. Sets mxComputeGradientDescent messaging level, defaults to 0.
useOptimizer	Logical. Defaults to TRUE. Passes argument to mxRun, useful for using custom optimizers or fitting to specified parameters.
omxStartValues	A named vector containing the raw (potentially log transformed) OpenMx starting values for free parameters, as captured by OpenMx function omxGetParameters(ctmodelobj\$mxobj) These values will take precedence over any starting values already specified using ctModel.
transformedParams	Logical indicating whether or not to log transform certain parameters internally to allow unconstrained estimation over entire 'sensible' range for parameters. When TRUE (default) raw OpenMx parameters (only reported if verbose=TRUE argument used for summary function) will reflect these transformations and may be harder to interpret, but summary matrices are reported as normal.
datawide	included for compatibility with scripts written for earlier versions of ctsem. Do not use this argument, instead use the dat argument, and the dataform argument now specifies whether the data is in wide or long format.

Details

For full discussion of how to structure the data and use this function, see the vignette using: `vignette('ctsem')`, or the data examples `data("longexample")` ; `longexample` for long and `data("datastructure")` ; `datastructure` for wide. If using long format, the subject id column must be numeric and grouped by ascending time within subject, and named 'id'. The time column must also be numeric, and representing absolute time (e.g., since beginning of study, *not* time intervals), and called 'time'. Models are specified using the `ctModel` function. For help regarding the summary function, see `summary.ctsemFit`, and for the plot function, `plot.ctsemFit`. Multi-group models may be specified using `ctMultigroupFit`. Confidence intervals for any matrices and or parameters may be estimated using `ctCI`. Difficulties during estimation can sometimes be alleviated using `ctRefineTo` instead of `ctFit` – this uses a multistep fit procedure.

Examples

```
## Examples set to 'dontrun' because they take longer than 5s.
## Not run:
mfrowOld<-par()$mfrow
par(mfrow=c(2, 3))

### example from Driver, Oud, Voelkle (2017),
### simulated happiness and leisure time with unobserved heterogeneity.
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(dat=ctExample1, ctmodelobj=traitmodel)
summary(traitfit)
plot(traitfit, wait=FALSE)

###Example from Voelkle, Oud, Davidov, and Schmidt (2012) - anomia and authoritarianism.
data(AnomAuth)
AnomAuthmodel <- ctModel(LAMBDA = matrix(c(1, 0, 0, 1), nrow = 2, ncol = 2),
  Tpoints = 5, n.latent = 2, n.manifest = 2, MANIFESTVAR=diag(0, 2), TRAITVAR = NULL)
AnomAuthfit <- ctFit(AnomAuth, AnomAuthmodel)
summary(AnomAuthfit)

### Single subject time series - using Kalman filter (OpenMx statespace expectation)
data('ctExample3')
model <- ctModel(n.latent = 1, n.manifest = 3, Tpoints = 100,
  LAMBDA = matrix(c(1, 'lambda2', 'lambda3'), nrow = 3, ncol = 1),
  CINT= matrix('cint'),
  MANIFESTMEANS = matrix(c(0, 'manifestmean2', 'manifestmean3'), nrow = 3,
    ncol = 1))
fit <- ctFit(dat = ctExample3, ctmodelobj = model, objective = 'Kalman',
  stationary = c('T0VAR'))

###Oscillating model from Voelkle & Oud (2013).
data("Oscillating")
```



```

inits <- c(-39, -.3, 1.01, 10.01, .1, 10.01, 0.05, .9, 0)
names(inits) <- c("crosseffect", "autoeffect", "diffusion",
  "T0var11", "T0var21", "T0var22", "m1", "m2", 'manifestmean')

oscillatingm <- ctModel(n.latent = 2, n.manifest = 1, Tpoints = 11,
  MANIFESTVAR = matrix(c(0), nrow = 1, ncol = 1),
  LAMBDA = matrix(c(1, 0), nrow = 1, ncol = 2),
  T0MEANS = matrix(c('m1', 'm2'), nrow = 2, ncol = 1),
  T0VAR = matrix(c("T0var11", "T0var21", 0, "T0var22"), nrow = 2, ncol = 2),
  DRIFT = matrix(c(0, "crosseffect", 1, "autoeffect"), nrow = 2, ncol = 2),
  CINT = matrix(0, ncol = 1, nrow = 2),
  MANIFESTMEANS = matrix('manifestmean', nrow = 1, ncol = 1),
  DIFFUSION = matrix(c(0, 0, 0, "diffusion"), nrow = 2, ncol = 2),
  startValues=inits)

oscillatingf <- ctFit(Oscillating, oscillatingm, carefulFit = FALSE)

## End(Not run)

```

ctGenerate

ctGenerate

Description

This function generates data according to the specified ctsem model object.

Usage

```

ctGenerate(ctmodelobj, n.subjects = 100, burnin = 0, dtmean = 1,
  logdtsd = 0, dtmat = NA, wide = TRUE)

```

Arguments

ctmodelobj	ctsem model object from ctModel .
n.subjects	Number of subjects to output.
burnin	Number of initial time points to discard (to simulate stationary data)
dtmean	Positive numeric. Average time interval (delta T) to use.
logdtsd	Numeric. Standard deviation for variability of the time interval.
dtmat	Either NA, or numeric matrix of n.subjects rows and burnin+Tpoints-1 columns, containing positive numeric values for all time intervals between measurements. If not NA, dtmean and logdtsd are ignored.
wide	Logical. Output in wide format?

Details

TRAITVAR and MANIFESTTRAITVAR are treated as Cholesky factor covariances of CINT and MANIFESTMEANS, respectively. TRAITTDPREDCOV and TIPREDCOV matrices are not accounted for, at present. The first 1:n.TDpred rows and columns of TDPREDCOV are used for generating tdpreds at each time point.

Examples

```
#generate data for 2 process model, each process measured by noisy indicator,
#stable individual differences in process levels.

generatingModel<-ctModel(Tpoints=8,n.latent=2,n.TDpred=0,n.TIpred=0,n.manifest=2,
  MANIFESTVAR=diag(.1,2),
  LAMBDA=diag(1,2),
  DRIFT=matrix(c(-.2,-.05,-.1,-.1),nrow=2),
  TRAITVAR=matrix(c(.5,.2,0,.8),nrow=2),
  DIFFUSION=matrix(c(1,.2,0,4),2),
  CINT=matrix(c(1,0),nrow=2),
  T0MEANS=matrix(0,ncol=1,nrow=2),
  T0VAR=diag(1,2))

data<-ctGenerate(generatingModel,n.subjects=15,burnin=10)
```

ctGenerateFromFit	<i>Generates data according to the model estimated in a ctsemFit object.#'</i>
-------------------	--

Description

Generates data according to the model estimated in a ctsemFit object.#'

Usage

```
ctGenerateFromFit(fit, timestep = "asdata", n.subjects = 100,
  timerange = "asdata", predictorSubjects = "all", ...)
```

Arguments

fit	object of class ctsemFit as returned from <code>ctFit</code>
timestep	positive numeric value indicating the time interval to use for data generation.
n.subjects	integer. Number of subjects worth of data to generate
timerange	either 'asdata' to calculate range based on data in fit object, or vector of length 2 specifying min and max times for generation.
predictorSubjects	vector of integers, or string 'all', defining which subjects to sample time dependent and independent predictors from.
...	parameters to pass to ctGenerate function, such as wide=FALSE.

Value

matrix of generated data

Examples

```
data(AnomAuth)
AnomAuthmodel <- ctModel(LAMBDA = matrix(c(1, 0, 0, 1), nrow = 2, ncol = 2),
  Tpoints = 5, n.latent = 2, n.manifest = 2, MANIFESTVAR=diag(0, 2))
AnomAuthfit <- ctFit(AnomAuth, AnomAuthmodel)

dwide <- ctGenerateFromFit(AnomAuthfit,timestep=1,n.subjects=5)

par(mfrow=c(1,2))
ctIndplot(datawide = dwide,n.subjects = 5,n.manifest = 2,vars=1,Tpoints = 4)
ctIndplot(datawide = AnomAuth+rnorm(length(AnomAuth)),vars=1,n.subjects = 5,
n.manifest = 2,Tpoints = 4)
```

ctIndplot

ctIndplot

Description

Convenience function to simply plot individuals trajectories from ctsem wide format data

Usage

```
ctIndplot(datawide, n.manifest, Tpoints, n.subjects = "all",
  colourby = "variable", vars = "all", opacity = 1,
  varnames = NULL, xlab = "Time", ylab = "Value", type = "b",
  start = 0, legend = TRUE, legendposition = "topright",
  new = TRUE, jittersd = 0.05, ...)
```

Arguments

datawide	ctsem wide format data
n.manifest	Number of manifest variables in data structure
Tpoints	Number of discrete time points per case in data structure
n.subjects	Number of subjects to randomly select for plotting, or character vector 'all'.
colourby	set plot colours by "subject" or "variable"
vars	either 'all' or a numeric vector specifying which manifest variables to plot.
opacity	Opacity of plot lines
varnames	vector of variable names for legend (defaults to NULL)
xlab	X axis label.

ylab	Y axis label.
type	character specifying plot type, as per usual base R plot commands. Defaults to 'b', both points and lines.
start	Measurement occasion to start plotting from - defaults to T0.
legend	Logical. Plot a legend?
legendposition	Where to position the legend.
new	logical. If TRUE, creates a new plot, otherwise overlays on current plot.
jittersd	positive numeric indicating standard deviation of noise to add to observed data for plotting purposes.
...	additional plotting parameters.

Examples

```
data(ctExample1)
ctIndplot(ctExample1, n.subjects=1, n.manifest=2, Tpoints=6, colourby='variable')
```

ctIntervalise	<i>Converts absolute times to intervals for wide format ctsem panel data</i>
---------------	--

Description

Converts absolute times to intervals for wide format ctsem panel data

Usage

```
ctIntervalise(datawide, Tpoints, n.manifest, n.TDpred = 0,
  n.TIpred = 0, imputedefs = F, manifestNames = "auto",
  TDpredNames = "auto", TIpredNames = "auto", digits = 5,
  mininterval = 0.001, individualRelativeTime = TRUE,
  startoffset = 0)
```

Arguments

datawide	Wide format data, containing absolute time measurements, to convert to interval time scale. Otherwise as used in ctFit . See ctLongToWide to easily convert long format data.
Tpoints	Maximum number of discrete time points (waves of data, or measurement occasions) for an individual in the input data structure.
n.manifest	number of manifest variables per time point in the data.
n.TDpred	number of time dependent predictors in the data structure.
n.TIpred	number of time independent predictors in the data structure.

imputedefs	if TRUE, impute time intervals based on the measurement occasion (i.e. column) they are in, if FALSE (default), set related observations to NA. FALSE is recommended unless you are certain that the imputed value (mean of the relevant time column) is appropriate. Noise and bias in estimates will result if wrongly set to TRUE.
manifestNames	vector of character strings giving variable names of manifest indicator variables (without _Tx suffix for measurement occasion).
TDpredNames	vector of character strings giving variable names of time dependent predictor variables (without _Tx suffix for measurement occasion).
TIpredNames	vector of character strings giving variable names of time independent predictor variables.
digits	How many digits to round to for interval calculations.
mininterval	set to lower than any possible observed measurement interval, but above 0 - this is used for filling NA values where necessary and has no impact on estimates when set in the correct range. (If all observed intervals are greater than 1, mininterval=1 may be a good choice)
individualRelativeTime	if TRUE (default), the first measurement for each individual is assumed to be taken at time 0, and all other times are adjusted accordingly. If FALSE, new columns for an initial wave are created, consisting only of observations which occurred at the earliest observation time of the entire sample.
startoffset	if 0 (default) uses earliest observation as start time. If greater than 0, all first observations are NA, with distance of startoffset to first recorded observation.

Details

Time column must be numeric!

Examples

```
#First load the long format data with absolute times
data('longexample')

#Then convert to wide format
wideexample <- ctLongToWide(dataLong = longexample, id = "id",
time = "time", manifestNames = c("Y1", "Y2", "Y3"),
TDpredNames = "TD1", TIpredNames = c("TI1", "TI2"))

#Then convert the absolute times to intervals, using the Tpoints reported from the prior step.
wide <- ctIntervalise(datawide = wideexample, Tpoints = 4, n.manifest = 3,
n.TDpred = 1, n.TIpred = 2, manifestNames = c("Y1", "Y2", "Y3"),
TDpredNames = "TD1", TIpredNames = c("TI1", "TI2") )

print(wide)
```

 ctKalman

ctKalman

Description

Outputs predicted, updated, and smoothed estimates of manifest indicators and latent states, with covariances, for specific subjects from data fit with [ctStanFit](#), based on medians of parameter distribution.

Usage

```
ctKalman(fit, datalong = NULL, timerange = "asdata",
         timestep = "asdata", subjects = 1, plot = FALSE, ...)
```

Arguments

fit	fit object as generated by ctStanFit .
datalong	Optional long format data object as used by ctStanFit . If not included, data from fit will be used.
timerange	Either 'asdata' to just use the observed data range, or a numeric vector of length 2 denoting start and end of time range, allowing for estimates outside the range of observed data.
timestep	Either 'asdata' to just use the observed data (which also requires 'asdata' for timerange) or a positive numeric value indicating the time step to use for interpolating values. Lower values give a more accurate / smooth representation, but take a little more time to calculate.
subjects	vector of integers denoting which subjects (from 1 to N) to plot predictions for.
plot	Logical. If TRUE, plots output instead of returning it. See ctKalmanPlot for the possible arguments.
...	additional arguments to pass to ctKalmanPlot .

Value

Returns a list containing matrix objects `etaprior`, `etaupd`, `etasmooth`, `y`, `yprior`, `yupd`, `ysmooth`, `pred-error`, `time`, `loglik`, with values for each time point in each row. `eta` refers to latent states and `y` to manifest indicators - `y` itself is thus just the input data. Covariance matrices `etapriorcov`, `etaupdcov`, `etasmoothcov`, `ypriorcov`, `yupdcov`, `ysmoothcov`, are returned in a row * column * time array. If `plot=TRUE`, nothing is returned but a plot is generated.

Examples

```
## Not run:
#Basic
ctKalman(ctstantestfit, timerange=c(0,60), timestep=.5, plot=TRUE)

#Multiple subjects, y and yprior, showing plot arguments
```

```

ctKalman(ctsttestfit, timerange=c(0,60), timestep=.1, plot=TRUE,
  subjects=2:3,
  kalmanvec=c('y','yprior'),
  errorvec=c(NA,'ypriorcov'), #'auto' would also have achieved this
  ltyvec="auto",
  colvec='auto',
  lwdvec='auto',
  subsetindices=2, #Only plotting 2nd dimension of y and yprior
  pchvec='auto', typevec='auto',grid=TRUE,legend=TRUE,
  plotcontrol=list(xlim=c(0,55),main='Observations and priors'),
  polygoncontrol=list(steps=5))

## End(Not run)

```

ctKalmanPlot

ctKalmanPlot

Description

Plots Kalman filter output from ctKalman.

Usage

```

ctKalmanPlot(x, subjects, kalmanvec = c("y", "yprior"),
  errorvec = "auto", errormultiply = 1.96, ltyvec = "auto",
  colvec = "auto", lwdvec = "auto", subsetindices = NULL,
  pchvec = "auto", typevec = "auto", grid = FALSE, add = FALSE,
  plotcontrol = list(ylab = "Value", xlab = "Time", xaxs = "i"),
  polygoncontrol = list(steps = 20), polygonalpha = 0.3,
  legend = TRUE, legendcontrol = list(x = "topright", bg = "white"))

```

Arguments

x	Output from ctKalman . In general it is easier to call ctKalman directly with the <code>plot=TRUE</code> argument, which calls this function.
subjects	vector of integers denoting which subjects (from 1 to N) to plot predictions for.
kalmanvec	string vector of names of any elements of the output you wish to plot, the defaults of 'y' and 'yprior' plot the original data, 'y', and the prior from the Kalman filter for y. Replacing 'y' by 'eta' will plot latent variables instead (though 'eta' alone does not exist) and replacing 'prior' with 'upd' or 'smooth' respectively plotting updated (conditional on all data up to current time point) or smoothed (conditional on all data) estimates.
errorvec	vector of names of covariance elements to use for uncertainty indication around the kalmanvec items. 'auto' uses the latent covariance when plotting latent states, and total covariance when plotting expectations of observed states. Use NA to skip uncertainty plotting.
errormultiply	Numeric denoting the multiplication factor of the std deviation of errorvec objects. Defaults to 1.96, for 95% intervals.

ltyvec	vector of line types, varying over dimensions of the kalmanvec object.
colvec	color vector, varying either over subject if multiple subjects, or otherwise over the dimensions of the kalmanvec object.
lwdvec	vector of line widths, varying over the kalmanvec objects.
subsetindices	Either NULL, or vector of integers to use for subsetting the (columns) of kalmanvec objects.
pchvec	vector of symbol types, varying over the dimensions of the kalmanvec object.
typevec	vector of plot types, varying over the kalmanvec objects. 'auto' plots lines for any 'prior', 'upd', or 'smooth' objects, and points otherwise.
grid	Logical. Plot a grid?
add	Logical. Create a new plot or update existing plot?
plotcontrol	List of graphical arguments (see par), though lty,col,lwd,x,y, will all be ignored.
polygoncontrol	List of arguments to the ctPoly function for filling the uncertainty region.
polygonalpha	Numeric for the opacity of the uncertainty region.
legend	Logical, whether to include a legend if plotting.
legendcontrol	List of arguments to the legend function.

Value

Nothing. Generates plots.

Examples

```
### Get output from ctKalman
x<-ctKalman(ctstantestfit,subjects=2)

### Plot with ctKalmanPlot
ctKalmanPlot(x, subjects=2)

###Single step procedure:
ctKalman(ctstantestfit,subjects=2,plot=TRUE)
```

ctLongToWide	<i>ctLongToWide Restructures time series / panel data from long format to wide format for ctsem analysis</i>
--------------	--

Description

ctLongToWide Restructures time series / panel data from long format to wide format for ctsem analysis

Usage

```
ctLongToWide(datalong, id, time, manifestNames, TDpredNames = NULL,
             TIpredNames = NULL)
```


Arguments

<code>datalong</code>	dataset in long format, including subject/id column, observation time (or change in observation time, with 0 for first observation) column, indicator (manifest / observed) variables, any time dependent predictors, and any time independent predictors.
<code>id</code>	character string giving column name of the subject/id column
<code>time</code>	character string giving column name of the time column
<code>manifestNames</code>	vector of character strings giving column names of manifest indicator variables
<code>TDpredNames</code>	vector of character strings giving column names of time dependent predictor variables
<code>TIpredNames</code>	vector of character strings giving column names of time independent predictor variables

Details

Time column must be numeric

See Also

[ctIntervalise](#)

Examples

```
#First load the long format data with absolute times
data('longexample')

#Then convert to wide format
wideexample <- ctLongToWide(datalong = longexample, id = "id",
  time = "time", manifestNames = c("Y1", "Y2", "Y3"),
  TDpredNames = "TD1", TIpredNames = c("TI1", "TI2"))

#Then convert the absolute times to intervals, using the Tpoints reported from the prior step.
wide <- ctIntervalise(datawide = wideexample, Tpoints = 4, n.manifest = 3,
  n.TDpred = 1, n.TIpred = 2, manifestNames = c("Y1", "Y2", "Y3"),
  TDpredNames = "TD1", TIpredNames = c("TI1", "TI2") )
```

`ctModel`

Define a ctsem model

Description

This function is used to specify a continuous time structural equation model, which can then be fit to data with function `ctFit`, or `ctStanFit` for Bayesian models.

Usage

```
ctModel(n.manifest, n.latent, LAMBDA, type = "omx", Tpoints = NULL,
  manifestNames = "auto", latentNames = "auto", T0VAR = "auto",
  T0MEANS = "auto", MANIFESTMEANS = "auto", MANIFESTVAR = "auto",
  DRIFT = "auto", CINT = "auto", DIFFUSION = "auto", n.TDpred = 0,
  TDpredNames = "auto", n.TIpred = 0, TIpredNames = "auto",
  TRAITVAR = NULL, T0TRAIT EFFECT = NULL, MANIFESTTRAITVAR = NULL,
  TDPREDMEANS = "auto", TDPREDEFFECT = "auto", T0TDPREDCOV = "auto",
  TDPREDVAR = "auto", TRAITTDPREDCOV = "auto", TDTIPREDCOV = "auto",
  TIPREDMEANS = "auto", TIPREDEFFECT = "auto",
  T0TIPREDEFFECT = "auto", TIPREDVAR = "auto", PARS = NULL,
  startValues = NULL, timeVarying = NULL)
```

Arguments

n.manifest	Number of manifest indicators per individual at each measurement occasion / time point. Manifest variables are included as the first element of the wide data matrix, with all the 1:n.manifest manifest variables at time 1 followed by those of time 2, and so on.
n.latent	Number of latent processes.
LAMBDA	n.manifest*n.latent loading matrix relating latent to manifest variables, with latent processes 1:n.latent along the columns, and manifest variables 1:n.manifest in the rows.
type	character string. If 'omx' (default) configures model for maximum likelihood fitting with ctFit, using OpenMx. If 'stanc' or 'standt' configures either continuous ('stanc') or discrete ('standt') time model for Bayesian fitting with ctStanFit , using Stan.
Tpoints	For type='omx' only. Number of time points, or measurement occasions, in the data. This will generally be the maximum number of time points for a single individual, but may be one extra if sample relative time intervals are used, see ctIntervalise .
manifestNames	n.manifest length vector of manifest variable names as they appear in the data structure, without any _Tx time point suffix that may be present in wide data. Defaults to Y1, Y2, etc.
latentNames	n.latent length vector of latent variable names (used for naming parameters, defaults to eta1, eta2, etc).
T0VAR	lower triangular n.latent*n.latent cholesky matrix of latent process initial variance / covariance. "auto" freely estimates all parameters.
T0MEANS	n.latent*1 matrix of latent process means at first time point, T0. "auto" freely estimates all parameters.
MANIFESTMEANS	n.manifest*1 matrix of manifest intercept parameters. "auto" frees all parameters.
MANIFESTVAR	lower triangular n.manifest*n.manifest cholesky matrix of variance / covariance between manifests at each measurement occasion (i.e. measurement error / residual). "auto" freely estimates variance parameters, and fixes covariances between manifests to 0. "free" frees all values, including covariances.

DRIFT	n.latent*n.latent DRIFT matrix of continuous auto and cross effects, relating the processes over time. "auto" freely estimates all parameters.
CINT	n.latent * 1 matrix of latent process intercepts, allowing for non 0 asymptotic levels of the latent processes. Generally only necessary for additional trends and more complex dynamics. "auto" fixes all parameters to 0.
DIFFUSION	lower triangular n.latent*n.latent cholesky matrix of diffusion process variance and covariance (latent error / dynamic innovation). "auto" freely estimates all parameters.
n.TDpred	Number of time dependent predictor variables in the dataset.
TDpredNames	n.TDpred length vector of time dependent predictor variable names, as they appear in the data structure, without any _Tx time point suffix that may appear in wide data. Default names are TD1, TD2, etc.
n.TIpred	Number of time independent predictors. Each TIpredictor is inserted at the right of the data matrix, after the time intervals.
TIpredNames	n.TIpred length vector of time independent predictor variable names, as they appear in the data structure. Default names are TI1, TI2, etc.
TRAITVAR	For type='omx' only. Either NULL, if no trait / unobserved heterogeneity effect, or lower triangular n.latent*n.latent cholesky matrix of trait variance / covariance across subjects. "auto" freely estimates all parameters.
T0TRAITEFFECT	For type='omx' only. Either NULL, if no trait / individual heterogeneity effect, or lower triangular n.latent*n.latent cholesky matrix of initial trait variance / covariance. "auto" freely estimates all parameters, if the TRAITVAR matrix is specified.
MANIFESTTRAITVAR	For type='omx' only. Either NULL (default) if no trait variance / individual heterogeneity in the level of the manifest indicators, otherwise a lower triangular n.manifest * n.manifest variance / covariance matrix. Set to "auto" to include and free all parameters - but identification problems will arise if TRAITVAR is also set.
TDPREDMEANS	For type='omx' only. (n.TDpred * (Tpoints - 1)) rows * 1 column matrix of time dependent predictor means. If 'auto', the means are freely estimated. Otherwise, the means for the Tpoints observations of your first time dependent predictor are followed by those of TDpred 2, and so on.
TDPREDEFFECT	n.latent*n.TDpred matrix of effects from time dependent predictors to latent processes. Effects from 1:n.TDpred columns TDpredictors go to 1:n.latent rows of latent processes. "auto" freely estimates all parameters.
T0TDPREDCOV	For type='omx' only. n.latent rows * (Tpoints * n.TDpred) columns covariance matrix between latents at T0 and time dependent predictors. Default of "auto" restricts covariance to 0, which is consistent with covariance to other time points. To freely estimate parameters, specify either 'free', or the desired matrix.
TDPREDVAR	For type='omx' only. lower triangular (n.TDpred * Tpoints) rows * (n.TDpred * Tpoints) columns variance / covariance cholesky matrix for time dependent predictors. "auto" (default) freely estimates all parameters.

TRAITTPREDCOV	For type='omx' only. $n.\text{latent}$ rows * $(n.\text{TDpred} * \text{Tpoints})$ columns covariance matrix of latent traits and time dependent predictors. Defaults to zeroes, assuming predictors are independent of subjects baseline levels. When predictors depend on the subjects, this should instead be set to 'free' or manually specified. The Tpoints columns of the first predictor are followed by those of the second and so on. Covariances with the trait variance of latent process 1 are specified in row 1, process 2 in row 2, etc. "auto" (default) sets this matrix to zeroes, (if both traits and time dependent predictors exist, otherwise this matrix is set to NULL, and ignored in any case).
TDTIPREDCOV	For type='omx' only. $(n.\text{TDpred} * \text{Tpoints})$ rows * $n.\text{TIpred}$ columns covariance matrix between time dependent and time independent predictors. "auto" (default) freely estimates all parameters.
TIPREDMEANS	For type='omx' only. $n.\text{TIpred} * 1$ matrix of time independent predictor means. If 'auto', the means are freely estimated.
TIPREDEFFECT	For type='omx' only. $n.\text{latent} * n.\text{TIpred}$ effect matrix of time independent predictors on latent processes. "auto" freely estimates all parameters and generates starting values. TIPREDEFFECT parameters for type='stan' are estimated by default on all subject level parameters, to restrict this, manually edit the model object after creation.
T0TIPREDEFFECT	For type='omx' only. $n.\text{latent} * n.\text{TIpred}$ effect matrix of time independent predictors on latents at T0. "auto" freely estimates all parameters, though note that under the default setting of stationary for ctFit, this matrix is ignored as the effects are determined based on the overall process parameters.
TIPREDVAR	For type='omx' only. lower triangular $n.\text{TIpred} * n.\text{TIpred}$ Cholesky decomposed covariance matrix for all time independent predictors. "auto" (default) freely estimates all parameters.
PARS	for types 'stanc' and 'standt' only. May be of any structure, only needed to contain extra parameters for certain non-linear models.
startValues	For type='omx' only. A named vector, where the names of each value must match a parameter in the specified model, and the value sets the starting value for that parameter during optimization. If not set, random starting values representing relatively stable processes with small effects and covariances are generated by ctFit. Better starting values may improve model fit speed and the chance of an appropriate model fit.
timeVarying	For type='omx' only. character vector of matrices to allow to vary over measurement occasions. Currently only accepts 'MANIFESTMEANS'.

Examples

```
### Frequentist example:
### impulse and level change time dependent predictor
### example from Driver, Oud, Voelkle (2015)
data('ctExample2')
tdpredmodel <- ctModel(n.manifest = 2, n.latent = 3, n.TDpred = 1,
  Tpoints = 8, manifestNames = c('LeisureTime', 'Happiness'),
  TDpredNames = 'MoneyInt',
  latentNames = c('LeisureTime', 'Happiness', 'MoneyIntLatent'),
```

```

LAMBDA = matrix(c(1,0, 0,1, 0,0), ncol = 3), TRAITVAR = "auto")

tdpredmodel$TRAITVAR[3, ] <- 0
tdpredmodel$TRAITVAR[, 3] <- 0
tdpredmodel$DIFFUSION[, 3] <- 0
tdpredmodel$DIFFUSION[3, ] <- 0
tdpredmodel$T0VAR[3, ] <- 0
tdpredmodel$T0VAR[, 3] <- 0
tdpredmodel$CINT[3] <- 0
tdpredmodel$T0MEANS[3] <- 0
tdpredmodel$TDPREDEFFECT[3, ] <- 1
tdpredmodel$DRIFT[3, ] <- 0

###Bayesian example:
model<-ctModel(type='stanct',
n.latent=2, latentNames=c('eta1','eta2'),
n.manifest=2, manifestNames=c('Y1','Y2'),
n.TDpred=1, TDpredNames='TD1',
n.TIpred=3, TIpredNames=c('TI1','TI2','TI3'),
LAMBDA=diag(2))

```

ctModelFromFit	<i>Extract a ctsem model structure with parameter values from a ctsem fit object.</i>
----------------	---

Description

Extract a ctsem model structure with parameter values from a ctsem fit object.

Usage

```
ctModelFromFit(fit)
```

Arguments

`fit` object output by `ctFit`

Value

object of class 'ctsemInit' (as generated by `ctModel`), which can be used with `ctFit` and `Kalman` functions.

Examples

```

data(AnomAuth)
AnomAuthmodel <- ctModel(LAMBDA = matrix(c(1, 0, 0, 1), nrow = 2, ncol = 2),
  Tpoints = 5, n.latent = 2, n.manifest = 2, MANIFESTVAR=diag(0, 2))
AnomAuthfit <- ctFit(AnomAuth, AnomAuthmodel)

fitmodel <- ctModelFromFit(AnomAuthfit)

```

ctMultigroupFit *Fits a multiple group continuous time model.*

Description

Fits a single continuous time structural equation models to multiple groups (where each group contains 1 or more subjects), by default, all parameters are free across groups. Can also be used to easily estimate separate models for each group.

Usage

```

ctMultigroupFit(dat, groupings, ctmodelobj, dataform = "wide",
  fixedmodel = NA, freemodel = NA, carefulFit = TRUE,
  omxStartValues = NULL, retryattempts = 15, showInits = FALSE, ...)

```

Arguments

dat	Wide format data, as used in <code>ctFit</code> . See <code>ctLongToWide</code> to easily convert long format data.
groupings	For wide format: Vector of character labels designating group membership for each row of dat. For long format: Named list of groups, with each list element containing a vector of subject id's for the group. In both cases, group names will be prefixed on relevant parameter estimates in the summary.
ctmodelobj	Continuous time model to fit, specified via <code>ctModel</code> function.
dataform	either "wide" or "long" depending on which input format you wish to use for the data. See details of <code>ctFit</code> and or vignette.
fixedmodel	Modified version of ctmodelobj, wherein any parameters you wish to keep fixed over groups should be given the value 'groupfixed'. If specified, all other parameters will be free across groups.
freetmodel	Modified version of ctmodelobj, wherein any parameters you wish to free across groups should be given the label 'groupfree'. If specified, all other parameters will be fixed across groups. If left NULL, the default, all parameters are free across groups.
carefulFit	if TRUE, first fits the specified model with a penalised likelihood function to discourage parameters from boundary conditions, then fits the specified model normally, using these estimates as starting values. Can help / speed optimization, though results in user specified inits being ignored for the final fit.

omxStartValues	A named vector containing the raw (potentially log transformed) OpenMx starting values for free parameters, as captured by OpenMx function <code>omxGetParameters(ctmodelobj\$mxobj)</code> . These values will take precedence over any starting values already specified using <code>ctModel</code> .
retryattempts	Number of fit retries to make.
showInits	Displays start values prior to optimization
...	additional arguments to pass to <code>ctFit</code> .

Details

Additional `ctFit` parameters may be specified as required. Confidence intervals for any matrices and or parameters may be estimated after fitting using `ctCI`.

Value

Returns an OpenMx fit object.

See Also

[ctFit](#) and [ctModel](#)

Examples

```
## Not run:

#Two group model, all parameters except LAMBDA[3,1] constrained across groups.
data(ctExample4)
basemodel<-ctModel(n.latent=1, n.manifest=3, Tpoints=20,
  LAMBDA=matrix(c(1, 'lambda2', 'lambda3'), nrow=3, ncol=1),
  MANIFESTMEANS=matrix(c(0, 'manifestmean2', 'manifestmean3'),
  nrow=3, ncol=1), TRAITVAR = 'auto')

freemodel<-basemodel
freemodel$LAMBDA[3,1]<-'groupfree'
groups<-paste0('g',rep(1:2, each=10),'_')

multif<-ctMultigroupFit(dat=ctExample4, groupings=groups,
  ctmodelobj=basemodel, freemodel=freemodel)
summary(multif,group=1)

#fixed model approach
fixedmodel<-basemodel
fixedmodel$LAMBDA[2,1]<-'groupfixed'
groups<-paste0('g',rep(1:2, each=10),'_')

multif<-ctMultigroupFit(dat=ctExample4, groupings=groups,
  ctmodelobj=basemodel, fixedmodel=fixedmodel)
summary(multif)
```

```
## End(Not run)
```

 ctPlot

ctPlot

Description

Plots mean trajectories, autoregression, and crossregression plots, for ctsemFit objects. More customizable than basic plot.ctsemFit function.

Usage

```
ctPlot(x, plotType, xlim, resolution = 50, impulseIndex = NULL,
       subject = 1, typeVector = "auto", colVector = "auto",
       ltyVector = "auto", ...)
```

Arguments

x	ctsemFit object as generated by <code>ctFit</code> .
plotType	string. "mean" for expectation independent of any data, "AR" for autoregressions, "CR" for cross regressions, "standardiseCR" for standardised cross regressions (standardised based on estimated within subject variance), "within-Var" for within variance and covariance, "randomImpulse" for expected change in processes given a random fluctuation of +1 for each process (so a mixture of DIFFUSION and DRIFT characteristics), "experimentalImpulse" for expected change in processes given an exogenous input of +1 for each process, provides alternate characterisation of autoregressive and cross regressive plots.
xlim	vector. As per usual for plot(), but xlim may not be negative.
resolution	Numeric. Plot points between each unit of time. Default of 'auto' adapts to xlim and results in 500 points in total.
impulseIndex	Numeric. Only required for impulse plot types, specifies which column of the DRIFT matrix the impulse relates to.
subject	numeric. Specifies the subject (row of data from the mxobj) to plot for factorScores type plot.
typeVector	Vector of plot types to use for plotting.
colVector	vector of colours to use for plotting.
ltyVector	Vector of line types to use for plotting.
...	Other options passed to plot(). ylim is required.

Value

Character vector of labels from the DRIFT matrix in order plotted - useful for legends. Side-effect: plots graphs.

Examples

```
## Examples set to 'dontrun' because they take longer than 5s.

### example from Driver, Oud, Voelkle (2016),
### simulated happiness and leisure time with unobserved heterogeneity.
## Not run:
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(dat=ctExample1, ctmodelobj=traitmodel)
ctPlot(traitfit, plotType='CR', xlim=c(0,5),ylim=c(-1,1))

## End(Not run)
```

ctPlotArray

Plots three dimensional y values for quantile plots

Description

1st margin of \$Y sets line values, 2nd sets variables, 3rd quantiles.

Usage

```
ctPlotArray(input, grid = FALSE, add = FALSE, colvec = "auto",
  lwdvec = "auto", ltyvec = "auto", typevec = "auto",
  plotcontrol = list(ylab = "Array values", xaxs = "i"), legend = TRUE,
  legendcontrol = list(), polygon = TRUE, polygonalpha = 0.1,
  polygoncontrol = list(steps = 25))
```

Arguments

input	list containing 3 dimensional array to use for Y values, \$y and vector of corresponding x values \$x.
grid	Logical. Plot with a grid?
add	Logical. If TRUE, plotting is overlaid on current plot, without creating new plot.
colvec	color vector of same length as 2nd margin.
lwdvec	lwd vector of same length as 2nd margin.
ltyvec	lty vector of same length as 2nd margin.
typevec	type vector of same length as 2nd margin.
plotcontrol	list of arguments to pass to plot.
legend	Logical. Draw a legend?
legendcontrol	list of arguments to pass to legend .
polygon	Logical. Draw the uncertainty polygon?
polygonalpha	Numeric, multiplier for alpha (transparency) of the uncertainty polygon.
polygoncontrol	list of arguments to pass to ctPoly

Value

Nothing. Generates plots.

Examples

```
## Not run:
input<-ctStanTIPreEffects(ctstantestfit, plot=FALSE, whichpars='CINT',
  nsamples=10, nsubjects=10)

ctPlotArray(input=input)

## End(Not run)
```

 ctPoly

Plots uncertainty bands with shading

Description

Plots uncertainty bands with shading

Usage

```
ctPoly(x, y, ylow, yhigh, steps = 20, ...)
```

Arguments

x	x values
y	y values
ylow	lower limits of y
yhigh	upper limits of y
steps	number of polygons to overlay - higher integers lead to smoother changes in transparency between y and yhigh / ylow.
...	arguments to pass to polygon()

Value

Nothing. Adds a polygon to existing plot.

Examples

```
plot(0:100, sqrt(0:100), type='l')
ctPoly(x=0:100, y=sqrt(0:100),
  yhigh=sqrt(0:100) - runif(101),
  ylow=sqrt(0:100) + runif(101),
  col=adjustcolor('red', alpha.f=.1))
```

ctPostPredict	<i>Posterior predictive type check for ctsemFit.</i>
---------------	--

Description

Samples data according to the ctsemFit object, computes quantiles over time based on model fit, plots these against original data.

Usage

```
ctPostPredict(fit, timestep = 0.1, n.subjects = 100, probs = c(0.025,
  0.5, 0.975), plot = TRUE, ctPlotArrayArgs = list(grid = FALSE, legend
  = FALSE), indPlotArgs = list(colourby = "subject", lwd = 2, new =
  FALSE, type = "p", opacity = 0.3), mfrow = "auto")
```

Arguments

fit	object of class ctsemFit as returned from ctFit
timestep	positive value denoting the time interval to use for sampling.
n.subjects	Number of subjects worth of data to sample.
probs	Vector of values between 0 and 1 denoting quantiles to generate. For plotting, vector should be of length 3 and values should be rising.
plot	Whether to plot or return the generated data.
ctPlotArrayArgs	additional arguments to pass to ctPlotArray function, for plotting generated distributions.
indPlotArgs	list of parameters to pass to ctIndplot, for plotting original data. Only used if plot=TRUE.
mfrow	2 dimensional integer vector defining number of rows and columns of plots, as per the mfrow argument to par . 'auto' determines automatically, to a maximum of 4 by 4, while NULL uses the current system setting.

Value

Either nothing (if plot=TRUE) or an array containing generated data over quantiles.

Examples

```
data("AnomAuth")
AnomAuthmodel <- ctModel(LAMBDA = matrix(c(1, 0, 0, 1), nrow = 2, ncol = 2),
  Tpoints = 5, n.latent = 2, n.manifest = 2, MANIFESTVAR=diag(0, 2), TRAITVAR = 'auto')
AnomAuthFit <- ctFit(AnomAuth, AnomAuthmodel)
ctPostPredict(AnomAuthFit, timestep=.5, n.subjects=100)
```

ctRefineTo	<i>ctRefineTo</i>
------------	-------------------

Description

Fits a ctsem *m* in a stepwise fashion to help with difficult optimization.

Usage

```
ctRefineTo(datawide, ctmodelobj, modfunc = NULL, ...)
```

Arguments

<code>datawide</code>	Data in ctsem wide format
<code>ctmodelobj</code>	A continuous time <i>m</i> specified via the <code>ctModel</code> function.
<code>modfunc</code>	function to run prior to each optimization step, that takes ctsem fit object, modifies it as desired, and returns the fit object.
<code>...</code>	additional parameters to pass to <code>ctFit</code> .

Details

This function fits a sequence of ctsem models increasing in complexity, starting with a *m* involving fixed and relatively strong auto effects, no cross effects, no predictors, and no off-diagonal covariances. For many models this can improve the speed and robustness of fitting

Value

Returns a fitted ctsem object in the same manner as `ctFit`.

ctsem	<i>ctsem</i>
-------	--------------

Description

ctsem is an R package for continuous time structural equation modelling of panel ($N > 1$) and time series ($N = 1$) data, using either a frequentist or Bayesian approach. The frequentist approach is faster but can only estimate random-effects on the intercepts, while the Bayesian approach allows for random-effects across all model parameters.

Details

The general workflow begins by specifying a model using the `ctModel` function, in which the type of model is also specified. Then the model is fit to data using either `ctFit` if an 'omx' (OpenMx, frequentist) model is specified or `ctStanFit` if a 'stanct' or 'standt' (Stan, continuous / discrete time, Bayesian) model is specified. For examples, see either `ctFit` or `ctStanFit`. For more detailed information, see the frequentist vignette by running: `vignette('ctsem')` For citation info, please run `citation('ctsem')`.

References

- <https://www.jstatsoft.org/article/view/v077i05>
- Driver, C. C., & Voelkle, M. C. (2018). Hierarchical Bayesian continuous time dynamic modeling. *Psychological Methods*. Advance online publication. <http://dx.doi.org/10.1037/met0000168>
- Stan Development Team (2018). RStan: the R interface to Stan. R package version 2.17.3. <http://mc-stan.org>

ctStanContinuousPars *ctStanContinuousPars*

Description

Returns the continuous time parameter matrices for specified subjects of a ctStanFit fit object

Usage

```
ctStanContinuousPars(ctstanfitobj, subjects = "all", iter = "all",
  calcfunc = quantile, calcfuncargs = list(probs = 0.5))
```

Arguments

ctstanfitobj	fit object from ctStanFit
subjects	Either 'all', or integers denoting which subjects to perform the calculation over. When multiple subjects are specified, the returned matrices will be a mean over subjects.
iter	Either character string 'all' which will then use all post-warmup iterations, or an integer specifying which iteration/s to use.
calcfunc	Function to apply over samples, must return a single value. By default the median over all samples is returned using the quantile function, but one might also be interested in the mean or sd , for instance.
calcfuncargs	A list of additional parameters to pass to calcfunc. For instance, with the default of calcfunc = quantile, the probs argument is needed to ensure only a single value is returned.

Examples

```
## Not run:
#posterior median over all subjects (also reflects mean of unconstrained pars)
ctStanContinuousPars(ctstantestfit)

#posterior 97.5% quantiles for subject 2
ctStanContinuousPars(ctstantestfit, subjects=2, calcfunc=quantile,
  calcfuncargs=list(probs=0.975))

## End(Not run)
```

ctStanDiscretePars *ctStanDiscretePars*

Description

Calculate model implied regressions for a sequence of time intervals based on a continuous time model fit from ctStanFit, for specified subjects.

Usage

```
ctStanDiscretePars(ctstanfitobj, subjects = "all", times = seq(from =
  0, to = 10, by = 0.1), quantiles = c(0.025, 0.5, 0.975),
  nsamples = 500, observational = FALSE, standardise = FALSE,
  plot = FALSE, ...)
```

Arguments

ctstanfitobj	Continuous time model fit from ctStanFit
subjects	Either 'all', to take the average over all subjects, or a vector of integers denoting which subjects.
times	Numeric vector of positive values, discrete time parameters will be calculated for each.
quantiles	Which quantiles to return. If plotting, specify 3 quantiles, the 2nd will be plotted as a line with 1 and 3 as uncertainty bounds.
nsamples	Number of samples from the stanfit to use for plotting. Higher values will increase smoothness / accuracy, at cost of plotting speed. Values greater than the total number of samples will be set to total samples.
observational	Logical. If TRUE, outputs expected change in processes *conditional on observing* a 1 unit change in each – this change is correlated according to the DIFFUSION matrix. If FALSE, outputs expected regression values – also interpretable as an independent 1 unit change on each process, giving the expected response under a 1 unit experimental impulse.
standardise	Logical. If TRUE, output is standardised according to expected total within subject variance, given by the asymDIFFUSION matrix.
plot	Logical. If TRUE, plots output using ctStanDiscreteParsPlot instead of returning output.
...	additional plotting arguments to control ctStanDiscreteParsPlot

Examples

```
ctStanDiscretePars(ctstantestfit, times=seq(.5, 4, .1),
  plot=TRUE, indices='all')
```

 ctStanDiscreteParsPlot

ctStanDiscreteParsPlot

Description

Plots model implied regression strengths at specified times for continuous time models fit with ctStanFit.

Usage

```
ctStanDiscreteParsPlot(x, indices = "all", add = FALSE,
  legend = TRUE, polygon = TRUE, quantiles = c(0.025, 0.5, 0.975),
  times = seq(0, 10, 0.1), latentNames = "auto", lwdvec = "auto",
  colvec = "auto", ltyvec = "auto", plotcontrol = list(ylab =
  "Value", xlab = "Time interval", main = "Regression coefficients", type =
  "l", xaxs = "i"), grid = FALSE, legendcontrol = list(x = "topright",
  bg = "white"), polygonalpha = 0.1, polygoncontrol = list(steps = 20))
```

Arguments

x	list object returned from ctStanDiscretePars .
indices	Either a string specifying type of plot to create, or an n by 2 matrix specifying which indices of the output matrix to plot. 'AR' specifies all diagonals, for discrete time autoregression parameters. 'CR' specifies all off-diagonals, for discrete time cross regression parameters. 'all' plots all AR and CR effects at once.
add	Logical. If FALSE, a new plot is generated, if TRUE, specified plot/s are overlaid on existing plot.
legend	Logical. If TRUE, generates a legend.
polygon	Logical. If TRUE, fills a polygon between the first and last specified quantiles.
quantiles	numeric vector of length 3, with values between 0 and 1, specifying which quantiles to plot. The default of c(.05,.5,.95) plots 95% credible intervals and the posterior median at 50%.
times	Numeric vector of positive values, discrete time parameters will be calculated for each.
latentNames	Vector of character strings denoting names for the latent variables. 'auto' just uses eta1 eta2 etc.
lwdvec	Either 'auto', or a vector of positive integers denoting line widths for each quantile. 'auto' specifies c(1,3,1) if there are 3 quantiles to be plotted (default), otherwise simply 3.
colvec	Either 'auto', or a vector of color values denoting colors for each index to be plotted. 'auto' generates colors using the <code>grDevices::rainbow</code> function.

ltyvec	Either 'auto', or a vector of line type integers (as for the lty parameter normally) denoting line types for each quantile. 'auto' specifies c(3, 1, 3) if there are 3 quantiles to be plotted (default), otherwise simply 1.
plotcontrol	list of arguments to pass to plot function. The following arguments are ignored: ylim,lwd,lty,col,x,y.
grid	Logical. Plot with a grid?
legendcontrol	list of arguments to pass to legend function. 'legend=' and 'text.col=' arguments will be ignored.
polygonalpha	Numeric between 0 and 1 to multiply the alpha (transparency) of colvec by for the fill polygon.
polygoncontrol	list of arguments to pass to ctPoly function (if polygon=TRUE). x,y, and col arguments will be ignored. Steps specifies the number of polygons to overlay to create a graduated transparency. Set to 1 for a flat looking plot.

Examples

```
x <- ctStanDiscretePars(ctstantestfit)
ctStanDiscreteParsPlot(x, 'CR')
```

ctStanFit

ctStanFit

Description

Fits a ctsem model specified via `ctModel` with type either 'stanct' or 'standt', using Bayesian inference software Stan.

Usage

```
ctStanFit(datalong, ctstanmodel, stanmodeltext = NA, iter = 1000,
  intoverstates = TRUE, binomial = FALSE, fit = TRUE,
  intoverpop = FALSE, stationary = FALSE, plot = FALSE,
  derrind = "all", optimize = FALSE, optimcontrol = list(),
  nlcontrol = list(), nopriors = FALSE, chains = 1,
  cores = "maxneeded", inits = NULL, forcerecompile = FALSE,
  savescores = TRUE, gendata = FALSE, control = list(),
  verbose = 0, ...)
```

Arguments

datalong	long format data containing columns for subject id (numeric values, 1 to max subjects), manifest variables, any time dependent (i.e. varying within subject) predictors, and any time independent (not varying within subject) predictors.
ctstanmodel	model object as generated by <code>ctModel</code> with type='stanct' or 'standt', for continuous or discrete time models respectively.

stanmodeltext	already specified Stan model character string, generally leave NA unless modifying Stan model directly. (Possible after modification of output from fit=FALSE)
iter	number of iterations, half of which will be devoted to warmup by default when sampling. When optimizing, this is the maximum number of iterations to allow – convergence hopefully occurs before this!
intoverstates	logical indicating whether or not to integrate over latent states using a Kalman filter. Generally recommended to set TRUE unless using non-gaussian measurement model.
binomial	Deprecated. Logical indicating the use of binary rather than Gaussian data, as with IRT analyses. This now sets intoverstates = FALSE and the manifesttype of every indicator to 1, for binary.
fit	If TRUE, fit specified model using Stan, if FALSE, return stan model object without fitting.
intoverpop	if TRUE, integrates over population distribution of parameters rather than full sampling. Allows for optimization of non-linearities and random effects.
stationary	Logical. If TRUE, TOVAR and TOMEANS input matrices are ignored, the parameters are instead fixed to long run expectations. More control over this can be achieved by instead setting parameter names of TOMEANS and TOVAR matrices in the input model to 'stationary', for elements that should be fixed to stationarity.
plot	if TRUE, a Shiny program is launched upon fitting to interactively plot samples. May struggle with many (e.g., > 5000) parameters, and may leave sample files in working directory if sampling is terminated.
derrind	vector of integers denoting which latent variables are involved in dynamic error calculations. latents involved only in deterministic trends or input effects can be removed from matrices (ie, that obtain no additional stochastic inputs after first observation), speeding up calculations. If unsure, leave default of 'all' ! Ignored if intoverstates=FALSE.
optimize	if TRUE, use <code>optimstan</code> function for maximum a posteriori estimates.
optimcontrol	list of parameters sent to <code>optimstan</code> governing optimization / importance sampling.
nlcontrol	List of non-linear control parameters. <code>nldynamics</code> defaults to "auto", but may also be a logical. Set to FALSE to use estimator that assumes linear dynamics, TRUE to use non-linear estimator. "auto" selects linear when the model is obviously linear, otherwise nonlinear – nonlinear is slower. <code>nlmeasurement</code> defaults to "auto", but may also be a logical. Set to TRUE to use non linear measurement model estimator, FALSE to use linear model. "auto" selects linear if appropriate, otherwise nonlinear. Non-linear methods are slower but applicable to both linear and non linear cases. <code>ukffull</code> may be TRUE or FALSE. If FALSE, non-linear filtering via the unscented filter uses a minimal number of sigma points, that does not capture skew in the resulting distribution. <code>maxtimestep</code> must be a positive numeric, specifying the largest time span covered by the numerical integration. The large default ensures that for each observation time interval, only a single step of exponential integration is used. When <code>maxtimestep</code> is smaller than the observation time interval, the integration is nested within an

Euler like loop. Smaller values may offer greater accuracy, but are slower and not always necessary. Given the exponential integration, linear model elements are fit exactly with only a single step. ukfspread should be a small positive numeric value, indicating what fraction of a standard deviation to use for unscented sigma points. Values between 1e-4 and 2 have tended to be reasonable, in our experience. In general, larger values may not make sense when using the default of ukffull=FALSE.

nopriors	logical. If TRUE, any priors are disabled – sometimes desirable for optimization.
chains	number of chains to sample, during HMC or post-optimization importance sampling.
cores	number of cpu cores to use. Either 'maxneeded' to use as many as available, up to the number of chains, or a positive integer.
inits	vector of parameter start values, as returned by the rstan function <code>rstan::unconstrain_pars</code> for instance.
forcerecompile	logical. For development purposes. If TRUE, stan model is recompiled, regardless of apparent need for compilation.
savescores	Logical. If TRUE, output from the Kalman filter is saved in output. For datasets with many variables or time points, will increase file size substantially.
gendata	Logical – If TRUE, uses provided data as a time and missingness structure only, and generates random data according to the specified model / priors. Generated data is in the \$Ygen subobject after running <code>extract</code> on the fit object. For datasets with many manifest variables or time points, file size may be large. To generate data based on the posterior of a fitted model, see ctStanGenerateData .
control	List of arguments sent to <code>stan</code> control argument, regarding warmup / sampling behaviour. Unless specified, values used are: <code>list(adapt_delta = .8, adapt_window=2, max_treedepth=10, adapt_init_buffer=2, stepsize = .001)</code>
verbose	Integer from 0 to 2. Higher values print more information during model fit – for debugging.
...	additional arguments to pass to <code>stan</code> function.

Examples

```
## Not run:
#test data with 2 manifest indicators measuring 1 latent process each,
# 1 time dependent predictor, 3 time independent predictors
head(ctstantestdat)

#generate a ctStanModel
model<-ctModel(type='stanct',
n.latent=2, latentNames=c('eta1','eta2'),
n.manifest=2, manifestNames=c('Y1','Y2'),
n.TDpred=1, TDpredNames='TD1',
n.TIpred=3, TIpredNames=c('TI1','TI2','TI3'),
LAMBDA=diag(2))

#set all parameters except manifest means to be fixed across subjects
```

```

model$pars$indvarying[-c(19,20)] <- FALSE

#fit model to data (takes a few minutes - but insufficient
# iterations and max_treedepth for inference!)
fit<-ctStanFit(ctstantestdat, model, iter=200, chains=2,
control=list(max_treedepth=6))

#output functions
summary(fit)

plot(fit)

##### EXTENDED EXAMPLES #####

library(ctsem)
set.seed(3)

#recommended to adjust these to appropriate number of cores on machine /
# chains desired. (min 3 chains recommended, but not necessary here)
setcores <- 3
setchains <- 3

#### Data generation (this section needs to be run, but not necessary to understand!)
Tpoints <- 20
nmanifest <- 4
nlatent <- 2
nsubjects<-20

#random effects
age <- rnorm(nsubjects) #standardised
cint1<-rnorm(nsubjects,2,.3)+age*.5
cint2 <- cint1*.5+rnorm(nsubjects,1,.2)+age*.5
tdpredeffect <- rnorm(nsubjects,5,.3)+age*.5

for(i in 1:nsubjects){
  #generating model
  gm<-ctModel(Tpoints=Tpoints,n.manifest = nmanifest,n.latent = nlatent,n.TDpred = 1,
  LAMBDA = matrix(c(1,0,0,0, 0,1,.8,1.3),nrow=nmanifest,ncol=nlatent),
  DRIFT=matrix(c(-.3, .1, 0, -.5),nlatent,nlatent),
  TDPREDEFFECT=matrix(c(tdpredeffect[i],0),nrow=nlatent),
  TDPREDMEANS=matrix(c(rep(0,Tpoints-10),1,rep(0,9)),ncol=1),
  DIFFUSION = matrix(c(.5, 0, 0, .5),2,2),
  CINT = matrix(c(cint1[i],cint2[i]),ncol=1),
  T0VAR=diag(2,nlatent,nlatent),
  MANIFESTVAR = diag(.5, nmanifest))

  #generate data
  newdat <- ctGenerate(ctmodelobj = gm,n.subjects = 1,burnin = 2,
  dtmat<-rbind(c(rep(.5,8),3,rep(.5,Tpoints-9))),

```

```

    wide = FALSE)
  newdat[, 'id'] <- i #set id for each subject
  newdat <- cbind(newdat, age[i]) #include time independent predictor
  if(i == 1) {
    dat <- newdat[1:(Tpoints-10),] #pre intervention data
    dat2 <- newdat #including post intervention data
  }
  if(i > 1) {
    dat <- rbind(dat, newdat[1:(Tpoints-10),])
    dat2 <- rbind(dat2, newdat)
  }
}
colnames(dat)[ncol(dat)] <- 'age'
colnames(dat2)[ncol(dat)] <- 'age'

#plot generated data for sanity
plot(age)
matplot(dat[, gm$manifestNames], type='l', pch=1)
plotvar <- 'Y1'
plot(dat[dat[, 'id']==1, 'time'], dat[dat[, 'id']==1, plotvar], type='l',
      ylim=range(dat[, plotvar], na.rm=TRUE))
for(i in 2:nsubjects){
  points(dat[dat[, 'id']==i, 'time'], dat[dat[, 'id']==i, plotvar], type='l', col=i)
}

#### Model fitting (from here it is good to understand!)

#Specify univariate linear growth curve
#page 5 of https://cran.r-project.org/web/packages/ctsem/vignettes/hierarchical.pdf
# documents these arguments (or use ?ctModel )

m1 <- ctModel(n.manifest = 1, n.latent = 1, n.TIpred = 1, type = 'stanct',
  manifestNames = c('Y1'), latentNames=c('L1'), TIpredNames = 'age',
  DRIFT=matrix(-1e-5, nrow=1, ncol=1),
  DIFFUSION=matrix(0, nrow=1, ncol=1),
  CINT=matrix(c('cint1'), ncol=1),
  T0MEANS=matrix(c('t0m1'), ncol=1),
  T0VAR=matrix(0, nrow=1, ncol=1),
  LAMBDA = diag(1),
  MANIFESTMEANS=matrix(0, ncol=1),
  MANIFESTVAR=matrix(c('merror1'), nrow=1, ncol=1))

#modify between subject aspects -- alternatively, run: edit(m1$pars)
m1$pars$indvarying[-which(m1$pars$matrix %in% c('T0MEANS', 'CINT'))] <- FALSE
m1$pars$age_effect[-which(m1$pars$matrix %in% c('T0MEANS', 'CINT'))] <- FALSE

plot(m1) #plot prior distributions

```

```

#fit
f1 <- ctStanFit(datalong = dat, ctstanmodel = m1,
  cores = setcores,chains = setchains,plot=TRUE,
  control=list(max_treedepth=7),iter=150)

summary(f1)

#plots of individual subject models v data
ctKalman(f1,timestep=.01,plot=TRUE,subjects=1:4,kalmanvec=c('y','etasmooth'))
ctKalman(f1,timestep=.01,plot=TRUE,subjects=1,kalmanvec=c('y','ysmooth'))

ctStanPlotPost(f1) #compare prior to posterior distributions
ctStanPlotPost(f1, priorwidth = FALSE) #rescale to width of posterior

ctStanPostPredict(f1) #compare randomly generated data from posterior to observed data

cf<-ctCheckFit(f1) #compare covariance of randomly generated data to observed cov
plot(cf)

#accessing the stan object directly
library(rstan)
postsamples <- extract(f1$stanfit,pars='Ygen') #extract data generated from posterior
plot( f1$data$time,
  postsamples$Ygen[1,1, ,1]) #iteration 1 (already shuffled), chain 1, all occasions, var 1.
points(f1$data$time, f1$data$Y[,1],col='red') #1st manifest variable

#Specify model including dynamics
m2 <- ctModel(n.manifest = 1,n.latent = 1,n.TIpred = 1, type = 'stanct',
  manifestNames = c('Y1'), latentNames=c('L1'),TIpredNames = 'age',
  DRIFT=matrix('drift11',nrow=1,ncol=1),
  DIFFUSION=matrix('diffusion11',nrow=1,ncol=1),
  CINT=matrix(c('cint1'),ncol=1),
  T0MEANS=matrix(c('t0m1'),ncol=1),
  T0VAR=matrix('t0var11',nrow=1,ncol=1),
  LAMBDA = diag(1),
  MANIFESTMEANS=matrix(0,ncol=1),
  MANIFESTVAR=matrix(c('merror1'),nrow=1,ncol=1))

m2$pars$indvarying[-which(m2$pars$matrix %in% c('T0MEANS','CINT'))] <- FALSE
m2$pars$age_effect[-which(m2$pars$matrix %in% c('T0MEANS','CINT'))] <- FALSE

f2 <- ctStanFit(datalong = dat, ctstanmodel = m2, cores = setcores,
  chains = setchains,plot=TRUE,
  control=list(max_treedepth=7),iter=150)

summary(f2,parmatrices=TRUE,timeinterval=1)

```

```

ctKalman(f2,timestep=.01,plot=TRUE,subjects=1,kalmanvec=c('y','etaprior'))
ctKalman(f2,timestep=.01,plot=TRUE,subjects=1:4,kalmanvec=c('y','etasmooth'))
ctKalman(f2,timestep=.01,plot=TRUE,subjects=1:2,kalmanvec=c('y','ysmooth'))

ctStanPlotPost(f2)

ctStanPostPredict(f2)

#Include intervention
m3 <- ctModel(n.manifest = 1,n.latent = 1,n.TIpred = 1, type = 'stanct',
  manifestNames = c('Y1'), latentNames=c('L1'),TIpredNames = 'age',
  n.TDpred=1,TDpredNames = 'TD1', #this line includes the intervention
  TDPREDEFFECT=matrix(c('tdpredeffect'),nrow=1,ncol=1), #intervention effect
  DRIFT=matrix('drift11',nrow=1,ncol=1),
  DIFFUSION=matrix('diffusion11',nrow=1,ncol=1),
  CINT=matrix(c('cint1'),ncol=1),
  T0MEANS=matrix(c('t0m1'),ncol=1),
  T0VAR=matrix('t0var11',nrow=1,ncol=1),
  LAMBDA = diag(1),
  MANIFESTMEANS=matrix(0,ncol=1),
  MANIFESTVAR=matrix(c('merror1'),nrow=1,ncol=1))

m3$pars$indvarying[~which(m3$pars$matrix %in%
  c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE

m3$pars$age_effect[~which(m3$pars$matrix %in%
  c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE

f3 <- ctStanFit(datalong = dat2, ctstanmodel = m3, cores = setcores,
  chains = setchains,plot=TRUE,
  control=list(max_treedepth=7),iter=150)

summary(f3,parmatrices=TRUE)

ctKalman(f3,timestep=.01,plot=TRUE,subjects=1,kalmanvec=c('y','etaprior'))
ctKalman(f3,timestep=.01,plot=TRUE,subjects=1:4,kalmanvec=c('y','etasmooth'))
ctKalman(f3,timestep=.01,plot=TRUE,subjects=1:2,kalmanvec=c('y','ysmooth'))

ctStanPlotPost(f3)

ctStanPostPredict(f3, datarows=0:100)

#include 2nd latent process

```

```

#use either full explicit specification
m4 <- ctModel(n.manifest = 2,n.latent = 2,n.TIpred = 1, type = 'stanct', #no of vars updated
  manifestNames = c('Y1','Y2'), latentNames=c('L1','L2'),TIpredNames = 'age',
  n.TDpred=1,TDpredNames = 'TD1',
  TDPREDEFFECT=matrix(c('tdpredeffect1','tdpredeffect2'),nrow=2,ncol=1),
  DRIFT=matrix(c('drift11','drift21','drift12','drift22'),nrow=2,ncol=2),
  DIFFUSION=matrix(c('diffusion11','diffusion21',0,'diffusion22'),nrow=2,ncol=2),
  CINT=matrix(c('cint1','cint2'),nrow=2,ncol=1),
  T0MEANS=matrix(c('t0m1','t0m2'),nrow=2,ncol=1),
  T0VAR=matrix(c('t0var11','t0var21',0,'t0var22'),nrow=2,ncol=2),
  LAMBDA = matrix(c(1,0,0,1),nrow=2,ncol=2),
  MANIFESTMEANS=matrix(c(0,0),nrow=2,ncol=1),
  MANIFESTVAR=matrix(c('merror1',0,0,'merror2'),nrow=2,ncol=2))

#restrict between subjects variation / covariate effects
m4$pars$indvarying[-which(m4$pars$matrix %in% c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE
m4$pars$age_effect[-which(m4$pars$matrix %in% c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE

#or rely on defaults (MANIFESTMEANS now free instead of CINT --
# no substantive difference for one indicator factors)
m4 <- ctModel(n.manifest = 2,n.latent = 2,n.TIpred = 1, type = 'stanct',
  manifestNames = c('Y1','Y2'), latentNames=c('L1','L2'),TIpredNames = 'age',
  n.TDpred=1,TDpredNames = 'TD1',
  LAMBDA = matrix(c(1,0,0,1),nrow=2,ncol=2))

#restrict between subjects variation / covariate effects
m4$pars$indvarying[-which(m4$pars$matrix %in% c('T0MEANS','MANIFESTMEANS','TDPREDEFFECT'))] <- FALSE
m4$pars$age_effect[-which(m4$pars$matrix %in% c('T0MEANS','MANIFESTMEANS','TDPREDEFFECT'))] <- FALSE

f4 <- ctStanFit(datalong = dat2, ctstanmodel = m4, cores = setcores,chains = setchains,plot=TRUE,
  optimize=TRUE,verbose=1,
  control=list(max_treedepth=7),iter=150)

summary(f4,parmatrices=TRUE)

ctStanDiscretePars(f4,plot=TRUE) #auto and cross regressive plots over time

ctKalman(f4,timestep=.01,plot=TRUE,subjects=1,kalmanvec=c('y','etaprior'))
ctKalman(f4,timestep=.01,plot=TRUE,subjects=1:2,kalmanvec=c('y','etasmooth'))
ctKalman(f4,timestep=.01,plot=TRUE,subjects=1:2,kalmanvec=c('y','ysmooth'))

ctStanPlotPost(f4)

ctStanPostPredict(f4,wait=F)

#non-linear dependencies - based on m3 model (including intervention)
#specify intervention as dependent on extra parameter in PARS matrix, and latent process 1

m3nl <- ctModel(n.manifest = 1,n.latent = 1,n.TIpred = 1, type = 'stanct',
  manifestNames = c('Y1'), latentNames=c('L1'),TIpredNames = 'age',
  n.TDpred=1,TDpredNames = 'TD1',

```

```

TDPREDEFFECT=matrix(c('PARS[1,1] * state[1]'),nrow=1,ncol=1),
PARS=matrix(c('tdpredeffect'),1,1),
DRIFT=matrix('drift11',nrow=1,ncol=1),
DIFFUSION=matrix('diffusion11',nrow=1,ncol=1),
CINT=matrix(c('cint1'),ncol=1),
T0MEANS=matrix(c('t0m1'),ncol=1),
T0VAR=matrix('t0var11',nrow=1,ncol=1),
LAMBDA = diag(1),
MANIFESTMEANS=matrix(0,ncol=1),
MANIFESTVAR=matrix(c('merror1'),nrow=1,ncol=1))

m3nl$pars$indvarying[~which(m3nl$pars$matrix %in%
  c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE

m3nl$pars$age_effect[~which(m3nl$pars$matrix %in%
  c('T0MEANS','CINT','TDPREDEFFECT'))] <- FALSE

#here fit using optimization instead of sampling -- not appropriate in all cases!
f3nl <- ctStanFit(datalong = dat2, ctstanmodel = m3nl,
  cores = setcores, chains = setchains,
  optimize=TRUE)

summary(f3nl)

#plot functions need updating for non-linearities! (as of ctsem v 2.7.3)
#extract can be used to extract samples and create own plots.
#last index of kalaman subobject denotes element of Kalman output.
# 1 = ll on std scale, 2= ll scale, 3=error, 4=prediction,
# 5= eta prior, 6= eta upd

ctStanPostPredict(f3nl, datarows=1:100)

e=extract(f3nl)
subindex = which(f3nl$data$subject ==3) #specify subject

matplot(f3nl$data$time[subindex], # Y predictions given earlier Y
  t(e$kalman[,subindex,4]),
  type='l',lty=1,col=rgb(0,0,0,.1))

points(f3nl$data$time[subindex], #actual Y
  f3nl$data$Y[subindex,1],type='p',col='red')

matplot(f3nl$data$time[subindex], add = TRUE, #Generated Y from model
  t(e$Ygen[,subindex,1]),
  type='l',lty=1,col=rgb(0,0,1,.05))

## End(Not run)

```

ctStanGenerateData *Add a \$generated object to ctstanfit object, with random data generated from posterior of ctstanfit object*

Description

Add a \$generated object to ctstanfit object, with random data generated from posterior of ctstanfit object

Usage

```
ctStanGenerateData(fit, nsamples = 1, fullposterior = FALSE)
```

Arguments

fit	ctstanfit object
nsamples	Positive integer specifying number of datasets to generate.
fullposterior	Logical indicating whether to sample from the full posterior (original nsamples) or the posterior mean.

Value

Matrix of generated data – one dataset per iteration, according to original time and missingness structure.

Examples

```
## Not run:
gen <- ctStanGenerateData(ctstantestfit, nsamples=3,fullposterior=TRUE)
plot(gen$generated$Y[,3,2],type='l') #Third random data sample, 2nd manifest var, all time points.

## End(Not run)
```

ctStanKalman

Get Kalman filter estimates from a ctStanFit object

Description

Get Kalman filter estimates from a ctStanFit object

Usage

```
ctStanKalman(fit)
```

Arguments

fit	fit object from ctStanFit .
-----	---

Value

list containing Kalman filter elements, each element in array of iterations, data row, variables. lrow is the log likelihood for each row of data.

Examples

```
ctStanKalman(ctstantestfit)
```

ctStanModel	<i>Convert a frequentist (omx) ctsem model specification to Bayesian (Stan).</i>
-------------	--

Description

Convert a frequentist (omx) ctsem model specification to Bayesian (Stan).

Usage

```
ctStanModel(ctmodelobj, type = "stanct", indvarying = "all")
```

Arguments

ctmodelobj	ctsem model object of type 'omx' (default)
type	either 'stanct' for continuous time, or 'standt' for discrete time.
indvarying	either 'all' or a logical vector of the same length as the number of free parameters in the model. Generally it is much simpler to set 'all' and then restrict this by modifying the output model object afterwards.

Value

List object of class ctStanModel

Examples

```
model <- ctModel(type='omx', Tpoints=50,
  n.latent=2, n.manifest=1,
  manifestNames='sunspots',
  latentNames=c('ss_level', 'ss_velocity'),
  LAMBDA=matrix(c( 1, 'ma1' ), nrow=1, ncol=2),
  DRIFT=matrix(c(0, 1, 'a21', 'a22'), nrow=2, ncol=2, byrow=TRUE),
  MANIFESTMEANS=matrix(c('m1'), nrow=1, ncol=1),
  # MANIFESTVAR=matrix(0, nrow=1, ncol=1),
  CINT=matrix(c(0, 0), nrow=2, ncol=1),
  DIFFUSION=matrix(c(
    0, 0,
    0, "diffusion"), ncol=2, nrow=2, byrow=TRUE))

stanmodel=ctStanModel(model)
```

ctStanParMatrices	<i>Returns population system matrices from a ctStanFit object, and vector of values for free parameters.</i>
-------------------	--

Description

Returns population system matrices from a ctStanFit object, and vector of values for free parameters.

Usage

```
ctStanParMatrices(fit, parvalues, timeinterval = 1, sf = NA)
```

Arguments

fit	ctStanFit object.
parvalues	vector of parameter values to assign to free parameters in the model
timeinterval	time interval to use for discrete time (dt) matrix calculations.
sf	stanfit object. Generally not necessary, but for repeated calls to this function, can speed things up.

Value

A list containing various matrices related to a continuous time dynamic model. Matrices with "dt" in front refers to discrete time, "asym" refers to asymptotic (time interval = infinity), and "cor" refers to correlations.

Examples

```
## Not run:
ctStanParMatrices(ctstantestfit, rnorm(17, 0, .1))

## End(Not run)
```

ctStanParnames	<i>ctStanParnames</i>
----------------	-----------------------

Description

Gets internal stan parameter names of a ctStanFit object based on specified substrings.

Usage

```
ctStanParnames(x, substrings = c("pop_", "popsd"))
```

Arguments

x	ctStanFit object
substrings	vector of character strings, parameter names of the stan model containing any of these strings will be returned. Useful strings may be 'pop_' for population means, 'popsd' for population standard deviations, or specific combinations such as 'pop_DRIFT' for the population means of temporal dynamics parameters

Value

vector of character strings.

Examples

```
ctStanParnames(ctstantestfit,substrings=c('pop_', 'popsd'))
```

ctStanPlotPost

ctStanPlotPost

Description

Plots prior and posterior distributions of model parameters in a ctStanModel or ctStanFit object.

Usage

```
ctStanPlotPost(obj, rows = "all", priorwidth = TRUE, mfrow = "auto",
  lwd = 2, smoothness = 1, parcontrol = list(mgp = c(1.3, 0.5, 0),
  mar = c(3, 2, 2, 1) + 0.2), wait = FALSE)
```

Arguments

obj	fit or model object as generated by ctStanFit , ctModel , or ctStanModel .
rows	vector of integers denoting which rows of obj\$setup\$popsetup to plot priors for. Character string 'all' plots all rows with parameters to be estimated.
priorwidth	if TRUE, plots will be scaled to show bulk of both the prior and posterior distributions. If FALSE, scale is based only on the posterior.
mfrow	2 dimensional integer vector defining number of rows and columns of plots, as per the mfrow argument to par . 'auto' determines automatically, to a maximum of 4 by 4, while NULL uses the current system setting.
lwd	line width for plotting.
smoothness	Positive numeric – multiplier to modify smoothness of density plots, higher is smoother but can cause plots to exceed natural boundaries, such as standard deviations below zero.
parcontrol	parameters to pass to par which temporarily change plot settings.
wait	If true, user is prompted to continue before plotting next graph. If false, graphs are plotted one after another without waiting.

Examples

```
ctStanPlotPost(ctstantestfit, rows=3:4)
```

ctStanPostPredict	<i>Compares model implied density and values to observed, for a ctStanFit object.</i>
-------------------	---

Description

Compares model implied density and values to observed, for a ctStanFit object.

Usage

```
ctStanPostPredict(fit, legend = TRUE, diffsize = 1, jitter = 0.02,
  wait = TRUE, probs = c(0.025, 0.5, 0.975), shading = TRUE,
  datarows = "all", ...)
```

Arguments

fit	ctStanFit object.
legend	Logical, whether to plot a legend.
diffsize	Integer > 0. Number of discrete time lags to use for data viz.
jitter	Positive numeric between 0 and 1, if TRUE, jitters empirical data by specified proportion of std dev.
wait	Logical, if TRUE, waits for input before plotting next plot.
probs	Vector of length 3 containing quantiles to plot – should be rising numeric values between 0 and 1.
shading	Logical – show smoothed shading over generated data points? Otherwise, plot shaded polygon based on quantile estimate. Shading is better for non-linearities.
datarows	integer vector specifying rows of data to plot. Otherwise 'all' uses all data.
...	extra arguments to pass to plot function.

Details

This function relies on the data generated during each iteration of fitting to approximate the model implied distributions – thus, when limited iterations are available, the approximation will be worse.

Value

If plot=FALSE, an array containing quantiles of generated data. If plot=TRUE, nothing, only plots.

Examples

```
## Not run:
ctStanPostPredict(ctstantestfit,wait=FALSE, shading=FALSE, datarows=1:25,diffsize=2)

## End(Not run)
```

 ctstantestdat

ctstantestdat

Description

Generated dataset for testing `ctStanFit` from `ctsem` package.

Format

matrix

Examples

```
## Not run:
Tpoints=20
n.manifest=2
n.TDpred=1
n.TIpred=3
n.latent=2
n.subjects=5
gm<-ctModel(type='omx', Tpoints=Tpoints,n.latent=n.latent,
n.TDpred=n.TDpred,n.TIpred=n.TIpred,n.manifest=n.manifest,
  MANIFESTVAR=diag(0.5,2),
  TIPREDEFFECT=matrix(c(.5,0,0,-.7,0,2),nrow=2),
  TIPREDFVAR=matrix(c(1,-.2,0,0,1,0,0,0,.5),nrow=3),
  TDPREDFVAR=matrix(0,nrow=n.TDpred*(Tpoints),ncol=n.TDpred*(Tpoints)),
  TDPREDFMEANS=matrix(round(exp(rnorm(n.TDpred*(Tpoints),-1.9,1)),0),
  nrow=n.TDpred*(Tpoints)),
  TDPREDEFFECT = matrix(c(1,-1),ncol=1),
  LAMBDA=diag(1,2),
  DRIFT=matrix(c(-.3,.2,0,-.2),nrow=2),
  DIFFUSION=matrix(c(2,1,0,2),2),
  CINT=matrix(c(0,0),nrow=2),
  T0MEANS=matrix(0,ncol=1,nrow=2),
  T0VAR=diag(100,2))

ctstantestdat<-ctGenerate(gm,n.subjects=n.subjects,burnin=30,
wide=FALSE,logdtsd=.4)

ctstantestdat[2,'Y1'] <- NA
ctstantestdat[ctstantestdat[, 'id']==2, 'TI1'] <- NA
ctstantestdat[2, 'TD1'] <- NA

save(ctstantestdat,file='.\data\ctstantestdat.rda')

## End(Not run)
```

 ctstantestfit

ctstantestfit

Description

Minimal output from `ctStanFit` from ctsem package.

Format

stanfit class.

Examples

```
## Not run: #'
checkm<-ctModel(type='stanct',
  n.latent=n.latent,n.TDpred=n.TDpred,n.TIpred=n.TIpred,
  MANIFESTVAR=matrix(c('merror',0,0,'merror'),2,2),
  MANIFESTMEANS=matrix(0,nrow=n.manifest),
  CINT=matrix(c('cint1','cint2'),ncol=1),
  n.manifest=n.manifest,LAMBDA=diag(2))

checkm$pars$indvarying[-c(7,13)] <- FALSE
checkm$pars$sdscale <- .1

checkm$pars[c(-1,-2, -21,-22) ,c('TI1_effect','TI2_effect','TI3_effect')] <- FALSE

ctstantestfit<-ctStanFit(ctstantestdat,checkm,iter=500, warmup=460,thin=2,chains=2,
  control=list(max_treedepth=5,adapt_delta=.8),save_warmup=FALSE)
summary(ctstantestfit)
save(ctstantestfit,file='.\data\ctstantestfit.rda')
paths <- sort(Sys.glob(c("data/*.rda", "data/*.RData")))
library(tools)
resaveRdaFiles(paths)

## End(Not run)
```

 ctStanTIpredeffects

Get time independent predictor effect estimates

Description

Computes and plots combined effects and quantiles for effects of time independent predictors on subject level parameters of a `ctStanFit` object.

Usage

```
ctStanTIpredEffects(fit, returndifference = FALSE, probs = c(0.025,
  0.5, 0.975), includeMeanUncertainty = FALSE, whichTIpreds = 1,
  parmatrices = TRUE, whichpars = "all", nsamples = 100,
  timeinterval = 1, nsubjects = 50, filter = NA, plot = FALSE, ...)
```

Arguments

<code>fit</code>	fit object from <code>ctStanFit</code>
<code>returndifference</code>	logical. If FALSE, absolute parameter values are returned. If TRUE, only the effect of the covariate (i.e. without the average value of the parameter) are returned. The former can be easier to interpret, but the latter are more likely to fit multiple plots together. Not used if <code>parmatrices=TRUE</code> .
<code>probs</code>	numeric vector of quantile probabilities from 0 to 1. Specify 3 values if plotting, the 2nd will be drawn as a line with uncertainty polygon based on 1st and 3rd.
<code>includeMeanUncertainty</code>	if TRUE, output includes sampling variation in the mean parameters. If FALSE, mean parameters are fixed at their median, only uncertainty in time independent predictor effects is included.
<code>whichTIpreds</code>	integer vector specifying which of the tipreds in the fit object you want to use to calculate effects. Unless quadratic / higher order versions of predictors have been included, selecting more than one probably doesn't make sense. If for instance a squared predictor has been included, then you can specify both the linear and squared version. The x axis of the plot (if generated) will be based off the first indexed predictor. To check what predictors are in the model, run <code>fit\$ctstanmodel\$TIpredNames</code> .
<code>parmatrices</code>	Logical. If TRUE (default), the <code>ctStanParMatrices</code> function is used to return an expanded range of possible matrices of interest.
<code>whichpars</code>	if <code>parmatrices==TRUE</code> , character vector specifying which matrices, and potentially which indices of the matrices, to plot. <code>c('dtDRIFT[2,1]', 'DRIFT')</code> would output for row 2 and column 1 of the discrete time drift matrix, as well as all indices of the continuous time drift matrix. If <code>parmatrices==FALSE</code> , integer vector specifying which of the subject level parameters to compute effects on. The integers corresponding to certain parameters can be found in the <code>param</code> column of the <code>fit\$setup\$popsetup</code> object. In either case 'all' uses all available parameters.
<code>nsamples</code>	Positive integer specifying the maximum number of saved iterations to use. Character string 'all' can also be used.
<code>timeinterval</code>	positive numeric indicating time interval to use for discrete time parameter matrices, if <code>parmatrices=TRUE</code> .
<code>nsubjects</code>	Positive integer specifying the number of subjects to compute values for. Character string 'all' can also be used. Time taken is a function of <code>nsubjects*niterations</code> .
<code>filter</code>	either NA, or a length 2 vector, where the first element contains the time independent predictor index to filter by, and the second contains the comparison

operator in string form (e.g. "< 3", to only calculate effects for subjects where the tipreds of the denoted index are less than 3).

plot Logical. If TRUE, nothing is returned but instead `ctPlotArray` is used to plot the output instead.

... arguments to pass to `ctPlotArray` for plotting.

Value

Either a three dimensional array of predictor effects, or nothing with a plot generated.

Examples

```
## Not run:
#samples reduced here for speed
ctStanTIpredEffects(ctStanTestFit, plot=TRUE, whichpars='CINT', nsamples=10, nsubjects=10)

## End(Not run)
```

ctStanTIpredMarginal *Plot marginal relationships between covariates and parameters for a ctStanFit object.*

Description

Plot marginal relationships between covariates and parameters for a ctStanFit object.

Usage

```
ctStanTIpredMarginal(fit, tipred, pars, probs = c(0.025, 0.5, 0.975),
  useimputed = TRUE, plot = TRUE)
```

Arguments

fit ctStanFit object.

tipred Integer representing which tipred to use – integer corresponds to TIpredNames specification.

pars Subject level matrices from the ctStanFit output – e.g. 'DRIFT' or 'DIFFUSION'.

probs vector of 3 quantile probabilities, the 2nd will be plotted as a line, the outer two as shaded regions.

useimputed Logical, include imputed tipreds or only observed?

plot Logical, whether to plot.

Value

If plot=TRUE, nothing, otherwise an array that can be used with ctPlotArray.

Examples

```
## Not run:
ctStanTIPredMarginal(ctstantestfit,pars='CINT',tipred=3)

## End(Not run)
```

<code>ctStanUpdModel</code>	<i>Update an already compiled and fit ctStanFit object</i>
-----------------------------	--

Description

Allows one to change data and or model elements that don't require recompiling, then re fit.

Usage

```
ctStanUpdModel(fit, datalong, ctstanmodel, ...)
```

Arguments

<code>fit</code>	ctStanFit object
<code>dalong</code>	data as normally passed to ctStanFit
<code>ctstanmodel</code>	model as normally passed to ctStanFit
<code>...</code>	extra args for ctStanFit

Examples

```
## Not run:
newm<-ctModel(type='stanct',
  n.latent=ctstantestfit$ctstanmodel$n.latent,
  n.TDpred=ctstantestfit$ctstanmodel$n.TDpred,
  n.TIPred=ctstantestfit$ctstanmodel$n.TIPred,
  MANIFESTVAR=matrix(c('merror',0,0,'merror'),2,2),
  MANIFESTMEANS=matrix(0,nrow=ctstantestfit$ctstanmodel$n.manifest),
  CINT=matrix(c(0,'cint2'),ncol=1),
  n.manifest=ctstantestfit$ctstanmodel$n.manifest,
  LAMBDA=diag(2))

newdat <- ctstantestdat
newdat <- newdat[newdat[, 'id']!=1,]
newfit <- ctStanUpdModel(ctstantestfit, newdat, newm)

## End(Not run)
```

ctWideNames	<i>ctWideNames sets default column names for wide ctsem datasets. Primarily intended for internal ctsem usage.</i>
-------------	--

Description

ctWideNames sets default column names for wide ctsem datasets. Primarily intended for internal ctsem usage.

Usage

```
ctWideNames(n.manifest, Tpoints, n.TDpred = 0, n.TIpred = 0,
  manifestNames = "auto", TDpredNames = "auto", TIpredNames = "auto")
```

Arguments

n.manifest	number of manifest variables per time point in the data.
Tpoints	Maximum number of discrete time points (waves of data, or measurement occasions) for an individual in the input data structure.
n.TDpred	number of time dependent predictors in the data structure.
n.TIpred	number of time independent predictors in the data structure.
manifestNames	vector of character strings giving column names of manifest indicator variables
TDpredNames	vector of character strings giving column names of time dependent predictor variables
TIpredNames	vector of character strings giving column names of time independent predictor variables

ctWideToLong	<i>ctWideToLong Convert ctsem wide to long format</i>
--------------	---

Description

ctWideToLong Convert ctsem wide to long format

Usage

```
ctWideToLong(datawide, Tpoints, n.manifest, n.TDpred = 0, n.TIpred = 0,
  manifestNames = "auto", TDpredNames = "auto", TIpredNames = "auto")
```

Arguments

datawide	ctsem wide format data
Tpoints	number of measurement occasions in data
n.manifest	number of manifest variables
n.TDpred	number of time dependent predictors
n.TIpred	number of time independent predictors
manifestNames	Character vector of manifest variable names.
TDpredNames	Character vector of time dependent predictor names.
TIpredNames	Character vector of time independent predictor names.

Details

Names must account for **all** the columns in the data - i.e. do not leave certain variables out just because you do not need them.

Examples

```
#First load the example ctsem wide format data with absolute times
data('datastructure')
datastructure #contains two time intervals (dTx), therefore 3 time points.
#Then convert to long format
longexample <- ctWideToLong(datawide = datastructure, Tpoints=3,
n.manifest=3, manifestNames = c("Y1", "Y2", "Y3"),
n.TDpred=1, TDpredNames = "TD1",
n.TIpred=2, TIpredNames = c("TI1", "TI2"))

#Then convert the time intervals to absolute time
long <- ctDeintervalise(datalong = longexample, id='id', dT='dT')
long
```

datastructure

datastructure

Description

Simulated example dataset for the ctsem package

Format

2 by 15 matrix containing containing ctsem wide format data. 3 measurement occasions of manifest variables Y1 and Y2, 2 measurement occasions of time dependent predictor TD1, 2 measurement intervals dTx, and 2 time independent predictors TI1 and TI2, for 2 individuals.

Examples

```
## Not run:
Tpoints=30
testm<-ctModel(Tpoints=Tpoints,n.latent=1,n.TDpred=1,n.TIpred=2,n.manifest=3,
  LAMBDA=matrix(1,ncol=1,nrow=3),
  DRIFT=diag(-.3,1),
  DIFFUSION=diag(.1,1),
  CINT=diag(2,1),
  MANIFESTVAR=diag(1,3),
  TDPREDEFFECT=diag(.2,1),
  TIPREDEFFECT=matrix(.8,nrow=1,ncol=2),
  TDPREDVAR=diag(1,1*(Tpoints)),
  TIPREDVAR=diag(1,2)
)
longexample<-round(ctGenerate(testm,n.subjects=2,logdtsd = 1,burnin=3,wide=FALSE)[c(1:3,32:34),],2)
longexample[2,c(2,7)]<-NA
longexample[4,c(3)]<-NA
datastructure <- ctLongToWide(datalong = longexample,id='id',time='time',
  manifestNames = testm$manifestNames,TDpredNames = testm$TDpredNames,
  TIpredNames=testm$TIpredNames)
datastructure<-ctIntervalise(datawide = datastructure,
  Tpoints = 3,n.manifest = testm$n.manifest,n.TDpred = testm$n.TDpred,
  n.TIpred=testm$n.TIpred)
save(datastructure,file='.\data\datastructure.rda')

## End(Not run)
```

 extract

Extract samples from a ctStanFit object

Description

Extract samples from a ctStanFit object

Usage

```
extract(object, ...)
```

Arguments

object	ctStanFit object, samples may be from Stan's HMC, or the importance sampling approach of ctsem.
...	additional arguments to pass to <code>rstan::extract</code> .

Value

Array of posterior samples.

Examples

```
e = extract(ctstantestfit)
head(e)
```

inv_logit	<i>Inverse logit</i>
-----------	----------------------

Description

Maps the stan function so the same code works in R.

Usage

```
inv_logit(x)
```

Arguments

x value to calculate the inverse logit for.

Examples

```
inv_logit(-3)
```

isdiag	<i>Diagnostics for ctsem importance sampling</i>
--------	--

Description

Diagnostics for ctsem importance sampling

Usage

```
isdiag(fit)
```

Arguments

fit Output from ctStanFit when optimize=TRUE and isloops > 0

Value

Nothing. Plots convergence of parameter mean estimates from initial Hessian based distribution to final sampling distribution.

Examples

```

## Not run:
#get data
sunspots<-sunspot.year
sunspots<-sunspots[50: (length(sunspots) - (1988-1924))]
id <- 1
time <- 1749:1924
datalong <- cbind(id, time, sunspots)

#setup model
model <- ctModel(type='stanct', n.latent=2, n.manifest=1,
  manifestNames='sunspots',
  latentNames=c('ss_level', 'ss_velocity'),
  LAMBDA=matrix(c( -1, 'ma1' ), nrow=1, ncol=2),
  DRIFT=matrix(c(-.0001, 'a21', 1, 'a22'), nrow=2, ncol=2),
  MANIFESTMEANS=matrix(c('m1'), nrow=1, ncol=1),
  CINT=matrix(c(0, 0), nrow=2, ncol=1),
  T0VAR=matrix(c(1,0,0,1), nrow=2, ncol=2), #Because single subject
  DIFFUSION=matrix(c(0.0001, 0, 0, "diffusion"), ncol=2, nrow=2))

model$pars$indvarying<-FALSE #Because single subject
model$pars$transform[14]<- '(param)*5+44 ' #Because not mean centered
model$pars$transform[4]<- '-log(exp(-param*1.5)+1)' #To avoid multi modality

#fit and plot importance sampling diagnostic
fit <- ctStanFit(datalong, model, chains=1,
  optimcontrol=list(isloops=5,finishsamples=500),optimize=TRUE)
isdiag(fit)

## End(Not run)

```

 Kalman

Kalman

Description

Takes list containing ctsem subject matrices, as well as long form data object, and calculates predicted and updated latent states, likelihoods, and predicted observations using the Kalman filter.

Usage

```

Kalman(kpars, datalong, manifestNames, latentNames,
  imputeMissings = FALSE, TDpredNames = NULL, continuoustime = TRUE,
  idcol = "id", timecol = "time", derrind = "all",
  optimize = FALSE, ukf = FALSE, plotoptim = FALSE)

```

Arguments

<code>kpars</code>	list object containing DRIFT,TOVAR,DIFFUSION,CINT,TOMEANS,TDPREDEFFECT, MANIFESTMEANS, LAMBDA, and MANIFESTVAR matrices, with list elements named accordingly. Such a list is returned by <code>ctStanContinuousPars</code> .
<code>datalong</code>	long format data object as used by <code>ctStanFit</code> , but must contain only a single subjects' data and does not need an id column.
<code>manifestNames</code>	String vector of names of manifest variables to use from <code>datalong</code> .
<code>latentNames</code>	String vector of names of latent variables.
<code>imputeMissings</code>	Logical. If TRUE, randomly generate any missing observations of manifest variables according to model.
<code>TDpredNames</code>	If model contains time dependent predictors, string vector of their names in the data.
<code>continuoustime</code>	Logical, whether to use a continuous time Kalman filter or discrete time. Refers only to latent states, observations are always at discrete time points.
<code>idcol</code>	Character string giving name of subject identification column in data.
<code>timecol</code>	name of time column in <code>datalong</code> . Note that time column must be an ascending sequence of numeric values from row 1 to row n. Ignored if <code>continuous-time=FALSE</code> .
<code>derrind</code>	vector of integers denoting which latent variables are involved in covariance calcs.
<code>optimize</code>	Set to TRUE when using for optimization.
<code>ukf</code>	set to TRUE to use the unscented Kalman filter, only necessary for fitting non-linear models, currently only for optimizing.
<code>plotoptim</code>	set to TRUE to plot / print optimization steps.

Value

When `optimize=TRUE`, returns log likelihood. Else, returns a list containing matrix objects `etaprior`, `etaupd`, `etasmooth`, `y`, `yprior`, `yupd`, `ysmooth`, `prederror`, `time`, `loglik`, with values for each time point in each row. `eta` refers to latent states and `y` to manifest indicators - `y` itself is thus just the input data. Covariance matrices `etapriorcov`, `etaupdcov`, `etasmoothcov`, `ypriorcov`, `yupdcov`, `ysmoothcov`, are returned in a row * column * time array.

Examples

```
### ctstantestfit is a dummy ctStanFit object with 2 manifest indicators,
### 4 latents, and 1 time dependent predictor.

### get parameter matrices
kpars <- ctStanContinuousPars(ctstantestfit)

#construct dummy data
datalong <- cbind(0:9, 1, matrix(rnorm(20,2,1),ncol=2))
datalong[c(1:3,9:10),3:4]<-NA #missing data to pre/fore cast
colnames(datalong) <- c('time', 'id', paste0('Y',1:2))
print(datalong)
```



```
#obtain Kalman filtered estimates
kout <- Kalman(kpars=kpars, datalong=datalong,
  manifestNames=paste0('Y',1:nrow(kpars$MANIFESTMEANS)),
  latentNames=paste0('eta',1:nrow(kpars$DRIFT)))

#print and plot smoothed estimates (conditional on all states) of indicators.
print(kout$smooth)
matplot(kout$time,kout$smooth,type='l')
matplot(kout$time,datalong[,3:4],type='p',add=TRUE,pch=1)
```

longexample

longexample

Description

Simulated example dataset for the ctsem package

Format

7 by 8 matrix containing ctsem long format data, for two subjects, with three manifest variables Y1, Y2, Y3, one time dependent predictor TD1, two time independent predictors TI1 and TI2, and absolute timing information Time.

Examples

```
## Not run:
#long example (using datastructure base)
Tpoints=30
testm<-ctModel(Tpoints=Tpoints,n.latent=1,n.TDpred=1,n.TIpred=2,n.manifest=3,
  LAMBDA=matrix(1,ncol=1,nrow=3),
  DRIFT=diag(-.3,1),
  DIFFUSION=diag(.1,1),
  CINT=diag(2,1),
  MANIFESTVAR=diag(1,3),
  TDPREDEFFECT=diag(.2,1),
  TIPREDEFFECT=matrix(.8,nrow=1,ncol=2),
  TDPREDVAR=diag(1,1*(Tpoints)),
  TIPREDVAR=diag(1,2)
)
longexample<-round(ctGenerate(testm,n.subjects=2,logdtsd = 1,burnin=3,wide=FALSE)[c(1:3,32:35),],2)
longexample[2,c(2,7)]<-NA
longexample[4,c(3)]<-NA
longexample
save(longexample,file='.\data\\longexample.rda')

## End(Not run)
```

msquare	<i>Right multiply a matrix by its transpose.</i>
---------	--

Description

Right multiply a matrix by its transpose.

Usage

```
msquare(x)
```

Arguments

x matrix.

Value

matrix.

Examples

```
msquare(t(chol(diag(3,4)+1)))
```

optimstan	<i>Optimize / importance sample a stan or ctStan model.</i>
-----------	---

Description

Optimize / importance sample a stan or ctStan model.

Usage

```
optimstan(standata, sm, init = "random", sampleinit = NA,  
deoptim = FALSE, estonly = FALSE, tol = 1e-12,  
decontrol = list(), stochastic = TRUE, plotsgd = FALSE,  
isloops = 0, isloopsize = 1000, finishsamples = 500, tdf = 50,  
verbose = 0, nopriors = FALSE, cores = 1)
```

Arguments

standata	list object conforming to rstan data standards.
sm	compiled stan model object.
init	vector of unconstrained parameter values, or character string 'random' to initialise with random values very close to zero.
sampleinit	either NA, or an niterations * nparams matrix of samples to initialise importance sampling.
deoptim	Do first pass optimization using differential evolution? Slower, but better for cases with multiple minima / difficult optimization.
estonly	if TRUE, just return point estimates under \$rawest subobject.
tol	absolute object tolerance
decontrol	List of control parameters for differential evolution step, to pass to DEoptim.control .
stochastic	Logical. Use stochastic gradient descent instead of ucminf (bfgs with trust region) optimizer. Generally more robust, a little slower with few parameters, faster with many.
plotsgd	Logical. If TRUE, plot iteration details when using stochastic optimizer.
isloops	Number of iterations of adaptive importance sampling to perform after optimization.
isloopsize	Number of samples per iteration of importance sampling.
finishesamples	Number of samples to use for final results of importance sampling.
tdf	degrees of freedom of multivariate t distribution. Higher (more normal) generally gives more efficient importance sampling, at risk of truncating tails.
verbose	Integer from 0 to 2. Higher values print more information during model fit – for debugging.
nopriors	logical.f If TRUE, any priors are disabled – sometimes desirable for optimization.
cores	Number of cpu cores to use.

Value

ctStanFit object

Examples

```

sunspots<-sunspot.year
sunspots<-sunspots[50:(length(sunspots) - (1988-1924))]
id <- 1
time <- 1749:1924
datalong <- cbind(id, time, sunspots)

#setup model
ssmodel <- ctModel(type='stanct', n.latent=2, n.manifest=1,
  manifestNames='sunspots',
  latentNames=c('ss_level', 'ss_velocity'),

```

```

LAMBDA=matrix(c( 1, 'ma1' ), nrow=1, ncol=2),
DRIFT=matrix(c(0, 'a21', 1, 'a22'), nrow=2, ncol=2),
MANIFESTMEANS=matrix(c('m1'), nrow=1, ncol=1),
MANIFESTVAR=diag(0,1),
CINT=matrix(c(0, 0), nrow=2, ncol=1),
T0VAR=matrix(c(1,0,0,1), nrow=2, ncol=2), #Because single subject
DIFFUSION=matrix(c(0, 0, 0, "diffusion"), ncol=2, nrow=2))

ssmodel$pars$indvarying<-FALSE #Because single subject
ssmodel$pars$offset[14]<- 44 #Because not mean centered
ssmodel$pars[4,c('transform','offset')]<- c(1,0) #To avoid multi modality

#fit using optimization without importance sampling
ssfit <- ctStanFit(datalong[1:50,], #limited data for example
  ssmodel, optimize=TRUE,optimcontrol=list(deoptim=FALSE,isloops=0,finishsamples=50))

#output
summary(ssfit)

```

Oscillating

Oscillating

Description

Simulated example dataset for the ctsem package.

Format

200 by 21 matrix containing containing ctsem wide format data. 11 measurement occasions and 10 measurement intervals for each of 200 individuals

Source

See <http://onlinelibrary.wiley.com/doi/10.1111/j.2044-8317.2012.02043.x/abstract>

plot.ctsemFit

Plotting function for object class ctsemFit

Description

Outputs mean trajectories, autoregression, and crossregression plots. For more customization possibilities, see [ctPlot](#).

Usage

```
## S3 method for class 'ctsemFit'
plot(x, resolution = 50, wait = TRUE,
     max.time = "auto", mean = TRUE, withinVariance = TRUE, AR = TRUE,
     CR = TRUE, standardiseCR = FALSE, randomImpulse = FALSE,
     experimentalImpulse = FALSE, xlab = "Time", meansylim = "auto",
     ARylim = "auto", CRylim = "auto", ylab = "Value", ...)
```

Arguments

x	ctsemFit object as generated by <code>ctFit</code> .
resolution	Numeric. Plot points between each unit of time. Default of 'auto' adapts to max.time and results in 500 in total.
wait	If true, user is prompted to continue before plotting next graph. If false, graphs are plotted one after another without waiting.
max.time	Time scale on which to plot parameters. If auto, parameters are plotted for full range of observed variables.
mean	if TRUE, plot of means from 0 to max.time included in output.
withinVariance	if TRUE, plot within subject variance / covariance.
AR	if TRUE, plot of autoregressive values from 0 to max.time included in output.
CR	if TRUE, plot of cross regressive values from 0 to max.time included in output.
standardiseCR	if TRUE, cross regression values are standardised based on estimated within subject variance.
randomImpulse	if TRUE (default), plots expected change in processes given a random fluctuation of +1 for each process – plot is then a mixture of DIFFUSION and DRIFT characteristics.
experimentalImpulse	if TRUE (default), plots expected change in processes given an exogenous input of +1 for each process – alternate characterisation of autoregressive and cross regressive plots.
xlab	X axis label.
meansylim	Vector of min and max limits for mean trajectory plot. 'auto' calculates automatically.
ARylim	Vector of min and max limits for autoregression plot. 'auto' is c(0,1), and expands if necessary.
CRylim	Vector of min and max limits for cross regression plot. 'auto' is c(-1,1), and expands if necessary.
ylab	Y axis label.
...	Other options passed to <code>plot()</code> .

Value

Nothing. Side-effect: plots graphs.

Examples

```
## Examples set to 'dontrun' because they take longer than 5s.

### example from Driver, Oud, Voelkle (2015),
### simulated happiness and leisure time with unobserved heterogeneity.
## Not run:
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(datawide=ctExample1, ctmodelobj=traitmodel)
plot(traitfit, wait=FALSE)

## End(Not run)
```

plot.ctsemFitMeasure *Misspecification plot using ctCheckFit output*

Description

Misspecification plot using ctCheckFit output

Usage

```
## S3 method for class 'ctsemFitMeasure'
plot(x, indices = "all",
  corrplotargs = list(method = "square", is.corr = FALSE, addgrid.col =
  NA), labels = TRUE, ...)
```

Arguments

x	Object output from ctsemFitMeasure function.
indices	Either 'all' or a vector of integers denoting which observations to include (from 1 to maximum time points).
corrplotargs	Extra arguments to pass to corrplot function.
labels	Logical. Plot labels for each row / column?
...	not used.

Value

Nothing, just plots.

Examples

```
## Not run:
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(datawide=ctExample1, ctmodelobj=traitmodel)

check <- ctCheckFit(traitfit,niter=5)
plot(check)

## End(Not run)
```

plot.ctsemMultigroupFit

Plot function for ctsemMultigroupFit object

Description

Plots [ctMultigroupFit](#) objects.

Usage

```
## S3 method for class 'ctsemMultigroupFit'
plot(x, group = "show chooser", ...)
```

Arguments

x	ctsemMultigroupFit object as generated by ctMultigroupFit
group	character string of subgroup to plot. Default of 'show chooser' displays list and lets you select.
...	additional parameters to pass to plot.ctsemFit function.

Value

Nothing. Side-effect: plots graphs.

plot.ctStanFit	<i>plot.ctStanFit</i>
----------------	-----------------------

Description

Plots for ctStanFit objects

Usage

```
## S3 method for class 'ctStanFit'
plot(x, types = "all", wait = TRUE, ...)
```

Arguments

x	Fit object from ctStanFit .
types	Vector of character strings defining which plots to create. 'all' plots all possible types, including: 'regression', 'kalman', 'priorcheck', 'trace', 'density', 'intervals'.
wait	Logical. Pause between plots?
...	Arguments to pass through to the specific plot functions. Bewar of clashes may occur if types='all'. For details see the specific functions generating each type of plot.

Details

This function is just a wrapper calling the necessary functions for plotting - it may be simpler in many cases to access those directly. They are: [ctStanDiscretePars](#), [ctKalman](#), [ctStanPlotPost](#), [stan_trace](#), [stan_dens](#), [stan_plot](#) rstan offers many plotting possibilities not available here, to use that functionality one must simply call the relevant rstan plotting function. Use `x$stanfit` as the stan fit object (where x is the name of your ctStanFit object). Because a ctStanFit object has many parameters, the additional argument `pars=ctStanParnames(x, 'pop_')` is recommended. This denotes population means, but see [ctStanParnames](#) for other options.

Value

Nothing. Generates plots.

Examples

```
## Not run:
plot(ctstantestfit, types=c('regression', 'kalman', 'priorcheck'))

### complete example
plot(ctstantestfit)

#### example plot using rstan functions
rstan::stan_trace(ctstantestfit$stanfit,
pars=ctStanParnames(ctstantestfit, 'pop_DRIFT'))
```



```
## End(Not run)
```

```
plot.ctStanModel      Prior plotting
```

Description

Plots priors for free model parameters in a ctStanModel.

Usage

```
## S3 method for class 'ctStanModel'
plot(x, rows = "all", wait = FALSE,
      nsamples = 1e+06, rawpopsd = "marginalise", inddifdevs = c(-1, 1),
      ...)
```

Arguments

x	ctStanModel object as generated by <code>ctModel</code> with <code>type='stanct'</code> or <code>'standt'</code> .
rows	vector of integers denoting which rows of <code>ctstanmodel\$pars</code> to plot priors for. Character string 'all' plots all rows with parameters to be estimated.
wait	If true, user is prompted to continue before plotting next graph.
nsamples	Numeric. Higher values increase fidelity (smoothness / accuracy) of density plots, at cost of speed.
rawpopsd	Either 'marginalise' to sample from the specified (in the <code>ctstanmodel</code>) prior distribution for the raw population standard deviation, or a numeric value to use for the raw population standard deviation for all subject level prior plots - the plots in dotted blue or red.
inddifdevs	numeric vector of length 2, setting the means for the individual differences distributions.
...	not used.

Details

Plotted in black is the prior for the population mean. In red and blue are the subject level priors that result given that the population mean is estimated as 1 std deviation above the mean of the prior, or 1 std deviation below. The distributions around these two points are then obtained by marginalising over the prior for the raw population std deviation - so the red and blue distributions do not represent any specific subject level prior, but rather characterise the general amount and shape of possible subject level priors at the specific points of the population mean prior.

Examples

```

model <- ctModel(type='omx', Tpoints=50,
  n.latent=2, n.manifest=1,
  manifestNames='sunspots',
  latentNames=c('ss_level', 'ss_velocity'),
  LAMBDA=matrix(c( 1, 'ma1' ), nrow=1, ncol=2),
  DRIFT=matrix(c(0, 1, 'a21', 'a22'), nrow=2, ncol=2, byrow=TRUE),
  MANIFESTMEANS=matrix(c('m1'), nrow=1, ncol=1),
  # MANIFESTVAR=matrix(0, nrow=1, ncol=1),
  CINT=matrix(c(0, 0), nrow=2, ncol=1),
  DIFFUSION=matrix(c(
    0, 0,
    0, "diffusion"), ncol=2, nrow=2, byrow=TRUE))

stanmodel=ctStanModel(model)
plot(stanmodel,rows=8)

```

sdpcor2cov

sdcor2cov

Description

Converts a lower triangular matrix with standard deviations on the diagonal and partial correlations on lower triangle, to a covariance (or cholesky decomposed covariance)

Usage

```
sdpcor2cov(mat, cholesky = FALSE)
```

Arguments

mat	input square matrix with std dev on diagonal and lower tri of partial correlations.
cholesky	Logical. To return the cholesky decomposition instead of full covariance, set to TRUE.

Examples

```

testmat <- diag(exp(rnorm(5,-3,2)),5) #generate arbitrary std deviations
testmat[row(testmat) > col(testmat)] <- runif((5^2-5)/2, -1, 1)
print(testmat)
covmat <- sdpcor2cov(testmat) #convert to covariance
cov2cor(covmat) #convert covariance to correlation

```

stanWplot	<i>Runs stan, and plots sampling information while sampling.</i>
-----------	--

Description

Runs stan, and plots sampling information while sampling.

Usage

```
stanWplot(object, iter = 2000, chains = 4, ...)
```

Arguments

object	stan model object
iter	Number of iterations
chains	Number of chains
...	All the other regular arguments to stan()

Examples

```
## Not run:
#### example 1
scode <- "
parameters {
  real y[2];
}
model {
  y[1] ~ normal(0, .5);
  y[2] ~ double_exponential(0, 2);
}
"
sm <- stan_model(model_code = scode)
fit1 <- stanWplot(object = sm, iter = 100000, chains=2, cores=1)

## End(Not run)
```

stan_checkdivergences	<i>Analyse divergences in a stanfit object</i>
-----------------------	--

Description

Analyse divergences in a stanfit object

Usage

```
stan_checkdivergences(sf, nupars = "all")
```

Arguments

sf	stanfit object.
nupars	either the string 'all', or an integer reflecting how many pars (from first to nupars) to use.

Value

A list of four matrices. \$locationssort and \$sdssort contain the bivariate interactions of unconstrained parameters, sorted by either the relative location of any divergences, or the relative standard deviation. \$locationmeans and \$sdmeans collapse across the bivariate interactions to return the means for each parameter.

Examples

```
## Not run:
stan_checkdivergences(myfitobj)

## End(Not run)
```

stan_confidenceRegion *Extract functions of multiple variables from a stanfit object*

Description

Can be useful for determining quantiles or plotting multidimensional regions – for instance in case of colinearity of predictors.

Usage

```
stan_confidenceRegion(stanfit, parstrings, prefuncstring = "(",
  joinfuncstring = " + ", postfuncstring = ")")
```

Arguments

stanfit	object of class stanfit.
parstrings	vector of strings containing partial (or full) matches of parameter names. When more than one string is passed, functions are computed based on the combination of the first match for each string, then the second match for each string, etc. The first match of the first string is only ever combined with the first match of the second, similarly for the 2nd match, etc.
prefuncstring	string containing front element of function. E.g., 'exp(' for an exponential region.
joinfuncstring	string used to join the (possibly) multiple parameters involved.
postfuncstring	string containing end element of function. E.g., ')' *2' to multiply the result by 2.

Value

matrix of values of the specified interactions at each iteration.

Examples

```
temp<-stan_confidenceRegion(stanfit=ctstantestfit$stanfit,
  parstrings=c('pop_DRIFT[1,2]', 'pop_DRIFT[2,1]'))
t(apply(temp,2,quantile))
```

stan_postcalc	<i>Compute functions of matrices from samples of a stanfit object</i>
---------------	---

Description

Compute functions of matrices from samples of a stanfit object

Usage

```
stan_postcalc(stanfit, object, calc = "object", objectindices = "all",
  summary = TRUE)
```

Arguments

stanfit	object of class stanfit.
object	name of stan sub object from stanfit to use for calculations.
calc	string containing R calculation to evaluate, with the string 'object' in place of the actual object name.
objectindices	matrix of indices, with the number of columns matching the number of dimensions of the object. 'all' computes <code>which(array(1,objdims)==1, arr.ind=TRUE)</code> , where <code>objdims</code> is what would be returned by <code>dim(object)</code> if the object existed in the R environment.
summary	if FALSE, a iterations * parameters matrix is returned, if TRUE, <code>rstan::monitor</code> is first run on the output.

Value

matrix of values of the specified interactions at each iteration.

Examples

```
temp<-stan_postcalc(stanfit=ctstantestfit$stanfit,
  object='DRIFT', objectindices='all', calc='exp(object)')
```

`stan_unconstrainsamples`*Convert samples from a stanfit object to the unconstrained scale*

Description

Convert samples from a stanfit object to the unconstrained scale

Usage

```
stan_unconstrainsamples(fit, standata = NA)
```

Arguments

<code>fit</code>	stanfit object.
<code>standata</code>	only necessary if R session has been restarted since fitting model – used to reinitialize stanfit object.

Value

Matrix containing columns of unconstrained parameters for each post-warmup iteration.

Examples

```
## Not run:  
umat <- stan_unconstrainsamples(ctstantestfit$stanfit, ctstantestfit$standata)  
  
## End(Not run)
```

`summary.ctsemFit`*Summary function for ctsemFit object*

Description

Provides summary details for ctsemFit objects.

Usage

```
## S3 method for class 'ctsemFit'  
summary(object, ridging = FALSE, timeInterval = 1,  
         verbose = FALSE, ...)
```

Arguments

object	ctsemFit object as generated by ctFit.
ridging	if TRUE, adds a small amount of variance to diagonals when calculating standardised (correlation) matrices, should only be used if standardised matrices return NAN.
timeInterval	positive numeric value specifying time interval to use for discrete parameter matrices, defaults to 1.
verbose	Logical. If TRUE, displays the raw, internally transformed (when fitting with default arguments) OpenMx parameters and corresponding standard errors, as well as additional summary matrices. Parameter transforms are described in the vignette, vignette('ctsem'). Additional summary matrices include: 'discrete' matrices – matrices representing the effect for the given time interval (default of 1); 'asymptotic' matrices – represents the effect as time interval approaches infinity (therefore asymCINT describes mean level of processes at the asymptote, asymDIFFUSION describes total within- subject variance at the asymptote, etc); 'standardised' matrices – transforms covariance matrices to correlation matrices, and transforms discreteDRIFT based on DIFFUSION, to give effect sizes.
...	additional parameters to pass.

Details

Important: Although `ctModel` takes cholesky decomposed variance-covariance matrices as input, the summary function displays the full variance-covariance matrices. These can be cholesky decomposed for comparison purposes using `t(chol(summary(ctfitobject)$covariancematrix))`. Standard errors are displayed in the `$ctparameters` section, however if `ctFit` was used with `transformedParams=TRUE` (the default, and recommended) covariance matrix standard errors will have been approximated using the delta method. For inferential purposes, maximum likelihood confidence intervals may be estimated using the `ctCI` function.

Value

Summary of ctsemFit object

Examples

```
## Examples set to 'dontrun' because they take longer than 5s.

## Not run:
### example from Driver, Oud, Voelkle (2015),
### simulated happiness and leisure time with unobserved heterogeneity.
data(ctExample1)
traitmodel <- ctModel(n.manifest=2, n.latent=2, Tpoints=6, LAMBDA=diag(2),
  manifestNames=c('LeisureTime', 'Happiness'),
  latentNames=c('LeisureTime', 'Happiness'), TRAITVAR="auto")
traitfit <- ctFit(datawide=ctExample1, ctmodelobj=traitmodel)
summary(traitfit,timeInterval=1)

## End(Not run)
```

```
summary.ctsemMultigroupFit
```

Summary function for ctsemMultigroupFit object

Description

Provides summary details for objects fitted with `ctMultigroupFit`.

Usage

```
## S3 method for class 'ctsemMultigroupFit'
summary(object, group = "show chooser", ...)
```

Arguments

<code>object</code>	ctsemMultigroupFit object as generated by <code>ctMultigroupFit</code>
<code>group</code>	character string of subgroup to display summary parameters for. Default of 'show chooser' displays list and lets you select.
<code>...</code>	additional parameters to pass to <code>summary.ctsemFit</code> .

Value

Summary of ctsemMultigroupFit object

```
summary.ctStanFit      summary.ctStanFit
```

Description

Summarise a ctStanFit object that was fit using `ctStanFit`.

Usage

```
## S3 method for class 'ctStanFit'
summary(object, timeinterval = 1, digits = 3,
        parmatrices = FALSE, priorcheck = TRUE, ...)
```

Arguments

<code>object</code>	fit object from <code>ctStanFit</code> , of class ctStanFit.
<code>timeinterval</code>	positive numeric indicating time interval to use for discrete time parameter calculations reported in summary.
<code>digits</code>	integer denoting number of digits to report.

<code>parmatrices</code>	if TRUE, also return additional parameter matrices – can be slow to compute for large models with many samples.
<code>priorcheck</code>	Whether or not to use <code>ctsem:::priorchecking</code> to compare posterior mean and sd to prior mean and sd.
<code>...</code>	Additional arguments to pass to <code>ctsem:::priorcheckreport</code> , such as <code>meanlim</code> , or <code>sdlim</code> .

Value

List containing summary items.

Examples

```
summary(ctstantestfit)
```

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